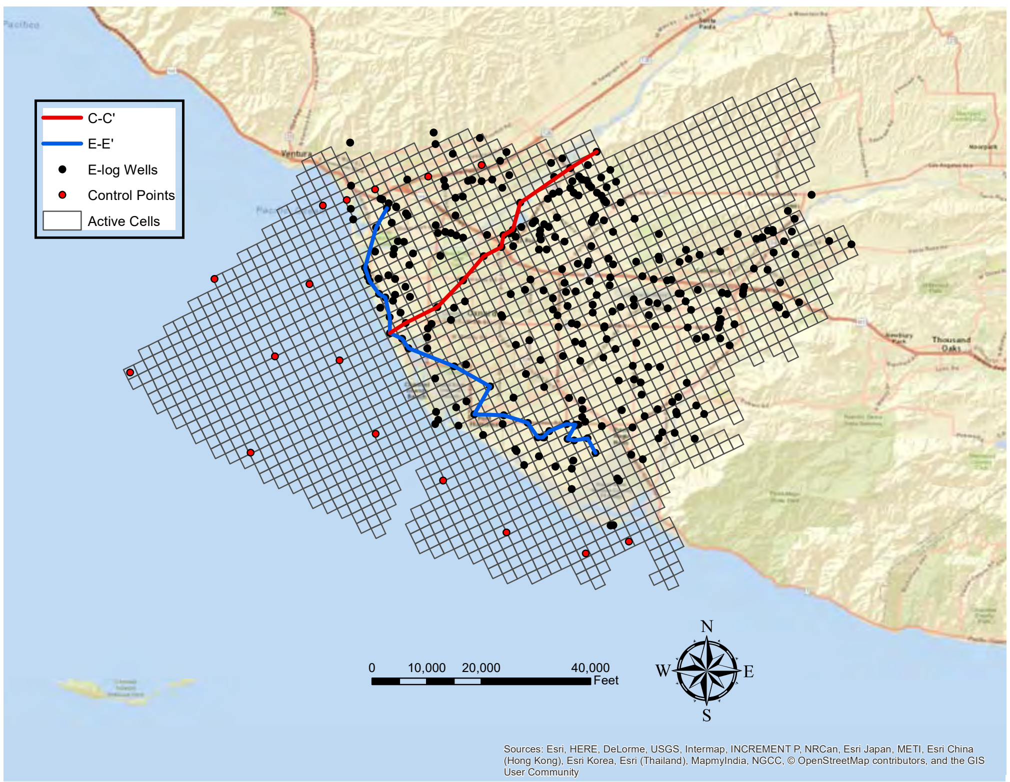
APPENDIX E

UWCD Model Report

VENTURA REGIONAL GROUNDWATER FLOW MODEL AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL: OXNARD PLAIN, OXNARD FOREBAY, PLEASANT VALLEY, WEST LAS POSAS, AND MOUND GROUNDWATER BASINS

Open-File Report 2018-02
July 2018



PREPARED BY
GROUNDWATER
RESOURCES
DEPARTMENT

UNITED WATER
CONSERVATION
DISTRICT

Cover Image: Model grid superimposed on map of the study area for this investigation.

Preferred Citation: United Water Conservation District, 2018, Ventura Regional Groundwater Flow Model and Updated Hydrogeologic Conceptual Model: Oxnard Plain, Oxnard Forebay, Pleasant Valley, West Las Posas, and Mound Basins, United Water Conservation District Open-File Report 2018-02, July.

VENTURA REGIONAL GROUNDWATER FLOW MODEL AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL: OXNARD PLAIN, OXNARD FOREBAY, PLEASANT VALLEY, WEST LAS POSAS, AND MOUND GROUNDWATER BASINS

Open-File Report 2018-02
July 2018

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FOREWORD

United Water Conservation District's (United) effort of the past six years to develop a significantly improved groundwater flow model for the Oxnard Plain and adjacent basins, as described in this report, is part of a broader effort by United and other agencies in the region to better understand the key factors that affect availability and usability of our area's groundwater resources. Use of these resources, which have been supplemented for the past 90 years by spreading (artificial recharge) of surface water diverted from the Santa Clara River, has been key to the past growth and the future sustainability of cities and agriculture on the Oxnard coastal plain. Groundwater of suitable quality for a wide range of beneficial uses can be withdrawn from wells and delivered to cities or farms on the Oxnard coastal plain and in the Santa Clara River valley without construction of extensive, costly infrastructure projects (such as the aqueducts and surface reservoirs of the State Water Project), and provides a reliable water supply and resilience against potential major disruptions such as earthquakes and droughts. Although imported surface water from northern California began contributing significantly to the region's municipal water-supply portfolio over the past half century, and desalination of brackish water or seawater may play an important water-supply role for the region in the future, neither of these alternative sources of water-supply can match the low cost and small environmental footprint of the existing groundwater resources, as enhanced by United's recharge operations.

Unfortunately, the relative accessibility, reliability, and low cost of groundwater for water supply has resulted in it being extracted from the aquifers underlying the Oxnard coastal plain at a faster rate than it has been replenished over the long term. This "overdraft" has resulted in corresponding groundwater-level declines in regional aquifers that have only been partly reversed during wet climatic cycles. In turn, these groundwater-level declines have resulted in seawater intrusion into the regional aquifers near the coast (since the 1930s), and could potentially exacerbate other water-quality problems or cause subsidence of land surface if allowed to continue. United coordinated with other regional water-supply stakeholders to plan and implement major projects in the 1950s, 1980s, and 1990s to mitigate the effects of overdraft, and these efforts have been partially successful. However, under California's Sustainable Groundwater Management Act (SGMA) of 2015, groundwater sustainability plans (GSPs) must be developed and implemented by 2020 to provide long-term solutions that will prevent further negative impacts in "critically overdrafted basins," including the Oxnard Plain and Pleasant Valley basins, and by 2022 for other groundwater basins in United's service area.

The geometry and physical characteristics of the aquifers, combined with the interactions of the stresses acting on those aquifers, within the regional groundwater basins are complex. The complexity is compounded by spatial and temporal variability of groundwater recharge and discharge. In order to forecast the effects of potential future water-supply alternatives with a sufficient level of certainty to evaluate and design new projects, it became evident to United in 2011 that the region needed a numerical groundwater-flow model that could discretely simulate each of the seven individual aquifer systems and six intervening aquitards that comprise the multi-layered regional aquifer system beneath the Oxnard and Pleasant Valley groundwater basins. The California Department of Water Resources notes that "while models are, by definition, a simplification of a more complex reality, they have proven to be useful tools over several decades for addressing a range of groundwater problems and supporting the decision-making process. Models can be useful tools for estimating the potential hydrologic effects of proposed water management activities" (Joseph and others, 2016).

Numerical models of local groundwater basins developed by California Department of Water Resources in the 1970s, and by the U.S. Geological Survey in the 1990s, were useful for answering the questions about groundwater being asked at those times. However, these models assumed a greatly simplified hydrologic system, consisting of one, two, or three "lumped" aquifers, rather than explicitly modeling the seven aquifers (and six aquitards) that actually exist in the region. This over-simplification was necessary at the time due to limitations in available data, as well as limitations in computer processing power. Consequently, these models produced simulated groundwater elevations that did not always match measured groundwater elevations very well in some key areas, including near the coast and in recharge zones, reducing the reliability and increasing the uncertainty of forecasts for future conditions. Therefore, in 2012 United initiated, with financial and technical support from regional stakeholders, development of the numerical model described in this report ("Ventura Regional Groundwater Flow Model," or VRGWFM), which discretely simulates each aquifer and aquitard underlying the Oxnard coastal plain as a distinct "layer" (in modeling terminology). The goal of this effort is to achieve significant improvement in calibration compared to previous models, allowing simulation of a greater range of natural and man-made hydrogeologic processes that have occurred in the past, and thereby increase the reliability of model predictions for the future. That said, the California Department of Water Resources warns, "there should be no expectation that a single 'true' model exists. All models and model results will have some level of uncertainty" (Joseph and others, 2016). For this reason, United is committed to continuous improvement of the VRGWFM as new data and improved methods become available, to minimize potential uncertainty.

United would like to acknowledge the financial support provided by the Fox Canyon Groundwater Management Agency (FCGMA) and the Santa Clara River Watershed Committee, as well as the technical input and assistance provided by the FCGMA Technical Advisory Group (TAG), the Calleguas Municipal Water District's technical staff and consultants, and the participants of the Expert Panel convened by United to review and provide guidance for improving the model (Dr. Sorab Panday, James Rumbaugh, and John Porcello). United would also like to acknowledge the various water and sanitation districts (including Ventura County Watershed Protection District), municipalities, and individuals that provided data to support development of the VRGWFM. We especially want to acknowledge the importance of the U.S. Geological Survey effort in the 1990s and 2000s to establish a regional groundwater monitoring-well network and construct the first MODFLOW model for the basins underlying the entire Santa Clara River and Calleguas Creek watersheds; their model was a critical "jumping-off point" for the VRGWFM. Finally, United's Groundwater Department staff would like to recognize the foresight and patience of United's Board of Directors, previous and present

General Managers, and—most notably—former Groundwater Department Manager Tony Morgan, for their efforts in kicking off this modeling effort six years ago and guiding/pushing staff to completion of "Version 1.0" today.

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VENTURA REGIONAL GROUNDWATER FLOW MODEL AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL: OXNARD PLAIN, OXNARD FOREBAY, PLEASANT VALLEY, WEST LAS POSAS, AND MOUND GROUNDWATER BASINS

EXECUTIVE SUMMARY

This report documents the purpose, background, conceptualization, construction, and calibration of United's Ventura regional groundwater flow model (VRGWFM), which currently includes the Oxnard Plain (including the Forebay), Pleasant Valley, West Las Posas, and Mound groundwater basins (study area) of southern Ventura County. The VRGWFM incorporates a significant update of the hydrostratigraphic conceptual model for the study area and simulates individual aquifers and aquitards, thus representing a major upgrade from the previously available tools and information for understanding hydrogeologic conditions and forecasting effects of future aquifer stresses. Over the coming months, United intends to expand the model area to include the Santa Paula, Fillmore, and Piru basins, incorporate relevant new data received, and apply new modeling software (modules or packages) as they become available and are deemed helpful in answering regional groundwater and water-supply questions. Additional technical memoranda or reports will be prepared as needed in the future to document anticipated expansion of the model domain, modification of input parameters as a result of collection of new data, and selection of new or different modeling packages that improve simulation of hydrogeologic conditions within the study area.

BACKGROUND AND PURPOSE

In 2003, the U.S. Geological Survey (USGS) released documentation of their groundwater flow model for the lower portions of the Santa Clara River and Calleguas Creek watersheds (referred to herein as "the USGS model"), including the Piru, Fillmore, Santa Paula, Mound, Oxnard Plain (including the Forebay), Pleasant Valley, Santa Rosa, and Las Posas Valley (West, East, and South) basins. The USGS model included two layers, representing the Upper Aquifer System (UAS) and Lower Aquifer System (LAS). Although the USGS model was an effective starting point for developing an understanding of hydrogeologic conditions in the area, its relatively coarse discretization limited the level of detail at which it could be calibrated and prevented its use for evaluating impacts of future pumping/recharge scenarios on specific aquifers, particularly those impacted by seawater intrusion. Furthermore, the USGS model did not explicitly simulate the shallow Semi-perched Aquifer, including recharge and discharge processes occurring in that aquifer that are significant components of the groundwater budget in the Oxnard and Pleasant Valley basins. Therefore, in 2011 United and

FCGMA determined that an updated and more detailed conceptual model of hydrostratigraphy should be developed, followed by construction and calibration of a higher-resolution numerical groundwater-flow model that (unlike earlier models) would provide discrete simulation capabilities for each individual aquifer and aquitard. The purpose of the current modeling effort described in this report has been to construct the VRGWFM envisioned by United and FCGMA in 2011, and verify (via historical calibration, sensitivity analysis, and review) that it would serve as an improved tool for simulating the future occurrence and movement of groundwater within the study area.

The VRGWFM is anticipated to be used in support of United's and FCGMA's groundwater planning and management activities, which will require predictive simulations of potential future pumping, recharge, and land- and water-use scenarios in the study area. United intends to use the model as a planning tool to maximize the regional benefits of its conjunctive use operations and to forecast effects of water-supply projects operated by United and other local agencies. The FCGMA may elect to use the model to evaluate the effectiveness of potential groundwater management strategies and regulatory policies on eliminating overdraft and saline-intrusion in the coastal areas of the Oxnard Plain.

HYDROGEOLOGIC CONCEPTUAL MODEL

In order to construct an improved numerical groundwater flow model that explicitly and accurately represents all of the major hydrostratigraphic units (HSUs) in the study area, United staff collected and reviewed more than 900 borehole resistivity logs (electric logs or "e-logs") from oil/gas and water wells within the model domain and nearby areas, with the goal of updating and refining the hydrostratigraphic conceptual model. This updated hydrostratigraphic model forms the basic "framework" required to define the geometry and layering of the numerical flow model, as described in Section 3 of this report.

The conceptual model for groundwater flow in the study area can be distilled down to the following key points or elements:

- Most groundwater in the study area is stored in, and flows through, two aquifers comprising the UAS and four aquifers comprising the LAS. A relatively small quantity of groundwater also occurs in the uppermost (shallow) aquifer system, referred to as the Semi-perched Aquifer in the Oxnard coastal plain area (where a thick clay unit is present between this shallow aquifer and the underlying UAS). Due to the limited quantity and poor quality of groundwater typically found in the shallow aquifer system, it is largely unused by agriculture, municipalities, or industry.
- Most of the adjacent groundwater basins within the study area are in hydraulic connection with each other, and groundwater within each aquifer can flow from one basin to an adjacent basin with moderate to no impediment (depending on hydraulic conductivity and gradients) in most instances.
- Groundwater generally flows from areas of recharge to areas of discharge. The largest single source of groundwater recharge to the UAS and LAS in the study area is the artificial recharge introduced to the Forebay by United. In the Forebay, the sediments comprising the shallow aquifer system have been uplifted and eroded away, exposing the highly permeable aquifers

of the UAS at land surface, providing an ideal situation for recharge via spreading basins. Some of this artificial recharge percolates downward to the aquifers of the LAS in the Forebay and adjacent basins in response to vertical hydraulic gradients between the UAS and LAS. Smaller quantities of groundwater recharge the UAS and LAS as a result of:

  - groundwater underflow from upgradient basins,
  - mountain-front and stream-channel recharge,
  - seawater intrusion near the coast,
  - downward flux from the shallow aquifer system, and
  - deep percolation of precipitation, agricultural return flows, municipal/industrial return flows, and treated wastewater in the few areas where the UAS and LAS are exposed at land surface.

- Most groundwater discharge from the UAS and LAS in the study area occurs via pumping from hundreds of water-supply wells located in the Oxnard Plain (including the Forebay) and Pleasant Valley basins, and a smaller number of wells in the Mound, West Las Posas, and Santa Paula basins.

- Because the preponderance of recharge in the study area occurs in the Forebay, while most discharge consists of pumping in surrounding basins, groundwater in the UAS and LAS typically flows radially outward from the Forebay to the adjacent basins. However, two notable disruptions to this pattern can occur, as follows:

  - When United's recharge operations are limited due to drought conditions, groundwater elevations in the UAS have periodically dropped below sea level as far north as the northern part of the Forebay area, and the typical pattern of radial groundwater flow outward from the Forebay becomes replaced by landward gradients at the coastline across the Oxnard Plain basin. This results in seawater intrusion from the adjacent Pacific Ocean to the aquifers underlying the Oxnard coastal plain.
  - A large groundwater "cone of depression" has persisted for decades in the LAS in the agricultural area east of Oxnard and south of Camarillo as a result of the concentration of pumping from water-supply wells in this area and the substantial distance from the Forebay (where most recharge occurs). Groundwater elevations in this cone of depression have long been tens to over 100 feet below sea level, producing landward hydraulic gradients and strong vertical gradients from the UAS to the LAS that contribute to seawater intrusion in the LAS.

- In the shallow aquifer system, recharge occurs throughout the study area (mostly via deep percolation of precipitation, agricultural and municipal/industrial return flows, and treated wastewater), as does groundwater discharge (mostly via evapotranspiration and tile drains, with relatively small amounts of groundwater discharging to the lower Santa Clara River and the Pacific Ocean). Because most land in the study area is used for municipal, industrial, or agricultural purposes, and agricultural irrigation occurs year-round, groundwater elevations in the shallow aquifer system typically remain stable at elevations within approximately 5 to 8 feet of land surface (where most evapotranspiration occurs and tile drains are installed, respectively).

A summary of estimates for inflow and outflow components to the groundwater system in the study area is provided in Table ES-1, below. Approximately half of the total inflow consists of artificial recharge, which is metered by United and, therefore, volumes are known with a high level of certainty. Over the past 50 years, United's recharge operations in the Forebay are estimated to have contributed a greater volume of recharge to the aquifers of the UAS and LAS in the study area than all other sources of recharge combined (the Semi-perched Aquifer is not present in the Forebay, so does not receive artificial recharge from United's spreading basins). Therefore, artificial recharge can be considered the most important long-term groundwater influx term to the study area. Similarly, groundwater pumping from water-supply wells is, by far, the largest component of estimated groundwater discharges (or outflows) from the overall groundwater system in the study area, and comprises 100 percent of the net discharge from the UAS and LAS in the study area (some discharge from the UAS and LAS to the Pacific Ocean occurs, but this is countered over the long-term by seawater intrusion; therefore, net inflow of seawater is occurring rather than net discharge).

The small magnitude of the other inflows and outflows relative to artificial recharge and groundwater pumping—the major inflow and outflow components—means that even if there is relatively large percentage uncertainty (e.g. +/-25%) in deep infiltration of precipitation, for example, which could result in a hypothetical "error" of +/-4,500 AF/yr, the magnitude of this uncertainty is less than 10% of the average artificial recharge rate of 48,000 AF/yr (which is known to a high level of certainty since it is carefully monitored by United). Therefore, despite some uncertainties, the water budget in the study area is better suited to construction of a groundwater flow model than are water budgets for many other basins. Furthermore, much of the recharge in the study area derived from sources other than artificial recharge enters the groundwater system in the Semi-perched Aquifer, which is not used for water supply. This recharge is removed from the groundwater system via the extensive drainage systems in the Semi-perched Aquifer (and ET) within hours, days, or a few weeks, at most, and has little influence on groundwater conditions in the aquifers of the UAS and LAS.

Many, but not all, of the inflow and outflow components listed in Table ES-1 are required groundwater flow-model input parameters (shown in bold in Table ES-1). There are varying degrees of uncertainty associated with some of the smaller inflow and outflow components (i.e. stream-channel recharge, deep infiltration of precipitation, agricultural and M&I return flows, mountain-front recharge, percolation of treated wastewater, drainage, ET, underflow to/from adjacent basins, and seawater intrusion), as is common in regional-scale flow models. Therefore, consistent with standard modeling practice, the values for these uncertain inflow components were adjusted during model calibration to improve the overall model calibration. The inflow and outflow components not required as input to the model (shown in italics in Table ES-1) are calculated by the model based on simulated boundary conditions, aquifer stresses, and aquifer parameters.

NUMERICAL MODEL CONSTRUCTION

The first step in construction of the VRGWFM was selection of a suitable modeling "platform" (software) and determination of appropriate spatial and temporal limits or boundaries for the model (the domain). The next step was to decide how to subdivide (discretize) both space and time in the model such that the simulation results were produced at an appropriate scale to meet the modeling objectives, while keeping computing and post-processing requirements reasonable. Next, estimates of aquifer hydraulic parameters were entered into digital input files ("packages"), completing

Table ES-1. Comparison of Previous Estimates of Groundwater Inflow and Outflow Components in Study Area to VRGWFM Recharge and Discharge Rates for Historic Calibration Period

Groundwater Inflow or Outflow Component	Estimates from Available Data or Previous Investigations (AF/yr)[a]	VRGWFM Recharge and Discharge Rates (AF/yr)
Inflows: (**bold** font used for components that are required as input to the VRGWFM, *italic* font used for flows that are calculated by the VRGWFM [provided solely for comparative purposes])		
Artificial Recharge (at Saticoy and El Rio Spreading Grounds)	**48,000**	**48,000**
Areal Recharge (combined deep infiltration of precipitation and return flows [Ag + M&I])	**38,000 to 43,000**	**48,000[b]**
Mountain-Front Recharge (sum of ungauged streamflow and bedrock recharge)	**3,000**	**7,900[b]**
Percolation of Treated Wastewater at WWTPs	**280**	**280**
Stream-Channel Recharge in Santa Clara River	*8,400*	*9,600*
Stream-Channel Recharge in Arroyo Las Posas	*4,000*	*4,300*
Groundwater Underflow from Santa Paula Basin	*1,800 to 7,400*	*3,800*
Groundwater Underflow from East Las Posas Basin	*700 to 1,900*	*1,600*
Net Seawater Intrusion into UAS and LAS	*12,000*	*9,400*
Outflows: (**bold** font used for components that are required as input to the VRGWFM, *italic* font for flows that are calculated by the VRGWFM [provided solely for comparative purposes])		
Pumping from Water-Supply Wells	**130,000[c]**	**130,000[b]**
Shallow groundwater drainage (to tile and other manmade drain systems)	*8,000 to 12,000*	*12,000*
ET	*15,000*	*9,900*
Discharge of Shallow Groundwater in Semi-perched Aquifer to Santa Clara River	*1,500*	*1,200*
Semi-perched Aquifer Discharge to Pacific Ocean	*No previous estimates*	*1,100*

Notes:

All numbers rounded to two significant digits.

[a] Details regarding sources and calculation methods for averages calculated from existing data or estimated by previous investigators are provided in Section 2.7 and Table 2-2. Most of the averages summarized in this column are for the combined area of the Oxnard Plain, Forebay, Pleasant Valley, Mound, and West Las Posas basins. The relatively small inflow and outflow quantities occurring in the minor area of the active domain of the VRGWFM located outside of those basins (e.g., western margin of Santa Paula basin) are generally not included in the averages presented in this column.

[b] The VRGWFM-input or -calculated quantities listed in this table for these inflows and outflows include the entire active model domain, including small areas outside of the Oxnard Plain, Forebay, Pleasant Valley, Mound, and West Las Posas basins. Therefore, these quantities can be somewhat higher than those listed in the first column of this table, which generally focus specifically on these basins.

[c] Unlike most quantities listed in this column, the estimated total pumping from water-supply wells was calculated for the entire active model domain. Therefore, it is identical to the VRGWFM-input average pumping rate.

construction of the basic model framework. Next, known and estimated aquifer stresses over the calibration period (CY 1985 through 2015) were entered into input files. With this information, together with instructions regarding how the model should process input and output, the modeling software computes heads and flows throughout the model domain based on a numerical solution of the partial-differential equation that defines groundwater flow (the continuity equation). Comparison of model-simulated groundwater elevations to measured historical groundwater elevations, typically accompanied by adjustment of modeled aquifer parameters as needed to reduce any differences (residuals), is referred to as calibration, and was conducted iteratively with refinement of the model. Finally, sensitivity of the model to variability and uncertainty in its input parameters was analyzed.

The USGS software package MODFLOW-NWT was selected by United to be the modeling platform for initial development of the VRGWFM. The groundwater system in the study area is influenced by cycles of extended drought and wet periods that cause groundwater levels to fluctuate over 100 feet, requiring a numerical model capable of simulating the desaturation and resaturation (drying and wetting) of portions of the aquifers. MODFLOW-NWT was developed in large part to simulate this type of condition.

The current active domain of the VRGWFM includes the Forebay, Mound, Oxnard Plain, Pleasant Valley, and West Las Posas basins, part of the Santa Paula basin, and the submarine (offshore) outcrop areas of the principal aquifers that underlie the Oxnard Plain and Mound basins. The active model domain spans approximately 176,000 acres (275 square miles). The domain of the VRGWFM was discretized (subdivided) into finite-difference grid cells and layers such that basin-scale hydrogeologic features, boundaries, and flow patterns could be simulated at an acceptable level of resolution, while keeping model run-times to a reasonable length during calibration and sensitivity analysis. At present, the VRGWFM model-grid spacing is a uniform 2,000 feet (in both the north-south and east-west directions), divided into 13 layers of variable thickness.

Initial values were input to the VRGWFM for horizontal hydraulic conductivity, vertical conductance between layers, specific yield, storage coefficient, and conductance across horizontal flow barriers (faults). Conductance values and other input parameters applied to local-scale features and stresses were also input. Previous investigators have typically estimated aquifer hydraulic parameters for the UAS and LAS rather than for individual aquifers within those systems. Best-management practices for modeling suggest modifying input values for aquifer parameters during model calibration. This was United's approach to assigning aquifer hydraulic parameters in the VRGWFM; start with values based on available data (or typical values reported in the literature for the soil and rock types present), then adjust the values as appropriate (within reasonable ranges) during model calibration.

Table ES-1 summarizes the stresses (recharge and discharge rates) input to the model, and compares them to the long-term average inflow and outflow components in the study area that were estimated by previous investigators (as discussed above). Some of inflow and outflow components to the study area are known with a reasonable level of confidence and can be directly translated to the model as recharge and discharge components, on a one-to-one basis (e.g., pumping and artificial recharge rates). However, some of the inflow and outflow components estimated by previous investigators were subject to substantial uncertainty due to limited data availability, or were estimated for limited time periods in the past that may not be representative for current hydrologic conditions in the region, and thus do not necessarily match model recharge and discharge quantities (e.g., irrigation return flows and ET rates) very closely. In such cases, reasonable application rates were estimated from the previous investigations or from other methods, and applied to current land uses to calculate total recharge or discharge volumes in the model to be used for a starting point. These volumes (or rates) were then adjusted in the calibration process (the final calibrated average flow rates are what is shown in Table ES-1).

Several of the groundwater flow components within the study area are calculated by the model as the product of hydraulic gradients and conductivities, rather than being input directly (e.g., groundwater underflows and seawater intrusion rates). These inflows and outflows are typically among the most difficult to measure or estimate in the field, and are subject to large uncertainty; therefore, groundwater modeling is commonly considered to provide the best estimates. Inflows and outflows calculated by the model, rather than input directly, are shown in Table ES-1 in italics, and are provided solely for comparison purposes.

RESULTS OF MODEL CALIBRATION AND SENSITIVITY ANALYSIS

By comparing simulated groundwater levels with measured groundwater levels, and adjusting model input parameters to minimize differences between the two, a set of calibrated input parameters was determined to yield an optimal fit based on thousands of manual and automated calibration simulations. Input parameters that were adjusted during calibration of the VRGWFM included:

- hydraulic conductivity
- specific yield and storage coefficient
- stream-channel conductance
- general-head boundary conductance
- horizontal flow barrier conductance
- areal recharge rates
- multi-node wells

To better define the effects of parameter uncertainty on calibration results, a sensitivity analysis was conducted on the VRGWFM. The sensitivity analysis was conducted by adjusting key model input parameters and quantitatively evaluating the impact of each adjustment on the resulting simulated groundwater elevations and flow budget. Results of sensitivity analysis indicate that the VRGWFM is most sensitive to changes in the following input parameters:

- hydraulic conductivity in Layer 6 (the aquitard between the UAS and LAS)
- agricultural return flows (affecting chiefly the Semi-perched Aquifer)
- streambed conductance of the Santa Clara River, Conejo Creek, Arroyo Las Posas, and Calleguas Creek

- conductance of the general-head boundary representing interaction between the Pacific Ocean and the aquifers of the UAS and LAS

REVIEW

The process of internal review and refinement of both the conceptual and numerical models for the VRGWFM was iterative and occurred frequently from 2013 through 2018. This internal review included comparison of model input files to available data in the study area. The goal of the internal review was to ensure that reasonable values were input to the model and that model output (primarily groundwater levels) throughout the calibration period were consistent with measured values. United hydrogeologists also reviewed calibration results to evaluate potential causes for substantial deviations between measured and simulated groundwater elevations—in some cases, reported groundwater elevation measurements were rejected as likely being erroneous or the result of damage to the well in which the measurement was obtained, and in other cases changes were required in either the hydrostratigraphic model or as input to the numerical model.

Since 2015, United has led and participated in several workshops, presentations, and meetings designed to provide information and solicit input from the FCGMA and other stakeholders in the study area regarding development of the VRGWFM. United held an all-day "TAG-review workshop" in coordination with the FCGMA during March 2017. At the conclusion of discussion of model calibration, no "fatal flaws" in the VRGWFM were noted by the TAG. TAG members concurred that the calibration of the VRGWFM generally was a significant improvement compared to the USGS model, and that including 13 model layers in the VRGWFM should prove valuable for simulating potential future water-supply projects. A follow-up workshop was held in April 2017 to focus on key issues in Pleasant Valley basin.

Following the TAG-review and Pleasant Valley workshops described above, United regularly updated the TAG on modeling progress during monthly TAG meetings, and met separately with individual members of the TAG and other stakeholder representatives on several occasions to further discuss various aspects of the VRGWFM and its potential future uses. In addition, United staff gave several presentations to stakeholder groups in Ventura County regarding VRGWFM construction, calibration, and how it could potentially be applied to future evaluation of sustainable yield and water-supply projects in the study area. Feedback from those meetings was noted and given consideration as model development progressed.

The Expert Panel reviews were conducted by three groundwater modeling experts focused on appropriateness of model construction, as well as the procedures used by United to convert raw data to model-input files, conduct calibration, and evaluate model sensitivity to the different input parameters. Key components of the Expert Panel's review included, but were not limited to, qualitative and quantitative evaluation of model calibration, and consideration of whether the VRGWFM was suitable for its intended uses. The Expert Panel concluded:

- "In summary, the expert panel finds the model to be a well-designed and well-calibrated tool, and a tool that is a substantial enhancement and upgrade over previously available tools. Version 1.0

of the VRGWFM provides a newly robust and detailed method of evaluating how the multiple aquifers in the region behave and how they might respond to the design and implementation of specific regional management programs and specific projects in the five groundwater basins that the model currently simulates in southern Ventura County."

- "Version 1.0 of the VRGWFM is viewed by the expert panel as being ready for use in regional and local planning efforts, and is of sufficient quality to support development of GSPs under SGMA, including conducting water budget analyses, estimating the sustainable yield of the regional aquifers under various long-term management alternatives, and evaluating the ability of specific projects and management actions to meet minimum threshold levels that will be established in basin-specific GSPs."

LIMITATIONS

USGS guidance notes that non-unique configurations of model parameters can produce reasonably good calibration statistics, but not necessarily yield a good model. This issue is of particular concern in models where calibration data are limited over space or time. However, the abundant pumping, groundwater-level, and aquifer-parameter data that have been collected over the past several decades in the VRGWFM study area result in a detailed conceptualization of the groundwater systems in the study area, while also providing a spatially and temporally extensive calibration dataset. This combination greatly reduces both the potential for conceptual model error and the number of possible alternative configurations of model input parameters that could produce a similar result.

Similar to the USGS model of the Santa Clara-Calleguas watersheds, the VRGWFM is a regional-scale model, and should not be applied to questions about well performance at individual farms or contaminant-transport at corner gas station sites, for example, unless finer discretization is applied to the model and site-specific data are reviewed (and incorporated into the model, as appropriate). However, as noted previously, the VRGWFM incorporates a significant update of hydrostratigraphic conceptual model for the study area and discretely simulates individual aquifers and aquitards, and thus represents a major upgrade from the previously available tools and information available for understanding hydrogeologic conditions and forecasting effects of future aquifer stresses. As needed for future simulations, the VRGWFM can be further discretized or otherwise modified to more precisely or elegantly simulate actual groundwater flow processes that occur in specific areas of interest.

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VENTURA REGIONAL GROUNDWATER FLOW MODEL AND UPDATED HYDROGEOLOGIC CONCEPTUAL MODEL: OXNARD PLAIN, OXNARD FOREBAY, PLEASANT VALLEY, WEST LAS POSAS, AND MOUND GROUNDWATER BASINS

1 INTRODUCTION

United Water Conservation District (United) is a public agency (i.e., a California special district) with a service area of approximately 335 square miles (214,000 acres) of southern Ventura County. United's service area includes the Ventura County portion of the Santa Clara River Valley and much of the Oxnard coastal plain, including the lower part of the Calleguas Creek watershed, as shown on Figure 1-1. United serves as a steward for managing the surface water and groundwater resources within all or part of eight groundwater basins and subbasins. It is governed by a seven-person board of directors elected by region, and receives revenue from property taxes, pump charges, recreation fees, and water delivery charges. United is authorized under the California Water Code to conduct water resource investigations, acquire water rights, build facilities to store and recharge water, construct wells and pipelines for water deliveries, commence actions involving water rights and water use, prevent interference with or diminution of stream/river flows and their associated natural subterranean supply of water, and to acquire and operate recreational facilities (California Water Code, section 74500 et al).

The developed areas of the District include agricultural, municipal, and industrial land, with prime farmland supporting high-value crops such as strawberries, avocados, row crops, lemons, and flowers. Approximately 400,000 people live within United's service area, including residents of the Cities of Oxnard, Port Hueneme, Santa Paula, Fillmore, the east part of San Buenaventura (Ventura), and unincorporated areas of Ventura County. The City of Camarillo borders United's service area to the east, and some of the suburban and industrial/commercial areas surrounding Camarillo have grown into United's service area.

Groundwater has been an important component of the water supply in the watersheds of the Santa Clara River and Calleguas Creek since the early 1900s (Hanson and others, 2003). Since the 1920s water users in the area have been concerned that increasing agricultural and municipal demand for groundwater could exceed replenishment (recharge), resulting in wells going dry. In 1927, the Santa Clara Water Conservation District (United's predecessor agency) was established, and the practice of "conjunctive use" (artificial recharge of surface water during wet periods to increase the volume of groundwater available for withdrawal during dry periods) commenced on the Oxnard coastal plain, although recharge quantities were small during those early years. In the 1930s, potential displacement of fresh water under the Oxnard coastal plain resulting from seawater intrusion was recognized as a potential future concern, and in the 1940s it became reality, with declining groundwater levels measured throughout the area and seawater intrusion occurring near the coastline (Edmonston, 1956). These problems motivated the reorganization of the Santa Clara Water Conservation District into United Water Conservation District in 1950. A new partnership with the cities within United's boundaries provided a much greater bonding capacity, allowing the construction of Santa Felicia Dam on Piru Creek, new spreading grounds at El Rio and a potable water system to deliver water to coastal areas threatened by seawater intrusion. United's records indicate that artificial recharge rates on the Oxnard coastal plain have increased from an average of 23,000 acre-feet per year (AF/yr) during the 1950s to over 50,000 AF/yr in the 2000s, with an additional 16,000 AF/yr delivered as surface water in lieu of pumping since the 1990s. This combination of increased recharge and delivery of surface water in lieu of pumping has raised groundwater levels and mitigated seawater intrusion in some areas and aquifers (United, 2017b). However, between wet and dry periods, large variations in groundwater levels (more than 100 feet in some areas) and flow directions (seaward versus landward) still occur in some of the aquifers underlying the Oxnard coastal plain, creating complex groundwater flow patterns that cannot be completely understood or predicted by the simplified analytical solutions used by early researchers. For this reason, it was recognized that a quantitative tool, specifically a well-calibrated numerical groundwater flow model that explicitly simulates conditions in each aquifer, would be needed to better understand the groundwater flow dynamics in southern Ventura County and to aid in planning for groundwater resources management.

This report documents the purpose, background, conceptualization, construction, and calibration of United's Ventura regional groundwater flow model (VRGWFM), which currently includes the Mound, Oxnard Plain (including Oxnard Forebay), Pleasant Valley, and West Las Posas groundwater basins (study area) of southern Ventura County. The VRGWFM incorporates a significant update of the hydrostratigraphic conceptual model for the study area and simulates individual aquifers and aquitards, thus representing a major upgrade from the previously available tools and information available for understanding hydrogeologic conditions and forecasting effects of future aquifer stresses. Over the coming months to years, United intends to expand the model area, incorporate relevant new data received, and apply new modeling software (modules or packages) as they become available and are deemed helpful to United's efforts to answer regional groundwater and water-supply questions. Additional technical memoranda or reports will be prepared as needed in the future to document anticipated expansion of the model domain, modification of input parameters as a result of collection of new data, and selection of new or different modeling packages that improve simulation of hydrogeologic conditions within the study area.

1.1 LOCATION

The domain (active and inactive area) of the VRGWFM extends from near Lake Piru in eastern Ventura County to several miles offshore of the Pacific Ocean coastline in the southwest, as shown on Figure 1-2. This domain includes all of the area of interconnected groundwater basins and subbasins along the Santa Clara River watershed within Ventura County and part of the Calleguas Creek watershed. Currently, the active portion of the model domain includes the Mound, Oxnard Plain, Oxnard Forebay (Forebay), Pleasant Valley, and West Las Posas groundwater basins and subbasins (the study area) as defined by John F. Mann Jr. & Associates (Mann) in 1959 (for the sake of brevity, groundwater subbasins are commonly referred to as "basins" in this report). The study area coincides with the following groundwater basins and subbasins as described in California Department of Water Resources (DWR) Bulletin 118 (DWR, 2003):

- Oxnard (4-004.02) and Mound (4-004.03) subbasins of the Santa Clara River Valley basin (4-004)
- Pleasant Valley basin (4-006)
- western part of Las Posas Valley basin (4-008)

A small (approximately 5-square-mile) portion of the Santa Paula basin along its southwest boundary with the Mound and Forebay basins is also included in the active model domain, to allow groundwater flow in this area to be simulated with a general-head boundary (GHB) condition (discussed further in Section 3 of this report). Outside of the active portions of the VRGWFM, the model domain is inactive (groundwater levels and movement are neither input nor simulated in these portions of the model), at present. However, in the next 6 to 18 months United plans to add the area representing the remainder of the Santa Paula basin, together with the Fillmore and Piru basins (Figure 1-2), to the active domain of the VRGWFM, and calibrate the model in these areas. Calleguas Municipal Water District (Calleguas or CMWD) has developed a numerical groundwater flow model for the eastern and southern parts of the Las Posas Valley basin (Intera, 2018), which is also within the Calleguas Creek watershed. The eastern boundary of the active model domain of the VRGWFM in Las Posas Valley approximately aligns with the western boundary of the Calleguas model.

1.2 PREVIOUS INVESTIGATIONS

In the 1920s, State officials found it necessary to study the water resources of Ventura County before ruling on the various applications for water rights. The initial progress reports for a *Ventura County Investigation* were published by the California Division of Water Rights in 1928 and the California Division of Water Resources in 1929. The final report was printed in 1933, as Bulletin No. 46 – Ventura County Investigation (California Division of Water Resources, 1933). This report included consideration of groundwater resources, percolation of streamflow, and relationships between surface water and groundwater resources. A significant advancement of Bulletin No. 46 was the concept of the regional resources of the Santa Clara watershed operating as part of a single large system: "the Coastal Plain (Oxnard Plain and Pleasant Valley basins) derives its natural supply from overflow of water which has percolated into the Santa Clara River Valley and also from percolation of floods crossing Montalvo (Forebay) Basin."

In the late 1940s, the region experienced several years of below-average precipitation. Seawater intrusion was recognized as a threat to the groundwater resources underlying the Oxnard coastal plain at this time, and population was increasing in this period of post-war American prosperity. The California State Water Resources Board (Edmonston, 1956) published Bulletin 12, an update to the earlier *Ventura County Investigation*, including details from subsequent investigations of the groundwater resources of the region. Bulletin 12 introduced the seven groundwater basins of the Santa Clara River Hydrologic Unit as the most important in Ventura County. Consistent with earlier investigations, groundwater occurring in the Piru, Fillmore, Santa Paula, and Forebay basins was classified as unconfined, while the aquifers of the Mound, Oxnard Plain, and Pleasant Valley basins were identified as being confined by clay beds of low permeability. Recharge mechanisms for the unconfined basins were identified: "The unconfined ground water basins are replenished by percolation of flow in the Santa Clara River and its tributaries, percolation of direct precipitation, artificial spreading and percolation of surface waters, and by percolation of the unconsumed residuum of water applied for irrigation and other uses" and "recharge to the confined aquifers of the Mound, Oxnard Plain, and Pleasant Valley Basins" was noted to be "largely supplied by subsurface flow from areas of free (unconfined) ground water." The major mechanisms for groundwater losses from the basins were also identified: "Ground water in the seven major basins of the Santa Clara River Hydrologic Unit is disposed of by effluent discharge to lower basins, by pumped extractions to meet beneficial consumptive uses, by consumptive use of phreatophytes in areas of high ground water, and by subsurface flow to lower basins and to the ocean."

In the late 1950s, Mann was contracted by United to synthesize available information from previous investigations and data collected by United staff, with the following objectives:

1. "A refinement of the ground water geology of the District (United), in order to analyze the influence of the geologic complexities on ground water management;
2. A recalculation of the District's ground water inventories on the basis of the refined geologic framework;
3. A detailed study of ground water quality to spell out the influence of poor quality waters on continued ground water development;
4. A description of the current status of sea-water intrusion, and the development of a general plan for combating it."

Mann's (1959) final report estimated potential groundwater yields from the various basins, delineated hydrostratigraphic units (HSUs), and reported on water quality problems specific to certain aquifers and locations. This report also detailed the occurrence of groundwater underflow between the various groundwater basins within the district. Earlier reports had commonly focused on rising water and gains in surface water flow around basin boundaries, and less on the subsurface flow at these constrictions in the groundwater flow system.

The earliest numerical groundwater flow model of the aquifers underlying the Santa Clara River Valley and Oxnard coastal plain was developed by DWR in the early 1970s (Hasan and others, 1974); this flow model was coupled with a solute-transport model for the purpose of forecasting total-dissolved-solids (TDS) concentrations under alternative groundwater management plans under consideration at that time. The modeling software used by Hasan and others reportedly was an adaptation of DWR software (reference not available), which relied on the principle of superposition and used numerical methods to frame and solve the continuity equation for groundwater flow across a polygonal model grid. A total of 162 grid nodes, ranging in area from 100 to 1,000 acres each, were used to represent the study area, with the Piru, Fillmore, Santa Paula, Mound, Las Posas, Pleasant Valley, and Arroyo Santa Rosa Valley (Santa Rosa) basins simulated using a single layer, and the Oxnard Plain and Forebay basins simulated using two layers of model grid nodes (the upper layer represented the Semi-perched Aquifer). The model was calibrated using groundwater-level measurements from 1957 through 1967; during the calibration process, recharge, transmissivity, and storage coefficients were adjusted in the model to obtain a better match between measured and simulated groundwater levels. In some areas, simulation of historical groundwater levels was unachievable; review of measured groundwater levels in these areas indicated that they could be "reasonably modified to be consistent with the computed water levels from the model" (Hasan and others, 1974). Ultimately, simulated groundwater levels at a few model nodes remained "anomalous and were finally ignored."

The hydrogeologic information input to Hasan's model was subsequently released in two volumes by the Ventura County Department of Public Works, Flood Control District (Mukae and Turner, 1975). Mukae and Turner reviewed previous reports, water-well logs, and oil- and gas-well logs to update geologic maps and cross-sections presented in Bulletin 12, Ventura County Investigations (Edmonston, 1956), and refined delineation of the aquifers and base of fresh water in "the Oxnard-Calleguas Area" of Ventura County (including the Oxnard Plain, Forebay, Pleasant Valley, East, West, and South Las Posas, and Santa Rosa basins). Volume 2 of the Mukae and Turner (1975) report included new and reinterpreted evaluations of groundwater and surface-water parameters for much of the study area.

Following an extended period of population growth and several dry years in the mid-1970s, DWR published Bulletin 118-80, "Ground Water Basins in California" (DWR, 1980). This publication introduced the "Ventura Central Basin" and reasoned "the four valleys identified in Bulletin 118 (1975a) as the Santa Clara River Valley, Pleasant Valley, Arroyo Santa Rosa Valley and Las Posas Valley are contiguous and hydrologically continuous" and stated "ground water moves into the Santa Clara River Valley from the other three valleys, particularly into the Oxnard Plain." This change in naming convention was based on recognition that the local groundwater basins are more appropriately considered subbasins of a larger regional groundwater flow system.

In 1979, the State Water Resources Control Board (SWRCB) released a document simply titled "Staff Report—Oxnard Plain Groundwater Study," focusing on overdraft of groundwater in the Oxnard Plain, Forebay, and Pleasant Valley basins, and resultant seawater intrusion. The SWRCB (1979) report summarized hydrogeologic conditions in the area as understood at the time, recognized the mergence of UAS and LAS aquifers in certain areas vulnerable to seawater intrusion, and described potential actions that could be taken to prevent further seawater intrusion and permanent damage to the aquifer system, in particular the Fox Canyon Aquifer. The SWRCB threatened adjudication under Water Code Section 2100 if actions were not taken to correct overdraft and seawater intrusion on the Oxnard coastal plain. In response, the Fox Canyon Groundwater Management Agency (FCGMA) was created in 1982 to fill an oversight role in preventing further deterioration of the groundwater conditions causing seawater intrusion in the area. The FCGMA prepared a groundwater management plan in 1985 (Ventura County Public Works Agency, 1985) for the Oxnard Plain, Forebay, Pleasant Valley, East Las Posas, and West Las Posas basins, together with parts of Santa Rosa and South Las Posas basins. The FCGMA's 1985 groundwater management plan was updated in 2007 (FCGMA and others, 2007). The 2007 update included new interpretations of hydrogeologic conditions in the FCGMA's area of responsibility, including the Oxnard Plain and Pleasant Valley basins, based on extensive data collected by the U.S. Geological Survey (USGS) and others since 1985.

In the late 1980s, with financial support from United, Calleguas, and the FCGMA, the USGS began a major investigation of the regional alluvial-aquifer systems of the Santa Clara River and Calleguas Creek watersheds, including the basins of the current (VRGWFM) study area. This study of the hydrogeology of the Santa Clara-Calleguas watersheds was completed as part of the Southern California Regional Aquifer-System Analysis (RASA) program (Sun and Johnston, 1994). The regional groundwater system in southern Ventura County was selected as a representative southern California basin for study, with cultural practices and hydrogeologic processes common to other basins or groups of basins. The nested monitoring wells installed in Ventura County as part of the RASA program provided aquifer-specific groundwater-elevation and water-quality data that were key to improved understanding of groundwater conditions in the study area.

United also contracted the USGS to further study the basins and subbasins of the Santa Clara River Valley, this time focusing on the interaction between surface water and groundwater. The USGS report summarized "…the groundwater system and stream-aquifer interactions along the Santa Clara River," and included additional technical discussions of the hydrologic conditions (e.g., rising groundwater at subbasin boundaries, correlations of water quality with surface water flow magnitudes, interaction between various aquifers) in the Santa Clara River Valley (Reichard and others, 1998).

The USGS followed up with development of a numerical groundwater flow model (Hanson and others, 2003) for the Santa Clara River and Calleguas Creek watersheds, as shown on Figure 1-3 (referred to herein as "the USGS model"). The USGS model was constructed using their MODFLOW software (McDonald and Harbaugh, 1988) together with the subsequently developed streamflow-routing (Prudic, 1989), subsidence (Leake and Prudic, 1991), and horizontal-flow-barrier (Hsieh and Freckleton, 1993) packages. The USGS model included two layers, representing the Upper Aquifer System (UAS) and Lower Aquifer System (LAS), which are described in Section 2.5 of this report. The model domain included the Piru, Fillmore, Santa Paula, Mound, Oxnard Plain (including the Forebay), Pleasant Valley, Santa Rosa, East Las Posas, West Las Posas, and South Las Posas basins. The USGS model was calibrated to estimated historical surface-water flows and measured groundwater levels during the period from calendar year (CY) 1891 through CY 1993, and was an effective starting point for developing an understanding of aquifer boundary conditions and basin-scale hydraulic effects of complex stratigraphic and structural relationships between the UAS and LAS. However, its relatively coarse discretization (uniform 1/2-mile grid spacing and representation of six distinct aquifers, several of which are separated by thick aquitards, using only two model layers) limited the level of detail at which it could be calibrated and prevented it from being able to evaluate impacts of future pumping/recharge scenarios on specific aquifers, particularly those impacted by seawater intrusion. Furthermore, the USGS model did not explicitly simulate the shallow Semi-perched Aquifer, including recharge and discharge processes occurring in that aquifer that are significant components of the groundwater budget in the Oxnard and Pleasant Valley basins. Although calibration statistics for the USGS model indicated that simulated heads were commonly within 20 feet of measured heads in model layer 1 (UAS) near the coast, model residuals exceeding 50 feet were common in layer 2 (LAS) throughout the model domain. And calibration of the Semi-perched Aquifer was impossible, since it was not simulated in that model. A subsequent adaptation of the USGS model by United in the mid-2000s, adding a third model layer to represent a shallow Semi-perched Aquifer system overlying the UAS and LAS in the study area, allowed simulation of groundwater conditions at the near-surface, but did not significantly improve calibration in the deeper aquifers, where most groundwater extractions occur.

1.3 PURPOSE AND SCOPE

United, FCGMA, and other stakeholders tasked with management of groundwater resources in the study area have been working toward quantifying sustainable yields and mitigating impacts of groundwater overdraft. In 2011, United and FCGMA realized that to effectively interpret historic groundwater-level trends and, more importantly, forecast impacts of potential future groundwater extraction, recharge, and management scenarios under consideration within the study area, an updated and more detailed conceptual model of hydrostratigraphy would be required, followed by construction and calibration of a higher-resolution numerical groundwater-flow model that (unlike earlier models) provides discrete simulation capabilities for each individual aquifer and aquitard. The purpose of the current modeling effort to date has been to construct the VRGWFM envisioned by United and others in 2011, and verify (via historical calibration, review, and sensitivity analysis) that it can adequately simulate the future occurrence and movement of groundwater within the study area.

Development of the current VRGWFM consisted of four primary tasks, including:

- **Update of Hydrostratigraphic Conceptual Model**: An updated hydrostratigraphic conceptual model for the Mound, Oxnard Plain, Forebay, Pleasant Valley, and West Las Posas basins was developed from review of geophysical and lithologic logs from hundreds of gas, petroleum, and water wells in the area, followed by preparation of detailed hydrostratigraphic cross sections, resulting in significant adjustment to the top and bottom elevations of aquifers and aquitards in key areas. Information used to support development of the hydrostratigraphic conceptual model, together with other hydrogeological data and information relevant to this modeling effort, is described in Section 2 of this report.

- **Numerical Model Construction**: Available data for aquifer geometry, hydraulic parameters, stresses (recharge and discharge), and boundary conditions were compiled, reviewed, and entered into the “packages” (model input files with specific functions) required for the numerical modeling software, MODFLOW-NWT (Niswonger and others, 2011), which is an updated version of McDonald and Harbaugh’s (1988) MODFLOW software package. Details of how the information from the hydrostratigraphic conceptual model and other required hydrogeologic data were input to the numerical model are described in Section 3 of this report.

- **<u>Calibration and Sensitivity Analysis</u>**: Following initial numerical model development, the transient calibration of the VRGWFM was conducted for the period from January 1985 through December 2012, and later extended to December 2015. United selected 1985 as the starting point for historical calibration of the VRGWFM chiefly because that is when pumping rates for individual wells in the FCGMA became consistently available; in addition, the quality and quantity of other groundwater data used for model input and calibration markedly increased in the 1980s compared to previous decades. Calibration of the VRGWFM was conducted iteratively during conceptual and numerical model development. This process continued until: a) calibration targets were achieved at key locations, or b) a point of diminishing returns was reached, where further improvement in calibration was negligible. After internal and external model review efforts had begun and no major concerns were raised regarding development and calibration of the VRGWFM, a sensitivity analysis was conducted for the purpose of determining the degree to which model output was influenced by adjustment of model input parameters (within a reasonable range).

- **<u>Review</u>**: After the differences between the numerical model and the conceptual model were resolved and progress made on initial model calibration, internal and external reviews of the model began. Review continued throughout model calibration, and model input revised as necessary in response to reviewer comments.

The VRGWFM is anticipated to be used in support of United's and FCGMA's groundwater planning and management activities, which will require predictive simulations of potential future pumping, recharge, and land- and water-use scenarios in the study area. United intends to use the model as a planning tool to maximize the regional benefits of its conjunctive use operationsand to forecast effects of water-supply projects operated by other local agencies. The FCGMA may elect to use the model to evaluate the effectiveness of potential groundwater management strategies and regulatory policies on eliminating overdraft and saline-intrusion in the coastal areas of the Oxnard Plain.

The content and structure of this report conforms to USGS guidance for documenting groundwater flow models, and includes the following "specific topics that should be addressed in reports that describe studies in which simulation is used" (Alley, 1996):

1. "Describe the purpose of the study and the role that simulation plays in addressing that purpose" (Section 1).
2. "Describe the hydrologic system under investigation" (Section 2).
3. "Describe the mathematical methods used and their appropriateness to the problem being solved" (Section 3).
4. "Describe the hydrogeologic character of the boundary conditions used in the simulation of the system" (Sections 2 and 3).
5. "If the method of simulation involves discretizing the system (finite-difference and finite-element methods for example), describe and justify the discretized network used" (Section 3).
6. "Describe the aquifer system properties that are modeled" (Sections 2 and 3).
7. "Describe all the stresses modeled such as pumpage, evapotranspiration from ground water, recharge from infiltration, river stage changes, leakage from other aquifers, and source concentrations in transport models" (Sections 2 and 3).
8. "For transient models, describe the initial conditions that are used in the simulations" (Section 3).

9. “If a model is calibrated, present the calibration criteria, procedure, and results” (Section 4).
10. “Discuss the limitations of the model’s representation of the actual system…” (Sections 4 and 5).

This report documents construction, historical calibration, and sensitivity analysis of United’s current version of the VRGWFM, as of June 2018. Moving forward, as United applies the VRGWFM to estimate the effects of past or future conditions or stresses on groundwater conditions in the study area, separate memoranda or reports will be prepared by United describing the goals and outcomes of those modeling efforts. Any significant updates or modifications made to the VRGWFM as required to conduct such investigations will also be described in these memoranda or reports.

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2 HYDROGEOLOGIC CONCEPTUAL MODEL

This section provides a summary of the hydrogeologic conceptual model for the study area, focusing on those aspects of basin geology and hydrology that are relevant to development of the VRGWFM. As recommended in DWR modeling guidance (Joseph and others, 2016), "The development of a mathematical model starts with assembling applicable information relevant to the basin or site-specific characteristics. A detailed HCM (hydrogeologic conceptual model) forms the basis of the model by providing relevant physical information of the aquifer and surface systems, as well as applicable boundary conditions of the basin and stressors (such as pumping and artificial recharge)." More detail regarding historical groundwater conditions in the study area can be found in:

- Mann, 1959 ("A Plan for Groundwater Management—United Water Conservation District")
- Mukae and Turner, 1975 ("Ventura County Water Resources Management Study-Geologic Formations, Structures and History in the Santa Clara Calleguas Area")
- Hanson and others, 2003 ("Simulation of ground-water/surface water flow in the Santa Clara-Calleguas ground-water basin, Ventura County, California, U.S. Geological Survey Water-Resources Investigations Report 02-4136")

In addition, the FCGMA released preliminary draft Groundwater Sustainability Plans (GSPs) that provide comprehensive descriptions of groundwater occurrence and movement in the Oxnard Plain (including Forebay), Pleasant Valley, and Las Posas basins from 1985 through 2015 (Dudek, 2017a, 2017b, and 2017c). These plans are currently available on the FCGMA's website (http://fcgma.org/component/ content/article/8-main/115-groundwater-sustainability-plans).

This section also presents new data and revisions to the hydrostratigraphic conceptual model resulting from United's ongoing update effort. As noted previously in this report, past groundwater flow models represented the hydrogeologic system in the study area using just two or three layers to represent the seven aquifers and six aquitards present in the study area. In order to construct the VRGWFM in a manner that explicitly and accurately represents all 13 of these hydrostratigraphic units, including some important lateral variations occurring within and between groundwater basins, United staff made a significant effort to review available lithologic data and revise the hydrostratigraphic conceptual model for the study area. Section 2.6 of this report provides documentation of this updated conceptual model, which incorporates some important changes in the understanding of the characteristics of aquifers and aquitards in the study area based on United's review of the data.

The descriptions provided in this section of the various geographic, climatic, geologic, hydrologic, and cultural conditions occurring in the study area that influence groundwater flow and were incorporated into the VRGWFM during its construction and calibration are extensive. To help the reader keep track of which parameters and stresses play significant roles in regional flow and model development, the conceptual model can be distilled down to the following key points or elements:

1. Most groundwater in the study area is stored in, and flows through, two aquifers comprising the UAS and four aquifers comprising the LAS. A relatively small quantity of groundwater also occurs in the uppermost (shallow) aquifer system, referred to as the Semi-perched Aquifer in the Oxnard coastal plain area (where a thick clay unit is present between this shallow aquifer and the underlying UAS). Due to the limited quantity and poor quality of groundwater typically found in the shallow aquifer system, it is largely undeveloped.
2. Most of the adjacent groundwater basins within the study area are in hydraulic connection with each other, and groundwater within each aquifer can flow from one basin to an adjacent basin with moderate to no impediment (depending on hydraulic conductivity and gradients) in most instances.
3. Groundwater generally flows from areas of recharge to areas of discharge. The largest single source of groundwater recharge to the UAS and LAS in the study area is, by far, the artificial recharge introduced to the Forebay by United. In the Forebay, the sediments comprising the shallow aquifer system have been tectonically uplifted and eroded away, exposing the highly permeable aquifers of the UAS at land surface, providing an ideal situation for recharge in spreading basins. Some of this artificial recharge percolates downward to the aquifers of the LAS in the Forebay and adjacent basins in response to vertical hydraulic gradients between the UAS and LAS. Smaller quantities of groundwater recharge the UAS and LAS as a result of:
    a. groundwater underflow from upgradient basins,
    b. mountain-front and stream-channel recharge,
    c. seawater intrusion near the coast,
    d. downward flux from the shallow aquifer system, and
    e. deep percolation of precipitation, agricultural return flows, municipal/industrial return flows, and treated wastewater in the few areas where the UAS and LAS are exposed at land surface.
4. Most groundwater discharge from the UAS and LAS in the study area occurs via pumping from hundreds of water-supply wells located in the Oxnard Plain and Pleasant Valley basins, and a smaller number of wells in the Mound, West Las Posas, and Santa Paula basins.
5. Because the preponderance of recharge in the study area occurs in the Forebay, while most discharge occurs as a result of pumping in surrounding basins, groundwater in the UAS and LAS typically flows radially outward from the Forebay to the adjacent basins. However, two notable disruptions to this pattern can occur, as follows:
    a. When United's recharge operations are limited due to drought conditions, groundwater elevations in the UAS have periodically dropped below sea level as far north as the northern part of the Forebay area, and the typical pattern of radial groundwater flow outward from the Forebay becomes replaced by landward gradients at the coastline areas across the Oxnard Plain basin, resulting in groundwater flux and seawater intrusion from the adjacent Pacific Ocean.
    b. A large groundwater-elevation "cone of depression" has persisted for decades in the LAS in the agricultural area east of Oxnard and south of Camarillo, as a result of the concentration of water-supply wells in this area and distance from the Forebay (where most recharge occurs). Groundwater elevations in this cone of depression have long been tens to over 100 feet below sea level, producing landward hydraulic gradients and strong vertical gradients from the UAS to the LAS that contribute to seawater intrusion in the LAS.

6. In the shallow aquifer system, recharge occurs throughout the study area (mostly via deep percolation of precipitation, agricultural and municipal/industrial return flows, and treated wastewater), as does groundwater discharge (mostly via evapotranspiration and tile drains, with relatively small amounts discharging to the lower Santa Clara River and the Pacific Ocean). Because most land in the study area is used for municipal, industrial, or agricultural purposes, and agricultural irrigation occurs year-round, groundwater elevations in the shallow aquifer system typically remain stable at elevations within approximately 5 to 8 feet of land surface (where most evapotranspiration occurs and tile drains are installed, respectively).

Details and supporting references for hydrogeologic conditions in the study area are provided in the following sub-sections.

2.1 PHYSIOGRAPHY AND LAND USE

The major physiographic features within the study area include the Oxnard coastal plain, the Camarillo Hills, the western portion of the Las Posas Valley, and a portion of the Pacific Ocean that overlies the regional aquifers, as shown on Figure 2-1. This area comprises approximately 176,000 acres (108,000 acres on land, 68,000 acres under the Pacific Ocean), bounded by:

- the Sulfur Mountain foothills, mouth of the Santa Clara River Valley, and South Mountain to the north
- the eastern Las Posas Valley, Santa Rosa Hills, Santa Rosa Valley, and Santa Monica Mountains to the east
- the southern margin of the Ventura Shelf and Hueneme-Mugu Shelf on the floor of the Pacific Ocean (3 to 10 miles offshore from the coastline to the south and west)

The dominant physiographic feature of the onshore portion of the study area is the relatively flat-lying Oxnard coastal plain, which slopes gently southwestward from elevations of approximately 150 feet at the base of South Mountain and the Camarillo Hills, to sea level at the coastline (Figure 2-1). The City of Oxnard (the most populous in Ventura County) and much of the farmland within the study area occupy the Oxnard coastal plain. North and east from the Oxnard coastal plain, land surface rises more steeply to the hills and valleys at the margins of the study area, with elevations typically ranging from 300 to 600 ft msl. The dominant physiographic features of the offshore portion of the study area are the gently sloping Ventura and Hueneme-Mugu Shelves, with elevations ranging from 0 ft bls at the coast to approximately -400 ft msl at their southwest margin, and the Hueneme and Mugu submarine canyons (Figure 2-1).

While the modern extent of the lower portion of the Santa Clara River watershed occupies a limited portion of the model domain, the hydrology of the Santa Clara River is of primary significance across the Oxnard coastal plain. The total area of the Santa Clara River watershed is 1,634 square miles, most of which is outside of the study area. Land surface elevations in the watershed range from sea level at the coast to 8,847 ft msl at Mount Pinos. The Santa Clara River watershed encompasses three significant tributary watersheds—those of Santa Paula, Sespe, and Piru Creeks (Figure 1-1). Much of the discharge in the Santa Clara River is derived from streamflow originating in the mountain regions drained by these tributaries. More than half of the study area (including the West Las Posas, Pleasant Valley, and east part of the Oxnard Plain basins) is within the Calleguas Creek watershed, which has an area of 343 square miles (most of which also lies outside of the study area), with elevations ranging from sea level at Mugu Lagoon to approximately 3,600 ft msl in the Santa Susana Mountains northeast of Simi Valley. Rainfall and runoff volumes from the valley and foothill areas of the Calleguas Creek watershed are smaller than those from the Santa Clara River watershed.

Figure 2-2 shows the extent of farmland and "urban/built-up" (municipal and industrial) land in southern Ventura County as of 2016, based on data available online from the California Department of Conservation's Farmland Mapping and Monitoring Program (http://www.conservation.ca.gov/dlrp/fmmp). Approximately 14,000 acres of land along the coastline and in the floodplain of the Santa Clara River within the study area is neither farmland nor urban/built-up land, instead consisting of State and County park land, privately-held wetlands and nature preserves, and open space within Navy Base Ventura County (primarily the Point Mugu facility) and the Channel Islands Air National Guard Station. Figure 2-2 also shows the expansion of urban and built-up land since 1984, immediately prior to the beginning of the historical model calibration period, in 6- to 8-year increments. Inspection of Figure 2-2 indicates that the largest expansion of urban/built-up land within the study area during this period occurred by 1990, chiefly in northwest and northeast Oxnard. Total urban and built-up land in the study area as of 2016 was approximately 44,000 acres. The vast majority of farmland in the study area is used for growing fruits and vegetables, dominated by avocadoes, lemons, strawberries, and celery (Ventura County Office of the Agricultural Commissioner, 2016). Total farmland in the study area as of 2016 was approximately 50,000 acres. The estimated gross value of Ventura County agriculture in 2015 was $2.2 billion (Ventura County Office of the Agricultural Commissioner, 2016), with approximately half of that value coming from the study area (Highland Economics, LLC, 2017).

Historical census data (available at http://docs.vcrma.org/images/pdf/planning/demographics/Census_Pop_Ventura_Co_1850-2000.pdf) indicate that the population of the four incorporated cities within or adjacent to the study area has increased from 8,573 as of the 1920 census (Port Hueneme did not exist and Camarillo was not incorporated at that time), to 243,910 in 1980, to 400,897 in 2015 (estimated by the U.S. Census Bureau, "American Community Survey 5-Year Estimates" at https://www.census.gov/programs-surveys/acs/). Population growth in each city is summarized as follows:

City	1920 Census	1980 Census	2015 Estimate
Oxnard	4,417	108,195	203,495
Port Hueneme	*did not exist*	17,803	22,058
Camarillo	*not incorporated*	44,138	66,445
Ventura	4,156	73,774	108,899
Sum:	*8,573*	*243,910*	*400,897*

The greatest population growth in or adjacent to the study area since 1980 has occurred in Oxnard, consistent with the land-use mapping (Figure 2-2), which indicates most of the growth in urban and built-up land from 1984 to 2016 has occurred in Oxnard.

2.2 CLIMATE

According to the Köppen-Geiger climate classification system (Peel and others, 2007), the climate type for most of the study area is classified as warm-summer Mediterranean (Csb), grading to a hot-summer Mediterranean (Csa) climate type along the inland margins of the study area (see Oregon State University's "Parameter-elevation Regressions on Independent Slopes Model" [PRISM] website at http://prism.oregonstate.edu for data and additional information). The average annual maximum temperature at Oxnard Airport, near the center of the study area, is 74 degrees Fahrenheit (occurring in August), and the average annual minimum temperature is 47 degrees (in December). Mediterranean climates are characterized by warm, dry summers and cool winters with variable precipitation. They typically occur along the mid-latitude western edges of continents, which are subject to polar fronts in winter but are dominated by subtropical high-pressure systems during summer and fall, blocking most storms. Cold ocean currents along the coast allow a cool marine layer to intrude into coastal valleys in these zones during early summer, moderating temperatures and often producing fog. As a result of the Mediterranean climate of coastal California, very little rain falls in the study area during the peak growing season, when warm temperatures increase both evaporation rates and agricultural productivity. Therefore, application of groundwater pumped from wells has been used by farmers in the study area for over a century to supplement rainfall as a source of irrigation water.

The annual precipitation in the study area tends to cycle between periods of above-average and below-average rainfall, as shown on Figure 2-3, which illustrates annual water-year (WY) precipitation and cumulative departure from average precipitation at Oxnard Airport (VCWPD Station 168), together with pan evaporation at United's El Rio spreading grounds (VCWPD Station 239). These stations were selected as examples for the study area based on their central locations and long period of record. During development of the VRGWFM, precipitation data from 70 rain gauges in the region (many of which are shown on Figure 2-1) were used to interpolate monthly precipitation across the study area; analysis of these data indicate that average annual precipitation in the study area from 1985 through 2015 was 13.4 inches, with more than half of precipitation occurring in winter and much of the remainder occurring in spring and fall. Average annual precipitation rates in the study area are lowest near the coast and increase inland (north and east), coincident with increasing land-surface elevation. A strong orographic effect on rainfall occurs in central and northern Ventura County, where land surface elevation ranges from 2,500 to 8,800 ft msl; annual rainfall exceeds 30 inches per year on the higher mountains of the Santa Clara River watershed in Ventura County (outside of the study area). Virtually all of the precipitation in the study area consists of rain; however, 2 to 4 feet of snow falls annually, on average, on the highest peaks in the watershed, occurring north of the study area.

In addition to the wet-winter/dry-summer pattern of a Mediterranean climate, rainfall in coastal California, including Ventura County, is also influenced by multi-year, cyclical climate phenomena, most importantly the El Niño-Southern Oscillation and the Pacific Decadal Oscillation. Most of the recorded extreme rainfall and flooding events in the southwestern U.S., including Ventura County, have occurred during "El Niño" years (e.g. 1992, 1995, 1998, 2005), characterized by warmer-than-normal sea-surface temperatures in the central and eastern Pacific Ocean (see the U.S. National Oceanic and Atmospheric Administration's website at https://www.ncdc.noaa.gov/teleconnections/enso/ for data and information). However, not all El Nino years produce abundant precipitation in the region.

Average annual pan evaporation recorded by United at its El Rio spreading grounds (approximately 4.5 miles north of the Oxnard Airport) for the period of record (1974-2013) was 63.2 inches, approximately four times the annual average precipitation. Pan evaporation is measured as a proxy for the evaporation and transpiration (evapotranspiration [ET]) processes that remove water from the surface and subsurface of soil following a rainfall event. Despite this annual-average excess of potential ET relative to precipitation in the study area, during the wet season the rate of precipitation occasionally exceeds ET, resulting in rainfall percolating through the soil to become groundwater recharge, especially during years with average to above-average rainfall amounts. Recharge is discussed further in Section 2.7 of this report.

2.3 SURFACE-WATER HYDROLOGY

Within the study area, there are several surface-water bodies that interact with groundwater to a significant degree, as shown on Figure 2-4. In the Oxnard Plain basin, fresh surface-water bodies that are in hydraulic communication with groundwater include parts of the Santa Clara River (including its estuary), Revolon Slough/Beardsley Wash, McGrath Lake, Ormond Beach wetlands, and Mugu Lagoon wetlands (Figure 2-4). In the Pleasant Valley basin, fresh surface-water bodies that are hydraulically connected to groundwater in some reaches include Conejo Creek and Arroyo Las Posas, which converge and become Calleguas Creek (which overlies both the Oxnard Plain and Pleasant Valley basins). In addition, a significant quantity of imported surface water is used in the study area, then discharged to streams as treated wastewater. Each of the above surface-water bodies, as well as imported water, is discussed in more detail below.

The interaction of surface water with groundwater near these surface-water bodies can affect the occurrence, movement, and quality of groundwater in the shallow groundwater system, and thus is relevant to development of the VRGWFM. Furthermore, areas of interaction between surface water and shallow groundwater commonly are of ecological importance, and are a focus of evaluations of groundwater sustainability. This section focuses on those inland bodies of water, including freshwater streams and brackish-water lagoons and wetlands along the coast that interact with shallow groundwater. The interaction of groundwater (both shallow and deep) with seawater in the Pacific Ocean is also important, but has distinct effects on groundwater elevations and quality; therefore, groundwater-seawater interaction is discussed separately in Section 2.7.

The primary sources for fresh surface water in the study area include:

- Overland flow of stormwater runoff (much of which eventually collects in stream channels and storm drains),

- Continuation of surface-water flows from upstream watersheds into the study area (generally in defined stream channels, as opposed to overland flow)
- Collection and diversion of treated wastewater or collected stormwater runoff into streams, wetlands, and natural or artificial ponds, lakes, or basins,
- Discharge of shallow groundwater to stream channels, lakes, and wetlands.

Direct interaction between surface-water and groundwater occurs where there is exchange of water between a surface-water body and the water table (i.e., where the saturated zone of an aquifer intersects land surface, without an intervening unsaturated, or vadose, zone). In areas where an unsaturated zone of significant thickness occurs between a surface-water body and the water table, the interaction is indirect and effectively one-way—surface water can percolate downward to become groundwater recharge, but groundwater cannot discharge to land surface or have an effect on surface-water flows. Accordingly, direct hydraulic interaction usually occurs in surface water bodies that are predominantly perennial in nature, whereas ephemeral streams are predominantly decoupled from underlying aquifers because of the presence of an unsaturated zone between the stream channel and the water table, thus flow only in response to storm flows and/or artificial influx from sources such as drainage systems and wastewater discharges. The occurrence of coupled versus decoupled stream/aquifer systems fundamentally defines where the potential for impacts to streamflow can arise from upward or downward movement of the water table; perennial reaches are the only stream reaches that receive sustained groundwater discharge over long time periods. Furthermore, if a surface-water body is separated from an aquifer by one or more confining units, then groundwater pumping from the aquifer will have a limited (potentially negligible) effect on the surface-water body.

2.3.1 Santa Clara River

The Santa Clara River is the largest fresh surface-water body (in terms of both areal extent and discharge) in the study area (Figure 2-4). Its watershed extends well beyond the domain of the VRGWFM, with a total area of 1,634 square miles (Figure 2-1). The average discharge of the Santa Clara River at Freeman Diversion, which is located immediately upstream from the northern boundary of the Forebay (11 miles inland from the Pacific Ocean), was 287 cubic feet per second (208,000 AF/yr) during the period of record (WY 1956 through 2016). However, annual discharge of the Santa Clara River, like most largely ephemeral streams in southern California, is highly variable, ranging from 8 cubic feet per second (5,800 AF/yr) in WY 2016 to 1,590 cubic feet per second (1,150,000 AF/yr) in WY 2005, as shown on Figure 2-5. The primary sources of surface-water flow in the Santa Clara River within the study area are surface runoff originating as precipitation in the watershed and groundwater discharge to the river (in a few locations). The majority of the flow occurring in the Santa Clara River in the study area discharges to the Pacific Ocean or infiltrates in the dry, sandy, ephemeral reach of the river in the Forebay area. Prior to 1985, a minor quantity of surface water may have been diverted from the river within the study area for agricultural use, but this has not been the case in recent decades.

Within the study area, the Santa Clara River is perennial only within the 5-mile reach that is closest to the Pacific Ocean, from approximately ¼-mile upstream of U.S. Highway 101 to the mouth of the river (Figure 2-4). Baseflow in this reach (consisting of discharge of shallow groundwater to the stream channel) has been estimated to be approximately 2 cfs (1,500 AF/yr; Stillwater Sciences, 2017). Phreatophytic plants are abundant in the river channel throughout this reach, likely taking up shallow groundwater that would otherwise contribute to baseflow. Therefore, the estimated baseflow likely does not represent all of the rising groundwater in this reach. Historical observations from the 1800s indicate that the 6-mile reach of the river from just north of U.S. Highway 101 to the Santa Paula basin has typically been ephemeral (Beller and others, 2011), except for extended periods of flow during portions of extremely high rainfall years. The locations of the typically perennial and ephemeral reaches correspond to the presence and absence, respectively, of the Semi-perched Aquifer (which is not used for significant groundwater production) and the underlying confining unit (the Clay Cap), which separates the Semi-perched Aquifer from the Oxnard Aquifer (the uppermost of the aquifers used for groundwater production in the region, as discussed further in Section 2.5). Where the Semi-perched Aquifer is present (from approximately ¼-mile upstream of the U.S. Highway 101 bridge to the coastline), groundwater typically discharges to the Santa Clara River. Such a condition is often referred to as "rising groundwater" in a "gaining reach" of stream channel. The ultimate source of the rising groundwater in this gaining reach is a mixture of applied irrigation water (agricultural and municipal) and rainfall that has percolated through the farmland north and south of the river to recharge the Semi-perched Aquifer.

Annual discharge totals recorded at stream gauges on the Santa Clara River (since 1950) are shown on Figure 2-5. The upper chart shows records for a gauge at Freeman Diversion, which is located in the Santa Paula basin 0.6 miles upstream (east) from the margin of the Forebay and just outside of the study area for this investigation. The lower chart on Figure 2-5 shows records for a series of three gauges located downstream from Freeman Diversion (Figure 2-4). Note that discharge was not recorded from 2005 through 2007 downstream from Freeman Diversion due to gauging station 708a being destroyed during record-high flows in 2005. United diverts some of the surface water flows in the Santa Clara River at Freeman Diversion to its recharge facilities (spreading basins) and two of its pipelines (Pleasant Valley Pipeline [PVP] and Pumping Trough Pipeline [PTP]), as discussed further in Sections 2.7 and 2.8. Due to the presence of bedrock immediately underlying the river bed near Freeman Diversion, the Santa Clara River flows perennially at the Freeman Diversion, except in periods of extended drought. Downstream of the Freeman Diversion, in the Forebay, the presence of highly permeable stream-channel deposits and the Oxnard Aquifer immediately underlying these deposits allows this surface water to readily percolate back into the ground. For these reasons, even in drier years some discharge (typically less than 20,000 AF) may be recorded at the Freeman Diversion gauge, while no discharge is recorded at the downstream gauges in the Forebay (upstream of the perennial reach near the ocean). Following major rainfall events, however, the volume of flow in the river can temporarily exceed infiltration capacity of the river bed, allowing the river to flow all the way through the Forebay to the Pacific Ocean for periods lasting from several hours to several days. Such flows do not occur every year.

In addition to runoff of precipitation and rising groundwater, treated wastewater has been (and, in some cases, still is) discharged to the Santa Clara River in the study area. Small wastewater treatment plants (WWTPs) in Saticoy and southeast Ventura (the Montalvo neighborhood) formerly discharged an estimated 300 AF/yr or less to the river (Figure 2-4), but now discharge their treated wastewater to percolation ponds, to recharge groundwater. Recharge of wastewater in the study area is discussed further in Section 2.7. In addition, Ventura operates a WWTP near the coast, which discharges approximately 9,000 AF/yr into the estuary at the mouth of the Santa Clara River. Because this discharge occurs so close (within ½ mile) to the Pacific Ocean in a coastal lagoon, its expected hydraulic effect on the underlying (semi-perched) aquifer is of minor significance compared to tidal influences on groundwater levels and gradients in this area.

2.3.2 Revolon Slough and Beardsley Wash

Revolon Slough and Beardsley Wash are the names applied to two reaches of a single continuous channel that conveys storm water and agricultural return flows from the western Las Posas Valley and central Oxnard coastal plain to Mugu Lagoon (Figure 2-4). North of U.S. 101, the channel is referred to as Beardsley Wash, and it is in a largely natural state (few manmade levees) in the western Las Posas Valley. On the Oxnard coastal plain, the channel is constrained by manmade earthen or concrete levees along most of its course to Mugu Lagoon (it is referred to as Revolon Slough south of U.S. 101), and most of its flow consists of irrigation return flows discharged from tile drains beneath agricultural fields. Revolon Slough/Beardsley Wash may, in places, receive a small influx of groundwater from the Semi-perched Aquifer, especially in the four miles of channel upstream of Mugu Lagoon where the channel is unlined. Flow in Revolon Slough is perennial; annual discharge rates are shown on Figure 2-6. Revolon Slough/Beardsley Wash is not in direct hydraulic communication with the deeper aquifers that are used for groundwater production in the region.

2.3.3 McGrath Lake, Ormond Beach wetlands, and Mugu Lagoon wetlands

McGrath Lake, the Ormond Beach wetlands, and the Mugu Lagoon wetlands (Figure 2-4) are hydraulically connected to, and exchange fresh- to brackish-water with, the Semi-perched Aquifer near the coast on the Oxnard coastal plain. These lakes and wetlands occur in shallow depressions where the southwesterly flow of surface water and shallow groundwater slows as hydraulic gradients flatten near the constant-head boundary represented by the Pacific Ocean, or is reversed due to higher groundwater elevations present below coastal dunes, which have 6 to 15 feet of topographic relief above the surrounding landscape. McGrath Lake is approximately 1 mile south from the mouth of the Santa Clara River; the Ormond Beach wetlands lie between Mugu Lagoon and Port Hueneme; and the Mugu Lagoon wetlands surround the tidally-influenced Mugu Lagoon. These surface-water bodies and wetlands are much too shallow to be in direct hydraulic communication with the Oxnard Aquifer or any of the deeper aquifers used for groundwater production in the region. These water bodies and wetlands act as groundwater "sinks" (areas where groundwater is discharged from the Semi-perched Aquifer) during much of the year, as a result of evaporation from surface water exposed directly to the atmosphere. In addition, transpiration from phreatophytes in and around these features likely contributes further to groundwater discharge rates. During the wet season, these lakes and wetlands may temporarily act as "sources" of groundwater (recharge areas) for the Semi-perched Aquifer, when rainfall exceeds ET rates.

2.3.4 Conejo Creek

Conejo Creek, a tributary of Calleguas Creek, flows along the eastern margin of the Pleasant Valley basin for nearly five miles upstream from its confluence with Calleguas Creek (Figure 2-4). Conejo Creek is formed by the confluence of Arroyo Conejo and Arroyo Santa Rosa, which drain the Conejo Valley and the Santa Rosa Valley, respectively. The Arroyo Conejo watershed includes much of the City of Thousand Oaks as well as the City's Hill Canyon WWTP. Streamflow occurs through the dry months of the year, primarily due to the discharge of reclaimed water from the Hill Canyon WWTP. This plant serves a population of more than 120,000 in the City of Thousand Oaks. The contribution of reclaimed water (treated wastewater) to Conejo Creek had made it a reliable source for diversions for irrigation supply. Other creeks with watersheds of this size in Ventura County, when left in their natural state, are typically dry or have very little flow throughout the summer and fall months.

In summer 2002, the Camrosa Water District completed construction of the Conejo Creek Diversion project and began diverting surface water from Conejo Creek near Highway 101 in Pleasant Valley basin for agricultural use. This diverted water is conveyed to Pleasant Valley County Water District for irrigation deliveries. A minimum of 6 cfs of flow must remain in the creek below this diversion for habitat maintenance purposes (SWRCB, 2012). A variable portion of this 6 cfs left in Conejo Creek reaches Calleguas Creek, approximately 1.5 miles downstream (Figure 2-4).

Annual flows in Conejo Creek at gauges 800 and 800A (above Highway 101 and at Ridge View Street in Camarillo, respectively) are shown on Figure 2-7. The Semi-perched Aquifer and an underlying fine-grained aquitard are thought to be present beneath Conejo Creek in Pleasant Valley basin. Shallow groundwater is thought to be a minor contributor to perennial flow in Conejo Creek in Pleasant Valley basin, and the creek is separated from the deeper aquifers used for water supply in the basin by the presence of underlying fine-grained deposits.

2.3.5 Arroyo Las Posas

Arroyo Las Posas flows into the northern Pleasant Valley basin from the adjoining East Las Posas basin through a gap between the Camarillo Hills and the Santa Rosa Hills (Figure 2-4), often referred to as the "Somis Gap." Arroyo Las Posas is usually perennial in its most-downstream reach within the East Las Posas basin, but all of its baseflow infiltrates through the stream channel shortly after entering the Pleasant Valley basin. Annual flows in Arroyo Las Posas at Highway 101 are shown on Figure 2-8. As described by Bachman (2016), baseflow in Arroyo Las Posas is a mixture of natural dry-weather flows, discharges from upstream WWTPs, discharge from dewatering wells in western Simi Valley, and agricultural tail waters. The terminus of the baseflow historically occurred in the East Las Posas basin, but in the early 1990s began to move downstream as the East Las Posas basin began to fill with groundwater as a result of higher baseflow contributions from Simi Valley. During the drought that began in 2012, the terminus of the baseflow began to retreat back upstream into the East Las Posas basin. In the future, baseflow in Arroyo Las Posas may decrease as a result of increased use of recycled water (i.e., the existing discharges from upstream WWTPs) in the South Las Posas basin.

Bachman (2016) reports that Arroyo Las Posas baseflow entering the Pleasant Valley basin has typically infiltrated along a 1,400-foot long reach of the creek at the northern margin of the Pleasant Valley basin. Bachman (2016) also estimated that the next 5,500 ft of stream channel can infiltrate some or all of the storm flows in Arroyo Las Posas that reach the Pleasant Valley basin during an individual storm event. In this area of the northern Pleasant Valley basin, the Semi-perched Aquifer is absent and surface water in Arroyo Las Posas readily percolates into the underlying regional aquifer system (Hopkins Groundwater Consultants, Inc., 2008). In summary, this creek's chief hydrogeologic role in the study area is as a source of recharge to the underlying regional aquifer system. Arroyo Las Posas is not perennial in the Pleasant Valley basin and lies above (is not hydraulically connected to) the water table.

2.3.6 Calleguas Creek

Calleguas Creek extends from the confluence of Arroyo Las Posas and Conejo Creek downstream (southward) to Mugu Lagoon and the Pacific Ocean (Figure 2-4). The sources of water to Calleguas Creek are a minimum flow of 6 cfs by Camrosa Water District below its diversion structure on Conejo Creek, discharges from the Camarillo Sanitary District WWTP next to Conejo Creek, and inflows from agricultural tile drains. Annual flows in Calleguas Creek at California State University Channel Islands are shown on Figure 2-9. The Semi-perched Aquifer is present throughout this area, but insufficient information is available to identify whether (and how much) shallow groundwater discharge from the Semi-perched Aquifer might also be providing a portion of the perennial flow in Calleguas Creek. Shallow groundwater is thought to be a minor contributor to perennial flow in the creek, which is separated from the pumped aquifers in the region by an aquitard below the Semi-perched Aquifer. However, within most its reach in the Oxnard Plain basin, the channel elevation of Calleguas Creek within its levees is higher than the surrounding land elevation. Under such conditions, discharge of groundwater to the creek would be highly unlikely.

2.3.7 Imported Surface Water

Imported surface water, primarily from northern California (via California State Water Project [SWP] aqueducts and pipelines), indirectly contributes to surface-water flows and groundwater recharge in the study area. As described above, most of the baseflow in Conejo Creek consists of reclaimed water from Thousand Oaks, which imports the vast majority of its municipal and industrial water supply via the SWP. Data provided by Calleguas MWD indicates that they, Camrosa Water District, and the Cities of Camarillo, Oxnard, and Port Hueneme, import an average of 22,000 AF/yr from the SWP, primarily for municipal and industrial use. Other water districts import smaller quantities of surface water from the SWP or groundwater from adjacent basins into the study area as needed to supplement their local groundwater supply. Approximately half of the SWP water imported by cities in the study area is used indoors and enters sewer systems, where a small percentage may leak out of sewer pipes and into underlying aquifers such as the Semi-perched Aquifer (where present). Camarillo's treated wastewater is discharged to Conejo Creek, while Oxnard and Port Hueneme have historically discharged their treated wastewater to the Pacific Ocean by means of an ocean-outfall pipe. Oxnard recently began treating a portion of their wastewater via an advanced water purification (AWPF) process, and is developing plans to store it in underlying aquifers for future use. The remaining half (approximately) of SWP water imported to cities in the study area is likely used for outdoor irrigation (landscaping), and some fraction of that water can percolate beyond the root zone to recharge underlying aquifers, most commonly the Semi-perched Aquifer. Recharge of wastewater and irrigation return flows are discussed further in Section 2.7 of this report. In addition, United imports up to 5,000 AF/yr of water from the SWP to Lake Piru or Castaic Lake, where it is released at optimal times for recharging groundwater in the Piru basin, upstream from the study area on the Santa Clara River. A fraction of these releases may ultimately reach the Mound, Oxnard Plain, and other basins in the study area as groundwater underflow from the Santa Paula basin.

2.4 GEOLOGY

Southern Ventura County is in the Transverse Ranges geomorphic province of California. Within this province, the axes of mountain ranges and valleys are oriented east-west rather than northwest-southeast as is typical in the adjacent Peninsular and Coastal Ranges geomorphic provinces. Most of the study area overlies an elongate, structurally complex syncline that trends east to west (Yeats and others, 1981), referred to as the Ventura structural basin. Active thrust faults border the Ventura structural basin, causing uplift of the adjacent mountains while the basin continues to deepen. The total stratigraphic thickness of upper Cretaceous, Tertiary, and Quaternary marine and terrestrial deposits in the Ventura structural basin reportedly exceeds 55,000 feet (Sylvester and Brown, 1988). Surface exposures of the major rock units and faults in the region are shown on Figure 2-10; hydrogeologically significant features are described below.

2.4.1 Geologic Units Present in Study Area

Geologic units (strata) exposed at land surface within the study area are commonly classified as follows, from youngest (top) to oldest (bottom):

- Recent (active) stream-channel deposits along the present course of the Santa Clara River and its tributaries;
- undifferentiated younger alluvium of Holocene age, covering most of the Oxnard coastal plain;
- Holocene- to Pleistocene-age alluvial-fan and stream-terrace deposits adjacent to surrounding mountains and the Santa Clara River, respectively;

- undifferentiated older alluvium of Holocene to late Pleistocene age, underlying the undifferentiated younger alluvium of Holocene age across most of the Oxnard coastal plain;
- semi-consolidated sand, gravel, and clay deposits of the San Pedro Formation (also referred to as the Saugus Formation by some researchers), of late Pleistocene age; and,
- sandstone, siltstone, and shale of the Santa Barbara Formation, of early Pleistocene age.

These exposed strata in the study area were classified based largely on their hydrogeologic characteristics, as these are the units that typically bear freshwater in usable quantities and are of primary interest for groundwater supply. Other researchers have divided these deposits in other, equally valid ways, based on their geomorphological or other characteristics (e.g., Mukae and Turner, 1975; Hanson and others, 2003).

Older (lower) strata, which are regarded as hydrologic bedrock in the region, typically are poorly permeable or contain water that is too brackish or saline for municipal or agricultural uses. These strata include (following the descriptions of Burton and others, 2011):

- marine siltstones, sandstones, and conglomerates of the Pico Formation, of Pliocene or early-Pleistocene age;
- terrestrial sandstones and shales of the Repetto Formation, of Pliocene age;
- shale of the Monterey Formation, of late Miocene age;
- basalt and other extrusive (mostly) volcanic rocks of the Conejo Volcanics, of mid-Miocene age;
- marine siltstones and sandstones of the Topanga and Vaqueros Sandstones, of early Miocene age; and,
- terrestrial sandstones and claystones of the Sespe Formation, of Oligocene age.

2.4.2 FAULTS

In some cases, geologic faults can be pathways or barriers for groundwater movement. In crystalline or cemented rocks, faults can create fractures that act as conduits to groundwater flow. However, the aquifers within the study area consist of semi-consolidated sedimentary formations, which tend to create fine-grained, low-permeability "smear zones" when faulted, effectively producing weak to strong barriers to groundwater flow, particularly in the deeper aquifers. Within the study area, the trend of many, but not all, of the faults is west-southwest to east-northeast, consistent with regional structural trends (Figure 2-10). The Ventura, Country Club, Oak Ridge, McGrath (sometimes referred to as Montalvo), and Bailey faults have previously been identified as significantly limiting or diverting groundwater flow (Mann, 1959; Mukae and Turner 1975; Weber and others, 1976). Additional faults in the study area identified by United and the USGS (Hanson and others, 2003) as limiting or diverting groundwater flow include the Springville, Camarillo, Simi-Santa Rosa, Long Canyon, Hueneme Canyon, Sycamore Canyon, and Somis faults, and an unnamed fault just southwest from Mugu

Lagoon (Figure 2-10). In general, the older (deeper) geologic units (e.g., LAS) show greater displacement across these faults than the younger (shallower) units (e.g., UAS); therefore, groundwater flow in the LAS can typically be expected to be more disrupted across faults than flow in the UAS. More details regarding effects of faults on groundwater flow in the study area can be found in the above-referenced works.

2.4.3 Folds

Similar to faults in the study area, the axes of major anticlines and synclines in the sedimentary strata tend to be oriented approximately west-southwest to east-northeast (Figure 2-10). Similar to the discussion of faulting, above, the works of Mann (1959), Hanson and others (2003), and other previous investigators provide more details on the potential effects of folds on groundwater flow within the study area. The folding is ongoing, with older strata (including the LAS) being more deformed than younger strata (UAS). The limbs of the folds are gently dipping within most of the freshwater-bearing strata in the study area; therefore, it is unlikely that the folds themselves commonly have a notable direct impact on groundwater flow. However, it is recognized that changes in thickness (which affects transmissivity), outcrop area (which affects where recharge occurs), and other hydrogeologic properties of strata can be indirectly influenced by fold geometry. The most important hydrogeologic effect of folding in the study area has been to uplift the strata in the Forebay area, such that the regional aquifers are exposed at land surface and can be readily recharged, both naturally and artificially.

2.5 HYDROSTRATIGRAPHIC UNITS

Strata with distinct hydrogeologic characteristics are commonly referred to as HSUs. Within the study area, 13 HSUs (7 aquifers and 6 aquitards) are currently recognized by United, and are generally grouped into three major "aquifer systems" by most investigators: Shallow, Upper, and Lower. This section provides a general description of these HSUs, based largely on reporting by previous investigators (Mann, 1959; Mukae and Turner, 1975; Hanson and others, 2003). Since 2012, United has been evaluating downhole geophysical and lithologic log for numerous water, oil, and gas wells in the region to develop an updated conceptual hydrostratigraphic model; results of that effort are discussed in Section 2.6.

2.5.1 General Characteristics

As noted above, the HSUs within the study area are typically grouped into three "systems" with distinct hydrogeologic characteristics, summarized in Table 2-1. The discussion presented in this section is intended to provide only a broad overview of the major HSUs present and their general characteristics; more information regarding the extents and hydraulic properties of each HSU is provided in Sections 2.6 and 3.4 of this report.

Table 2-1. Hydrostratigraphic Units in Study Area

System	Aquifer or Aquitard	General Characteristics
Shallow	Semi-perched Aquifer	Stream- and coastal-deposited sands and gravels with minor silt and clay interbeds, Holocene to recent age. Ranges from 0 to 200 feet thick (average thickness approximately 75 feet). Does not exist in the Forebay. Becomes hard to distinguish from underlying HSU in some parts of Pleasant Valley basin. Due to poor water quality and low yields, rarely used for water supply.
Upper Aquifer System (UAS)	Clay Cap	Silt and clay layers with interbedded sands, Holocene to recent age. Ranges from 0 to 160 feet thick (average thickness approximately 50 feet). Does not exist in the Forebay and northern Pleasant Valley basins. Becomes hard to distinguish from overlying and underlying units in some parts of Pleasant Valley basin. Limits downward migration of poor-quality groundwater from Semi-perched Aquifer to Oxnard Aquifer (and confines the Oxnard Aquifer).
	Oxnard Aquifer	Marine and non-marine sands, gravels, and cobbles, with clay and silt interbeds, of late-Pleistocene to Holocene age. Ranges from 0 to 265 feet thick (average thickness approximately 120 feet). Historically one of the most important and widely used aquifers in the Oxnard Plain basin.
	Oxnard-Mugu aquitard	Interbedded clay, sand, and gravel, of late Pleistocene age. Ranges from 0 to 240 feet thick (average thickness approximately 40 feet).
	Mugu Aquifer	Marine and non-marine sand and gravel with silt and clay interbeds, late-Pleistocene age. Ranges from 0 to 340 feet thick (average thickness approximately 160 feet).
Lower Aquifer System (LAS)	Mugu-Hueneme aquitard	Interbedded clay, silt, sand, and gravel of the upper San Pedro Formation, of late-Pleistocene age. Ranges from 0 to 70 feet thick in most areas, but increases to 590 feet thick in the area east of Port Hueneme. This aquitard thins in the Forebay area, and merges with the Hueneme-Fox Cyn. aquitard to become an aquitard between the Oxnard Aquifer and the Fox Cyn. Aquifer in the southeast Oxnard Plain basin, where the Hueneme Aquifer is absent.
	Hueneme Aquifer	Marine and non-marine interbedded sand, silt and clay, and minor gravel of the upper strata of the San Pedro Formation. Ranges from 0 to 1,500 feet thick (average thickness approximately 430 feet); absent from the southeast Oxnard Plain basin.
	Hueneme-Fox Cyn. aquitard	Marine and non-marine silt and clay, with interbedded sand and gravel, of the San Pedro Formation. Ranges from 0 to 200 feet thick (average thickness approximately 50 feet).
	Fox Cyn. Aquifer-upper	Marine interbedded fine to medium sand with stringers of gravel (80%), and silt, clay, and sandy clay (20%) of the San Pedro Formation. Ranges from 0 to 620 feet thick (average thickness approximately 270 feet).
	Mid-Fox Cyn. aquitard	Marine and non-marine silt and clay, with interbedded sand and gravel, of the basal San Pedro Formation. Ranges from 0 to 180 feet thick (average thickness approximately 50 feet).
	Fox Cyn.-Aquifer basal	Similar composition and age as Fox Canyon Aquifer-upper. Comprises the basal member of the San Pedro Formation. Ranges from 0 to 300 feet thick (average thickness approximately 125 feet).

Table 2-1. Hydrostratigraphic Units in Study Area

System	Aquifer or Aquitard	General Characteristics
	Fox Cyn.-Grimes Cyn. aquitard	Primarily silt and clay, with interbedded sand and gravel, of the basal San Pedro Formation or the upper Santa Barbara Formation, of early-Pleistocene age. Ranges from 0 to 500 feet thick (average thickness approximately 70 feet).
	Grimes Canyon Aquifer	Local sands and gravels in the upper Santa Barbara Formation. Ranges from 0 to 520 feet thick (average thickness approximately 200 feet). Present in parts of Oxnard Plain, West Las Posas, and Pleasant Valley basins; not present in Forebay or Mound basins.
Hydrologic bedrock		Older sedimentary and igneous rocks of low permeability and/or containing saline groundwater.
Information in this table is primarily from Mukae and Turner (1975), Mann (1959), and Hanson and others (2003), or new information from United's conceptual model update (Section 2.6 of this report).		

Schematic hydrogeologic cross sections A-A' and B-B' that conceptually illustrate the vertical (depth) relationships between the major aquifers are provided on Figure 2-11. The correlation of HSUs to geologic units is shown on Figure 2-12. The Semi-perched Aquifer is the sole HSU of the shallow aquifer system. The Semi-perched Aquifer is assumed to extend from land surface to the top of the underlying aquitard (the Clay Cap) in the area where the Clay Cap exists, which includes the Oxnard Plain basin (excluding the Forebay) and part of the Pleasant Valley basin. The Semi-perched Aquifer is unconfined and varies in composition from sand and gravel along the Santa Clara River to silty or clayey sand in other areas. The Semi-Perched Aquifer is believed to be continuous across most of the Oxnard Plain basin (excluding the Forebay). In the Forebay, folding has resulted in uplift of the underlying aquifer systems, and the Semi-perched Aquifer (and Clay Cap) have been eroded away, exposing the Oxnard Aquifer at land surface. The depositional history in the Pleasant Valley basin, which is in the Calleguas Creek watershed, is different from the Oxnard Plain and Forebay basin. In the Pleasant Valley basin, the shallow and the Oxnard Aquifer have increasing clay content from west to east, becoming less and less distinguishable from each other or the Clay Cap.

The UAS consists of two important confined, regional aquifers—the Oxnard and Mugu Aquifers; and two aquitards—the Clay Cap and the Oxnard-Mugu aquitard. These four HSUs consist of alluvial and near-shore marine deposits of Holocene to late Pleistocene age. The Oxnard and Mugu Aquifers are present throughout the Forebay and Oxnard Plain basins, transitioning into finer-grained, stratigraphically equivalent units with different hydrogeologic characteristics in the Mound and Pleasant Valley basins. The Oxnard Aquifer consists of a highly-permeable assemblage of marine- and non-marine sands, gravels, and cobbles, with clay and silt interbeds. The Mugu Aquifer consists of slightly older marine and non-marine sands and gravels, with interbedded silt and clay.

The LAS is more folded, tilted, and faulted than the UAS, and has been eroded along an unconformity that separates the UAS from the LAS (Turner, 1975). The Hueneme, Fox Canyon (main and basal members), and Grimes Canyon Aquifers comprise the LAS. Where they occur in the Forebay and Oxnard Plain basins, these aquifers correlate with the San Pedro and Santa Barbara formations of early- to late-Pleistocene age (Hanson and others, 2003). The aquifers of the LAS are isolated from each other vertically by relatively low-permeability silt and clay layers. The base of the LAS is considered to be the base of fresh water (Mukae and Turner, 1975). Beneath the LAS lies older sedimentary and volcanic rocks that are generally considered to contain brackish to saline water or to be poorly transmissive (Mukae and Turner, 1975), and are rarely used for water supply.

2.5.2 Hydraulic Parameters

Although many specific capacity measurements (and some aquifer tests or slug tests) have been conducted at water-supply and monitoring wells in the study area, estimates of hydraulic conductivity and storage coefficient (the key hydraulic parameters for groundwater modeling) for individual HSUs are generally lacking, for the following main reasons:

- Water-supply wells in the study area commonly are screened across multiple aquifers (and often across aquitards, as well), or the screened intervals only partially penetrate the aquifers that are intersected by the well;
- Most aquifer tests and specific capacity measurements have a duration of 2 to 24 hours, which is insufficient to evaluate the effects of other factors—such as delayed yield, leaky aquitards, or boundary effects—that can influence estimates of aquifer parameters;
- Most aquifer tests are for the pumped well only (no observation wells) or are affected by interference effects from nearby production wells turning on and off during aquifer tests;
- Very few wells (typically only monitoring wells) are screened solely in poorly producing zones, thus few data are available to estimate hydraulic parameters of the aquitards;

In addition to the above issues, it must be noted that even a properly conducted aquifer test is representative of a limited area around the pumped well and any observation wells measured during the test. Slug tests and specific capacity measurements are applicable to an even smaller area than aquifer tests, and are considered to provide only rough estimates of aquifer parameters. For these reasons, previous investigators have typically estimated aquifer parameters for the UAS and LAS (wells are commonly screened across multiple HSUs in each of these aquifer systems), rather than for individual aquifers within those aquifer systems.

2.5.2.1 Transmissivities and Hydraulic Conductivities

Mukae and Turner (1975) used specific capacity data to estimate transmissivities in the study area, which ranged from approximately 7,000 to 50,000 feet squared per day (ft^2/day) in the UAS, and 3,000 to 40,000 ft^2/day in the LAS. The USGS used the Mukae and Turner (1975) specific-capacity data, their own slug test data, and results of modeling to estimate transmissivities of <1,000 to 74,000 ft^2/day in the UAS and <1,000 to 27,000 ft^2/day in the LAS within the study area, as shown on Figures 2-13 and 2-14 (Hanson and others, 2003). The USGS divided these transmissivities by aquifer thickness to estimate horizontal hydraulic conductivities for input to their model, ultimately arriving at values ranging from <1 to 300 ft/day in the UAS, and <1 to 110 ft/day in the LAS. The USGS (Hanson and others, 2003) and Mukae and Turner (1975) recognized that hydraulic conductivity of the Oxnard Aquifer was higher than that of the Mugu Aquifer; therefore, the USGS's aggregate estimate of horizontal hydraulic conductivity for the UAS may underestimate the actual hydraulic conductivity of the Oxnard Aquifer, and overestimates the hydraulic conductivity of the Mugu Aquifer. Hydraulic conductivities of the aquitards in the study area have rarely been studied. Hydraulic conductivities for silt (which is the major component of the aquitards) are typically in the range from 0.001 to 10 ft/day (Heath, 1983). Neuman and Witherspoon (1972) conducted an aquifer test at a site in the southern Oxnard Plain using a single pumping well and multiple observation wells (piezometers), and estimated the vertical hydraulic conductivities of the Clay Cap and the Oxnard-Mugu aquitard at the test site to be 0.0078 ft/day and 0.0056 ft/day, respectively. Li and Neuman (2007) reevaluated the same data using a different approach and estimated the vertical hydraulic conductivities of the Clay Cap and the Oxnard-Mugu aquitard at the test site to be somewhat smaller, at 0.0060 ft/day and 0.0037 ft/day, respectively. It should be noted that these vertical hydraulic conductivity estimates represent only one aquifer test (the data were analyzed using two different methods by different researchers) at a single location in the Oxnard Plain basin; therefore, these estimates should not be assumed to be representative of vertical hydraulic conductivities across the entire domain of the VRGWFM.

2.5.2.2 Storage Coefficients

Field-testing for specific yield (for unconfined aquifers) and storage coefficient (for confined aquifers) generally requires observation-well data, which have been infrequently collected in the study area. Furthermore, such estimates of storage values from aquifer tests are even more sensitive than transmissivity to influence by the factors noted above that limit the usefulness of pumping test results for hydraulic conductivity and transmissivity. Therefore, Mukae and Turner (1975) relied primarily on reported typical literature values of specific yield, and the USGS (Hanson and others, 2003) relied on previous models in the region combined with theoretical values of storage coefficients computed from typical porosities, compressibility of water, and estimated thickness of HSUs. In addition, specific storage estimates were used in these calculations, using values derived from a few local aquifer tests and reported typical values for alluvial sediments. Considering the limited availability and reliability of aquifer-test-based estimates of specific yield and storage coefficients, the values used by the USGS were considered a reasonable starting point for this investigation, and were refined during model calibration (Section 4) in accordance with common model-construction practice. The USGS estimated specific yield to range from 10 to 19 percent and storage coefficients to range from $5x10^{-6}$ to $7x10^{-2}$ (unitless) in their model of the region (Hanson and others, 2003). As a point of comparison, Li and Neuman (2007) estimated that the storage coefficients for the Oxnard and Mugu Aquifers were $2.1x10^{-4}$ and $1.4x10^{-4}$ at their test site in the southern Oxnard Plain basin near Port Hueneme.

2.6 UPDATE OF HYDROSTRATIGRAPHIC CONCEPTUAL MODEL

In order to construct an improved numerical groundwater flow model that explicitly and accurately represented all of the major HSUs in the study area, United staff collected and reviewed more than 900 borehole resistivity logs (electric logs or "e-logs") from oil/gas and water wells within the model domain and nearby areas, with the goal of updating and refining the hydrostratigraphic conceptual model. This updated hydrostratigraphic model forms the basic "framework" required to define the geometry and layering of the numerical flow model, as described in Section 3.

The available borehole e-logs were reviewed to determine the depth and quality of the logs, and that locations of the wells were plotted appropriately. A subset of available e-logs (~575) was selected based on quality, depth and location, and sent to a private contractor to be digitized. The digitized logs were received in "log ASCII standard" (*.las) format, allowing import to RockWorks® (ver. 15), the software used to record aquifer picks and construct cross-sections. Lines for cross-sections were identified in GIS, where shapefiles of oil well and water well locations, faults, basin boundaries, surface geology and other pertinent features were available to aid in selection of optimal section lines. Alignments were selected to intersect locations of known structural and stratigraphic change in the subsurface while utilizing as many e-logs as practical. Land surface elevations for the well heads with e-logs were determined based on the USGS National Elevation Data Set digital elevation model of land surface within the model domain. E-logs from selected wells along the various sections were printed on plotter paper for identification of HSUs ("aquifer picks") and correlation of those units. Vertical exaggeration of the various plotted sections was determined by the depths of the well logs and the length of the section. Lithologic descriptions from wells along and near the lines of section were commonly noted on the working sections to help identify aquitards and aquifer units. Upon finalization of picks for a given section, depths of the various HSUs were entered into a RockWorks® database, along with notes supporting the aquifer picks as necessary.

As mentioned in Section 2.5 and shown in Table 2-1, thirteen HSUs consisting of seven aquifers and six aquitards were identified and picked on e-logs. The water-bearing HSUs identified by United generally conform to the traditional published aquifer delineations for southern Ventura County. With the location of e-logs and the picked HSU depth, thirteen surfaces (bottom elevation of the thirteen HSUs) were digitally interpolated using Kriging methods. The top elevation and thickness of each HSU are shown in Appendix A.

An early version of the hydrostratigraphic conceptual model (referred to herein as "basin conceptual model" [BCM] 11) relied on 159 e-logs to construct cross-sections covering the Oxnard Plain and the Mound basin, and included preliminary picks along a single section in the Pleasant Valley basin. Cross-section lines roughly following the alignment of those published by Mukae and Turner (1975) were included, so as to facilitate conformity with traditional published interpretations of aquifer units on the Oxnard coastal plain. Initially, the numerical model was constructed and calibration was started based on HSUs identified in BCM 11. As numerical model construction progressed, it was recognized that additional cross-sections were needed to provide sufficient data for HSU top and bottom elevations for critical areas such as the Oxnard Forebay and the onshore areas adjacent to the Hueneme and Mugu Submarine Canyons that are subject to saline intrusion. The additional cross sections resulted in adjustment of HSU picks in some areas. Additional cross-sections were also constructed for the Pleasant Valley basin, including the northernmost portion of the basin near Somis, where significant recharge associated with flow in Arroyo Las Posas is known to occur at times. Lastly, eight cross-section lines were added in the West Las Posas basin and HSUs were picked within that basin. The current version of the hydrostratigraphic model, BCM 13, relies on 414 e-logs, some of which are located just outside of the model domain, allowing extension of the cross-section lines to, and slightly beyond, basin boundaries. BCM 13 includes 13 layers (from top to bottom, Layers 1 through 13) representing each of the major hydrostratigraphic units in the study area. Most of the e-logs fall on one or more of the 43 cross-section lines, but a number of off-section wells were picked in areas where well density was poor or interpolated surfaces (representing tops and bottoms of HSUs in three dimensions) were considered to inadequately define HSU geometry. Figure 2-15 shows the location of the wells with e-logs used to develop BCM13, and the cross-section lines. A three-dimensional representation of the final hydrostratigraphic conceptual model is shown on Figure 2-16. The onshore portion of the model domain covers an area of approximately 169 square miles; 411 e-logs were picked within this area, resulting in a density of about 2.4 e-logs per square mile.

An additional 23 control points were added manually in specific areas to better define the geometry of known geologic structures. In the offshore portion of the model domain, few e-logs were available and some 12 additional offshore control points were added to represent the layering and thickness of HSUs as they exist near the coastline. In the Mound basin, control points were added to improve the interpolated surfaces defining the Ventura-Santa Clara River syncline (the wide spacing between wells with e-logs, combined with the tendency of the Kriging algorithm used for interpolation to excessively flatten structural folds if their axes were not sufficiently delineated, would have yielded an inaccurate representation of this syncline without addition of control points along the axis). Control points were also manually added along the northern portion of the West Las Posas basin at the base of the mapped outcrop of the San Pedro Formation, allowing the bottom of this unit to be more accurately represented in cross-sections and interpolated surfaces. Control points were also added near faults with significant vertical offset in order to more accurately represent these features. Several points were used along the Oakridge Fault which forms the basin boundary along the northern portion of the Oxnard Plain basin.

The following subsections describe key areas and issues in the hydrostratigraphic conceptual model of the study area that were better understood as a result of United's effort to develop BCM 13.

2.6.1 Areas of Aquifer Mergence

Throughout much of the model domain, aquitards of various thickness are known to exist between aquifers. However, in some areas, such as the Forebay and the northernmost portion of the Pleasant Valley basin, aquitards (most notably the Clay Cap) are absent or discontinuous. In these areas unconfined conditions exist in the underlying aquifers, allowing water to move downward from recharge sources, such as stream channels and recharge basins, to the water table with minimal impediment or lateral flow. In areas where BCM 13 Layers 1 and 2 (typically representing the Semi-perched Aquifer and the Clay Cap) were not identified in the e-logs, Layer 3 (typically representing the Oxnard Aquifer) was commonly mapped to land surface (as shown in Sections K, G, S; all cross-sections referred to in Section 2.6 are provided in Appendix A). These unconfined areas of the Oxnard Aquifer or other regionally important aquifers are relatively limited in extent and are limited to up-gradient areas of the Oxnard coastal plain. Regional aquitards exist between the major aquifers across much of the remainder of the coastal plain.

In the confined portions of the Oxnard Plain and Pleasant Valley basins, Layer 2 of BCM 13 (the Clay Cap) was mapped as continuous, but with variable thickness beneath Layer 1. In many areas, Layer 2 varied in thickness from 20 to more than 100 feet, but some water is thought to move through this layer (i.e., between Layer 1 and Layer 3). This flow between aquifers likely occurs in areas where the aquitard is thin, and where silts and fine sands rather than clays dominate the composition of Layer 2. Wells without deep surface seals also likely facilitate the movement of water between Layers 1 and 3.

The Layer 2 aquitard is mapped as being continuous outside of the Oxnard Forebay and northern Pleasant Valley, but areas of aquifer mergence were mapped among the deeper confined aquifers of the Oxnard Plain basin in the central and coastal portions of the basin. Layer 4, which commonly lies between the Oxnard aquifer and the underlying Mugu aquifer of the UAS, generally ranges from 40 to more than 100 feet thick in the Pleasant Valley basin. On the Oxnard Plain, Layer 4 is thickest in the areas adjacent to the West Las Posas and Pleasant Valley basins, with mapped thicknesses greater than 40 feet common in these eastern portions of the basin. Across the remainder of the Oxnard Plain basin, Layer 4 thickness is rarely greater than 20 feet. Mergence of the Oxnard and Mugu Aquifers is apparent in e-logs from wells in the area inland of McGrath Lake (Section H of Appendix A) and an area south of Hueneme Road (Section M of Appendix A). Previous studies have identified areas of Oxnard-Mugu aquifer mergence in the northwestern portion of the Oxnard Plain (SWRCB, 1979). Layer 4 is mapped as being absent throughout most of the Oxnard Forebay. These areas of aquifer mergence facilitate the vertical flow of water between aquifers when vertical gradients are present.

Layer 6 represents a layer of low permeability between the Mugu Aquifer of the UAS and the Hueneme Aquifer of the LAS. Layer 6 is generally thickest in the eastern portions of the model domain, but a thick deposit of clay located just east of Port Hueneme is included in this layer. Farther east, centered at the intersection of Hueneme Road and Rice Avenue, Layer 6 is absent, resulting in the base of the Mugu aquifer being in direct hydraulic connection with LAS aquifers. Layer 6 is also thin or absent in the vicinity of McGrath Lake, and near the intersection of Third Street and Oxnard Blvd. in the central portion of the Oxnard Plain basin. Layer 6 is observed to be thin or absent in certain wells in the central and northern portions of the Oxnard Forebay, but within a smaller area than the large, elongate area of Mugu-Hueneme aquifer mergence mapped by the SWRCB (1979) in the central Oxnard Plain basin.

2.6.2 Lower Aquifer System Uplift in Forebay

The Forebay is west of, and in alignment with, the tectonically uplifted terrain of South Mountain. Deposits of the San Pedro Formation are exposed in places on South Mountain, then plunge westward from South Mountain, extending under the Oxnard coastal plain. The youngest San Pedro Formation deposits have been removed by erosion in the northeast part of the Forebay, where tectonic uplift has been greatest—in places the aquifers of the UAS directly and unconformably overlie some of the deeper LAS aquifers (Section K). In these areas of the Forebay, surface water infiltration in the channel of the Santa Clara River and artificial recharge at United's Saticoy spreading basins can effectively recharge aquifers of both the UAS and the LAS.

2.6.3 Areas of Stratigraphic Change in the Northeast Oxnard Plain

The thickest portion of the Hueneme Aquifer is mapped in the southern Forebay along the axis of the Oxnard-Las Posas syncline, where the aquifer reaches a thickness of 1,100 feet. The aquifer thins to the east, and wells in the northeastern Oxnard Plain basin near the boundary with West Las Posas basin show the Hueneme Aquifer to be some 350 to 550 feet thick in this vicinity. In this area the character of the Hueneme Aquifer is distinct from other areas on the Oxnard Plain basin, being finer-grained and having thinner bedding (Section U). While the resistivity log signatures are not vastly different in this vicinity, driller's logs in the area commonly describe the Hueneme Aquifer as having abundant clay, along with sand. The more fine-grained nature of the Hueneme Aquifer in this area slows the flow of groundwater moving south from the Forebay. In the past there has been speculation that a "flow barrier" exists in this vicinity, given the change in LAS water levels between the northern Forebay and the area near the western terminus of the Camarillo Hills. United's hydrostratigraphic conceptual model includes a change in Hueneme Aquifer properties in this area, but evidence suggestive of significant faulting or other structural barrier was not recognized in the analysis of well logs in this area.

2.6.4 Upper San Pedro Formation in the West Las Posas Basin

The aquifers of the UAS only extend about ½-mile east of the Wright Road fault in the westernmost part of the West Las Posas basin. A shallow alluvial aquifer (BCM 13 Layer 1) is mapped across the floor of Las Posas Valley, overlying an aquitard (Layer 6) that varies from less than 50 to more than 300 feet thick; this aquitard serves to confine the deeper aquifers in the basin. Layer 7 is therefore the shallowest confined aquifer mapped across the West Last Posas basin. While Layer 7 is associated with the Hueneme Aquifer in the Oxnard Plain and Pleasant Valley basins, the common terminology for age-equivalent deposits in the West Las Posas basin is "upper San Pedro Formation." The thick sequence of sedimentary deposits in the upper San Pedro Formation is dominated by fine-grained materials. Some sand layers (indicated by higher resistivity in the e-logs) are present, but are generally less than 50 feet thick (Section Y, Section Z). Groundwater-level data are limited in the upper San Pedro Formation, but available data suggest that significant vertical gradients exist within this HSU.

2.6.5 Clay Deposits near Hueneme Canyon

As mentioned above, a thick clay deposit exists in BCM13 Layer 6 just east of the Port Hueneme harbor complex. The deposit is penetrated by well 01N22W28G01S (USGS monitoring well CM4) and two exploratory oil wells located north of Hueneme Road. The USGS logs hundreds of feet of "sandy mud," and the e-logs of all three wells show a thick interval of low resistivity without significant bedding. This feature may represent a former onshore extension of the nearby Hueneme submarine canyon that was subsequently filled with fine-grained material. This deposit was mapped as part of Layer 6 in BCM 13 (see Section H).

2.6.6 Upper Aquifer System in the Pleasant Valley Basin

The productive and typically well-defined aquifers of the UAS in the Oxnard Plain basin have a different character in the Pleasant Valley basin, becoming finer grained and less reliable as sources of groundwater. The sediments forming the UAS in the Pleasant Valley basin were deposited by streams draining the Calleguas Creek watershed, which is considerably smaller and less mountainous than the watershed of the Santa Clara River (which is the source of most UAS sediments occurring in the Oxnard Plain basin). Nevertheless, logs from wells in the Pleasant Valley basin do indicate some assemblages of aquifer material above the LAS. These "upper" aquifers are more interbedded than the UAS on the Oxnard Plain, and have lower hydraulic conductivities. United's BCM13 shows continuity within the Oxnard and Mugu Aquifers across much of the Pleasant Valley basin, but the character of the UAS deposits are different than they are within the Oxnard Plain basin. The degree of connectivity among the sandy lenses and interbeds of the UAS in the Pleasant Valley basin is not well known.

2.6.7 Extent of the Grimes Canyon Aquifer

The Grimes Canyon Aquifer is the deepest freshwater aquifer included in United's hydrostratigraphic conceptual model for the study area. This aquifer generally dips to the northwest in the groundwater basins underlying the Oxnard coastal plain, from the Santa Monica Mountains in the southeast to a line that extends from the Camarillo Hills to Port Hueneme. The Grimes Canyon Aquifer is mapped to depths as great as 2,400 feet below sea level in the area south of Hwy 101 and west of Del Norte Blvd. This is also the area of the Oxnard oil field, where the Vaca Tar Sands are mapped within hundreds of feet of the deepest mapped extent of the Grimes Canyon Aquifer.

2.6.8 Lower Aquifer System Uplift near Mugu Lagoon

Although the Oxnard and Mugu Aquifers are fairly flat-lying in the southernmost portions of the Oxnard Plain basin, the aquifers of the LAS dip northward (Sections M and N). The aquifers of the LAS appear to have been uplifted in the southern Oxnard Plain basin, possibly related to movement on the Sycamore Canyon fault, which is present a short distance offshore. Erosion of the Hueneme

Aquifer as far north as Hueneme Road near Nauman Road has resulted in the Mugu Aquifer directly overlying the Fox Canyon Aquifer in the area north of Mugu Lagoon.

2.6.9 Recent Deposits in Mound Basin

Some of the signatures of the Mugu, Hueneme, and Fox Canyon Aquifers (and the aquitards between these aquifers) observed in e-logs for wells in the Oxnard Plain basin can be traced northward across the Oak Ridge Fault and into the Mound basin (the Grimes Canyon Aquifer is absent this far north). However, late Pleistocene deposits that overlie the Mugu Aquifer appear to differ substantially across the basin boundary. United's BCM13 includes a surficial Layer 1 in Mound basin, commonly ranging from 30 to more than 100 feet in thickness, below which lies a thick sequence of clays and silts. These sediments are logged to depths of some 350 to 450 feet in a number of wells in Mound basin (Section A, Section D). In well 02N22W07M01S, located near the axis of the Ventura-Santa Clara River syncline, these fine-grained Pleistocene sediments are mapped to a depth of 585 feet. Along the Oxnard Plain basin boundary these deposits abut or interfinger with the Oxnard aquifer.

2.7 GROUNDWATER INFLOW AND OUTFLOW COMPONENTS

A summary of estimates for inflow and outflow components to the groundwater system in the study area is provided in Table 2-2, below. Approximately half of the total inflow consists of artificial recharge, which is metered by United and, therefore, volumes are known with a high level of certainty. Similarly, more than 80 percent of the total outflow consists of groundwater pumping from wells, which is also metered. The small magnitude of the other inflows and outflows relative to artificial recharge and groundwater pumping—the major inflow and outflow components—means that even if there is relatively large uncertainty (e.g. +/-25%) in deep infiltration of precipitation, for example, which could result in a hypothetical "error" of +/-4,500 AF/yr in the water balance, the magnitude of this uncertainty is less than 10% of the average artificial recharge rate of 48,000 AF/yr, which is known to a high level of certainty since it is carefully monitored by United. Furthermore, much of the recharge in the study area derived from sources other than artificial recharge enters the groundwater system in the Semi-perched Aquifer, which is not used for water supply. This recharge is removed from the groundwater system via the extensive drainage systems in the Semi-perched Aquifer (and ET) within hours, days, or a few weeks, at most, and has little influence on groundwater conditions in the aquifers of the UAS and LAS.

Table 2-2. Estimates of Groundwater Inflow and Outflow Components to Study Area

Groundwater Inflow or Outflow Component	Estimated Long-Term Averages from Previous Investigations (AF/yr)
<u>**Inflows:**</u> (**bold** font used for components that are required as input to the VRGWFM, *italic* font for flows that are calculated by the VRGWFM [provided solely for comparative purposes])	
Artificial Recharge (at Saticoy and El Rio Spreading Grounds)	**48,000[a]**

Table 2-2. Estimates of Groundwater Inflow and Outflow Components to Study Area

Groundwater Inflow or Outflow Component	Estimated Long-Term Averages from Previous Investigations (AF/yr)
Stream-Channel Recharge in Santa Clara River	*8,400*[b]
Stream-Channel Recharge in Arroyo Las Posas	*4,000*[b]
Deep Infiltration of Precipitation	**11,000**[c] **to 15,000**[d]
Return Flows (Ag + M&I)	**27,000**[e] **to 28,000**[f]
Mountain-Front Recharge (sum of ungauged streamflow and bedrock recharge)[g]	**3,000**[h]
Percolation of Treated Wastewater at WWTPs	**280**[i]
Groundwater Underflow from Santa Paula Basin	*1,800*[j] *to 7,400*[k]
Groundwater Underflow from East Las Posas Basin	*700 to 1,900*[l]
Net Seawater Intrusion into UAS and LAS	*12,000*[m]
<u>Outflows:</u> (**bold** font used for components that are required as input to the VRGWFM, *italic* font for flows that are calculated by the VRGWFM [provided solely for comparative purposes])	
Pumping from Water-Supply Wells	**130,000**[a]
Shallow groundwater drainage (to tile and other manmade drain systems)	*8,000 to 12,000*[n]
ET	*15,000*[o]
Discharge of Shallow Groundwater in Semi-perched Aquifer to Santa Clara River	*1,500*[p]
Semi-perched Aquifer Discharge to Pacific Ocean	*No previous estimates found*

Notes:

Most of the averages summarized in this table are those reported or estimated for the combined area of the Oxnard Plain, Forebay, Pleasant Valley, Mound, and West Las Posas basins. The relatively small inflow and outflow quantities occurring in the minor area of the active domain of the VRGWFM located outside of those basins (e.g., western margin of Santa Paula basin) are generally not included in the averages presented in this table.

[a] Calculated from United's records.

[b] Calculated from United's streamflow measurements and extrapolated over time using VCWPD stream gauge records.

[c] Deep infiltration of precipitation in the Pleasant Valley, Oxnard Plain, Forebay, and West Las Posas basin was estimated by Daniel B. Stephens & Associates, Inc. (DBSA; 2017a). United used DBSA's average infiltration rate to develop an estimate for the Mound basin, and 3,000 AF/yr was subtracted from the total to account for the fact that DBSA's estimate of deep infiltration of precipitation seems to include mountain-front recharge . More details are provided in Section 2.7.

Table 2-2. Estimates of Groundwater Inflow and Outflow Components to Study Area

Groundwater Inflow or Outflow Component	Estimated Long-Term Averages from Previous Investigations (AF/yr)
[d] Estimated by United using the Grunsky approach (see Section 2.7.3), solely for comparison. A more complex approach was used to apply deep infiltration of precipitation to the VRGWFM, as described in Section 3.5 [e] Adapted from DBSA (2017a) estimates of “irrigation infiltration” (including both agricultural and M&I return flows) as described later in Section 2.7. [f] Estimated by United using ITRC leaching rates (United, 2013) and total volume of applied water for agricultural use as described later in Section 2.7. [g] Sum of “bedrock recharge” and “ungauged streamflow” within study area. [h] Based on graphs and text presented by the USGS (Hanson and others, 2003) describing their mountain-front recharge estimates. [i] Sum reported discharges to percolation ponds of the Montalvo and Saticoy WWTPs (described later in Section 2.7). [j] Mann’s (1959) estimate of underflow from the Santa Paula basin to the Forebay during the period from WY 1937 through 1957 (Mann assumed underflow from the Santa Paula basin to the Mound basin was negligible). [k] DBSA’s (2017b) estimate of groundwater underflow from Santa Paula basin to the Mound basin and Forebay during the period from WY 1999 through 2012. [l] Range of estimates by Intera Geoscience and Engineering Solutions (2018) based on their model of the Las Posas Valley basin. [m] Mann’s (1959) estimate of seawater intrusion into the UAS and LAS in the Oxnard Plain basin during the period from WY 1946 through 1957. [n] Calculated by United based on Isherwood and Pillsbury (1958) estimated tile-drain discharges, modified by United to incorporate current land uses and irrigation practices (see Section 2.7 for details). [o] Calculated by United based on mapped area of wetlands (from the National Fish and Wildlife Service) in the study area that are believed to be fed by groundwater, and the average of USGS-estimated ET rates for wetlands (Hanson and others, 2003). [p] Estimated baseflow in Santa Clara River below Victoria Avenue (Stillwater Sciences, 2017).	

Many, but not all, of the inflow and outflow components listed in Table 2-2 are required groundwater flow-model input parameters (shown in bold in Table 2-2). There are varying degrees of uncertainty associated with some of the smaller inflow and outflow components (i.e. stream-channel recharge, deep infiltration of precipitation, agricultural and M&I return flows, mountain-front recharge, percolation of treated wastewater, drainage, ET, underflow to/from adjacent basins, and seawater intrusion), as is common in regional-scale flow models. Therefore, consistent with standard modeling practice, the values for these uncertain inflow components were adjusted during model calibration, as described in Section 4, to improve the overall model calibration. The inflow and outflow components not required as input to the model (shown in italics in Table 2-2) are calculated by the model based on simulated boundary conditions, aquifer stresses, and aquifer parameters, as described in Section 3. It should be noted that change in groundwater storage is often included in a water balance; however Table 2-2 is not intended as a water balance, and change in groundwater storage is an output from the VRGWFM, not an input parameter. Therefore, change in storage is not included in Table 2-2.

Each groundwater inflow and outflow component is described further in the following subsections.

2.7.1 Groundwater Inflows

Multiple sources of groundwater recharge (water that enters an underlying groundwater system from land surface) occur in the study area, including:

- "Artificial" recharge ("spreading")
- Stream-channel recharge
- Deep infiltration of precipitation
- Agricultural return flows
- Municipal and industrial return flows
- Mountain-front recharge
- Percolation of treated wastewater

In addition to the types of recharge (from land surface) listed above, subsurface inflow of groundwater also occurs in the study area as a result of:

- Groundwater underflow from adjacent basins
- Seawater intrusion
- Subsidence

Locations where each type of groundwater recharge are understood to occur in the study area are shown on Figure 2-17. Each of these recharge sources is discussed in further detail below. Groundwater underflow to/from other basins is discussed in Section 2.8.

2.7.1.1 Artificial Recharge

Artificial recharge consists of diverting surface water to "spreading" or infiltration basins for the express purpose of enhancing replenishment of groundwater supplies. The average rate of artificial recharge in the Forebay by United from 1985 through 2015 was approximately 48,000 AF/yr, which constitutes approximately half of the previously estimated total influx to groundwater in the study area (as a long-term average), and is nearly twice the magnitude of the next largest recharge component (sum of agricultural and M&I return flows). Over the past 50 years, United's recharge operations in the Forebay are estimated to have contributed a greater volume of recharge to the aquifers of the UAS and LAS in the study area than all other sources of recharge combined (the Semi-perched Aquifer is not present in the Forebay, so does not receive artificial recharge from United's spreading basins). Therefore, artificial recharge can be considered the most important long-term groundwater influx term to the study area. Fortunately for development of the VRGWFM, volumes of water recharged in each of United's facilities have been accurately recorded throughout the period of interest (1985 through 2015). Recharge quantities vary from year to year, with the highest volumes occurring in years of high rainfall (usually, but not always, associated with "El Nino" years, including 1992, 1995, 1998, and 2005), and the lowest volumes are associated with periods of drought. Annual recharge volumes at United's Forebay spreading facilities from 1985 through 2015 are shown graphically on Figure 2-18. Artificial recharge rates in the study area also vary by season, with the highest rates occurring during spring and the lowest during summer. Some recharge also occurs in fall, largely as a result of releases of water stored by United in Lake Piru (Figure 1-1).

United and its predecessor agency (the Santa Clara Water Conservation District) have been conducting artificial recharge in the Forebay since 1928, using surface water diverted from the Santa Clara River at the Saticoy Diversion, and later at the Freeman Diversion. Water releases from Lake Piru and a portion of the natural runoff from the Santa Clara River are diverted at that point. The Freeman Diversion is located on the Santa Clara River about 11 miles upstream from the Pacific Ocean. The concrete Freeman Diversion structure was completed in 1991, replacing the previous diversion method of building temporary sand and gravel diversion dikes, levees, and canals in the river channel using bulldozers and other heavy equipment. Most of the diverted surface water from the Santa Clara River is conveyed to United's Saticoy and El Rio recharge facilities (Figure 2-17). The remainder of the diverted water is delivered directly to agricultural users to satisfy irrigation demands "in lieu" of the users pumping groundwater. These surface-water deliveries are designed to reduce groundwater pumping in areas where overdraft is common and to mitigate groundwater conditions that contribute to saline intrusion.

2.7.1.2 Stream-Channel Recharge

Infiltration of surface-water flows in "losing" reaches of the Santa Clara River and Arroyo Las Posas (Figure 2-17) is the second largest source of recharge from land surface to the aquifers of the UAS and LAS in the study area. The average total stream-channel recharge rate in the study area from this source has been estimated by United to be approximately 12,000 AF/yr (details and references provided below). Most of this recharge occurs in the Forebay and northern Pleasant Valley basin, where the Semi-perched Aquifer and Clay Cap are absent. Therefore, the UAS and LAS directly receive the majority of this recharge, and only a small portion recharges the Semi-perched Aquifer (which is also the source of some groundwater ***discharges*** to stream channels).

The interaction of groundwater with surface water in streams can be complex; locations, extents, and rates of exchange between surface-water and groundwater vary from season to season and year to year. At times and places where the water table rises above the elevation of the water surface in the stream, discharge from the aquifer to the stream (rising groundwater) occurs instead of recharge. In areas where the Clay Cap is present, including all of the Oxnard Plain basin and the southern part of the Pleasant Valley basin, streams in the study area typically act as drains for (receive water from) the Semi-perched Aquifer, although small amounts of stream-channel recharge to the Semi-perched Aquifer are possible. Much of the Revolon Slough and many of the creeks and storm drains located in urban areas of the study area are lined with concrete, which is less permeable than soil and rapidly conveys surface flows to discharge outfalls, thereby reducing the opportunity for stream-channel recharge.

Surface-water flows in the Santa Clara River can infiltrate into the underlying UAS (Oxnard Aquifer, specifically) in the Forebay, where the Semi-perched Aquifer and Clay Cap are absent. On rare occasions, the reach of Santa Clara River overlying the northern portion of the Forebay is the site of groundwater discharge to the river (gaining stream) rather than recharge, as a result of the presence of exceptionally high groundwater levels in the alluvial deposits adjacent to the river channel. This condition occurred in 1999 and 2006, following periods of record-setting rainfall in 1998 and 2005, which allowed United to recharge exceptionally large volumes of groundwater in the adjacent Saticoy spreading grounds. Estimates by United's lead hydrologist of stream-channel recharge rates from CY 1985 through 2012 (the most recent year estimated) in the Forebay reach of the Santa Clara River range from -11,500 AF/yr (signifying a net ***outflow***, or discharge, of groundwater to the stream channel) in 2006 to 36,800 AF/yr (this is a positive value, signifying recharge) in 1993. The estimated average stream-channel recharge rate in the Santa Clara River during this period was 8,400 AF/yr. For comparison, Mann (1959) estimated stream-channel recharge in the Santa Clara River during the period from WY 1937 to 1957 to range from 1,000 to 39,300 AF/yr.

Surface water in Arroyo Las Posas infiltrates into aquifers of the LAS in the northern Pleasant Valley basin, where overlying fine-grained deposits have been eroded away resulting in more permeable layers coming into direct contact with coarse-grained stream-channel deposits. Estimates by United's lead hydrologist of stream-channel recharge rates from CY 1985 through 2011 (the most recent complete year estimated) for Arroyo Las Posas in northern Pleasant Valley basin range from 800 AF/yr in 1989 to 8,900 AF/yr in 2005. The estimated average stream-channel recharge rate in Arroyo Las Posas during this period was 4,000 AF/yr. For comparison, the USGS estimated stream-channel recharge in the Calleguas Creek watershed portion of their study area during the period from 1956 to 1993 to range from 0 to 6,100 AF/yr (Hanson and others, 2003). However, their estimate excluded treated wastewater flows in the watershed, which comprised a substantial fraction of flows in Arroyo Las Posas beginning in the early 1990s and continuing through the 2000s (subsequent to the timeframe for the USGS estimate).

2.7.1.3 Deep Infiltration of Precipitation

Much of the rain that falls in the study area quickly returns to the atmosphere via evaporation, or runs off to creeks, storm drains, and ultimately the ocean; the remainder percolates into the soil beneath land surface where it is subject to absorption by the soil matrix, uptake by plant roots, or delayed evaporation back into the atmosphere during subsequent dry periods. However, a part of the rainfall that percolates into the soil continues downward past the root zone and reaches an underlying aquifer—this recharge process is referred to as deep infiltration (or percolation) of precipitation.

Deep infiltration of precipitation is highly variable over time and location, as it depends on multiple factors, including: precipitation rate and duration, evaporation rate, ambient temperature, texture and slope of land surface, soil type and texture, antecedent soil moisture, vegetation cover, seasonal plant activity, and others (Stonestrom and Harrill, 2007). For these reasons, estimates of deep infiltration of precipitation at a given location or time are typically subject to substantial uncertainty. However, there are methods for estimating long-term average deep infiltration of precipitation that are generally accepted as giving reasonable results on a basin-wide scale. Estimates using these methods for deep infiltration of precipitation in the study area have ranged from 11,000 to 15,000 AF/yr, as discussed further below.

On portions of the Oxnard coastal plain where the Clay Cap exists, much of the precipitation (and agricultural return flows, which are discussed in a subsequent subsection of this report) that infiltrates to the Semi-perched Aquifer is then removed by tile drains installed under agricultural fields, or flows laterally to storm drains, streams, and wetlands, where it is discharged as surface water or evaporated (drainage of shallow groundwater is discussed further in Section 2.7.2). Due to the presence of the Clay Cap and urban infrastructure (e.g. pavement) across much of the Oxnard coastal plain, deep infiltration of precipitation is not as important of a source of recharge to the UAS and LAS within the study area as are artificial recharge and stream-channel recharge. However, deep infiltration of precipitation is still an important source of recharge to the Semi-perched Aquifer, and also provides a limited quantity of recharge to the Oxnard Aquifer in the Forebay, and the Fox Canyon Aquifer along the margins of the Mound, West Las Posas, and northeastern Pleasant Valley basins. Typically, deep infiltration of precipitation in Ventura County has the best chance of occurring during winter and spring, particularly during years of above-average rainfall, when storms are more frequent and longer in duration, and temperatures and evaporation rates are relatively low (compared to summer and fall).

As noted above, due to the complex interplay of factors that influence deep infiltration of precipitation and the difficulty in measuring some key parameters, the quantities of this source of recharge are usually subject to substantial uncertainty in basinwide studies. The USGS noted in a report on groundwater recharge in the southwestern United States that two approaches were appropriate for estimating spatially distributed recharge at a regional scale for the purpose of groundwater flow modeling (Flint and Flint, 2007). These approaches are:

- Empirical transfer methods that relate precipitation to ground-water discharge, and
- Distributed-parameter water-balance models.

Watershed-scale empirical relationships that compare rainfall with runoff, ET, and natural recharge within southern California basins have been developed by Grunsky (1915) and Turner (1991). Recently, the Grunsky method has been demonstrated to be valid for estimating watershed yield in a variety of Meditteranean climates (Santos and Hawkins, 2011). Both the Grunsky and Turner methods calculate annual recharge as approximately equal to the annual precipitation rate multiplied by a dimensionless factor that is 1/100th of the precipitation rate. For example, across the study area, where average annual precipitation is approximately 15 inches, deep infiltration using the Grunsky method would be 0.15 x 15 inches, or 2.3 inches; this would equate to approximately 21,000 AF/yr of recharge on average over the entire inland portion of the study area, if accepted without modification. Turner's approach is an evolution of the Grunsky method, with a maximum recharge rate (the recharge rate might achieve a constant value for precipitation rates greater than 36 inches per year), an exponential rainfall-vs-recharge curve, and a lower limit for annual precipitation capable of producing recharge (e.g., recharge would be zero during years with less than 3 inches of precipitation). Both the Turner and Grunsky methods assume that the watersheds are largely undeveloped, although they still provide reasonable results for areas with agricultural land use. The quantity of deep infiltration of rainfall on agricultural lands of the Oxnard coastal plain may be influenced to some degree by anthropogenic changes to soil conditions (e.g. tilling or irrigation) and vegetation cover (e.g. crop type), while deep infiltration of rainfall in municipal and industrial areas is likely to be significantly decreased due to the widespread presence of man-made impermeable surfaces (pavement and rooftops) and storm drains. If it is assumed that only 5 percent of rainfall in municipal/industrial areas (44,000 acres) infiltrates deeply enough to become recharge, while deep infiltration of rainfall in the remainder of the study area (both agricultural and undeveloped areas; 64,000 acres) follows Grunsky's rule, then total deep infiltration of precipitation in the study area would be estimated to be approximately 15,000 AF/yr.

The previous basinwide hydrogeologic investigations conducted in the study area (Section 1.2) focused on the aquifers of the UAS and LAS, and generally did not make estimates of recharge (or most other groundwater inflow and outflow components) occurring in the Semi-perched Aquifer. For example, Mann (1959), included "rainfall penetration" in the Forebay as an inflow component to the water budget (at an average rate of 2,320 AF/yr), but did not include it in the remainder of Oxnard Plain basin or the Mound basin (the Mann study did not include the West Las Posas or Pleasant Valley basins). Mann calculated rainfall penetration as monthly rainfall minus the sum of crop demand and the volume of water required to restore the soil to field moisture capacity. The USGS (Hanson and others, 2003) estimated recharge resulting from deep infiltration of rainfall (which they referred to as direct infiltration) "as a percentage of precipitation" based on the modified rational method, "in which the amount of potential recharge is the fraction of runoff from the index subdrainage basin multiplied by the total volume of precipitation for each ground-water subbasin." Similar to Mann, the USGS assumed that deep infiltration of rainfall did not reach the aquifers of the UAS and LAS in the Mound basin and areas of the Oxnard Plain and Pleasant Valley basins where widespread, near-surface confining layers (such as the Clay Cap) are present.

The other approach to estimating deep infiltration of precipitation—distributed-parameter water-balance modeling—computes the theoretical deep percolation at a watershed or larger scale using an analytical or numerical solution for a water-balance equation. The water-balance equations represent the complex processes and parameters that are believed to control evaporation, transpiration, runoff, and infiltration (described earlier in this section) on a daily to monthly basis, using a mathematical expression and requiring simplifying assumptions for parameters that are uncertain or are rarely measured in the field. Basinwide distributed-parameter water-balance models can usually only be calibrated to runoff, and the calculated quantities of runoff versus recharge can be sensitive to several parameters. Flint and Flint (2007) reported that both the empirical-transfer and the water-balance modeling approaches produce results that should be considered to be "initial" recharge estimates. In a comparison study of 12 basins in eastern Nevada, the authors reported that the recharge rates estimated by the water-balance model were "somewhat higher, but relatively close to the estimates" obtained using an empirical transfer relationship. Distributed-parameter water-balance models can take into account the effects of agriculture and urban development on rates of deep infiltration of rainfall, but require input of several soil, climate, and other parameters, many of which have uncertain values over much of the area and timeframe of interest.

Daniel B. Stephens & Associates, Inc. (DBSA, 2017a), was contracted by the FCGMA to estimate water-balance components for the Oxnard Plain (including the Forebay), Pleasant Valley, West Las Posas, and East Las Posas basins, including estimation of recharge from deep infiltration of precipitation and irrigation water using their proprietary distributed-parameter watershed model. DBSA noted that their model was not calibrated, and, therefore, the "recharge estimates are subject to a greater amount of uncertainty as compared to a calibrated soil-moisture balance model." However, their recharge estimates are still useful for comparison to those of previous investigators. The DBSA estimates of average annual deep infiltration of precipitation in individual basins within the VRGWFM study area for the period from 1985 through 2015 were (rounded to the nearest 100 AF/yr):

- Oxnard Plain (including Forebay) basin: 7,000 AF/yr
- Pleasant Valley basin: 3,300 AF/yr
- West Las Posas subbasin: 1,700 AF/yr (includes recharge in "external alluvial channels")
- Mound basin: not included

The average combined deep infiltration of precipitation in the Oxnard Plain, Forebay, Pleasant Valley, and West Las Posas basins estimated using the DBSA approach is 12,000 AF/yr; however, the Mound basin was not included in DBSA's estimate. Applying DBSA's average rate of deep infiltration of precipitation for the Oxnard Plain, Forebay, and Pleasant Valley basins (0.129 feet per year) to the area of the Mound basin (14,800 acres) would increase the total rate of deep infiltration of precipitation by approximately 1,900 AF/yr. It is assumed that DBSA's deep infiltration of precipitation estimate incorporates mountain-front recharge, since that is not accounted for elsewhere in their water-balance tables. Therefore, the USGS-estimate (Hanson and others, 2003) of mountain-front recharge (3,000 AF/yr, as discussed subsequently in this section) should be subtracted from DBSA's estimate of deep infiltration of precipitation (because mountain-front recharge is accounted for separately in this report), bringing the adjusted total of DBSA's deep infiltration of precipitation to 11,000 AF/yr. This value is somewhat lower than the estimate developed using the Grunsky approach (15,000 AF/yr), highlighting uncertainty associated with estimating deep infiltration of precipitation.

2.7.1.4 Agricultural Return Flows

Agricultural return flows are defined as applied irrigation water (water applied in addition to rainfall) that infiltrates to a depth beyond which removal by ET can occur to a significant degree (referred to as "the ET extinction depth"). This applied irrigation water that infiltrates beyond the ET extinction depth eventually reaches the underlying water table to become recharge. The long-term average rate of recharge from this source has been estimated to be 25,000 to 27,000 AF/yr in the study area, as discussed further below. Estimated agricultural return flows of this magnitude might appear to be a potentially significant fraction of the water budget within the study area. However, as discussed further in Section 2.8, tile drains remove most of the agricultural return flows in the Oxnard Plain (excluding the Forebay) and Pleasant Valley basins almost immediately after infiltration (within the Semi-perched Aquifer), and rapidly convey it to the ocean via drainage ditches. Therefore, similar to deep infiltration of precipitation, agricultural return flows are not as important of a source of recharge to the UAS and LAS within the study area as are artificial recharge and stream-channel recharge in the Forebay, but are believed to provide much of the recharge to the Semi-perched Aquifer, and some recharge to the aquifers of the UAS and LAS in the Forebay and northeastern Pleasant Valley basins, where the Clay Cap does not exist.

The major sources of water applied for agricultural use in the study area include:

- Groundwater extracted from the UAS and LAS at wells located on or adjacent to the farms where the water is applied
- Groundwater extracted from the UAS and LAS at wells located within the study area (e.g. United's Saticoy wellfield in the Forebay), but at some distance from farms where the water is used, and delivered via pipeline
- Surface water diverted from the Santa Clara River at Freeman Diversion and conveyed to farms via pipeline
- Surface water diverted from Conejo Creek and conveyed to farms via pipeline
- Rainfall

In addition, relatively minor volumes (compared to total agricultural water use in the study area) of irrigation water used in the study area are obtained from imported SWP water and groundwater extractions located outside of the study area, conveyed to farms within the study area via pipeline. Within a few years, up to 7,000 AF/yr of municipal wastewater from the City of Oxnard that has undergone an advanced-treatment process may also become available in the study area for agricultural and other uses.

Isherwood and Pillsbury (1958) were probably the first investigators to attempt quantification of irrigation return flows in the study area, based on measurement of outflow from tile drains. They estimated irrigation return flows of 22 percent of applied water at a farm field near the intersection of Del Norte Boulevard and 5th Avenue, in the northern Oxnard coastal plain between Oxnard and Camarillo, during a single season in 1953. Their study was performed at a site representing a small portion of the study area, more than 60 years ago, and thus should not be assumed to be representative of modern irrigation practices across the Oxnard coastal plain.

More recently, the Irrigation Training and Research Center (ITRC) at California Polytechnic State University in San Luis Obispo, California, investigated efficiency of agricultural water use in Ventura County for the FCGMA in 2010 by analyzing the percentages of applied irrigation water that were lost to evaporation, taken up by plant roots for transpiration, and required in excess of ET demand to flush (or leach) out salts that would otherwise concentrate in the root zone to the point where crop productivity was reduced. This evaluation was conducted for a variety of crops and soil conditions. ITRC determined that the leaching requirement ranges from 5 percent for sod to 19 percent for avocados (Table A-3 in ITRC, 2010). Based on the ITRC analysis, United calculated an average leaching requirement of 14 percent for the Oxnard Plain basin based on crop types and crop area. This leaching requirement assumes perfect distribution of irrigation, which is seldom achievable in practice. When variations in distribution uniformity are considered, agricultural return flows are estimated to be in the range from 22 to 25 percent of applied water (United, 2013).

Annual volumes of water reportedly applied for agricultural use in the study area are shown on Figure 2-19; the average (1985 through 2015) is approximately 99,300 AF/yr. Therefore, an average of approximately 2 feet of irrigation water was applied to the 50,200 acres of farmland in the study area per year during that period (there is significant variability in irrigation application rates within the study area and over time, due to differences in crop types, local-scale climate zones, and efficiency measures implemented by farmers). Southern Ventura County has a year-round growing season, thus irrigation occurs during all months of the year. However, less irrigation water is typically required during the winter and spring months, when rainfall is greatest and ET is minimal, than in summer or fall months. Assuming 25 percent, or 0.5 feet, of irrigation water is applied in excess of ET requirements (for the purpose of leaching salt out of the root zone), then approximately 25,000 AF/yr of irrigation water can be assumed to become recharge as agricultural return flows on average. For comparison, the USGS assumed a 70 percent irrigation efficiency factor (30 percent irrigation return) in their modeling of the Santa Clara-Calleguas watershed areas, based on general U.S. Department of Agriculture guidance for irrigation requirements developed in the 1950s and 1960s (Hanson and others, 2003). However, the USGS did not include the Semi-perched Aquifer (and associated recharge) in their model. Therefore, the USGS estimates for irrigation return flows cannot be directly translated to this study.

As noted previously, DBSA (2017a), estimated recharge from "irrigation infiltration" using their distributed-parameter watershed model as part of a water-balance study they conducted on behalf of the FCGMA. The DBSA estimates of irrigation return flows include both agricultural and municipal (landscaping) return flows in a single, combined output value. The DBSA estimates of annual average irrigation return flows (both agricultural and municipal) in individual basins within the VRGWFM study area for the period from 1985 through 2015 include (rounded to the nearest 100 AF/yr):

- Oxnard Plain (including Forebay) basin: 21,000 AF/yr
- Pleasant Valley basin: 3,700 AF/yr
- West Las Posas subbasin: 1,300 AF/yr (includes recharge in "external alluvial channels")
- Mound basin: not part of DBSA's analysis

The sum of "irrigation infiltration" (combined return flows from agricultural and M&I uses) for the Oxnard Plain, Forebay, Pleasant Valley, and West Las Posas basins as estimated by DBSA (2017a) is 26,000 AF/yr. The Mound basin was not included in DBSA's study area. If combined return flows in the Mound basin are added (assumed to be approximately 1,300 AF/yr, equal to DBSA's estimate for the West Las Posas basin, which is similar in area), DBSA's estimate for total (the sum of agricultural and M&I) return flows for the study area would be approximately 27,000 AF/yr. As noted previously in this report, the majority of recharge occurring in the Oxnard Plain basin can only briefly be considered to effectively recharge the Semi-perched Aquifer, which is not used for water supply, before exiting the groundwater system via tile drains. This recharge has a modest to negligible effect on the aquifers of the UAS and LAS. Therefore, any uncertainty in agricultural-return-flow rates is countered in large part by their minor impact on the water budget and hydraulic conditions in the primary water-supply aquifers of the study area.

2.7.1.5 Municipal and Industrial Return Flows

In urban, suburban, commercial, and industrial settings, groundwater recharge can result from deep infiltration of:

- Excess water applied for irrigation of landscaping (e.g. yards, parks, golf courses)
- Leaked water from water-supply pipes, sewer lines, and storm drains
- Storm-water collection/infiltration systems (e.g. detention basins with permeable bottoms, or dry wells)

Recharge from these and similar sources is termed “municipal and industrial (M&I) return flows” in this report. The estimated long-term average recharge rate from this source is approximately 3,000 AF/yr, although it should be noted that much of this recharge occurs in the Semi-perched Aquifer, and thus M&I return flows represent a minor source of recharge to the UAS and LAS compared to the sources noted previously in this report.

The major sources of water used for municipal and industrial purposes within the study area include:

- Groundwater extracted from the UAS and LAS at wells operated within each city
- Groundwater extracted from the UAS and LAS at wells located within the study area, but at some distance from cities (e.g. United’s El Rio well field in the Forebay) and delivered via pipeline
- Imported water from the SWP

Annual volumes of water reportedly applied for M&I use in the study area are shown on Figure 2-20; the average (for 1985 through 2015) is approximately 63,500 AF/yr. Comparison of Figure 2-19 with Figure 2-20 indicates that M&I water use is less variable from year to year compared to agricultural water use. Agricultural water use fluctuates depending on whether annual rainfall is above or below average (i.e., during wet years less water must be applied for irrigation and during dry years more irrigation is required). In contrast, a significant fraction of M&I water is typically used indoors (e.g. to meet sanitation needs) and, therefore, is less influenced by outdoor conditions.

Estimates of M&I return flows are subject to substantial uncertainty; estimates of losses from water and sewer pipes in typical cities vary widely, and return flows from irrigation of landscaping are not well studied. Despite this uncertainty, much of the M&I return flows in the area’s largest city by area and population, Oxnard, reach the Semi-perched Aquifer. Therefore, similar to deep infiltration of precipitation and agricultural return flows, M&I return flows are not as important of a source of recharge to the UAS and LAS within the study area as are artificial recharge and stream-channel recharge in the Forebay. However, M&I return flows are believed to provide some recharge to the Semi-perched Aquifer, and directly contribute to recharge of the UAS and LAS in urban and built-up areas in the Forebay and northeastern Pleasant Valley basins (Figure 2-2), where the Clay Cap does not exist. To provide a reasonable estimate as a starting point, M&I return flows were assumed to comprise 5 percent of ***total*** M&I water use (the values for recharge ultimately input to the model are presented in Section 3 of this report).

2.7.1.6 Mountain-Front Recharge

Two types of mountain-front recharge were identified by the USGS as occurring in the study area (Hanson and others, 2003); the combined long-term average recharge rate to the basin from these sources has been estimated to be approximately 3,000 AF/yr. One type is infiltration of surface water occurring in small stream channels along the margins of the groundwater basins; this surface water emanates from the mountains immediately east and north of the basin boundaries in the study area (Figures 1-1 and 2-1). Rainfall in the mountains is typically greater than in the basins due to the orographic effect, while the steeper stream gradients and relatively low-permeability of rocks in the mountains limit opportunity for deep infiltration until the streams reach the basins, where stream-channel gradients flatten, flow velocities decrease, and the substrate commonly consists of permeable alluvial sand and gravel. Consequently, surface-water runoff from small watersheds in the hills and mountains can be significant during rainfall events, and a portion of that runoff can infiltrate the groundwater basins near their margins. The USGS (Hanson and others, 2003) referred to this process as "ungauged streamflow" in their modeling report for the Santa Clara-Calleguas watersheds, and estimated a few hundred acre-feet per season (6 months) in the Oxnard Plain basin, which has mountainous areas along only a small fraction of its eastern boundary, to 8,000 acre-feet per season (during exceptionally wet years) in the Pleasant Valley basin, which borders the Santa Monica Mountains. The USGS estimated this ungauged streamflow as a percentage of the precipitation occurring in each mountain sub-watershed area that drains to the study area. The percentages they used were 4 percent and 7.5 percent of precipitation for the dry and wet seasons, respectively.

The other type of mountain-front recharge occurring in the study area is what the USGS referred to as "bedrock recharge" (Hanson and others, 2003), which consists of deep infiltration of precipitation into permeable (usually young and poorly consolidated) "bedrock" outside of the defined groundwater basins. This process can recharge aquifers within the study area. Specifically, the San Pedro Formation (described in Section 2.4) crops out in the foothills north of the Mound basin and dips southward below the unconsolidated alluvial deposits that define the limits of the Mound basin. The precipitation that infiltrates deeply enough in these outcrop areas to avoid evaporation and transpiration percolates down-dip and until it recharges the main and basal portions of the Fox Canyon Aquifer (Section 2.5). This is essentially the same process described above as "deep infiltration of precipitation," but this bedrock recharge directly affects aquifers that lie deep below the surface, instead of just the uppermost aquifer (such as the Semi-perched Aquifer, in most of the study area). Because this form of mountain-front recharge "bypasses" the Semi-perched Aquifer, it can have a direct effect on groundwater conditions in the main and basal Fox Canyon Aquifers, which are important sources of groundwater supply throughout the study area. The USGS used a precipitation-recharge relationship developed by the Santa Barbara County Water Agency in 1977 to estimate bedrock recharge in the USGS Santa Clara-Calleguas model study area ranging from a few hundred to a few thousand acre-feet per year, depending on annual rainfall (Hanson and others, 2003).

2.7.1.7 Percolation of Treated Wastewater

Percolation of treated wastewater contributes a relatively small portion of recharge to the study area, estimated to be approximately 1,200 AF/yr, on average. Two small community WWTPs adjacent to the Santa Clara River in the study area, one in Saticoy (just west of Highway 118) and one in Montalvo (just west of US 101), discharge treated effluent to percolation ponds (Figure 2-17). The average annual volumes of effluent discharged to the percolation ponds are approximately 80 and 200 AF, respectively, based on reports provided by California's State Water Resources Control Board online database, GeoTracker (http://geotracker.waterboards.ca.gov/). The Saticoy WWTP is within the Forebay basin, where percolating water can directly recharge the UAS. The Montalvo WWTP is in the Oxnard Plain basin, where percolating water recharges the Semi-perched Aquifer, which is not used for water supply (it should be noted that the Montalvo WWTP ceased operating in 2016, subsequent to the VRGWFM calibration period). Treated effluent from other WWTPs in the study area is discharged to surface water bodies where it may subsequently interact with groundwater, as described in Section 2.3.

Recharge resulting from the diminishing number of remaining domestic septic systems in the Oxnard Plain, Pleasant Valley, and West Las Posas basins, as of 2015, was estimated by DBSA (2017a) to be:

- 324 AF/yr in the Oxnard Plain basin (including the Forebay)
- 115 AF/yr in the Pleasant Valley basin
- 341 AF/yr in the West Las Posas basin

DBSA's (2017a) investigation area did not include the Mound basin. There are estimated to be approximately 2,000 domestic septic systems distributed throughout the agricultural, undeveloped, and portions of the suburban lands within the study area, and are each estimated to recharge approximately 0.16 AF/yr, on average, as of 2015 (DBSA, 2017a). These estimated quantities of recharge (less than 1,000 AF/yr total, distributed across the entire study area) represent less than 1 percent of the estimated total recharge in the study area, and can be most effectively incorporated into a groundwater flow model implicitly with agricultural or municipal/industrial return flows, rather than attempting to simulate each domestic septic system as a distinct source of recharge.

Within the next few years, both the City of Oxnard and the City of Ventura are planning to test, and will likely implement, aquifer storage and recovery (ASR) projects that involve injection and extraction of a portion (several thousand acre-feet per year) of their treated wastewater effluent ("recycled water"), following advanced water purification and filtration (AWPF) processes. The City of Oxnard is also considering future recharge of AWPF-treated effluent at United's Saticoy spreading grounds. Details regarding volume and timing of such recharge efforts are uncertain at this time, but could involve a few thousand acre-feet recharged each winter, when demand for irrigation water for agriculture and municipal landscaping is low.

2.7.1.8 Groundwater Underflow from Santa Paula and East Las Posas Basins

Underflow from the Santa Paula and East Las Posas basins is described in more detail (including references) in Section 2.8. To summarize the inflow components, groundwater underflow into the study area from Santa Paula basin has been estimated by previous investigators to be 1,800 to 7,400 AF/yr; underflow into the study area from East Las Posas basins has been estimated to be 700 to 1,900 AF/yr. Underflow estimates are typically subject to significant uncertainty and long-term variability; therefore, groundwater flow models, such as the VRGWFM, are often used to improve estimates of underflow.

2.7.1.9 Seawater Intrusion

Within the study area, both the Oxnard Plain and Mound basins are adjacent to the Pacific Ocean; therefore, groundwater in these basins can discharge to the ocean (see Section 2.7.2), or seawater can enter the aquifer, depending on hydraulic gradients, as described further below. Mann (1959) estimated the net rate of seawater intrusion into the Oxnard Plain and Mound basins to be 12,000 AF/yr from WY 1946 through 1957. Considering the seaward hydraulic gradient reported at that time in the Mound basin, most of the seawater intrusion would have occurred in the Oxnard Plain basin. The USGS (Hanson and others, 2003) used groundwater flow modeling to estimate time-averaged "mean coastal flows" into and out of the UAS and LAS in the Oxnard Plain and Mound basins during a "pre-development" period and a "reported pumpage period" (1984 through 1993), as follows:

- Pre-development: 16,000 AF/yr of seaward flow in the UAS, and 2,900 AF/yr of seaward flow in the LAS
- 1984 through 1993: 950 AF/yr of seaward flow in the UAS, and 6,400 AF/yr of landward flow in the LAS

These "mean coastal flow" values from the USGS are simulated fluxes toward land or toward the ocean in each of the two USGS model layers (simulating the UAS and the LAS) at the coastline, not where the aquifers are simulated to crop out under the seafloor. Furthermore, these values integrate simulated inflows and outflows along the entire coastline, over multi-year periods. Therefore, although the values may approximately represent average rates of seawater intrusion or discharge of groundwater to the ocean in the study area (for the specific periods evaluated), they should not be considered to be directly comparable to actual fluxes of seawater into the aquifers at Port Hueneme and Mugu Lagoon, where seawater intrusion is known to have occurred. Groundwater elevations in the Semi-perched Aquifer are nearly always above sea level; therefore, groundwater in the study area generally discharges from the Semi-perched Aquifer to the Pacific Ocean.

Much of the most recent information on seawater intrusion that is summarized below was obtained from United's recent detailed report on the presence of saline water in the Oxnard Plain and Pleasant

Valley basins (United, 2016); details and supporting documentation can be found in that document. Additional interpretation of the timing and expansion of seawater intrusion in the study area is provided in the 2007 FCGMA groundwater management plan update (FCGMA and others, 2007). The primary cause of seawater intrusion in coastal aquifers of the UAS and LAS is formation of landward hydraulic gradients in areas where groundwater withdrawals have caused inland groundwater elevations to decline below sea level. The Pacific Ocean is effectively a constant-head source of potential seawater influx to the basins when groundwater elevations inland of the coast fall below sea level. Groundwater quality may also be degraded by chloride in isolated areas not directly affected by lateral seawater intrusion, due to upwelling of connate saline water from deeper formations or the compaction of marine clays within aquifers, usually as a result of declining groundwater levels. The Pleasant Valley basin appears to have brines that originate at greater depths, and some of the deeper wells in the basin routinely produce water with moderately-elevated chloride concentrations, not related to seawater intrusion.

The aquifers of the UAS and the LAS in the southern Oxnard Plain basin are particularly vulnerable to lateral seawater intrusion where the aquifers crop out below sea level in the Hueneme and Mugu submarine canyons (Figure 2-10). Such a situation allows direct interchange of groundwater with seawater. When and where the potentiometric head of groundwater in the aquifer is greater than that of seawater at the submarine outcrop, groundwater flows seaward and discharges to the ocean; when and where the potentiometric head in the aquifer declines below that of seawater, the flow direction is landward and seawater intrusion can occur. The aquifers of the UAS and LAS also crop out along the more gently sloping Ventura and Hueneme-Mugu Shelves, farther offshore (Figure 2-10). However, as noted by the USGS (Hanson and others, 2003), “submarine leakage through the tops of the upper- and lower-aquifer systems that crop out along the submarine shelf probably is small.” This is partly because these outcrops occur 1 to 7 miles offshore--distant from the supply wells that draw down groundwater levels beneath farms and cities on the Oxnard coastal plain--and partly because younger, fine-grained marine sediments overlie the aquifers where they outcrop on the submarine shelf, potentially reducing transmissivity at the interface between groundwater and seawater. Therefore, most lateral seawater intrusion into the aquifers is believed to originate in the submarine canyons (which are located near the shore and have steeper slopes than the outer shelves).

Available data further suggests that lateral seawater is not intruding directly into the LAS in the vicinity of Mugu Lagoon. The USGS model (which was used as a starting point for the VRGWFM) included faults in the Mugu Lagoon area that limit the hydraulic connection of the LAS in the Oxnard Plain basin to the Pacific Ocean (Hanson and others, 2003). Calibration of the VRGWFM, discussed later in this report, supports the USGS conceptual model regarding fault-related horizontal flow barriers in the Mugu Lagoon area that limit connection of the LAS to the ocean. In addition, United’s recent saline intrusion update report (United, 2016) interpreted the dominant source of elevated chloride concentrations in the LAS near Mugu Lagoon to be saline water yielded from marine clays and/or from adjacent Tertiary-age sedimentary rocks as a result of large declines in potentiometric head in the LAS over the past several decades, rather than direct lateral seawater intrusion through the aquifer.

High chloride levels were first detected in groundwater inland from the Hueneme and Mugu submarine canyons in the early 1930s (DWR, 1971) and became a wider concern in the 1950s. Historically, groundwater quality problems resulting from saline intrusion under the Oxnard coastal plain were limited to the aquifers of the UAS, from which most groundwater production occurred. Over time, production increased from the aquifers of the LAS as drilling technology improved and groundwater users recognized the value of the lower total dissolved solids (TDS) concentrations in some of the deeper aquifers, and as degradation continued in the UAS. Seawater intrusion is not a problem in the Semi-perched Aquifer, as essentially no groundwater pumping occurs in this aquifer and groundwater levels are normally above sea level, resulting in groundwater discharging from the Semi-perched Aquifer to the Pacific Ocean.

In fall 1975, potentiometric heads in the UAS and LAS across much of the southeastern Oxnard Plain and southern Pleasant Valley basin were below sea level. These conditions led the State Water Resources Control Board (SWRCB) to consider adjudication of water rights in the basins (SWRCB, 1979). To improve groundwater conditions without resorting to adjudication, the FCGMA was formed in 1983, and its initial goals were to bring the aquifers of the UAS into balance by the year 2000, and of the LAS by the year 2010 (FCGMA and others, 2007). Since 1983, major investments have been made in infrastructure to enhance recharge and convey surface water to areas with the greatest pumping depressions, importation of water from the State Water Project was increased, and programs to reduce groundwater pumping were implemented by the FCGMA, United, and Calleguas MWD. These actions achieved some degree of success at limiting and even reversing the extent of seawater intrusion in the UAS. However, groundwater levels in much of the LAS in the southern Oxnard Plain and Pleasant Valley basins has remained below sea level during the intervening years. As a result of drought conditions since 2012, groundwater elevations in large areas of both the UAS and LAS in the coastal basins declined to record or near- record low levels (below sea level) in 2016, exacerbating the potential for seawater intrusion (United, 2016).

Despite the efforts to mitigate the conditions that cause saline intrusion in the UAS and LAS, such conditions persist in the coastal areas of the southern Oxnard Plain basin. In wet and normal years since the mid-1990s, existing groundwater recharge facilities and surface water delivery pipelines generally have distributed enough water to maintain groundwater levels above sea level in the UAS. However, much of the existing water infrastructure is reliant on flow in the Santa Clara River to be effective. During periods of drought the recharge facilities and surface water distribution pipelines are largely idle for lack of surface water, and groundwater extraction lowers groundwater elevations in the basins. Following the recent four years of drought conditions, water levels are below sea level in the UAS in all but the most northerly portions of the coastal basins, and a new episode of seawater intrusion is degrading water quality in the coastal areas of the southern Oxnard Plain (United, 2016). Recent samples from UAS wells near Hueneme Canyon show increasing chloride concentrations. The Oxnard aquifer monitoring well near Mugu Canyon consistently records chloride concentrations near that of seawater. When groundwater levels in the UAS are eventually restored, much of the seawater that entered the UAS aquifers via Hueneme Canyon will likely be swept down the coast to the southeast by the prevailing groundwater gradients, and not exit via the same submarine outcrops by which it entered the groundwater flow system.

In recent decades there has been increased groundwater production from the aquifers of the LAS, and, as a result of the drought beginning in 2012, water levels are now as much as 180 feet below sea level in these deeper aquifer units. Areas with significant groundwater extraction from the LAS do not record water levels above sea level, even in the wettest of years. Chloride concentrations are rising steadily in many of the LAS monitoring wells surrounding Mugu Lagoon. This is believed to largely be a result of upwelling of connate saline water from deeper formations and the compaction of marine clays within aquifers in response to declining groundwater levels, together with downward migration of seawater-impacted groundwater from the UAS in the area, and migration of seawater-impacted groundwater from the Port Hueneme area. The inland extent of saline intrusion near Hueneme Canyon appears to be more limited than in the area surrounding Mugu Lagoon, as historic seawater "plumes" near Port Hueneme have been swept east during non-drought periods by prevailing southeastward hydraulic gradients. The locations of the existing monitoring wells may be poorly positioned to document intrusion moving east from Port Hueneme (United, 2016).

2.7.1.10 SUBSIDENCE

Subsidence has been recognized by the USGS both as a potential consequence of groundwater-level decline and as a potential source of groundwater inflow (as a result of release of groundwater from pore spaces during compaction of layers and lenses of fine-grained sediments present within the UAS and LAS) to the groundwater system in the study area (Hanson and others, 2003). Although subsidence is not incorporated into the current version of the VRGWFM, a subsidence package is available for MODFLOW-NWT and could be applied to a future version of the VRGWFM if needed to simulate effects of potential future groundwater-level decline. For the historical calibration period of the VRGWFM, land subsidence has not been reported to be a significant problem in the study area, and the quantity of groundwater released throughout the study area was estimated by the USGS to be relatively small (3,700 AF/yr, occurring primarily during the late 1980s drought) compared to total groundwater outflows (142,000 AF/yr). However, as noted by the USGS, land subsidence can be expected to continue "…when water levels drop below previous maximum declines" (Hanson and others, 2003).

The potential relationship between subsurface fluid extractions (e.g., groundwater and hydrocarbons) and inelastic land subsidence has been known for several decades (e.g., Poland and Davis, 1969). Subsidence associated with fluid withdrawals includes the permanent compaction of fine-grained sediments due to the increase in the effective stress caused by the fluid removal. This process also releases groundwater present in the pore spaces between these fine-grained sediments. The hydrologic record in the study area has been punctuated by drought periods, sometimes lasting 2 to 5 years or longer, that are indicated in the hydrologic record by extreme low groundwater elevations in the Oxnard Plain, Pleasant Valley, and West Las Posas basins. It is well known that low groundwater levels can be the causal force that initiates the compaction of fine-grained deposits. The propagation of compaction to, or near, the land surface can result in subsidence. However, once the fine-grained sediments have been compacted, there is a low probability for additional subsidence unless the groundwater elevations decline below the historical lows for a significant length of time (a few months to years, typically).

Hanson (1994) discuss the likelihood of three potential causal factors for measured land subsidence of 2.6 feet during the period from 1939 to 1978 along a coastal traverse in the study area:

- Extraction of oil, gas, and brines from deep formations: estimated to account for most of (1.5 to 2.0 ft) the measured subsidence.
- Groundwater extraction from the UAS and LAS: subsidence from this potential source is not quantified, but anecdotal reports of subsurface collapse of well casings, the need to relevel fields, and lowering of levees along Calleguas Creek are cited as "indirect evidence that subsidence may be related to groundwater withdrawals" (Hanson and others, 2003).
- Tectonic activity: Hanson (1994) opines that a benchmark on the southern edge of the Oxnard Plain (Z 583) suggests 0.17 ft of tectonic-caused subsidence from 1939 to 1978.

The USGS reported that "Although the amount of subsidence from various sources remains unknown, ground-water withdrawals and oil and gas production probably are major causes of subsidence in the Oxnard Plain subbasin, and tectonic activity probably is a minor cause," and that groundwater released from fine-grained sediments during subsidence "can be a significant additional one-time source of water…in aquifer systems" (Hanson and others, 2003). However, excessive rates of land subsidence (as a result of groundwater withdrawals) would only be expected to occur in the future if groundwater elevations declined substantially below historic lows (as seen in the 1960s, 1980s, and 2010s). More recently, DWR (2014) prepared a summary document dealing with recent, historical, and future subsidence potential for groundwater basins in California. The stated intent of the document was to provide screening-level information with respect to potential for subsidence. The Oxnard Plain basin is listed with a medium-high potential, the West Las Posas basin is listed as having a medium-low potential, and the Pleasant Valley and Mound basins are listed as having a low potential.

2.7.2 Groundwater Outflow

Within the study area, groundwater discharges to water-supply wells, man-made drains (tile drains, ditches, storm drains, and older sewer lines), streams, the atmosphere (via ET), and the Pacific Ocean. Each of these components of groundwater outflow from the study area is described in more detail below.

2.7.2.1 Pumping from Water-Supply Wells

Groundwater pumping from water-supply wells is, by far, the largest component of estimated groundwater discharges (or outflows) from the overall groundwater system in the study area, and comprises 100 percent of the net discharge from the UAS and LAS in the study area (some discharge from the UAS and LAS to the Pacific Ocean occurs, but this is countered over the long-term by seawater intrusion; therefore, net inflow of seawater is occurring rather than net discharge). The average annual volume of groundwater pumped from water-supply wells during the period from 1985 through 2015 in the Mound, Oxnard Plain, Forebay, Pleasant Valley, and West Las Posas basins (most of the study area) was 117,000 AF. An additional 3,000 AF/yr, on average were each pumped from the margins of the study area that are outside of the boundaries of these groundwater basins (e.g., the part of Santa Paula basin that is in the active domain of the VRGWFM), for a total average pumping rate of 133,000 AF/yr in the entire study area. The next largest discharge component is ET (estimated to be 15,000 AF/yr), followed by discharge to manmade drainage systems and to the Santa Clara River (discussed later in this section); these discharge components solely affect the Semi-perched Aquifer, not the UAS or LAS. Similar to artificial recharge rates, groundwater pumping rates have been reported to local agencies throughout the period of interest (1985 through 2015), meaning that both the dominant recharge and discharge components required for input to the VRGWFM are well known.

Construction of water-supply wells in the study area began in 1870, when the first of many artesian wells reportedly were drilled in the Oxnard Plain basin; by the 1920s, however, due to drought and extraction of groundwater during the previous decades, groundwater elevations in the area had declined to depths that required installation of deeper wells equipped with pumps (Freeman, 1968). The USGS estimated that groundwater extraction in the study area increased rapidly from the 1920s to the 1950s, based on the expansion of irrigated agriculture shown on land-use maps for the region (Hanson and others, 2003). Since 1980 and 1985, respectively, United and the FCGMA have required semi-annual reporting of pumping by well owners within their service areas, improving the accuracy of pumping estimates in the study area. These records show a sharp rise in pumping rates during the 1980s, followed by slightly lower pumping rates from the 1990s to present. Reported annual volumes of groundwater pumped from wells in the study area since 1985 (when both FCGMA and United records of pumping become available, corresponding to the start of the historical calibration period selected for the VRGWFM) are shown on Figure 2-21.

The locations and screened depths of water-supply wells in the Oxnard Plain and Pleasant Valley basins have shifted over time, largely in response to concerns about water quality—particularly seawater intrusion—but also in response to increasing urbanization of the region. Overdraft conditions and increasing seawater intrusion during a drought period from the late 1940s through the mid-1960s resulted in United constructing additional facilities to increase recharge to the aquifers and to decrease groundwater pumping in areas and aquifers most affected by seawater intrusion. In 1958, the PVP and a terminal reservoir were completed to deliver diverted surface water from the Santa Clara River to Pleasant Valley County Water District, which serves agricultural water to the portion of Pleasant Valley basin south of Highway 101. In 1986, United partnered with Ventura County to construct the PTP to convey Santa Clara River water to agricultural pumpers in the east-central area of the Oxnard Plain, thus reducing the amount of groundwater pumping in this critical area. A chronic pumping depression in the Oxnard Aquifer in this vicinity was a major concern, as these low water levels were expected to eventually draw saline water from the coastal areas to the center of the basin (SWRCB, 1979). In addition, five new wells were constructed to produce groundwater from the LAS, so that pumping in the UAS could be reduced. Although pumping the deep wells would exacerbate overdraft in the Fox Canyon Aquifer, the project was designed to address the more immediate concern of overdraft and saline intrusion in the UAS. In 2003, United constructed the Saticoy well field to pump down the groundwater mound that develops beneath the Saticoy recharge facility during periods of above-average recharge. Water pumped from the Saticoy well field is distributed to agricultural users on the PVP and PTP, in order to reduce pumping in those areas.

The FCGMA has been the agency with primary regulatory authority over groundwater extraction quantities in the Oxnard Plain (including Forebay), Pleasant Valley, and Las Posas basins since 1983. Their authority does not extend to the Mound basin. Following an allocation-establishment “base period” in the late 1980s, the FCGMA required a series of 5 percent pumping reductions, approximately every five years, to reduce pumping demands within its area of jurisdiction. Agricultural water users had the option of demonstrating efficient irrigation practices, thereby avoiding specified pumping reductions. Despite the implementation of these various measures to reduce pumping from the coastal basins, chronic overdraft conditions persisted in the aquifers of both the UAS and the LAS (FCGMA, 2015). In 2014, the FCGMA Board adopted Emergency Ordinance E, crafted in response to the severely depleted groundwater conditions in the coastal basins following a drought that began in spring 2011. Temporary extraction allocations were applied to wells within the FCGMA, adding additional pumping restrictions. In February 2015, Ventura County passed a well ordinance prohibiting the construction of new wells in overdrafted basins, including those within the study area. Construction of replacement wells is allowed, as the ordinance was intended to prevent increased groundwater use rather than to limit existing use.

Locations and relative magnitude of groundwater pumping as of 1985 and 2015 in the study area, from wells screened in aquifers of the UAS, LAS, and both systems, are shown on Figures 2-23 and 2-24. Groundwater pumping from the Semi-perched Aquifer is negligible. Many of the water-supply wells constructed in the study area are screened across multiple aquifers, because the objective of drilling a supply well is typically to yield a specified production rate of acceptable-quality groundwater, preferably without drilling any deeper than necessary (to minimize costs). Unfortunately, it can be difficult to delineate total groundwater pumping within each aquifer due to the large number of wells with screens that span multiple aquifers. Therefore, United generally maps pumping by system (UAS or LAS) rather than by individual aquifer. The most notable changes in pumping patterns from 1985 to 2015 are:

- Reduction in pumping from the UAS and a corresponding increase in pumping from the LAS in the south-central Oxnard Plain basin
- Reductions in pumping from the northeast and northwest quadrants of the City of Oxnard, where farms have been replaced by municipal and industrial development over the past 30 years

A small portion (relative to total recharge and discharge) of the groundwater withdrawn by water-supply wells in the study area is conveyed and used outside of the study area (“exported”). A long-term average of approximately 1,300 AF/yr of groundwater has been pumped from two water-supply wells operated by the Alta Mutual Water Company in the Forebay since the mid-1980s and exported to agricultural lands in and north of the Santa Paula basin. This is the single largest quantity of known groundwater exports from the study area. In addition, review of aerial photos suggest that a portion of the groundwater pumped from some wells just inside the study area boundaries may be used on nearby hillside orchards immediately outside of the study area along the northern margins of the Mound and West Las Posas basins, and the eastern margin of the Pleasant Valley basin. Agricultural return flows from these orchards most likely return to the study area as mountain-front recharge, meaning that the net effect of "exporting" the source water a short distance (typically less than ½ mile) to a hillside orchard would have little net impact on the water balance for the basin.

2.7.2.2 Drainage

Tile drains were installed in the study area beginning in the early 20th century to remove shallow groundwater from the uppermost part of the Semi-perched Aquifer. Areas where tile drains are known or suspected to exist are shown on Figure 2-24. The long-term average discharge rate for groundwater via tile drains has been estimated to be approximately 8,000 AF/yr, while municipal drainage may account for another 700 AF/yr, as described below.

The surficial soils in the study area historically were alkaline due to poor drainage and evaporative concentration of salts. As a result, agricultural productivity was limited until 1918, when tile and other drainage systems began to be installed across much of the Oxnard coastal plain (Beller and others, 2011), leaching salts out of the soil and lowering groundwater levels below the root zone for row crops and orchards (Isherwood and Pillsbury, 1958). This improvement in drainage, combined with new pump technology, resulted in rapid expansion of irrigated agriculture during the subsequent three decades, and by 1947 over 93 percent of the irrigable area on the Oxnard coastal plain consisted of farmland (Isherwood and Pillsbury, 1958).

In 1958, Isherwood and Pillsbury noted that across the Oxnard coastal plain:

> *"Drainage from the area is accomplished by means of an extensive system of tile drains and a relatively small number of open ditches. Farm ditches are being replaced gradually by collector lines (Fig.1). The lateral tile lines usually discharge into collection lines from which the water flows to the district ditch system, thence to the ocean via one of the main drainage channels"* (clarified elsewhere in their report to be Revolon Slough and Calleguas Creek).

Figures in Isherwood and Pillsbury's (1958) report show tile drains and drainage ditches extending across nearly all of the Oxnard Plain and Pleasant Valley basins south of U.S. 101. Their study area did not extend north of U.S. 101. However, it can reasonably be assumed that other areas with shallow groundwater in the study area, most notably along the north bank of the Santa Clara River in the Mound basin and along Beardsley Wash in the far southwest portion of West Las Posas basin, likely also had some sort of drainage systems in place to reduce soil alkalinity and prevent waterlogging of the root zone for crops.

Reports specifying the depth of the tile drains installed in the study area were not found by United during a literature review, but tile drains are typically installed at depths ranging from 6 to 8 feet below land surface, to keep the water table below the root zone (personal communication, Jordan, 2015). Isherwood and Pillsbury (1958) installed 140 shallow (11-feet deep) piezometers at ½-mile spacing across the Oxnard coastal plain, and noted that "Mean depth to water (in the Semi-perched Aquifer) is 6.8 ft and shows little difference between January and June readings during the years 1953-1956." This depth to the water table in the Semi-perched Aquifer is consistent with installation of tile drains to depths ranging from 6 to 8 feet.

Since the Isherwood and Pillsbury (1958) investigation, the population of the Oxnard coastal plain has increased substantially, with a corresponding increase in land area developed for housing, commercial, and industrial uses, as discussed in Section 2.1. United staff have been told that the tile drains in the study area are typically destroyed when this land-use conversion occurs (personal communication, Smith, 2015). An extensive network of storm drains has been constructed within the Cities of Oxnard and Port Hueneme, many of which are observed to contain flowing water year round. Ingress of shallow groundwater into storm drains via weep holes, and into sewer lines via joints and cracks, likely occurs in developed areas within the study area, effectively acting in a similar manner to agricultural tile drains. Groundwater elevation data obtained from the state's Geotracker web site for the period from 1989 through 2015 indicates that Semi-perched Aquifer groundwater elevations in Oxnard and Port Hueneme are consistently about 8 feet below land surface, with little variation, consistent with Semi-perched Aquifer groundwater elevations in agricultural areas elsewhere on the Oxnard coastal plain. This similarity supports the occurrence of drainage in the Semi-perched Aquifer in municipal and industrial areas of the Oxnard coastal plain, as well as agricultural areas. Groundwater elevations in the Semi-perched Aquifer throughout the study area are discussed further in Section 2.9.

This smaller seasonal and annual variability of groundwater elevations observed in the Semi-perched Aquifer, compared to those in the UAS or LAS, in the Oxnard Plain and Pleasant Valley basins (described in Section 2.9) indicates that the drainage systems are very effective at removing recharge resulting from return flows and deep infiltration of precipitation, and that the Semi-perched Aquifer is poorly connected to the underlying aquifers of the UAS and LAS across much of the Oxnard coastal plain. Although some of the recharge that reaches the Semi-perched Aquifer migrates downward to deeper aquifers (Hanson and others, 2003) or discharges to naturally occurring surface-water bodies (see Sections 2.4 and 2.9), a substantial portion discharges to the tile and other drains in the study area.

Isherwood and Pillsbury (1958) estimated that discharge of irrigation return flows into agricultural drains in their investigation area 3, near Del Norte Boulevard and 5th Avenue, was approximately 1 acre-inch per acre (0.083 AF per acre) during a single irrigation cycle, with four irrigation cycles typically occurring per year. Agricultural land overlying the Oxnard Plain and Pleasant Valley basins combined was approximately 35,000 acres in 2015, suggesting that groundwater discharge to agricultural drains could presently be approximately 12,000 AF/yr, if Isherwood and Pillsbury's (1958) return-flow estimates from the 1950s were still applicable today. Given that the ITRC's (2010) evaluation suggests recent return flows across the Oxnard coastal plain are likely one-third smaller

(Section 2.7), discharge from agricultural drains could be closer to 8,000 AF/yr. Some of the recharge from irrigation returns and deep infiltration of precipitation that enters the Semi-perched Aquifer is known to migrate downward to aquifers of the UAS and LAS. Therefore, discharge from drains does not consist solely of irrigation return flows, and not all return flows discharge to drains.

United has not found references that provide estimates of the quantity of discharge to drains in areas of shallow groundwater within M&I portions in the study area (17,000 acres, primarily in the Cities of Oxnard and Port Hueneme). Water use per acre by the cities in the study area is about one-third less than water applied to agricultural land, and approximately half to two-thirds is typically applied to landscaping in most southern California cities, with the remainder being used indoors (ultimately directed to sewer lines and WWTPs). Therefore, it is likely that discharge of groundwater from the Semi-perched Aquifer to drains in municipal/industrial portions of the study area is smaller (on a per-acre basis) than discharge from tile drains in agricultural areas. Assuming the rate of M&I drainage per acre is half the rate of agricultural drainage, or 0.042 feet per year, then the total volume of M&I drainage would be approximately 700 AF/yr.

2.7.2.3 Discharge to Streams

As discussed in Section 2.3, shallow groundwater in the Semi-perched Aquifer discharges to natural surface-water bodies in the study area—the net discharge rate to most of these water bodies likely is small (less than a few hundred AF/yr), although they have typically not been quantified. However, a baseflow of 1,500 AF/yr has been estimated for the reach of the lower Santa Clara River below Victoria Avenue (Stillwater Sciences, 2017). The primary source of the shallow groundwater discharging to the Santa Clara River in this reach is agricultural return flows from irrigation of adjacent farmland (Figure 2-1).

2.7.2.4 Evapotranspiration (ET)

ET removes much of the water that falls as precipitation in Ventura County before it reaches the water table. The majority of ET occurs at land surface or within the root zone of the soil horizon, in the unsaturated zone. This near-surface ET does not directly affect groundwater levels or flow in the saturated zone, and thus is not explicitly included in most groundwater flow models. However, near-surface ET is included implicitly as part of net recharge calculations applied as input to the VRGWFM. Discharge of groundwater via ET from the saturated zone can occur where the water table is present at very shallow depths (typically within the upper 5 feet of the soil zone). Such conditions mostly occur in the study area where the Semi-perched Aquifer interacts with surface water bodies (Section 2.3), which is also where riparian vegetation is typically found in the study area. The U.S. Fish and Wildlife Service online "Wetlands Mapper" (https://www.fws.gov/wetlands/data/mapper.html) indicates that the combined area of riparian vegetation along stream channels within the study area, together with the coastal lakes and wetlands described in Section 2.3 of this report, could be as large as 4,600 acres (Figure 2-24). Applying the USGS estimates of ET rates as described below (1.1 to 5.2 feet per year) to this acreage results in calculated long-term annual average groundwater discharge as ET from the study area in the range from 5,100 to 24,000 AF/yr, with a midpoint of 15,000 AF/yr. It should be noted that nearly all of the riparian vegetation that takes up groundwater in the study area occurs in land overlying the Semi-perched Aquifer, which is rarely, if ever, pumped as a source of agricultural or M&I water supply.

Hypothetically, ET could also discharge groundwater from the aquifers of the UAS and LAS where they outcrop at land surface in the Forebay, West Las Posas, and parts of the Pleasant Valley basins, but only in the situation where groundwater in these aquifers occurs within approximately 5 feet of land surface. This situation is rare in the study area and is not known to result in discharge of a significant quantity of groundwater. Roots of some trees take up water at depths greater than 5 feet, but the quantities are minor compared to the volumes of water evaporated from near-surface soil or taken up and transpired by the shallow-rooted crops, landscaping, and other vegetation that occur across most of the study area. Similar to deep infiltration of precipitation, ET is variable over time and location, since it is highly dependent on complex interactions between many of the same climate, soil, hydrologic, and vegetation inputs. Therefore, estimates of ET at a given location or time are typically subject to substantial uncertainty similar to deep infiltration of precipitation. Unlike deep infiltration of precipitation, discharge of groundwater as ET occurs primarily where (and when) groundwater is present within approximately 5 feet of land surface, whereas deep infiltration of precipitation can occur virtually any place or time where land surface is permeable. Within much of the study area, depth to the water table in the shallow aquifer system is maintained 6 to 8 ft bgs, which is below the root zone of most plants, by tile drains or other drainage systems, and can occur as deep as 150 ft bgs where the Clay Cap is not present. Therefore, the locations where ET can directly remove groundwater from the saturated zone of aquifers within the study area are limited, as are the potential volumes of groundwater discharge as ET.

The USGS estimates of average annual ET rates for the study area ranged from 1.1 to 5.2 feet per year, all assumed to occur within riparian zones and floodplains along the Santa Clara River and Calleguas Creek (Hanson and others, 2003). This range of estimated ET rates is consistent with the reported annual average pan evaporation rate of 63.2 inches (5.3 feet) on the Oxnard coastal plain (Section 2.2)—80 percent of the pan evaporation rate is generally considered to be representative of the maximum evaporation rate possible from an open water body. Transpiration from phreatophytic plants around such water bodies could make total ET somewhat higher than this value. Where groundwater does not discharge directly to land surface, actual ET rates can be expected to be less than the maximum (open water) evaporation rate, declining to small values in areas where the water table is deeper than 5 feet (the limit of most plant roots as well as the effects of direct evaporation of soil moisture to the atmosphere). The area of riparian zones and floodplains along the Santa Clara River and Calleguas Creek watersheds as of 1969 was estimated by the USGS to be 2,265 acres (Hanson and others, 2003); however, that estimate included stream reaches beyond the current study area of the VRGWFM. The USGS did not consider ET from wetlands and surface water bodies fed directly by the Semi-perched Aquifer, which was not explicitly simulated in their model.

DBSA (2017a) estimated the annual average volumes of groundwater removed via ET by riparian vegetation in the Pleasant Valley and West Las Posas basins to be approximately 1,700 and 700 AF/yr (rounded to the nearest 100 AF/yr), respectively, based on the following data and assumptions:

- 4 ft/yr of ET from native riparian vegetation
- 24 ft/yr of ET from non-native *Arundo donax* (arundo)
- 274 acres of riparian vegetation in the Pleasant Valley basin, 20 percent of which consists of arundo
- 138 acres of riparian vegetation in the West Las Posas basin, 10 percent of which consists of arundo

DBSA (2017a) did not estimate ET from riparian vegetation in the Oxnard Plain basin (because virtually all groundwater discharge as ET from the Oxnard Plain basin is assumed to occur in the Semi-perched Aquifer), or from the Mound basin (which was outside of their study area).

2.7.2.5 Groundwater Discharge to the Ocean

As described in Section 2.7.1, groundwater in the Oxnard Plain and Mound basins can discharge to the Pacific Ocean when and where the potentiometric head of groundwater in the aquifer is greater than that of seawater at the submarine outcrop. During most of the latter half of the 20th century, a net influx of seawater has occurred in the UAS and LAS, particularly near the heads of the Mugu and Hueneme submarine canyons (Section 2.7.1). Small volumes of groundwater may discharge to the ocean in the Mound and northwestern Oxnard Plain basins during periods of relatively high groundwater elevations (discussed further in Sections 2.8.1), but such outflows have not previously been quantified.

Groundwater elevations in the Semi-perched Aquifer are nearly always above sea level; therefore, groundwater in the study area would be expected to discharge from the Semi-perched Aquifer to the Pacific Ocean. The rate of such discharge has not been studied extensively because groundwater in the Semi-perched Aquifer is not typically considered an important water resource (due to its poor quality). Quantification of groundwater discharge from the Semi-perched Aquifer to the ocean may prove difficult using traditional approaches (based on hydraulic gradients and conductivities) because of the complicating effects of tidal reversals and groundwater discharge via ET in the coastal surface-water bodies and wetlands that occur along much of the coastline in the study area.

2.8 GROUNDWATER OCCURRENCE AND MOVEMENT

This section summarizes the observed effects that the hydrostratigraphic framework, coupled with groundwater recharge and discharge have had on groundwater occurrence and movement within the basins and subbasins of the study area, focusing primarily on the historic calibration period of the VRGWFM, 1985 through 2015. Details regarding historical groundwater conditions in the study area are provided by Mukae and Turner (1975) and Mann (1959). In addition, Hanson and others (2003) estimated groundwater levels and movement in Ventura County from predevelopment to the early 1990s, based on data synthesis and modeling.

2.8.1 Groundwater Elevations

Hydrographs showing changes in groundwater elevations over time, combined with maps showing typical groundwater elevations, can help illustrate groundwater occurrence and movement in an aquifer system. Accordingly, hydrographs for selected representative wells in each groundwater basin in the study area are shown on Figures 2-25, 2-26, and 2-27. A location map for selected wells in the Semi-perched Aquifer is provided on Figure 2-28, and groundwater-elevation contour maps prepared by United staff for the UAS and LAS in fall 2012 are provided on Figures 2-29 and 2-30. Groundwater-level contours for the UAS and LAS during fall 2012 were selected for inclusion in this report because 2012 was the most recent year when groundwater elevations were not extensively influenced by anomalously wet or dry conditions. Fall is the period when groundwater elevations in the study area are typically at seasonal lows, and 2012 is now recognized as the first year of an exceptional drought throughout California. However, inspection of the hydrographs shown on Figures 2-26 and 2-27 indicates that groundwater elevations during fall 2012, while slightly lower than long-term averages, were still within their typical ranges. Therefore, the groundwater-level contour maps shown on Figures 2-29 and 2-30 are suitable for their intended purpose in this report, which is to provide the reader with a conceptual representation of recent "typical" hydraulic conditions in the UAS and LAS across the study area (those portions with sufficient data for contouring). Insufficient data were available for United to interpolate groundwater elevation contours for 2012 in the Semi-perched Aquifer across most of the study area. However, comparison of land-surface elevations to groundwater elevations at wells screened in the Semi-perched Aquifer where the Clay Cap exists, as shown on Figure 2-31, indicates a close correlation exists. Specifically, the depth to groundwater measured in most wells screened in the Semi-perched Aquifer consistently occurs at depths of 5 to 10 feet below land surface, as discussed further below.

2.8.1.1 Semi-Perched Aquifer

Most of the groundwater-level data available for the Semi-perched Aquifer in the study area were obtained from monitoring wells installed during the 1990s at leaking underground storage tank (UST) remediation sites associated with fueling facilities. Monitoring wells at these sites are typically screened to depths of just 5 to 40 feet below "first water," which is within the Semi-perched Aquifer in much of the study area. These groundwater elevation data were downloaded by United from the California State Water Resources Control Board's (SWRCB) "GeoTracker" on-line database (https://geotracker.waterboards.ca.gov/). Many of these leaking UST sites closed or reduced their frequency of monitoring after 2009 in response to SWRCB Resolution 2009-0042. The pace of site closures increased further after California adopted a low-threat UST closure policy in 2012. Because of the site closures and reductions in monitoring frequency associated with these policy changes, the availability of groundwater elevation data from the Semi-perched Aquifer diminished rapidly after 2009. United attempted to obtain widely-distributed (spatial and temporal) groundwater elevation data from the Semi-perched Aquifer, trying to avoid both "clustering" (excessive data over a small area or timeframe) and large gaps between data points. Data were commonly available for three to twenty (and occasionally more) monitoring wells at each UST or other remediation site in GeoTracker, and most sites were smaller than 1 acre in area. A review of the available data indicated that groundwater elevations within the Semi-perched Aquifer varied little (from a few inches or feet) across each site. Therefore, data from only one or two representative wells at each site were downloaded by United. There were many UST or other remediation sites in urban and suburban areas, typically clustered on multiple corners of a street intersection, or aligned along a single street in a business district. There were very few sites with available data in agricultural areas. Unfortunately, no useful data (for this evaluation) were available for the period from 1985 through 2015 in the West Las Posas basin.

As can be seen on Figure 2-25, groundwater elevations at most wells screened in the Semi-perched Aquifer varied by less than 3 feet on a seasonal basis, and less than 10 feet between longer-term dry and wet periods. Groundwater levels in the Semi-perched Aquifer vary least in the Oxnard Plain and western Pleasant Valley basins, where the Clay Cap is present, and vary most near the margin of the Forebay, in the Mound basin, and in northeastern Pleasant Valley basin, where the aquitard between the Semi-perched Aquifer and underlying aquifers consists of discontinuous silts and clays. Where the Clay Cap is absent, the water table in the shallow aquifer system is typically deeper, tile drains are less likely to be needed or present, and the hydraulic connection to underlying aquifers is greater, resulting in larger variations in groundwater elevation.

Where the Clay Cap is present, groundwater elevations in the Semi-perched Aquifer have a high degree of correlation with land-surface elevations, as shown on Figure 2-31. This figure indicates that groundwater elevations are consistently about 5 to 10 feet below land surface (average is 8.6 feet below land surface) in the Semi-perched Aquifer, excluding wells that are located along the margins of the Forebay, in the Mound basin, West Las Posas basin, and northeast Pleasant Valley basin, where the Clay Cap is missing and where the uppermost aquifer consists of discontinuous silt and clay lenses. Near the coastline, groundwater elevations in the Semi-perched Aquifer tend to fall in the range from +2 to +5 ft msl, sufficiently above sea level to suggest that discharge from the Semi-perched Aquifer to the ocean generally occurs, rather than seawater intrusion into this aquifer.

The close correlation between groundwater elevations and land-surface elevations, as well as the stability of groundwater elevations, in the Semi-perched Aquifer across most of the Oxnard coastal plain is largely a result of two factors. First, the Clay Cap provides a degree of hydraulic separation between the Semi-perched Aquifer and the underlying Oxnard Aquifer; therefore, the large variations in groundwater elevations occurring in the Oxnard Aquifer as a result of United's recharge operations as well as pumping for agricultural and municipal supply have little effect on groundwater levels in the Semi-perched Aquifer. Second, subsurface tile drains and other drainage systems installed across the Oxnard coastal plain (see Section 2.8) quickly remove pulses of recharge that would otherwise cause groundwater elevations in the Semi-perched Aquifer to rise closer to land surface than the typical depth of 5 to 10 feet.

2.8.1.2 Upper Aquifer System

Early newspaper accounts suggest that the confined aquifers of the UAS on the Oxnard coastal plain were first drilled for water supply wells in the early 1870s. Artesian conditions existed on the Oxnard coastal plain at this time, persisting through the turn of the century. However, the water demands associated with expanding irrigated agriculture on the plain, along with the growing population and industrial demand, lowered the artesian pressure in the UAS. By the early 1900s, widespread artesian conditions were generally absent, requiring wells to be fitted with pumps to lift water from below land surface (Freeman, 1968). Since that time, artesian conditions have periodically returned to parts of the Oxnard Plain basin during wet climatic cycles. Documentation of groundwater levels in the aquifers of the Oxnard Plain basin are sparse until the early 1930s, but artesian conditions were documented in Oxnard city well #9 during the winters of 1917, 1919, 1922 and 1923 (Jamison, 1928). The early 1940s was a wet period, and widespread artesian conditions likely existed at that time. The year 1945 marked the beginning of a long dry period during which water levels fell across the Oxnard coastal plain. Widespread artesian conditions were again present in the UAS on the Oxnard coastal plain in the late 1990s following the completion of the Freeman Diversion and high precipitation totals in 1992, 1995 and 1998. As recently as the 2000s, artesian conditions periodically existed in coastal areas surrounding Port Hueneme and in the northwest Oxnard Plain, and are more common in UAS wells than in wells with deeper screened intervals. As can be seen on Figure 2-26, groundwater elevations at most wells screened in the UAS fluctuate 5 to 20 feet seasonally, and 40 to 100 feet between longer-term dry and wet periods. During the calibration period of the VRGWFM (1985 through 2015), the effects of two major droughts can be seen in groundwater elevations shown on these hydrographs, with significant groundwater-level declines in the late 1980s and early 2010s.

Groundwater elevation contours for the UAS in fall 2012 are shown on Figure 2-29. In the UAS across most of the study area, groundwater elevations in the Mugu Aquifer are similar to or a few feet lower than those in the Oxnard Aquifer. On the southern Oxnard Plain, and most notably in the area surrounding Mugu Lagoon, groundwater levels in the Mugu Aquifer may be as much as 30 feet lower than in the Oxnard Aquifer. Figure 2-29 indicates groundwater flow occurring radially from recharge areas in the Forebay to surrounding areas. Recharge from the Forebay serves to raise or sustain water levels in wells on the Oxnard Plain, countering the decline in groundwater elevations resulting from groundwater extractions. When groundwater levels are high across the study area, groundwater may flow past the coastline to the offshore extension of the aquifers, or exit the system at near-shore submarine canyons as discharge to the sea. By fall 2015, 3 years into an exceptional drought, UAS groundwater elevations were below sea level across much of the Oxnard Plain and Pleasant Valley basins. The hydraulic gradient in the interior of the basin was still nearly flat, and the lowest Oxnard Aquifer water levels were recorded in the Forebay near United's El Rio spreading grounds where the O-H well field is in operation (United, 2017a).

2.8.1.3 Lower Aquifer System

Strategies implemented in the past to mitigate saline intrusion in the UAS in the Oxnard Plain basin included delivery of surface water to agriculture with the goal of reduced groundwater pumping (starting in the 1950s), and a shift of pumping from the UAS to the LAS (starting in the 1980s). These mitigation strategies raised groundwater levels in the UAS, but did not help with overdraft in the LAS. As can be seen on Figure 2-27, groundwater elevations at most wells screened in the LAS fluctuate 10 to 60 feet seasonally, and 50 to 100 feet between longer-term dry and wet periods. Similar to groundwater levels in the UAS, the effects of droughts in the late 1980s and early 2010s are apparent in these hydrographs.

Groundwater elevation contours for the LAS in fall 2012 are shown on Figure 2-30; these contours indicate groundwater flow occurring radially from recharge areas in the Forebay to surrounding areas, similar to the UAS. A “mound” of groundwater associated with recharge of surface-water flows in the Arroyo Las Posas has also been observed in the northern Pleasant Valley basin, under the City of Camarillo. Groundwater elevations in the LAS in this area rose from -140 ft msl in 1993 to +120 ft msl in 2012, and then gradually decreased to +40 ft msl in 2015 in response to diminishing flows in Arroyo Las Posas (Bachman, 2016). By fall 2015, groundwater elevations in the LAS were below sea level throughout most of the Oxnard Plain and Pleasant Valley basins. The highest groundwater levels were recorded in the northern Forebay and the northern Pleasant Valley basins, which are areas of recharge. An area of more than three square miles had groundwater elevations deeper than -150 ft msl. LAS groundwater elevations at the coast near Mugu Lagoon were measured at -98 ft msl. LAS piezometers surrounding Port Hueneme recorded groundwater levels ranging from -19 to -40 ft msl (United, 2017a).

2.8.2 Groundwater Flow Conditions Summarized by Basin

Although the groundwater basins in the study area are interconnected, they have distinctive characteristics that can affect the occurrence and movement of groundwater within each basin. This section summarizes groundwater flow conditions in each groundwater basin or subbasin.

2.8.2.1 Forebay Subbasin

The Forebay subbasin occupies 10 square miles of the northern portion of Oxnard Plain basin and is where most of the groundwater recharge to the Oxnard Plain basin occurs. Recharge in the Forebay benefits all of the other basins in the study area (Oxnard Plain, Mound, West Las Posas, Pleasant Valley). The shallow sediments of the Forebay are dominated by coarse-grained, permeable alluvial deposits of the ancestral Santa Clara River. The distinguishing feature of the Forebay is the absence of the Semi-perched Aquifer and Clay Cap. This allows unimpeded groundwater recharge of the UAS. In the area of the Forebay between United’s Saticoy and El Rio recharge facilities, the LAS has been uplifted and truncated along its contact with the UAS (Mann, 1959). This allows rapid transmission of recharge to the underlying LAS. In the southern portions of the Forebay the LAS becomes more hydraulically isolated from the UAS.

Reported extractions of groundwater from the Forebay in 2015 totaled 19,400 acre-feet, which was 21 percent less than the average annual extraction rate of 24,600 AF/yr (1985 through 2015). United's O-H well field is the largest pumping center in the basin, delivering water to coastal areas for M&I use as part of a management strategy to move pumping away from coastal areas vulnerable to saline intrusion. As of 2015, approximately 62 percent of pumping in the Forebay was from the UAS, 26 percent was from the LAS, and 12 percent was from wells screened in both the UAS and the LAS.

During 2015, only 2,645 acre-feet of water was spread (artificially recharged) at United's spreading grounds in the Forebay (in contrast to an average of 48,000 AF/yr of artificial recharge on average since construction of the Freeman Diversion in 1991). United artificially recharges nearly twice as much water per year, on average than is withdrawn from wells in the Forebay. Natural infiltration of surface water from the Santa Clara River and deep percolation of rainfall and return flows provide additional recharge in the Forebay.

Changes in groundwater elevation in the Forebay affect hydrostatic head in the confined aquifers extending from the margins of the Forebay, through the Oxnard Plain basin, to the coastal and offshore portions of the aquifers of the UAS and LAS. Higher groundwater levels in the Forebay associated with wet periods, such as those that occurred during the late-1990s and mid-2000s, are beneficial, as they maintain seaward hydraulic gradients from the Forebay to coastal areas. In the dry conditions that have prevailed since 2012, groundwater elevations in the Forebay have fallen to record lows, resulting in flattened hydraulic gradients and only minor groundwater flow out of the Forebay. Groundwater underflow ***into*** the Forebay occurs from the Santa Paula basin. The quantity of inflow is limited to some degree by relatively low horizontal hydraulic conductivities across the Oak Ridge and Country Club faults, which form the boundary between these two basins. Mann (1959) estimated average groundwater underflow from the Santa Paula basin to the Forebay for WY 1937 through 1957 to be approximately 1,800 AF/yr. DBSA (2017b) estimated underflow from the Santa Paula basin to the Forebay for WY1999 through 2012 to be much greater, at 7,400 AF/yr. This large difference in underflow estimates may be partly due to different hydrogeologic conditions during the different timeframes evaluated, and partly due to different assumptions regarding the conceptual model for groundwater flow from Santa Paula basin to the Forebay.

2.8.2.2 Oxnard Plain Basin

The Oxnard Plain basin (excluding the Forebay) occupies approximately 75 square miles of the Oxnard coastal plain (Figure 2-1). The aquifers of the Oxnard Plain basin are continuous with those of the Forebay, described above; however, the Clay Cap and Semi-perched Aquifer overlie the principal aquifers across most of the Oxnard Plain basin, limiting direct hydraulic connection between land surface and the underlying aquifers. The tile drains and other drainage systems constructed across much of the Oxnard coastal plain further limit hydraulic connection from land surface to the underlying aquifers of the UAS and LAS. Therefore, the largest source of recharge for these aquifers in the Oxnard Plain basin is lateral groundwater flow from the Forebay, rather than deep percolation of rainfall or irrigation return flows directly on the Oxnard coastal plain. While the physical movement of groundwater out of the Forebay is fairly slow, the pressure response in the confined aquifers of the Oxnard Plain basin is rapid. When groundwater elevations are below sea level along the coastline, there can be significant lateral inflow of seawater into the aquifers, mixing with or displacing fresh water (United, 2016). In areas near Port Hueneme and Mugu Lagoon, where submarine canyons extend nearly to the coastline, the fresh-water aquifers are likely in direct contact with seawater a short distance offshore. Consequently, these are areas where seawater intrusion has historically been observed.

Vertical gradients commonly exist between aquifers in the Oxnard Plain basin, resulting in some degree of vertical groundwater movement through low-permeability aquitards that occur between the major aquifers. When LAS groundwater levels are substantially lower than UAS groundwater levels (creating a downward gradient), there is leakage of UAS groundwater into the LAS through the various aquitards that separate the aquifer units, through wells that are screened across both aquifer systems, and in areas where the aquitards are thin or absent (areas of mergence). Likewise, a downward gradient can exist between the Semi-perched Aquifer and the Oxnard Aquifer when hydraulic heads in the Oxnard Aquifer are lowered, either regionally by drought conditions or locally by pumping wells. The movement of poor quality groundwater from the Semi-perched Aquifer to the Oxnard Aquifer has been documented in some locations, with abandoned or improperly constructed wells being a notable pathway for this downward flow (Izbicki and others, 1992; Stamos and others, 1992; Predmore, 1993). Conversely, during rare periods of artesian conditions, upward vertical gradients may exist between deeper confined aquifers and the Semi-perched Aquifer.

Deposits comprising the aquifers of the LAS are generally finer-grained than those of the UAS, resulting in lower hydraulic conductivities, and have been more extensively deformed by folding and faulting. An uneven distribution of pumping, along with structural and stratigraphic changes within the LAS, results in varied hydraulic heads among the deep wells across the Oxnard Plain. Faulting and uplift associated with the Sycamore fault, and changes in LAS stratigraphy, are believed to prevent or limit direct contact of the LAS with seawater in the area offshore from Mugu Lagoon (Izbicki, 1996; Hanson and others, 2003).

Reported 2015 groundwater extractions from the Oxnard Plain basin totaled 59,600 acre-feet, which was 8 percent greater than the long-term average annual extraction rate of 55,200 AF/yr (1985 through 2015). Groundwater withdrawals from the Oxnard Plain basin are somewhat variable, with less demand in years when surface water is available for agricultural water supply (via the PTP). Water supply wells are common throughout the agricultural areas of the Oxnard Plain basin, with few wells located in the City of Oxnard. In the western part of the Oxnard Plain basin most of the pumping occurs from the UAS, while in the eastern part of the Oxnard Plain basin most of the pumping occurs from the LAS (Figure 2-23).

2.8.2.3 Pleasant Valley Basin

The Pleasant Valley basin, with an area of 33 square miles, is bounded to the south and east by the Santa Monica Mountains, to the north by the Camarillo Hills, and to the west by the Oxnard Plain basin (Figure 2-1). The Bailey fault is a major structural feature that trends NE near the base of the Santa Monica Mountains, and the Springville fault bounds the basin along the Camarillo Hills to the north (Figure 2-10). The Pleasant Valley basin is differentiated from the Oxnard Plain basin by a general lack of productive UAS aquifers (Turner, 1975). In Pleasant Valley basin, much of the UAS is fine grained and not extensively pumped for groundwater supply (Turner, 1975; Hanson and others, 2003). UAS deposits in the Pleasant Valley basin are approximately 400 feet thick and consist of sediments from the Calleguas Creek watershed, a smaller and less mountainous drainage than that of the Santa Clara River, which deposited the coarser UAS deposits of the Oxnard Plain basin. Some coarse-grained UAS deposits do exist in the Pleasant Valley basin, but these deposits tend to be thin or discontinuous. For this reason, limited pumping in the Pleasant Valley basin occurs from wells screened in the UAS (Figure 2-23).

The LAS in the Pleasant Valley basin is composed of the Hueneme, Fox Canyon, and Grimes Canyon Aquifers to depths greater than 1,500 ft. The Hueneme Aquifer is relatively thin in the Pleasant Valley basin and composed of alternating layers of sand and finer-grained deposits. The Fox Canyon and Grimes Canyon Aquifers are composed of thick sequences of relatively uniform marine sand. The Fox Canyon Aquifer is the major water-bearing unit in the Pleasant Valley basin. In Pleasant Valley basin the LAS is surrounded and underlain by partly consolidated marine deposits and volcanic rocks, which typically do not yield a sufficient quantity or quality of groundwater to wells for most uses.

Under pre-development conditions in the Pleasant Valley basin, groundwater movement was likely from recharge areas in the northeast toward the Oxnard Plain basin to the southwest. Groundwater underflow into the Pleasant Valley basin occurs from the East Las Posas basin through the "Somis Gap" in the Camarillo Hills, along the northern boundary of Pleasant Valley basin. Recent groundwater modeling by Intera Geoscience and Engineering Solutions (2017) suggests that the average rate of underflow from the East Las Posas basin to the Pleasant Valley basin was approximately 700 AF/yr in 1983, increasing to approximately 1,900 AF/yr by 2000 (due to increased wastewater discharges in upstream basins), and then declining to 1,400 AF/yr by 2015 (in response to the recent drought and conservation measures that reduced upstream wastewater discharges). Little groundwater underflow occurs from Santa Rosa basin to the Pleasant Valley basin due to the presence of shallow bedrock that acts as a flow constriction between the basins. The rate and direction of groundwater underflow between the Oxnard Plain and Pleasant Valley basins is variable over time, location, and depth, largely as a result of variations in recharge rates and groundwater withdrawals that have occurred in each basin over seasonal to multi-year time frames.

Reported 2015 groundwater extractions from the Pleasant Valley basin totaled 17,800 acre-feet, which was 14 percent greater than the average annual extraction rate of 15,600 AF/yr (1985 through 2015). Most water-supply wells in the Pleasant Valley basin are screened in the LAS (Figure 2-23), due to the abundance of fine-grained sediments and discontinuous nature of the UAS in the Pleasant

Valley basin. Similar to the Oxnard Plain basin, groundwater withdrawals from the Pleasant Valley basin are somewhat variable, with less demand in years when surface water is available for agricultural water supply (via the PVP and from Conejo Creek). Also similar to the Oxnard Plain basin, water supply wells are common throughout the agricultural areas of the Pleasant Valley basin, with a lower density of wells in the City of Camarillo.

Over the previous two decades, groundwater levels recorded in at least two wells in northern Pleasant Valley basin rose more than 250 feet (United, 2017a). The degree to which this large recharge mound serves to recharge the LAS in the central portion of the basin is not well established, as the distribution of wells available for groundwater-level monitoring in the northern Pleasant Valley basin is limited. The City of Camarillo has plans to construct a large-scale desalter to treat and utilize this groundwater, which tends to be more mineralized than the older and deeper groundwater native to the basin. This groundwater mound has decreased in size since 2012 as flow in Arroyo Las Posas has diminished.

2.8.2.4 Mound Basin

The principal fresh water-bearing strata of the Mound basin are the upper units of the San Pedro Formation and the overlying Pleistocene-age deposits that are interpreted to be correlative with the Mugu Aquifer of the Oxnard Plain basin. These strata extend several miles westward offshore from the coast, and are overlain and confined by Pleistocene-age clay approximately 300 feet in thickness. The sediments of the basin have been warped into a syncline (Ventura-Santa Clara River syncline) that is oriented in an east-west direction approximately parallel to Highway 126 (Figure 2-10). Structural disruption along the Oak Ridge fault in the southern portion of the basin has resulted in considerable uplift and erosion of the San Pedro Formation and younger sediments. This disruption is the cause of the topographic “mounds” near the intersection of Victoria Avenue and U.S. 101, for which the basin is named. The Montalvo anticline (Figure 2-10) has traditionally been used to define the southern extent of the basin. These structural features generally offset only the deeper LAS units of the adjacent Oxnard Plain basin. The deposits of the UAS overlie the faults and folds along the southern margins of the Mound basin, but the character of the deposits change as they extend to the north, becoming more thin-bedded and fine-grained (United, 2012).

The limited number of wells in the Mound basin, especially in the northern half of the basin, complicates efforts to ascertain its primary sources of recharge. The USGS (Hanson and others, 2003) indicated that some mountain-front (bedrock) recharge to the Fox Canyon Aquifer occurs as a result of precipitation falling on San Pedro Formation outcrops in the hills along the northern margin of the Mound basin (Figure 2-10), as discussed in Section 2.7. There is general agreement that the basin benefits from groundwater underflow from the Forebay and Oxnard Plain to the south, especially during periods of high groundwater levels in the Oxnard Plain basin and from Santa Paula basin, to the east (Geotechnical Consultants, Inc., 1972; Fugro West, Inc., 1996; United 2012). Mann (1959) suggested that there is little underflow from the Santa Paula basin to the Mound basin, although more recent studies suggest it may be significant (Fugro West, Inc., 1996; United, 2012; DBSA, 2017b).

Reported 2015 groundwater extracted from the Mound basin totaled 6,600 acre-feet, which was 12 percent less than the average annual extraction rate of 7,500 AF/yr (1985 through 2015). Locations for water-supply wells in the Mound basin are shown on Figure 2-23.

Groundwater flow in the Mound basin is generally to the west and southwest. The limited number and distribution of wells with groundwater-level records complicates efforts to contour groundwater elevations in the basin. During periods of drought and increased pumping, an elongate pumping depression forms in the southern portion of the basin that significantly modifies groundwater gradients. Groundwater elevations fall below sea level in this area during dry periods, creating a landward hydraulic gradient and groundwater flux, but saline intrusion has not been observed in the Mound basin to date. Fresh groundwater is likely present in the offshore portions of the aquifers extending south and west from the Mound basin; when landward hydraulic gradients form in the basin during dry periods, fresh water is drawn inland rather than seawater. The volume of fresh water present in aquifers offshore from the Mound basin is uncertain.

2.8.2.5 West Las Posas Basin

The West Las Posas basin is located east of the Oxnard Plain basin, between South Mountain and the Camarillo Hills (Figure 2-1). The West Las Posas basin mostly consists of a broad alluvial plain sloping to the south, and approximately three quarters of its surface watershed area is drained by Beardsley Wash, which flows southwest to the Oxnard Plain basin. The eastern one-quarter of the watershed drains southeast to the Arroyo Las Posas, then into the Pleasant Valley basin through the Somis Gap. Tree crops (orchards) are the dominant land use in this agricultural area.

Most groundwater production in the West Las Posas basin is from the LAS (Figure 2-23). Reported 2015 groundwater extraction from the West Las Posas basin totaled 15,800 acre-feet, which was 9 percent greater than the long-term average annual extraction rate of 14,500 AF/yr (1985 through 2015). The UAS is present only along the western margin of the West Las Posas basin.

Beneath most of the Las Posas Valley (including the West and East Las Posas basins), the upper San Pedro Formation consists of low permeability sediments with lenses of permeable sediments which are age-equivalent to the Hueneme Aquifer of the Oxnard Plain basin (DWR, 1975b). The permeable lenses form isolated, yet locally important, water sources. The water-bearing zones in the upper San Pedro Formation do not appear to be well connected. Some recharge to the deeper Fox Canyon Aquifer may result from downward leakage from the upper San Pedro Formation. Mukae (1988) wrote that many wells in the West Las Posas basin are screened in the Fox Canyon Aquifer, making it the principal water-bearing unit, but United's mapping of HSUs in the basin includes extensive mapping of the Grimes Canyon Aquifer, most notably in the southern portion of the basin (which may have been mapped as Fox Canyon Aquifer by Mukae, 1988). The Fox Canyon Aquifer is exposed almost continuously along the southern flank of South Mountain. South of the outcrop, beds of the Fox Canyon Aquifer dip below land surface and are folded into a series of anticlines and synclines. Groundwater in the Fox Canyon Aquifer exists under confined conditions beneath the valley and unconfined conditions at the valley margins where the Fox Canyon Aquifer is folded upward and exposed at the surface.

Much of the groundwater present in the LAS in the western portion of the West Las Posas basin results from eastward underflow from the Oxnard Plain basin, although there may be a limited quantity of groundwater underflow in the opposite direction in the shallower aquifers. Limited underflow from the East Las Posas and Pleasant Valley basins may also occur, suggested by northward and eastward hydraulic gradients near the boundaries of these basins with the West Las Posas basin. Recent groundwater modeling of the East and South Las Posas basins (Intera, 2018) suggests that less than 100 AF/yr of groundwater underflow occurs from East Las Posas basin to West Las Posas basin.

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3 NUMERICAL MODEL CONSTRUCTION

DWR's best-management practices for modeling include guidance stating that "Models should maintain simplicity and parsimony of hydrogeologic parameters, while simultaneously simulating the important hydrogeologic details that will drive basin sustainability" (Joseph and others, 2016). Although this DWR guidance was published only recently, the simple and economical approach has long been preferred by groundwater modelers, and was used by United during construction of the VRGWFM.

The first step in construction of the VRGWFM was selection of a suitable modeling "platform" (software) and determination of appropriate spatial and temporal limits or boundaries for the model (the domain). The next step was to decide how to subdivide (discretize) both space and time in the model such that the simulation results were produced at an appropriate scale to meet the modeling objectives (described in Section 1), while keeping computing requirements reasonable. Next, estimates of aquifer hydraulic parameters were entered into digital input files ("packages"), completing construction of the basic model framework. Finally, known and estimated aquifer stresses over the calibration period (1985 through 2015) were entered into input files. With this information, together with instructions regarding how the model should process input and output, the modeling software computes heads and flows throughout the model domain based on a numerical solution of the partial-differential equation defining groundwater flow (the continuity equation). Comparison of model-simulated groundwater elevations to measured historical groundwater elevations, typically accompanied by adjustment of modeled aquifer parameters as needed to reduce any differences, is referred to as calibration, which is discussed in Section 4.

3.1 MODEL SOFTWARE SELECTION

The USGS software package MODFLOW-NWT was selected by United to be the modeling platform for initial development of the VRGWFM. MODFLOW-NWT "is a Newton-Raphson formulation for MODFLOW-2005 to improve solution of unconfined groundwater-flow problems" (Niswonger and others, 2011). As described in Section 2, the groundwater system in the study area is influenced by cycles of extended drought and wet periods that cause groundwater levels to fluctuate over 100 feet, requiring a numerical model capable of simulating the desaturation and resaturation (drying and wetting) of portions of the aquifers. MODFLOW-NWT was developed in large part to simulate this type of condition.

The first version of MODFLOW was released to the public in 1984 by the USGS, with the intent of producing a new groundwater flow modeling software package that "could be readily modified, was simple to use and maintain, could be executed on a variety of computers with minimal changes, and was relatively efficient with respect to computer memory and execution time" (McDonald and Harbaugh, 1988). As noted by the USGS, "MODFLOW's modular structure has provided a robust framework for integration of additional simulation capabilities that build on and enhance its original scope. The family of MODFLOW-related programs now includes capabilities to simulate coupled groundwater/surface-water systems, solute transport, variable-density flow (including saltwater), aquifer-system compaction and land subsidence, parameter estimation, and groundwater management" (Anderson and others, 2015). MODFLOW is currently recognized as "the most widely used code for solving groundwater flow problems," and its success is in large part due to the fact that "MODFLOW allows for addition of modules and linking or coupling with other codes; it is freely available with detailed documentation" (Anderson and others, 2015).

Specific MODFLOW-2005 packages used for the historical calibration version of the VRGWFM described in this report include:

- Basic (BAS)—Specifies the type of each grid cell in the model (active, inactive, or constant head) and initial heads throughout the model domain.
- Discretization (DIS)—Defines the spatial and temporal discretization of the model.
- Upstream Weighting (UPW)—Specifies properties controlling flow between model grid cells (e.g., hydraulic conductivity and storage properties).
- Newton Solver (NWT)—Provides parameters for the solution to the finite-difference equations used in each time step of the model period.
- Output Control (OC)—Specifies which head, drawdown, or water budget data will be saved for each model simulation.
- General Head Boundary (GHB)—Simulates head-dependent flux boundaries (i.e., the southwest boundary of the model representing aquifer interaction with the Pacific Ocean, and the northeast boundary of the model representing interaction with the Santa Paula basin).
- Multi-Node Well (MNW2)—Represents wells in the model, and is the preferred package for simulating wells that are screened across multiple layers.
- Recharge (RCH)—Simulates United's artificial recharge operations areal recharge (from deep percolation of precipitation, agricultural irrigation return flows, and M&I return flows), and recharge of treated wastewater via WWTP percolation ponds.
- Well (WEL)—Simulates a specified flux (inflow or outflow) to specific model grid cells for each stress period; used in the VRGWFM along the model's outer active boundary to represent the following:
- Mountain-front recharge (both the "bedrock recharge" and the "ungauged streamflow" described in Section 2.7),
- Underflow of groundwater from the East Las Posas to the Pleasant Valley basin.
- Stream (STR)—Simulates groundwater inflow and outflow to streams with a significant hydraulic connection to shallow groundwater (Santa Clara River, Conejo Creek, and Arroyo Las Posas).
- Horizontal Flow Barrier (HFB)—Simulates faults that have significant influence on groundwater flow patterns (i.e., form a barrier or conduit to flow).
- Drain (DRN)—Simulates the effects of tile drains and other drainage systems present in areas of shallow groundwater.

- Evapotranspiration (EVT)—Simulates the removal of water from the saturated zone via evaporation and transpiration (by phreatophytic plants)

MODFLOW-NWT (and all other MODFLOW versions and packages developed by the USGS) are available to the public at no charge from the USGS, as is the software documentation (https://water.usgs.gov/ogw/modflow-nwt/). Because of this availability, documentation, and abundant peer review, selection of MODFLOW-NWT for the VRGWFM conforms with DWR "guiding principles for models used in support of GSPs," regarding model selection:

1. "Model documentation (documentation of model codes, algorithms, input parameters, calibration, output results, and user instructions) is publicly available at no cost. In particular, the model documentation should explain (or refer to available literature that explains) how the mathematical equations for the various model code components were derived from physical principles and solved, and guidance on limitations of the model code."
2. "The mathematical foundation and model code have been peer reviewed for the intended use. Peer review is not intended to be a "stamp-of-approval" or disapproval of the model code. Instead, the goal of peer review is to inform stakeholders and decision-makers as to whether a given model code is a suitable tool for the selected application, and whether there are limits on the temporal or spatial uses of the model code, or other analytic limits."

United staff felt that due to the large fluctuations observed in groundwater elevations in the study area and the potential for aquifers to fluctuate between confined and unconfined conditions repeatedly over time, MODFLOW-NWT would yield the most efficient solution for each simulation. In the future, the VRGWFM may be adapted to the unstructured-grid version of MODFLOW, "MODFLOW-USG" (Panday and others, 2013), which could provide an even more efficient solution for modeling at a finer spatial resolution in specific areas of interest.

3.2 MODEL DOMAIN, OUTER BOUNDARIES, AND GRID DESIGN

The current active domain of the VRGWFM includes the Forebay, Mound, Oxnard Plain, Pleasant Valley, and West Las Posas basins, part of the Santa Paula basin, and the submarine (offshore) outcrop areas of the principal aquifers that underlie the Oxnard Plain and Mound basins (see Figure 1-2). The active model domain spans approximately 176,000 acres (275 square miles), of which 62 percent (108,000 acres or 170 square miles) is onshore and 38 percent (68,000 acres or 106 square miles) is offshore.

3.2.1 Model Domain and Outer Boundaries

Lateral boundaries of the VRGWFM vary by layer, as shown on Figures 3-1 through 3-13, but can generally be defined as follows:

- The eastern edge of the active model domain in the West Las Posas and Pleasant Valley basins adopts a no-flow boundary coincident with the East Las Posas basin boundary and the Central Las Posas Fault (Figures 1-2 and 2-10). Modeling conducted for Calleguas suggests that groundwater flow from the East to West Las Posas basin is so small as to be negligible (Intera, 2018).
- The northeastern boundary of the active model domain currently terminates just inside Santa Paula basin. In the future, the VRGWFM will extend up the Santa Clara River valley to include the Santa Paula, Piru, and Fillmore basins, eliminating the need for this general-head boundary. This boundary is currently simulated as a general-head boundary in Layers 3 through 11 (Layers 1 and 2 are not known to extend into Santa Paula Basin, and Layers 12 and 13 terminate south east of the Forebay), with groundwater fluxes influenced by historical groundwater elevation data from seven wells, including , 02N22W01M01S, 02N22W02K07S, 02N22W02K09S, 02N22W03K02S, 02N22W03M02S, , 02N22W03M03S, and 02N22W10C02S.
- The northern boundary of the active model domain coincides with the contact of Pleistocene and Holocene alluvial deposits with the San Pedro Formation at the base of the hills along the northern edge of the Mound and West Las Posas basins. Deep percolation of rainfall in the San Pedro Formation in this area recharges the upper San Pedro Formation (Layer 7, corresponding to the Hueneme Aquifer farther south) and Fox Canyon Aquifers (Layers 9 and 11); this process is simulated using the WEL package in model grid cells along this boundary, and recharge catchment areas are calculated based on the extent of the San Pedro Formation outcrop north of the model boundary (discussed further in Section 3.5).
- The southeastern boundary of the active model domain coincides with the contact between Holocene alluvial fill deposits and poorly permeable bedrock of the Conejo Volcanics along the foothills of the Santa Monica Mountains. Mountain-front recharge to the Semi-perched Aquifer is implemented in the model adjacent to this boundary using the WEL package. In the southernmost part of this area, where the Oxnard Plain basin abuts La Jolla Peak, the drainage areas are very small, and are assumed to produce negligible mountain-front recharge.
- The southwestern boundary of the active model domain extends offshore to the submarine outcrop areas of the UAS and LAS. The interaction of seawater with freshwater in aquifers that outcrop under the seafloor and in submarine canyons is implemented as a general-head boundary, as shown on Figures 3-1 through 3-13.
- The northwest boundary of the active model domain corresponds with an assumed hydraulic divide offshore from the western margin of the Mound basin. Little is known regarding the specific hydrogeologic conditions along this boundary, which is not only under the Pacific Ocean, but is up to 10 miles from the nearest water-supply well. However, because this boundary is so far distant from the nearest water-supply well, it is unlikely to have a significant effect on calibration of the model or on simulation of future water-supply scenarios.

3.2.2 Grid Design and Resolution

The domain of the VRGWFM was discretized (subdivided) into finite-difference grid cells and layers such that basin-scale hydrogeologic features, boundaries, and flow patterns could be simulated at an acceptable level of resolution, while keeping model run-times to a reasonable length (typically less than 30 minutes) during calibration and sensitivity analysis. At present, the VRGWFM model-grid spacing is a uniform 2,000 feet (in both the north-south and east-west directions), divided into 13 layers of variable thickness. The uniform grid spacing allows for efficient processing of input and output parameters, and avoids potential numerical issues that can result from having grid cells with high aspect ratios. The model grid currently consists of 137 columns by 75 rows, and is rotated 26 degrees counter-clockwise from true north to align the dominant groundwater flow directions (southwest and southeast) with the primary axes of the model grid, as recommended by the USGS (McDonald and Harbaugh, 1988). The coordinate offsets are 6,151,000 and 1,790,000 feet relative to the NAD 1983 State Plane Zone 5 system. The current active area of the model domain is approximately 18 percent of the total. Initially, the grid size was set at a uniform 2,000-feet per side. The computation time for the 2,000-foot-grid model was reasonable, less than 10 minutes per simulation, and was used for the model calibration and sensitivity analyses described in this report.

3.3 MODEL LAYERING

The VRWGFM includes the seven aquifers and six aquitards occurring in the study area (details provided in Section 2.5) as individual model layers; Figure 3-14 illustrates how the model layers are adapted to the variable hydrostratigraphy in each basin. The top elevations and thicknesses of each aquifer and aquitard in the hydrostratigraphic conceptual model were used to input top and bottom elevations for each model layer. Where HSUs pinch out, the corresponding model layer thickness is set to 1 foot to preserve the integrity of finite difference grid. Where doing so would not interrupt simulation of flow between layers, these “pinched out” areas were set as inactive (typically Layers 1 or 2).

3.4 ASSIGNMENT OF INITIAL AQUIFER PARAMETERS

This section presents the input values to the VRGWFM for horizontal hydraulic conductivity, vertical conductance between layers, specific yield, storage coefficient, and conductance across horizontal flow barriers (faults). Conductance values and other input parameters applied to local-scale features and stresses (e.g. drains or stream channels), are presented in Section 3.5. As noted in Section 2, previous investigators have typically estimated aquifer hydraulic parameters for the UAS and LAS rather than for individual aquifers within those systems. This is because most wells in the study area are screened across multiple aquifers, resulting in a very small number (typically just a few per basin) of aquifer-specific, long-term, multi-well analyses of hydraulic conductivity or storage coefficients within the study area, often separated by distances measured in miles. The more common single-well specific capacity tests in the study area can provide an indication of the general range of hydraulic conductivity in the immediate vicinity of each well, but such values should be considered only as initial estimates applicable within a few hundred feet to yards of each well. Therefore, significant uncertainty regarding aquifer hydraulic parameters exists in the “real world” even before model construction begins, and it is rarely feasible to conduct an aquifer testing program that would eliminate all such data gaps. Rarely is the hydraulic conductivity matrix known with confidence across a basin. The DWR’s best-management practices for modeling state that “hydrogeologic parameters such as hydraulic conductivity, specific yield and leakance coefficients are often modified during model calibration” (Joseph and others, 2016). This was United’s approach to assigning aquifer hydraulic parameters in the VRGWFM; start with values based on available data (or typical values reported in the literature for the soil and rock types present), then adjust the values as appropriate (within reasonable ranges) during model calibration, as described in Section 4.

3.4.1 Hydraulic Conductivity

A number of aquifer tests and slug tests have been performed within the study area by United and the USGS. The aquifer test results are tabulated in Table 3-1. The slug test results are tabulated in Table 3-2. Inspection of the aquifer test results (Table 3-1) suggests that the hydraulic conductivity for the UAS in the Forebay basin is in the range of 50 to 300 ft/day, and the hydraulic conductivity of the LAS in the Forebay basin is in the range of 10 to 50 ft/day. The slug test results suggest that in the Oxnard Plain basin, the hydraulic conductivity of the UAS ranges from less than 1 ft/day to 128 ft/day, with most results in the range from 20 to 40 ft/day, while hydraulic conductivity in the LAS ranges from 0.01 ft/day to 70 ft/day, with most results in the range from 1.0 to 20 ft/day. The inferred hydraulic conductivity values from the tabulated aquifer and slug tests were used to set the range of initial aquifer parameters in the mode; the initial vertical anisotropy ratio was set to 0.1. The most sensitive parameter influencing calibration of simulated to measured heads is typically hydraulic conductivity; this parameter is typically also subject to the greatest variability and uncertainty. Therefore, hydraulic conductivity commonly receives the greatest degree of adjustment during model calibration. The final calibrated aquifer parameters are more influenced by the transient water level measurements from all the available wells than by individual aquifer tests and slug tests, which are typically representative of only the local area around the wells during the time they were tested. The horizontal hydraulic conductivities ultimately applied to the calibrated model are shown on Figures 3-15 through 3-27.

3.4.2 Specific Yield and Storage Coefficient

The default values for specific yield in Semi-perched Aquifer, UAS aquifers, and LAS aquifers are 0.15, 0.15 and 0.1, respectively. The default value for specific yield in all aquitards is 0.05. The model calibration (Section 4) shows that only the specific yields in Semi-perched Aquifer and UAS aquifers have limited effect on simulated water level. The final calibrated specific yields are the same as the default value. The default values for dimensionless storage coefficient in all aquifers and aquitards is 0.001. After model calibration, the storage coefficient remains 0.001 in semi-perched aquifer and UAS system. The dimensionless storage coefficient in LAS system varies from 0.0005 to 0.002.

3.4.3 Horizontal Flow Barriers (Faults)

Several faults have been documented as affecting groundwater flow in the study area, and were modeled as horizontal flow barriers during previous modeling by the U.S. Geological Survey (Hanson and others, 2003). The fault locations and potential for affecting groundwater flow were reviewed by United geologists, then were implemented in the VRGWFM using the Horizontal Flow Barrier (HFB) package. Figures 3-15 through 3-27 show the locations of faults in each model layer that act as horizontal flow barriers, together with the conductance across those faults.

3.5 ASSIGNMENT OF AQUIFER STRESSES

This section presents the input values to the VRGWFM for aquifer stresses, categorized as recharge or discharge. Table 3-3 summarizes the recharge and discharge rates (as annual averages) input to the model and compares them to the estimated long-term average inflow and outflow components in the study area that were estimated by previous investigators (as discussed in Section 2 and summarized in Table 2-2). Some of inflow and outflow components to the study area are known with a reasonable level of confidence and can be directly translated to the model as recharge and discharge components, on a one-to-one basis (e.g., pumping and artificial recharge rates). However, some of the inflow and outflow components estimated by previous investigators were associated with significant uncertainty due to limited data availability, or were averages for limited time periods in the past that may not be representative for current hydrologic conditions in the region, and thus do not necessarily match model recharge and discharge quantities (e.g., irrigation return flows and ET rates) very closely. In such cases, reasonable application rates were estimated from the previous investigations or from other methods (described below in this section) and applied to current land uses to calculate total recharge or discharge volumes in the model to be used for a starting point. These volumes (or rates) were then adjusted in the calibration process (the final calibrated average flow rates are what is shown in Table 3-3).

Several of the groundwater flow components in the study area are calculated by the model as the product of hydraulic gradients and conductivities, rather than being input directly (e.g., groundwater underflows and seawater intrusion rates). These inflows and outflows are typically among the most difficult to measure or estimate in the field, and are subject to large uncertainty; therefore, groundwater modeling is commonly considered to provide the best estimates. Inflows and outflows calculated by the model, rather than input directly, are shown in Table 3-3 in italics, and are provided solely for comparison purposes.

3.5.1 RECHARGE PROCESSES

Each of the known sources of groundwater recharge within the study area required for input to the VRGWFM is described in this section. The RCH package was used to input artificial recharge, deep infiltration of precipitation, agricultural and M&I return flows, and percolation of treated wastewater (via ponds at two WWTPs) to the VRGWFM. The WEL package was used to input mountain-front recharge, and the STR package was used to simulate stream-channel recharge in the VRGWFM.

Table 3-3. Comparison of Previous Estimates of Groundwater Inflow and Outflow Components in Study Area to VRGWFM Recharge and Discharge Rates for Historic Calibration Period

Groundwater Inflow or Outflow Component	Estimates from Available Data or Previous Investigations (AF/yr)[a]	VRGWFM Recharge and Discharge Rates (AF/yr)
Inflows: (**bold** font used for components that are required as input to the VRGWFM, *italic* font used for flows that are calculated by the VRGWFM [provided solely for comparative purposes])		
Artificial Recharge (at Saticoy and El Rio Spreading Grounds)	**48,000**	**48,000**
Areal Recharge (combined deep infiltration of precipitation and return flows [Ag + M&I])	**38,000 to 43,000**	**48,000[b]**
Mountain-Front Recharge (sum of ungauged streamflow and bedrock recharge)	**3,000**	**7,900[b]**
Percolation of Treated Wastewater at WWTPs	**280**	**280**
Stream-Channel Recharge in Santa Clara River	*8,400*	*9,600*
Stream-Channel Recharge in Arroyo Las Posas	*4,000*	*4,300*
Groundwater Underflow from Santa Paula Basin	*1,800 to 7,400*	*3,800*
Groundwater Underflow from East Las Posas Basin	*700 to 1,900*	*1,600*
Net Seawater Intrusion into UAS and LAS	*12,000*	*9,400*
Outflows: (**bold** font used for components that are required as input to the VRGWFM, *italic* font for flows that are calculated by the VRGWFM [provided solely for comparative purposes])		
Pumping from Water-Supply Wells	**130,000[c]**	**130,000[b]**
Shallow groundwater drainage (to tile and other manmade drain systems)	*8,000 to 12,000*	*12,000*
ET	*15,000*	*9,900*
Discharge of Shallow Groundwater in Semi-perched Aquifer to Santa Clara River	*1,500*	*1,200*
Semi-perched Aquifer Discharge to Pacific Ocean	*No previous estimates*	*1,100*

Notes:

[a] Details regarding sources and calculation methods for averages calculated from existing data or estimated by previous investigators are provided in Section 2.7 and Table 2-2. Most of the averages summarized in this column are for the combined area of the Oxnard Plain, Forebay, Pleasant Valley, Mound, and West Las Posas basins. The relatively small inflow and outflow quantities occurring in the minor area of the active domain of the VRGWFM located outside of those basins (e.g., western margin of Santa Paula basin) are generally not included in the averages presented in this column.

[b] The VRGWFM-input or -calculated quantities listed in this table for these inflows and outflows include the entire active model domain, including small areas outside of the Oxnard Plain, Forebay, Pleasant Valley, Mound, and West Las Posas basins. Therefore, these quantities can be somewhat higher than those listed in the first column of this table, which generally focus specifically on these basins.

[c] Unlike most quantities listed in this column, the estimated total pumping from water-supply wells was calculated for the entire active model domain. Therefore, it is identical to the VRGWFM-input average pumping rate.

3.5.1.1 Artificial Recharge

Monthly artificial recharge rates (measured and recorded by United) at the Saticoy and El Rio spreading basins during the model calibration period (January 1985 through December 2015) were input to the model grid cells representing those basins using the recharge (RCH) package (typically in Layer 3). The time-averaged rates of areal (including artificial) recharge input to each grid cell in the VRGWFM are shown on Figure 3-28. During the model calibration period, the largest time-averaged areal recharge rates have occurred in the Saticoy and El Rio spreading basins. Because artificial recharge rates have been measured by United and reported on a monthly basis, they could be directly entered into the recharge package without modification and without adjustment during the calibration process.

3.5.1.2 Stream-Channel Recharge

Interaction between surface-water and groundwater is known to occur in the Santa Clara River, Arroyo Las Posas, Conejo Creek, and Calleguas Creek. Stream-channel recharge (losing reaches) is the dominant process, but some discharge of groundwater from the Semi-perched Aquifer to surface water (gaining reaches) occurs in the lowest reaches of the Santa Clara River and Calleguas Creek, near the coast. This interaction is modeled with the stream (STR) package in the VRGWFM. Locations (reaches) where the STR package was applied to the model are shown on Figures 3-1 through 3-3.

The monthly stream flow rates estimated for the Santa Clara River are listed in Table 3-4. The stream flows along Arroyo Las Posas from East Las Posas were based on the groundwater modeling by Calleguas (Intera, 2018). Stream-channel recharge was simulated using the stream package (STR). There is also stream-channel recharge in Arroyo Las Posas. This was simulated in the well package (WEL). The monthly inflow for Arroyo Las Posas from 1985 to 2015 is listed in Table 3-5.

The monthly stream flow rates for Conejo Creek (Table 3-6) are based on a stream gauge in the Santa Rosa basin, just outside of the active model domain for the VRGWFM. A portion of the surface water in Conejo Creek is diverted in Pleasant Valley basin, just downstream from U.S. Highway 101 in Camarillo. The monthly volumes diverted are also listed in Table 3-6. Approximately one mile south from Highway 101, a WWTP operated by the Camarillo Sanitation District (CamSan) discharges approximately 4,000 AF/yr of treated wastewater. A portion of the discharge is sent to nearby farms for irrigation. The WWTP discharge to Conejo Creek is estimated to be 2 cubic feet per second (cfs), or about 1450 AF/yr (e-mail communication with Mark Richardson). Calleguas Creek receives the combined flows from Conejo Creek and Arroyo Las Posas.

The STR package requires the input of stream channel hydraulic parameters, including width, slope, and roughness. The stream channels of the Santa Clara River, Arroyo Las Posas, Conejo Creek, and Calleguas Creek vary greatly over time, as storms can significantly change their characteristics. The average active stream channel width for Santa Clara River was assumed to be 100 feet in the Forebay and gradually increase to 120 feet near its mouth at the coast. The channel width for other streams (Arroyo Las Posas, Conejo Creek and Calleguas Creek) is assumed to average 50 feet. The stream slope was calculated based on the stream bed elevation. The Manning's roughness coefficient for each channel is assumed to be 0.035.

3.5.1.3 Deep Infiltration of Precipitation

Monthly precipitation data were collected from 180 rainfall gauge stations across Ventura County (See Table 3-7). The monthly precipitation records were downloaded from the Ventura County Watershed Protection District (http://www.vcwatershed.net/hydrodata/). The Kriging method of geostatistical analysis was used to generate monthly precipitation distributions across Ventura County. Areal recharge from deep infiltration of precipitation was input to the VRGWFM using the RCH package, and was calculated as described below.

After determining the distribution of monthly rainfall across Ventura County, land use (agricultural, urban, or undeveloped) was the primary variable for estimating deep infiltration of precipitation. The baseline for land use was determined using the 2008 Southern California Association of Governments (SCAG) geographic information system (GIS) data for Ventura County (http://gisdata-scag.opendata.arcgis.com/datasets/land-use-ventura). Land-use changes over the years (1984, 1990, 1996, 2002, 2008, and 2012) were obtained from the California Department of Conservation "Farmland Monitoring and Mapping Program" (FMMP) GIS data http://www.conservation.ca.gov/dlrp/fmmp/Pages/Ventura.aspx), and were used to adjust the baseline (2008) land use in the corresponding years (Figure 2-2).

For agricultural land, three recharge rates (the percent of groundwater recharge relative to the precipitation) were considered for estimating deep infiltration of precipitation:

1. A constant percentage of annual precipitation.
2. The Grunsky (1915) method, described in Section 2.7.
3. An adaptation of the Turner (1991) method (also described in Section 2.7), with a minimum monthly rainfall rate that could produce deep infiltration and a maximum percentage of rainfall assigned to deep infiltration.

Of these three potential approaches, the first method assumes a constant percentage of rainfall becomes deep infiltration; this approach, while simple, does not take into account minimum rainfall required to produce deep infiltration, or the greater infiltration rates expected to occur during particularly wet months or years. The second method (Grunsky, 1915) accounts for increasing recharge with increasing rainfall, but relies on annual precipitation totals to establish recharge rates; this approach poorly represents monthly precipitation subtotals in Ventura County (most precipitation falls during a limited number of storms in winter months). For these reasons, deep infiltration of precipitation on agricultural and undeveloped land was input to the VRGWFM using the third approach, adjusted and guided by model calibration. This approach is based on monthly precipitation rather than annual, and the recharge rate increases with monthly precipitation. Specifically, the first 0.75 inch of monthly precipitation is assumed to evaporate or wet the soil matrix in the vadose zone, and does not infiltrate deeply enough to recharge the underlying groundwater. If monthly precipitation in an agricultural or undeveloped area exceeds 0.75 inches, a fraction of that precipitation will infiltrate deeply enough to become recharge, according to the following rules:

- If monthly precipitation is less than 0.75 inch, then no recharge is assigned in that area;
- If monthly precipitation is 0.75 to 1 inch, then recharge is assigned from 0 to 10 percent of precipitation (on a sliding scale);
- If monthly precipitation is 1 to 3 inches, then recharge is assigned from 10 to 30 percent of precipitation
- If monthly precipitation is greater than 3 inches, then recharge is assigned as 30 percent of precipitation.

All three approaches to estimating deep infiltration of precipitation on agricultural land were tested during model development. For the first approach, the constant fraction of precipitation that was assumed to become recharge was specified (after several trial-and-error attempts) as 15 percent. This value yielded the best calibration during dry and average years, but tended to result in simulated groundwater elevations that were higher than measured groundwater elevations in wet years. The second (Grunsky) and third approaches yielded similar results, except in extreme wet years when the simulated groundwater elevations resulting from the Grunsky method tended to be higher than measured values. Therefore, the third approach was applied to the current version of the VRGWFM.

For urban and built-up lands, including residential, commercial, and industrial areas, a fixed percentage of 5 percent of precipitation was used to account for deep percolation of rainfall.

And for the limited area of undeveloped land within the active domain of the VRGWFM, 10 percent of rainfall was assumed to become recharge.

The recharge from deep infiltration of precipitation is implemented using the RCH package. The following example illustrates how precipitation recharge was calculated for each model grid cell; due to the size of each grid cell (2,000 by 2,000 feet), many cells include multiple land use types. Assuming land use in a model cell is 45 percent agricultural, 35 percent urban, and 20 percent undeveloped, and that monthly precipitation is 2.5 inches, the recharge rate for agricultural land use is set at 25 percent of monthly precipitation. Based on these assumptions, the total precipitation recharge to this model cell would be:

Total Monthly Rainfall x (Agricultural Recharge Rate x Percentage of Agricultural Land + Urban Recharge x Percentage of Urban Land + Undeveloped Recharge Rate x Percentage of Undeveloped Land)

= 2.5 inches per month x (0.25 x 0.45 + 0.05 x 0.35 +0.10 x 0.20) = 0.375 inches per month

3.5.1.4 Agricultural Return Flows

Areal recharge resulting from infiltration of agricultural return flows to the underlying aquifer is also simulated in the VRGWFM using the recharge package (RCH). Water for agricultural irrigation in the study area typically comes from three sources: groundwater pumped from nearby wells, groundwater and surface water (diverted from the Santa Clara River) delivered via the PTP and PVP, and surface water diverted from Conejo Creek. Agricultural return flow was calculated based on applied groundwater and surface water in each model grid cell.

Farmers apply irrigation water to meet evaporation, transpiration, and salt-leaching demands on their fields (when rainfall is insufficient to meet those demands), with the goal of maintaining acceptable crop yields. The salt-leaching requirement (LR) is the percentage of "extra" irrigation water required to control salt concentrations in root zone. Water applied to meet the LR is assumed to flow past the root zone and reach the underlying aquifer; most water applied to meet evaporation and transpiration demands are assumed not to reach the aquifer. As described in Section 2.7, the ITRC (2010) lists LRs for various crops in Ventura; using these LRs, United calculated the average LR for the study area (based on crop acreage and the distribution uniformity factor of 0.8) to be 0.14, as listed in Table B3 (United, 2013). This average LR of 14%, was used as the initial value to calculate the recharge resulting from agricultural return flows for the RCH package. During model calibration, the LR values were evaluated basin by basin. The model calibration shows that a LR value of 0.20 is more appropriate for all basins except that the LR value in Oxnard Basin (Oxnard Plain and Oxnard Forebay) is 0.25.

3.5.1.5 Municipal and Industrial Return Flows

Similar to agricultural return flows, areal recharge resulting from infiltration of M&I return flows to the underlying aquifer is simulated in the VRGWFM using the recharge package. As noted in Section 2.7, recharge resulting from deep percolation of M&I return flows was initially assumed to be 5 percent of total M&I water use. During development of the VRGWFM, a study of urban recharge in a portion of Los Angeles County, the adjacent county to the east of Ventura County, was completed by the Water Replenishment District of Southern California (WRD) and the USGS (Hevesi and Johnson, 2016). Their investigation used a daily precipitation-runoff model to estimate recharge and runoff for the greater Los Angeles area, and found average recharge in the urban portion of their study area to be 8 percent of the combined inflow from precipitation and urban irrigation. Applying the Hevesi and Johnson (2016) results to urban portions of the VRGWFM study area, and assuming that 50 percent of M&I water is used for outdoor irrigation (landscaping and parks), the calculated percentage of M&I water that becomes return-flow recharge is 4%, which is close to the 5 percent assumed in the VRGWFM.

3.5.1.6 Mountain-Front Recharge

Mountain-front recharge is input to the model as specified fluxes in the model grid cells adjacent to each small drainage system (sub-watershed) along the margins of the model area, using the WEL package. Mountain-front recharge rates in outcrops of the San Pedro Formation in the northern and northeastern portions of the study area, and at the base of the Santa Monica Mountains (Figure 2-17), are calculated based on monthly precipitation rates and the area of each sub-watershed receiving the precipitation. Model grid cells receiving mountain-front recharge are shown on Figure 3-29. The monthly mountain-front-recharge rates input to the model follow the precipitation/recharge-percentage relationship used for agricultural return flows, but use sub-watershed area (immediately upstream from the active model domain) rather than grid-cell area to calculate monthly volumetric recharge rates. Mountain-front recharge at the base of the Santa Monica Mountains is applied to the uppermost active grid cell. Mountain-front recharge entering the San Pedro Formation along the margins of the Mound, West Las Posas, and Pleasant Valley basins is applied to Layers 7, 9, and 11 (corresponding to the LAS aquifers that receive recharge via outcrops of the San Pedro Formation).

3.5.1.7 Percolation of Treated Wastewater

Recharge of treated wastewater occurring in percolation ponds at the Saticoy and Montalvo WWTPs is simulated in the VRGWFM using the recharge package (RCH). The monthly percolation volumes reported to in the State's GeoTracker system (as described in Section 2.7) are simply added to other areal recharge rates specified for the model grid cells corresponding to the WWTP percolation-pond sites. As noted in Section 2.7, the small volume of percolation from septic tanks (1,000 AF/yr total, distributed across the entire study area) represents approximately 1 percent of the estimated total recharge in the study area, and is implicitly included with agricultural or municipal/industrial return flows, rather than attempting to simulate each domestic septic system as a distinct source of recharge.

3.5.2 Discharge Processes

Each component of groundwater discharge required for input to the VRGWFM is described in this section.

3.5.2.1 Pumping from Water-Supply Wells

Of the 1,790 water-supply wells for which United and the FCGMA have extraction records, 943 are present in the active model domain of the current version of the VRGWFM. Most of the extraction records for these wells consist of reported pumping volumes for 6-month periods (most, but not all, are for the periods January-June, and July-December). To estimate monthly pumping from each well based on these records, a precipitation-weighted formula was used. The volume pumped in a particular month was assumed to be inversely proportional to the precipitation for that month. When monthly precipitation was less than 0.6 inch (0.05 feet), the monthly precipitation is assumed to be 0.6 inch for the purpose of estimating monthly pumping from each well.

Groundwater withdrawals from wells in the study area were implemented using the multi-node well (MNW2) package. The location and construction information for each well is tabulated in Table 3-8. In the MNW2 package, the option "SPECIFYcwc" is used. The minimum conductance is set to be 2,000 square feet. If the well casing diameter is larger than 12 inches, the conductance is increased proportionally.

3.5.2.2 Drainage

Tile drains were implemented using MODFLOW's drain package (DRN). Model grid cells with simulated tile drains in the uppermost active layer are shown on Figure 3-30, corresponding with agricultural areas where tile drains are known or suspected to exist, as discussed in Section 2.7 and shown on Figure 2-24. The tile drain depths are set at 7 feet below ground surface (see Section 2.7 for rationale). The conductance for drains is assumed to be 10,000 square feet.

3.5.2.3 Evapotranspiration

ET was implemented using MODFLOW's evapotranspiration package (EVT). Model grid cells with simulated evapotranspiration in the uppermost active layer are shown on Figure 3-30, corresponding with areas of mapped wetlands fed by shallow groundwater (as discussed in Section 2.7 and shown on Figure 2-24). The maximum ET flux is 0.010 feet per day (3.65 ft/yr) for model grid cells that are subject to ET over their entire area, slightly higher than the midpoint of USGS-estimates of ET from wetlands in the study area. The maximum ET flux is scaled down proportionally for grid cells that are only partially occupied by wetlands. The ET surface elevation is set at 3 feet below ground surface, and the ET extinction depth is set at 5 feet.

3.5.3 Groundwater/Seawater Interface Parameters

Groundwater/seawater interaction—outflow of groundwater from the aquifers of the Oxnard Plain and Mound basins to the Pacific Ocean, and inflow of seawater to those aquifers when hydraulic gradients are reversed—is simulated using a general head boundary along the southwestern (offshore) margin of the active model domain. Groundwater/seawater interaction is allowed in all aquifers except the Grimes Canyon Aquifer, which is not known to crop out offshore within the study area. The Grimes Canyon Aquifer is known to extend offshore, but outcrops have not been mapped in the Hueneme and Mugu submarine canyons where seawater intrusion is likely to occur. Groundwater/seawater interaction on the seafloor is assumed to be insignificant within the six aquitards due to their much lower hydraulic conductivities compared to the aquifers; however, once seawater enters the aquifer system, the model allows lateral and vertical groundwater flow within and through the aquitards. Groundwater/seawater interaction at the aquifer/ocean interface is currently simulated using a general-head boundary, as this approach is significantly less numerically intensive than attempting to model variable-density flow for the 31-year historical calibration period of the VRGWFM. In addition, insufficient data are currently available to define the current extents and sources of saline groundwater in each aquifer, let alone historical extents, with the level of accuracy that would be needed to construct and calibrate a variable-density flow model. At present, simulating seawater intrusion as a general-head boundary is suitable for United's intended uses of the VRGWFM. In the future, should the need arise to conduct a detailed simulation of variable-density flow in the study area—and assuming additional groundwater quality data are obtained in the area of suspected seawater intrusion to justify such an effort—a MODFLOW-compatible seawater-intrusion package could potentially be applied to the VRGWFM.

In the Semi-perched (uppermost) Aquifer, represented by Layer 1 of the model, the interaction with seawater is assumed to take place on the seafloor adjacent to the coast. In the Oxnard and Mugu Aquifers (UAS), represented by model Layers 3 and 5, groundwater/seawater interaction is assumed to occur at the depth and location of the Mugu Aquifer submarine outcrop (Figure 3-5). In the Hueneme, main Fox Canyon, and basal Fox Canyon Aquifers (LAS), represented by model Layers 7, 9, and 11, groundwater/seawater interaction is assumed to occur at the depth and location of the San Pedro Formation submarine outcrop (Figures 3-7, 3-9, and 3-11), each layer's location varying slightly with depth.

Actual mean sea level along the Ventura County coast is 2.73 feet above the 1988 NAVD datum, which is used to define elevations in the VRGWFM (including land surface). Therefore, the prescribed head for the general-head boundary representing the Pacific Ocean is increased above 0 feet msl to account for the greater density of seawater compared to fresh water, as follows:

$$\text{prescribed head (feet)} = 2.73 + 0.0245*(2.73 - \text{cell elevation})$$

The modeled conductance of the general-head boundary representing the Pacific Ocean was initially set to 1,000 feet squared per day (ft^2/day) in Layers 3, 5, 7, 9, and 11. In Layer 1, initial conductance was set to 10,000 ft^2/day, reflecting the larger contact area present between the ocean and the Semi-perched Aquifer on the gently sloping Ventura and Hueneme-Mugu Shelves, compared to the deeper aquifers that crop out primarily along steeper slopes farther offshore and in the walls of the Hueneme and Mugu submarine canyons.

3.6 ASSIGNMENT OF INITIAL HEADS

The starting water level on January 1st, 1985 for the transient flow model was iteratively modified in the model calibration. Initially the water level measurements for UAS and LAS in December 1984 were selected to calculate the starting water level by Kriging. The Kriged groundwater levels for the UAS and LAS form the initial heads matrix for the transient flow model simulation. In model calibration, a portion of the December 1984 groundwater level measurements were adjusted and more control points were added to modify the Kriged initial head. The final initial heads for the Semi-perched Aquifer, the UAS, and the LAS are shown on Figures 3-31, 3-32, and 3-33, respectively.

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4 RESULTS OF MODEL CALIBRATION AND SENSITIVITY ANALYSIS

By comparing simulated groundwater levels with measured groundwater levels, and adjusting model input parameters (as described in Section 3) to minimize the differences, a set of calibrated input parameters was determined to yield a reasonably good fit, while remaining consistent with the hydrogeologic conceptual model. The DWR's BMPs for modeling (Joseph and others, 2016) note that:

> *"Calibration is performed to demonstrate that the model reasonably simulates known, historical conditions. Calibration generally involves iterative adjustments of various model aspects until the model results match historical observations within an agreed-to tolerance. Hydrogeologic parameters such as hydraulic conductivity, specific yield and leakance coefficients are often modified during model calibration... Aspects of the water budget, such as recharge rate or private pumping rate, may also be modified during calibration."*

Input parameters that were adjusted during calibration of the VRGWFM included:

- hydraulic conductivity
- specific yield and storage coefficient
- stream-channel conductance
- general-head boundary conductance
- horizontal flow barrier conductance
- areal recharge rates
- multi-node well parameters

Following calibration, sensitivity analysis of the VRGWFM was conducted to identify model input parameters and boundary conditions that have a particularly strong influence on model output. As suggested by DWR, "Parameters that are both highly sensitive and poorly constrained may be good candidates for future data collection" (Joseph and others, 2016). Results of both the calibration process and sensitivity analysis for the VRGWFM are described below.

4.1 CALIBRATION

Few groundwater basins in agricultural regions have been studied and monitored to the extent that the basins in the study area for the VRGWFM have. The location, timing, and magnitude of the major inflow (artificial recharge) and outflow (groundwater pumping) components to and from the principal aquifers in the study area are known (since 1980 and 1985) to a much higher degree of accuracy than is typical in most basins, and groundwater elevation data are available from an extensive network of monitoring wells. This data richness not only provides for understanding of the environmental setting (conceptual model) for groundwater flow in the study area, but also allows extensive calibration of the numerical model, reducing the potential for non-uniqueness of model solutions and the uncertainty in model output. When construction of the VRGWFM began in 2013, the calibration period was intended to include January 1985 through December 2012, with monthly stress periods consisting of a single time step each. The model calibration period was selected in consideration of the following:

- Pumping records for individual wells became available over most of the study area in 1985. United began requiring reporting of semi-annual pumping rates in their service area in 1980, and the FCGMA required reporting of semi-annual pumping rates at wells in their service area by 1985. United's and the FCGMA's service areas overlie most of the active domain of the VRGWFM.
- Reporting of groundwater level elevations became more frequent and widespread starting in the early- to mid-1980s.
- The late-1980s was a drought period in southern California, associated with record-setting groundwater-level declines, which was then followed by the wettest period on record in the region (1992 through 2005), resulting in rapid recovery of groundwater elevations. Calibrating the VRGWFM to these widely varying hydrogeologic conditions was thought to increase the likelihood that the model would be capable of forecasting groundwater elevations and flow rates under a broad range of potential future climate and water-supply scenarios.

Another major drought began in 2012 in the region, resulting in new record-low groundwater levels in the study area. In 2016, the model-calibration period was extended through December 2015, to include groundwater elevation changes observed during this latest drought. Currently the calibration period of the VRGWFM is from January 1985 through December 2015, with 372 monthly stress periods.

An extensive groundwater level monitoring network in Ventura County has been maintained by FCGMA and UWCD for decades. This network includes wells screened in the UAS, LAS and across both aquifer systems. There are also production wells being monitored for water level measurements. For evaluation of water level changes over time (hydrographs), wells with more than 100 water level measurements were selected to adequately cover the modeling area. Where coverage by wells with 100 and more measurements was poor, wells with less than 100 measurements were selected. In the case of monitoring wells screened across multiple aquifers (and, therefore, model layers), the maximum of simulated water levels from the layers the well is screened through was used for calibration target in most instances. If some cases, the water levels measured in multiple-aquifer wells appeared to be primarily representative of one specific aquifer (based on comparison to surrounding wells); in these cases, the simulated water level from the model layer representing that specific aquifer was used as the calibration target. It is also important to note that the simulated water level from production wells is based on the simulated water level in the aquifers adjacent to each well's screened interval, not the simulated water level output from the MNW2 package of MODFLOW, because most water level measurements from production wells were obtained while the production wells were turned off (to measure a static groundwater level representative of the water level in the aquifer).

The USGS recognizes that "most models of specific ground-water systems…are calibrated by matching observed heads and flows," and recommends that "the evaluation of the adequacy of the calibration of a model should be based more on the insight of the investigators and the appropriateness of the conceptual model rather than the exact value of the various measures of goodness of fit" (Reilly and Harbaugh, 2004). United calibrated the VRGWFM by comparing simulated to measured groundwater elevations and flow rates, and adjusting selected model input parameters (listed above) within a reasonable range as necessary and appropriate, such that simulation results better matched measured values. Following are the primary comparison approaches used during calibration of the VRGWFM:

- Simulated groundwater elevations in each aquifer at specific times were plotted on contour maps and compared to measured groundwater levels at those times, to qualitatively evaluate the model's ability to simulate overall groundwater flow pattern within the study area.
- Simulated groundwater elevations over time at specific wells were plotted together with measured groundwater levels at those wells, using hydrographs, to evaluate the model's ability to simulate groundwater-level declines and recoveries during past droughts and wet periods.
- Simulated groundwater elevations at each calibration well were compared against groundwater elevations measured at those wells, using scatterplots, to evaluate the model's overall ability to simulate the range of groundwater elevations that occurred within the study area during the calibration period.
- Residuals (the difference between simulated and measured groundwater elevations) were plotted on maps, to evaluate whether significant spatial bias was present in the model (e.g., areas where the model consistently under- or over-predicted groundwater elevations).
- Simulated groundwater underflows between basins and at the boundaries of the study area were compared to each other and to available information (which was often limited) for actual underflows within the study area to qualitatively evaluate how well the numerical model simulated overall trends of groundwater movement within the study area.

As DWR cautions in their modeling BMPs, "No model is perfectly calibrated, and establishing desired calibration accuracy *a priori* is difficult" (Joseph and others, 2016). Despite this difficulty, United felt that setting an initial, specific calibration target for groundwater-elevation residuals during development of the model was important, to provide a quantitative measure of how well each model run (using a different set of input parameters) compared to real-world conditions. Therefore, an initial goal during model calibration was to target an absolute residual mean (ARM) of 20 feet or smaller—additional, related calibration statistics are presented in the following subsections. This ARM target is 5 percent of the observed range of groundwater elevations (from -200 to +200 ft msl) in the study area, substantially smaller than the industry standard of 10 percent.

The following subsections describe the degree to which the resultant, calibrated numerical model compares to, or "fits," the hydrogeologic conceptual model based on the qualitative and quantitative approaches described above.

4.1.1 Simulated Groundwater Levels

Simulated groundwater elevations (commonly referred to as hydraulic heads, or simply "heads") were contoured for each the seven aquifers in the study area at two key historical times—October 1991 (near the end of previous major drought in the region), and October 2006 (a year of high groundwater elevations following record-setting rainfall in 2005 and associated recharge in 2005 and 2006). In addition, simulated groundwater elevations were contoured for December 2015, which is the most recent month in the model-calibration period and falls in another major drought period. These groundwater-elevation contours are shown on Figures 4-01 through 4-21.

Figures 4-02, 4-05, 4-09, 4-12, 4-16, and 4-19, which show simulated groundwater-elevation contours for Layer 3 (representing the Oxnard Aquifer) and Layer 9 (representing the Fox Canyon Aquifer), also show contours in the UAS and LAS, respectively, prepared by United staff from measured groundwater elevation during fall of the corresponding year in the Oxnard Plain and Pleasant Valley basins. United staff prepared the UAS contours based on groundwater elevations measured at wells screened partially or completely through the Oxnard Aquifer, Mugu Aquifer, or both aquifers; United did not extend these contours into the Pleasant Valley basin as there are few UAS wells there. United staff prepared the LAS contours based on groundwater elevations measured at wells screened partially or completely through the Hueneme, Fox Canyon (main and basal), and Grimes Canyon Aquifers. Because many of the measured groundwater elevations were obtained from wells screened partially through an aquifer, or across more than one aquifer, the corresponding contours drawn by United for the UAS and LAS can only be considered to be approximately representative of actual groundwater elevations within the Oxnard Aquifer and the main Fox Canyon Aquifer, and would not be expected to perfectly match simulated groundwater elevations in Layers 3 or 9. In addition, there are some data gaps between well locations and other issues that require significant interpretation and professional judgment when the measured groundwater levels are contoured.

Despite these differences between simulated contours for specific model layers versus contours drawn by United staff more generally for the UAS and LAS, the overall trends are qualitatively similar, confirming that the VRGWFM reasonably simulates overall patterns of groundwater flow in these aquifer systems during periods of both high and low groundwater elevations. The largest differences between model-derived contours and the hand-drawn contours occur in Layer 9 near the El Rio Spreading Grounds (Figures 4-05, 4-09, and 4-12). In this area, there are typically large differences between measured groundwater elevations in the Hueneme Aquifer and the main Fox Canyon Aquifer. United draws its LAS contours based on measured groundwater elevations in the Hueneme Aquifer, rather than the main Fox Canyon Aquifer, near the El Rio Spreading Grounds. Therefore, the LAS contours are not expected to be similar to simulated groundwater elevations in Layer 9 better represent groundwater elevations in the main Fox Canyon Aquifer in this area than the hand-drawn contours for the LAS. Historically, there have been notable differences between measured groundwater elevations in the UAS versus those in the LAS; however, measured groundwater elevation differences between aquifers that comprise the UAS are typically relatively small (this is true for the LAS, as well, except in the Hueneme Aquifer near El Rio Spreading Grounds, as noted above). Therefore, groundwater elevations in Layer 5 of the model (Mugu Aquifer) would be expected to be similar to those in Layer 3 (Oxnard Aquifer) except in the vicinity of Mugu Lagoon, where measured groundwater elevations in the Mugu Aquifer are typically lower than those in the Oxnard Aquifer. Similarly, groundwater elevations in Layers 7, 11, and 13 (Hueneme, basal Fox Canyon, and Grimes Canyon Aquifers) would be expected to be similar to those in Layer 9 (main Fox Canyon Aquifer). Figures 4-02 through 4-21 indicate that these expected similarities are reflected in the output from the VRGWFM.

United does not prepare groundwater elevation contour maps for the Semi-perched Aquifer, and is not aware of mapping by others of groundwater elevations in the Semi-perched Aquifer at a basinwide scale suitable for comparison to simulated groundwater elevation contours for Layer 1. The patterns of the simulated Layer 1 contours are generally consistent over time, as shown on Figures 4-01, 4-08, and 4-15: groundwater elevations rise gently from the coastline to the interior of the Oxnard coastal plain, then rise more steeply in the Mound and the West Las Posas basins, in general conformance with land surface elevations. This is consistent with the historical groundwater elevation trends measured in the Semi-perched Aquifer, as described in Section 2.8.

4.1.2 Hydrographs at Selected Wells

In transient groundwater flow models, it is important to compare simulated to observed (measured) groundwater elevations over time to evaluate how well the model simulates aquifer reaction to short- and long-term changes in stresses (chiefly recharge and pumping). Time-series hydrographs comparing simulated to measured groundwater elevations were prepared for selected wells in the study area, as discussed above in Section 4.1. Wells screened in the UAS, LAS, or both aquifer systems and used for model calibration are shown on Figures 4-22 through 4-24. Hydrographs showing simulated and measured groundwater elevations over time at selected, representative wells in each basin or sub-basin in the study area (in the Semi-perched Aquifer, UAS, and LAS) are shown on Figures 4-25 through 4-35. Due to space limitations, not all hydrographs used or considered during model calibration could be plotted on these figures at a readable size. Hydrographs that show simulated and measured water levels for all wells used for model calibration are provided in Appendix B.

In the Forebay, the simulated hydrographs are mostly in close agreement with measured water levels (Figures 4-25 and 4-26). A notable exception is well 02N22W26B03S (Appendix B, page B-9), screened in the LAS, has simulated water levels similar to measured water levels in the UAS. This apparent discrepancy may simply be indicative of well construction that allows transmission of UAS hydraulic heads to the screened interval of this well (e.g., leaky casing or a gravel pack that extends above the screened interval into an aquifer of the UAS).

In the Oxnard Plain basin, simulated hydrographs are also generally in good agreement with measured water levels (Figures 4-28 through 4-31). The UAS and LAS show distinct patterns in timing and magnitude of fluctuations in groundwater levels; this is reflected in simulated groundwater levels at most wells. However, there are a few wells reportedly screened in UAS with water-level trends similar to the LAS (e.g., 01N21W32Q05S and 01S22W01H03S). There are also some wells reportedly screened in LAS with water-level trends similar to the UAS (e.g., 01N22W03F05S and 01N22W20J05S). At these wells with anomalous measured water-level trends, simulated heads can deviate substantially from measured heads. However, it is not always clear whether the anomalous measured groundwater levels accurately represent heads in the aquifer system the well is believed to be screened across. In other words, there is sometimes uncertainty regarding which aquifer a ***measured*** groundwater level is representative of. In these cases, differences between measured and simulated groundwater levels may indicate inaccurate or misinterpreted data rather than numerical-model issues. It is important to note that the VRGWFM is appropriately calibrated to the majority of wells in the Oxnard Plain basin (and the study area, overall).

In the Pleasant Valley basin, simulated hydrographs again are generally in good agreement with measured water levels (Figures 4-32 and 4-33). It is notable that the pronounced groundwater mounding observed from 1993 to 2015 in the northern Pleasant Valley basin (resulting from increased Arroyo Las Posas flows during that period, as described in Section 2) was accurately simulated (e.g., wells 02N20W19F04S and 02N20W19L05S). Similar to the Oxnard Plain basin, there are some wells reportedly screened in the UAS that have patterns of water-level fluctuation more consistent with wells in the LAS (e.g., 01N20W06C01S and 02N21W34G05S), resulting in substantial residuals. A significant effort was made to improve the calibration at these wells. However, it was found that when the calibration for these particular wells were improved, calibration of a large percentage of other wells suffered. Ultimately, these larger residuals were accepted at this small number of UAS wells to preserve the calibration at the majority of the remaining LAS wells, since most water-supply wells in Pleasant Valley are screened in the LAS.

In the Mound basin, because of its small area and largely urbanized (rather than agricultural) land use, there are fewer wells compared to other basins in the study area. Most wells in the Mound basin are screened in the LAS. The simulated hydrographs are generally in good agreement with measured water levels (Figure 4-27). Most residual means (discussed further in Section 4.1.4) in this basin are less than 10 feet, and the ARM is less than 20 feet. However, two Mound basin wells screened in the UAS (i.e., 02N23W15J03S and 02N22W07M03S) have relatively "flat" measured water levels through both wet years and dry years, inconsistent with trends at most other wells in the study area. Review of well construction logs indicated that these wells were screened in fine-grained materials, leading to uncertainty regarding whether measured water levels at these two wells are truly reflective of actual heads in the aquifer. Due to this uncertainty, these two wells were excluded as targets for calibration. There are three wells where simulated hydrographs match poorly with measured water levels, which are also of short duration; these wells are 02N22W09K05S, 02N22W09L03S, and 02N22W09L04S (Appendix B). These wells are located near well 02N22W09K04S, which is well-calibrated. All four wells of these wells are screened in the Hueneme Aquifer (model Layer 7). However the water levels in 02N22W09K04S are much lower than the other three wells (02N22W09K05S, 02N22W09L03S, and 02N22W09L04S), and well 02N22W09K04S is located up-gradient of those three wells. It was decided that adjustment of model parameters to improve model calibration at the three wells (02N22W09K05S, 02N22W09L03S, and 02N22W09L04S) with short periods of record and anomalously low water levels, at the expense of calibration at other wells, would not be appropriate at this time.

In the West Las Posas basin, there are three distinct hydrogeologic features that influenced the water-level calibration effort. First, the UAS of the Oxnard Plain basin does not extend into West Las Posas basin, being replaced by a shallow alluvial aquifer (Figure 3-14). Second, the Hueneme Aquifer of the Oxnard Plain basin does extend into the West Las Posas basin. Third, faults known or suspected to influence groundwater flow (Section 2.4) are present along the southern flank of South Mountain (La Loma, Fox Canyon, Berylwood Faults), and the Springville Fault occurs along the south margin of West Las Posas basin. Three corresponding “signatures” can be discerned in measured water levels in the West Las Posas basin (Figures 4-34 and 4-35). Water levels in the shallow alluvial and the upper San Pedro Formation are relatively stable and typically greater than 100 ft msl (e.g., wells 02N21W01L01S, 02N21W11J06S, 02N21W11A02S, and 02N21W16J01S). Simulated hydrographs match measured water levels reasonably well in the shallow alluvial aquifer (except in well 02N21W16J01S). Measured water levels in the LAS fluctuate substantially between wet and dry years, ranging from below -200 to 0 ft msl. The groundwater model was able to mimic the trends in measured water levels in the LAS, and the simulated hydrographs fit well with measured water levels in a majority of wells screened in the LAS. Most of the measured water levels near the faults along South Mountain fluctuate seasonally, except at well 02N21W03L01S (Appendix B), which exhibits an increasing water level trend, perhaps influenced by unknown local geologic features that have not been incorporated into the hydrogeologic conceptual model. The groundwater model was able to simulate water levels in a number of wells in the area near the southern flank of South Mountain (e.g., 02N21W08L02S, 03N21W35P01S, and 03N21W35P02S), while simulated water levels in wells 02N21W08G01S, 02N21W09D02S, 03N20W32G02S, and 03N20W32F02S are close to the measured data. Overall, the groundwater model was able to simulate water level trends in most shallow and LAS wells, but not in wells 02N21W03L01S and 02N21W16J01S. It should be noted that the wells near the boundary between Oxnard Plain and West Las Posas basins (i.e., 02N21W08D01S, 02N21W07Q01S, 02N21W07R01S, 02N21W18H03S, 02N21W19A03S, 02N21W19B02S, 02N21W20F02S, and 02N21W29L02S) are well calibrated, which should provide accurate simulation of underflow between the Oxnard Plain and West Las Posas basins.

4.1.3 Scatter Plots

All measured groundwater levels from 1985 to 2015 within the model domain are compared with simulated groundwater levels in scatter plots, which are shown (organized by groundwater basin) on Figures 4-36 through 4-40. The scatter plots are further divided based on the aquifer system each well is screened in (UAS, LAS, or both).

Figure 4-36 shows the scatter plots for wells in the Forebay. For wells screened in the UAS, the simulated water levels fit very well with the water level measurements. For wells screened in the LAS, the simulated water levels also fit well with the water level measurements, except the simulated water levels in one production well 02N22W26B03S (El Rio #14) are significantly lower than measured water levels (as discussed further in Section 4.1.2). For wells screened in both the UAS and the LAS, the simulated water levels are consistent with measured water levels.

Figure 4-37 shows the scatter plots for wells in the Oxnard Plain basin. For wells screened in the UAS, the simulated water levels are similar to measured water levels, except for a few wells (e.g., 01N21W32Q05S and 01N21W32Q07S) screened in Mugu Aquifer (model Layer 5), which have measured water levels that are more consistent with the LAS than the UAS (discussed in more detail in Section 4.1.2). Simulated water levels at these wells are fairly stable at approximately 0 ft msl, while measured water levels are lower. For wells screened in the LAS and in both the UAS and LAS, most of the simulated water levels are within 20 feet of measured water levels and there is little to no significant bias apparent in the scatter plots.

Figure 4-38 shows the scatter plots for wells in the Pleasant Valley basin. For wells screened in the UAS, many of the simulated water levels are greater than the measured water levels, consistent with the discussion in Section 4.1.2. Efforts to further reduce the residuals in the UAS led to greater residuals in LAS (where the vast majority of production wells in the Pleasant Valley basin are screened), thus were halted during calibration of this version of the VRGWFM. For wells screened in the LAS (and across both the UAS and LAS), most of the simulated water levels are within 20 feet of measured water levels, and there is no obvious bias.

Figure 4-39 shows scatter plots for wells in the Mound basin. Relatively few measured water levels are available from a handful of wells in the Mound basin, and this paucity of data is reflected in the scatter plot. The majority of simulated water levels are similar to measured water levels, except for the anomalous measured water levels as noted in Section 4.1.2.

Figure 4-40 shows the scatter plots for wells in the West Las Posas basin. Note that the range between the highest to lowest measured groundwater levels in the West Las Posas basins is much greater than all other basins in the study area. This is reflected in the scales for the horizontal and vertical axes of Figure 4-40. Similar to the Mound basin, historical water level data are limited in the West Las Posas basin. Because there are no calibration wells screened solely within the shallow alluvial aquifer, only scatter plots for wells screened across the LAS, and both the shallow alluvial and the LAS, are included. The scatter plots indicate that the majority of simulated water levels are similar to measured water levels, although there are some wells with substantial differences between simulated and measured water levels, as mentioned in Section 4.1.2.

4.1.4 Residual Plots

To evaluate the potential for spatial bias of model residuals, the mean residual (the mean of measured minus simulated water levels) at each well used for model calibration is shown in map view on Figures 4-41 through 4-43. A positive mean residual indicates measured water levels are, on average, higher than simulated water levels. Conversely, a negative mean residual indicates that measured water levels are, on average, lower than simulated water levels. Wells with fewer than 100 water level measurements were excluded from these maps, so that wells with limited data would not have undue influence. The wells with at least 100 water level data were further divided into three groups: UAS, LAS, and both aquifer systems, based on the well screen interval.

Figure 4-41 shows the mean residuals at UAS wells. The mean residuals at the majority of UAS wells are small (between -10 and +10 feet), and most of the remainder are within the target range (-20 to +20 feet). This is consistent with calibration measures discussed in previous subsections. There are two UAS wells in the Pleasant Valley basin and one in the Oxnard Plain basin with mean residuals exceeding +/-30 feet (Figure 4-41); further discussion of the larger differences between simulated and measured water levels is provided in the preceding subsections. In the southern Oxnard Plain basin (near Mugu Lagoon) and eastern Pleasant Valley basin, the mean residuals in the UAS that exceed +/-10 feet are all negative, indicating simulated water levels are, on average, somewhat higher than measured water levels in these areas.

Figure 4-42 shows the mean residuals at LAS wells. Similar to the UAS, the majority of mean residuals in the LAS fall in the +/-10-foot range or the the +/-20-foot range. Several wells have mean residuals falling in the +/-30-foot range. Two LAS wells in the Pleasant Valley basin and one in the Oxnard Plain basin have mean residuals that fall outside of the +/-30-foot range (Figure 4-42).

Figure 4-43 shows the mean residuals at wells screened across both the UAS and the LAS. A relatively small number of wells that are screened across both the UAS and LAS meet the minimum number of water-level measurements for plotting on Figure 4-43. The mean residuals that are plotted mostly fall in the +/-10-foot range or the +/-20-foot range, with two falling in the +/-30-foot range.

Overall these mean residual plots suggest no overall trends of spatial bias across the study area that would indicate basinwide problems with the hydrogeologic conceptual model or numerical-model calibration. The larger mean residuals (greater than +/-30 feet) present at a few locations can mostly be attributed to uncertainty regarding well construction, rather than numerical model problems.

4.1.5 Flow Budget

The flow budget from a groundwater model may serve as an important verification of the conceptual model as well as a tool to better understand groundwater flow dynamics, particularly in areas of inter-basin flow and flow at basin boundaries. The flow budget of the VRGWFM is summarized below by zone—Forebay, Oxnard Plain, Pleasant Valley, Mound, and Las Posas basins—as well as by aquifer system (shallow/Semi-perched, UAS, and LAS). These flow-budget zones are slightly different from the areas of the groundwater basins, as the active domain of the VRGWFM commonly extends beyond the traditional basin boundaries as defined by DWR or United. Also, the flow-budget zone for Las Posas basin includes the boundary between the Pleasant Valley basin and both the East and West Las Posas basins north of Camarillo. The calculated flux between Las Posas and Pleasant Valley in the flow budget is actually the flow budget between the Somis area in East Las Posas and Pleasant Valley. Figure 4-44 shows the flow-budget zones discussed in this section.

Monthly flow quantities from January 1985 through December 2015 output from the model for each flow budget zone (basin) are provided in Appendix C. In this section, annual-average flow budgets for each zone (basin) are discussed and presented in Tables 4-1 through 4-5. It should be noted that the annual flow budgets provide an approximate description of groundwater interaction within basins and between basins. To fully understand the groundwater flow dynamics, the monthly budgets provided in Appendix C show the variability in a basin's flow budget from wet to dry periods.

Table 4-1 summarizes the annual average flow budget for the Forebay flow-budget zone. Artificial recharge (by United) is the dominant source of inflow, while underflow to the Oxnard Plain basin and pumping from wells in the Forebay represent the major sources of outflow. Underflow to the Mound basin, while much smaller than underflow to the Oxnard Plain, is also a significant outflow component from the Forebay. This observation underscores the importance of United's spreading operations as a major source of recharge not only to the Forebay, but also to the adjacent Oxnard Plain and Mound basins as groundwater underflow, consistent with the hydrogeologic conceptual model (Section 2).

Table 4-2 summarizes the annual average flow budget for the Oxnard Plain flow-budget zone. Underflow from the Forebay represents the largest inflow component, while pumping from wells represents the largest outflow component. Areal recharge (from precipitation and return flows), ET, and discharge to tile drains also represent fairly large inflow and outflow components, respectively, but they occur primarily in the Semi-perched Aquifer. The combined net flux crossing the coastline (including both seawater and freshwater from the offshore extension of the aquifers) is the third largest inflow component, and is divided into three segments in Table 4-2 (from the Mound basin boundary to Channel Islands Harbor, Channel Islands Harbor to Arnold Road, and Arnold Road to Point Mugu). The large majority of simulated coastal influx across the coastline occurs between Channel Islands Harbor and Point Mugu, consistent with the hydrogeologic conceptual model.

Table 4-3 summarizes the annual average flow budget for the Pleasant Valley flow-budget zone. The majority of the inflow consists of the combined percolation of streamflow from Arroyo Las Posas, Conejo Creek, and Calleguas Creek, while the vast majority of outflow occurs as pumping from wells. Similar to the Oxnard Plain, areal recharge (from precipitation and return flows), ET, and discharge to tile drains also represent fairly large inflow and outflow components, respectively, in Pleasant Valley, but they occur primarily in the shallow aquifer system (including the Semi-perched Aquifer). A small component of outflux from Pleasant Valley to Las Posas is indicated (980 AF/yr), correlating with the timing and presence of groundwater mounding in the northern Pleasant Valley basin. However, it is uncertain what fraction of this small flux represents actual northward underflow of groundwater from the Pleasant Valley to the Las Posas basins in this area and how much is just an artifact of simulation of this boundary using a numerical model with 2,000-foot grid cells, which can only calculate fluxes orthogonally to the primary axes of the model grid.

Table 4-4 summarizes the annual average flow budget for the Mound flow-budget zone. Underflow from the Santa Paula basin represents the largest inflow component, with areal recharge (from precipitation and return flows), mountain-front recharge (from the San Pedro Formation outcrops to the north), and influx of underflow from the Forebay each contributing nearly as much. Pumping from wells represents the largest outflow component, while discharge from the Semi-perched Aquifer to the lower reach of the Santa Clara River represents a smaller, but important outflux. There is also a small net outflux of groundwater across the coastline to the offshore portions of the aquifer systems.

Table 4-5 summarizes the annual average flow budget for the Las Posas flow-budget zone, which is the combination of the West Las Posas basin and a small part of the East Las Posas basin. Areal recharge represents the largest inflow component, with mountain-front recharge (from the San Pedro Formation along the margins of the basin) and underflow from the Oxnard Plain contributing smaller inflows. “Release” of groundwater from storage contributes a significant fraction of the simulated total influx to the Las Posas flow-budget zone, and is a result of the net decline in groundwater levels from the beginning to the end of the model calibration period (1985-2015), which is apparent in the hydrographs shown on Figures 4-34 and 4-35. Pumping from wells is the dominant groundwater outflux component in the Las Posas flow-budget zone.

4.2 SENSITIVITY ANALYSIS

The input parameters to the VRGWFM were calibrated to optimally fit the measured groundwater elevations at wells in the study area, and to be consistent with the hydrogeologic conceptual model of groundwater flow directions and rates, to the extent they are known. However, as noted by the National Groundwater Association (NGWA), “modelers recognize groundwater models are not unique representations of a particular hydrogeologic system, and therefore will have a degree of uncertainty” (Bean and others, 2017). To better define the effects of parameter uncertainty on calibration results, a sensitivity analysis was conducted on the VRGWFM. The sensitivity analysis was conducted by adjusting key model input parameters and quantitatively evaluating the impact of each adjustment on the resulting simulated groundwater elevations and flow budget.

The spatially varied parameters in each layer used during sensitivity analysis for the VRGWFM are distributed by zones, which are shown on Figures 4-45 through 4-57. In each layer, the zones have a corresponding number linked to a value (see Table 4-6). Each zone value was adjusted by a factor one at a time during the sensitivity analysis. Each adjustment corresponds to one simulation of the calibration period with the VRGWFM, and production of a set of residual statistics (for groundwater levels) and a flow budget. To evaluate the effect of changing each input parameter on output from the VRGWFM, the residual statistics, including residual mean (RM), ARM, and root mean square residual (RMS), were compared in each of the five basins within the active model domain (Forebay, Oxnard Plain, Pleasant Valley, West Las Posas, and Mound). The effects on key model flow budget components were also evaluated, including inter-basin flows and fluxes across the coastline.

The effect on model calibration as well as on the flow budget by parameter variation may be categorized into four groups, or “types:”

- Type I - Low sensitivity:
    - Model Calibration
        - RM change less than 2 feet, and

        - RMS change less than 1 foot, and
        - ARM change less than 1 foot
    - Flow Budget: The range of flow budget variation is less than 1,000 AF/yr
- Type II - Low sensitivity in model calibration but high sensitivity in flow budget
    - Model Calibration
        - RM change less than 2 feet, and
        - RMS change less than 1 foot, and
        - ARM change less than 1 foot
    - Flow Budget: The range of flow budget variation is larger than 1,000 AF/yr
- Type III - High sensitivity in model calibration but low sensitivity in flow budget
    - Model Calibration
        - RM change larger than 2 feet, or
        - RMS change larger than 1 foot, or
        - ARM change larger than 1 foot
    - Flow Budget: The range of flow budget variation is less than 1,000 AF/yr
- Type IV - High Sensitivity
    - Model Calibration
        - RM change larger than 2 feet, or
        - RMS change larger than 1 foot, or
        - ARM change larger than 1 foot
    - Flow Budget: The range of flow budget variation is larger than 1,000 AF/yr

Input parameters with a Type I sensitivity do not have a strong influence on simulated groundwater elevations or flow budget. Therefore, the model is considered to be relatively insensitive to changes in the values input to these parameters. Input parameters with a Type VI sensitivity are considered to have a potentially significant impact on both simulated groundwater levels and flow budget. Input parameters with a Type II sensitivity may lead to significant uncertainty in flow budget while the model is still calibrated with regard to groundwater levels. Parameters with a Type II sensitivity are important when evaluating the uncertainty in flow budget. Parameters with a Type III sensitivity may have a significant impact on calibration to groundwater levels, but do not have significant effects on the flow budget. In terms of model calibration to groundwater levels, the parameters with a Type III or Type VI sensitivity have the largest influence. In terms of flow budget, parameters with a Type II sensitivity are important to consider, because they can cause significant changes to inflows and outflows without having significant impact on calibration of the model to groundwater levels.

In the following subsections, parameters with Type II, III, and IV sensitivity are the primary focus, as they have the greatest effect on simulated groundwater elevations and flow budgets. The changes in residual statistics and the flow budget resulting from each parameter adjustment are tabulated in Appendix D, Tables D-1 through D-20. The residual statistics and flow budget components from the calibrated VRGWFM (as described Section 3) are listed in the first row under "default," for comparison. The rows below "default" are ordered by model layer and zone number. For ease of finding parameters with the greatest sensitivity, the changes in residual statistics are highlighted in red when the residual statistic change is greater than 1.0 foot, and in yellow when the residual statistic change is less than -1.0 foot. The changes in flow budget are highlighted in red when the flow budget change is greater than 500 AF/yr, and in yellow when the flow budget change is less than -500 AF/yr.

4.2.1 Horizontal Hydraulic Conductivity

The horizontal hydraulic conductivity (HHK) in each zone and in each layer was adjusted by factors of 0.1, 0.5, 5.0, and 10.0 during the sensitivity analysis. Review of Appendix D, Tables D-1 and D-2, indicates that most adjustments of HHK were Type I (low sensitivity). Table 4-7 summarizes the adjustments to HHK that produce Type II, III, and IV sensitivities in the VRGWFM. In Layers 1 and 2, there are more Type II sensitivities to HHK than in other layers. This sensitivity is likely a result of HHK in the uppermost model layers directly affecting the ability of surface water recharge to reach the UAS. The VRGWFM is sensitive to changes in HHK in Zone 11 of Layers 1, 6, 7, and 9 because this area is near the cone of depression between Oxnard Plain and Pleasant Valley basins, and thus influences groundwater flow between the two basins. The model is sensitive (Type IV) to HHK in parameter Zone 9 of Layers 3 and 5 (representing the UAS) under the Forebay, as this area influences the rate at which water artificially recharged to the UAS by United can flow outward to other basins. Model Layers 6 and 7 (representing the Mugu-Hueneme aquitard and the Hueneme Aquifer) have the most zones with Type IV sensitivity to HHK, as these two layers play a critical role in vertical movement of groundwater between the UAS and LAS. The model is also sensitive (Type IV) to HHK in Zone 4 (Oxnard Plain) and Zone 5 (Mound basin) of Layers 7 and 9.

4.2.2 Vertical Anisotropy

Similar to HHK, the vertical anisotropy ratio (ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity) in each zone and in each layer was adjusted by factors of 0.1, 0.5, 5.0, and 10.0. The changes in residual statistics and flow budgets resulting from adjusting vertical anisotropy are tabulated in Appendix D, Tables D-3 and D-4. Table 4-8 summarizes the adjustments to vertical anisotropy that produce Type II, III, and IV sensitivities in the VRGWFM. Type IV sensitivities to vertical anisotropy are most common in Layer 6 of the model. Layer 6 represents the Mugu-Hueneme aquitard across most of the study area, and vertical anisotropy in this layer is a key factor influencing vertical flux of groundwater between the UAS and LAS. Vertical anisotropy in Zone 12 (West Las Posas basin) in Layer 7 (representing the upper San Pedro Formation in that area) also has a Type IV sensitivity.

4.2.3 Storage Coefficient

The storage coefficient in each zone and in each layer was adjusted by factors of 0.01, 0.1, 10, and 100. The changes in residual statistics and flow budgets resulting from adjusting storage coefficient are tabulated in Appendix D, Tables D-5 and D-6. Table 4-9 summarizes the adjustments to storage coefficient that produce Type II and III sensitivities in the VRGWFM. A great majority of storage coefficient adjustments resulted in in Type I (low) sensitivity. There were no zones or layers with Type IV sensitivity to storage coefficient. Zone 12 (West Las Posas basin) in Layers 8 to 11 and 13 has a Type III sensitivity to storage coefficient, and Zone 9 (Forebay) in Layers 4 and 5 has a Type II sensitivity to storage coefficient.

4.2.4 Specific Yield

The specific yield in each zone and in each layer was adjusted by factors of 0.33, 0.67, 1.33, 1.67, and 2. The changes in residual statistics and flow budgets resulting from adjusting specific yield are tabulated in Appendix D, Tables D-7 and D-8. Table 4-10 summarizes the adjustments to specific yield that produce Type II, III, and IV sensitivities in the VRGWFM. Similar to storage coefficient, a majority of specific yield adjustments resulted in Type I (low) sensitivity. This is partly because specific yield only affects unconfined aquifers (most of the aquifers in the study area are confined), and partly because changing specific yield mostly affects groundwater-level fluctuation rather than long-term trends. However, Zone 9 in Layer 3 (Oxnard Aquifer in the Forebay) has a Type IV sensitivity to specific yield. The Oxnard Aquifer is unconfined in the Forebay, and the amount of recharge in this area can vary substantially over time due to United's spreading operations.

4.2.5 Recharge

As described in Section 3, recharge was applied the VRGWFM as a function of water source (precipitation vs. applied water) and land use (agricultural or M&I). The sensitivity analysis for recharge was performed by adjusting the recharge rates resulting from precipitation and applied water on agricultural and M&I lands, within each of the five basins in the study area. Each recharge component was multiplied by factors of 0.0, 0.5, 1.5, 2, 2.5, and 3 in each basin. The changes in residual statistics and flow budgets resulting from adjusting recharge components are tabulated in Appendix D, Tables D-9 and D-10. Table 4-11 summarizes the adjustments to recharge that produce Type II, III, and IV sensitivities in the VRGWFM. Of the 30 adjusted recharge scenarios simulated during the sensitivity analysis, 18 produced Type I (low) sensitivity. Only changes in recharge on agricultural land resulted in Type IV sensitivities in the VRGWFM, likely due to the much larger agricultural return flows compared to M&I return flows.

4.2.6 Horizontal Flow Barriers

The faults simulated by the horizontal flow barrier (HFB) package in MODFLOW are listed in Table 4-12. The conductance along each fault was adjusted by factors of 0.01, 0.1, 10, and 100. The changes in residual statistics and flow budgets resulting from adjusting fault conductance are tabulated in Appendix D, Tables D-11 and D-12. Table 4-13 summarizes the adjustments to fault conductance that produce Type II, III, and IV sensitivities in the VRGWFM. Most (12 out of 17) adjustments to fault conductance result in Type I (low) sensitivity. Adjustment of conductivity along the Oak Ridge Fault results in a Type IV sensitivity, likely because these changes affect how much groundwater outflow from the Forebay can reach the Mound basin (the remainder flows into the Oxnard Plain basin).

4.2.7 Streambed Conductance

There are four streams simulated with the stream package (STR) in the VRGWFM: Arroyo Las Posas, Conejo Creek, Calleguas Creek, and the Santa Clara River. The streambed conductance in each of these streams was adjusted by factors of 0.01, 0.1, 10, and 100. The changes in residual statistics and flow budgets resulting from adjusting streambed conductance are tabulated in Appendix D, Tables D-13 and D-14. Table 4-14 summarizes the adjustments to streambed conductance that produce Type IV sensitivities in the VRGWFM (there were no Type II or III sensitivities to streambed conductance). Adjustment of conductivity along all four stream channels results in Type IV sensitivity, because the conductivity is a key factor controlling how much interaction occurs between surface water and groundwater in the study area (particularly stream-channel recharge).

4.2.8 General Head Boundary Conditions

GHBs were used in the VRGWFM to simulate groundwater exchanges occurring between the study area and: a) the Santa Paula basin, and b) the Pacific Ocean. The boundary with the Pacific Ocean is divided into two GHBs based on location. The GHB in Layer 1 represents a “blanket” of model grid cells below mean sea level interacting with seawater on the sea floor. A deeper GHB represents the submarine outcrop areas for aquifers of the UAS and LAS (Layers 3, 5, 7, 9, and 11). The conductance of each of the GHBs was adjusted by factors of 0.01, 0.1, 10 and 100. The changes in residual statistics and flow budgets resulting from adjusting GHB conductance are tabulated in Appendix D, Tables D-15 and D-16. Table 4-15 summarizes the Type I, II, and IV sensitivities to GHB conductance in the VRGWFM. Adjustment of conductivity of the GHBs representing interaction of the Semi-perched Aquifer and deeper aquifers with the Pacific Ocean result in Type II and Type IV sensitivities, respectively.

4.2.9 Tile Drains

Tile drains in the study area are simulated by the drain package (DRN) in the VRGWFM. The conductance applied to tile drains in the VRGWFM is 10,000 feet squared. This conductance was adjusted by factors of 0.01, 0.1, 10, and 100 for the sensitivity analysis. The results of these four sensitivity analysis simulations are provided in Appendix D, Tables D-17 and D-18. The results of all four simulations indicate that adjustment to drain conductance results in Type I (low) sensitivity.

4.2.10 Evapotranspiration

Discharge of groundwater from shallow aquifers via ET in the study area was simulated by the evapotranspiration package (EVT) in the VRGWFM. Two parameters in the EVT package, evapotranspiration rate (EVTR) and ET extinction depth (EXDP), were adjusted during the sensitivity analysis. EVTR was adjusted by factors of 0.01, 0.1, 10, and 100, and EXDP was replaced by four different depths: 2.5, 10, 15, and 20 feet (default value in the VRGWFM was 5 feet). The results of these eight sensitivity analysis simulations are provided in Appendix D, Tables D-19 and D-20. Adjustment of both EVTR and EXDP result in Type II sensitivities, indicating that the simulated flow budget (but not groundwater elevations), can be sensitive to ET.

5 REVIEW

This section summarizes the goals, processes, and results of internal and external reviews of the VRGWFM. The primary goal of the review process was to evaluate the suitability of the VRGWFM for its intended uses, which are described in Section 1.

5.1 INTERNAL

The VRGWFM was first reviewed by selected members of United's Groundwater Department staff with experience in local hydrogeologic conditions. This internal review included comparison of model input files to available data in the study area. The goal of the internal review was to ensure that reasonable values were input to the model and that model output (primarily groundwater levels) throughout the calibration period were consistent with measured values. During construction of the VRGWFM, United's hydrogeologists conducted ongoing review of model input files, to verify that reported quantities and values, such as groundwater recharge and discharge components, were accurately entered into the model. United hydrogeologists also reviewed calibration results to evaluate potential causes for substantial deviations between measured and simulated groundwater elevations—in some cases, reported groundwater elevation measurements were rejected as likely being erroneous or the result of damage to the well in which the measurement was obtained, and in other cases changes were required in either the hydrostratigraphic model or as input to the numerical model. United hydrogeologists and hydrologists reviewed other model output, such as simulated groundwater-elevation contours and stream gains or losses, to verify that the model did reasonably well at simulating groundwater elevation trends and patterns in the basin, in addition to simulating changes in head at individual wells. The process of internal review and refinement of both the conceptual and numerical models for the VRGWFM was iterative and occurred frequently from 2013 through 2018.

5.2 FCGMA/TAG REVIEW AND OUTREACH TO OTHER STAKEHOLDERS

Since 2015, United has led and participated in several workshops, presentations, and meetings designed to provide information and solicit input from the FCGMA and other stakeholders in the study area regarding development of the VRGWFM. DWR guidance states that "Stakeholder input is an important component of model development; specifically, during the early planning phase of model development when the purpose and objectives of the model are being considered and near the end of the modeling process when various modeling scenarios are being considered." By summer 2015, United had incorporated its revised hydrostratigraphic conceptual model for the Oxnard Plain (including Forebay) and Pleasant Valley basins into the VRGWFM and completed the first model calibration for those basins. Also during that summer, the FCGMA formed the TAG for the GSPs for the Oxnard Plain and Pleasant Valley basins. Although United anticipated that it would take a year or longer (from 2015) to complete calibration and documentation of the model in the study area, it was thought to be beneficial to share information with stakeholders regarding model construction, calibration, and potential use as a forecasting tool early in the process of calibrating and documenting the model. Such early stakeholder involvement would allow scientists and engineers with knowledge of hydrogeologic conditions in the study area to help review and provide input that could be used to refine the VRGWFM before completion of model calibration and documentation.

United's first workshop-style extended meeting to share details of the VRGWFM was held with FCGMA technical staff in August 2015, shortly after United implemented the revised hydrostratigraphic conceptual model for the Oxnard Plain and Pleasant Valley basins. Calleguas MWD technical staff and their consultant, CH2M HILL, were also invited to that workshop because they were developing a hydrostratigraphic conceptual model for the East and South Las Posas basins, and had plans to develop a numerical model that could be used to simulate groundwater and surface water fluxes adjacent to the study area for the VRGWFM. At this workshop, United provided an overview of the VRGWFM hydrostratigraphic conceptual model, numerical model calibration results, and a summary of the types of additional information that would be needed to use the model to forecast future water-use scenarios for the study area.

United provided the TAG with occasional updates on the VRGWFM in 2016, and in December 2016 some TAG members requested an extended meeting with United to learn more details regarding input parameters and early calibration results from the model. In response, United held an all-day "TAG-review workshop" in coordination with the FCGMA as a TAG "special meeting" during March 2017, open to interested regional stakeholders and the public. Questions were raised and input provided by the TAG and stakeholders on several issues, but at the conclusion of discussion of model calibration, no "fatal flaws" in the VRGWFM were noted by the TAG. TAG members concurred that the calibration of the VRGWFM generally was a significant improvement compared to the USGS model, and that including 13 model layers in the VRGWFM should prove valuable for simulating potential future water-supply projects (United, 2017c). The TAG had additional questions regarding how the VRGWFM incorporated the Pleasant Valley basin, and asked if a second workshop could be held to further discuss this topic. United agreed to hold a half-day "Pleasant Valley workshop" as part of another TAG special meeting in April 2017.

The goal of the Pleasant Valley workshop was for United to provide additional information about the VRGWFM, with specific emphasis on key aspects of hydrogeology in the Pleasant Valley basin as requested by some TAG members at the previous (March 2017) workshop. The Pleasant Valley workshop was structured as a "round-table" discussion, with a suggested list of discussion topics rather than an agenda, and no formal presentations. Key discussion topics and action items from this workshop included (United, 2017d):

- The TAG discussed the complexity of the faults and folds in the northern Pleasant Valley basin, and agreed that the United conceptual model was appropriate. Unless data became available indicating otherwise, use of United's conceptual model was not expected to produce significantly different results than previous conceptual models for the area.

- Two TAG members felt that it might make sense to shift the “picks” for the UAS HSUs upward in some portions of the Pleasant Valley basin, but there was significant uncertainty regarding the stratigraphy in those areas. It was noted that United’s reduced horizontal hydraulic conductivity values in the upper three layers of the VRGWFM in the Pleasant Valley basin (compared to those for the adjacent Oxnard Plain basin) effectively achieved the desired result of making the UAS in the Pleasant Valley basin somewhat “disconnected” from the UAS in the Oxnard Plain basin. Upon subsequent review, United made a few minor adjustments to the geometry of the HSUs in the western part of the Pleasant Valley basin.
- United and Calleguas MWD agreed to continue collaborating on estimated surface and groundwater flowrates from East Las Posas basin (being modeled by Calleguas MWD) to the Pleasant Valley basin.
- United would seek review by its Expert Panel of vertical flow through active wells that are screened across both the UAS to the LAS.
- United would continue reviewing dry-weather streamflow and other related information in Arroyo Las Posas for possible incorporation into the VRGWFM.
- United would continue reviewing groundwater elevations in the Semi-perched Aquifer for possible incorporation into the VRGWFM.

Following the TAG-review and Pleasant Valley workshops described above, United regularly updated the TAG on modeling progress during monthly TAG meetings, and met separately with individual members of the TAG and other stakeholder representatives on several occasions to further discuss various aspects of the VRGWFM and its potential future uses. In addition, United staff gave several presentations to stakeholder groups in Ventura County regarding VRGWFM construction, calibration, and how it could potentially be applied to future evaluation of sustainable yield and water-supply projects in the study area. Feedback from those meetings was noted and given consideration as model development progressed.

5.3 EXPERT PANEL

To provide an additional level of confidence that the VRGWFM would be capable of meeting the modeling objectives and ultimately become a valid, reliable tool for evaluating groundwater supply options in the study area, United contracted with the members of the Expert Panel in 2016 to conduct peer review of the VRGWFM, to be followed with continuing input and review during planning and implementation of predictive modeling for future water-use scenarios. The Expert Panel review was conducted by three groundwater modeling experts focused on appropriateness of model construction, as well as the procedures used by United to convert raw data to model-input files, conduct calibration, and evaluate model sensitivity to the different input parameters. One member of the Expert Panel was selected based on both his extensive applied modeling experience in western U.S. groundwater basins, and his familiarity with the hydrogeology of the study area. The other two members of the Expert Panel were selected based on their theoretical understanding of groundwater modeling and their extensive experience with developing groundwater modeling software tools and applying those tools to projects across the U.S. The Expert Panel included:

- Dr. Sorab Panday, of GSI Environmental, Inc., co-author of the two most recent versions of MODFLOW: MODFLOW-NWT and MODFLOW-USG;
- Jim Rumbaugh, of Environmental Simulations Inc., creator of the widely used MODFLOW pre- and post-processor, Groundwater Vistas; and,
- John Porcello, of GSI Water Solutions, Inc., a consultant with extensive experience in groundwater modeling in general, and specific experience with hydrogeologic conditions in Ventura County.

The Expert Panel was tasked with providing ongoing peer review starting in 2016 (after the hydrostratigraphic conceptual model was largely completed and the basic framework of the numerical model was in development). During their initial review, the Expert Panel was asked to consider whether the VRGWFM was capable of achieving the modeling objectives defined in Section 1.3 and if United's model construction and calibration efforts conformed with USGS and ASTM guidance for these activities. The Expert Panel was also asked to review and provide comment on the following model components and activities:

- Model extent, grid size, discretization, and orientation
- Model layering compared to conceptual stratigraphic model
- Time discretization
- Numerical convergence criteria and closure
- Aquifer parameters, including horizontal hydraulic conductivity and vertical anisotropy, storage coefficient/specific yield
- Boundary conditions, including no-flow, constant-flux, constant-head, and general-head boundaries within model, as well as initial head configuration and horizontal-flow barriers representing geologic faults
- Implementation of transient aquifer stresses, including pumping, recharge from various sources, drains, surface-water/groundwater interaction (including groundwater interaction with seawater)
- Water budget results over time, including groundwater underflow between basins, between aquifers, and discharge and recharge to/from surface-water bodies (e.g., rivers and ocean)
- Calibration data and representativeness of calibration period
- Calibration results, methods of evaluation, bias (geographically and by layer)
- Consistency of calibrated input parameters and water-budget results with conceptual models
- Overall suitability of the model for the intended purposes, and potential limitations on its use.

Following their initial review of the model, the expert panel provided "the following key observations regarding the model's significant and most substantive simulation capabilities" in a preliminary review memorandum (Porcello and others, 2016):

- "The model's layering and choice of boundary conditions is appropriate for simulation of the very complex geologic and hydrostratigraphic conditions that exist in the Oxnard and Pleasant Valley groundwater basins – specifically the discrete multiple layered aquifers and aquitards; the moderate to strong compartmentalization of certain aquifers by faults; the significant well-to-well variability in the depths and aquifers which are furnishing groundwater to production wells in each groundwater basin; the strong influence of UWCD's managed aquifer recharge programs (spreading basins) on groundwater elevations and flow directions; and the complex three-dimensional nature of the ocean interface and its interaction with each shallow and deep aquifer zone along the coast and offshore.

- The model provides an accounting of groundwater budgets and flow conditions for current land use and water use conditions. This includes the conditions that have been observed during the current drought, which began during the end of the calibration period and has continued through the period being used for model verification (2013 through 2015).
- The model is well-calibrated to changes in groundwater levels over time, including through multiple series of drought years (1985 through 1991; 1999 through 2003; 2012 to present) and above-normal rainfall years (1992-1993, 1997-1998, 2004-2005) which together comprise a hydrologic cycle composed of highly variable rainfall and streamflow conditions. Additionally, the calibration time period accounts for the gradual historical increase in dry-weather baseflows that occurred in Arroyo Las Posas from the late 1980s through the 1990s, which has substantially increased the annual volume of groundwater recharge to the Pleasant Valley basin.
- UWCD has invested considerable time and resources in updating and refining the hydrostratigraphic model, creating a new model with discrete representation of each aquifer and aquitard, and estimating the detailed recharge processes of a nearly three-decade time period. This effort has had a direct beneficial effect on the ability of the model to simulate the historical fluctuations in groundwater levels that have occurred in the past. Model-simulated hydrographs of groundwater level changes and scatter plots of the groundwater-level-change residuals (the differences between modeled and measured changes) indicate that the model is simulating the month-by-month and year-by-year aquifer system responses to fluctuating natural hydrologic conditions (rainfall and streamflows), groundwater pumping, and managed aquifer recharge quite well, though in a few areas it was noted that groundwater level recovery during high-rainfall years is under-predicted."

Although the Expert Panel concluded that the VRGWFM was "nearly ready for use in planning studies" at the time of their initial review, they recommended additional "activities be conducted as part of the final stages of the model development and documentation effort," including the following:

- Turn on the evapotranspiration (ET) package in MODFLOW along the Santa Clara River, and possibly along Conejo Creek and Calleguas Creek;
- Conduct localized refinements in the Mound Basin;
- Conduct localized refinements in the eastern portion of the Pleasant Valley Basin;
- Refine the initial conditions;
- Evaluate potential means of improving the match to absolute groundwater elevations, and not just changes in groundwater elevations;
- Use two additional types of targets for calibration (vertical head differences and stream baseflow);
- Test the model using PEST;
- Conduct qualitative assessments of the model's calibration quality;
- Convert to MODFLOW-USG rather than using MODFLOW-NWT with finer grid spacing;
- Release the final modeling report before, or simultaneously with, the model.

During subsequent discussions, the Expert Panel noted that not all of the above recommendations were required to complete construction and calibration of the VRGWFM, as some of the activities were just suggestions for long-term model development (e.g. convert the model to MODFLOW-USG), particularly with regard to future predictive simulations. United staff spent the remainder of 2016 and most of 2017 implementing many of the Expert Panel's recommendation, while simultaneously updating the hydrostratigraphic conceptual model and data for surface-water imports in the West Las Posas basin.

In fall 2017 through spring 2018, United asked its Expert Panel to again review the VRGWFM, which had been updated since the initial 2016 review. The updated model incorporated many of the Expert Panel's recommendations (listed above) as well as other modifications implemented by United (e.g. the updated hydrostratigraphic conceptual model for West Las Posas basin). Key components of the Expert Panel's second (2017/18) review (Porcello and others, 2018) included, but were not limited to, qualitative and quantitative evaluation of model calibration, and consideration of whether the VRGWFM was suitable for its intended uses. Selected, relevant comments from the Expert Panel on these topics include the following:

- Overall Opinion: "In summary, the expert panel finds the model to be a well-designed and well-calibrated tool, and a tool that is a substantial enhancement and upgrade over previously available tools. Version 1.0 of the VRGWFM provides a newly robust and detailed method of evaluating how the multiple aquifers in the region behave and how they might respond to the design and implementation of specific regional management programs and specific projects in the five groundwater basins that the model currently simulates in southern Ventura County."
- Qualitative Review: "The qualitative analysis consisted of visual inspection of hydrographs prepared by UWCD, from which the panel identified the total number of wells with good versus poor matches in each groundwater basin and for the entire model domain."
    - "Of 277 hydrographs reviewed, only 34 were judged to be of poor quality and 41 were adequate. Most hydrographs (202, or 73%) showed a good match between modeled and measured values. The largest number of poor matches (14) was in West Las Posas, basin where some wells are screened in the lithologically complex San Pedro Formation, which contains lenses of unknown lateral continuity within a thick sequence of fine-grained sediments. The other basins, which have more discrete and continuous aquifers and aquitards, typically had between 0 and 3 poor matches."
    - "In our opinion, matching a high percentage of available hydrographs is difficult to do and means the calibration is very good."
- Quantitative Review: "The quantitative assessment was accomplished by the panel using residual statistics for groundwater elevations, residual statistics of changes in groundwater elevations over time, and maps of the locations of the worst matches in each model layer (to look for any spatial bias in the locations of poorly matched wells)."
    - "In our experience, scaled statistics less than 0.1 (i.e., 10 percent) are indicative of good calibration. The scaled groundwater elevation statistics for this model (for residual mean, residual standard deviation, RMS error, and absolute residual mean) are in the 2 to 4 percent range when considering groundwater elevations themselves (i.e., are water levels too high or too low) and in the 2 to 3 percent range when considering month-to-month changes in groundwater elevations over time (i.e., is the model simulating the fluctuations in water levels that occur). In our experience, having a good match to both absolute elevations and to changes in elevation is not often achieved and points again to the fact that the VRGWFM is very well calibrated (as previously suggested by the hydrographs)."

- o "Except for some outliers (shown in red ellipse) the degree of scatter about the 45 degree line is good and does not indicate the existence of any significant spatial or temporal bias."

- Adequacy for Intended Uses: "Version 1.0 of the VRGWFM is viewed by the expert panel as being ready for use in regional and local planning efforts, and is of sufficient quality to support development of GSPs under SGMA, including conducting water budget analyses, estimating the sustainable yield of the regional aquifers under various long-term management alternatives, and evaluating the ability of specific projects and management actions to meet minimum threshold levels that will be established in basin-specific GSPs."

5.4 LIMITATIONS

The DWR noted in their best-management practice for groundwater modeling that "there should be no expectation that a single 'true' model exists. All models and model results will have some level of uncertainty" (Joseph and others, 2016). The National Groundwater Association listed potential root causes of modeling "errors" that lead to uncertainty (Luis and others, 2017), summarized as follows:

- Conceptual model error, resulting from assumptions that have to be made about the hydrogeologic system prior to input to the model—conceptual model errors can be classified as follows:
- Incorrect hypotheses (e.g., assuming that an aquifer is confined, when it may not be)
- Missing processes (e.g., ignoring a water-budget component that provides a significant fraction of recharge or discharge in the study area)
- Structural complexity (or oversimplification; e.g., treating different depth zones in a HSU as a single layer with uniform properties)
- Temporal complexity (or oversimplification; e.g., failing to recognize the significance of changes in aquifer stresses, such as pumping, that occur in a smaller time scale than the time discretization of the model)
- Parameter error, resulting from error or uncertainty in the input values or aquifer stresses that are applied to the model—parameter errors can be classified as follows:
- Measurement errors (e.g., under- or over-reporting of pumping rates)
- Interpolation errors (e.g. assuming and applying hydraulic conductivities to model grid cells located far from wells where hydraulic conductivities have been measured)
- Scaling errors (e.g. assigning a local-scale hydraulic conductivity value from a site-specific aquifer test to a much wider area of the model, without allowing adjustment of that hydraulic conductivity value during calibration)
- Structural noise, resulting from "the imperfect nature of a model to simulate reality" (can be quantified as the difference between measured and simulated values that is not attributable to measurement error).
- Predictive error ("scenario uncertainty"), resulting from incorrect assumptions about future conditions (e.g., changes in land use result in less actual groundwater pumping in the future than simulated); this source of uncertainty is not applicable to the historical model calibration described in this report

And USGS guidance provides this caution regarding the potential for non-unique configurations of model parameters to produce reasonably good calibration statistics, but not necessarily yield a good model:

> *"Just because a model is constructed and calibrated, does not ensure that it is an accurate representation of the system. The appropriateness of the boundaries and the system conceptualization is frequently more important than achieving the smallest differences between simulated and observed heads and flows"* (Reilly and Harbaugh, 2004).

This issue is of particular concern in models where calibration data are limited over space or time. Fortunately, abundant pumping, groundwater-level, and aquifer-parameter data have been collected over the past several decades in the VRGWFM study area. These data have allowed development of a detailed conceptualization of the groundwater systems in the study area, while also providing a spatially—and temporally—extensive calibration dataset. This combination greatly reduces both the potential for conceptual model error and the number of possible alternative configurations of model input parameters that could produce a similar result. Results of sensitivity analysis indicate that the VRGWFM is most sensitive to changes in the following input parameters:

- Hydraulic conductivity in Layer 6 (the aquitard between the UAS and LAS).
- Agricultural return flows.
- Streambed conductance of the Santa Clara River, Conejo Creek, Arroyo Las Posas, and Calleguas Creek.
- Conductance of the general head boundary representing interaction between the Pacific Ocean and the aquifers of the UAS and LAS.

Similar to the USGS model of the Santa Clara-Calleguas watersheds, the VRGWFM is a regional-scale model. Therefore, the following important limitation noted by Hanson and others (2003) for the USGS model also applies to the VRGWFM: "...regional models can be useful for simulating subregional and regional performance of a flow system and for providing boundary information for more detailed local-scale models even though the results of the regional model for a local scale may not be appropriate for site-specific problems such as the performance at a particular well." In other words, models such as the VRGWFM that represent aquifer systems of more than 200 square miles in areal extent and thicknesses exceeding 1,000 feet should not be applied to questions about well performance at individual farms or contaminant-transport at corner gas station sites, for example, unless finer discretization is applied to the model and site-specific data are reviewed (and incorporated into the model, as appropriate). However, as noted previously, the VRGWFM incorporates a significant update of hydrostratigraphic conceptual model for the study area and discretely simulates individual aquifers and aquitards, and thus represents a major upgrade from the previously available tools and information available for understanding hydrogeologic conditions and forecasting effects of future aquifer stresses. As needed for future simulations, the VRGWFM can be further discretized or otherwise modified to more precisely or elegantly simulate actual groundwater flow processes that occur in specific areas of interest.

6 REFERENCES

Alley, W.M., 1996, Office of Ground Water Technical Memorandum No. 96.04, Subject: Publications—Policy on Documenting the Use of Ground-Water Simulation in Project Reports, dated April 24, 1996.

Anderson, M.P., Woessner, W.W., and Hunt, R.J., 2015, Applied Groundwater Modeling: Simulation of Flow and Advective Transport (Second Edition), Elsevier, London, UK, 564 p.

Bachman, S., 2016, Northern Pleasant Valley Desalter Groundwater Analysis and Modeling: Report to Desalter Working Group, prepared for Ventura County Water Works District #1.

Beller, E.E., R.M. Grossinger, M.N. Salomon, S.J. Dark, E.D. Stein, B.K. Orr, P.W. Downs, T.R. Longcore, G.C. Coffman, A.A. Whipple, R.A. Askevold, B. Stanford, and J.R. Beagle, 2011, Historical Ecology of the Lower Santa Clara River, Ventura River, and Oxnard Plain: An Analysis of Terrestrial, Riverine, and Coastal Habitats, prepared for the State Coastal Conservancy, a report of SFEI's Historical Ecology Program, SFEI Publication #641, San Francisco Estuary Institute, Oakland, CA (report and GIS layers are available on SFEI's website, at: www.sfei.org/projects/VenturaHE).

Burton, C.A., Montrella, J., Landon, M.K., and Belitz, K., 2011, Status and understanding of groundwater quality in the Santa Clara River Valley, 2007—California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2011–5052, 86 p.

California Department of Water Resources, 1971, Seawater intrusion: aquitards in the coastal ground water basin of Oxnard Plain, Ventura County: California Department of Water Resources Bulletin 63-4, 567 p.

California Department of Water Resources, 1975a, Bulletin 118-75: California's Ground Water, dated September 1975, 135 p.

California Department of Water Resources, 1975b, Compilation of Technical Information Records for the Ventura County Cooperative Investigation: California Department of Water Resources, Volume 1.

California Department of Water Resources, 1980, Bulletin 118-80: Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924, dated January 1980, 73 p.

California Department of Water Resources, 2003, Bulletin 118 - Update 2003: California's Groundwater, dated October 2003, 222 p.

California Department of Water Resources, 2014, Summary of Recent, Historical, and Estimated Future Land Subsidence in California, 13 p.

California Division of Water Resources, 1933, Bulletin No. 46 – Ventura County Investigation, 200 p.

Daniel B. Stephens & Associates, Inc., 2017a, Fox Canyon Groundwater Management Agency Groundwater Balance Study, Ventura County, California, dated November 2017, 35 p.

Daniel B. Stephens & Associates, Inc., 2017b, Santa Paula Basin Hydrogeologic Characterization and Safe Yield Study, Ventura County, California, 81 p.

Dudek, 2017a, Preliminary Draft (Subject to Change) Groundwater Sustainability Plan for the Oxnard Subbasin, dated November 2017, 430 p.

Dudek, 2017b, Preliminary Draft (Subject to Change) Groundwater Sustainability Plan for the Pleasant Valley Basin, dated November 2017, 294 p.

Dudek, 2017c, Preliminary Draft (Subject to Change) Groundwater Sustainability Plan for the Las Posas Valley Basin, dated November 2017, 352 p.

Edmonston, A.D., 1956, State Water Resources Board Bulletin No. 12, Ventura County Investigation, original prepared 1953, revised in October 1956.

Flint, L.E., and Flint, A.L., 2007, Regional Analysis of Ground-Water Recharge: U.S. Geological Survey Professional Paper 1703-B, 60 p.

Fox Canyon Groundwater Management Agency, 2015, Calendar Year 2014 Annual Report, 65 p.

Fox Canyon Groundwater Management Agency, United Water Conservation District, and Calleguas Municipal Water District, 2007, 2007 Update to the Fox Canyon Groundwater Management Agency Management Plan, 88 p.

Freeman, V.M., 1968, People-Land-Water: Santa Clara River Valley and Oxnard Plain, Ventura County , California, Lorrin L. Morrison, 227 p.

Fugro West, Inc., 1996, Calendar Year 1995 Annual Report, Mound Groundwater Basin, Ventura County, California, unpublished consultant's report prepared for City of San Buenaventura, January.

Geotechnical Consultants, Inc., 1972, Hydrogeologic Investigation of the Mound Groundwater Basin for the City of San Buenaventura, California, unpublished consultant's report prepared for City of San Buenaventura.

Grunsky, C.E., (1915), Discussion: Run-off from Rainfall and Other Data, in Transactions of the American Society of Civil Engineers, Volume LXXIX, p. 1165-1167.

Hanson, R.T., 1994, Land subsidence in the Oxnard Plain of the Santa Clara-Calleguas basin, Ventura County, California. In K.R. Prince, D.L. Galloway, and S.A. Leake, eds., U.S. Geological Survey Subsidence Interest Group Conference, Edwards Air Force Base, Antelope Valley, California, November 18-19, 1992, Abstracts and summary, U.S. Geological Survey Open-File Report 94-532, p. 32-34 (https://pubs.usgs.gov/of/1994/ofr94-532).

Hanson, R.T. Martin, P., Koczot, K.M., 2003, Simulation of ground-water/surface water flow in the Santa Clara-Calleguas ground-water basin, Ventura County, California, U.S. Geological Survey Water-Resources Investigations Report 02-4136, 214p, (https://pubs.er.usgs/usgspubs/wri/wri024136).

Hasan, A.A., Kleinecke, D.C., Johanson, S.J., and Pierchala, C.E., 1974, Mathematical Modeling of Water Quality for Water Resources Management, Volume 1: Development of the Ground Water Quality Model, California Department of Water Resources, Southern District, District Report, August 1974.

Heath, R.C., 1983, Basic Groundwater Hydrology, U.S. Geological Survey Water-Supply Paper 2220, 78 p.

Highland Economics, LLC, 2017, Socioeconomic Importance of Freeman Diversion Water to Ventura County, dated July 2017, 81 p.

Hopkins Groundwater Consultants, Inc., 2008, Preliminary Hydrogeologic Study: Northeast Pleasant Valley Basin Surface Water and Groundwater Study, Somis, California, prepared for Calleguas Municipal Water District.

Hsieh, P.A., and Freckleton, J.R., 1993, Documentation of a Computer Program to Simulate Horizontal-Flow Barriers Using the U.S. Geological Survey's Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Open-File Report 92-477.

Intera Geoscience and Engineering Solutions, 2018, Groundwater Flow Model of the East and South Las Posas Sub-Basins – Preliminary Draft Report, 208 p.

Irrigation Training and Research Center, 2010, Evaluation of Strengths and Weaknesses of the Existing FCGMA IE Program and Specific Suggestions for Improvement, Final Task 2.2.

Isherwood, J.D., and Pillsbury, A.F., 1958, Shallow Ground Water and Tile Drainage in the Oxnard Plain, in Transactions of the American Geophysical Union, Vol. 39, No. 6, p. 1101-1110.

Izbicki, J.A., 1996, Source movement and age of groundwater in a coastal California aquifer, U.S. Geological Survey, Fact Sheet 126-96, 4p.

Izbicki, J.A., Michel, R.L., and Martin, Peter, 1992, ^{3}H and ^{14}C as Tracers of Groundwater Recharge, in Engman, Ted, Saving a threatened resource—In Search of Solutions: American Society of Civil Engineers, IR Division/ASCE, p. 122-127

Jamison, R.H., 1928, Ventura County Investigation—Report for the Period August 20, 1927, to July 31, 1928, California Division of Water Rights, 228 p.

John F. Mann Jr. and Associates, 1959, A Plan for Groundwater Management—United Water Conservation District.

Jordan, D., 2015, notes from conversation between Denton “Bill” Jordan (tile-drain installer from Fowler, CA) and Dan Detmer (supervising hydrogeologist at United Water Conservation District), May.

Joseph, T., Godwin, T., McManus, D., Nordberg, M., Shannon, H., and Springhorn, S., 2016, Best Management Practices for the Sustainable Management of Groundwater: Modeling BMP, 43 p.

Leake, S.A., and Prudic, D.E., 1991, Documentation of a Computer Program to Simulate Aquifer-System Compaction Using the Modular Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Techniques of Water-Resources Investigations, Book 6, Chapter A2.

Li, Y., and Neuman, S.P., 2007, Flow to a Well in a Five-Layer System with Application to the Oxnard Basin, in Ground Water, Vol. 45, No. 6, p. 672-682.

Luis, S., Schulmeyer, P., Sheets, R., Martin, P., LeFrancois, M., Bean, D., 2017, NGWA White Paper—Uncertainty in Modeling, dated October 4, 2017.

McDonald, M.G., and Harbaugh, A.W., 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 6, Chapter A1.

Mukae, M., 1988, General Geology and Groundwater Occurrence within Calleguas Municipal Water District Service Area. Progress Report No. 9. Prepared for Metropolitan Water District of Southern California.

Mukae, M. and Turner, J.M., 1975, Ventura County Water Resources Management Study-Geologic Formations, Structures and History in the Santa Clara Calleguas Area, January.

Neuman, S.P., and Witherspoon, P.A., 1972, Field Determination of the Hydraulic Properties of Leaky Multiple Aquifer Systems, in Water Resources Research 8, No. 5, p. 1284-1298.

Niswonger, R.G., Panday, S., and Ibarki, M., 2011, MODFLOW-NWT, A Newton formulation for MODFLOW-2005: U.S. Geological Survey Techniques and Methods 6-A37, 44 p.

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013, MODFLOW-USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Peel, M.C., Finlayson, B.L., and McMahon, T.A., 2007, Updated World Map of the Köppen-Geiger Climate Classification, in Hydrology and Earth System Sciences, Vol. 11, No. 5, p. 1633-1644.

Poland, J.F., and Davis, G.H., 1969, Land Subsidence Due to Withdrawal of Fluids, Geological Society of America, Reviews in Engineering Geology -II.

Porcello, J., Panday, S. and Rumbaugh, J., 2016, Peer review team evaluation of UWCD groundwater flow model for the Oxnard Plain, Oxnard Forebay, and Pleasant Valley basins (Ventura County, California) [Draft Interim Memorandum], dated June 30, 2016.

Porcello, J., Rumbaugh, J., and Panday, S., 2018, Expert Panel Review of Version 1.0 of the Ventura Regional Groundwater Flow Model (VRGWFM) (Ventura County, California), Memorandum dated June 26, 2016.

Predmore, Steven K., 1993, Use Of A Geographic Information System to Identify Abandoned Wells: U.S. Geological Survey Open-File Report 93-147.

Prudic, D.E., 1989, Documentation of a Computer Program to Simulate Stream-Aquifer Relations Using a Modular, Finite-Difference, Ground-Water Flow Model, U.S. Geological Survey Open-File Report 88-729.

Reichard, E.G., Crawford, S.M., Paybins, K.S., Martin, P., Land, M., and Nishikawa, T., 1998, Evaluation of Surface-Water/Ground-Water Interactions in the Santa Clara River Valley, Ventura County, California: U.S. Geological Survey Water-Resources Investigations Report 98-4208, Prepared in Cooperation with United Water Conservation District, 58 p.

Reilly, T.E., and Harbaugh, A.W., 2004, Guidelines for Evaluating Ground-Water Flow Models, USGS Scientific Investigations Report 2004-5038, 37 p.

Santos, F.L., and Hawkins, R.H., 2011, Generalized Mediterranean Annual Water Yield Model: Grunsky's Equation and Long-Term Average Temperature, in Journal of Hydrologic Engineering, Vol. 16, No. 11, p. 874-879.

Smith, W., 2015, conversation between William Smith (attorney from Ferguson, Case, Orr, & Paterson, LLP, representing Oxnard Drainage District #1) and Dan Detmer (supervising hydrogeologist at United Water Conservation District), May.

Stamos, C.L., Predmore, S.K., and Zohdy, A.A.R., 1992, Use of D-C resistivity to map saline ground water: American Society of Civil Engineers National Conference, Water Forum 1992, Baltimore, Maryland, August 2-6, 1992, Proceedings, 80-85p.

State Water Resources Control Board Division of Water Rights, 1979, Oxnard Plain Groundwater Study – Water Code Section 2100, 68 p.

State Water Resources Control Board Division of Water Rights, 2012, Amended Permit for Diversion and Use of Water, Permit 20952.

Stillwater Sciences, 2017, Draft Report, City of Ventura Special Studies—Phase 3: Assessment of the Physical and Biological Conditions of the Santa Clara River Estuary, Ventura County, California, dated November 2017, 304 p.

Stonestrom, D.A., and Harrill, J.R., 2007, Ground-Water Recharge in the Arid and Semiarid Southwestern United States—Climatic and Geologic Framework: U.S. Geological Survey Professional Paper 1703-A, 27 p.

Sylvester, A.G., 1997, Aseismic Growth of Ventura Avenue Anticline (1978 to 1997): Evidence of an Elastic Strain Release in Ventura Basin, Southern California, from Precise Leveling. Transactions of the American Geophysical Union 78, F156-157.

Sylvester, A.G., and Brown, G.C., 1988, Santa Barbara and Ventura Basins; Tectonics, Structure, Sedimentation, Oilfields along an East-West Transect: Coast Geological Society Guidebook 64, Ventura, California, 167 p.

Sun, R.J., and Johnston, R.H., 1994, Regional Aquifer-System Analysis Program of the U.S. Geological Survey, 1978-1992: U.S. Geological Survey Circular 1099, dated 1994, 126 p.

Turner, J.M., 1975, Aquifer delineation in the Oxnard-Calleguas area, Ventura County, in Compilation of Technical Information Records for the Ventura County Cooperative Investigation: California Department of Water Resources, 28 p.

Turner, K.M., 1991, Annual Evapotranspiration of Native Vegetation in a Mediterranean-Type Climate, in Water Resources Bulletin, Vol. 27, No. 1, p. 1-6.

United Water Conservation District, 2012, Hydrogeologic Assessment of the Mound Basin, United Water Conservation District Open-File Report 2012-01, June 11, 2012 Update, 25 p.

United Water Conservation District, 2013, Technical Memorandum: Infiltration Potential of Precipitation Falling on Developed Lands and the Fate of Applied Groundwater within UWCD, dated June 2013, 20 p.

United Water Conservation District, 2014, Groundwater and Surface Water Conditions Report - 2013, United Water Conservation District Open-File Report 2014-02, 96 p.

United Water Conservation District, 2016, Saline Intrusion Update, Oxnard Plain and Pleasant Valley Basins, United Water Conservation District Open-File Report 2016-04, 120 p.

United Water Conservation District, 2017a, Groundwater and Surface Water Conditions Report - 2015, United Water Conservation District Open-File Report 2017-01.

United Water Conservation District, 2017b, Preliminary Evaluation of Impacts of Potential Groundwater Sustainability Indicators on Future Groundwater Extraction Rates – Oxnard Plain and Pleasant Valley Groundwater Basins, United Water Conservation District Open-File Report 2017-02, 68 p.

United Water Conservation District, 2017c, Summary: UWCD Groundwater Flow Model Technical Workshop at FCGMA Special Meeting, March 24, 2017, 3 p.

United Water Conservation District, 2017d, Summary: United's Groundwater Flow Model – "Pleasant Valley Workshop" at FCGMA Special Meeting, April 27, 2017, 4 p.

Ventura County Office of the Agricultural Commissioner, 2016, 2015 Ventura County Crop and Livestock Report, dated December 2016, 20 p.

Ventura County Public Works Agency (Flood Control and Water Resources Department), 1985, Fox Canyon Groundwater Management Agency Planning Study, Task 86-3, Groundwater Management Plan for the Fox Canyon Groundwater Management Agency, dated September 1985, 54 p.

Weber, F.H., Kiessling, E.W., Sprotte, E.C., Johnson, J.A., Sherburne, R.W., and Cleveland, G.B., 1976, Seismic hazards study of Ventura County, California: California Department of Conservation, California Division of Mines and Geology Open-File Report 76-5, 396 p., pls. 3A and 3B.

Yeats, R.S., Clark, M.N., Keller, E.A., and Rockwell, T.K., 1981, Active Fault Hazard in Southern California: Ground Rupture Versus Seismic Shaking: Geol. Soc. America Bull, Part 1, v. 92, p. 189-196.

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TABLES

Tables 2-1, 2-2, and 3-3 are embedded in Sections 2 and 3 of the report.

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Table 3-1. Aquifer Test Results

Well ID	Aquifer System	Reported Top of Perfs. (ft bgs)	Reported Bottom of Perfs. (ft bgs)	Reported Well Depth (ft bgs)	Reported Casing Depth (ft bgs)	Reported Casing Diameter (inches)	Reported Screen Length (feet)	Estimated Hydraulic Cond. (ft/day)	Estimated Trans. (gpd/ft)	Estimated Trans. (ft^2/day)	K (ft/day)	Reported Specific Capacity (gpm/ft)	Reported Specific Capacity (ft^3/d/ft)	Reported Hydraulic Cond. (ft/day)	Notes
01N21W06J05S	LAS	750	1,290	1,410	1,310	18	540	10	40,600	5,427	10	19	3,658		PTP #3
01N21W06J05S	LAS	750	1,290	1,410	1,310	18	540		42,240	5,647	10				PTP #3 (recovery)
01N21W07J02S	LAS	590	1,280	1,370	1,300	18	690	26	101,540	13,574	20	43	8,278		PTP #1
01N21W07J02S	LAS	590	1,280	1,370	1,300	18	690		165,000	22,057	32				PTP #1 (recovery)
01N21W31A05S	LAS	720	740	0	0	2	20	76.9						76.9	GP1
01N21W31A06S	LAS	440	460	0	0	2	20	1.85						1.85	GP1
01N21W31A07S	UAS	295	315	0	0	2	20	3.55						3.55	GP1
01N21W31A08S	UAS	220	240	0	0	2	20	42.4						42.4	GP1
01N22W01M03S	LAS	730	1,480	1,560	1,500	18	750	16	83,400	11,149	15	27	5,198		PTP #4
01N22W01M03S	LAS	730	1,480	1,560	1,500	18	750		93,170	12,455	17				PTP #4 (recovery)
01N22W13D03S	LAS	600	1,200	1,240	1,220	18	600	21	87,000	11,630	19	35.1	6,757		PTP #5
01N22W13D03S	LAS	600	1,200	1,240	1,220	18	600		99,000	13,234	22				PTP #5
02N21W07L07S	Uncertain (probably UAS)	70	250	360	280	20	45	181	100,350	13,415	298	66.9	12,878		SATICOY #3
02N21W07L07S	Uncertain (probably UAS)	70	250	360	280	20	105		50,800	6,791	65				SATICOY #3
02N21W32E01S	LAS	716	1,266	1,400	1,286	18	550	36	220,000	29,410	53	26	5,005		PTP #2
02N21W32E01S	LAS	716	1,266	1,400	1,286	18	550		73,300	9,799	18	25	4,813		PTP #2 (recovery)
02N22W01P01S	Uncertain	310	480	705	490	16	170	79	100,000	13,368	79	49	9,433		COUNTY YARD #1
02N22W02K08S	Uncertain	24	108	240	240	14	240	35	63,723	8,519	35				VANONI
02N22W12H01S	Uncertain	100	365	390	375	18	133	59	91,500	12,232	92	61	11,743		SATICOY #1 (unconfined)
02N22W12H01S	Uncertain	100	365	390	375	18	133		25,800	3,449	26	12.9	2,483		SATICOY #1 (confined)
02N22W13N02S	LAS	752	1,092	1,220	1,112	18	340	9	19,000	2,540	7	11.5	2,214		El RIO #12
02N22W13N02S	LAS	752	1,092	1,220	1,112	18	340		29,000	3,877	11				El RIO #12 (recovery)
02N22W23G04S	UAS	115	340	457	340	18	225	236	397,500	53,138	236				El RIO #16
02N22W23H04S	LAS	850	1,390	1,442	1,410	18	540	10	37,000	4,946	9				El RIO #13
02N22W23H04S	LAS	850	1,390	1,442	1,410	18	540		42,000	5,615	10				El RIO #13 (recovery)
02N22W26B03S	LAS	575	1,475	1,722	1,495	18	900		62,000	8,288	9				El RIO #14
02N22W26B03S	LAS	575	1,475	1,722	1,495	18	900		74,000	9,892	11				El RIO #14 (recovery)
B-1	Uncertain						41		4,550	608	15				Freeman Diversion

Data from USGS and United, as described in Section 3.

Notes: ft bgs = feet below ground surface
ft/day = feet per day
gpd/ft = gallons per day per foot
ft^2/day = feet squared per day
gpm/ft = gallons per minute per foot
ft^3/d/ft = cubic feet per day per foot

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
01S21W08L03S	CM1a#1	525-565	7.4	10.7
			13.8	
			7.6	
			14.1	
01S21W08L04S	CM1a#2	200-220	3.4	3.7
			5.5	
			2.2	
			3.6	
			2.9	
			4.6	
			2.8	
			4.5	
01N22W29D01S	CM2#1	830-870	0.32	0.43
			0.54	
			0.32	
			0.53	
01N22W29D02S	CM2#2	720-760	7.1	8.1
			12.8	
			6	
			11.1	
			7.1	
			12.8	
			6.8	
			1.3	
01N22W29D03S	CM2#3	500-520	19	25.7
			33	
			18.6	
			32.2	
01N22W29D04S	CM2#4	260-280	59.3	60.0
			97.7	
			47.1	
			79	
			32.3	
			55.1	
			41	
			68.8	
01N23W01C02S	CM3#1	1390-1410	0.86	1.0
		1430-1450	1.45	
		1470-1490	0.65	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			1.11	
01N23W01C03S	CM3#2	965-1065	3.97	5.7
			7.36	
			4.07	
			7.53	
01N23W01C04S	CM3#3	630-695	2.72	2.4
			4.73	
			0.8	
			1.37	
			1.67	
			2.86	
01N23W01C05S	CM3#4	120-145	0.19	0.2
			0.33	
			0.04	
			0.08	
01N22W28G01S	CM4#1	1295-1395	1.6	2.4
			3.2	
01N22W28G02S	CM4#2	995-1095	1.3	2.0
			2.7	
			1.7	
			3.6	
			0.96	
			2.1	
			1.1	
			2.4	
01N22W28G03S	CM4#3	720-760	0.06	0.1
			0.1	
			0.03	
			0.06	
01N22W28G04S	CM4#4	255-275	14.6	19.6
			26	
			13.6	
			24.3	
01N22W28G05S	CM4#5	180-200	59.3	79.4
			97.7	
			60.7	
			100	
01N22W35E01S	CM5#1	1140-1200	0.35	0.7
			0.95	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			0.49	
			0.84	
01N22W35E02S	CM5#2	840-900	1.41	2.2
			2.97	
01N22W35E03S	CM5#3	420-470	7.97	11.5
			14.9	
			7.97	
			14.9	
			7.97	
			14.9	
			8.15	
			15.3	
01N22W35E04S	CM5#4	300-320	20.3	27.6
			35.6	
			19.8	
			34.8	
01N22W35E05S	CM5#5	200-220	23.2	31.5
			36.7	
			25.5	
			40.5	
02N21W34G02S	PV1#1	938-998	2.9	3.0
			4.9	
			1.7	
			2.8	
			3	
			5.1	
			1.5	
			2.7	
			2.2	
			3.8	
			1.8	
			3.1	
02N21W34G03S	PV1#2	800-860	1.9	2.4
			3.3	
			1.7	
			3	
			1.7	
			2.9	
			1.8	
			3.1	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			1.9	
			2.3	
02N21W34G04S	PV1#3	360-380	0.14	0.2
			0.24	
			0.13	
			0.22	
			0.13	
			0.23	
			0.13	
			0.23	
02N21W34G05S	PV1#4	170-190	6.8	9.2
			10.8	
			7.4	
			11.8	
			7	
			11.2	
			7.2	
			11.4	
01N22W27K05S	DP#1	680-700	14.7	20.2
			25.1	
			15	
			25.7	
			15	
			25.7	
			15	
			25.7	
01N22W36K05S	DP#2	540-580	18.4	25.0
			31.9	
			18.4	
			31.9	
			18	
			31.2	
			18.4	
			31.9	
01N22W36K07S	DP#3	410-450	7.1	8.8
			11.5	
			6.5	
			10.6	
			7	
			11.6	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			6	
			10	
01N22W36K08S	DP#4	310-330	14.7	20.5
			26.6	
			14.7	
			26.6	
			14.7	
			26.6	
			14.7	
			26.6	
			14.7	
			26.6	
			14.1	
			25.4	
01N22W36K09S	DP#5	175-195	26	35.3
			45.9	
			26.6	
			46.9	
			22.4	
			39.7	
			27.2	
			48	
02N21W07L03S	SAT#1	640-700	2.7	3.4
			4.6	
			2.3	
			3.9	
			2.8	
			4.6	
			2.3	
			3.8	
			3	
			5.1	
			2.3	
			3.8	
02N21W07L04S	SAT#2	500-540	0.66	1.0
			1.11	
			0.82	
			1.36	
			0.78	
			1.3	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			0.78 1.3	
02N21W07L05S	SAT#3	270-310	2.2 3.6 1.1 1.8 1.1 1.9 1 1.7 1.1 2	1.8
02N21W07L06S	SAT#4	135-155	2.6 4.1 2.4 3.8 2.7 4	3.3
01N22W26J03S	SWIFT#1	310-350	19.6 38.4 22.5 44	31.1
01N22W26J04S	SWIFT#2	185-205	3.2 5.1 3 4.8 3.5 5.6 3.4 5.4	4.3
01N22W26J05S	SWIFT#3	55-65	2.7 4.4 1.4 2.4	2.7
01N22W27C02S	SEAWEED1	275-295	12.1 22.2 13 23.8 11.9 21.7	17.1

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			11.9	
			21.7	
			11.9	
01N22W27C02S *(continued)*	SEAWEED1	275-295	21.7	
			11.9	
			21.7	
01N22W27C03S	SEAWEED2	175-195	20	28.4
			35.4	
			20.9	
			37.1	
01N22W27C04S	SEAWEED3	55-65	16.1	22.1
			24.8	
			22	
			34.2	
			13.2	
			20.4	
			18.3	
			28.1	
02N20W16A02S	TKS#1	260-280	1.54	1.80
			2.46	
			1.21	
			1.97	
02N20W16A03S	TKS#2	170-180	1.56	2.43
			2.45	
02N20W16A03S *(continued)*	TKS#2	170-180	2.23	
			3.49	
02N20W16A03S	TKS#3	90-100	0.48	0.62
			0.75	
01S22W01H01S	CM6#1	490-550	0.0078	0.011
			0.014	
01S22W01H02S	CM6#2	380-400	14.1	20.1
			25.1	
			15.5	
			27.5	
			13.8	
			24.5	
01S22W01H03S	CM6#3	310-330	3.9	6.1
			6.2	
			5.2	
			8.2	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			4.7	
			7.4	
			5.1	
			8.2	
01S22W01H03S *(continued)*	CM6#3	310-330	4.4	
			7.1	
			4.9	
			7.7	
01S22W01H04S	CM6#4	180-200	6.8	9.2
			10.9	
			7.47	
			12	
			6.9	
			10.9	
01N22W27R03S	CM7#1	330-350	30.1	40.4
			50.6	
			30.1	
			50.6	
			30.1	
			50.6	
			30.1	
			50.6	
01N22W27R04S	CM7#2	170-190	22.9	32.1
			40.6	
			26.1	
			45.9	
			20.9	
			37.1	
01N22W27R04S *(continued)*	CM7#2	170-190	22.9	
			40.6	
01N22W27R05S	CM7#3	100-110	2.06	3.5
			3.24	
			3.36	
			5.22	
03N20W35R02S	P7#1	1050-1110	0.078	0.17
			0.139	
			0.17	
			0.3	
03N20W35R03S	P7#2	800-900	2.4	2.3
			4.2	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			1.4	
			2.5	
			1.3	
			2.4	
			1.5	
03N20W35R03S	P7#2	800-900	2.6	
03N20W35R04S	P7#3	490-530	0.29	0.32
			0.47	
			0.22	
			0.36	
			0.21	
			0.35	
01N22W20J04S	A1#1	870-890	7.8	9.6
		910-930	8.8	
			7.5	
			13.2	
			7	
			12.3	
			7.2	
			12.6	
01N22W20J05S	A1#2	640-680	11.2	19.1
			21.8	
			11.2	
			21.8	
			16.1	
			27.5	
			14.7	
			25.1	
			14.7	
			25.1	
			14.7	
			25.1	
01N22W20J06S	A1#3	385-425	0.17	0.15
			0.29	
			0.09	
			0.17	
			0.07	
			0.13	
			0.1	
			0.17	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
01N22W20J07S	A1#4	280-320	13.9	21.5
			24.6	
			13.9	
			24.6	
			14.3	
			25.2	
01N22W20J07S *(continued)*	A1#4	280-320	18.2	
			32.3	
			17.4	
			30.8	
01N22W20J08S	A1#5	155-195	18	28.0
			30.5	
			18.8	
			32	
			18	
			30.5	
			22.9	
			40.6	
			22.4	
			39.7	
			22.4	
			39.7	
01N22W20M01S	A2#1	900-940	0.56	0.79
			0.95	
			0.62	
			1.04	
01N22W20M02S	A2#2	700-740	22.3	21.4
			38.4	
			14.4	
			24.9	
			14.4	
			24.9	
			13.7	
			23.8	
			13.7	
			23.8	
01N22W20M03S	A2#3	520-560	3.1	3.6
			5.1	
			2.6	
			4.3	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			2.4	
			4	
01N22W20M04S	A2#4	300-320	25.3	39.4
			43.4	
			31.5	
			54.2	
			30.1	
01N22W20M04S	A2#4	300-320	51.8	
01N22W20M05S	A2#5	150-170	73	128.6
			120.9	
			134.3	
			217	
			104	
			168	
			107	
			172	
			71.3	
			118	
01N22W20M06S	A2#6	50-70	20.3	28.9
			32.5	
			25.3	
			37.6	
01N21W19L10S	SCE#1	394-414	51.9	70.5
			85.8	
			54.4	
			89.9	
			53.1	
			87.8	
01N21W19L11S	SCE#2	300-320	5	8.0
			7.9	
			7	
			10.8	
			4.7	
			7.4	
			6.7	
			10.6	
			4.9	
			7.8	
			8.8	
			14	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
01N21W19L12S	SCE#3	200-220	39.7	45.4
			67.7	
			41.6	
			70.9	
			26.8	
			46.3	
			25.6	
			44.2	
01N21W19L13S	SCE#4	110-130	41.1	53.4
			65.7	
01N21W19L14S	SCE#5	18-38	0.75	0.90
			1.22	
			0.56	
			0.91	
			0.69	
			1.1	
			0.76	
			1.21	
01N21W32O02S	O2#1	930-970	0.34	0.36
			0.57	
			0.25	
			0.42	
			0.2	
			0.34	
			0.32	
			0.55	
			0.2	
			0.36	
01N21W32O03S	O2#2	800-840	15.3	23.2
			26.6	
			15.3	
			26.6	
			15	
			26	
			18.6	
			31.7	
			18.6	
			31.7	
			19.4	
			33.2	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
01N21W32O04S	O2#3	600-640	7.2	10.2
			13.4	
			6.6	
			12.2	
			6.4	
			12.2	
			7.7	
			14.1	
			7.7	
01N21W32O04S	O2#3	600-640	14.1	
01N21W32O05S	O2#4	330-370	18.8	28.9
			33	
			24.4	
			42.3	
			18.8	
			33	
			24.4	
			42.3	
			18.8	
			33	
01N21W32O06S	O2#5	180-220	13.1	19.1
			23.8	
			14.1	
			25.5	
01N21W32O07S	O2#6	275-285	45.7	66.0
			77.2	
			44.7	
			75.5	
			54.3	
			92.5	
			51.8	
			86.3	
02N22W33B03S	SG#1	1210-1250	3.7	5.3
			6.1	
			4.8	
			7.9	
			3.6	
			5.9	
			4.4	
			7.2	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			3.6 5.9	
02N22W33B04S	SG#2	1110-1150	1.57 2.66 1.54 2.57	2.1
02N22W33B05S	SG#3	830-870	2 3.3	2.6
			1.9 3.1	
02N22W33B05S *(continued)*	SG#3	830-870	1.9 3 1.9 3.1 3.2 2.3 1.9 3.2	
02N22W33B06S	SG#4	460-500	5.4 10.3 5.1 9.6 5.6 10.6	7.8
02N22W33B07S	SG#5	260-300	3.48 5.72 3.95 6.5 4.34 7.15	5.19
02N21W11J03S	LP#1	1020-1080	3.71 7.09 4.67 8.92	6.10
02N21W11J04S	LP#2	615-655	very low	
02N21W11J05S	LP#3	340-380	0.14 0.25 0.14 0.24 0.14	0.20

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
			0.25	
			0.16	
			0.27	
04N18W31D03S	RP1#1	590-610	5.46	7.10
			8.77	
			5.45	
			8.73	
04N18W31D05S	RP1#2	310-330	24.7	28.4
			42.7	
			16.7	
			29.5	
04N18W31D05S	RP1#3	220-240	27.6	35.6
			47.9	
			19.9	
			35.1	
			43.2	
			58.7	
			18.9	
			33.5	
04N18W31D06S	RP1#4	140-160	29.8	36.5
			52.3	
			25.9	
			45.7	
			23.7	
			41.7	
04N18W31D08S	RP1#5	50-70	16.6	24.5
			29.2	
			18.1	
			34.1	
03N21W15G01S	SP1#1	660-680	47.9	44.3
			44.3	
			42.3	
			42.7	
03N21W15G02S	SP1#2	520-540	12.3	29.7
			121.6	
			11.4	
			20.3	
			10.9	
			19.4	
			11.9	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
03N21W15G03S	SP1#3	370-390	65.4	73.0
			106.8	
			46.1	
			73.4	
			55.6	
			90.9	
03N21W15G04S	SP1#4	260-280	13.5	21.9
			24.6	
			21.3	
			38.3	
			12.1	
			21.8	
03N21W15G05S	SP1#5	60-80	50.6	67.3
			89.1	
			48.9	
03N21W15G05S	SP1#5	60-80	86.1	
(continued)			46.7	
			82.2	
03N21W16H06S	SP2#1	530-550	20.4	28.6
			34.9	
			21.5	
			36.7	
			24.1	
			40.9	
			18.4	
			31.5	
03N21W16H07S	SP2#2	290-310	20.6	30.7
			36.3	
			22.3	
			39.3	
			23.2	
			40.4	
			23.3	
			40.4	
03N21W16H08S	SP2#3	150-170	65	94.9
			109.1	
			99.3	
			163.3	
			49.1	
			83.6	

Table 3-2. Slug Test Results

Well ID	Other Name	Perforated Interval (ft bgs)	Estimated Hydraulic Cond. (ft/day)	Average Hydraulic Cond. (ft/day)
03N21W16H09S	SP2#4	60-70	67.9 106.7	87.3

Data from USGS and United, as described in Section 3.

Notes: ft bgs = feet below ground surface
ft/day = feet per day

Table 3-4. Monthly Discharge, Santa Clara River

Year	January	February	March	April	May	June	July	August	September	October	November	December
1985	7.1	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6
1986	205.1	1,692.6	706.3	69.5	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
1987	0.6	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2
1988	45.7	143.3	136.1	43.2	0.0	0.0	10.1	13.6	0.0	2.6	0.0	6.2
1989	1.3	8.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	26.4	1,234.8	36.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.9
1992	49.0	3,060.4	940.8	246.4	0.0	0.0	0.0	0.0	0.0	16.2	0.5	120.5
1993	3,599.6	6,182.7	2,764.5	1,030.0	263.2	181.9	60.7	0.0	0.0	0.0	10.3	6.9
1994	15.0	553.6	232.6	17.8	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
1995	4,108.4	607.5	1,653.6	571.4	164.6	18.6	0.0	0.0	2.6	16.1	23.2	18.9
1996	50.3	664.3	152.5	0.0	0.0	0.0	0.0	0.0	0.0	76.1	41.2	474.4
1997	560.6	118.4	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	7.8	406.2
1998	72.1	7,124.8	1,066.0	1,610.0	1,101.8	206.2	7.7	0.0	0.0	0.0	30.1	0.0
1999	137.6	121.7	82.1	127.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.7	511.4	231.2	128.3	0.4	0.0	3.9	0.0	0.1	5.4	1.0	0.0
2001	113.2	515.0	1,781.3	78.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.5	0.2	67.7	34.8
2003	0.0	271.3	213.4	122.8	122.4	0.4	0.0	0.1	0.0	0.0	5.0	19.4
2004	0.0	420.4	22.1	0.0	0.0	0.0	0.0	0.0	0.0	127.2	0.0	945.6
2005	8,196.6	5,987.3	1,443.7	398.8	184.2	5.7	2.8	1.4	4.1	40.6	1.3	0.6
2006	337.8	264.9	260.4	1,406.8	113.9	6.1	0.5	1.0	1.1	2.6	0.4	0.5
2007	3.7	0.0	0.5	4.0	0.0	0.4	0.0	0.0	0.0	1.3	0.0	16.6
2008	1,955.1	385.1	92.7	21.8	0.0	0.3	0.0	0.0	0.9	1.5	21.6	0.6
2009	0.0	350.5	66.1	0.0	0.0	0.0	0.1	0.1	0.2	30.5	0.2	80.1
2010	817.6	307.4	127.6	138.4	0.0	1.2	0.2	0.2	0.0	0.3	13.5	544.7
2011	10.1	160.6	1,538.0	239.2	108.6	25.6	0.0	0.0	0.1	0.0	0.8	0.0
2012	0.0	0.0	94.0	69.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	306.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0	37.0
2015	0.0	0.0	0.0	0.1	2.1	0.0	0.0	0.0	0.0	0.0	1.0	5.0

Estimates derived from United monitoring data. Units are cubic feet per second.

Table 3-5. Monthly Groundwater Recharge in Arroyo Las Posas in Northern Pleasant Valley Basin

	January		February		March		April		May		June		July		August		September		October		November		December	
Year	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water	Surface Water	Ground water
1985	10	18	15	15	10	16	4	13	4	12	4	10	5	8	5	7	4	5	5	4	144	26	11	15
1986	379	40	1,219	56	900	74	26	59	11	53	12	49	11	51	11	51	22	51	13	50	54	60	14	53
1987	33	55	25	48	33	55	17	50	19	51	15	48	17	51	23	53	20	51	194	73	66	72	603	87
1988	469	91	265	86	27	77	363	86	33	78	22	68	25	68	23	66	34	65	20	63	42	66	420	84
1989	21	70	296	77	40	78	22	68	24	69	14	62	15	62	14	59	17	56	20	57	25	55	24	56
1990	289	81	296	83	23	81	22	76	34	82	19	77	18	78	14	77	13	72	16	74	22	72	14	72
1991	38	80	272	88	1,352	117	23	102	20	97	16	91	16	90	14	86	13	81	12	81	12	76	653	101
1992	445	110	9,455	137	3,484	160	156	149	66	144	58	132	63	132	50	128	44	120	144	130	38	119	858	136
1993	7,220	166	8,714	158	1,951	179	251	166	232	165	229	156	181	156	141	152	116	144	173	147	146	141	307	147
1994	319	148	1,023	140	758	157	206	150	209	154	116	147	93	149	79	147	68	140	46	139	100	137	218	145
1995	9,488	174	383	156	6,411	184	494	174	387	175	276	166	184	168	162	165	131	157	104	160	81	152	449	160
1996	171	158	1,319	156	691	168	213	160	147	163	140	156	140	161	143	161	154	156	384	165	549	162	1,782	179
1997	1,515	181	262	158	219	169	197	158	199	161	197	154	174	157	164	155	175	149	282	155	651	152	2,583	172
1998	1,342	177	17,347	168	2,464	190	1,026	182	1,326	187	678	177	465	178	395	174	446	165	341	168	522	161	383	164
1999	658	162	534	145	836	162	947	158	413	162	290	154	253	157	260	155	258	148	201	151	348	145	318	149
2000	493	148	1,892	149	764	158	778	151	314	153	239	145	242	156	245	160	255	156	351	162	249	156	272	161
2001	1,747	172	3,421	168	3,182	191	731	181	567	183	400	174	384	172	376	167	374	159	442	162	767	158	621	163
2002	640	154	442	133	478	143	418	136	382	138	368	132	325	149	315	157	291	156	303	163	1,054	165	1,231	176
2003	326	175	2,881	171	1,171	190	708	181	601	184	300	175	266	179	265	176	263	169	258	172	285	165	650	171
2004	368	170	1,789	169	366	178	341	170	241	173	193	165	203	169	173	167	190	161	2,002	179	288	171	3,616	189
2005	12,259	195	14,806	179	1,971	199	851	188	740	190	529	181	428	184	390	182	321	175	665	180	497	174	454	179
2006	1,003	182	934	167	1,142	187	1,163	184	578	188	386	179	338	183	360	181	312	173	311	177	327	170	463	174
2007	527	174	568	158	390	174	545	169	373	174	363	168	338	173	376	172	499	167	319	171	272	165	551	171
2008	4,501	189	707	175	322	182	308	172	287	175	251	168	211	171	202	170	198	163	219	168	430	163	575	170
2009	237	168	1,599	161	308	176	315	168	153	170	129	162	146	166	170	165	245	160	495	167	165	159	811	167
2010	3,334	185	1,520	171	369	183	497	173	452	176	242	168	196	170	179	168	199	161	436	168	275	162	2,500	182
2011	458	179	1,259	164	3,246	191	515	180	493	181	255	171	183	172	144	168	131	159	331	165	587	161	286	166
2012	368	165	171	153	822	167	685	163	143	164	128	156	148	160	117	157	97	150	114	154	136	148	352	156
2013	333	157	133	139	324	155	137	148	71	149	48	138	30	134	28	129	27	121	31	123	51	122	24	119
2014	194	131	51	116	622	138	499	137	41	133	36	122	46	125	36	121	31	114	39	118	49	117	230	130
2015	388	136	379	126	29	127	28	117	48	123	23	113	22	113	16	109	14	102	17	104	24	101	15	100

Estimated from Intera (2018) model, as discussed in Section 3.

Units are in acre-feet.

Table 3-6. Monthly Discharge and Diversions, Conejo Creek

Year	January		February		March		April		May		June		July		August		September		October		November		December	
	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)	Conejo Creek Inflow (cfs)	Diversion (acre-ft)
1985	24.2	-	26.1	-	21.3	-	14.5	-	14.1	-	12.8	-	14.1	-	14.0	-	14.8	-	15.6	-	44.4	-	21.4	-
1986	49.1	-	108.5	-	87.6	-	28.7	-	21.3	-	18.8	-	16.8	-	16.0	-	20.1	-	16.6	-	32.4	-	14.5	-
1987	25.7	-	22.5	-	21.2	-	16.0	-	15.0	-	14.1	-	14.2	-	15.0	-	13.4	-	38.4	-	26.4	-	56.7	-
1988	44.2	-	33.3	-	20.7	-	28.5	-	14.9	-	15.7	-	14.3	-	13.5	-	16.3	-	16.7	-	16.5	-	46.9	-
1989	21.7	-	45.6	-	24.1	-	17.4	-	16.3	-	16.2	-	15.0	-	16.2	-	18.6	-	20.6	-	18.0	-	17.5	-
1990	43.1	-	28.7	-	14.5	-	15.3	-	13.7	-	12.5	-	11.6	-	12.2	-	11.7	-	13.2	-	17.8	-	15.4	-
1991	18.2	-	36.3	-	115.0	-	17.9	-	12.3	-	12.2	-	10.6	-	10.3	-	11.9	-	13.9	-	10.2	-	65.4	-
1992	42.3	-	333.2	-	147.1	-	31.9	-	23.5	-	21.7	-	15.7	-	15.8	-	15.7	-	21.4	-	16.5	-	60.9	-
1993	303.6	-	281.5	-	80.5	-	34.1	-	24.9	-	21.0	-	19.4	-	18.5	-	17.1	-	23.2	-	24.3	-	33.0	-
1994	20.6	-	59.8	-	37.1	-	18.9	-	16.4	-	15.1	-	14.5	-	14.0	-	19.1	-	17.1	-	18.7	-	20.3	-
1995	326.6	-	40.0	-	147.9	-	43.4	-	32.5	-	27.8	-	20.1	-	17.9	-	19.1	-	19.2	-	18.8	-	40.7	-
1996	33.5	-	66.6	-	31.1	-	21.7	-	17.2	-	16.6	-	13.4	-	17.7	-	16.6	-	26.4	-	37.7	-	82.1	-
1997	73.1	-	23.9	-	17.4	-	16.0	-	13.7	-	14.6	-	17.5	-	18.4	-	18.3	-	20.5	-	44.4	-	100.2	-
1998	52.5	-	437.3	-	86.9	-	56.7	-	45.8	-	29.7	-	25.5	-	22.5	-	23.3	-	20.9	-	26.6	-	27.4	-
1999	30.5	-	31.0	-	39.1	-	29.4	-	19.8	-	18.2	-	15.2	-	15.7	-	18.6	-	16.2	-	22.8	-	17.3	-
2000	22.6	-	58.4	-	34.0	-	41.4	-	21.6	-	19.5	-	17.2	-	15.4	-	14.7	-	19.3	-	16.8	-	19.5	-
2001	57.0	-	84.4	-	118.1	-	32.3	-	23.6	-	20.1	-	20.1	-	17.8	-	18.0	-	19.5	-	32.6	-	25.0	-
2002	25.0	-	20.5	-	19.6	-	18.7	-	18.1	-	16.7	-	17.1	-	19.2	-	17.6	-	19.5	-	48.2	-	37.5	-
2003	22.7	-	78.0	-	48.5	-	33.5	-	33.8	-	21.8	620	20.5	549	18.5	456	19.0	540	19.8	698	19.8	545	25.9	565
2004	24.8	587	52.5	501	26.9	670	22.0	588	18.3	493	22.4	329	20.3	315	20.1	373	20.5	471	55.9	340	27.3	537	87.9	593
2005	210.1	181	228.9	132	73.2	261	41.6	485	36.2	529	31.7	538	28.1	246	23.8	550	21.1	672	34.2	507	26.4	737	25.4	819
2006	48.9	642	48.3	700	43.9	371	48.5	133	34.5	407	24.3	776	23.0	522	22.8	527	22.5	520	22.1	586	21.1	683	27.0	573
2007	29.6	669	30.6	432	24.1	718	25.1	581	21.6	519	20.7	471	19.7	467	20.4	359	22.0	379	22.2	314	21.5	569	25.5	563
2008	127.8	381	47.5	522	25.9	801	24.0	516	21.5	589	22.1	473	21.0	374	21.0	142	21.6	318	21.7	169	29.2	288	34.3	46.7
2009	23.2	330	74.9	215	27.0	447	22.7	434	19.2	533	17.7	326	15.8	318	15.5	162	15.6	92.8	29.4	291	19.1	512	40.2	338
2010	94.5	347	53.6	111	25.5	583	32.0	477	19.1	431	17.1	610	16.3	535	15.9	228	16.0	354	31.7	473	12.1	411	15.5	319
2011	36.2	512	90.9	605	293.4	452	35.2	572	28.8	609	22.5	541	16.8	567	15.4	457	14.7	398	21.8	515	41.6	561	23.8	639
2012	35.6	510	21.0	557	56.1	463	49.4	518	20.4	609	15.2	414	12.9	338	10.8	171	11.9	197	14.4	155	18.4	285	34.7	189
2013	24.6	281	19.4	478	22.4	506	14.8	327	13.3	323	14.7	313	10.7	39.8	7.8	76.7	8.6	117	10.9	191	15.9	276	13.9	325
2014	11.6	230	26.5	230	53.9	386	14.5	129	8.4	11.7	8.4	94.0	8.8	131	7.3	113	6.0	63.9	7.2	131	13.9	242	92.3	272
2015	45.4	510	18.1	500	25.4	478	8.4	109	8.1	74.5	9.5	140	15.9	118	6.1	10.8	9.8	0.0	5.0	39.4	5.7	110	11.9	285

Notes: cfs = cubic feet per second
acre-ft = acre-feet

Table 3-7. Precipitation Stations Used for Input to VRGWFM

Site Id	Station Name	Start Date	End Date	Easting	Northing
6	Ventura-Del Mar Ranch	9/30/1924	9/30/1998	6,198,325	1,925,847
18	Santa Paula-Limoneira Ranch	9/30/1904	9/30/1997	6,220,526	1,944,999
19	Santa Paula - Agriculture Office	9/30/1930	9/30/1991	6,240,820	1,952,865
25	Piru-Newhall Ranch	9/30/1927	9/30/2013	6,343,141	1,969,243
32	Oxnard-Water Department	9/30/1902	9/30/2003	6,206,388	1,897,748
39	Fillmore-Rancho Sespe	6/30/1912	10/21/2009	6,271,274	1,963,376
44	Santa Ana Valley-Selby Ranch	9/30/1927	9/30/1993	6,153,312	1,979,698
59	Ojai-Thacher School	9/30/1915	12/12/2013	6,205,925	1,994,199
65	Upper Ojai Summit-County Fire Station	9/30/1924	10/1/2001	6,219,699	1,983,122
85	Canada Larga	6/30/1934	12/11/2013	6,190,638	1,963,041
96	Bardsdale-Young Ranch	9/30/1931	10/1/1985	6,276,484	1,956,047
122	Ventura-Kingston Reservoir	9/30/1934	9/30/2013	6,170,771	1,949,845
140	Oak View-County Fire Station	9/30/1949	12/12/2013	6,169,169	1,968,671
152	Piedra Blanca Guard Station	9/30/1949	10/7/2013	6,210,340	2,028,317
160	Piru-Temescal Guard Station	9/30/1949	9/30/2013	6,332,365	1,995,808
163	Sulphur Mountain - Meher Mount	9/30/1956	10/1/1985	6,209,042	1,974,247
165	Ojai-Stewart Canyon	9/30/1956	12/12/2013	6,185,302	1,992,224
167	Ventura-Hall Canyon	9/30/1956	10/11/2013	6,181,215	1,926,764
168	Oxnard Airport	9/30/1956	10/10/2013	6,196,562	1,897,865
169	Thousand Oaks-Weather Station	9/30/1956	1/10/2011	6,304,417	1,888,572
171	Fillmore-Fish Hatchery	9/30/1956	10/15/2013	6,294,770	1,966,699
172	Piru Canyon	9/30/1956	10/16/2013	6,333,477	2,009,953
175	Saticoy Fire Station	9/30/1956	7/23/2008	6,212,616	1,928,105
177	Camarillo-Pacific Sod	9/30/1956	10/1/2004	6,235,271	1,881,047
187	Susana Knolls-County Fire Station	9/30/1955	10/1/2007	6,359,562	1,918,381
189	Somis-Deboni	9/30/1955	10/14/2013	6,237,536	1,927,829
190	Somis-Bard	9/30/1955	10/14/2013	6,257,159	1,926,615
191	Moorpark-Downing Ranch	9/30/1955	11/17/2008	6,291,452	1,942,263
194	Camarillo-Adohr	9/30/1955	10/1/1998	6,255,532	1,898,427
199	Fillmore-County Fire Station	9/30/1959	10/1/2009	6,282,484	1,970,246
204	Lake Casitas-Upper	9/30/1959	9/30/2012	6,158,542	1,976,191
209	Lockwood Valley-County Yard	9/30/1960	9/30/1993	6,230,432	2,091,075
215	Channel Islands Harbor	9/30/1963	9/30/2013	6,191,851	1,883,566
218	Meiners Oaks-County Fire Station	9/30/1964	12/12/2013	6,174,260	1,986,601
225	Wheeler Canyon	6/30/1966	12/6/2013	6,215,991	1,966,484
227	Lake Bard	9/18/1966	3/19/2013	6,311,245	1,911,766
230	Ventura-Sexton Canyon	9/30/1971	9/30/1998	6,191,101	1,939,177
231	El Rio-County Yard	9/30/1966	10/1/2006	6,205,970	1,912,210

Table 3-7. Precipitation Stations Used for Input to VRGWFM

Site Id	Station Name	Start Date	End Date	Easting	Northing
232	Santa Monica Mts-Deals Flat	9/30/1968	10/29/2013	6,268,564	1,856,142
235	Piru-L.A./Ventura County Line	9/30/1993	9/30/2006	6,349,338	1,968,492
238	South Mountain-Shell Oil	9/30/1970	10/14/2013	6,257,088	1,944,610
239	El Rio-UWCD Spreading Grounds	9/30/1972	11/26/2013	6,213,264	1,911,417
241	Cerro Noroeste	9/30/1984	10/1/1985	6,144,154	2,147,145
242	Tripas Canyon	9/30/1971	10/15/2013	6,330,897	1,956,898
243	Santa Paula-Dawes	9/30/1973	10/1/1987	6,227,197	1,949,070
244	Cuddy Valley-Cuddy Ranch	9/30/1974	9/30/2013	6,243,775	2,129,753
245	Santa Paula-UWCD	9/30/1960	9/30/1986	6,236,679	1,949,674
246	Simi Sanitation Plant NWS	9/30/1986	9/30/2008	6,316,653	1,926,683
248	Simi Hills-Burro Flat	9/30/1976	10/1/1985	6,347,433	1,912,298
249	Simi Hills-Rocketdyne Lab	9/30/1958	10/1/2003	6,357,651	1,908,689
250	Moorpark-Happy Camp Canyon	9/30/1976	10/14/2013	6,305,016	1,949,525
254	Casitas Station - Station Canyon	8/31/1979	12/12/2013	6,148,201	1,973,600
257	Oxnard South-Vance	9/30/1979	10/1/1989	6,201,137	1,887,094
258	Oak View-Raap	9/30/1981	9/30/1992	6,170,329	1,967,544
259	Camarillo-PVWD	9/30/1981	9/30/2013	6,238,347	1,901,536
260	Ventura-Emma Wood State Bch	9/30/1982	9/30/1995	6,164,189	1,927,589
261	Saticoy-Recharge Facility	9/30/1984	9/30/2013	6,222,407	1,925,770
262	Moorpark College	9/30/1985	10/1/1990	6,309,744	1,933,310
263	Camarillo-Leisure Village	9/30/1984	10/1/2004	6,262,135	1,903,516
264	Wheeler Gorge	9/30/1982	12/12/2013	6,179,190	2,012,317
267	Ormond Beach-Occidental Chemical	9/30/1989	10/1/1993	6,207,390	1,875,597
268	Last Chance (Type C)	9/30/2003	11/30/2011	6,245,374	2,003,466
271	Lockwood Valley nr Seymour Creek	9/30/1998	10/1/2002	6,247,917	2,103,121
272	Sage Ranch	9/30/2002	3/19/2013	6,357,157	1,910,209
278	Sespe - Dough Flat (Type B)	9/30/2003	2/29/2012	6,292,588	2,013,524
279	Borracho Saddle (Type C)	9/30/2006	11/30/2011	6,287,925	2,043,792
280	Circle X Ranch (Type B)	9/30/1997	1/10/2012	6,278,137	1,863,532
281	Cheeseboro RAWS	9/30/2005	12/31/2013	6,344,089	1,890,992
300	Senior Gridley Canyon (Type B)	9/30/1992	12/7/2011	6,197,452	1,999,860
301	Old Man Mountain (Type C)	9/30/1998	12/13/2011	6,128,011	2,008,963
302	Canada Larga-Verde Canyon (Type B)	9/30/1998	11/30/2011	6,195,218	1,953,483
303	Nordhoff Ridge (Type C)	9/30/1997	12/20/2011	6,190,964	2,010,149
304	Matilija Hot Springs at No Fork (Type B)	9/30/1998	5/23/2012	6,168,038	2,004,170
305	La Granada Mountain (Type B)	9/30/2004	12/1/2011	6,132,168	1,977,361
306	White Ledge Peak (Type C)	9/30/2004	10/1/2011	6,142,078	1,997,240
307	Upper Matilija Canyon (Type C)	9/30/2004	11/30/2011	6,148,528	2,022,122

Table 3-7. Precipitation Stations Used for Input to VRGWFM

Site Id	Station Name	Start Date	End Date	Easting	Northing
308	Red Mountain (Type B)	9/30/2002	11/28/2011	6,157,216	1,952,146
400	Fillmore-Grand Ave (Type B)	9/30/1998	6/11/2012	6,282,112	1,984,403
401	Sycamore Canyon (Type C)	9/30/1997	12/7/2011	6,237,440	2,036,305
402	Tommys Creek (Type C)	9/30/1998	12/7/2011	6,194,057	2,044,282
403	Silverstrand Alert (Type B)	9/30/2008	7/12/2012	6,192,902	1,880,116
404	Sisar North ALERT (Type C)	9/30/2004	12/7/2011	6,219,069	2,008,908
405	Choro Grande (Type C)	9/30/1998	11/30/2011	6,159,642	2,046,337
406	Fagan Canyon West (Type B)	9/30/2004	10/28/2010	6,233,868	1,961,229
407	Fagan Canyon East (Type B)	9/30/2004	10/28/2010	6,238,182	1,956,937
408	Rose Valley Alert (Type C)	9/30/2000	8/30/2012	6,204,831	2,022,215
409	Hopper Mountain (Type C)	9/30/2000	11/17/2011	6,301,076	1,998,286
410	Pyramid Lake Visitors Center (Type B)	9/30/2006	2/28/2012	6,331,876	2,063,545
411	Piru Creek above Pyramid Lake (Type B)	9/30/2006	2/28/2012	6,308,629	2,070,706
412	El Rio - Mesa School APCD	6/30/2012	12/31/2013	6,216,257	1,916,135
500	Santa Rosa Valley - Conejo (Type B)	9/30/2003	9/30/2008	6,270,425	1,909,805
501	Rocky Peak (Type B)	9/30/2003	5/1/2012	6,367,273	1,929,754
502	Santa Rosa Valley - Basin 2	9/30/2007	10/10/2013	6,294,289	1,912,011
503	Oxnard Plain - Laguna Rd (Type B)	6/30/2008	9/30/2010	6,229,045	1,888,191
504	South Mountain West (Type B)	9/30/2002	12/31/2011	6,230,637	1,926,286
505	Camarillo - CSUCI (Type B)	9/30/2003	10/28/2013	6,247,289	1,889,109
506	Wood Ranch - Sycamore Canyon Dam (Type B)	9/30/2003	11/8/2011	6,320,092	1,915,839
507	South Mountain East (Type B)	9/30/2002	11/11/2010	6,246,072	1,933,703
508	Moorpark - Home Acres ALERT (Type B)	9/30/2004	6/13/2012	6,282,295	1,922,330
509	Spanish Hills - Las Posas Res (Type B)	9/30/2003	6/15/2012	6,233,360	1,906,442
510	Lang Ranch (Type B)	9/30/2004	2/8/2012	6,314,074	1,898,399
512	Camarillo - Upland (Type B)	9/30/2012	3/27/2013	6,257,171	1,911,047
605	San Antonio Creek at Hwy 33	10/1/2011	10/1/2012	6,168,094	1,963,326
004A	Casitas Dam	9/30/1956	12/12/2013	6,160,073	1,958,881
017B	Port Hueneme - USN	9/30/1982	10/1/1996	6,197,414	1,877,838
017C	Port Hueneme - Oxnard Sewer Plant	9/30/1996	10/11/2013	6,202,687	1,876,057
018A	Santa Paula-Limoneira Ranch	10/1/1997	10/1/2010	6,220,526	1,944,999
018B	Santa Paula-Limoneira Ranch	9/30/2010	9/30/2013	6,217,431	1,945,640
020A	Rancho Matilija - West	9/30/1972	9/30/1989	6,165,809	1,980,947
020B	Ventura River County Water District	9/30/1989	9/30/2013	6,170,755	1,981,085
030D	Ojai-County Fire Station	9/30/1979	12/31/2013	6,190,521	1,987,711
032A	Oxnard Civic Center	9/30/2003	10/21/2013	6,204,787	1,897,261
036A	Piru-County Fire Station	9/30/1966	10/11/2013	6,321,391	1,973,755
049A	Santa Rosa Valley-Worthington Ranch	9/30/1977	9/30/2008	6,277,516	1,914,084

Table 3-7. Precipitation Stations Used for Input to VRGWFM

Site Id	Station Name	Start Date	End Date	Easting	Northing
063B	Upper Sespe - Pine Mountain Inn NWS	1/2/1971	11/25/2011	6,151,125	2,046,957
063C	Upper Sespe - Pine Mountain Inn	5/5/2013	7/22/2013	6,150,543	2,047,167
064B	Upper Ojai-Happy Valley	9/30/1970	12/12/2013	6,202,952	1,983,619
065A	Upper Ojai Summit-County Fire Station	9/30/2001	10/7/2013	6,219,449	1,983,226
066C	Ventura-Downtown (County Schools)	9/30/1978	10/1/1990	6,171,486	1,927,191
066D	Ventura-Downtown (Vista Bldg)	9/30/1990	10/1/2000	6,170,819	1,927,503
066E	Ventura-Downtown (City Hall-Historic Courthouse)	9/30/2000	10/17/2013	6,171,241	1,927,699
094B	Fillmore-Double H-N Ranch	9/30/1972	10/1/1987	6,306,180	1,968,420
094C	Fillmore-Fairview Ranch	9/30/1987	10/16/2008	6,302,241	1,968,150
096A	Bardsdale-Lander Ranch	9/30/1985	10/21/2009	6,274,887	1,955,456
101A	Piru-Camulos Ranch	9/30/1974	10/11/2013	6,333,350	1,970,933
106A	Piru RAWS	9/30/2001	12/31/2013	6,317,425	1,970,450
121C	Lake Sherwood-County Fire Station	9/30/1963	12/7/2013	6,296,566	1,874,790
126A	Moorpark - Ventura County Yard	7/31/2008	12/24/2013	6,296,552	1,930,997
128B	Thousand Oaks-County Fire Station	9/30/1972	10/1/2009	6,299,583	1,902,968
128C	Thousand Oaks APCD APCD	9/30/2008	12/31/2013	6,298,549	1,899,944
130A	Chuchupate Ranger Station NWS	9/30/1968	4/29/2009	6,258,076	2,117,878
132A	Saticoy-Buenaventura Lemon Co	9/30/1990	10/1/2003	6,215,886	1,927,764
132B	Saticoy-County Yard	9/30/2006	9/30/2008	6,217,299	1,926,636
134B	Matilija Dam	9/30/1977	12/24/2013	6,168,247	2,000,933
141A	Moorpark-County Fire Station	9/30/1965	10/1/2008	6,295,520	1,928,074
153A	Ojai-Bower Tree Farm	9/30/1976	9/30/2013	6,193,255	1,985,252
154B	Simi-County Fire Station	9/30/1971	10/1/2008	6,347,644	1,930,290
163A	Sulphur Mountain	9/30/1985	10/1/1988	6,207,601	1,972,848
163B	Sulphur Mountain	9/30/1988	9/30/1998	6,205,192	1,974,595
163C	Sulphur Mountain	9/30/1998	12/12/2013	6,207,356	1,973,357
169A	Thousand Oaks - Civic Center	9/30/2010	12/24/2013	6,304,991	1,887,152
173A	Santa Paula Canyon-Ferndale Ranch	9/30/1979	10/3/2013	6,233,982	1,979,527
174A	Ozena Guard Station (NWS)	9/30/1979	11/25/2011	6,154,910	2,073,497
175A	Saticoy-County Yard	9/30/2008	10/17/2013	6,217,048	1,926,639
177A	Camarillo-Pacific Sod	9/30/2004	12/10/2013	6,237,116	1,880,623
180A	Ortega Hill (Type C)	9/30/1998	9/18/2013	6,169,667	2,032,962
182A	Newbury Park-Rancho Sierra Vista	9/30/1972	10/1/1989	6,270,807	1,879,474
188A	Newbury Park-County Fire Station #35	9/30/1981	12/10/2013	6,280,414	1,891,413
192A	Moorpark-Everett	9/30/1980	9/30/2008	6,306,818	1,914,633
193A	Santa Susana	9/30/1980	12/10/2013	6,347,324	1,920,588
194A	Camarillo-Adohr (Sanitation Plant)	9/30/1998	10/10/2013	6,258,610	1,895,464
196B	Tapo Canyon	9/30/1977	9/30/2008	6,344,788	1,941,734

Table 3-7. Precipitation Stations Used for Input to VRGWFM

Site Id	Station Name	Start Date	End Date	Easting	Northing
196C	Tapo Canyon - County Park	9/30/2008	12/10/2013	6,347,046	1,940,707
199A	Fillmore Sanitation	9/30/2009	10/1/2013	6,278,167	1,965,737
206B	Somis-Fuller	9/30/1977	10/14/2013	6,265,819	1,936,942
207A	Matilija Canyon	9/30/1963	10/1/1985	6,153,533	2,008,507
207B	Matilija Canyon	9/30/1985	9/30/2008	6,153,949	2,008,300
207C	Matilija Canyon	9/30/2008	12/12/2013	6,153,857	2,007,694
209A	Lockwood Valley-County Yard	9/30/1993	6/18/2013	6,230,098	2,091,079
211A	Alamo Mountain	9/30/2009	9/18/2013	6,266,757	2,067,446
216A	Ventura Marina-CINP	9/30/1983	10/1/1989	6,179,140	1,915,265
216B	Ventura Marina-Port District	9/30/1989	10/1/2008	6,179,156	1,916,478
216C	Ventura Harbor	9/30/2008	10/10/2013	6,179,326	1,916,678
219A	Camarillo-Hauser	9/30/1972	9/30/2013	6,251,284	1,910,196
221B	Sea Cliff - County Fire Station	9/30/1982	10/10/2013	6,133,053	1,951,062
222A	Ventura-County Government Center	9/30/1977	10/16/2013	6,195,759	1,921,834
223A	Point Mugu-USN	10/1/1976	10/1/2013	6,222,825	1,865,310
224A	Sespe-Westates	9/30/1976	10/17/2013	6,295,797	1,997,927
230A	Ventura-Sexton Canyon	9/30/1998	12/6/2013	6,191,510	1,938,262
231A	El Rio - Riverpark	9/30/2006	8/18/2008	6,204,812	1,913,740
234A	Las Llajas Canyon	9/30/1970	10/1/2002	6,353,281	1,932,778
234B	Las Llajas Canyon	9/30/2002	12/10/2013	6,353,282	1,932,980
235A	Piru-L.A./Ventura County Line	9/30/2006	10/11/2013	6,349,002	1,968,494
245A	Santa Paula-UWCD	9/30/1986	10/27/2010	6,240,648	1,952,462
245B	Santa Paula - Wilson Ranch	9/30/2010	10/1/2013	6,243,151	1,959,209
246A	Simi Sanitation Plant	7/2/2008	12/10/2013	6,316,485	1,926,684
262A	Moorpark College (Type B)	9/30/1999	9/30/2008	6,309,743	1,933,209
263A	Camarillo-Leisure Village CIMIS 152	9/30/2004	5/31/2013	6,261,717	1,903,723
273A	Oxnard NWS	7/28/2010	10/21/2013	6,217,833	1,899,638
500A	Camrosa Water District	9/30/2009	10/11/2013	6,269,340	1,910,624

Station information and precipitation data downloaded from Ventura County Watershed Protection District, as described in Section 3.

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N20W06E01S	240	---	550	---	Pleasant Valley	27	96.5	2,604	709	2000	1	2013	2
01N21W01A01S	315	---	418	---	Pleasant Valley	21	0	0	0	2003	1	2013	2
01N21W01A03S	260	---	390	---	Pleasant Valley	58	103	5,993	217	1983	2	2013	2
01N21W01B01S	---	---	---	---	Pleasant Valley	59	207	12,236	1,499	1984	1	2014	2
01N21W01B03S	---	---	---	---	Pleasant Valley	14	71.9	1,007	202	1979	2	1997	2
01N21W01B04S	820	---	1,150	---	Pleasant Valley	48	59.7	2,865	377	1983	2	2013	2
01N21W01B05S	585	---	910	---	Pleasant Valley	21	145	3,035	247	2004	1	2015	2
01N21W01C02S	224	---	504	---	Pleasant Valley	75	144	10,789	640	1979	2	2016	2
01N21W01D01S	350	---	371	---	Pleasant Valley	75	1.2	89.8	5.0	1979	2	2016	2
01N21W01D02S	107	---	437	---	Pleasant Valley	5	93.9	469	123	1979	2	1997	2
01N21W01D05S	313	---	440	---	Pleasant Valley	49	42.0	2,060	205	1979	2	2003	2
01N21W01F02S	325	---	374	---	Pleasant Valley	60	60.4	3,622	459	1986	1	2015	2
01N21W01J01S	240	---	550	---	Pleasant Valley	10	59.9	599	152	2004	1	2015	2
01N21W01M02S	1,070	---	1,200	---	Pleasant Valley	6	274	1,645	549	2014	1	2016	2
01N21W01N02S	267	---	435	---	Pleasant Valley	7	19.0	133	62.5	1979	2	1997	2
01N21W02H04S	240	---	540	---	Pleasant Valley	24	69.7	1,674	158	2005	1	2016	2
01N21W02H05S	95	---	155	---	Pleasant Valley	14	0.4	6.0	1.0	2010	1	2016	2
01N21W02J01S	---	---	---	---	Pleasant Valley	75	0.6	45.6	1.0	1979	2	2016	2
01N21W02J02S	178	---	373	---	Pleasant Valley	75	54.4	4,078	349	1979	2	2016	2
01N21W02J03S	304	---	707	---	Pleasant Valley	75	57.7	4,326	134	1979	2	2016	2
01N21W02J04S	310	---	450	---	Pleasant Valley	8	0.6	4.4	1.0	2013	1	2016	2
01N21W03A02S	710	---	1,060	---	Pleasant Valley	9	0	0	0	1982	1	1997	2
01N21W03C01S	956	---	1,216	---	Pleasant Valley	19	43.2	821	113	1979	2	1989	2
01N21W03D01S	336	---	1,300	---	Pleasant Valley	75	70.9	5,320	449	1979	2	2016	2
01N21W03H02S	615	---	895	---	Pleasant Valley	24	171	4,114	681	2005	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W03J01S	658	---	1,090	---	Pleasant Valley	61	129	7,864	584	1979	2	2016	2
01N21W03K01S	403	---	1,433	---	Pleasant Valley	71	586	41,613	1,428	1981	2	2016	2
01N21W03L03S	674	---	990	---	Pleasant Valley	25	110	2,761	274	2004	2	2016	2
01N21W03N01S	712	---	1,036	---	Pleasant Valley	74	110	8,142	310	1979	2	2016	1
01N21W03N02S	688	---	883	---	Pleasant Valley	19	10.5	199	47.4	1980	1	1997	2
01N21W03P02S	430	---	980	---	Pleasant Valley	75	140	10,494	499	1979	2	2016	2
01N21W03R01S	443	---	1,013	---	Pleasant Valley	71	480	34,076	1,001	1981	2	2016	2
01N21W04A02S	800	---	1,160	---	Pleasant Valley	52	43.7	2,271	287	1991	1	2016	2
01N21W04C01S	613	---	1,003	---	Pleasant Valley	13	31.4	408	136	1979	2	2016	2
01N21W04D03S	100	---	175	---	Oxnard Plain	74	0.6	47.0	1.0	1979	1	2016	2
01N21W04D04S	571	---	1,321	---	Oxnard Plain	71	306	21,736	966	1981	2	2016	2
01N21W04K01S	400	---	1,220	---	Pleasant Valley	71	183	12,962	871	1981	2	2016	2
01N21W04M01S	522	---	1,290	---	Oxnard Plain	75	27.5	2,066	344	1979	1	2016	2
01N21W04M02S	---	---	---	---	Oxnard Plain	29	0.6	18.7	0.8	2002	2	2016	2
01N21W05A02S	120	---	208	---	Oxnard Plain	68	0.2	15.9	1.0	1979	2	2015	1
01N21W05F01S	120	---	200	---	Oxnard Plain	73	9.4	684	140	1979	2	2016	2
01N21W05G01S	106	---	170	---	Oxnard Plain	75	39.2	2,937	136	1979	2	2016	2
01N21W05K01S	102	---	178	---	Oxnard Plain	51	4.5	232	68.8	1991	2	2016	2
01N21W06A02S	---	---	---	---	Oxnard Plain	2	0	0	0	2013	1	2013	2
01N21W06C02S	105	---	130	---	Oxnard Plain	75	61.9	4,640	193	1979	2	2016	2
01N21W06G01S	980	---	1,030	---	Oxnard Plain	62	1.4	87.3	10.2	1984	1	2016	2
01N21W06H01S	110	---	200	---	Oxnard Plain	75	16.0	1,198	129	1979	2	2016	2
01N21W06J02S	106	---	192	---	Oxnard Plain	75	80.6	6,045	545	1979	2	2016	2
01N21W06J05S	750	---	1,290	---	Oxnard Plain	64	138	8,859	625	1985	1	2016	2
01N21W06L02S	150	---	173	---	Oxnard Plain	10	0.1	1.0	1.0	1979	2	1984	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W06L04S	110	---	182	---	Oxnard Plain	75	28.1	2,109	330	1979	2	2016	2
01N21W06L05S	624	---	964	---	Oxnard Plain	75	109	8,210	312	1979	2	2016	2
01N21W06R01S	98	---	196	---	Oxnard Plain	2	0	0	0	2001	1	2008	2
01N21W06R03S	138	---	158	---	Oxnard Plain	75	0.5	34.6	1.0	1979	2	2016	2
01N21W06R04S	130	---	423	---	Oxnard Plain	74	109	8,038	316	1979	2	2016	2
01N21W07A01S	125	---	150	---	Oxnard Plain	76	0.5	37.2	1.4	1979	1	2016	2
01N21W07H01S	125	---	176	---	Oxnard Plain	75	40.1	3,008	323	1979	2	2016	2
01N21W07H04S	122	---	170	---	Oxnard Plain	75	26.2	1,964	65.0	1979	2	2016	2
01N21W07J01S	136	---	198	---	Oxnard Plain	15	32.6	489	84.0	1979	2	1997	2
01N21W07J02S	590	---	1,280	---	Oxnard Plain	64	183	11,710	821	1985	1	2016	2
01N21W07P01S	80	---	154	---	Oxnard Plain	75	4.4	327	7.2	1979	2	2016	2
01N21W07R02S	120	---	202	---	Oxnard Plain	75	1.3	99.0	9.0	1979	2	2016	2
01N21W08A01S	700	---	1,300	---	Oxnard Plain	75	0.8	61.9	3.5	1979	2	2016	2
01N21W08A02S	670	---	1,190	---	Oxnard Plain	55	88.5	4,866	303	1979	2	2006	2
01N21W08D02S	268	---	716	---	Oxnard Plain	64	1.1	72.1	6.0	1984	2	2016	2
01N21W08D05S	700	---	1,200	---	Oxnard Plain	55	97.7	5,371	374	1979	2	2006	2
01N21W08F02S	663	---	1,163	---	Oxnard Plain	48	174	8,356	588	1979	2	2003	1
01N21W08F03S	700	---	1,170	---	Oxnard Plain	26	27.4	713	189	2003	2	2016	2
01N21W08N03S	700	---	1,140	---	Oxnard Plain	2	0	0	0	2016	1	2016	2
01N21W08R01S	603	---	1,363	---	Oxnard Plain	71	323	22,967	1,038	1981	2	2016	2
01N21W09C03S	700	---	1,120	---	Pleasant Valley	24	131	3,140	446	1979	2	1997	2
01N21W09C04S	720	---	1,120	---	Pleasant Valley	51	66.2	3,375	209	1991	2	2016	2
01N21W09D02S	131	---	251	---	Oxnard Plain	42	6.2	262	10.4	1979	2	2000	1
01N21W09D03S	120	---	260	---	Oxnard Plain	33	9.9	326	135	2000	2	2016	2
01N21W09J01S	474	---	954	---	Pleasant Valley	45	149	6,685	432	1979	2	2001	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W09J03S	480	---	960	---	Pleasant Valley	41	407	16,683	657	1996	2	2016	2
01N21W09M03S	160	---	300	---	Oxnard Plain	76	1.5	117	3.0	1979	1	2016	2
01N21W09M04S	766	---	1,270	---	Oxnard Plain	54	74.8	4,038	283	1979	2	2006	1
01N21W09M05S	860	---	1,160	---	Oxnard Plain	3	210	631	239	2015	2	2016	2
01N21W10A02S	240	---	320	---	Pleasant Valley	74	0.6	41.4	1.4	1980	1	2016	2
01N21W10G01S	420	---	1,000	---	Pleasant Valley	71	531	37,687	1,191	1981	2	2016	2
01N21W10L01S	900	---	1,050	---	Pleasant Valley	6	147	884	211	2014	1	2016	2
01N21W11B03S	---	---	---	---	Pleasant Valley	40	117	4,670	242	1997	1	2016	2
01N21W11D02S	284	---	1,000	---	Pleasant Valley	75	37.3	2,799	241	1979	2	2016	2
01N21W11G04S	270	---	730	---	Pleasant Valley	41	119	4,861	384	1979	2	1999	2
01N21W11P01S	403	---	843	---	Pleasant Valley	74	86.9	6,432	383	1980	1	2016	2
01N21W12C04S	250	---	400	---	Pleasant Valley	16	6.9	110	32.3	1979	2	1997	2
01N21W12C06S	240	---	390	---	Pleasant Valley	14	17.8	250	19.2	2010	1	2016	2
01N21W12D01S	253	---	414	---	Pleasant Valley	75	130	9,762	405	1979	2	2016	2
01N21W12E02S	---	---	---	---	Pleasant Valley	8	0.9	7.0	2.0	2013	1	2016	2
01N21W12F01S	---	---	---	---	Pleasant Valley	14	0.5	7.4	4.2	1980	1	1997	2
01N21W14C01S	270	---	880	---	Pleasant Valley	25	139	3,472	369	1979	2	1991	2
01N21W15B01S	336	---	852	---	Pleasant Valley	45	58.6	2,636	264	1979	2	2001	2
01N21W15B02S	340	---	880	---	Pleasant Valley	50	92.1	4,607	247	1992	1	2016	2
01N21W15C01S	128	---	671	---	Pleasant Valley	14	0	0	0	1995	1	2001	2
01N21W15C02S	---	---	---	---	Pleasant Valley	22	0.4	8.8	3.6	1979	2	1997	2
01N21W15D02S	383	---	1,083	---	Pleasant Valley	71	347	24,670	1,072	1981	2	2016	2
01N21W15H01S	120	---	200	---	Pleasant Valley	65	0.6	37.4	1.0	1984	2	2016	2
01N21W15J04S	377	---	857	---	Pleasant Valley	66	106	7,002	581	1982	1	2016	2
01N21W15L01S	256	---	282	---	Pleasant Valley	24	0	0	0	1995	1	2006	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W15L02S	354	---	904	---	Pleasant Valley	76	119	9,049	574	1979	1	2016	2
01N21W15M01S	492	---	892	---	Pleasant Valley	58	155	9,016	333	1988	1	2016	2
01N21W15P02S	520	---	1,015	---	Pleasant Valley	76	138	10,495	398	1979	1	2016	2
01N21W16A04S	434	---	916	---	Pleasant Valley	76	98.7	7,497	433	1979	1	2016	2
01N21W16A05S	620	---	770	---	Pleasant Valley	21	222	4,654	362	2006	2	2016	2
01N21W16B02S	257	---	377	---	Pleasant Valley	54	1.6	86.2	2.2	1979	1	2006	1
01N21W16B03S	640	---	900	---	Pleasant Valley	75	64.1	4,805	341	1979	2	2016	2
01N21W16E03S	314	---	602	---	Oxnard Plain	76	65.5	4,975	226	1979	1	2016	2
01N21W16M01S	240	---	1,194	---	Oxnard Plain	75	86.8	6,507	675	1979	2	2016	2
01N21W16M03S	620	---	1,100	---	Oxnard Plain	26	148	3,861	325	2004	1	2016	2
01N21W16N01S	418	---	893	---	Oxnard Plain	37	262	9,692	499	1998	2	2016	2
01N21W16P03S	750	---	1,050	---	Pleasant Valley	76	57.5	4,366	525	1979	1	2016	2
01N21W16P04S	600	---	1,000	---	Pleasant Valley	59	151	8,888	538	1987	2	2016	2
01N21W17B01S	175	---	450	---	Oxnard Plain	75	18.7	1,405	124	1979	2	2016	2
01N21W17B02S	600	---	1,100	---	Oxnard Plain	12	213	2,554	394	2011	1	2016	2
01N21W17C01S	128	---	470	---	Oxnard Plain	35	1.5	53.1	3.0	1999	2	2016	2
01N21W17C02S	128	---	200	---	Oxnard Plain	75	9.4	704	42.8	1979	2	2016	2
01N21W17D02S	114	---	186	---	Oxnard Plain	75	15.0	1,124	72.5	1979	2	2016	2
01N21W17E01S	119	---	335	---	Oxnard Plain	71	8.4	593	109	1979	2	2014	2
01N21W17G02S	176	---	488	---	Oxnard Plain	75	36.9	2,771	196	1979	2	2016	2
01N21W17G03S	554	---	1,104	---	Oxnard Plain	66	213	14,054	584	1984	1	2016	2
01N21W17K01S	540	---	940	---	Oxnard Plain	6	171	1,028	203	2014	1	2016	2
01N21W18A03S	114	---	186	---	Oxnard Plain	75	18.6	1,395	134	1979	2	2016	2
01N21W18A04S	130	---	400	---	Oxnard Plain	75	57.7	4,328	220	1979	2	2016	2
01N21W18D01S	380	---	660	---	Oxnard Plain	58	47.7	2,769	100	1988	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W18G02S	130	---	182	---	Oxnard Plain	75	89.4	6,704	187	1979	2	2016	2
01N21W18J01S	132	---	180	---	Oxnard Plain	41	67.5	2,769	404	1979	2	2016	2
01N21W18L03S	130	---	170	---	Oxnard Plain	75	3.7	279	7.8	1979	2	2016	2
01N21W18L04S	136	---	200	---	Oxnard Plain	53	47.7	2,530	173	1979	2	2005	2
01N21W18L05S	383	---	923	---	Oxnard Plain	72	60.4	4,352	170	1981	1	2016	2
01N21W18Q02S	150	---	190	---	Oxnard Plain	75	1.8	137	21.4	1979	2	2016	2
01N21W18Q03S	100	---	200	---	Oxnard Plain	5	35.4	177	49.8	2014	2	2016	2
01N21W19B01S	128	---	466	---	Oxnard Plain	75	101	7,547	304	1979	2	2016	2
01N21W19B03S	160	---	240	---	Oxnard Plain	70	2.3	161	5.2	1982	1	2016	2
01N21W19C01S	200	---	218	---	Oxnard Plain	38	7.8	298	83.4	1979	2	2015	2
01N21W19C02S	440	---	800	---	Oxnard Plain	72	29.7	2,139	154	1981	1	2016	2
01N21W19F01S	380	---	490	---	Oxnard Plain	52	4.7	244	16.0	1991	1	2016	2
01N21W19J04S	115	---	275	---	Oxnard Plain	18	0.9	15.5	1.5	1979	2	1997	2
01N21W19J05S	600	---	800	---	Oxnard Plain	75	14.6	1,096	70.9	1979	2	2016	2
01N21W19J06S	520	---	820	---	Oxnard Plain	54	103	5,587	225	1990	1	2016	2
01N21W19K03S	141	---	180	---	Oxnard Plain	71	1.6	117	8.8	1979	2	2016	2
01N21W19K08S	174	---	200	---	Oxnard Plain	71	5.3	374	16.8	1979	2	2016	2
01N21W19K09S	120	---	172	---	Oxnard Plain	75	2.3	175	7.3	1979	2	2016	2
01N21W19K10S	140	---	228	---	Oxnard Plain	75	0.7	53.1	1.5	1979	2	2016	2
01N21W19K11S	280	---	400	---	Oxnard Plain	10	0.6	5.9	2.3	2011	1	2016	2
01N21W19L07S	212	---	502	---	Oxnard Plain	68	33.7	2,290	254	1979	2	2015	1
01N21W19L08S	400	---	540	---	Oxnard Plain	75	1.5	109	3.2	1979	2	2016	2
01N21W19N02S	400	---	1,020	---	Oxnard Plain	19	85.0	1,615	157	1993	2	2002	2
01N21W19P03S	750	---	900	---	Oxnard Plain	47	43.1	2,023	102	1993	2	2016	2
01N21W19P05S	303	---	693	---	Oxnard Plain	28	88.1	2,466	504	2003	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W19Q01S	170	---	390	---	Oxnard Plain	25	74.6	1,864	109	2004	2	2016	2
01N21W20B01S	540	---	930	---	Oxnard Plain	15	255	3,831	397	2009	2	2016	2
01N21W20C05S	235	---	255	---	Oxnard Plain	75	87.4	6,555	782	1979	2	2016	2
01N21W20D02S	112	---	435	---	Oxnard Plain	71	51.4	3,646	234	1979	2	2014	2
01N21W20K02S	600	---	840	---	Oxnard Plain	69	63.3	4,367	147	1982	2	2016	2
01N21W20K03S	600	---	880	---	Oxnard Plain	51	123	6,253	334	1991	2	2016	2
01N21W20L02S	123	---	214	---	Oxnard Plain	75	12.0	897	82.6	1979	2	2016	2
01N21W20N07S	120	---	190	---	Oxnard Plain	70	0.5	36.2	1.7	1981	2	2016	2
01N21W20P02S	150	---	400	---	Oxnard Plain	6	66.3	398	98.9	2014	1	2016	2
01N21W20P03S	---	---	---	416	Oxnard Plain	75	51.9	3,895	359	1979	2	2016	2
01N21W20P04S	160	---	300	---	Oxnard Plain	24	40.9	983	59.8	2005	1	2016	2
01N21W20R01S	195	---	415	---	Oxnard Plain	42	43.6	1,831	276	1979	2	2002	2
01N21W21D02S	150	---	400	---	Oxnard Plain	61	13.4	816	711	1979	1	2009	2
01N21W21D03S	312	---	400	---	Oxnard Plain	75	6.5	490	14.0	1979	2	2016	2
01N21W21H01S	138	---	622	---	Pleasant Valley	76	2.9	217	53.8	1979	1	2016	2
01N21W21H02S	503	---	863	---	Pleasant Valley	71	362	25,696	1,106	1981	2	2016	2
01N21W21H03S	540	---	620	---	Pleasant Valley	18	11.1	201	21.5	2008	1	2016	2
01N21W21K01S	146	---	620	---	Oxnard Plain	75	1.4	107	2.0	1979	2	2016	2
01N21W21K03S	265	---	624	---	Oxnard Plain	75	106	7,954	325	1979	2	2016	2
01N21W21N02S	120	---	400	---	Oxnard Plain	28	67.5	1,889	121	2003	1	2016	2
01N21W21P01S	355	---	610	---	Oxnard Plain	45	83.0	3,737	165	1979	2	2001	2
01N21W22A01S	115	---	391	---	Pleasant Valley	75	117	8,796	435	1979	2	2016	2
01N21W22B02S	332	---	860	---	Pleasant Valley	75	24.3	1,824	236	1979	2	2016	2
01N21W22C01S	443	---	1,003	---	Pleasant Valley	71	391	27,792	1,198	1981	2	2016	2
01N21W22K02S	403	---	883	---	Pleasant Valley	30	77.9	2,336	247	2002	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W22L01S	505	---	996	---	Pleasant Valley	19	20.4	388	103	1979	2	1997	2
01N21W22P01S	400	---	872	---	Pleasant Valley	60	116	6,972	441	1979	2	2009	1
01N21W23A02S	38	---	108	---	Pleasant Valley	69	0.3	22.8	1.0	1979	2	2015	2
01N21W23E02S	86	---	348	---	Pleasant Valley	45	0.6	25.1	1.0	1979	2	2001	2
01N21W23E03S	140	---	370	---	Pleasant Valley	30	1.1	33.4	1.2	2002	1	2016	2
01N21W23G01S	230	---	650	---	Pleasant Valley	12	15.8	190	109	1979	2	1997	2
01N21W23G02S	220	---	625	---	Pleasant Valley	71	0.9	62.1	37.8	1979	2	2016	2
01N21W23H01S	---	---	---	---	Pleasant Valley	69	17.8	1,229	177	1979	2	2015	2
01N21W25M01S	---	---	---	---		45	3.9	177	42.4	1979	2	2001	2
01N21W26G01S	---	---	---	---	Pleasant Valley	75	42.3	3,170	217	1979	2	2016	2
01N21W26M01S	140	---	380	---	Pleasant Valley	3	8.6	25.8	12.7	2015	2	2016	2
01N21W27E01S	250	---	752	---	Pleasant Valley	75	97.7	7,328	459	1979	2	2016	2
01N21W27F02S	270	---	736	---	Pleasant Valley	54	54.4	2,936	488	1979	2	2006	1
01N21W28C01S	125	---	750	---	Oxnard Plain	55	53.3	2,934	473	1979	2	2006	2
01N21W28D01S	463	---	923	---	Oxnard Plain	71	464	32,940	1,239	1981	2	2016	2
01N21W28D02S	---	---	---	---	Oxnard Plain	71	0.2	15.2	1.0	1979	2	2016	2
01N21W28E01S	309	---	600	---	Oxnard Plain	20	0.1	1.4	1.4	1979	2	1997	2
01N21W28F02S	162	---	334	---	Oxnard Plain	21	0.2	4.8	1.6	1979	2	1997	2
01N21W28G01S	115	---	371	---	Oxnard Plain	75	52.4	3,928	224	1979	1	2016	2
01N21W28G03S	464	---	680	---	Oxnard Plain	75	58.1	4,357	315	1979	2	2016	2
01N21W28G04S	450	---	810	---	Oxnard Plain	59	134	7,895	531	1987	2	2016	2
01N21W28H02S	420	---	820	---	Oxnard Plain	60	152	9,092	682	1987	1	2016	2
01N21W28H03S	305	---	805	---	Oxnard Plain	26	166	4,304	341	2004	1	2016	2
01N21W28H04S	250	---	740	---	Pleasant Valley	11	270	2,966	482	2011	2	2016	2
01N21W28M01S	400	---	810	---	Oxnard Plain	75	203	15,225	476	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N21W29B03S	190	---	415	---	Oxnard Plain	75	72.4	5,433	208	1979	2	2016	2
01N21W29B06S	480	---	740	---	Oxnard Plain	76	145	11,045	440	1979	1	2016	2
01N21W29C01S	128	---	343	---	Oxnard Plain	21	4.3	91.0	6.9	1979	2	1997	2
01N21W29C02S	229	---	301	---	Oxnard Plain	21	3.6	76.1	22.4	1979	2	1997	2
01N21W29C03S	131	---	242	---	Oxnard Plain	21	0.2	5.0	1.9	1979	2	1997	2
01N21W29D03S	210	---	552	---	Oxnard Plain	20	127	2,531	210	1979	2	1997	2
01N21W29G01S	93	---	280	---	Oxnard Plain	72	0.8	59.8	2.0	1979	2	2016	2
01N21W29K02S	160	---	230	---	Oxnard Plain	75	1.1	83.1	2.2	1979	2	2016	2
01N21W30A02S	370	---	574	---	Oxnard Plain	75	123	9,217	304	1979	2	2016	2
01N21W30C03S	260	---	600	---	Oxnard Plain	75	57.5	4,314	351	1979	2	2016	2
01N21W30C04S	130	---	390	---	Oxnard Plain	24	90.4	2,169	146	2005	1	2016	2
01N21W30F02S	170	---	478	---	Oxnard Plain	75	65.3	4,897	115	1979	2	2016	2
01N21W30K01S	160	---	459	---	Oxnard Plain	75	141	10,600	330	1979	2	2016	2
01N21W30L01S	400	---	520	---	Oxnard Plain	45	69.5	3,127	242	1994	2	2016	2
01N21W31A01S	190	---	230	---	Oxnard Plain	75	127	9,523	1,100	1979	2	2016	2
01N21W31J01S	---	---	---	---	Oxnard Plain	46	0	0	0	1994	1	2016	2
01N21W31L01S	350	---	972	---	Oxnard Plain	46	0.1	3.0	3.0	1994	1	2016	2
01N21W32A01S	650	---	750	---	Oxnard Plain	46	2.3	105	30.7	1994	1	2016	2
01N21W32C01S	469	---	721	---	Oxnard Plain	63	41.3	2,604	172	1983	2	2016	2
01N21W32K01S	460	---	593	---	Oxnard Plain	46	0	0	0	1994	1	2016	2
01N21W33A01S	227	---	567	---	Oxnard Plain	17	157	2,667	368	2008	2	2016	2
01N22W01A01S	112	---	174	---	Oxnard Plain	60	44.8	2,687	281	1979	1	2008	2
01N22W01D01S	110	---	220	---	Oxnard Plain	20	288	5,766	505	1979	2	1997	2
01N22W01F01S	110	---	192	---	Oxnard Plain	49	58.1	2,847	230	1979	2	2003	2
01N22W01M01S	105	---	180	---	Oxnard Plain	75	137	10,261	387	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W01M02S	272	---	397	---	Oxnard Plain	75	33.1	2,483	168	1979	2	2016	2
01N22W01M03S	730	---	1,480	---	Oxnard Plain	64	393	25,144	1,449	1985	1	2016	2
01N22W01M04S	125	---	300	---	Oxnard Plain	3	63.2	190	149	2015	2	2016	2
01N22W02A02S	---	218	386	---	Oxnard Plain	12	52.5	630	95.8	1979	2	1997	2
01N22W02G01S	130	---	190	---	Oxnard Plain	16	62.1	994	154	1979	2	1997	2
01N22W02K01S	150	---	180	---	Oxnard Plain	74	105	7,776	271	1980	1	2016	2
01N22W02K03S	140	---	400	---	Oxnard Plain	49	47.5	2,326	231	1979	2	2003	2
01N22W02K04S	158	---	178	---	Oxnard Plain	65	0.7	47.6	2.0	1984	2	2016	2
01N22W02N03S	145	---	218	---	Oxnard Plain	37	2.1	78.6	4.4	1998	1	2016	2
01N22W03F01S	125	---	235	---	Oxnard Plain	66	23.0	1,516	253	1979	1	2011	2
01N22W03F02S	120	---	220	---	Oxnard Plain	66	25.9	1,710	285	1979	1	2011	2
01N22W03F03S	130	---	230	---	Oxnard Plain	25	5.7	143	31.4	1979	2	1991	2
01N22W03F04S	141	---	232	---	Oxnard Plain	71	18.6	1,317	273	1979	1	2014	1
01N22W03F05S	526	---	1,106	---	Oxnard Plain	61	405	24,721	2,266	1984	2	2016	2
01N22W03F06S	528	---	1,108	---	Oxnard Plain	57	252	14,341	1,838	1987	2	2016	1
01N22W03F07S	120	---	220	---	Oxnard Plain	52	461	23,952	2,408	1991	1	2016	2
01N22W03F08S	120	---	220	---	Oxnard Plain	51	424	21,600	2,182	1991	2	2016	2
01N22W03F12S	120	---	230	---	Oxnard Plain	17	662	11,250	1,746	2008	2	2016	2
01N22W03F13S	120	---	230	---	Oxnard Plain	15	488	7,319	1,605	2009	2	2016	2
01N22W03F14S	135	---	235	---	Oxnard Plain	17	408	6,934	1,429	2008	2	2016	2
01N22W03J02S	---	126	---	237	Oxnard Plain	19	122	2,313	585	1979	2	1997	2
01N22W03R01S	489	---	944	---	Oxnard Plain	69	273	18,854	929	1982	2	2016	2
01N22W04C01S	128	---	200	---	Oxnard Plain	17	3.8	64.0	6.1	1979	2	1997	2
01N22W04D01S	---	---	---	---	Oxnard Plain	75	3.8	286	12.5	1979	2	2016	2
01N22W04D03S	187	---	214	---	Oxnard Plain	15	0.7	11.0	1.0	1979	2	1997	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W04D07S	---	---	---	---	Oxnard Plain	74	1.3	98.9	5.2	1979	2	2016	2
01N22W04D08S	105	---	145	---	Oxnard Plain	74	1.6	116	5.0	1979	2	2016	2
01N22W04D09S	---	---	---	---	Oxnard Plain	75	1.3	95.6	2.0	1979	2	2016	2
01N22W04D10S	122	---	148	---	Oxnard Plain	74	1.1	81.0	1.5	1979	2	2016	1
01N22W04D11S	173	---	203	---	Oxnard Plain	75	0.8	60.9	3.1	1979	2	2016	2
01N22W04F02S	---	---	---	---	Oxnard Plain	69	4.9	335	16.9	1979	2	2013	2
01N22W04F04S	507	---	1,179	---	Oxnard Plain	23	3.0	70.0	30.9	1979	2	1990	2
01N22W04K01S	105	---	220	---	Oxnard Plain	20	32.7	654	65.2	1979	2	1997	2
01N22W04M01S	184	---	219	---	Oxnard Plain	32	43.3	1,385	120	1979	2	1997	2
01N22W05B01S	146	---	207	---	Oxnard Plain	75	148	11,116	300	1979	2	2016	2
01N22W05B04S	200	---	292	---	Oxnard Plain	75	23.2	1,737	76.6	1979	2	2016	2
01N22W05C02S	164	---	208	---	Oxnard Plain	75	116	8,705	204	1979	2	2016	2
01N22W05C03S	160	---	250	---	Oxnard Plain	1	124	124	124	2016	2	2016	2
01N22W05D01S	166	---	198	---	Oxnard Plain	75	23.8	1,787	65.6	1979	2	2016	2
01N22W05H01S	117	---	223	---	Oxnard Plain	13	0.8	11.0	1.0	1979	2	1997	2
01N22W05H02S	110	---	230	---	Oxnard Plain	72	25.1	1,807	128	1979	2	2015	2
01N22W05K01S	77	---	212	---	Oxnard Plain	20	57.4	1,148	112	1979	2	1997	2
01N22W05K03S	100	---	215	---	Oxnard Plain	26	55.8	1,452	238	1991	1	2003	2
01N22W05M01S	189	---	227	---	Oxnard Plain	49	70.8	3,471	174	1979	2	2003	2
01N22W06A02S	170	---	270	---	Oxnard Plain	72	48.4	3,484	220	1979	1	2014	2
01N22W06A04S	160	---	300	---	Oxnard Plain	76	51.5	3,914	109	1979	1	2016	2
01N22W06A05S	280	---	420	---	Oxnard Plain	68	21.5	1,462	53.5	1983	1	2016	2
01N22W06A06S	280	---	420	---	Oxnard Plain	68	50.4	3,424	110	1983	1	2016	2
01N22W06B01S	154	---	234	---	Oxnard Plain	75	58.7	4,400	93.5	1979	2	2016	2
01N22W06J04S	240	---	380	---	Oxnard Plain	75	142	10,634	484	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W06R02S	240	---	380	---	Oxnard Plain	75	165	12,357	484	1979	2	2016	2
01N22W07A03S	240	---	370	---	Oxnard Plain	57	119	6,773	391	1979	2	2008	1
01N22W07H02S	260	---	380	---	Oxnard Plain	57	65.9	3,755	268	1979	2	2008	1
01N22W08B07S	146	---	206	---	Oxnard Plain	12	8.3	100	14.9	1979	2	1997	2
01N22W08N01S	124	---	220	---	Oxnard Plain	45	19.6	881	103	1979	2	2001	2
01N22W10A03S	134	---	242	---	Oxnard Plain	58	2.4	140	11.7	1987	1	2016	2
01N22W10B02S	635	---	1,430	---	Oxnard Plain	66	1.2	76.4	71.1	1979	1	2011	2
01N22W10B03S	182	---	562	---	Oxnard Plain	66	8.2	539	333	1979	1	2011	2
01N22W10H01S	131	---	253	---	Oxnard Plain	15	86.1	1,291	192	1979	2	1997	2
01N22W10N03S	500	---	600	---	Oxnard Plain	75	4.8	363	8.9	1979	2	2016	2
01N22W11A01S	140	---	197	---	Oxnard Plain	75	60.1	4,510	372	1979	2	2016	2
01N22W11A03S	150	---	197	---	Oxnard Plain	51	0.6	32.2	1.0	1991	2	2016	2
01N22W11A05S	130	---	350	---	Oxnard Plain	3	21.5	64.5	50.0	2015	2	2016	2
01N22W11B01S	160	---	205	---	Oxnard Plain	66	0.8	52.7	2.4	1984	1	2016	2
01N22W11B03S	129	---	204	---	Oxnard Plain	75	14.4	1,080	75.2	1979	2	2016	2
01N22W11C02S	164	---	204	---	Oxnard Plain	71	43.0	3,052	508	1979	2	2016	2
01N22W11C03S	125	---	250	---	Oxnard Plain	4	66.7	267	121	2015	1	2016	2
01N22W11D01S	148	---	230	---	Oxnard Plain	17	84.5	1,437	221	1979	2	1997	2
01N22W11D03S	130	---	270	---	Oxnard Plain	3	13.7	41.1	23.0	2015	2	2016	2
01N22W11E01S	188	---	228	---	Oxnard Plain	15	59.0	885	120	1979	2	1997	2
01N22W12A02S	712	---	962	---	Oxnard Plain	16	144	2,299	370	2009	1	2016	2
01N22W12C02S	318	---	450	---	Oxnard Plain	46	50.3	2,312	125	1979	2	2016	2
01N22W12C03S	318	---	450	---	Oxnard Plain	66	142	9,359	324	1979	2	2012	1
01N22W12C04S	134	---	214	---	Oxnard Plain	12	2.9	34.9	4.2	2011	1	2016	2
01N22W12C05S	770	---	1,015	---	Oxnard Plain	9	149	1,339	276	2012	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W12F01S	310	---	460	---	Oxnard Plain	76	41.5	3,156	282	1979	1	2016	2
01N22W12H02S	596	---	988	---	Oxnard Plain	60	84.4	5,065	292	1979	2	2009	1
01N22W12J01S	152	---	183	---	Oxnard Plain	50	84.2	4,208	568	1979	2	2004	2
01N22W12J03S	120	---	406	---	Oxnard Plain	54	69.6	3,761	395	1979	2	2006	1
01N22W12M01S	120	---	249	---	Oxnard Plain	76	68.4	5,202	352	1979	1	2016	2
01N22W12N03S	602	---	1,122	---	Oxnard Plain	59	126	7,418	305	1987	2	2016	2
01N22W12P01S	169	---	210	---	Oxnard Plain	75	26.7	2,005	238	1979	2	2016	2
01N22W12P02S	146	---	193	---	Oxnard Plain	75	34.3	2,575	138	1979	2	2016	2
01N22W12Q01S	145	---	385	---	Oxnard Plain	55	87.8	4,828	237	1979	2	2006	2
01N22W12Q02S	155	---	395	---	Oxnard Plain	13	58.6	762	98.4	2007	2	2013	2
01N22W12Q03S	150	---	360	---	Oxnard Plain	8	287	2,299	450	2013	1	2016	2
01N22W12R01S	430	---	1,220	---	Oxnard Plain	53	184	9,743	426	1990	2	2016	2
01N22W13D02S	175	---	210	---	Oxnard Plain	16	85.3	1,365	199	1979	2	1987	1
01N22W13D03S	600	---	1,200	---	Oxnard Plain	64	237	15,148	912	1985	1	2016	2
01N22W13E03S	156	---	404	---	Oxnard Plain	75	45.6	3,419	540	1979	2	2016	2
01N22W13E04S	297	---	377	---	Oxnard Plain	75	1.2	88.4	8.2	1979	2	2016	2
01N22W13E05S	600	---	1,060	---	Oxnard Plain	74	60.9	4,506	172	1980	1	2016	2
01N22W13F01S	148	---	209	---	Oxnard Plain	75	68.8	5,160	109	1979	2	2016	2
01N22W13H01S	124	---	199	---	Oxnard Plain	75	17.3	1,298	60.3	1979	2	2016	2
01N22W13H03S	160	---	400	---	Oxnard Plain	20	65.8	1,316	154	1979	2	1997	2
01N22W13J01S	91	---	200	---	Oxnard Plain	15	24.5	367	119	1979	2	1997	2
01N22W13J04S	120	---	196	---	Oxnard Plain	75	45.7	3,429	254	1979	2	2016	2
01N22W13K01S	187	---	347	---	Oxnard Plain	75	2.6	194	5.0	1979	2	2016	2
01N22W13K02S	313	---	433	---	Oxnard Plain	75	24.6	1,843	106	1979	2	2016	2
01N22W13K04S	310	---	430	---	Oxnard Plain	76	20.3	1,541	91.2	1979	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W13L01S	162	---	205	---	Oxnard Plain	17	34.6	589	60.0	1979	2	1997	2
01N22W13N02S	160	---	202	---	Oxnard Plain	64	16.7	1,068	25.6	1985	1	2016	2
01N22W13Q01S	100	---	215	---	Oxnard Plain	18	9.8	176	40.1	1979	2	1997	2
01N22W13Q02S	280	---	402	---	Oxnard Plain	74	8.2	608	18.6	1979	2	2016	2
01N22W14C02S	164	---	208	---	Oxnard Plain	18	19.7	354	78.0	1981	1	1997	2
01N22W14D03S	150	---	220	---	Oxnard Plain	43	15.1	650	55.0	1979	2	2000	2
01N22W14R03S	155	---	220	---	Oxnard Plain	71	4.2	299	11.6	1979	2	2014	2
01N22W14R04S	185	---	235	---	Oxnard Plain	71	3.8	271	15.8	1979	2	2014	2
01N22W15C01S	131	---	250	---	Oxnard Plain	62	0.2	12.3	8.0	1986	1	2016	2
01N22W16D04S	520	---	940	---	Oxnard Plain	75	0.3	22.7	5.3	1979	2	2016	2
01N22W17B01S	554	---	1,079	---	Oxnard Plain	16	0	0	0	1994	1	2001	2
01N22W17C03S	520	---	1,100	---	Oxnard Plain	67	216	14,453	546	1983	2	2016	2
01N22W18L02S	496	---	781	---	Oxnard Plain	75	84.6	6,346	308	1979	2	2016	2
01N22W19A01S	610	---	738	---	Oxnard Plain	75	85.3	6,397	382	1979	2	2016	2
01N22W20E02S	940	---	974	---	Oxnard Plain	49	79.3	3,886	184	1979	2	2003	2
01N22W21B03S	535	---	950	---	Oxnard Plain	57	0.9	50.2	46.6	1980	1	2016	2
01N22W21B06S	720	---	1,180	---	Oxnard Plain	75	1.8	136	14.8	1979	2	2016	2
01N22W23A02S	156	---	201	---	Oxnard Plain	72	0.3	20.6	10.3	1979	2	2015	1
01N22W23A05S	333	---	483	---	Oxnard Plain	75	75.8	5,683	133	1979	2	2016	2
01N22W23J01S	---	---	---	---	Oxnard Plain	8	1.2	9.5	8.4	1979	2	1997	2
01N22W23N02S	120	---	240	---	Oxnard Plain	7	6.9	48.0	18.0	1979	2	1997	2
01N22W23R02S	460	---	660	---	Oxnard Plain	51	59.3	3,022	116	1991	2	2016	2
01N22W24A01S	170	---	197	---	Oxnard Plain	75	7.5	559	57.2	1979	2	2016	2
01N22W24A03S	410	---	550	---	Oxnard Plain	58	23.2	1,344	83.0	1987	1	2016	2
01N22W24B02S	126	---	358	---	Oxnard Plain	5	97.5	487	126	1979	2	1997	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W24B03S	154	---	204	---	Oxnard Plain	8	1.8	14.7	2.9	1998	2	2016	2
01N22W24B04S	444	---	1,022	---	Oxnard Plain	71	92.1	6,542	273	1981	2	2016	2
01N22W24C01S	---	---	---	---	Oxnard Plain	55	1.1	60.7	3.6	1979	2	2006	2
01N22W24C02S	160	---	320	---	Oxnard Plain	19	0.4	6.9	3.3	2007	2	2016	2
01N22W24C03S	330	---	450	---	Oxnard Plain	75	128	9,603	376	1979	2	2016	2
01N22W24D03S	315	---	450	---	Oxnard Plain	75	51.0	3,821	144	1979	2	2016	2
01N22W24H01S	136	---	188	---	Oxnard Plain	75	1.8	132	8.2	1979	2	2016	2
01N22W24M03S	330	---	470	---	Oxnard Plain	76	156	11,849	456	1979	1	2016	2
01N22W24P03S	458	---	618	---	Oxnard Plain	75	97.4	7,308	341	1979	2	2016	2
01N22W24Q01S	420	---	600	---	Oxnard Plain	53	45.6	2,417	126	1990	2	2016	2
01N22W25A02S	196	---	493	---	Oxnard Plain	6	91.3	548	114	1979	2	1997	2
01N22W25A03S	413	---	753	---	Oxnard Plain	70	118	8,239	295	1982	1	2016	2
01N22W25B04S	441	---	661	---	Oxnard Plain	49	122	5,982	221	1992	2	2016	2
01N22W25J02S	380	---	540	---	Oxnard Plain	64	191	12,214	296	1985	1	2016	2
01N22W25K01S	186	---	270	---	Oxnard Plain	26	0.8	20.0	1.0	2004	1	2016	2
01N22W25K02S	446	---	606	---	Oxnard Plain	75	217	16,311	393	1979	2	2016	2
01N22W25L02S	---	---	---	---	Oxnard Plain	49	0.9	43.6	1.0	1979	2	2003	2
01N22W26D02S	---	---	---	---	Oxnard Plain	9	0	0	0	1980	1	1997	2
01N22W26D05S	480	---	680	---	Oxnard Plain	26	379	9,866	693	2004	1	2016	2
01N22W26H02S	471	---	591	---	Oxnard Plain	75	70.6	5,297	130	1979	2	2016	2
01N22W26K03S	524	---	620	---	Oxnard Plain	75	222	16,663	374	1979	2	2016	2
01N22W26K04S	560	---	650	---	Oxnard Plain	75	113	8,480	345	1979	2	2016	2
01N22W26M03S	432	---	480	---	Oxnard Plain	75	184	13,787	391	1979	2	2016	2
01N22W26P02S	523	---	652	---	Oxnard Plain	75	222	16,658	434	1979	2	2016	2
01N22W26Q01S	310	---	476	---	Oxnard Plain	75	107	7,994	410	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
01N22W26Q02S	440	---	640	---	Oxnard Plain	26	0	0	0	1991	1	2003	2
01N22W26Q03S	420	---	560	---	Oxnard Plain	51	178	9,076	400	1991	2	2016	2
01N22W27H02S	470	---	630	---	Oxnard Plain	65	103	6,718	236	1984	2	2016	2
01N22W35C01S	180	---	230	---	Oxnard Plain	62	0.2	11.0	1.0	1984	1	2016	2
01N22W35G01S	192	---	220	---	Oxnard Plain	11	10.6	117	20.2	1979	2	1997	2
01N22W36B01S	600	---	700	---	Oxnard Plain	75	106	7,955	462	1979	2	2016	2
01N22W36B02S	593	---	680	---	Oxnard Plain	75	190	14,228	454	1979	2	2016	2
01N22W36H01S	437	---	572	---	Oxnard Plain	53	217	11,515	639	1990	2	2016	2
01N22W36J03S	421	---	521	---	Oxnard Plain	75	149	11,202	553	1979	2	2016	2
01N22W36K03S	155	---	210	---	Oxnard Plain	39	55.5	2,164	354	1991	2	2010	2
01N22W36K04S	407	---	719	---	Oxnard Plain	74	222	16,457	952	1980	1	2016	2
01N22W36L01S	126	---	208	---	Oxnard Plain	40	31.2	1,249	197	1979	2	1999	2
02N20W05D01S	720	---	1,080	---	West Las Posas	2	0	0	0	2013	1	2013	2
02N20W06D01S	560	---	1,000	---	West Las Posas	58	20.0	1,162	87.0	1983	2	2013	2
02N20W06J01S	973	---	1,373	---	West Las Posas	65	257	16,727	648	1983	2	2015	2
02N20W06N01S	1,269	---	1,579	---	West Las Posas	45	86.0	3,870	222	1983	2	2007	2
02N20W06R01S	1,090	---	1,512	---	West Las Posas	64	374	23,965	895	1983	2	2015	2
02N20W06R03S	1,041	---	1,381	---	West Las Posas	49	110	5,400	419	1991	2	2015	2
02N20W07F01S	1,240	---	1,600	---	West Las Posas	39	231	8,994	526	1983	2	2003	1
02N20W07L01S	1,246	---	1,567	---	West Las Posas	13	89.7	1,167	153	2009	1	2015	2
02N20W07R02S	960	---	1,360	---	West Las Posas	45	278	12,531	751	1993	2	2015	2
02N20W08B01S	1,050	---	1,300	---	West Las Posas	63	319	20,119	1,110	1983	2	2015	2
02N20W08E01S	1,041	---	1,481	---	West Las Posas	59	368	21,740	928	1986	2	2015	2
02N20W08F01S	752	---	1,406	---	West Las Posas	65	281	18,246	609	1983	2	2015	2
02N20W08H01S	870	---	1,300	---	East Las Posas	33	68.1	2,248	449	1983	2	2013	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N20W08M01S	1,040	---	1,400	---	West Las Posas	47	232	10,903	677	1992	1	2015	2
02N20W08Q01S	657	---	1,053	---	East Las Posas	54	103	5,573	382	1983	2	2015	2
02N20W16R01S	300	---	605	---		1	0	0	0	2015	2	2015	2
02N20W17E01S	448	---	748	---		24	51.2	1,228	178	2002	2	2015	2
02N20W17F01S	318	---	1,113	---	East Las Posas	53	213	11,310	576	1983	2	2015	1
02N20W17L01S	280	---	580	---	East Las Posas	14	662	9,270	1,364	2009	1	2015	2
02N20W18A01S	782	---	1,192	---	West Las Posas	62	204	12,653	463	1983	2	2014	1
02N20W19A01S	555	---	855	---	Pleasant Valley	24	213	5,119	427	2001	2	2013	2
02N20W19B01S	400	---	650	---	Pleasant Valley	16	73.1	1,169	225	2008	1	2015	2
02N20W19B02S	400	---	650	---	Pleasant Valley	4	109	434	165	2014	1	2015	2
02N20W19E01S	564	---	864	---	Pleasant Valley	65	202	13,133	410	1983	2	2015	2
02N20W19F04S	459	---	759	---	Pleasant Valley	65	714	46,422	1,383	1983	2	2015	2
02N20W19H01S	500	---	880	---	Pleasant Valley	29	112	3,244	393	1994	2	2013	2
02N20W19J02S	604	---	876	---	Pleasant Valley	27	250	6,751	506	1983	2	1997	2
02N20W19L05S	467	---	830	---	Pleasant Valley	65	280	18,214	1,068	1983	2	2015	2
02N20W19M05S	654	---	990	---	Pleasant Valley	54	123	6,635	487	1983	2	2013	2
02N20W19M06S	540	---	800	---	Pleasant Valley	42	201	8,436	344	1993	2	2015	2
02N20W20E02S	479	---	875	---	Pleasant Valley	48	43.2	2,075	335	1983	2	2013	2
02N20W20F01S	---	---	---	---	Pleasant Valley	22	0	0	0	2003	1	2013	2
02N20W20M04S	630	---	800	---	Pleasant Valley	22	0	0	0	2003	1	2013	2
02N20W20M05S	480	---	680	---	Pleasant Valley	45	89.2	4,013	148	1993	1	2015	2
02N20W21M01S	---	---	---	---	Pleasant Valley	7	0	0	0	2003	2	2012	1
02N20W29B02S	395	---	740	---	Pleasant Valley	40	363	14,523	702	1996	1	2015	2
02N20W31F03S	451	---	970	---	Pleasant Valley	16	92.9	1,487	254	1993	1	2004	2
02N21W01L01S	590	---	1,030	---	West Las Posas	59	232	13,678	590	1986	2	2015	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W03L01S	726	---	1,185	---	West Las Posas	10	137	1,370	172	1979	2	1997	2
02N21W04Q01S	300	---	1,089	---	West Las Posas	53	47.6	2,521	215	1990	1	2016	2
02N21W04Q02S	689	---	1,054	---	West Las Posas	33	117	3,846	241	2000	2	2016	2
02N21W07F01S	80	---	400	---	Oxnard Forebay	52	101	5,235	220	1991	1	2016	2
02N21W07G01S	182	---	452	---	Oxnard Forebay	6	92.3	554	175	2014	1	2016	2
02N21W07K01S	78	---	150	---	Oxnard Forebay	43	137	5,878	486	1979	2	2000	2
02N21W07K02S	250	---	750	---	Oxnard Plain	14	26.6	373	64.0	1982	2	1997	2
02N21W07K03S	377	---	842	---	Oxnard Forebay	6	166	996	214	2014	1	2016	2
02N21W07L07S	70	---	250	---	Oxnard Forebay	20	130	2,602	660	2007	1	2016	2
02N21W07M03S	360	---	720	---	Oxnard Forebay	45	148	6,675	868	1979	2	2001	2
02N21W07M04S	100	---	350	---	Oxnard Forebay	20	165	3,302	682	2007	1	2016	2
02N21W07N02S	565	---	965	---	Oxnard Forebay	54	98.7	5,329	609	1990	1	2016	2
02N21W07P02S	192	---	856	---	Oxnard Forebay	10	180	1,803	337	1979	2	1997	2
02N21W07P03S	550	---	1,000	---	Oxnard Forebay	66	121	7,974	402	1984	1	2016	2
02N21W07P04S	420	---	820	---	Oxnard Forebay	56	90.8	5,082	429	1989	1	2016	2
02N21W07Q01S	740	---	1,260	---	Oxnard Plain	75	57.9	4,339	161	1979	2	2016	2
02N21W07R01S	520	---	1,244	---	Oxnard Plain	75	41.8	3,133	379	1979	2	2016	2
02N21W08G02S	540	---	1,027	---	West Las Posas	49	214	10,484	448	1979	2	2003	2
02N21W08G04S	666	---	1,066	---	West Las Posas	34	196	6,652	417	2000	1	2016	2
02N21W08H03S	635	---	1,340	---	West Las Posas	4	333	1,330	452	2015	1	2016	2
02N21W08L01S	650	---	1,015	---	West Las Posas	75	50.3	3,776	204	1979	2	2016	2
02N21W08L02S	641	---	1,041	---	West Las Posas	53	146	7,755	221	1990	2	2016	2
02N21W08L03S	625	---	1,030	---	West Las Posas	6	162	972	184	2014	1	2016	2
02N21W09D01S	430	---	1,016	---	West Las Posas	17	84.5	1,437	245	1981	2	1997	2
02N21W09D02S	650	---	800	---	West Las Posas	55	144	7,938	376	1989	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W10F01S	---	---	---	---	West Las Posas	27	14.6	393	74.6	1988	2	2001	2
02N21W10G03S	1,080	---	1,560	---	West Las Posas	30	25.9	776	59.7	2002	1	2016	2
02N21W10Q03S	960	---	1,660	---	West Las Posas	75	80.5	6,040	309	1979	2	2016	2
02N21W10Q04S	1,290	---	1,610	---	West Las Posas	30	163	4,880	244	2002	1	2016	2
02N21W11A02S	407	---	740	---	West Las Posas	65	237	15,388	720	1983	2	2015	2
02N21W11A03S	880	---	1,630	---	West Las Posas	13	159	2,067	329	2009	2	2015	2
02N21W11H02S	352	---	460	---	West Las Posas	64	52.9	3,389	131	1983	2	2015	2
02N21W11J02S	375	---	1,150	---	West Las Posas	18	78.5	1,414	138	1983	2	1992	1
02N21W12G01S	---	---	---	---	West Las Posas	52	63.6	3,305	119	1990	1	2015	2
02N21W12H01S	928	---	1,765	---	West Las Posas	62	107	6,650	173	1985	1	2015	2
02N21W13A01S	1,290	---	1,590	---	West Las Posas	14	112	1,564	205	2009	1	2015	2
02N21W15M03S	406	---	1,030	---	West Las Posas	31	86.2	2,672	583	1983	2	2013	2
02N21W15M04S	524	---	1,044	---	West Las Posas	61	219	13,333	629	1983	2	2015	2
02N21W15M05S	550	---	900	---	West Las Posas	64	106	6,808	165	1984	1	2015	2
02N21W16A01S	---	---	---	---	West Las Posas	51	1.0	48.4	1.0	1991	2	2016	2
02N21W16J01S	182	---	295	---	West Las Posas	4	0.2	0.8	0.2	1979	2	1997	2
02N21W16J03S	560	---	1,120	---	West Las Posas	52	144	7,512	315	1991	1	2016	2
02N21W16K01S	370	---	900	---	West Las Posas	29	25.2	731	220	1979	2	1997	2
02N21W16N01S	---	---	---	---	West Las Posas	50	59.2	2,960	206	1979	1	2003	2
02N21W16N03S	610	---	830	---	West Las Posas	24	101	2,426	168	2005	1	2016	2
02N21W16R02S	240	---	814	---	West Las Posas	4	0	0	0	1979	2	1997	2
02N21W17D03S	100	---	215	---	Oxnard Plain	35	0	0	0	1979	2	1997	2
02N21W17F04S	156	---	174	---	Oxnard Plain	75	1.1	79.8	1.6	1979	2	2016	2
02N21W17F05S	525	---	1,105	---	Oxnard Plain	59	86.6	5,109	212	1987	2	2016	2
02N21W17M02S	95	---	330	---	Oxnard Plain	49	74.4	3,643	159	1979	2	2003	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W17M03S	120	---	360	---	Oxnard Plain	36	139	5,005	338	1999	1	2016	2
02N21W17N01S	85	---	182	---	Oxnard Plain	51	34.5	1,761	156	1979	2	2004	2
02N21W17N03S	190	---	410	---	Oxnard Plain	32	59.7	1,910	229	2001	1	2016	2
02N21W17R01S	520	---	960	---	West Las Posas	75	21.5	1,609	86.4	1979	2	2016	2
02N21W17R02S	520	---	860	---	West Las Posas	26	69.5	1,807	162	2004	1	2016	2
02N21W18A01S	98	---	138	---	Oxnard Plain	75	33.6	2,523	167	1979	2	2016	2
02N21W18A02S	824	---	1,424	---	Oxnard Plain	7	58.3	408	73.5	1983	2	1997	2
02N21W18B01S	70	---	160	---	Oxnard Plain	75	103	7,724	254	1979	2	2016	2
02N21W18B02S	552	---	1,101	---	Oxnard Plain	61	63.7	3,883	196	1986	2	2016	2
02N21W18H03S	98	---	151	---	Oxnard Plain	75	388	29,066	1,361	1979	2	2016	2
02N21W18H05S	80	---	122	---	Oxnard Plain	71	249	17,673	748	1981	2	2016	2
02N21W18H06S	90	---	150	---	Oxnard Plain	76	40.2	3,059	201	1979	1	2016	2
02N21W18H07S	120	---	300	---	Oxnard Plain	75	5.4	403	37.4	1979	2	2016	2
02N21W18H10S	606	---	1,310	---	Oxnard Plain	72	76.3	5,491	745	1981	1	2016	2
02N21W18H11S	762	---	1,302	---	Oxnard Plain	75	107	8,009	301	1979	2	2016	2
02N21W18H12S	600	---	1,300	---	Oxnard Plain	54	270	14,591	1,143	1990	1	2016	2
02N21W18H13S	510	---	590	---	Oxnard Plain	14	1.0	14.7	2.4	2010	1	2016	2
02N21W18H14S	1,105	---	1,275	---	Oxnard Plain	15	350	5,247	518	2009	2	2016	2
02N21W18P01S	100	---	200	---	Oxnard Plain	15	47.9	719	64.0	2009	2	2016	2
02N21W18Q02S	445	---	1,003	---	Oxnard Plain	24	183	4,394	410	1980	1	1997	2
02N21W18Q03S	400	---	1,000	---	Oxnard Plain	51	242	12,337	425	1991	1	2016	2
02N21W18R01S	98	---	310	---	Oxnard Plain	15	85.8	1,288	161	1979	2	1997	2
02N21W19A01S	95	---	147	---	Oxnard Plain	75	86.6	6,493	344	1979	2	2016	2
02N21W19A02S	100	---	212	---	Oxnard Plain	48	89.6	4,303	245	1979	2	2003	1
02N21W19A03S	528	---	1,007	---	Oxnard Plain	75	60.7	4,554	256	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W19B02S	99	---	137	---	Oxnard Plain	74	19.4	1,433	64.5	1979	2	2016	2
02N21W19G01S	64	---	220	---	Oxnard Plain	75	65.6	4,917	542	1979	2	2016	2
02N21W19G02S	120	---	147	---	Oxnard Plain	74	97.4	7,210	294	1979	2	2016	1
02N21W19G03S	575	---	785	---	Oxnard Plain	5	174	868	234	2014	2	2016	2
02N21W19L01S	---	---	---	212	Oxnard Plain	70	37.3	2,609	248	1979	2	2015	2
02N21W19L02S	103	---	175	---	Oxnard Plain	74	95.5	7,065	264	1979	2	2016	2
02N21W19P01S	641	---	1,201	---	Oxnard Plain	26	122	3,185	321	2004	1	2016	2
02N21W20A01S	520	---	800	---	West Las Posas	24	18.5	444	59.2	2005	1	2016	2
02N21W20E02S	550	---	900	---	Oxnard Plain	75	54.6	4,093	163	1979	2	2016	2
02N21W20J02S	640	---	920	---	West Las Posas	75	99.1	7,433	380	1979	2	2016	2
02N21W20M02S	100	---	160	---	Oxnard Plain	55	1.1	61.7	2.0	1989	2	2016	2
02N21W20M03S	128	---	200	---	Oxnard Plain	75	11.1	836	57.7	1979	2	2016	2
02N21W20M04S	760	---	1,100	---	Oxnard Plain	51	84.1	4,289	398	1991	2	2016	2
02N21W20M05S	820	---	1,160	---	Oxnard Plain	24	157	3,779	558	2005	1	2016	2
02N21W20M06S	670	---	880	---	Oxnard Plain	18	97.1	1,749	267	2008	1	2016	2
02N21W20Q04S	600	---	1,055	---	West Las Posas	58	54.5	3,159	221	1979	2	2008	1
02N21W20Q05S	600	---	950	---	West Las Posas	31	113	3,491	218	2000	1	2016	2
02N21W21D04S	590	---	830	---	West Las Posas	30	58.2	1,745	167	2002	1	2016	2
02N21W21E01S	540	---	800	---	West Las Posas	34	204	6,946	329	1999	2	2016	2
02N21W22A01S	780	---	1,400	---		39	91.5	3,568	262	1995	1	2014	2
02N21W22E01S	1,000	---	1,370	---		40	139	5,557	450	1983	2	2013	2
02N21W22G01S	603	---	903	---		59	205	12,098	397	1986	2	2015	2
02N21W23D01S	662	---	1,202	---		13	0	0	0	2009	1	2015	1
02N21W26R02S	157	---	491	---	Pleasant Valley	64	20.8	1,328	58.6	1983	2	2015	2
02N21W28A02S	550	---	800	---		19	203	3,862	349	2006	2	2015	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W28C01S	700	---	1,160	---		26	104	2,706	216	2003	1	2015	2
02N21W28D01S	513	---	867	---		58	67.2	3,897	340	1983	2	2013	2
02N21W28P02S	---	---	---	---	Pleasant Valley	9	40.0	360	96.0	1983	2	2013	2
02N21W28P07S	520	---	1,000	---	Pleasant Valley	23	116	2,678	214	2003	2	2015	1
02N21W28Q04S	510	---	1,140	---	Pleasant Valley	43	62.0	2,666	164	1991	2	2013	2
02N21W29C01S	150	---	266	---	Oxnard Plain	48	77.4	3,717	184	1979	2	2003	1
02N21W29E02S	640	---	1,080	---	Oxnard Plain	19	85.3	1,622	162	2007	2	2016	2
02N21W29E03S	640	---	1,200	---	Oxnard Plain	27	133	3,592	261	2003	2	2016	2
02N21W29G01S	---	---	---	---	Oxnard Plain	52	0.1	4.6	4.6	1991	1	2016	2
02N21W29K01S	100	---	150	---	Oxnard Plain	30	0.8	23.0	1.0	2002	1	2016	2
02N21W29K02S	597	---	679	---	Oxnard Plain	45	35.9	1,616	191	1979	2	2001	2
02N21W29L01S	85	---	150	---	Oxnard Plain	75	0.7	52.6	1.5	1979	2	2016	2
02N21W29L04S	641	---	1,161	---	Oxnard Plain	70	98.8	6,919	276	1982	1	2016	2
02N21W29M02S	630	---	1,130	---	Oxnard Plain	3	194	583	279	2015	2	2016	2
02N21W29N03S	100	---	150	---	Oxnard Plain	75	43.6	3,267	479	1979	2	2016	2
02N21W29N04S	110	---	146	---	Oxnard Plain	6	0	0	0	1982	1	1984	2
02N21W29N05S	115	---	146	---	Oxnard Plain	73	0.5	36.2	2.7	1979	2	2016	2
02N21W29N06S	105	---	300	---	Oxnard Plain	3	3.3	10.0	9.8	2015	2	2016	2
02N21W29P03S	102	---	166	---	Oxnard Plain	20	62.2	1,244	152	1979	2	1997	2
02N21W29Q01S	689	---	776	---		45	0.7	32.0	1.0	1979	2	2001	2
02N21W30A01S	600	---	1,240	---	Oxnard Plain	75	43.5	3,264	197	1979	2	2016	2
02N21W30F02S	630	---	1,200	---	Oxnard Plain	24	123	2,947	196	2005	1	2016	2
02N21W30G01S	103	---	155	---	Oxnard Plain	75	229	17,205	643	1979	2	2016	2
02N21W30P02S	102	---	162	---	Oxnard Plain	41	46.4	1,903	188	1979	2	1999	2
02N21W30R01S	115	---	146	---	Oxnard Plain	75	19.6	1,471	178	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W30R03S	110	---	146	---	Oxnard Plain	73	28.7	2,094	239	1979	2	2016	2
02N21W30R04S	120	---	140	---	Oxnard Plain	73	0.5	34.6	2.1	1979	2	2016	2
02N21W31L01S	700	---	1,200	---	Oxnard Plain	64	40.3	2,579	382	1985	1	2016	2
02N21W31P03S	713	---	967	---	Oxnard Plain	13	126	1,634	262	1979	2	1985	2
02N21W31P06S	743	---	943	---	Oxnard Plain	75	181	13,601	370	1979	1	2016	2
02N21W31R01S	118	---	174	---	Oxnard Plain	75	18.6	1,395	247	1979	2	2016	2
02N21W32C01S	84	---	200	---	Oxnard Plain	40	34.6	1,385	181	1997	1	2016	2
02N21W32E01S	716	---	1,266	---	Oxnard Plain	64	254	16,255	925	1985	1	2016	2
02N21W32J01S	640	---	1,270	---	Pleasant Valley	64	190	12,138	458	1985	1	2016	2
02N21W32J03S	570	---	990	---	Pleasant Valley	26	9.7	253	60.0	2004	1	2016	2
02N21W33A01S	120	---	244	---	Pleasant Valley	14	0	0	0	1979	2	1997	2
02N21W33P02S	801	---	1,149	---	Pleasant Valley	13	135	1,749	458	1982	2	1997	2
02N21W33R02S	801	---	1,051	---	Pleasant Valley	54	62.1	3,356	770	1990	1	2016	2
02N21W34C01S	700	---	890	---	Pleasant Valley	60	862	51,735	1,246	1986	1	2015	2
02N21W34D02S	712	---	900	---	Pleasant Valley	43	6.3	272	35.0	1979	2	2000	2
02N21W34G01S	403	---	1,463	---	Pleasant Valley	71	430	30,526	1,590	1981	2	2016	2
02N21W34H02S	160	---	861	---	Pleasant Valley	49	6.4	316	80.0	1979	2	2004	1
02N21W34J02S	532	---	892	---	Pleasant Valley	70	21.1	1,476	159	1982	1	2016	2
02N21W34L01S	822	---	944	---	Pleasant Valley	18	0	0	0	1979	2	1997	2
02N21W34L02S	252	---	1,000	---	Pleasant Valley	37	36.5	1,351	80.9	1990	1	2008	1
02N21W35D02S	644	---	810	---	Pleasant Valley	14	56.2	787	134	1979	2	1997	2
02N21W35J01S	169	---	980	---	Pleasant Valley	72	0.4	32.0	1.0	1979	2	2015	1
02N21W35M01S	717	---	1,113	---	Pleasant Valley	43	33.0	1,420	289	1979	2	2000	2
02N21W35M02S	700	---	1,100	---	Pleasant Valley	38	7.3	277	123	1998	1	2016	2
02N21W35P01S	285	---	325	---	Pleasant Valley	51	0.5	27.3	1.0	1991	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N21W36G02S	---	---	---	---	Pleasant Valley	37	41.6	1,538	217	1983	2	2002	2
02N21W36G03S	610	---	1,060	---	Pleasant Valley	30	151	4,539	367	1987	2	2003	2
02N21W36G04S	600	---	1,060	---	Pleasant Valley	23	98.7	2,271	226	1995	2	2013	2
02N21W36L02S	618	---	1,242	---	Pleasant Valley	75	4.1	310	70.9	1979	2	2016	2
02N21W36N01S	280	---	437	---	Pleasant Valley	28	3.5	98.4	46.9	2003	1	2016	2
02N22W01J01S	40	---	100	---	Oxnard Forebay	24	3.7	88.1	4.8	2005	1	2016	2
02N22W01J02S	60	---	160	---	Oxnard Forebay	24	2.3	55.0	4.8	2005	1	2016	2
02N22W01M01S	70	---	107	---	Santa Paula	21	35.6	748	40.8	1993	1	2003	1
02N22W01M02S	83	---	109	---	Santa Paula	28	6.1	172	40.8	2003	1	2016	2
02N22W01M03S	---	---	---	---	Santa Paula	48	0	0	0	1979	2	2003	1
02N22W01M04S	---	---	---	---	Santa Paula	51	44.9	2,290	48.0	1979	2	2004	2
02N22W01P01S	310	---	480	---	Oxnard Forebay	14	14.1	197	102	2010	1	2016	2
02N22W02G01S	72	---	121	---	Santa Paula	75	58.5	4,388	195	1979	2	2016	2
02N22W02H02S	312	---	652	---	Santa Paula	5	979	4,896	1,689	2014	2	2016	2
02N22W02J03S	94	---	154	---	Santa Paula	12	15.8	190	42.3	2011	1	2016	2
02N22W02J04S	94	---	154	---	Santa Paula	63	6.3	397	9.6	1979	2	2010	2
02N22W02K02S	92	---	113	---	Santa Paula	49	38.8	1,900	161	1979	2	2003	2
02N22W02K06S	110	---	290	---	Santa Paula	19	110	2,095	751	1979	2	1997	2
02N22W02K07S	168	---	698	---	Santa Paula	69	420	29,002	2,494	1979	2	2013	2
02N22W02K08S	24	---	108	---	Santa Paula	49	68.6	3,363	141	1979	2	2003	2
02N22W02K09S	300	---	400	---	Santa Paula	57	536	30,529	1,489	1988	2	2016	2
02N22W02K10S	125	---	700	---	Santa Paula	6	597	3,580	799	2014	1	2016	2
02N22W02N01S	---	---	---	---	Santa Paula	39	3.3	127	9.6	1979	2	1998	2
02N22W02N04S	---	---	---	---	Santa Paula	74	0.5	35.5	1.0	1979	2	2016	1
02N22W02Q01S	---	---	---	---	Santa Paula	75	0.5	37.5	1.0	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W02R04S	106	---	501	---	Oxnard Forebay	15	715	10,730	2,494	1979	2	1997	2
02N22W02R05S	106	---	520	---	Oxnard Forebay	65	625	40,656	1,450	1984	2	2016	2
02N22W03B01S	208	---	268	---	Santa Paula	65	34.1	2,219	47.5	1979	2	2011	2
02N22W03B02S	320	---	360	---	Santa Paula	15	32.3	484	55.1	2009	2	2016	2
02N22W03E01S	266	---	723	---	Santa Paula	75	168	12,637	262	1979	2	2016	2
02N22W03F02S	---	---	---	---	Santa Paula	75	50.1	3,760	80.9	1979	2	2016	2
02N22W03K02S	---	115	164	---	Santa Paula	75	35.5	2,660	118	1979	2	2016	2
02N22W03K03S	160	---	420	---	Santa Paula	46	1.6	75.0	2.8	1994	1	2016	2
02N22W03K04S	120	---	297	---	Santa Paula	12	0	0	0	2011	1	2016	2
02N22W03L01S	175	---	400	---	Santa Paula	56	18.0	1,010	67.0	1989	1	2016	2
02N22W03M03S	354	---	568	---	Santa Paula	20	18.5	370	28.5	1979	2	1989	1
02N22W03Q01S	---	---	---	---	Santa Paula	75	12.2	914	15.5	1979	2	2016	2
02N22W03Q02S	230	---	248	---	Santa Paula	40	14.0	559	51.3	1979	2	1999	2
02N22W03R02S	---	145	---	205	Santa Paula	17	77.2	1,312	173	1979	2	1987	2
02N22W07P01S	460	---	580	---	Mound	32	39.8	1,272	501	2001	1	2016	2
02N22W08F01S	580	---	1,180	---	Mound	37	1,180	43,655	2,331	1998	2	2016	2
02N22W08G01S	580	---	650	---	Mound	28	653	18,284	1,530	2003	1	2016	2
02N22W08L01S	460	---	1,405	---	Mound	75	550	41,277	2,391	1979	2	2016	2
02N22W08N01S	554	---	720	---	Mound	49	78.9	3,865	130	1979	2	2003	2
02N22W08P01S	160	---	321	---	Mound	15	4.9	73.4	23.8	1979	2	1997	2
02N22W09K01S	236	---	336	---	Mound	75	52.5	3,936	133	1979	2	2016	2
02N22W09K03S	424	---	545	---	Mound	52	85.1	4,423	200	1979	2	2005	1
02N22W09K05S	625	---	1,455	---	Mound	76	78.3	5,954	399	1979	1	2016	2
02N22W09K06S	420	---	560	---	Mound	1	12.7	12.7	12.7	2003	2	2003	2
02N22W09K07S	640	---	1,440	---	Mound	25	128	3,209	217	2004	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W09K08S	224	---	465	---	Mound	13	67.5	877	103	2010	2	2016	2
02N22W10N01S	200	---	300	---	Mound	49	73.0	3,579	151	1979	2	2003	2
02N22W10N02S	200	---	354	---	Mound	75	94.5	7,086	267	1979	2	2016	2
02N22W10N03S	200	---	280	---	Mound	25	51.6	1,291	92.5	2004	2	2016	2
02N22W11A01S	75	---	155	---	Oxnard Forebay	22	31.1	684	94.2	2006	1	2016	2
02N22W11C03S	180	---	470	---	Oxnard Forebay	22	4.3	94.9	12.0	1979	2	1997	2
02N22W11D02S	---	---	208	---	Santa Paula	12	11.7	140	20.0	1979	2	1997	2
02N22W11M01S	100	---	410	---	Oxnard Forebay	45	37.2	1,676	56.3	1979	2	2001	2
02N22W11R01S	95	---	142	---	Oxnard Forebay	3	0	0	0	1983	2	1997	2
02N22W11R02S	284	---	404	---	Oxnard Forebay	11	0	0.5	0.5	1979	2	1997	2
02N22W11R03S	290	---	410	---	Oxnard Forebay	73	41.0	2,994	166	1979	2	2016	2
02N22W12A02S	40	---	121	---	Oxnard Forebay	74	4.4	328	12.7	1979	2	2016	2
02N22W12B07S	130	---	350	---	Oxnard Forebay	35	14.1	495	16.8	1986	2	2003	2
02N22W12B08S	115	---	355	---	Oxnard Forebay	34	0.8	25.6	4.6	1999	2	2016	2
02N22W12E02S	205	---	355	---	Oxnard Forebay	23	512	11,781	665	1979	2	1997	2
02N22W12E04S	140	---	464	---	Oxnard Forebay	46	206	9,491	659	1990	1	2012	2
02N22W12E05S	160	---	480	---	Oxnard Forebay	8	12.4	99.0	22.6	2013	1	2016	2
02N22W12G03S	80	---	141	---	Oxnard Forebay	75	5.3	400	20.1	1979	2	2016	2
02N22W12G04S	110	---	230	---	Oxnard Forebay	2	10.2	20.4	13.4	2016	1	2016	2
02N22W12H01S	100	---	365	---	Oxnard Forebay	20	139	2,772	531	2007	1	2016	2
02N22W12J04S	100	---	320	---	Oxnard Forebay	20	174	3,476	708	2007	1	2016	2
02N22W12K02S	90	---	172	---	Oxnard Forebay	34	39.1	1,331	122	1979	2	1997	2
02N22W12K05S	68	---	233	---	Oxnard Forebay	75	62.3	4,675	423	1979	2	2016	2
02N22W12L02S	140	---	260	---	Oxnard Forebay	13	23.3	303	69.3	1990	1	1997	2
02N22W12L04S	60	---	317	---	Oxnard Forebay	34	42.5	1,446	76.8	1979	2	1997	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W12M02S	204	---	348	---	Oxnard Forebay	75	6.1	459	35.8	1979	2	2016	2
02N22W12M03S	40	---	300	---	Oxnard Forebay	12	29.3	352	58.3	2011	1	2016	2
02N22W12N03S	276	---	456	---	Oxnard Forebay	75	35.1	2,632	120	1979	2	2016	2
02N22W12N04S	192	---	336	---	Oxnard Forebay	75	40.6	3,045	183	1979	2	2016	2
02N22W12N07S	50	---	110	---	Oxnard Forebay	33	0.8	26.4	5.2	1984	2	2000	2
02N22W12N08S	160	---	560	---	Oxnard Forebay	52	10.9	567	27.2	1991	1	2016	2
02N22W12Q04S	120	---	148	---	Oxnard Forebay	75	6.2	466	73.8	1979	2	2016	2
02N22W12Q05S	243	---	703	---	Oxnard Forebay	75	60.8	4,560	244	1979	2	2016	2
02N22W12R03S	320	---	680	---	Oxnard Forebay	73	19.4	1,413	66.1	1979	2	2016	2
02N22W12R05S	340	---	715	---	Oxnard Forebay	4	7.7	30.7	22.8	2015	1	2016	2
02N22W13A04S	274	---	694	---	Oxnard Forebay	48	84.7	4,067	250	1979	2	2003	1
02N22W13B01S	420	---	790	---	Oxnard Forebay	15	152	2,273	282	2009	2	2016	2
02N22W13D01S	340	---	540	---	Oxnard Forebay	75	49.0	3,677	207	1979	2	2016	2
02N22W13G02S	80	---	190	---	Oxnard Forebay	45	66.6	2,996	631	1979	2	2001	2
02N22W13H02S	100	---	500	---	Oxnard Forebay	40	341	13,651	602	1997	1	2016	2
02N22W13K02S	95	---	308	---	Oxnard Forebay	75	82.6	6,192	418	1979	2	2016	2
02N22W13K04S	100	---	500	---	Oxnard Forebay	33	124	4,083	255	2000	2	2016	2
02N22W13L01S	95	---	215	---	Oxnard Forebay	75	103	7,705	263	1979	2	2016	2
02N22W13L03S	100	---	175	---	Oxnard Forebay	75	12.0	901	38.5	1979	2	2016	2
02N22W13L04S	120	---	244	---	Oxnard Forebay	20	54.8	1,097	120	1983	1	1997	2
02N22W13L05S	120	---	210	---	Oxnard Forebay	75	123	9,228	299	1979	2	2016	2
02N22W13L06S	120	---	520	---	Oxnard Forebay	51	13.1	668	23.8	1991	2	2016	2
02N22W13L07S	160	---	640	---	Oxnard Forebay	50	103	5,163	198	1992	1	2016	2
02N22W13M01S	---	---	178	---	Oxnard Forebay	42	40.3	1,691	152	1979	2	2000	1
02N22W13N02S	752	---	1,092	---	Oxnard Forebay	64	63.4	4,056	865	1985	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W13N03S	110	---	260	---	Oxnard Forebay	52	0	0	0	1991	1	2016	2
02N22W13N04S	350	---	620	---	Oxnard Forebay	33	28.5	941	273	2000	2	2016	2
02N22W14A02S	120	---	152	---	Oxnard Forebay	75	0.7	56.2	5.0	1979	2	2016	2
02N22W14A03S	---	---	---	---	Oxnard Forebay	66	0.9	60.6	1.6	1984	1	2016	2
02N22W14A04S	100	---	185	---	Oxnard Forebay	74	8.2	607	30.9	1979	2	2016	2
02N22W14A05S	119	---	179	---	Oxnard Forebay	75	21.8	1,635	231	1979	2	2016	2
02N22W14A08S	120	---	180	---	Oxnard Forebay	75	1.3	97.4	2.9	1979	2	2016	2
02N22W14B01S	414	---	762	---	Oxnard Forebay	75	36.7	2,750	244	1979	2	2016	2
02N22W14H02S	98	---	170	---	Oxnard Forebay	15	0	0	0	2009	2	2016	2
02N22W14H03S	128	---	178	---	Oxnard Forebay	75	77.9	5,840	135	1979	2	2016	2
02N22W14J01S	84	---	190	---	Oxnard Forebay	26	2.5	64.4	3.6	1979	2	1997	2
02N22W14J02S	145	---	410	---	Oxnard Forebay	75	130	9,763	294	1979	2	2016	2
02N22W14J03S	600	---	760	---	Oxnard Forebay	26	3.9	100	22.4	1991	1	2003	2
02N22W14L02S	100	---	200	---	Oxnard Forebay	75	9.5	712	21.1	1979	2	2016	2
02N22W14L04S	250	---	268	---	Oxnard Forebay	17	18.7	318	52.1	1979	2	1997	2
02N22W14L05S	164	---	404	---	Oxnard Forebay	75	32.2	2,415	85.3	1979	2	2016	2
02N22W14L06S	---	---	---	---	Oxnard Forebay	31	2.7	82.3	5.0	2001	2	2016	2
02N22W14P02S	149	---	277	---	Oxnard Forebay	75	659	49,414	2,011	1979	2	2016	2
02N22W14P03S	162	---	306	---	Oxnard Forebay	69	18.3	1,259	48.4	1982	2	2016	2
02N22W14Q01S	60	---	260	---	Oxnard Forebay	71	0.3	24.0	1.6	1979	2	2014	2
02N22W14Q02S	60	---	260	---	Oxnard Forebay	76	53.5	4,069	166	1979	1	2016	2
02N22W14Q03S	200	---	400	---	Oxnard Forebay	76	186	14,134	392	1979	1	2016	2
02N22W15B01S	352	---	442	---	Oxnard Forebay	20	104	2,088	179	2006	1	2016	2
02N22W15D02S	227	---	379	---	Mound	75	45.7	3,424	72.1	1979	2	2016	2
02N22W15E02S	120	---	320	---	Mound	4	6.3	25.2	12.0	2015	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W15M01S	160	---	400	---	Oxnard Forebay	48	97.2	4,664	176	1993	1	2016	2
02N22W15Q01S	78	---	150	---	Oxnard Forebay	55	278	15,316	691	1979	2	2006	2
02N22W15Q03S	206	---	314	---	Oxnard Forebay	42	155	6,528	295	1979	2	2000	1
02N22W15R01S	130	---	242	---	Oxnard Forebay	44	12.7	559	69.7	1979	2	2001	1
02N22W16H01S	---	---	---	---	Mound	75	58.8	4,409	220	1979	2	2016	2
02N22W16K01S	292	---	345	---	Mound	75	12.0	902	64.2	1979	2	2016	2
02N22W16Q01S	136	---	578	---	Oxnard Plain	75	62.5	4,685	139	1979	2	2016	2
02N22W16Q03S	180	---	350	---	Oxnard Plain	75	79.5	5,959	207	1979	2	2016	2
02N22W17M01S	440	---	600	---	Mound	20	39.4	787	65.4	1992	1	2001	2
02N22W17M02S	550	---	850	---	Mound	30	53.2	1,596	83.7	2002	1	2016	2
02N22W17Q05S	360	---	478	---	Mound	66	38.7	2,551	213	1982	1	2016	2
02N22W18N01S	660	---	1,200	---	Mound	75	117	8,805	332	1979	2	2016	2
02N22W19J02S	160	---	500	---	Oxnard Plain	75	214	16,073	632	1979	2	2016	2
02N22W19J03S	410	---	690	---	Oxnard Plain	40	149	5,941	505	1997	1	2016	2
02N22W19K02S	200	---	230	---	Mound	70	0.3	22.0	0.5	1979	2	2016	2
02N22W19K03S	450	---	600	---	Mound	16	134	2,152	266	2009	1	2016	2
02N22W19L02S	---	---	---	---	Mound	54	55.9	3,021	160	1988	1	2016	2
02N22W19M03S	350	---	625	---	Mound	30	41.8	1,255	106	1990	1	2004	2
02N22W19M04S	343	---	493	---	Mound	24	110	2,637	247	2005	1	2016	2
02N22W19P01S	160	---	300	---	Oxnard Plain	41	84.0	3,445	185	1996	2	2016	2
02N22W20B02S	180	---	320	---	Mound	8	106	848	224	1979	2	1997	2
02N22W20E01S	462	---	818	---	Mound	51	33.5	1,706	163	1991	2	2016	2
02N22W20J01S	310	---	910	---	Oxnard Plain	20	1,262	25,246	1,726	1979	2	1989	1
02N22W20K01S	403	---	853	---	Oxnard Plain	56	1,079	60,416	1,749	1989	1	2016	2
02N22W20L02S	354	---	830	---	Oxnard Plain	73	427	31,165	1,627	1979	2	2015	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W20L03S	403	---	853	---	Oxnard Plain	56	699	39,145	1,656	1989	1	2016	2
02N22W20M02S	365	---	927	---	Oxnard Plain	72	3.0	217	131	1979	2	2016	2
02N22W20M06S	319	---	600	---	Oxnard Plain	72	30.0	2,157	131	1979	2	2016	2
02N22W20M07S	352	---	552	---	Oxnard Plain	73	35.1	2,560	151	1979	2	2016	2
02N22W20Q01S	187	---	664	---	Oxnard Plain	75	10.6	795	140	1979	2	2016	2
02N22W21D02S	190	---	280	---	Oxnard Plain	49	0	0	0	1979	2	2003	2
02N22W21D03S	193	---	313	---	Oxnard Plain	54	17.6	951	23.6	1979	2	2006	1
02N22W21H01S	---	---	---	210	Oxnard Forebay	55	144	7,893	421	1979	2	2006	2
02N22W21J03S	200	---	308	---	Oxnard Forebay	19	60.7	1,153	204	1979	2	1997	2
02N22W21M01S	160	---	300	---	Oxnard Plain	64	62.5	4,002	183	1985	1	2016	2
02N22W21Q01S	143	---	178	---	Oxnard Plain	27	77.6	2,096	203	1979	2	1997	2
02N22W22G01S	120	---	200	---	Oxnard Forebay	51	100	5,079	335	1979	2	2004	2
02N22W22H01S	96	---	208	---	Oxnard Forebay	56	9.1	512	38.2	1979	1	2006	2
02N22W22J02S	124	---	200	---	Oxnard Forebay	55	79.8	4,389	172	1979	2	2006	2
02N22W22M04S	86	---	246	---	Oxnard Forebay	4	0.8	3.0	1.0	1979	2	1997	2
02N22W22Q01S	100	---	142	---	Oxnard Forebay	48	4.9	233	16.0	1979	2	2003	1
02N22W22Q02S	140	---	182	---	Oxnard Forebay	24	6.0	145	19.4	1979	2	1997	2
02N22W22Q03S	110	---	268	---	Oxnard Forebay	24	12.7	304	26.8	1979	2	1997	2
02N22W22Q05S	460	---	640	---	Oxnard Forebay	12	5.4	65.0	14.7	2011	1	2016	2
02N22W22R04S	120	---	290	---	Oxnard Forebay	75	154	11,556	257	1979	2	2016	2
02N22W23B01S	100	---	277	---	Oxnard Forebay	75	525	39,345	2,129	1979	2	2016	2
02N22W23B02S	163	---	277	---	Oxnard Forebay	75	524	39,265	2,003	1979	2	2016	2
02N22W23C01S	100	---	300	---	Oxnard Forebay	72	768	55,288	2,153	1979	2	2015	1
02N22W23C02S	139	---	290	---	Oxnard Forebay	75	933	69,953	2,250	1979	2	2016	2
02N22W23C03S	556	---	1,092	---	Oxnard Forebay	42	1.2	50.1	10.0	1979	2	2000	1

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W23C05S	140	---	310	---	Oxnard Forebay	32	1,579	50,516	3,123	2001	1	2016	2
02N22W23C06S	150	---	290	---	Oxnard Forebay	4	691	2,764	824	2015	1	2016	2
02N22W23D04S	76	---	180	---	Oxnard Forebay	43	63.5	2,729	154	1979	2	2000	2
02N22W23D05S	80	---	227	---	Oxnard Forebay	75	5.8	434	31.3	1979	1	2016	2
02N22W23D06S	130	---	370	---	Oxnard Forebay	51	35.7	1,822	242	1991	2	2016	2
02N22W23F01S	100	---	300	---	Oxnard Forebay	26	6.8	176	8.0	2004	1	2016	2
02N22W23F04S	124	---	250	---	Oxnard Forebay	49	5.7	280	8.0	1979	2	2003	2
02N22W23F05S	300	---	412	---	Oxnard Forebay	75	131	9,807	168	1979	2	2016	2
02N22W23F06S	80	---	250	---	Oxnard Forebay	56	54.3	3,043	161	1980	2	2016	2
02N22W23G02S	100	---	277	---	Oxnard Forebay	59	689	40,674	1,713	1979	2	2008	2
02N22W23G03S	100	---	300	---	Oxnard Forebay	75	875	65,629	2,130	1979	2	2016	2
02N22W23G04S	115	---	340	---	Oxnard Forebay	15	707	10,606	1,672	2009	2	2016	2
02N22W23H03S	120	---	182	---	Oxnard Forebay	75	124	9,326	242	1979	2	2016	2
02N22W23H04S	850	---	1,390	---	Oxnard Forebay	64	34.0	2,176	415	1985	1	2016	2
02N22W23J01S	116	---	206	---	Oxnard Forebay	75	91.6	6,872	169	1979	2	2016	2
02N22W23K01S	124	---	250	---	Oxnard Forebay	48	178	8,528	1,213	1979	2	2003	1
02N22W23K02S	133	---	232	---	Oxnard Forebay	74	105	7,738	222	1979	1	2016	2
02N22W23K04S	710	---	1,777	---	Oxnard Forebay	48	3.4	164	77.0	1979	2	2003	1
02N22W23K05S	144	---	336	---	Oxnard Forebay	74	894	66,171	3,090	1980	1	2016	2
02N22W23Q01S	98	---	162	---	Oxnard Forebay	75	90.7	6,799	281	1979	2	2016	2
02N22W23Q04S	301	---	501	---	Oxnard Forebay	26	159	4,141	271	2004	1	2016	2
02N22W24A01S	120	---	320	---	Oxnard Plain	75	184	13,793	445	1979	2	2016	2
02N22W24A02S	100	---	240	---	Oxnard Plain	14	156	2,186	259	2010	1	2016	2
02N22W24D01S	130	---	258	---	Oxnard Forebay	75	92.2	6,912	159	1979	2	2016	2
02N22W24K01S	80	---	150	---	Oxnard Plain	75	60.2	4,518	245	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W24P01S	290	---	480	---	Oxnard Plain	75	132	9,877	321	1979	2	2016	2
02N22W24P02S	300	---	1,210	---	Oxnard Plain	70	159	11,101	327	1982	1	2016	2
02N22W24Q02S	183	---	195	---	Oxnard Plain	75	0.7	54.0	1.2	1979	2	2016	2
02N22W24R01S	100	---	200	---	Oxnard Plain	75	8.1	610	26.0	1979	2	2016	2
02N22W24R02S	100	---	160	---	Oxnard Plain	68	0.4	26.2	1.0	1983	1	2016	2
02N22W25A02S	---	124	---	174	Oxnard Plain	74	15.3	1,133	54.1	1979	2	2016	2
02N22W25A03S	112	---	205	---	Oxnard Plain	75	147	11,046	334	1979	2	2016	2
02N22W25E01S	108	---	184	---	Oxnard Plain	26	85.0	2,211	190	2004	1	2016	2
02N22W25F01S	130	---	190	---	Oxnard Plain	75	0.4	32.1	2.0	1979	2	2016	2
02N22W25J01S	400	---	820	---	Oxnard Plain	46	70.4	3,240	109	1993	2	2016	2
02N22W25L02S	106	---	172	---	Oxnard Plain	49	52.9	2,591	130	1979	2	2003	2
02N22W25L03S	110	---	172	---	Oxnard Plain	75	3.0	225	30.0	1979	2	2016	2
02N22W25L05S	400	---	820	---	Oxnard Plain	40	101	4,055	139	1997	1	2016	2
02N22W25M01S	122	---	225	---	Oxnard Plain	24	8.7	209	13.0	1979	2	1997	2
02N22W25N03S	120	---	202	---	Oxnard Plain	20	5.6	112	17.0	1979	2	1997	2
02N22W25P01S	120	---	434	---	Oxnard Plain	61	114	6,939	418	1979	2	2009	2
02N22W25P04S	115	---	210	---	Oxnard Plain	68	146	9,961	400	1983	1	2016	2
02N22W25Q01S	100	---	180	---	Oxnard Plain	42	30.2	1,268	75.7	1979	2	2000	2
02N22W25Q04S	100	---	180	---	Oxnard Plain	16	6.1	97.2	16.8	1979	2	1997	2
02N22W25Q05S	220	---	390	---	Oxnard Plain	14	196	2,749	310	2010	1	2016	2
02N22W25R02S	104	---	162	---	Oxnard Plain	75	71.8	5,384	318	1979	2	2016	2
02N22W26B03S	575	---	1,475	---	Oxnard Forebay	64	205	13,119	2,174	1985	1	2016	2
02N22W26C01S	90	---	180	---	Oxnard Forebay	75	25.4	1,906	143	1979	2	2016	2
02N22W26C03S	98	---	220	---	Oxnard Forebay	75	27.6	2,069	53.3	1979	2	2016	2
02N22W26C05S	200	---	324	---	Oxnard Forebay	75	47.1	3,532	254	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W26E01S	150	---	292	---	Oxnard Forebay	75	11.7	879	29.9	1979	2	2016	2
02N22W26F02S	150	---	324	---	Oxnard Forebay	75	41.1	3,083	121	1979	2	2016	2
02N22W26H01S	120	---	266	---	Oxnard Plain	16	108	1,732	340	1979	2	1997	2
02N22W26H02S	440	---	680	---	Oxnard Plain	75	83.5	6,261	211	1979	2	2016	2
02N22W26M01S	150	---	180	---	Oxnard Forebay	31	21.5	668	39.4	1979	2	1997	2
02N22W26Q01S	127	---	193	---	Oxnard Plain	45	33.1	1,490	142	1979	2	2001	2
02N22W26R01S	140	---	190	---	Oxnard Plain	15	53.9	808	88.0	1979	2	1997	2
02N22W26R02S	145	---	175	---	Oxnard Plain	24	0.8	20.0	1.0	1979	2	1997	2
02N22W26R05S	140	---	185	---	Oxnard Plain	44	57.3	2,521	197	1979	1	2000	2
02N22W27A01S	100	---	150	---	Oxnard Forebay	1	0	0	0	2016	1	2016	1
02N22W27A02S	100	---	230	---	Oxnard Forebay	2	31.4	62.9	32.4	2016	1	2016	2
02N22W27A03S	140	---	230	---	Oxnard Forebay	75	102	7,678	147	1979	2	2016	2
02N22W27B01S	145	---	230	---	Oxnard Forebay	65	8.2	534	29.0	1979	2	2011	2
02N22W27D01S	100	---	180	---	Oxnard Plain	11	0	0	0	1979	2	1997	2
02N22W27K01S	130	---	246	---	Oxnard Forebay	75	76.3	5,721	198	1979	2	2016	2
02N22W27L01S	107	---	242	---	Oxnard Forebay	75	36.1	2,705	155	1979	2	2016	2
02N22W27M01S	102	---	288	---	Oxnard Plain	4	29.3	117	85.8	1979	2	1997	2
02N22W27M02S	180	---	212	---	Oxnard Plain	73	2.7	198	5.7	1979	2	2015	2
02N22W28A03S	100	---	180	---	Oxnard Plain	28	3.6	100	19.4	2003	1	2016	2
02N22W28C06S	170	---	430	---	Oxnard Plain	75	197	14,787	422	1979	2	2016	2
02N22W28H02S	125	---	280	---	Oxnard Plain	75	14.1	1,057	31.2	1979	2	2016	2
02N22W28L01S	186	---	286	---	Oxnard Plain	27	58.5	1,579	206	1979	2	1997	2
02N22W29D04S	22	---	52	---	Oxnard Plain	55	2.1	117	30.0	1989	2	2016	2
02N22W29D05S	185	---	255	---	Oxnard Plain	51	24.0	1,224	198	1991	2	2016	2
02N22W29D08S	200	---	290	---	Oxnard Plain	14	37.5	525	49.8	2010	1	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W29G01S	190	---	254	---	Oxnard Plain	11	82.3	905	161	1979	2	1997	2
02N22W29M01S	200	---	280	---	Oxnard Plain	52	155	8,047	395	1979	1	2004	2
02N22W29Q03S	97	---	238	---	Oxnard Plain	35	54.5	1,908	376	1984	2	2001	2
02N22W29R01S	---	---	---	---	Oxnard Plain	9	67.7	609	140	1980	2	1997	2
02N22W29R02S	202	---	310	---	Oxnard Plain	11	100	1,096	266	1979	2	1997	2
02N22W30C05S	22	---	52	---	Oxnard Plain	55	2.6	141	26.5	1989	2	2016	2
02N22W30C06S	22	---	52	---	Oxnard Plain	55	0.7	40.1	9.4	1989	2	2016	2
02N22W30F03S	452	---	653	---	Oxnard Plain	61	168	10,264	393	1986	2	2016	2
02N22W30J01S	230	---	280	---	Oxnard Plain	75	3.0	222	12.4	1979	2	2016	2
02N22W30J07S	295	---	485	---	Oxnard Plain	25	154	3,849	430	2004	2	2016	2
02N22W30K01S	190	---	250	---	Oxnard Plain	71	7.9	561	88.2	1981	2	2016	2
02N22W30L02S	35	---	75	---	Oxnard Plain	71	5.7	405	59.8	1981	2	2016	2
02N22W30P01S	100	---	200	---	Oxnard Plain	9	113	1,016	223	1986	2	1997	2
02N22W30P02S	202	---	401	---	Oxnard Plain	76	309	23,479	585	1979	1	2016	2
02N22W30P03S	370	---	490	---	Oxnard Plain	75	31.7	2,377	97.9	1979	2	2016	2
02N22W30Q01S	390	---	510	---	Oxnard Plain	64	17.0	1,089	45.8	1985	1	2016	2
02N22W30Q02S	390	---	510	---	Oxnard Plain	75	37.4	2,804	64.7	1979	2	2016	2
02N22W31A02S	114	---	254	---	Oxnard Plain	49	49.5	2,423	89.9	1979	2	2003	2
02N22W31A03S	200	---	500	---	Oxnard Plain	75	141	10,541	306	1979	1	2016	2
02N22W31B01S	100	---	300	---	Oxnard Plain	76	105	7,965	494	1979	1	2016	2
02N22W31C02S	186	---	292	---	Oxnard Plain	76	108	8,201	213	1979	1	2016	2
02N22W31D01S	130	---	430	---	Oxnard Plain	28	155	4,337	323	1979	2	1997	2
02N22W31D02S	220	---	400	---	Oxnard Plain	49	164	8,026	298	1992	2	2016	2
02N22W31K01S	125	---	235	---	Oxnard Plain	75	61.1	4,582	232	1979	2	2016	2
02N22W31N01S	168	---	342	---	Oxnard Plain	75	330	24,786	906	1979	2	2016	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W31Q01S	120	---	240	---	Oxnard Plain	72	36.5	2,626	77.0	1981	1	2016	2
02N22W31R04S	168	---	240	---	Oxnard Plain	53	4.7	250	36.8	1990	2	2016	2
02N22W31R05S	320	---	440	---	Oxnard Plain	75	79.9	5,992	175	1979	1	2016	2
02N22W32A02S	120	---	308	---	Oxnard Plain	20	223	4,463	527	1979	2	1997	2
02N22W32C01S	100	---	250	---	Oxnard Plain	76	120	9,087	468	1979	1	2016	2
02N22W32C04S	220	---	310	---	Oxnard Plain	53	107	5,697	220	1990	2	2016	2
02N22W32D01S	210	---	480	---	Oxnard Plain	27	80.1	2,164	140	2003	2	2016	2
02N22W32M01S	---	---	---	---	Oxnard Plain	46	57.1	2,627	122	1979	2	2002	2
02N22W32M03S	218	---	318	---	Oxnard Plain	28	79.0	2,211	173	2003	1	2016	2
02N22W32Q01S	160	---	296	---	Oxnard Plain	17	80.1	1,361	177	1979	2	1997	2
02N22W32Q03S	180	---	280	---	Oxnard Plain	59	47.0	2,772	156	1987	2	2016	2
02N22W33A01S	---	---	---	---	Oxnard Plain	20	0	0	0	1979	2	1997	2
02N22W33L03S	138	---	198	---	Oxnard Plain	58	0.6	32.4	1.5	1979	2	2008	1
02N22W33M02S	164	---	218	---	Oxnard Plain	24	6.9	165	27.0	1979	2	1997	2
02N22W33M03S	168	---	302	---	Oxnard Plain	19	49.9	947	198	1979	2	1997	2
02N22W33N04S	181	---	293	---	Oxnard Plain	51	86.2	4,395	189	1979	2	2004	2
02N22W33N05S	175	---	295	---	Oxnard Plain	67	45.2	3,027	172	1982	2	2016	2
02N22W34A02S	62	---	198	---	Oxnard Plain	38	92.6	3,520	155	1981	1	1999	2
02N22W34A03S	200	---	218	---	Oxnard Plain	43	101	4,345	243	1979	2	2000	2
02N22W34B01S	75	---	213	---	Oxnard Forebay	45	29.4	1,324	138	1979	2	2001	2
02N22W34B03S	80	---	200	---	Oxnard Plain	40	10.3	411	23.0	1979	2	1999	2
02N22W34H01S	150	---	242	---	Oxnard Plain	51	51.8	2,642	145	1979	2	2004	2
02N22W34J01S	80	---	200	---	Oxnard Plain	73	0.2	17.7	1.0	1979	1	2015	1
02N22W34K02S	171	---	251	---	Oxnard Plain	59	87.9	5,187	229	1979	2	2008	2
02N22W35A01S	135	---	185	---	Oxnard Plain	23	70.9	1,630	141	1979	2	1997	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N22W35B02S	128	---	198	---	Oxnard Plain	58	21.8	1,267	125	1979	2	2008	2
02N22W35C01S	96	---	192	---	Oxnard Plain	45	1.2	55.6	1.4	1979	2	2001	2
02N22W35C02S	415	---	540	---	Oxnard Plain	30	192	5,757	486	1979	2	1997	2
02N22W35C03S	660	---	1,620	---	Oxnard Plain	37	0	0	0	1987	2	2005	2
02N22W35C04S	441	---	741	---	Oxnard Plain	37	21.8	807	87.3	1993	2	2011	2
02N22W35C05S	135	---	185	---	Oxnard Plain	22	0	0	0	1996	1	2006	2
02N22W35K01S	134	---	293	---	Oxnard Plain	61	149	9,094	561	1979	2	2009	2
02N22W35K02S	460	---	700	---	Oxnard Plain	44	179	7,897	391	1984	2	2006	2
02N22W35K03S	361	---	711	---	Oxnard Plain	14	114	1,594	155	2010	1	2016	2
02N22W35M01S	384	---	534	---	Oxnard Plain	70	71.1	4,978	208	1980	2	2015	1
02N22W35P01S	119	---	173	---	Oxnard Plain	18	0	0	0	1979	2	1997	2
02N22W36E02S	475	---	580	---	Oxnard Plain	21	586	12,303	1,471	2006	2	2016	2
02N22W36E03S	360	---	420	---	Oxnard Plain	21	616	12,931	1,879	2006	2	2016	2
02N22W36E04S	195	---	285	---	Oxnard Plain	21	129	2,704	800	2006	2	2016	2
02N22W36E05S	130	---	170	---	Oxnard Plain	21	77.9	1,635	651	2006	2	2016	2
02N22W36F02S	170	---	366	---	Oxnard Plain	75	136	10,219	351	1979	2	2016	2
02N22W36L01S	128	---	426	---	Oxnard Plain	75	72.6	5,446	250	1979	2	2016	2
02N22W36M03S	112	---	292	---	Oxnard Plain	22	44.3	975	94.1	1979	2	1997	2
02N23W13E01S	523	---	1,123	---	Mound	67	231	15,498	733	1983	2	2016	2
02N23W13F02S	521	---	982	---	Mound	76	209	15,917	811	1979	1	2016	2
02N23W13G01S	360	---	860	---	Mound	13	292	3,794	473	2010	2	2016	2
02N23W13K01S	623	---	1,230	---	Mound	11	33.5	368	102	1979	2	1997	2
02N23W13K03S	800	---	1,200	---	Mound	75	307	23,017	757	1979	2	2016	2
02N23W13K04S	800	---	1,200	---	Mound	67	129	8,661	294	1983	2	2016	2
02N23W14B01S	223	---	733	---	Mound	11	59.4	654	123	1979	2	1997	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
02N23W14K01S	501	---	920	---	Mound	9	134	1,209	253	1979	2	1997	2
02N23W24F01S	---	---	---	---	Mound	75	124	9,275	521	1979	2	2016	2
02N23W24G01S	742	---	927	---	Mound	75	2.7	200	69.9	1979	2	2016	2
02N23W25H01S	130	---	238	---	Oxnard Plain	75	225	16,882	478	1979	2	2016	2
02N23W25M01S	130	---	230	---	Oxnard Plain	75	264	19,830	695	1979	2	2016	2
02N23W25Q01S	190	---	220	---	Oxnard Plain	74	2.0	150	12.3	1979	2	2016	2
02N23W25R02S	162	---	182	---	Oxnard Plain	14	142	1,989	286	1979	2	1997	2
02N23W36A01S	232	---	366	---	Oxnard Plain	75	116	8,690	390	1979	2	2016	2
02N23W36A02S	240	---	368	---	Oxnard Plain	45	190	8,530	862	1979	2	2001	2
02N23W36A04S	200	---	400	---	Oxnard Plain	36	147	5,305	387	1999	1	2016	2
02N23W36C04S	210	---	260	---	Oxnard Plain	75	2.0	153	12.9	1979	2	2016	2
02N23W36C05S	200	---	445	---	Oxnard Plain	24	6.9	166	13.5	2005	1	2016	2
02N23W36H02S	181	---	381	---	Oxnard Plain	58	312	18,110	578	1988	1	2016	2
02N23W36L01S	110	---	250	---	Oxnard Plain	75	3.9	291	20.9	1979	2	2016	2
03N19W32L01S	605	---	860	---	West Las Posas	1	40.2	40.2	40.2	2015	2	2015	2
03N20W28J05S	240	---	360	---	East Las Posas	6	0.4	2.6	0.6	2013	1	2015	2
03N20W28P01S	---	---	---	---	East Las Posas	22	1.0	21.7	4.6	2005	1	2015	2
03N20W28P02S	140	---	400	---	East Las Posas	34	0.7	22.5	3.5	1999	1	2015	2
03N20W28P03S	---	---	---	---	East Las Posas	11	0.2	1.9	0.7	2010	1	2015	1
03N20W28Q01S	550	---	1,110	---	East Las Posas	64	4.8	310	10.2	1983	2	2015	1
03N20W32F02S	1,010	---	1,510	---	West Las Posas	49	74.3	3,643	466	1984	1	2010	1
03N20W32G01S	---	---	---	---	West Las Posas	1	0	0	0	2013	2	2013	2
03N20W32G02S	1,295	---	1,540	---	West Las Posas	40	27.9	1,116	114	1988	2	2010	1
03N20W32H02S	762	---	1,090	---	West Las Posas	12	27.6	331	109	2000	1	2013	2
03N20W32H03S	900	---	1,100	---	West Las Posas	11	15.5	170	52.4	2010	2	2015	2

Table 3-8. Well Information

Well ID	Reported Depth to Top of Screen (ft bgs)	Estimated Depth to Top of Screen (ft bgs)	Depth to Bottom of Screen (ft bgs)	Estimated Depth to Bottom of Screen (ft bgs)	Basin ID	Number of Semi-Annual Pumping Records	Average Semi-Annual Reported Pumping (acre-ft)	Total Pumping Volume (acre-ft)	Maximum Semi-Annual Reported Pumping (acre-ft)	First Year of Well Records	First Semi-Annual Period of Well Records	Last Year of Well Records	Last Semi-Annual Period of Well Records
03N20W32K01S	870	---	1,160	---	West Las Posas	26	51.6	1,342	111	2003	1	2015	2
03N20W33B01S	844	---	1,141	---	East Las Posas	60	28.7	1,721	61.9	1983	2	2015	2
03N20W33B04S	1,058	---	1,300	---	East Las Posas	45	14.0	628	32.0	1992	1	2015	2
03N20W33C01S	---	---	---	---	East Las Posas	62	0.9	57.2	2.0	1985	1	2015	2
03N20W33M01S	470	---	600	---	East Las Posas	9	0	0	0	2008	2	2013	2
03N21W35L02S	1,300	---	1,770	---		21	9.0	190	172	2006	2	2016	2
03N21W35L03S	1,100	---	1,530	---		13	47.1	613	80.2	2010	2	2016	2
03N21W35P01S	807	---	1,879	---		19	105	1,988	150	1979	2	1997	2
03N21W35P02S	790	---	1,760	---	West Las Posas	58	101	5,842	276	1988	1	2016	2
03N21W35R01S	800	---	1,720	---	West Las Posas	65	67.8	4,410	617	1983	2	2015	2
03N21W36Q01S	860	---	1,700	---	West Las Posas	65	108	7,019	224	1983	2	2015	2
03N21W36Q02S	804	---	1,684	---	West Las Posas	64	130	8,306	285	1983	2	2015	2
03N21W36R02S	1,215	---	1,990	---	West Las Posas	18	17.3	311	72.6	2005	1	2013	2
03N21W36R03S	966	---	1,476	---	West Las Posas	12	90.4	1,085	157	2010	1	2015	2
03N22W34E01S	528	---	618	---	Santa Paula	18	0.4	8.0	3.5	2008	1	2016	2
03N22W34Q02S	---	---	---	---	Santa Paula	74	85.1	6,294	290	1979	2	2016	2
03N22W34Q03S	280	---	470	---	Santa Paula	8	85.2	681	123	2013	1	2016	2
03N22W34R01S	300	---	343	---	Santa Paula	74	27.1	2,006	92.8	1979	2	2016	1

Data from United and FCGMA records as described in Section 3.

Notes: ft bgs = feet below ground surface
acre-ft = acre-feet

Table 4-1. Summary of Simulated Annual-Average Flows in Forebay

Aquifer system	Storage	Areal Recharge	Underflow from Oxnard Plain Basin	Underflow from Mound Basin	Underflow from Santa Paula Basin	UWCD Spreading	Pumping from Wells	ET	Santa Clara River Percolation
Shallow	1	343	4	-	-	-	-	-	-
UAS	2,398	2,102	-34,245	-2,122	502	48,297	-22,547	-326	7,534
LAS	91	-	-857	236	251	-	-1,670	-	-
Sum	2,490	2,445	-35,098	-1,886	753	48,297	-24,217	-326	7,534

Units are in acre-feet per year. Positive values indicate inflows, negative values indicate outflows.

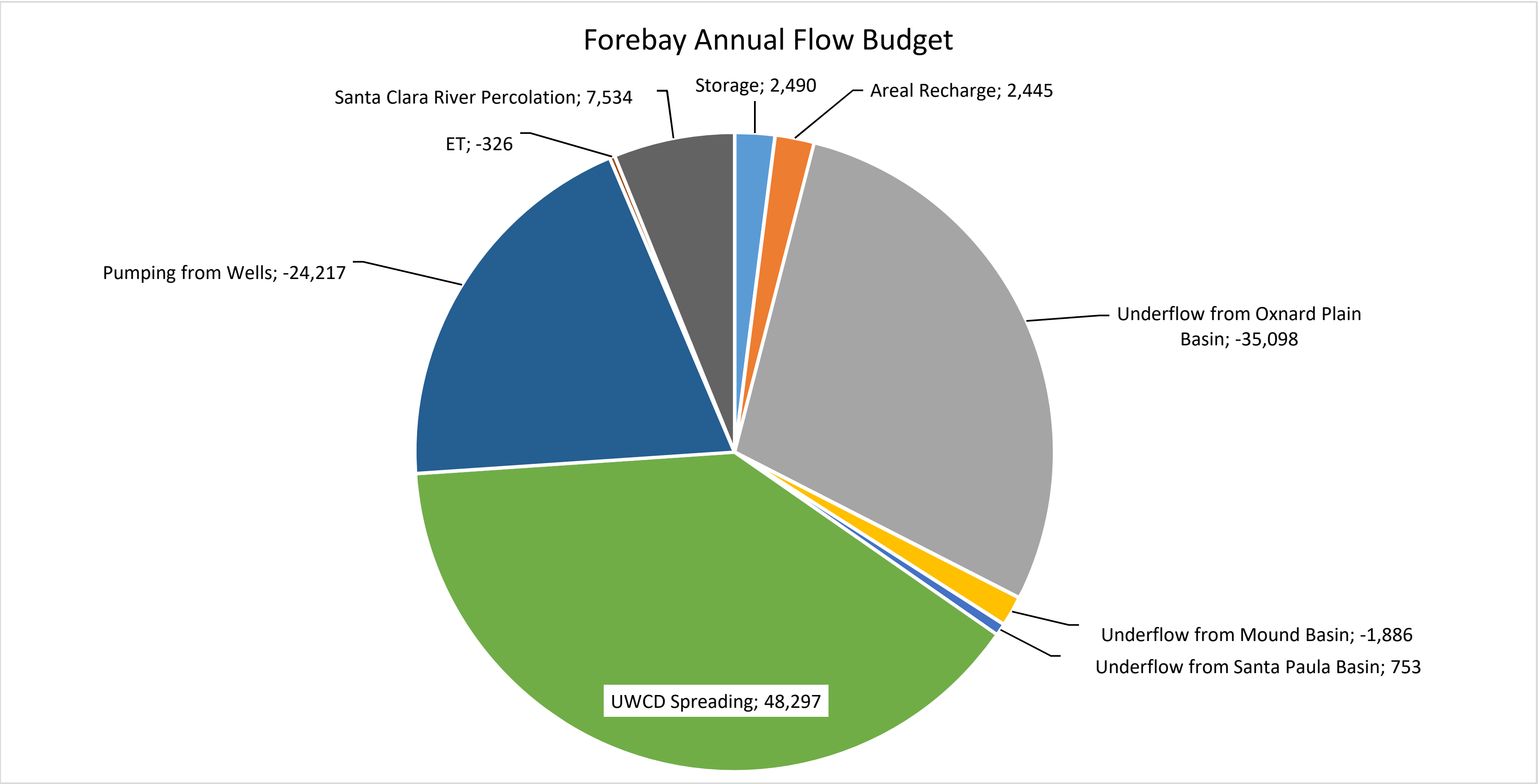

Table 4-2. Summary of Simulated Annual-Average Flows in Oxnard Plain Basin

Aquifer system	Storage	Tile Drains	Recharge	Pumping from Wells	ET	Underflow from Forebay	Underflow from Mound Basin	Underflow from Pleasant Valley Basin	Underflow from Las Posas Basin	Coastal Flux North of Channel Islands Harbor	Coastal Flux from Channel Islands Harbor to Arnold Road	Coastal Flux from Arnold Road to Point Mugu	Santa Clara River percolation	Calleguas Creek percolation
Shallow	659	-6,414	20,377	-21	-7,667	-4	-558	1,316	-128	-1,242	-540	663	506	2,177
UAS	1,705	-221	599	-28,056	-	34,245	-94	-170	-2,330	712	1,408	1,785	384	-
LAS	348	-	37	-26,722	-	857	2,151	-2,419	1,156	1,936	2,654	908	-	-
Sum	2,712	-6,636	21,013	-54,800	-7,667	35,098	1,499	-1,273	-1,302	1,406	3,523	3,357	889	2,177

Units are in acre-feet per year. Positive values indicate inflows, negative values indicate outflows.

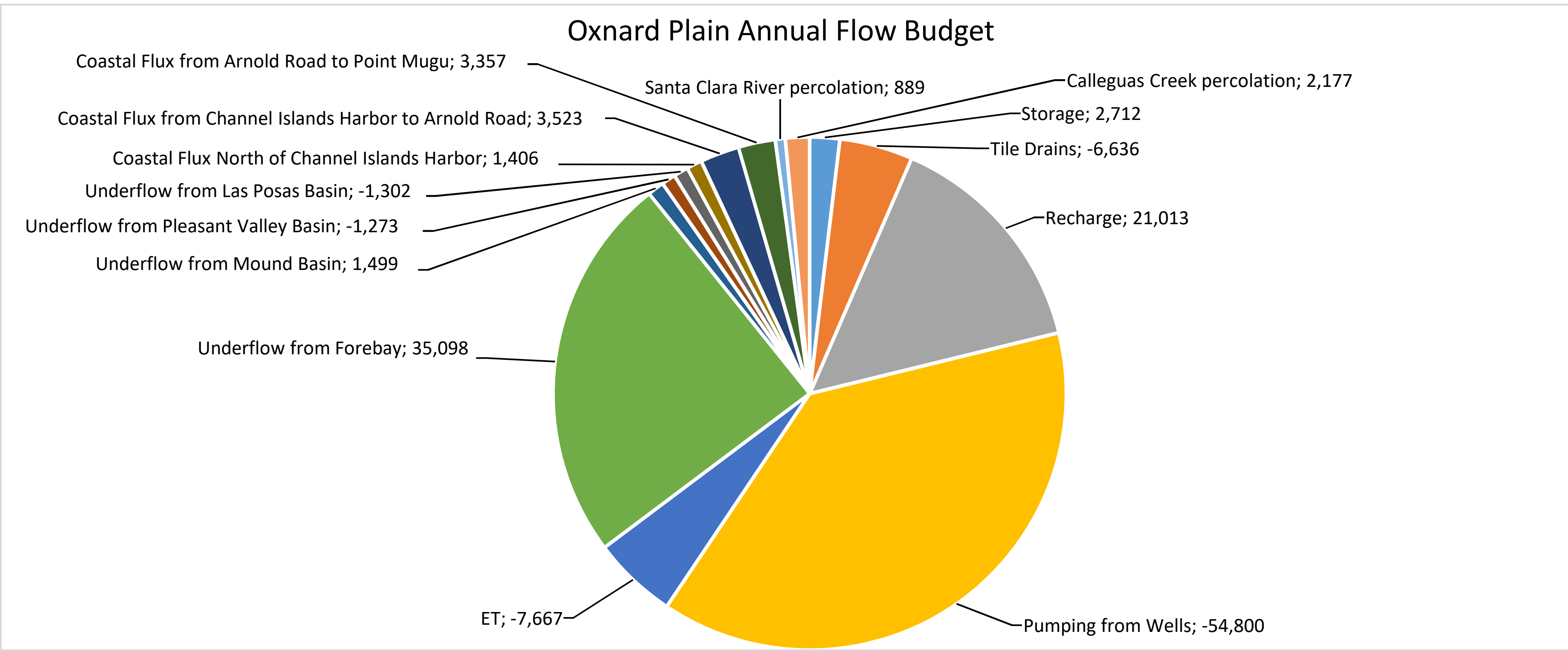

Table 4-3. Summary of Simulated Annual-Average Flows in Pleasant Valley Basin

Aquifer system	Storage	Tile Drains	Areal Recharge	Pumping from Wells	ET	Underflow from Oxnard Plain Basin	Underflow from Las Posas Basin	Arroyo Las Posas Percolation	Conejo Creek Percolation	Calleguas Creek Percolation	Mountain Front Recharge	GW Flux from East Las Posas
Shallow	-519	-5,196	8,204	-223	-903	-1,316	-	563	3,616	7,537	-	-
UAS	-1,154	-	692	-8,706	-981	170	-563	3,697	1,831	-	1,610	1,646
LAS	-262	-	384	-12,157	-	2,419	-418	-	-	-	-	-
Sum	-1,935	-5,196	9,280	-21,086	-1,884	1,273	-981	4,260	5,447	7,537	1,610	1,646

Units are in acre-feet per year. Positive values indicate inflows, negative values indicate outflows.

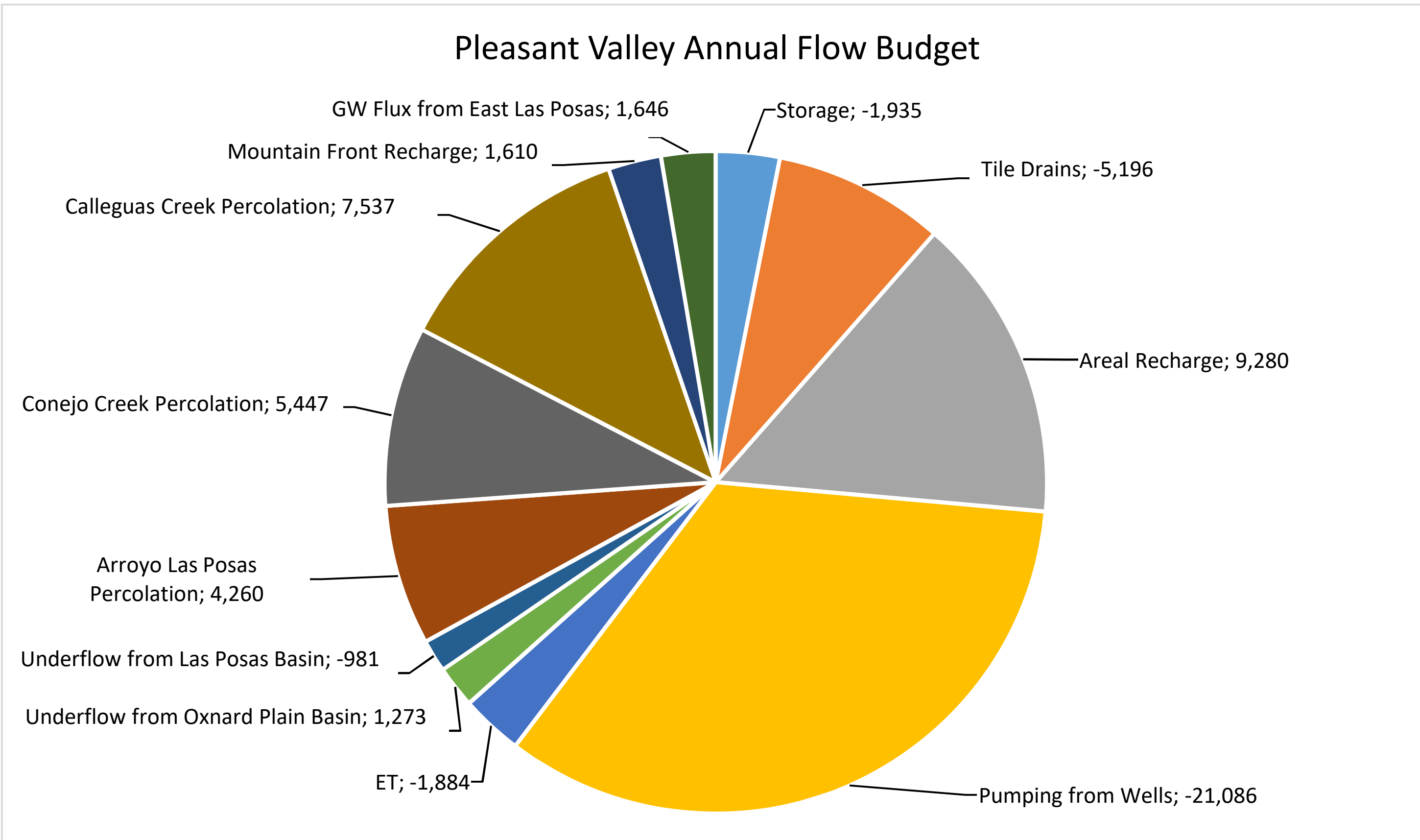

Table 4-4. Summary of Simulated Annual-Average Flows in Mound Basin

Aquifer system	Storage	Mountain-Front Recharge	Areal Recharge	Pumping from Wells	ET	Underflow from Santa Paula Basin	Underflow from Oxnard Plain Basin	Underflow from Forebay	Coastal Flux	Santa Clara River Percolation
Shallow	-2	-	2,238	-	-365	-3	558	-	-208	-1,168
UAS	303	-	26	-2,208	-	843	94	2,122	15	-
LAS	122	2,855	141	-5,162	-	2,253	-2,151	-236	-73	-
Sum	423	2,855	2,406	-7,369	-365	3,093	-1,499	1,886	-267	-1,168

Units are in acre-feet per year. Positive values indicate inflows, negative values indicate outflows.

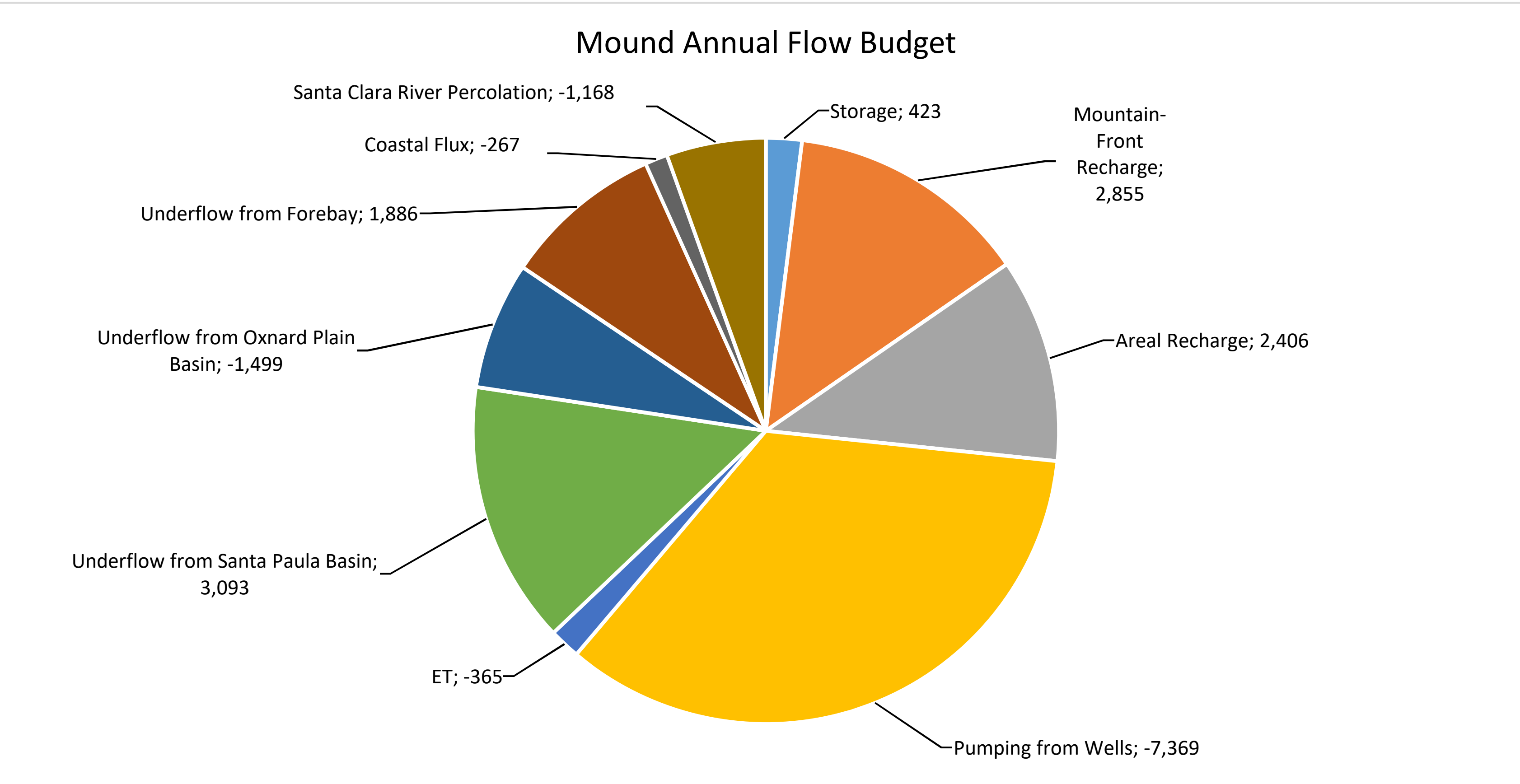

Table 4-5. Summary of Simulated Annual-Average Flows in Las Posas Basin

Aquifer system	Storage	Mountain-Front Recharge	Areal Recharge	Pumping from Wells	Underflow from Oxnard Plain Basin	Underflow from Pleasant Valley Basin
Shallow	255	-	5,155	-	2,458	563
UAS	2,256	1,734	1,135	-12,820	-1,156	418
LAS	2,511	1,734	6,291	-12,820	1,302	981
Sum	5,022	3,469	12,582	-25,639	2,605	1,962

Units are in acre-feet per year. Positive values indicate inflows, negative values indicate outflows.

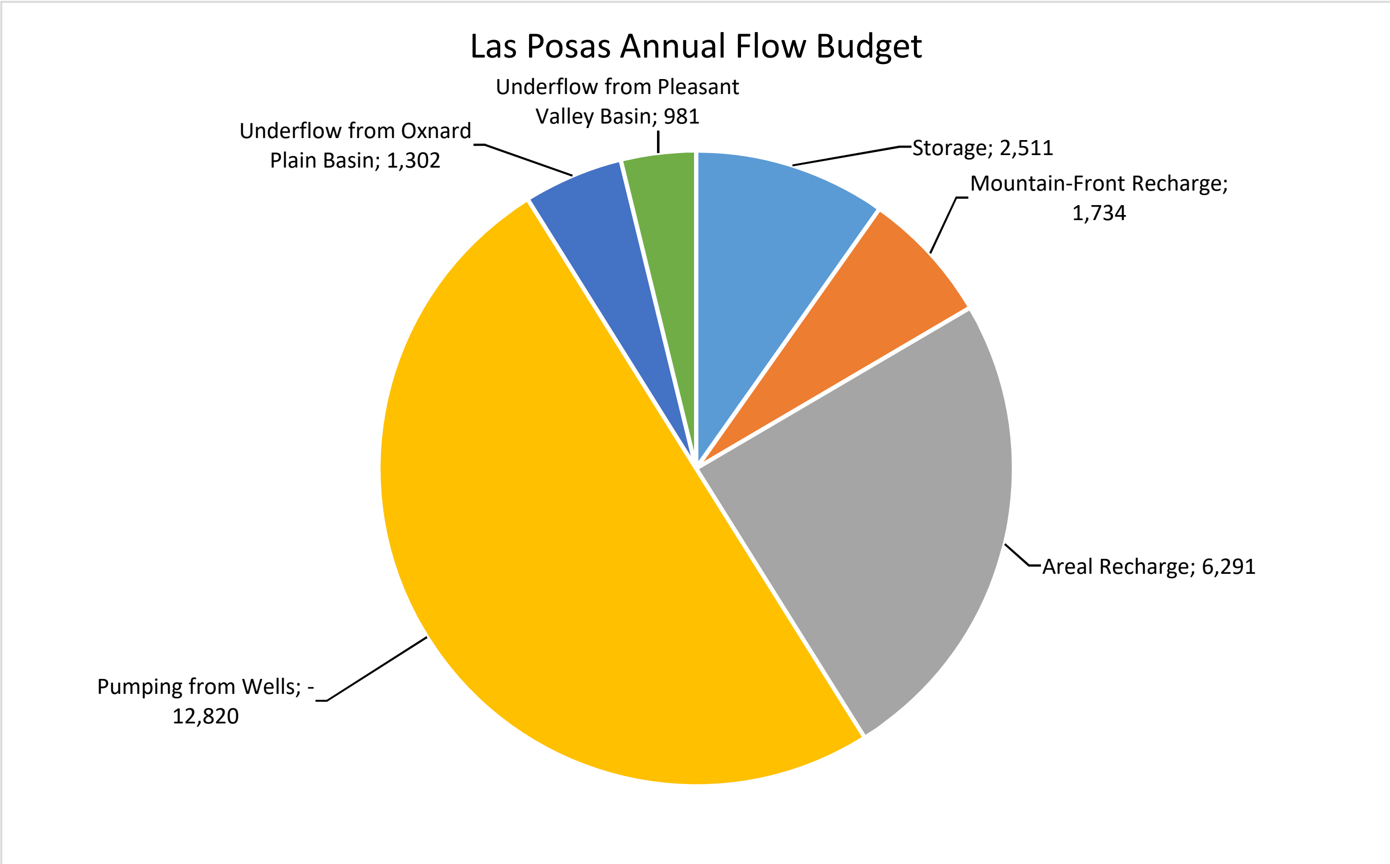

Table 4-6. Values Input for Parameters (by Zone) During Sensitivity Analysis

Horizontal Hydraulic Conductivity in Each Zone (ft/day)																														
Layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	1.0E-12	200	200	200	200	300	200	200	300	200	200	200	200	50	50	200	0.1	300	200	200	1.0E-12	200	100	100	100	100	1	200	200	200
2	1.0E-12	0.01	0.01	0.01	1.00E-02	0.01	0.01	1.0E-03	0.01	0.01	0.01	100	100	50	50	200	0.01	300	200	0.01	1.0E-12	1.0E-04	100	100	100	0.01	0.01	200	100	100
3	1.0E-12	100	100	100	1.00E-02	300	100	100	250	100	100	100	50	10	10	200	0.05	250	200	100	1.0E-12	100	50	80	1	100	1	200	100	100
4	1.0E-12	0.01	0.01	0.1	1.00E-02	1	1	1	200	1	20	100	20	1	1	200	1.00E-03	250	200	1	1.0E-12	1	20	50	1	1	0.01	200	100	100
5	1.0E-12	100	50	50	100	200	50	50	200	100	20	100	20	1	1	200	20	200	100	100	1.0E-12	50	20	50	1	100	1	200	100	100
6	1.0E-12	1.0E-03	1.0E-03	1.0E-03	1	3.0E-03	0.01	1.0E-03	1.0E-03	5.0E-04	1.0E-02	50	0.01	0.01	0.01	1.00E-03	0.01	1.0E-04	0.1	1.0E-03	0.01	1.0E-03	0.1	1	5.0E-03	1.0E-03	1.0E-03	50	0.1	0.1
7	1.0E-12	20	20	20	20	20	20	20	0.5	20	20	10	10	10	1	20	5	1.0E-04	20	20	1.0E-12	20	10	20	1	100	0.1	20	20	10
8	1.0E-12	0.1	0.1	0.1	1	0.1	0.1	0.1	0.05	0.1	0.1	1.0E-04	0.1	0.1	0.1	0.1	1	1.0E-04	0.1	0.1	1.0E-12	0.1	0.1	0.1	0.1	0.1	0.01	15	0.01	0.01
9	1.0E-12	10	10	10	10	10	10	10	0.5	10	20	5	1	1	1	10	5	1.0E-04	10	10	1.0E-12	10	5	10	1	100	0.1	10	10	5
10	1.0E-12	0.1	0.1	0.1	1	0.1	0.1	0.1	0.05	0.1	0.1	0.01	0.1	0.1	0.1	0.1	1	1.0E-04	0.1	0.1	1.0E-12	0.1	0.1	0.1	0.1	0.1	0.01	0.01	0.01	0.01
11	1.0E-12	5	5	5	1	5	5	5	0.5	5	5	5	1	1	1	10	1	1.0E-04	5	5	1.0E-12	10	1	5	1	50	0.1	5	5	2
12	1.0E-12	0.1	0.1	0.1	1	0.1	0.1	0.1	0.05	0.1	0.1	0.01	0.1	0.1	0.01	0.1	1	1.0E-04	0.1	0.1	1.0E-12	10	0.1	0.01	0.01	0.1	0.01	0.1	0.1	0.5
13	1.0E-12	1	1	1	1.0E-03	1	1	1	0.1	1	1	5	1	0.5	0.01	1	0.01	1.0E-04	1	1	1.0E-12	1	1	1	0.01	5	0.1	5	5	2

Vertical Anisotropy Ratio in Each Zone (unitless)																														
Layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
4	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
5	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
6	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
7	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
8	10	10	10	10	10	10	10	10	10	10	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
12	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
13	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Storage Coefficient in Each Zone (unitless)																														
Layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
2	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
6	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
7	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
8	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
9	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
10	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
11	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
12	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002
13	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.0005	0.0005	0.002	0.001	0.0005	0.0005	0.0005	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.001	0.001	0.002

Table 4-6. Values Input for Parameters (by Zone) During Sensitivity Analysis

	Specific Yield in Each Zone (unitless)																													
Layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.15	0.15	0.15	0.15	0.15
2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15
3	0.15	0.15	0.15	0.15	0.05	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.15	0.15	0.15	0.15	0.15
4	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15
5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.1	0.1	0.15	0.15	0.15	0.15	0.15
6	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
7	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1
8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1
10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1
12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
13	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	0.1	0.1

Table 4-7. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Horizontal Hydraulic Conductivity

Layer	Zone	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
1	4	Low	High	II
1	5	Low	High	II
1	11	High	High	VI
1	13	Low	High	II
1	20	Low	High	II
2	11	Low	High	II
2	13	Low	High	II
3	6	Low	High	II
3	9	High	High	VI
3	10	High	Low	III
3	11	Low	High	II
3	24	High	Low	III
5	5	Low	High	II
5	6	Low	High	II
5	9	High	High	VI
5	10	High	High	VI
6	4	High	High	VI
6	6	Low	High	II
6	7	High	High	VI
6	11	High	High	VI
6	13	High	High	VI
6	19	High	High	VI
7	2	Low	High	II
7	4	High	High	VI
7	5	High	High	VI
7	6	High	Low	III
7	7	High	Low	III
7	9	High	Low	III
7	10	High	High	VI
7	11	High	Low	III
7	12	High	High	VI
7	19	Low	High	II
9	4	High	High	VI
9	5	High	High	VI
9	6	Low	High	II
9	10	High	Low	III
9	11	High	Low	III
9	12	High	Low	III
9	20	Low	High	II
9	28	High	Low	III
10	28	High	Low	III
11	12	High	Low	III
13	12	High	Low	III

Table 4-8. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Vertical Hydraulic Conductivity

Layer	Zone	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
2	5	High	Low	III
2	11	Low	High	II
4	5	High	Low	III
6	4	High	High	VI
6	6	Low	High	II
6	7	High	High	VI
6	11	High	High	VI
6	13	High	High	VI
6	19	High	High	VI
7	6	Low	High	II
7	12	High	High	VI
12	12	High	Low	III

Table 4-9. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Storage Coefficient

Layer	Zone	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
4	9	Low	High	II
5	9	Low	High	II
8	12	High	Low	III
9	12	High	Low	III
10	12	High	Low	III
11	12	High	Low	III
13	12	High	Low	III

Table 4-10. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Specific Yield

Layer	Zone	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
2	5	High	Low	III
3	9	High	High	VI
7	12	High	Low	III

Table 4-11. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Recharge

Basin	Water Source	Land Use	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
Forebay	Precipitation	Ag.	Low	High	II
Forebay	Pumped Water	Ag.	High	High	VI
Mound	Precipitation	M&I	High	Low	III
Mound	Applied Water	M&I	High	Low	III
Mound	Pumped Water	Ag.	Low	High	II
Oxnard Plain	Precipitation	Ag.	High	High	VI
Oxnard Plain	Pumped Water	Ag.	High	High	VI
Pleasant Valley	Precipitation	Ag.	High	High	VI
Pleasant Valley	Pumped Water	Ag.	High	High	VI
West Las Posas	Precipitation	Ag.	High	High	VI
West Las Posas	Applied Water	Ag.	High	Low	III
West Las Posas	Pumped Water	Ag.	High	High	VI

Table 4-12. Input Parameters for Horizontal Flow Barriers (Faults)

ID	Fault Name	Uppermost Layer Affected	Lowest Layer Affected	Conductance
1	Round Mountain + Long Canyon	3	13	0.04
2	Sycamore Canyon	5	5	0.06
3a	Bailey in UAS	3	5	0.005, 1.0E-4
3b	Bailey in LAS	6	13	1.0E04, 1.0E-6
4	Springville	6	13	1.0E-4, 5.0E-4
5	Santa Rosa	3	13	1.0E-06
6	Hueneme Canyon	6	13	0.03
7	Montalvo	7	13	1
8	Oak Ridge in Mound and OP	7	13	1
9	Country Club	3	13	1.0E-05
10	Oak Ridge in Forebay	3	13	1.0E-04
11	North Mugu Lagoon	7	13	1.0E-04
51	Camarillo	3	13	1.0E-06
52	Santa Rosa Valley	3	13	1.0E-06
53	Las Posas + Santa Rosa	3	13	1.0E-06
75	La Loma + Fox Canyon	7	13	0.001
76	Unknown North WLP	7	13	0.001

Table 4-13. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Horizontal Flow Barrier (Fault) Conductance

Layer	Zone	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
4	Springville	High	Low	III
9	Country Club	Low	High	II
10	Oak Ridge (in Forebay)	High	High	VI
75	La Loma and Fox Canyon	High	Low	III
76	Unnamed in northern West Las Posas basin	High	Low	III

Table 4-14. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for Streambed Conductance

Stream	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
Arroyo Las Posas	High	High	VI
Conejo Creek	High	High	VI
Calleguas Creek	High	High	VI
Santa Clara River	High	High	VI

Table 4-15. Model Layers and Parameter Zones with Sensitivity Types II, III, or IV for General Head Boundary (GHB) Conductance

GHB Location	Groundwater Elevation Sensitivity	Flow Budget Sensitivity	Sensitivity Type
Santa Paula	Low	Low	I
Pacific Ocean, Layer 1	Low	High	II
Pacific Ocean, Layers 3, 5, 7, 9, & 11	High	High	VI

FIGURES

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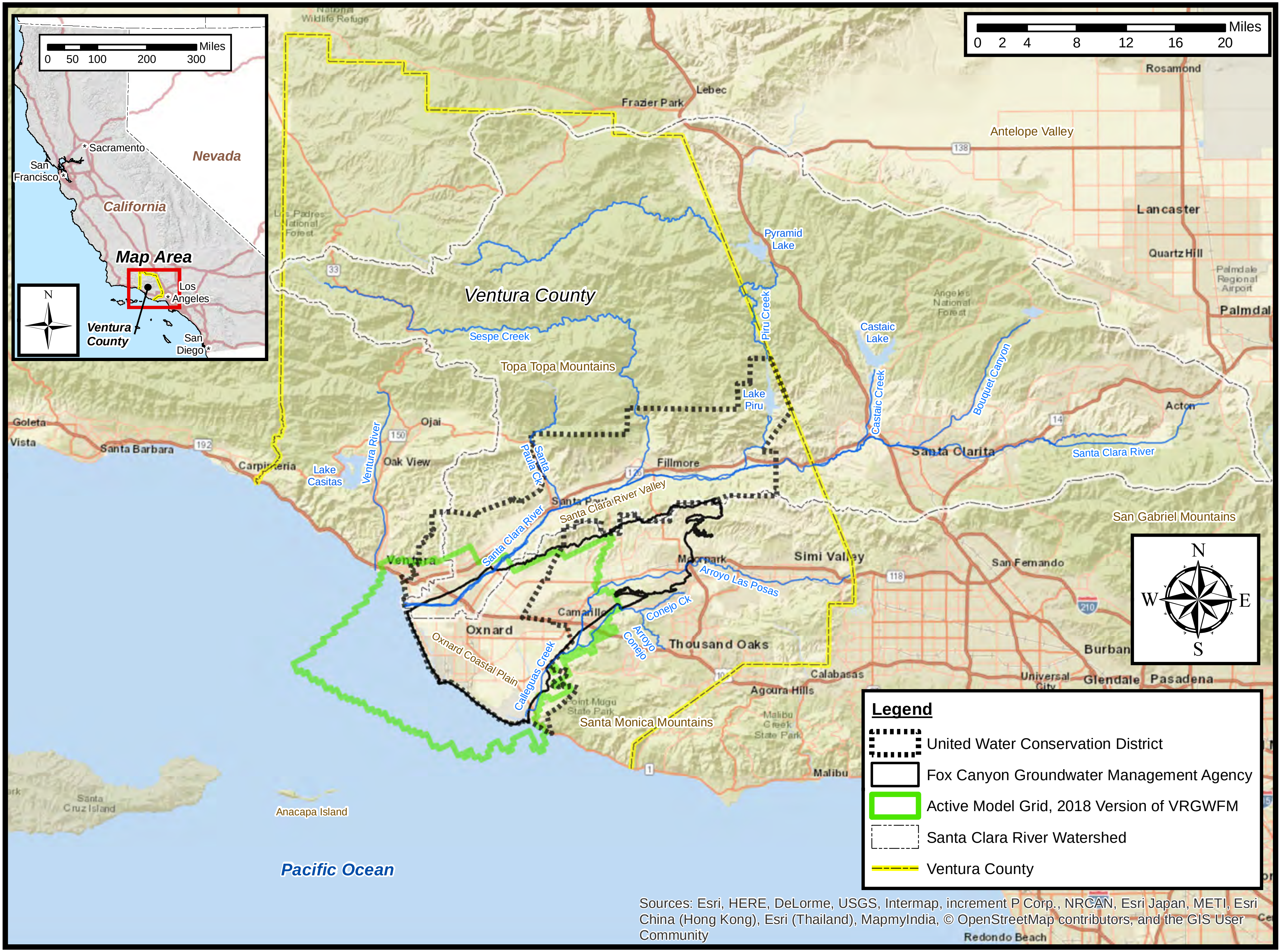


Figure 1-1. Location Map

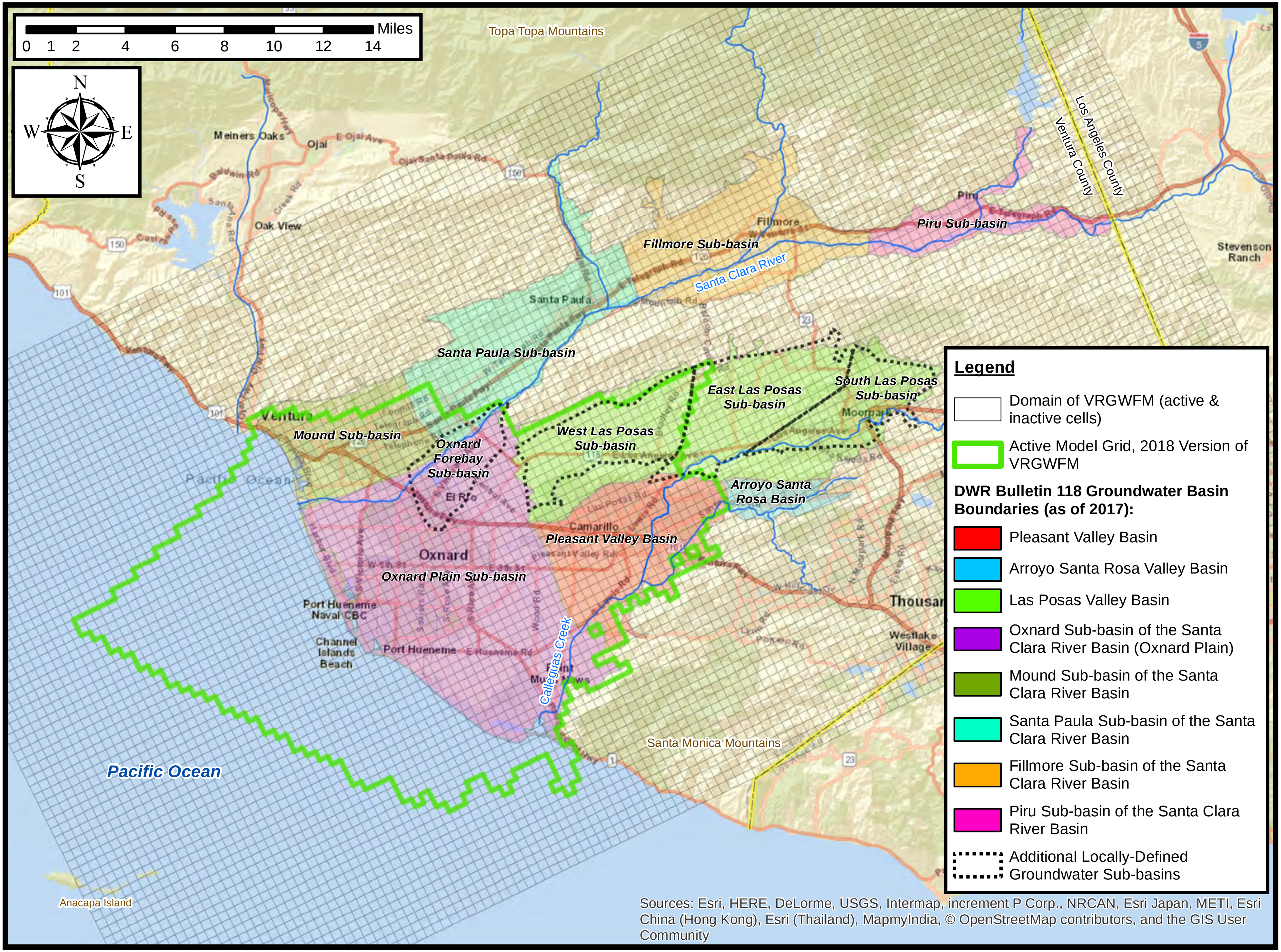


Figure 1-2. Ventura Regional Groundwater Flow Model (VRGWFM) Domain

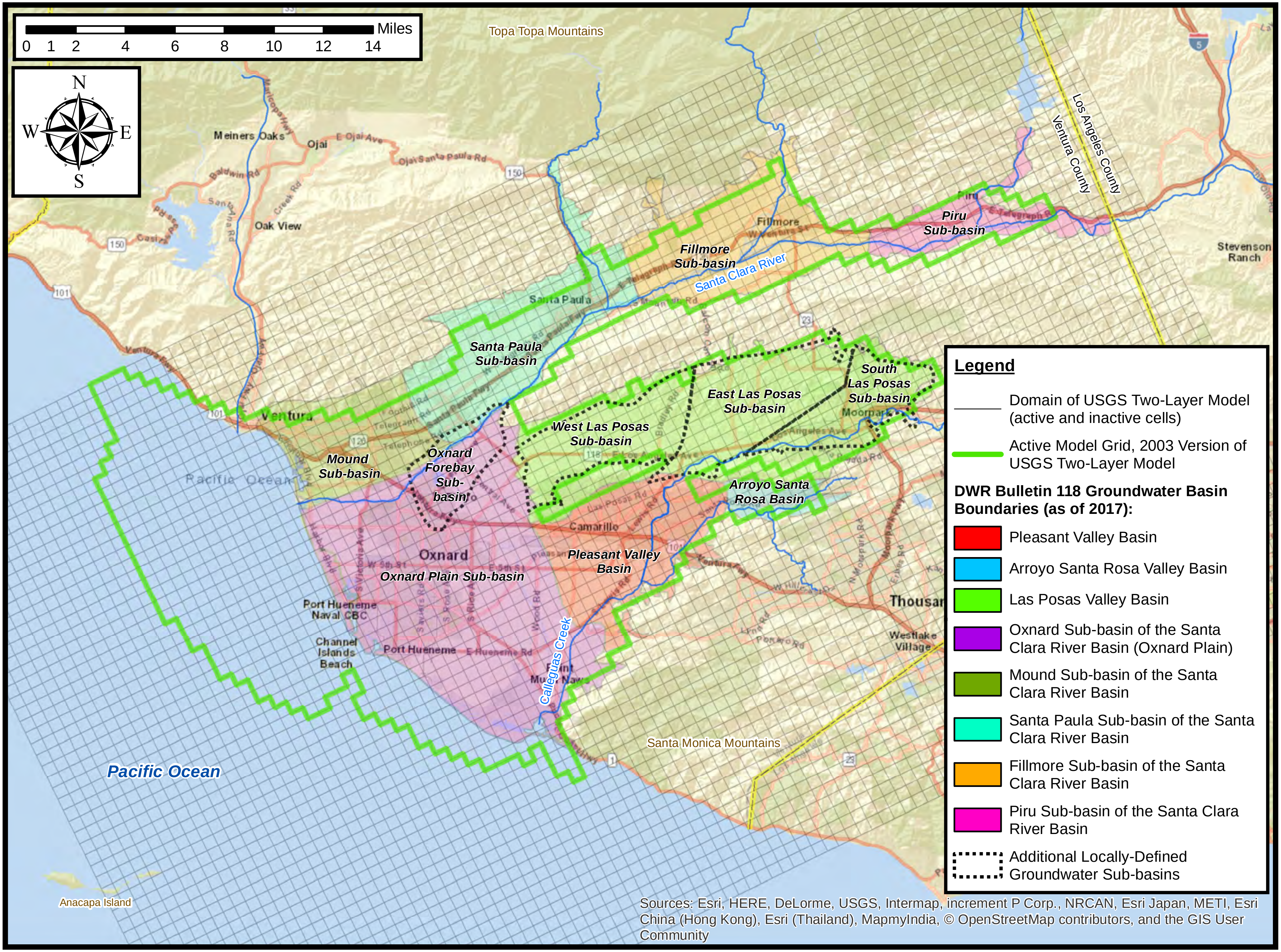


Figure 1-3. USGS Model Domain

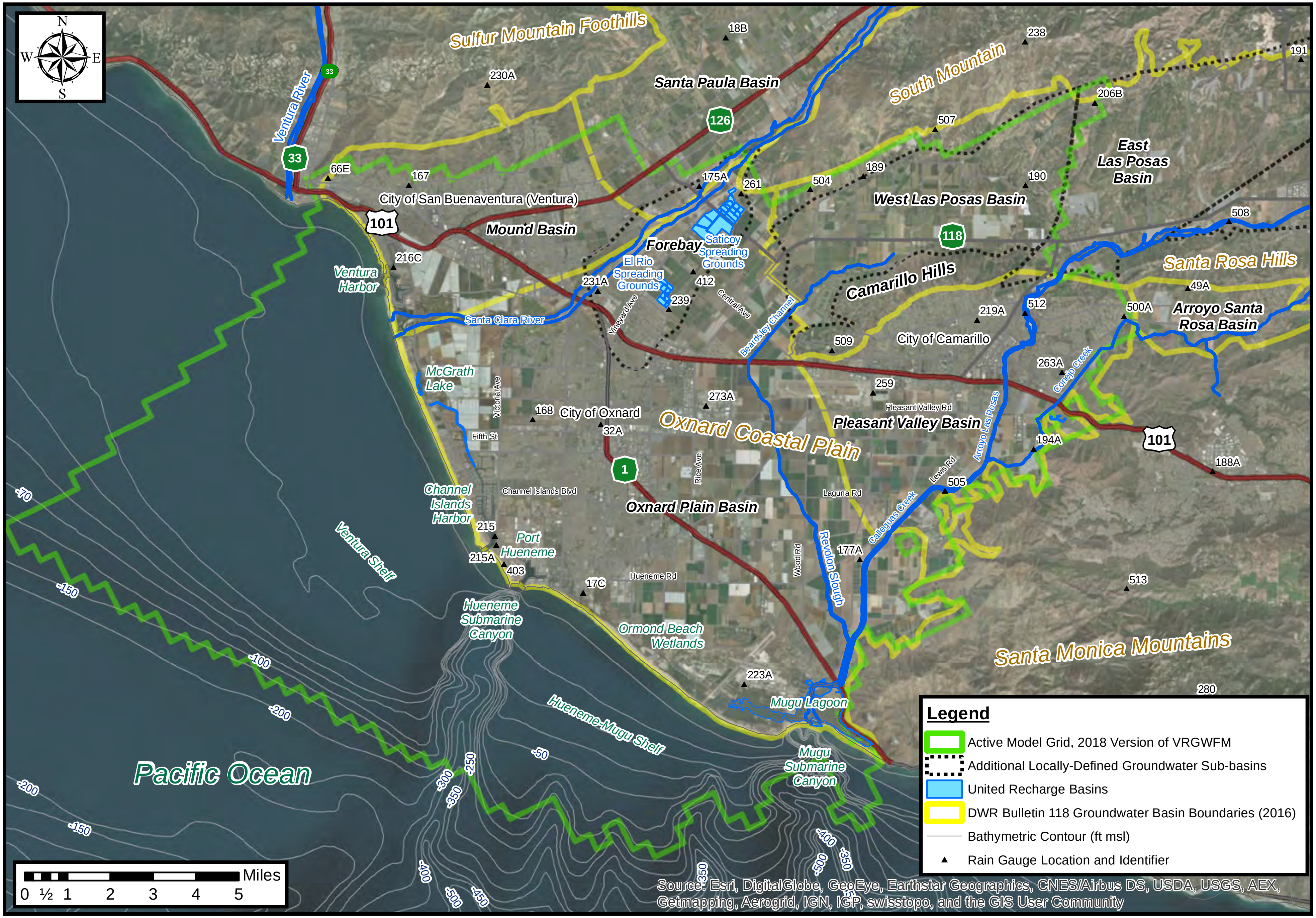


Figure 2-1. Study Area

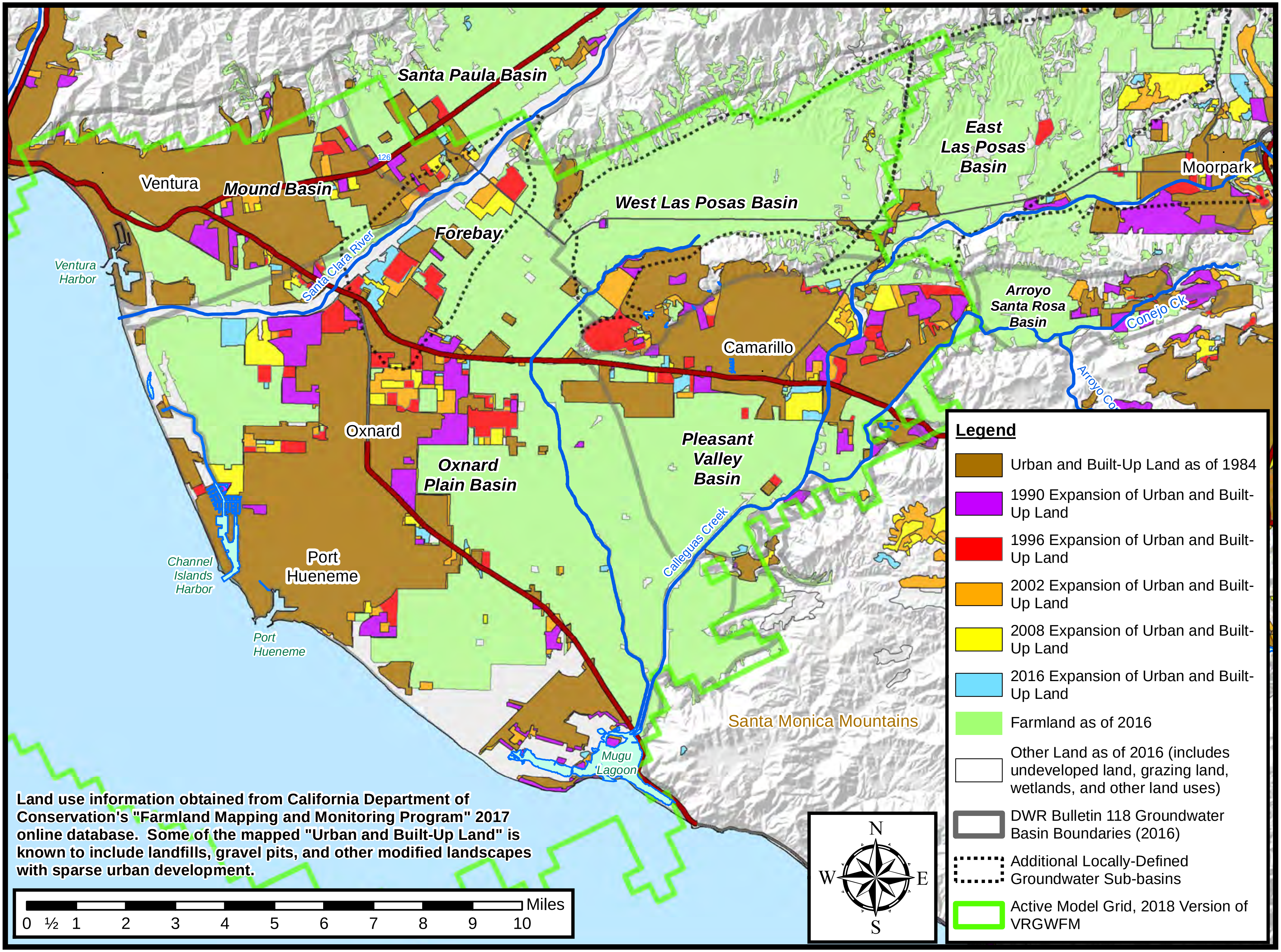


Figure 2-2. Land Use in Study Area

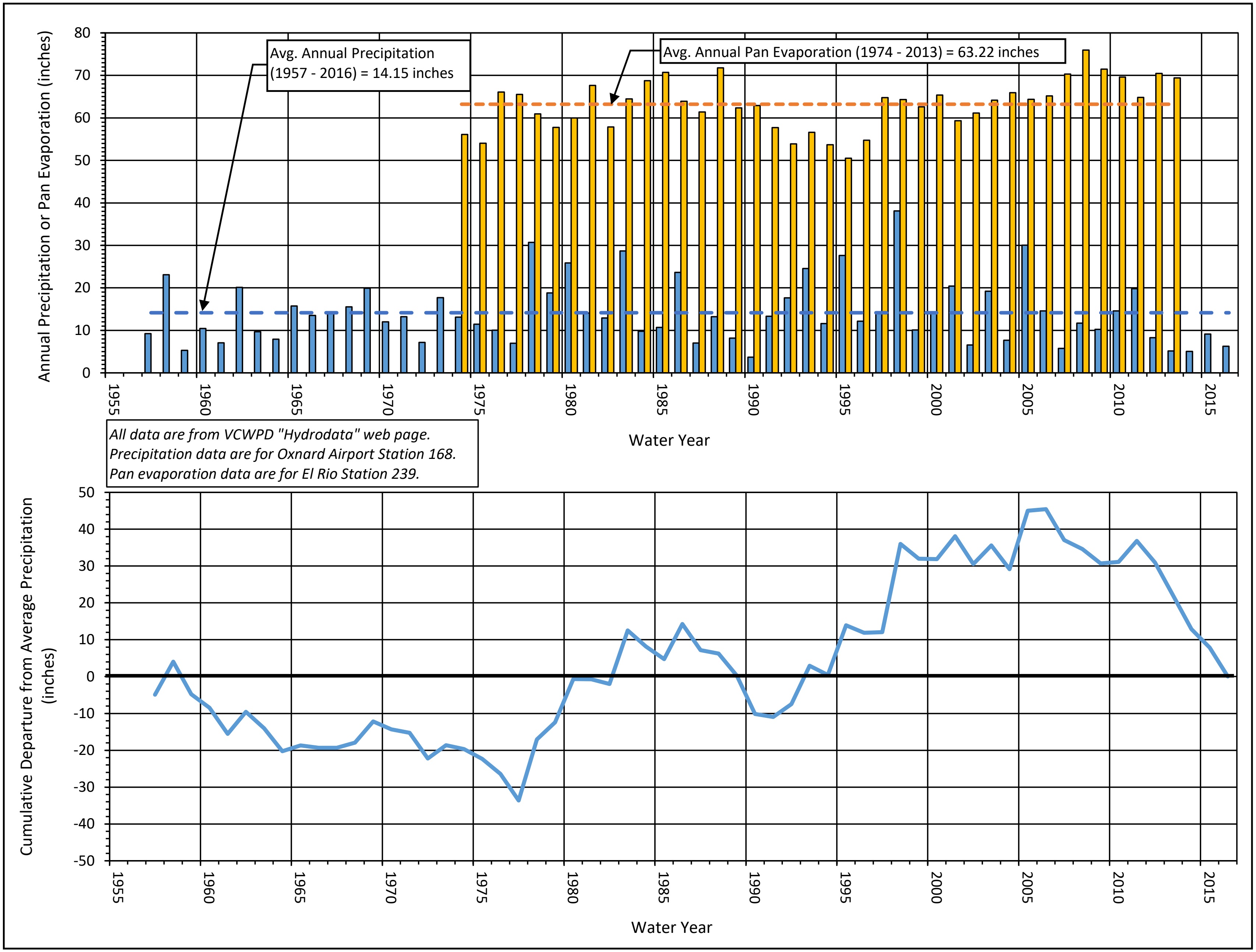


Figure 2-3. Annual Precipitation and Evaporation at Selected Locations in Study Area

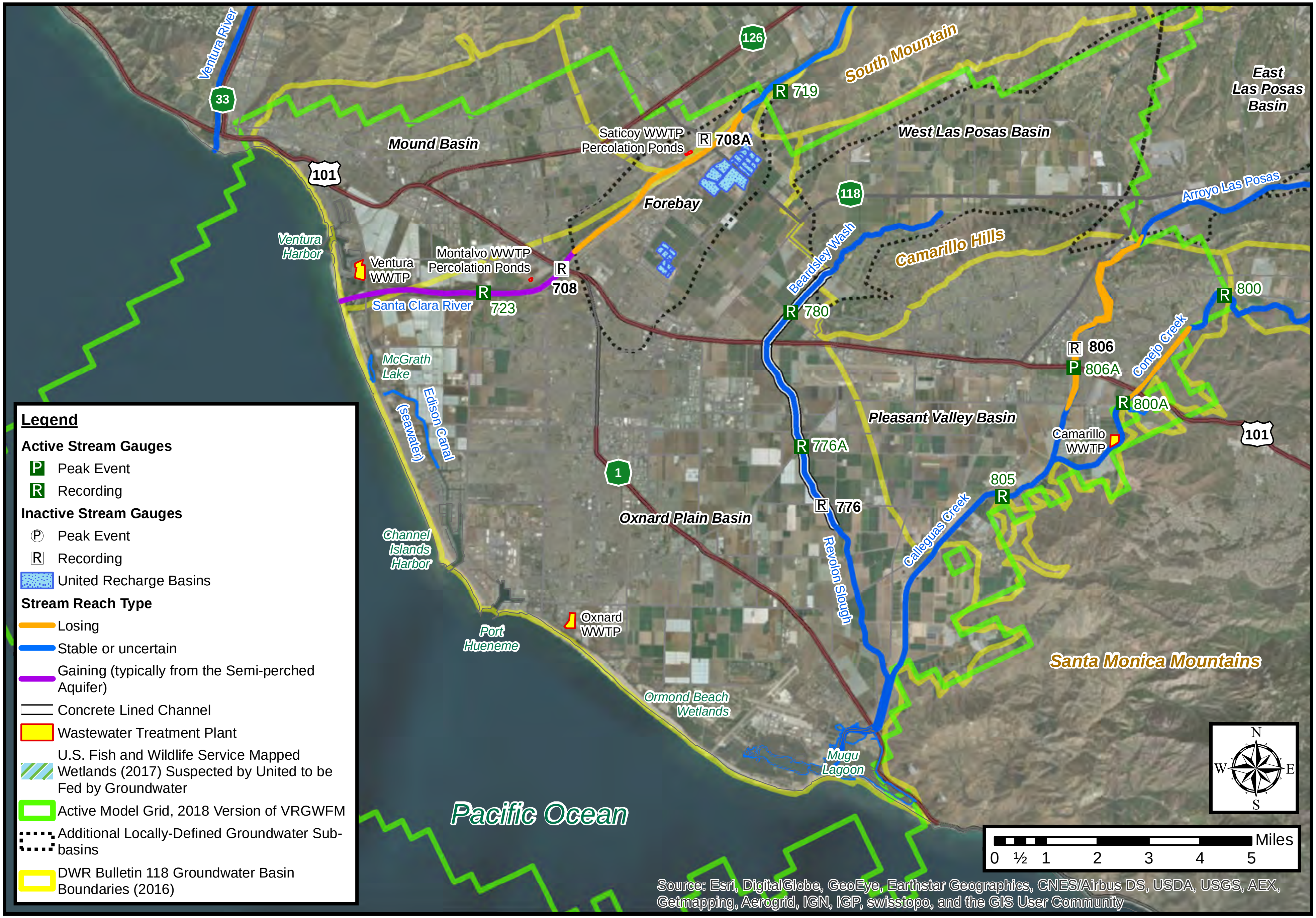
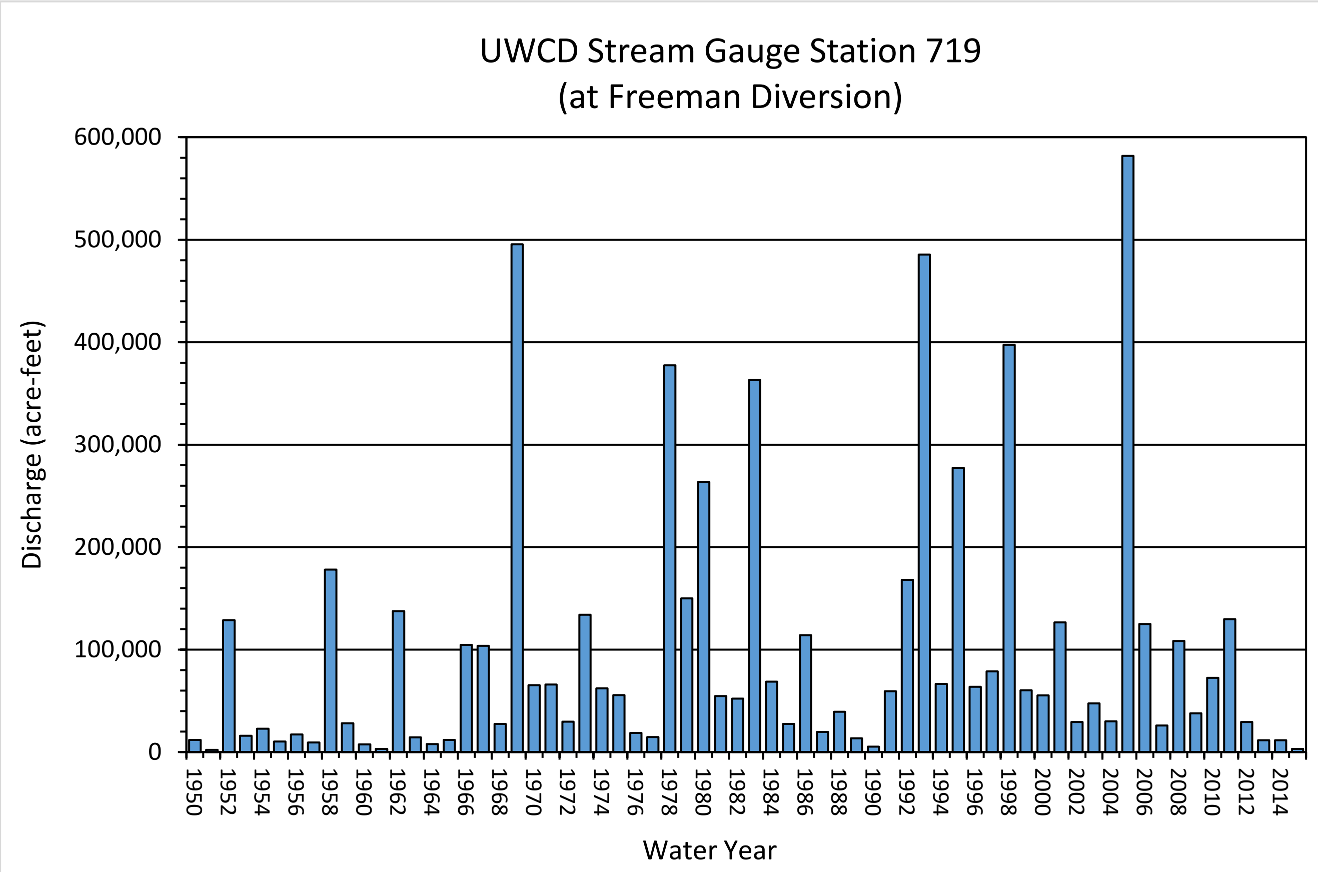


Figure 2-4. Surface Water Bodies in Study Area



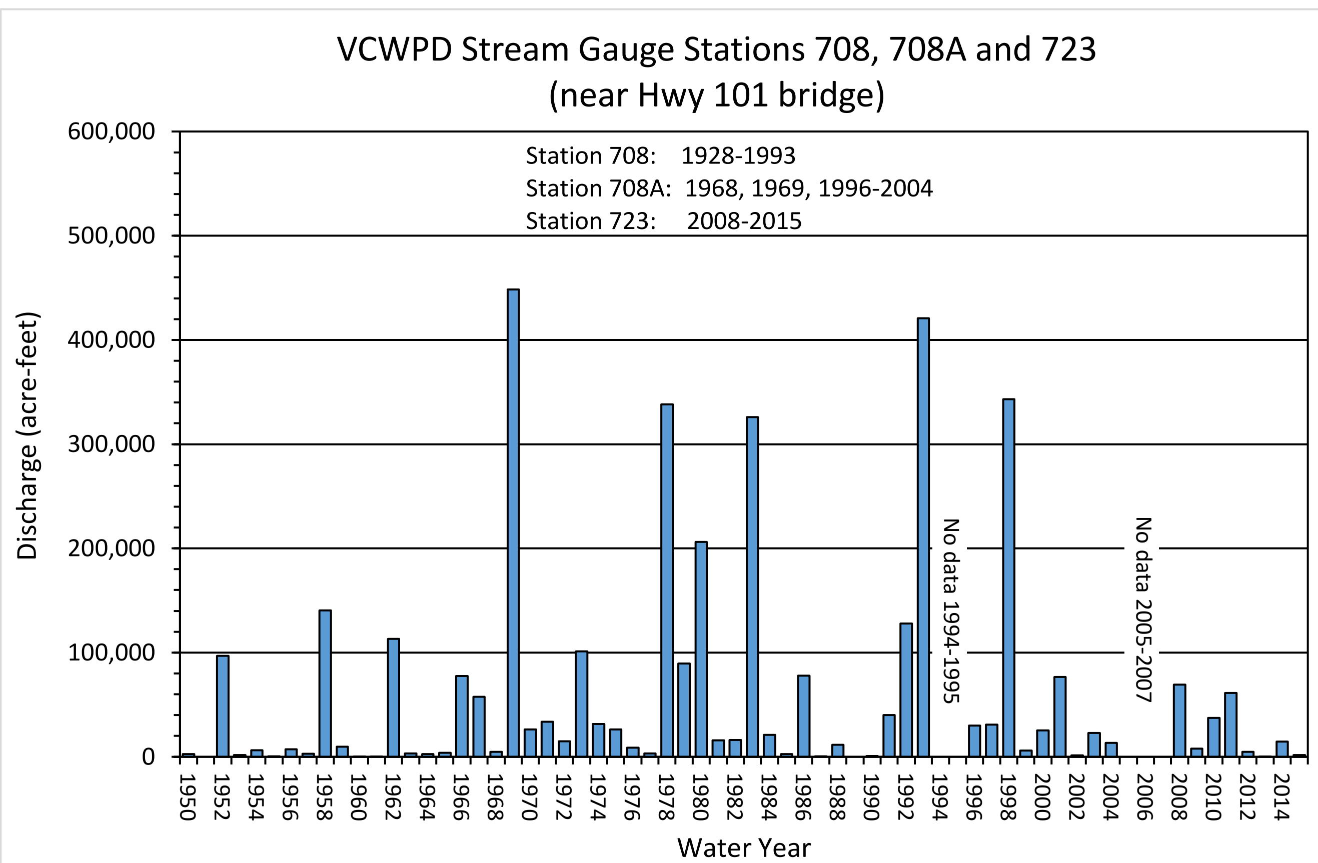
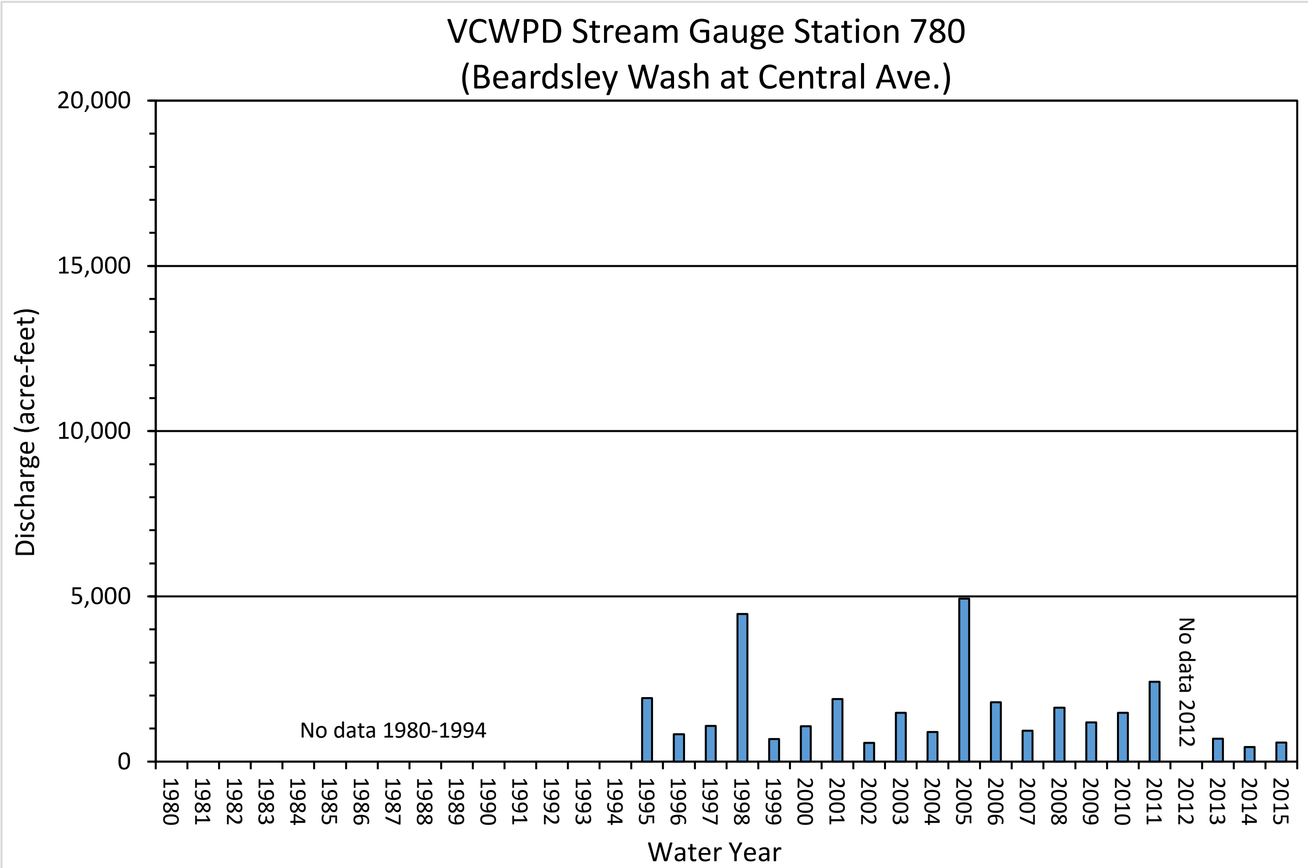


Figure 2-5. Annual Discharge in Santa Clara River



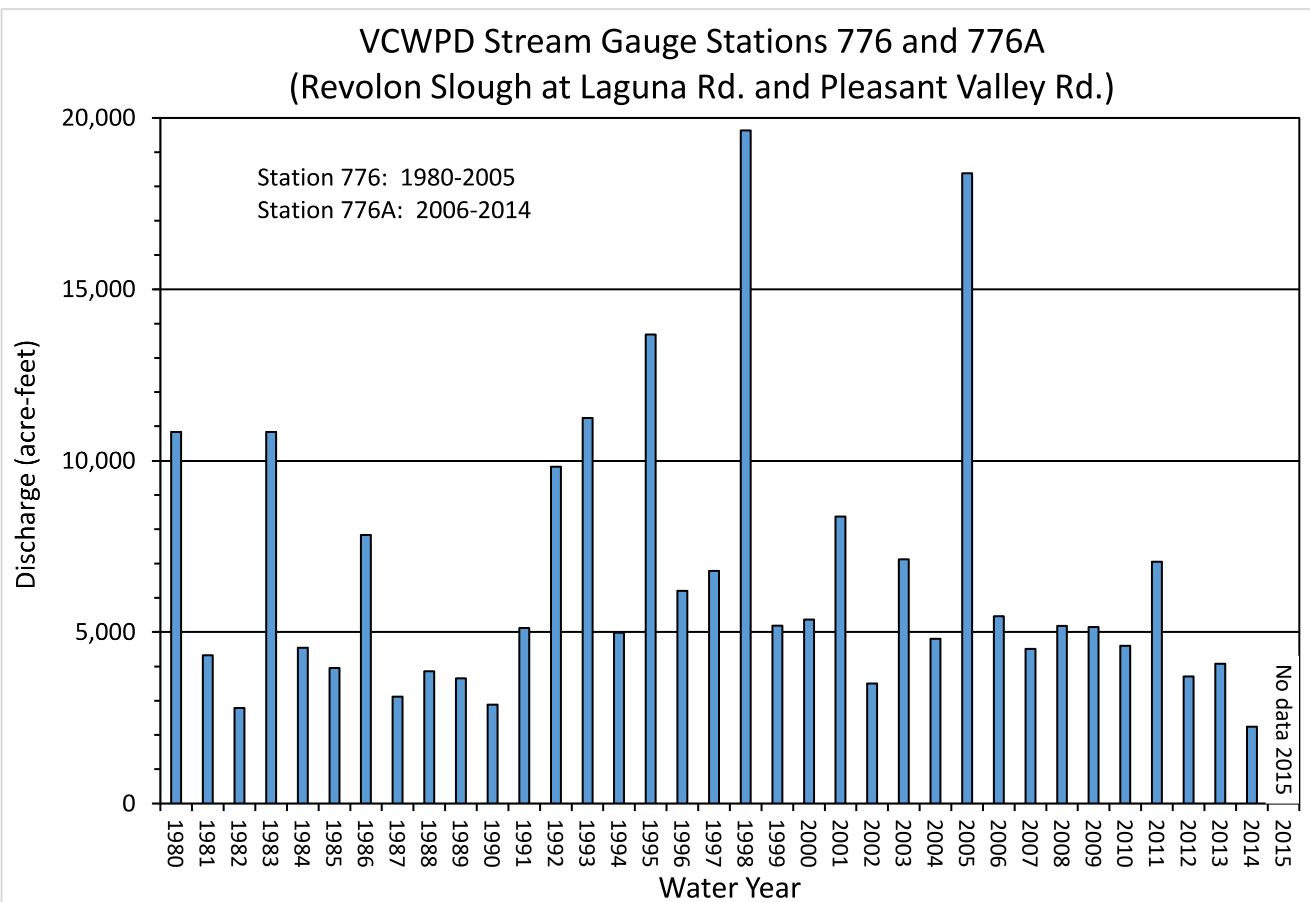


Figure 2-6. Annual Discharge in Revolon Slough/Beardsley Wash

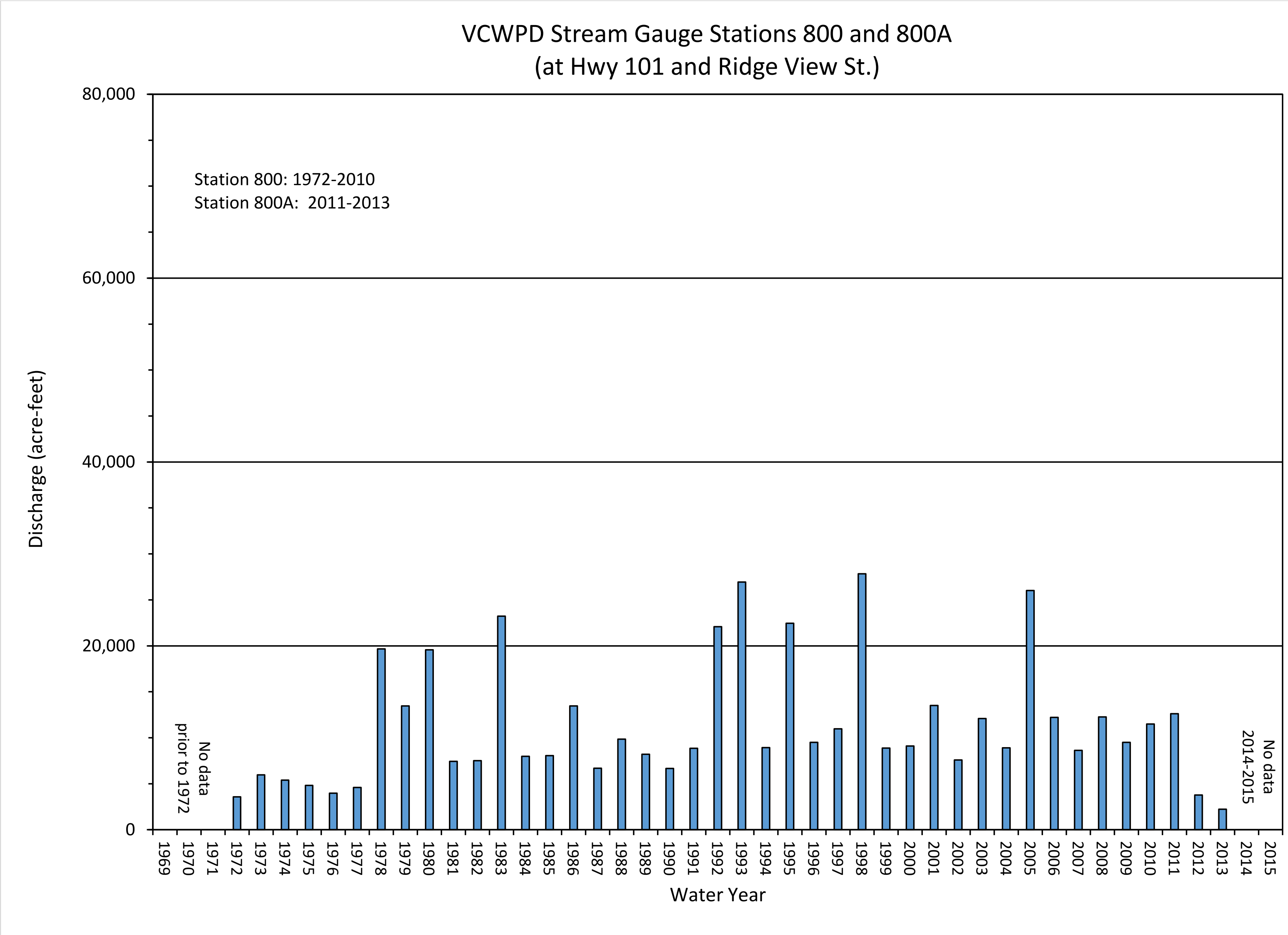


Figure 2-7. Annual Discharge in Conejo Creek

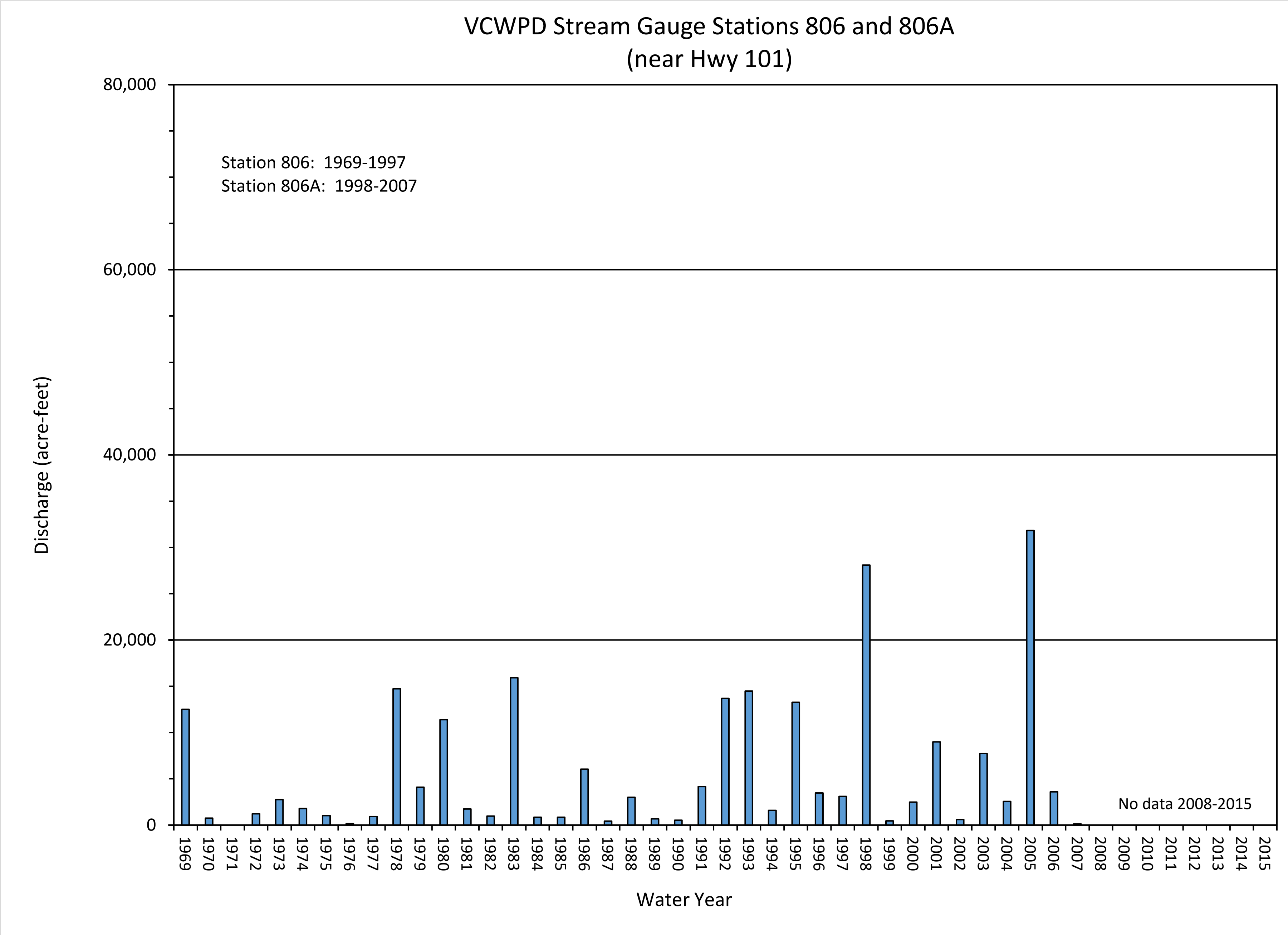


Figure 2-8. Annual Discharge in Arroyo Las Posas

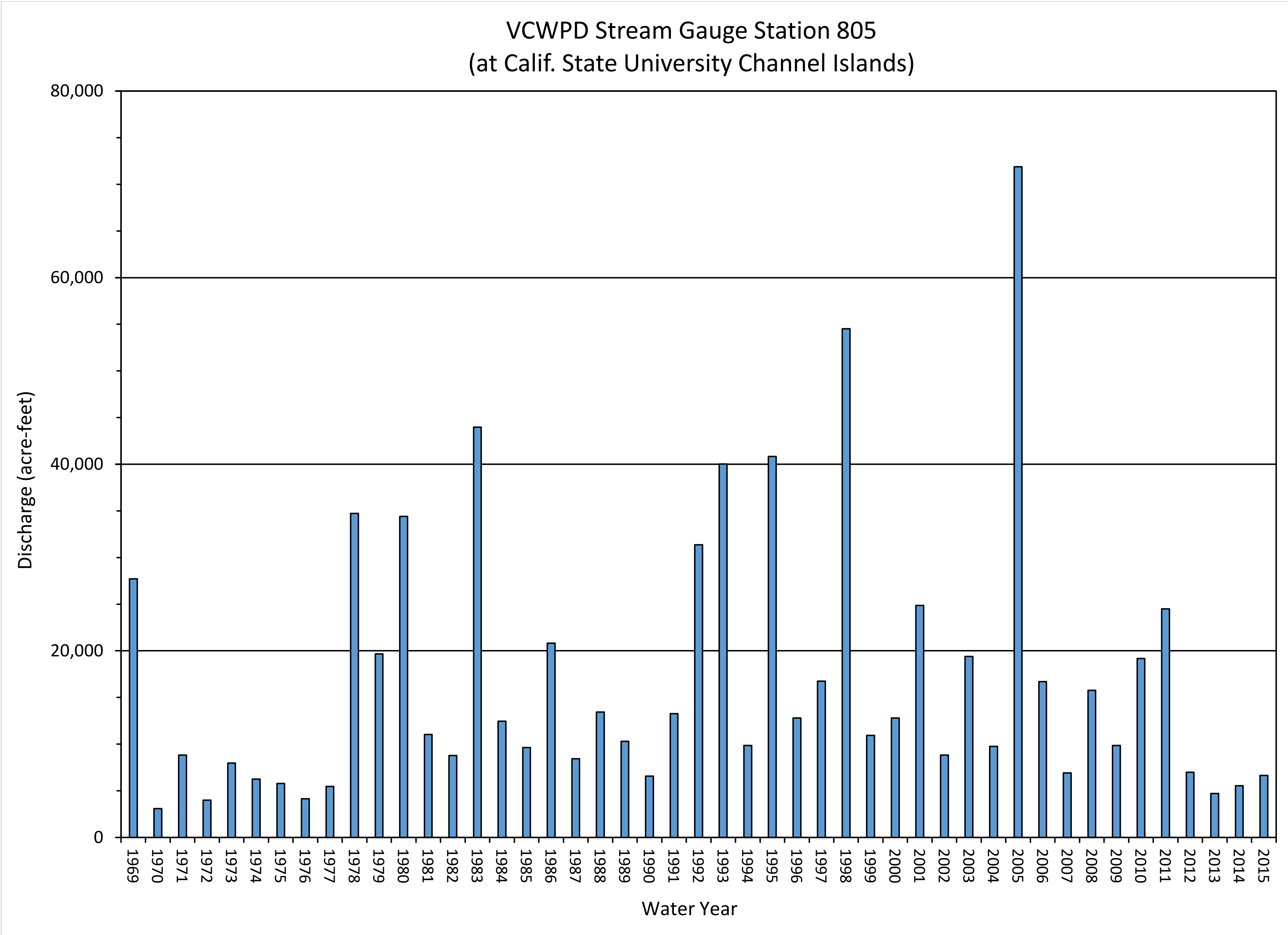


Figure 2-9. Annual Discharge in Calleguas Creek

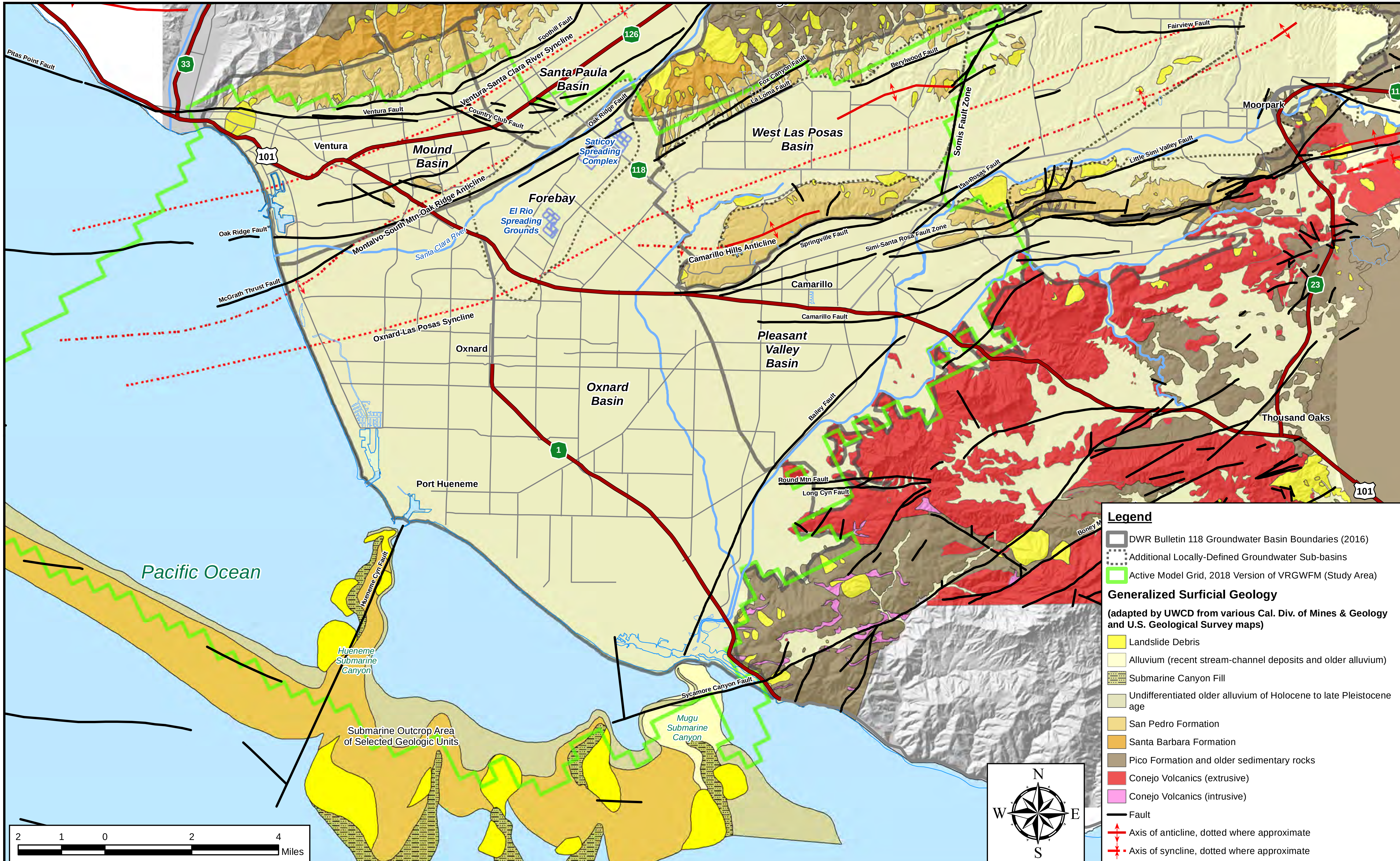
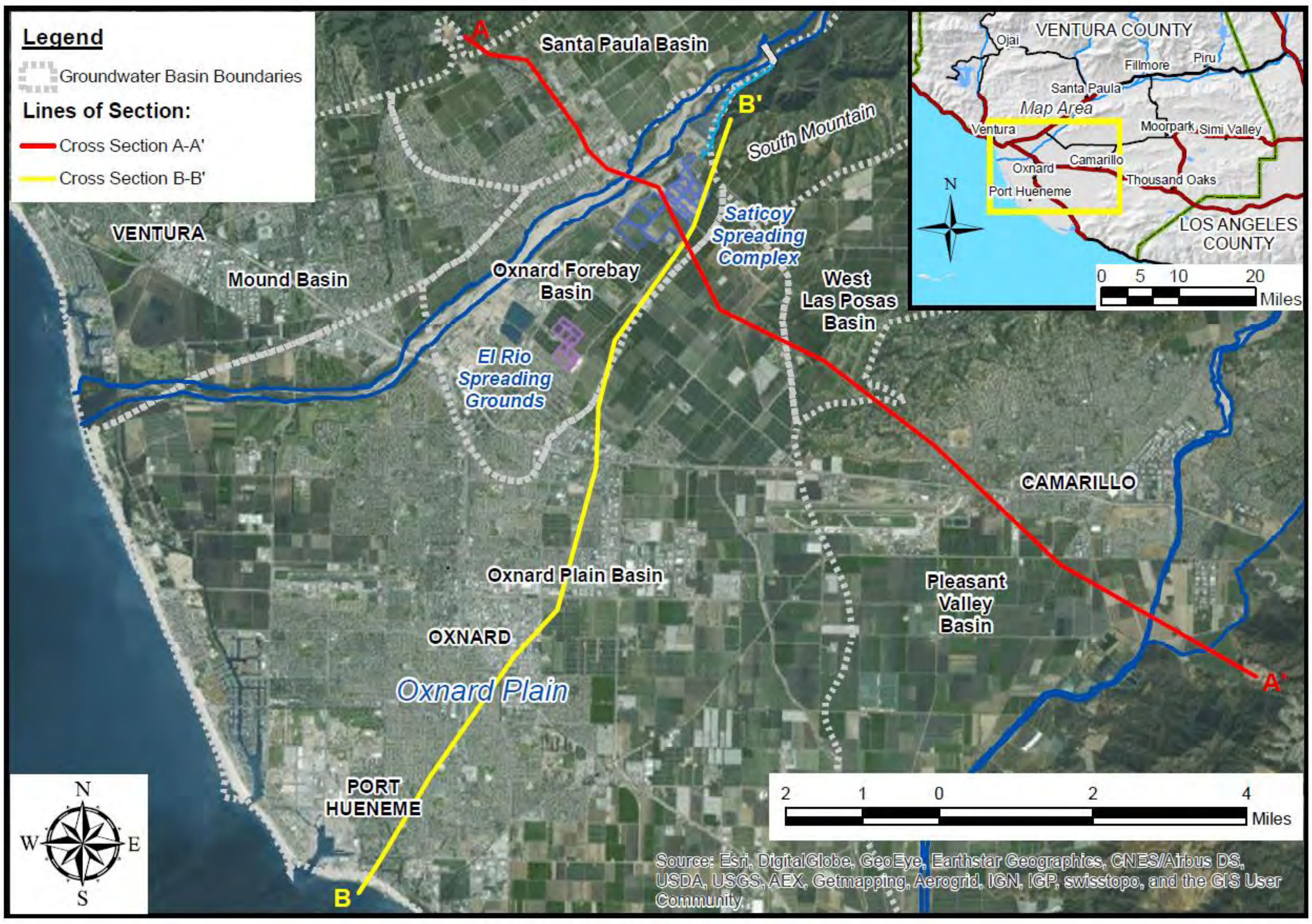
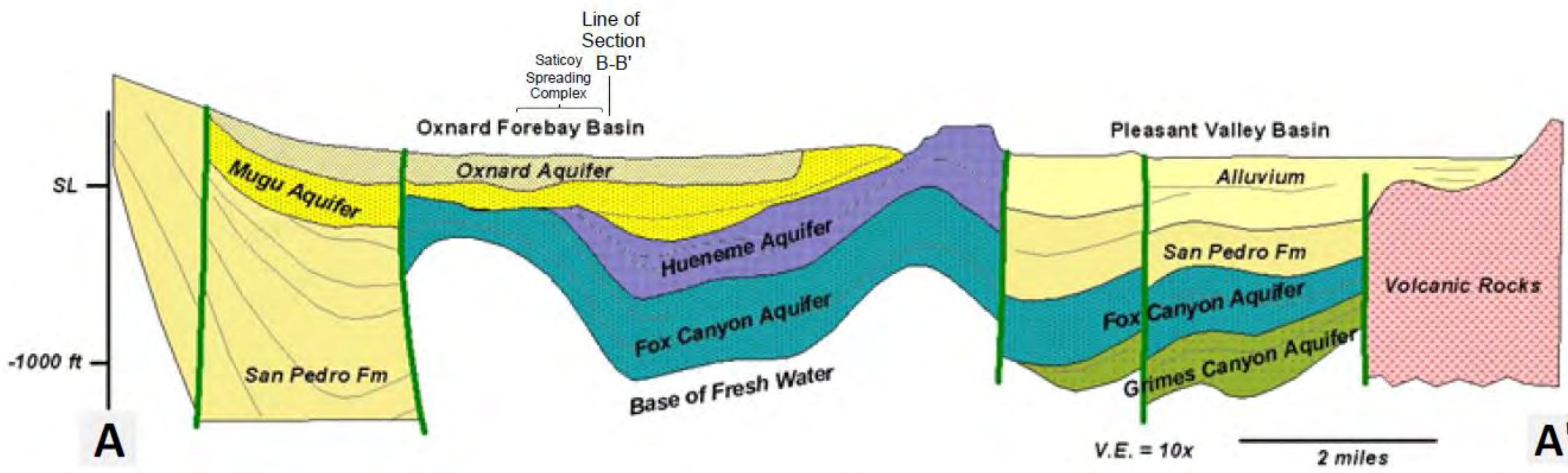


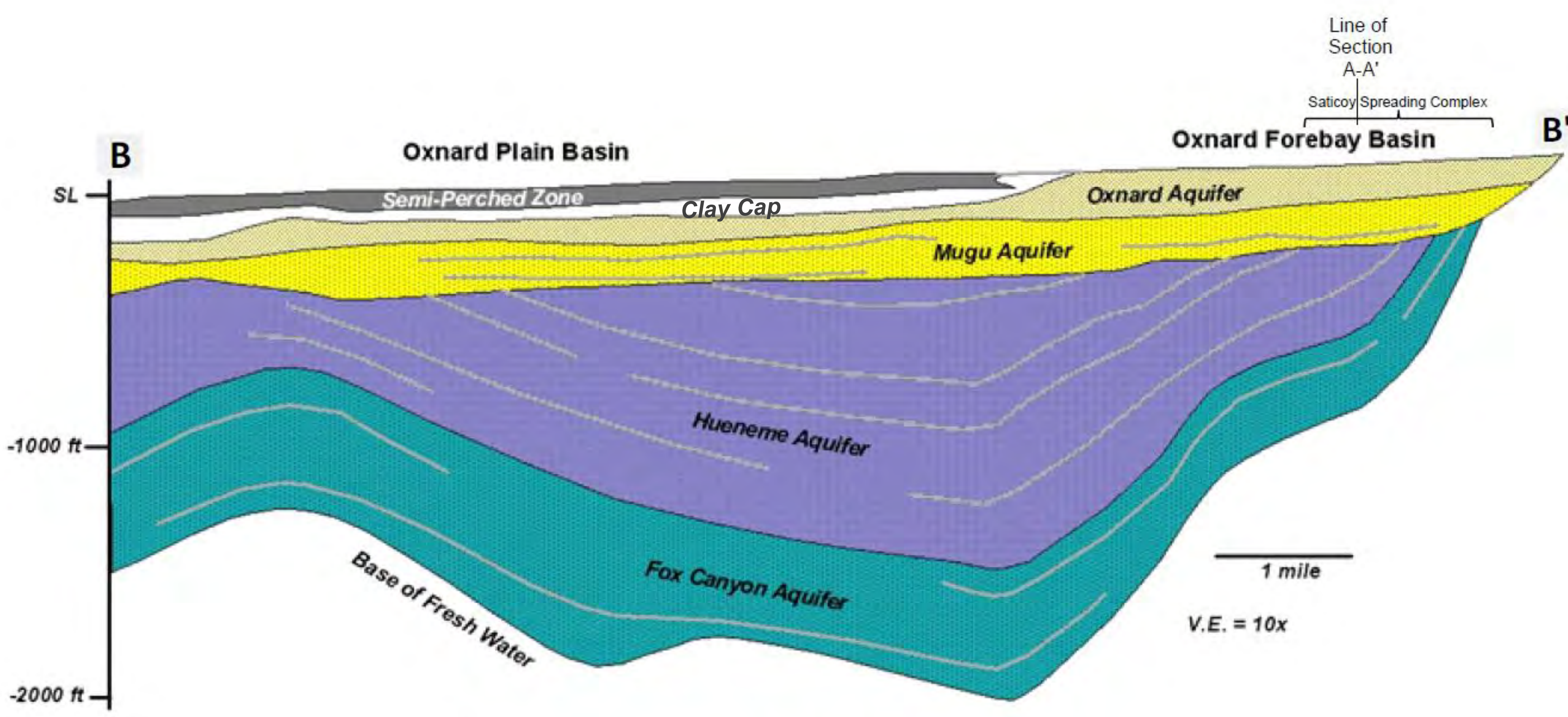
Figure 2-10. Regional Surface Geology



Cross-Section Locations



Cross-Section A-A'



Cross-Section B-B'

(Adapted from Mukae and Turner, 1975, cross-sections B-B' and C-C')

Figure 2-11. Conceptual Cross Sections A-A' and B-B'

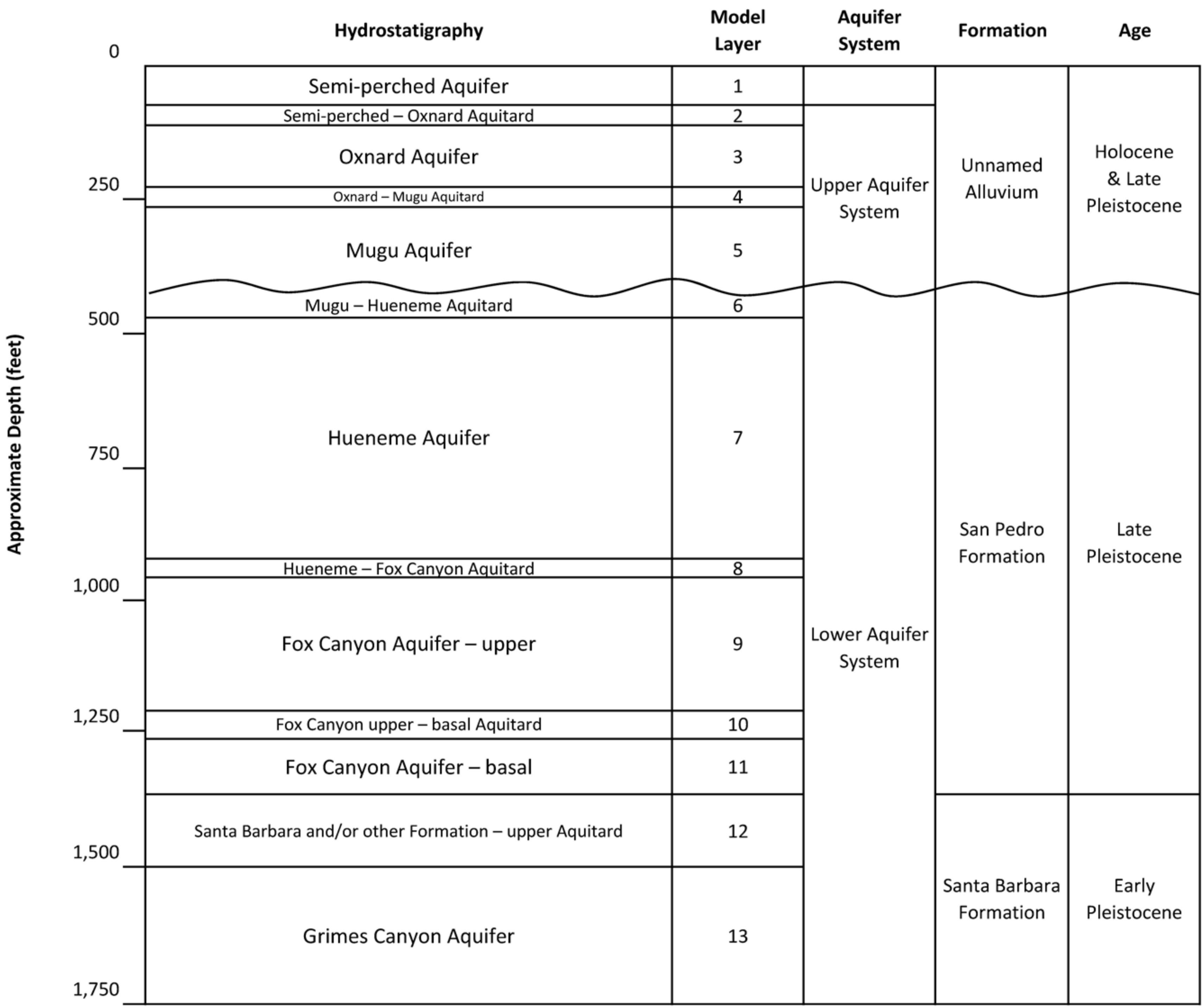


Figure 2-12. Major Hydrostratigraphic Units in Study Area

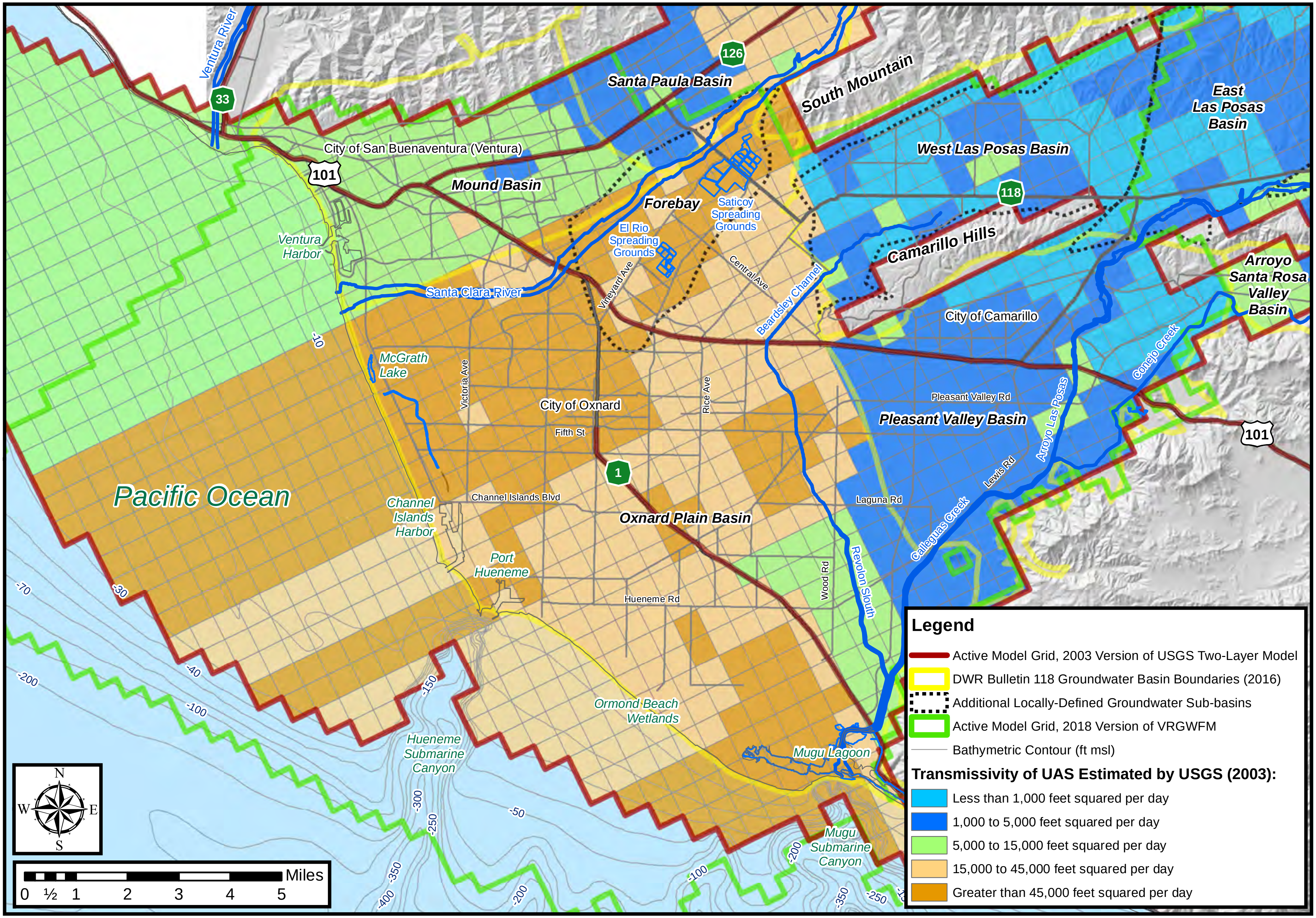


Figure 2-13. Transmissivity Estimated by the USGS for the Upper Aquifer System

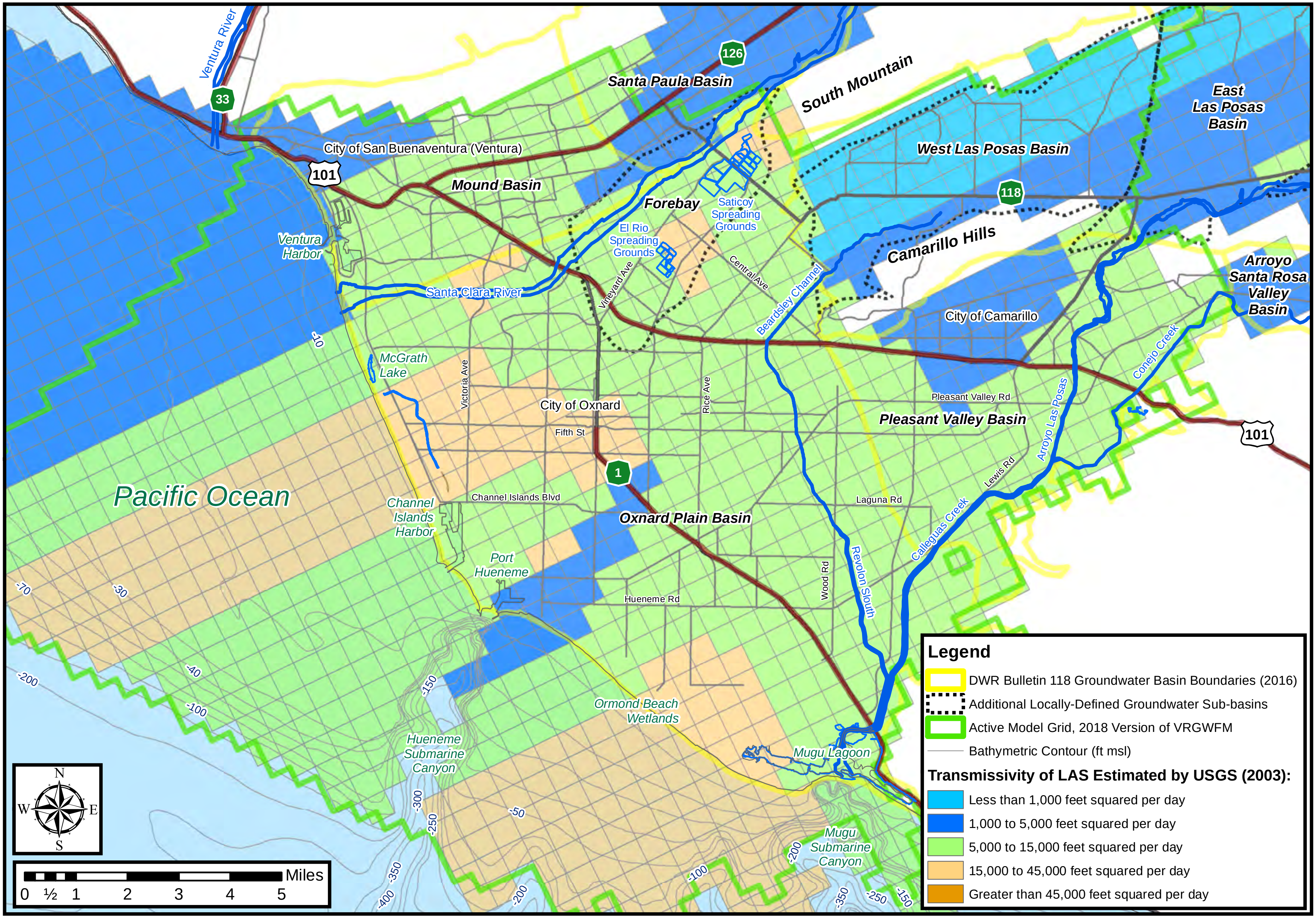


Figure 2-14. Transmissivity Estimated by the USGS for the Lower Aquifer System

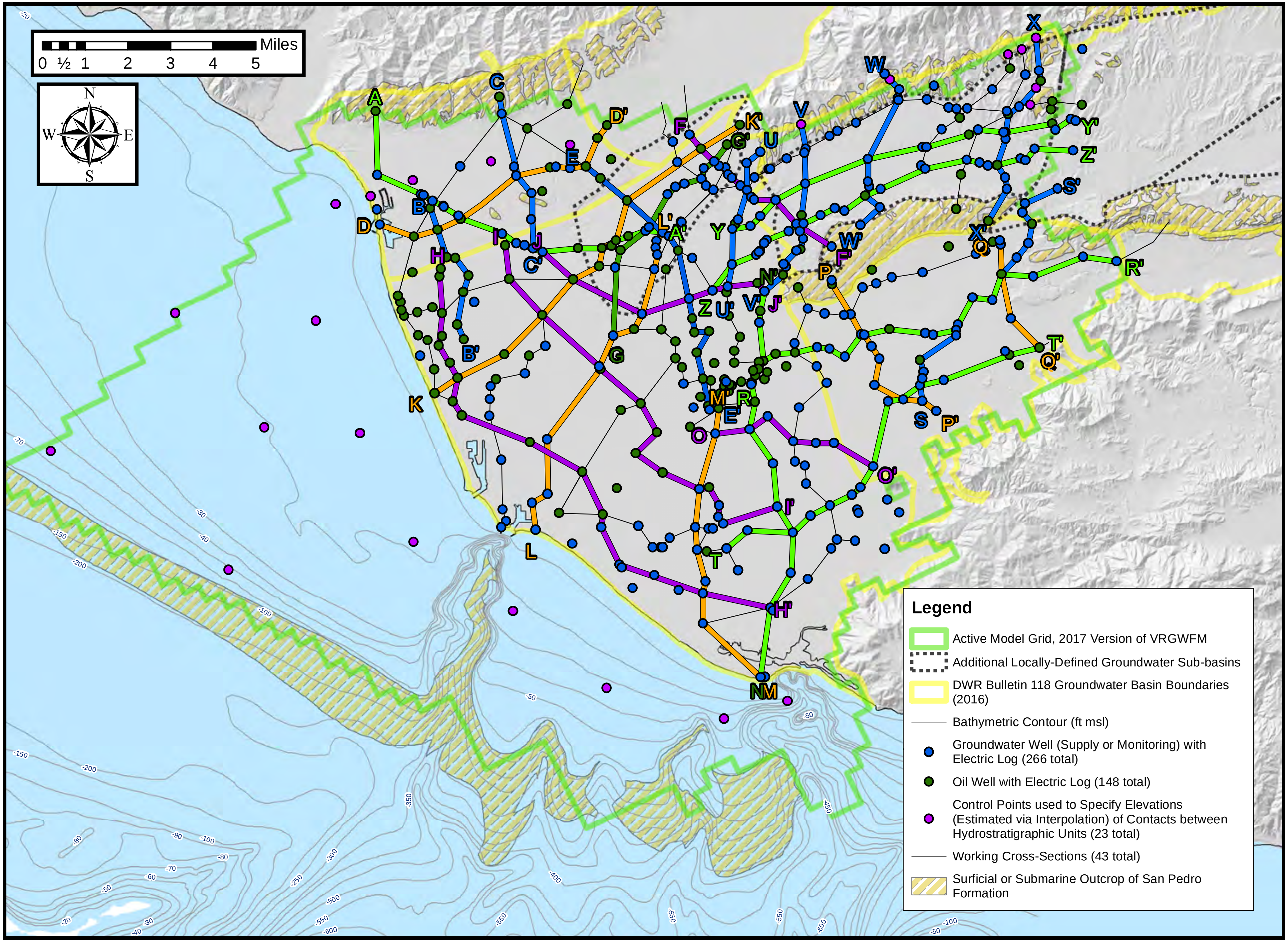


Figure 2-15. Locations of Boring Logs and Cross Sections Used to Update Hydrostratigraphic Conceptual Model

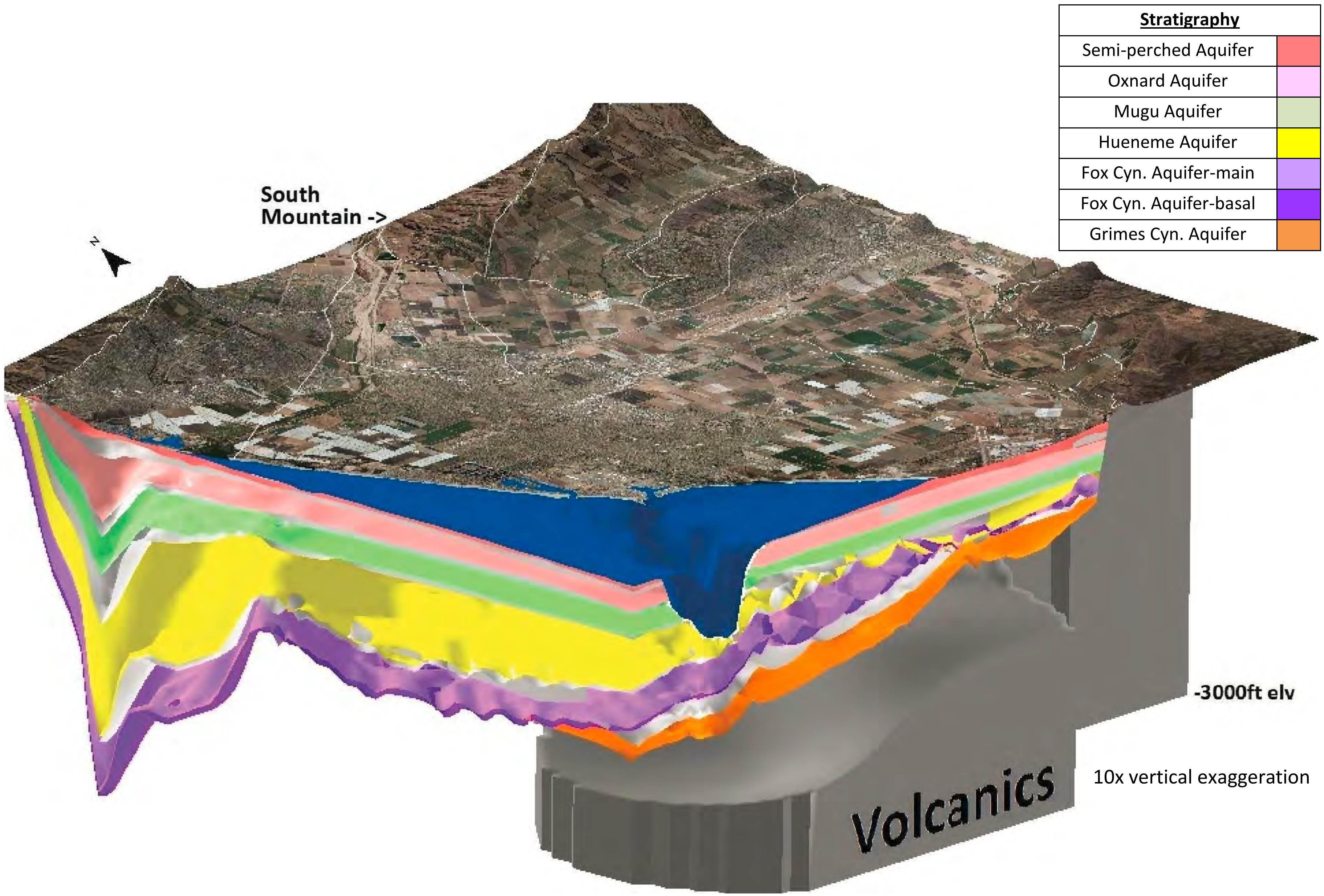


Figure 2-16. Three-Dimensional Representation of Updated Hydrostratigraphic Conceptual Model

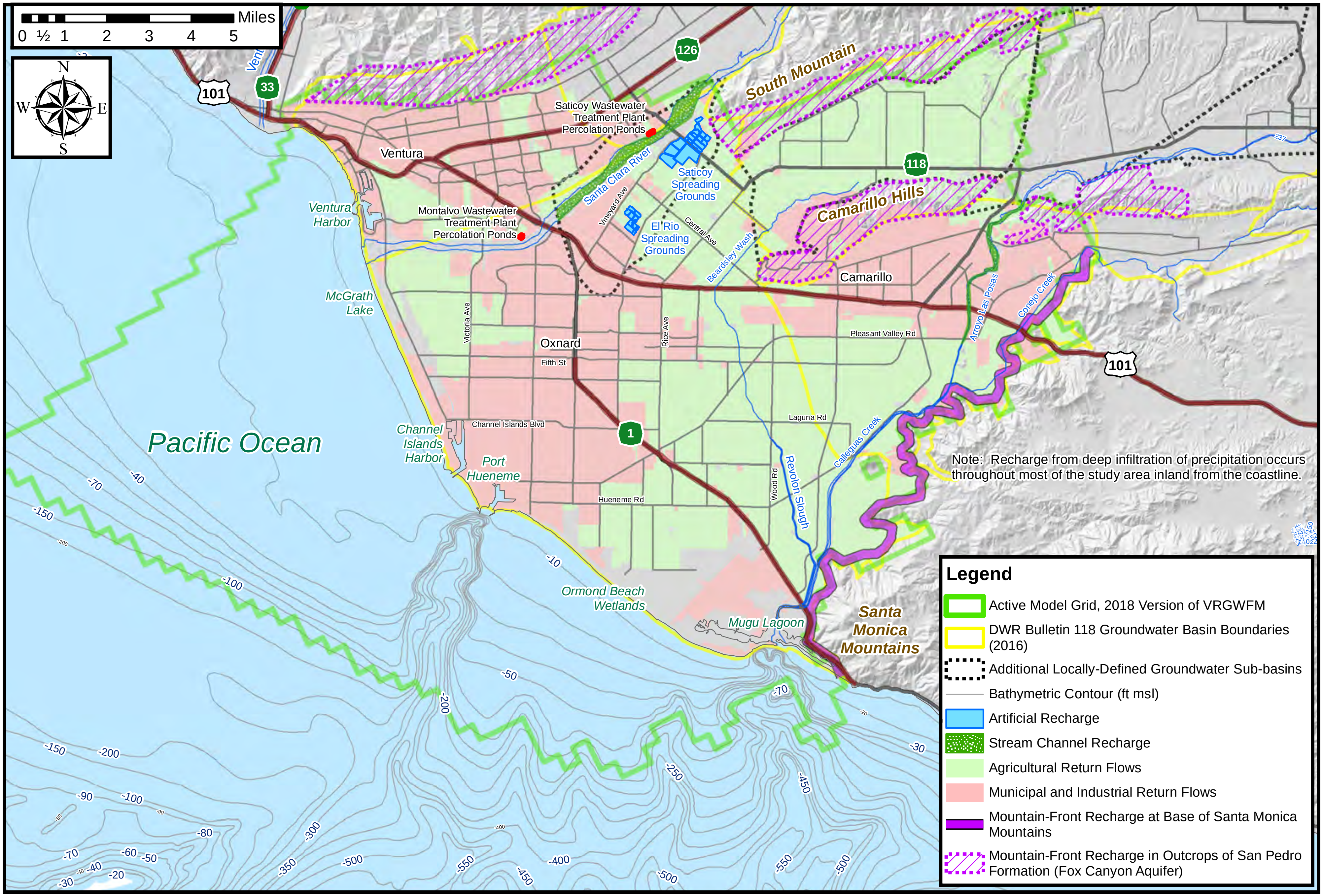


Figure 2-17. Areas of Groundwater Recharge in Study Area

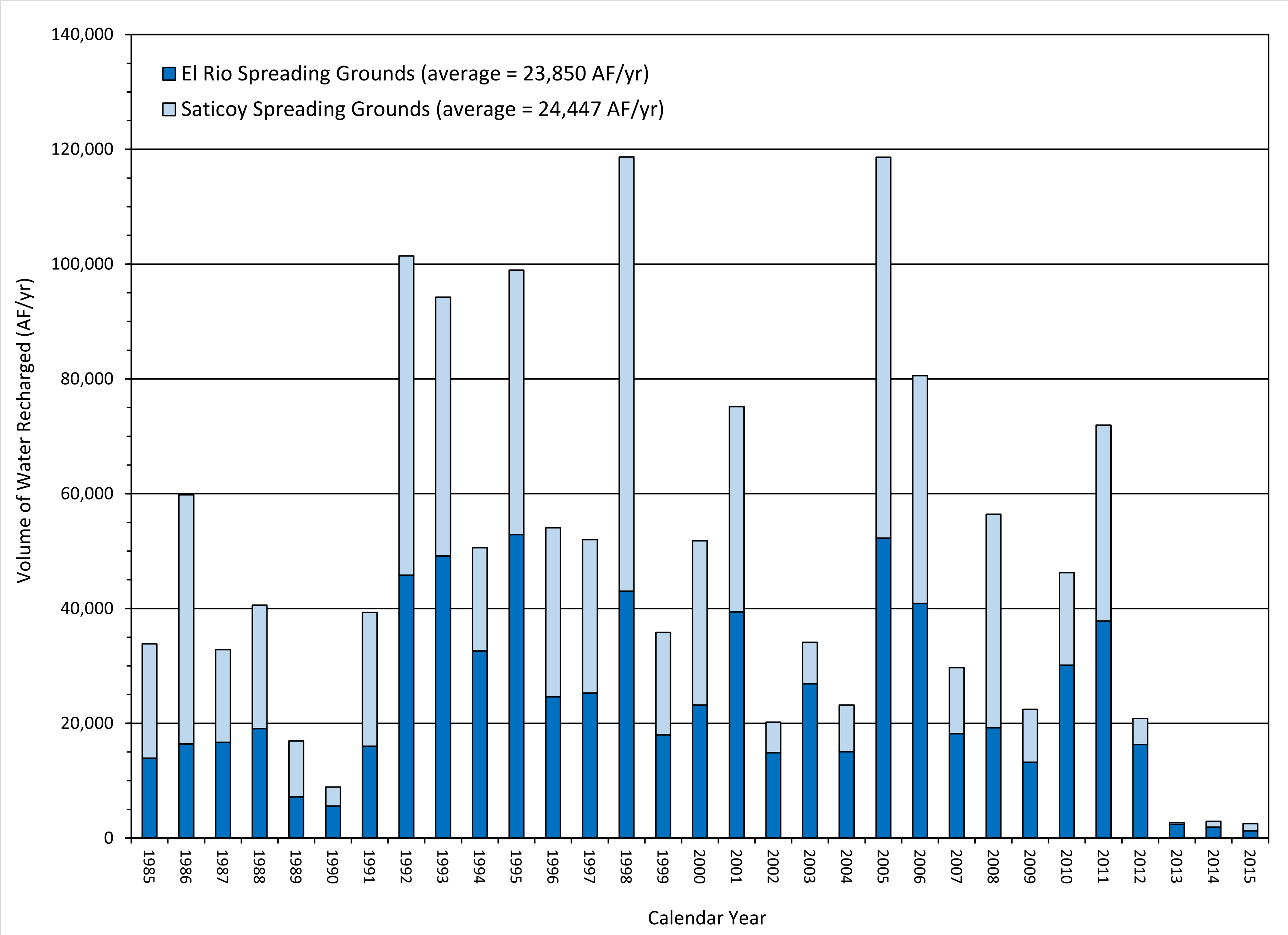
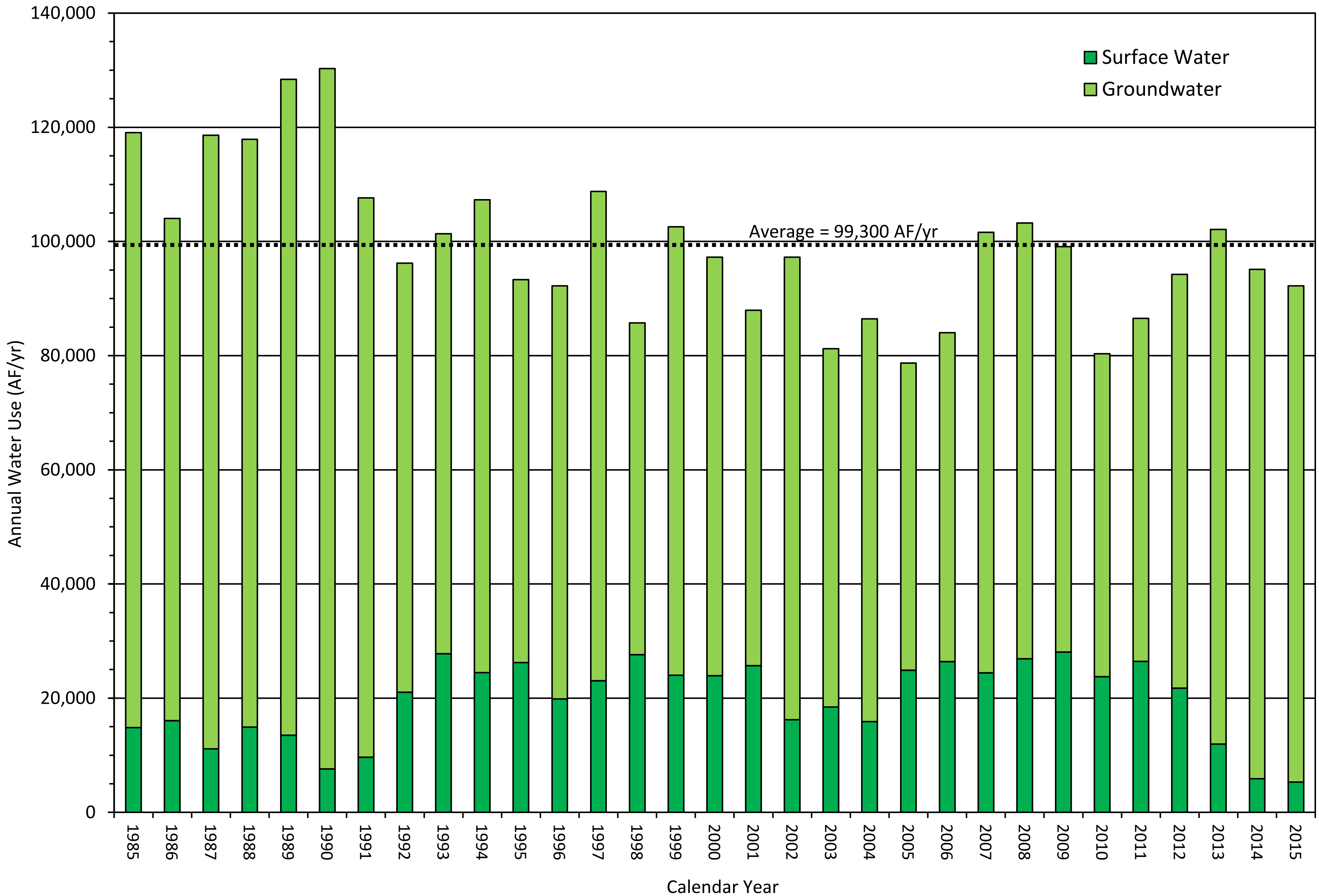


Figure 2-18. Annual Volumes of Water Recharged at United's Spreading Grounds



Note: The volumes of water shown on this graph are those reportedly used in the Mound, Oxnard Plain, Forebay, Pleasant Valley, and West Las Posas basins only. A small, additional volume is also used in portions of the active domain of the VRGWFM that are outside of these basins, and are not shown on this graph.

Figure 2-19. Annual Agricultural Water Use in Study Area

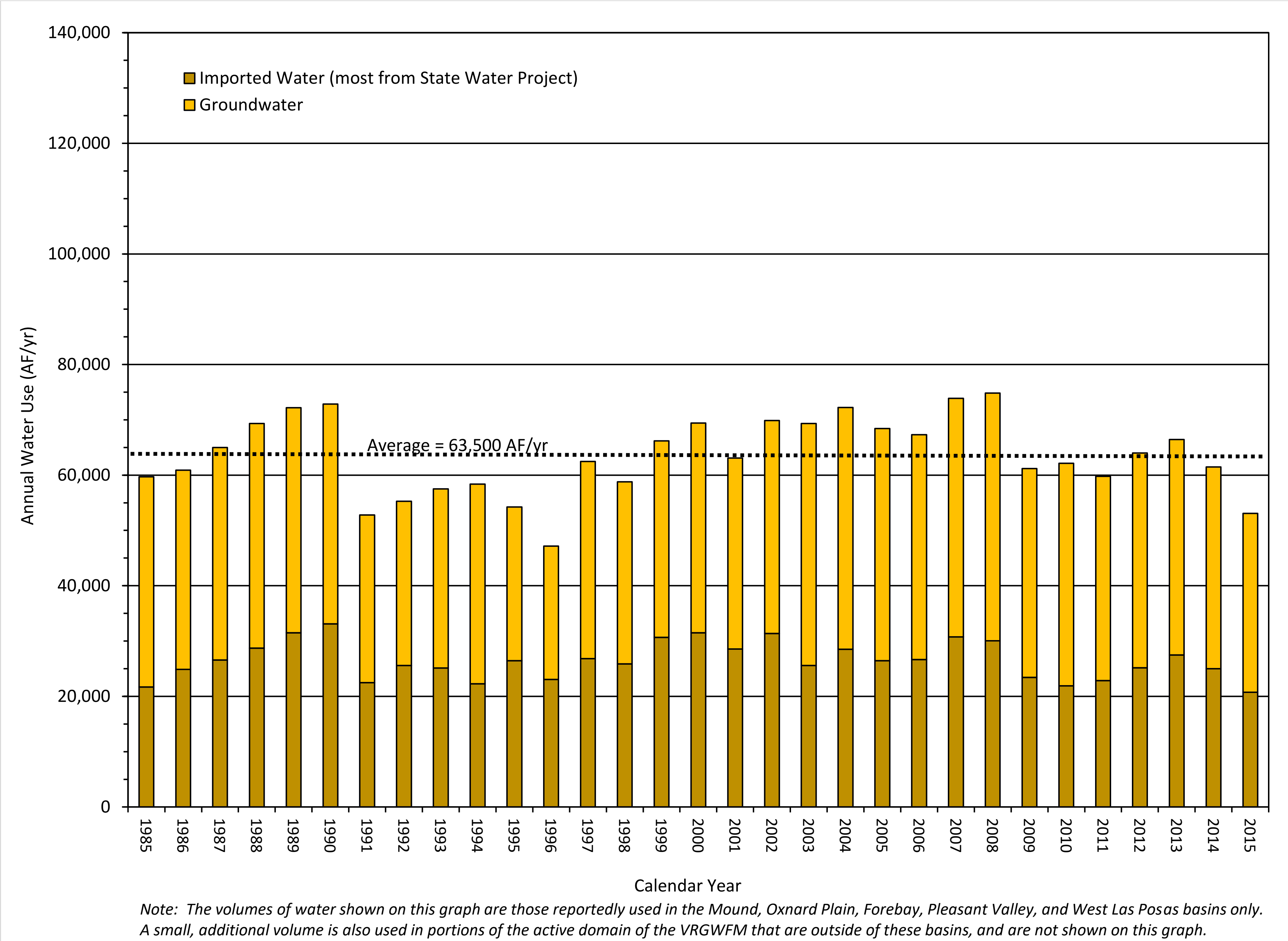


Figure 2-20. Annual Municipal and Industrial Water Use in Study Area

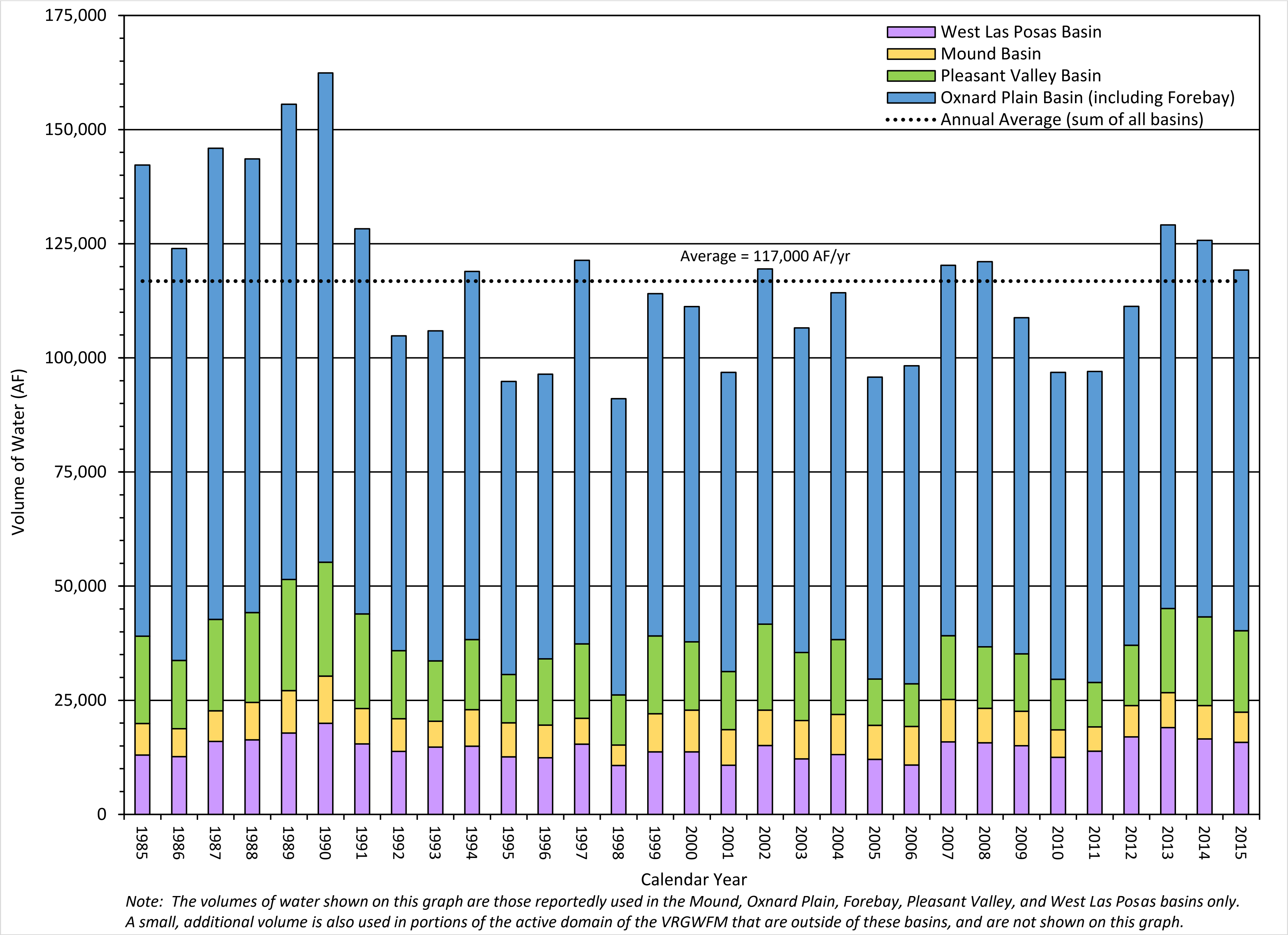


Figure 2-21. Annual Groundwater Extractions in Study Area

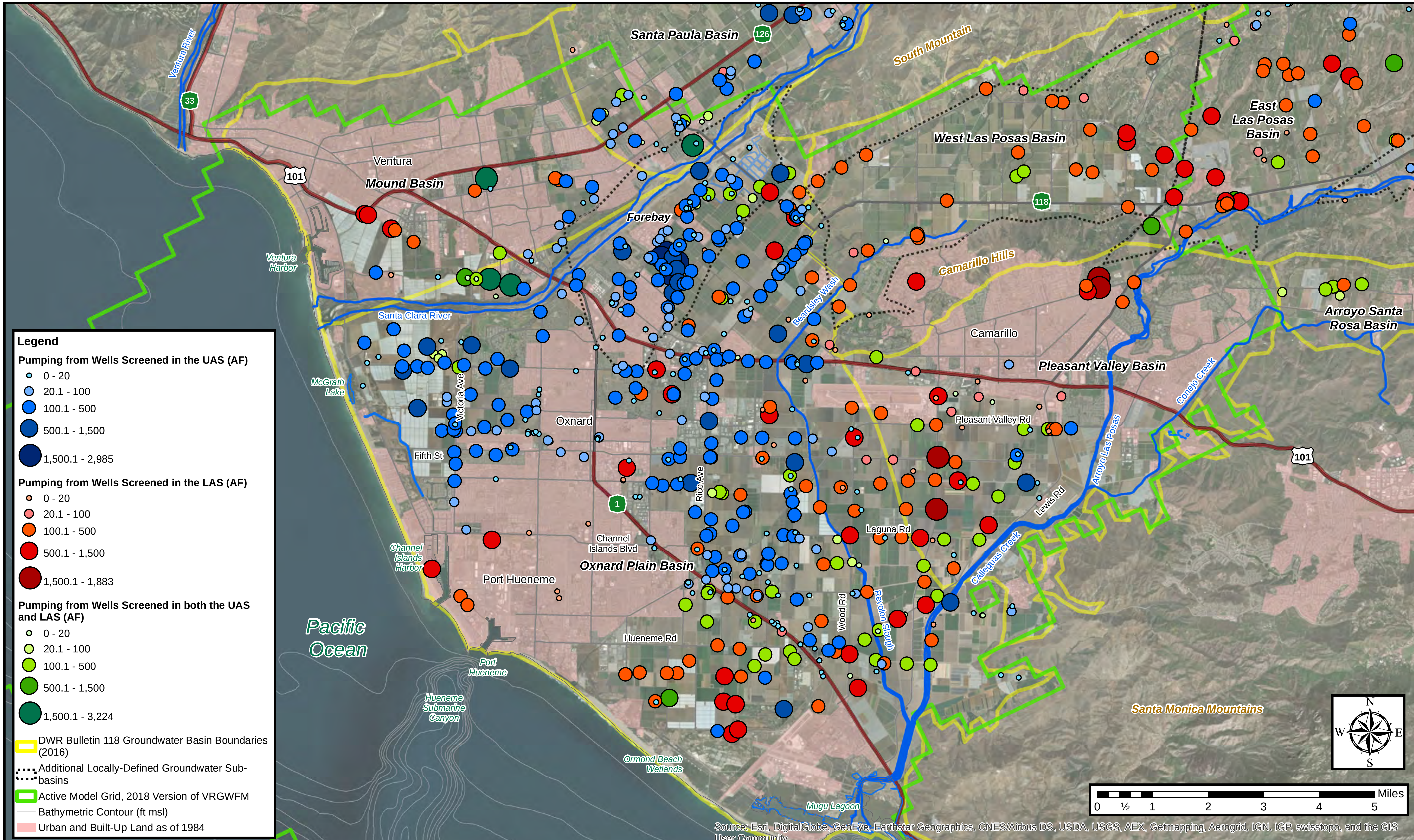


Figure 2-22. Locations of Groundwater Extractions, CY 1985

Pumping rates reported semi-annually to United and FCGMA by well owners. Aquifer system from which groundwater is extracted at each well was determined by United based on reported screened intervals and depths to aquifers indicated by updated hydrostratigraphic conceptual model.

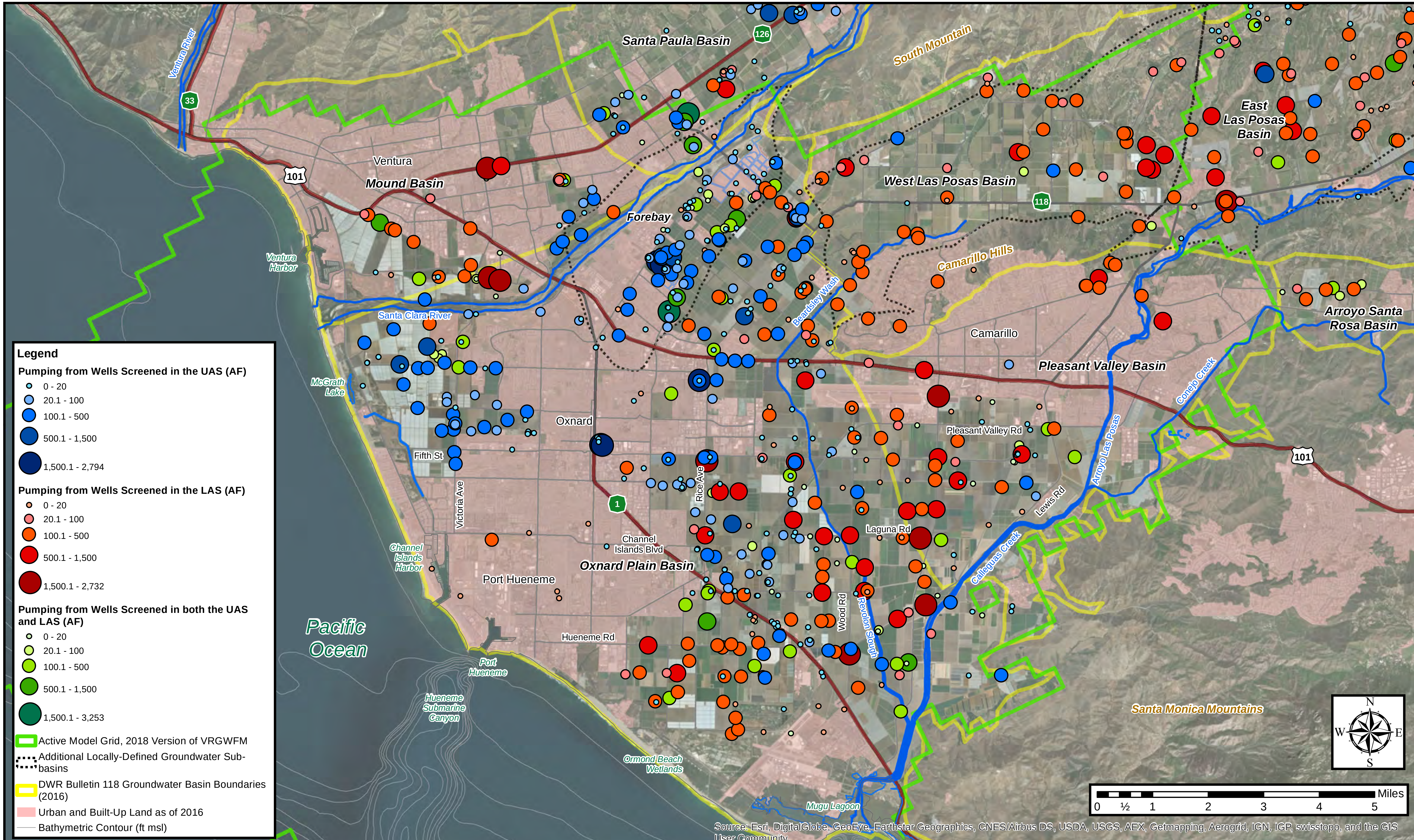


Figure 2-23. Locations of Groundwater Extractions, CY 2015

Pumping rates reported semi-annually to United and FCGMA by well owners. Aquifer system from which groundwater is extracted at each well was determined by United based on reported screened intervals and depths to aquifers indicated by updated hydrostratigraphic conceptual model.

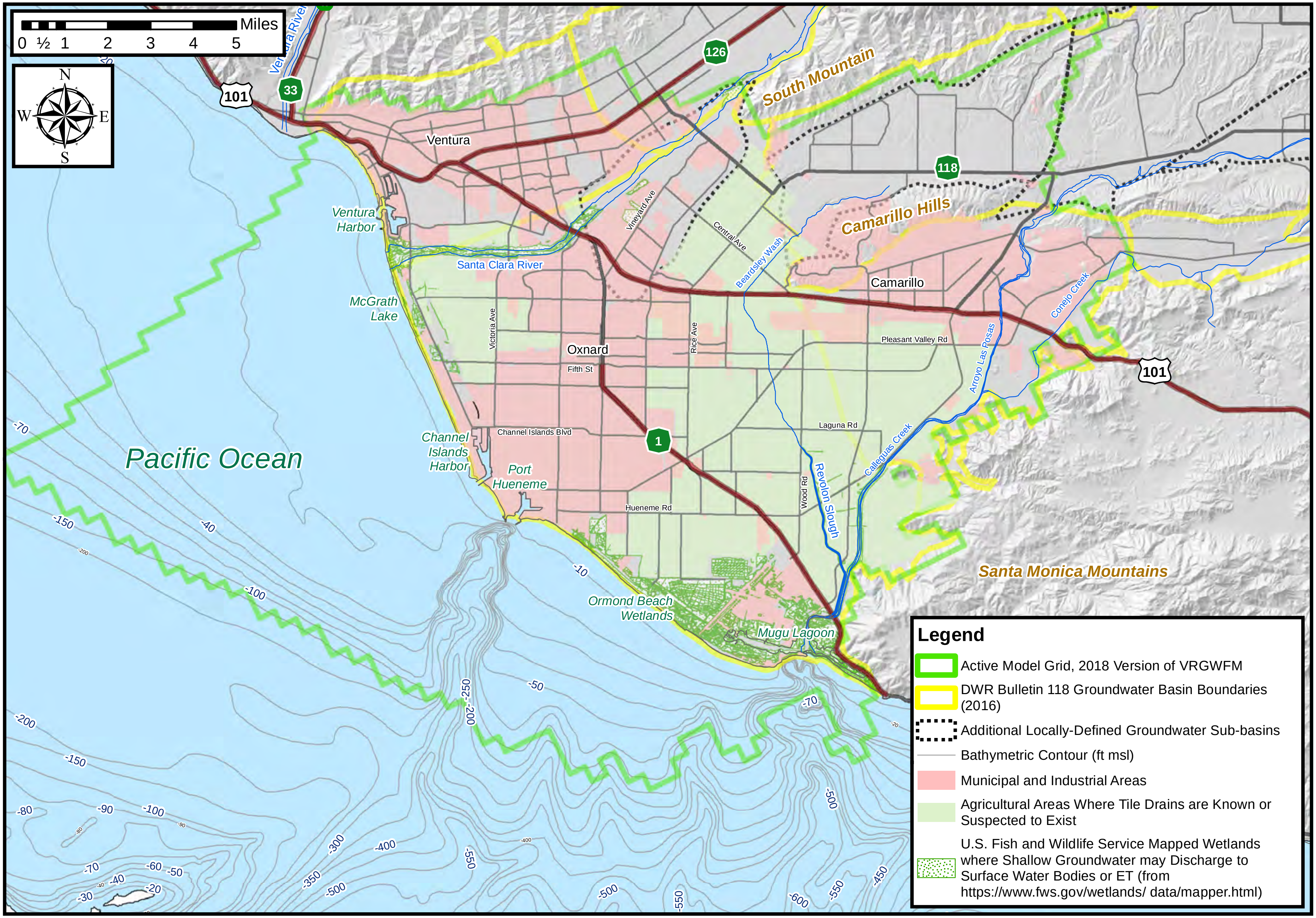


Figure 2-24. Areas of Groundwater Discharge in Study Area

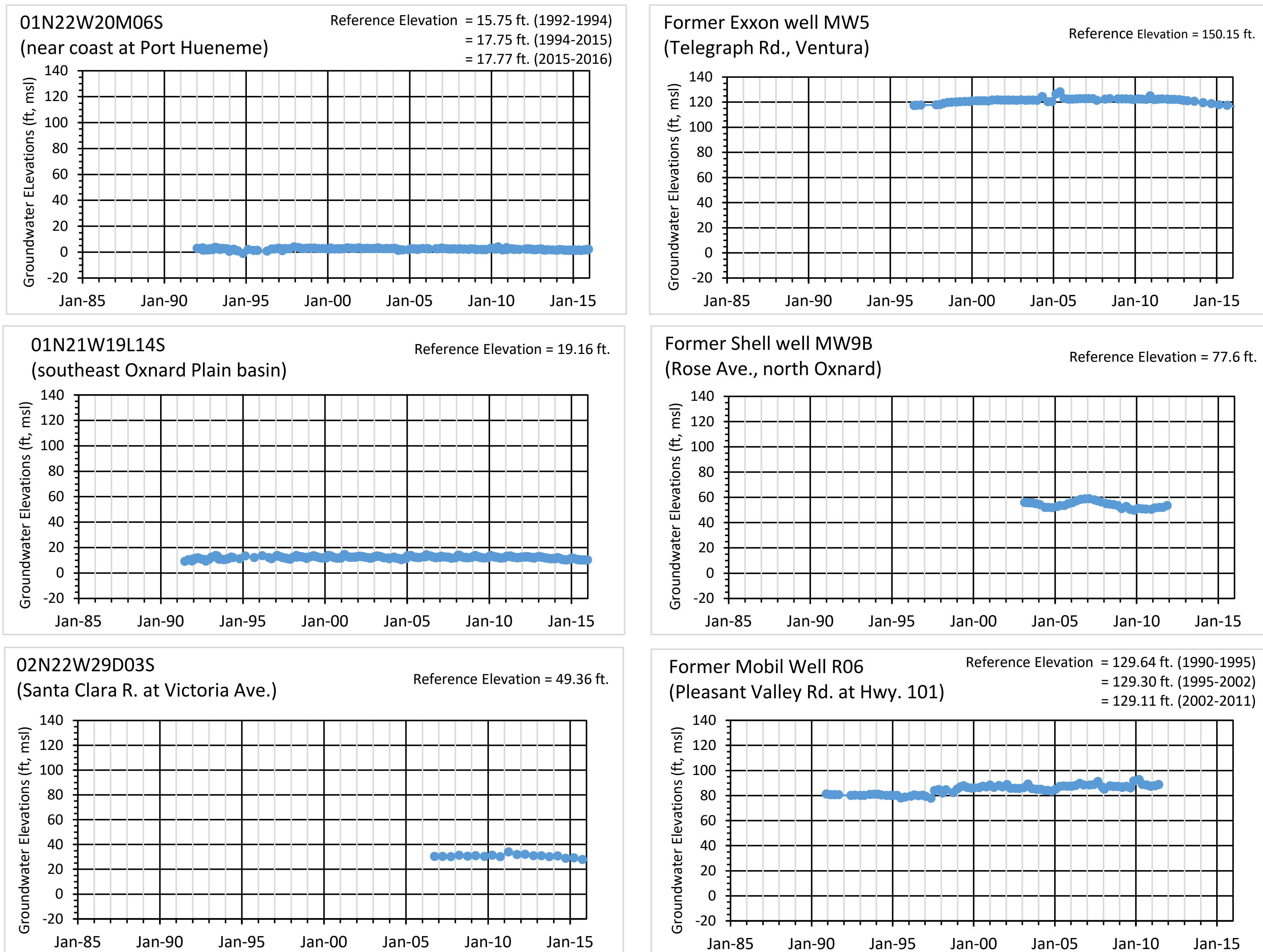


Figure 2-25. Groundwater Elevations Measured at Selected Wells Screened in the Semi-Perched Aquifer

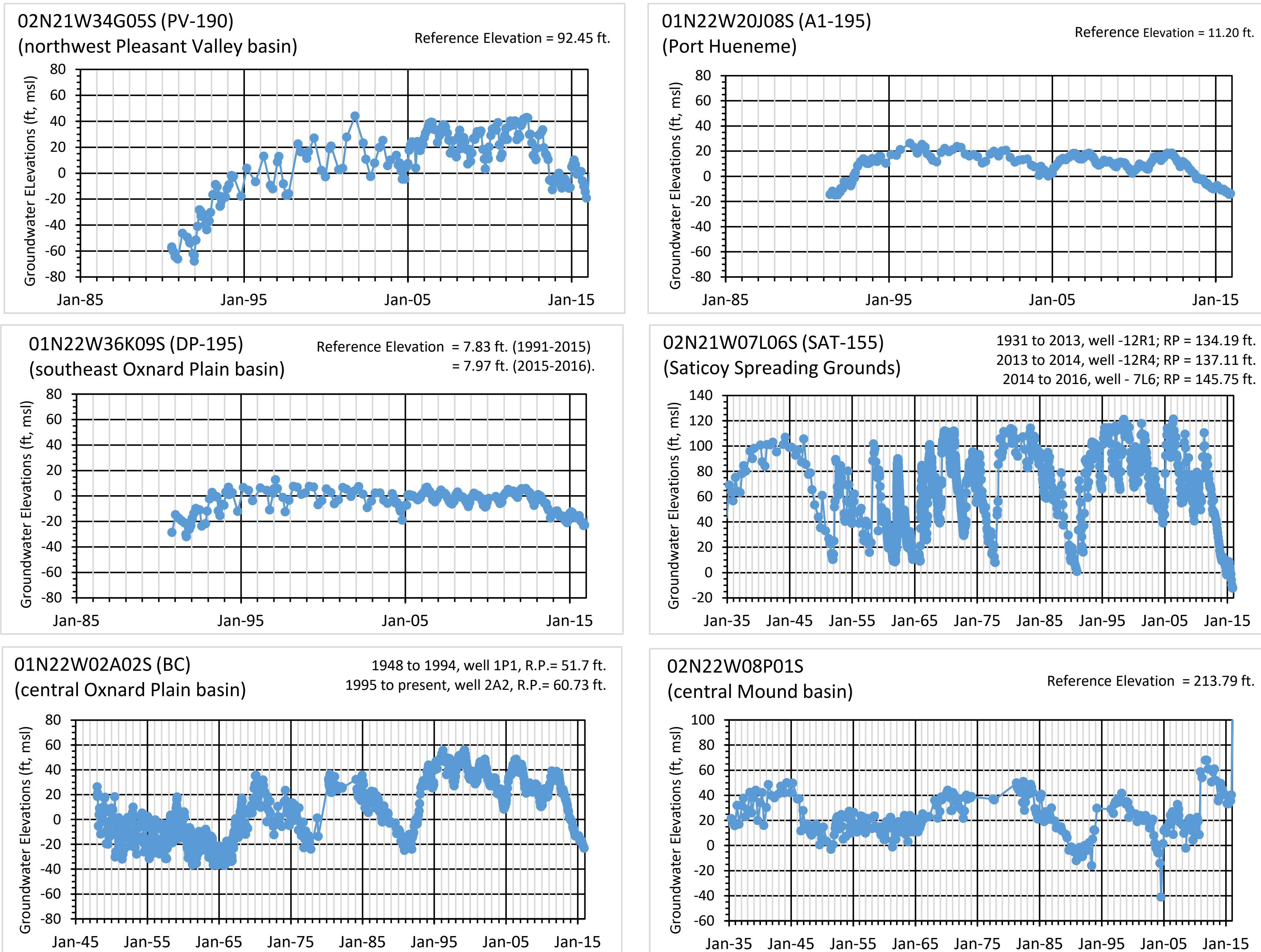


Figure 2-26. Groundwater Elevations Measured at Selected Wells Screened in the UAS

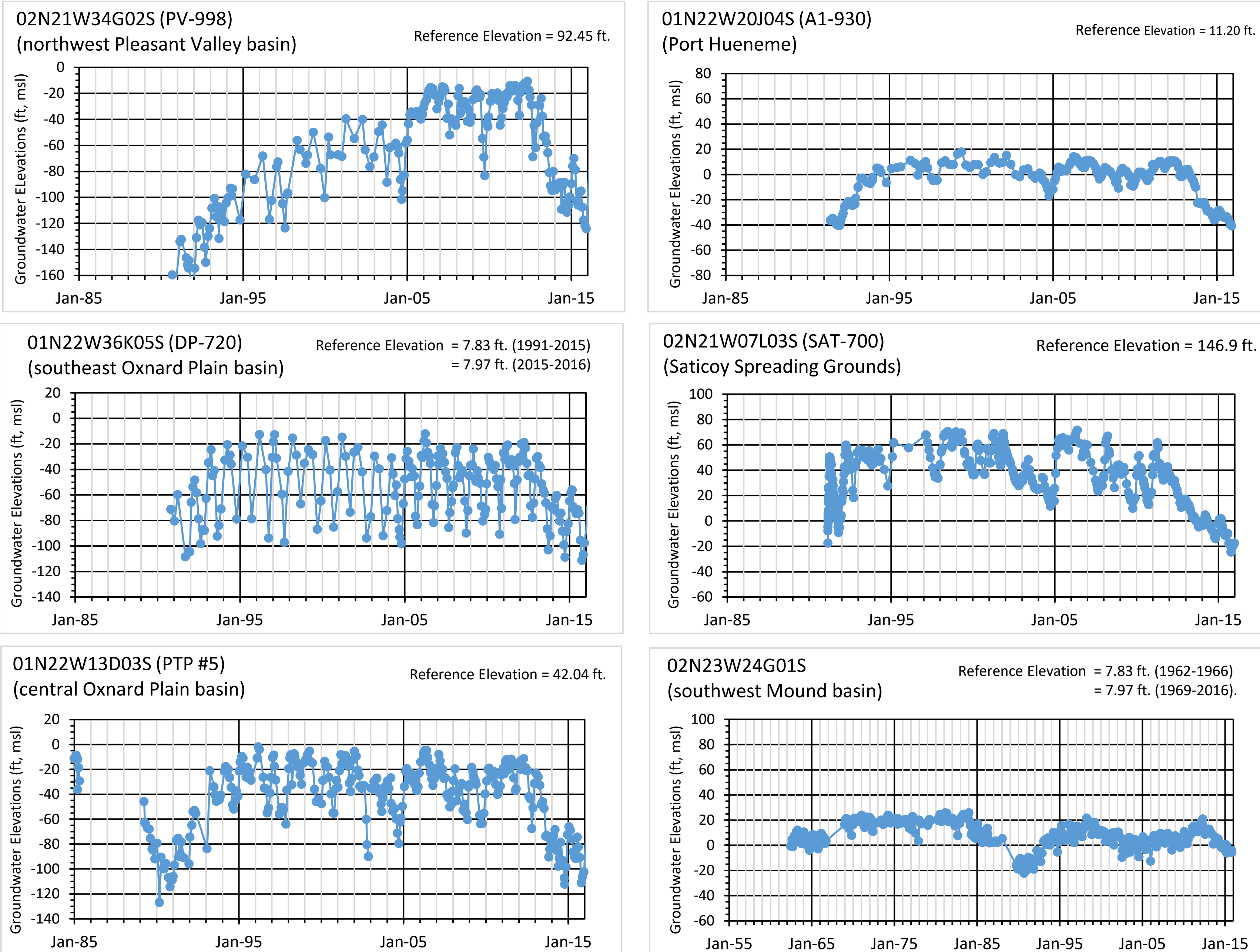


Figure 2-27. Groundwater Elevations Measured at Selected Wells Screened in the LAS

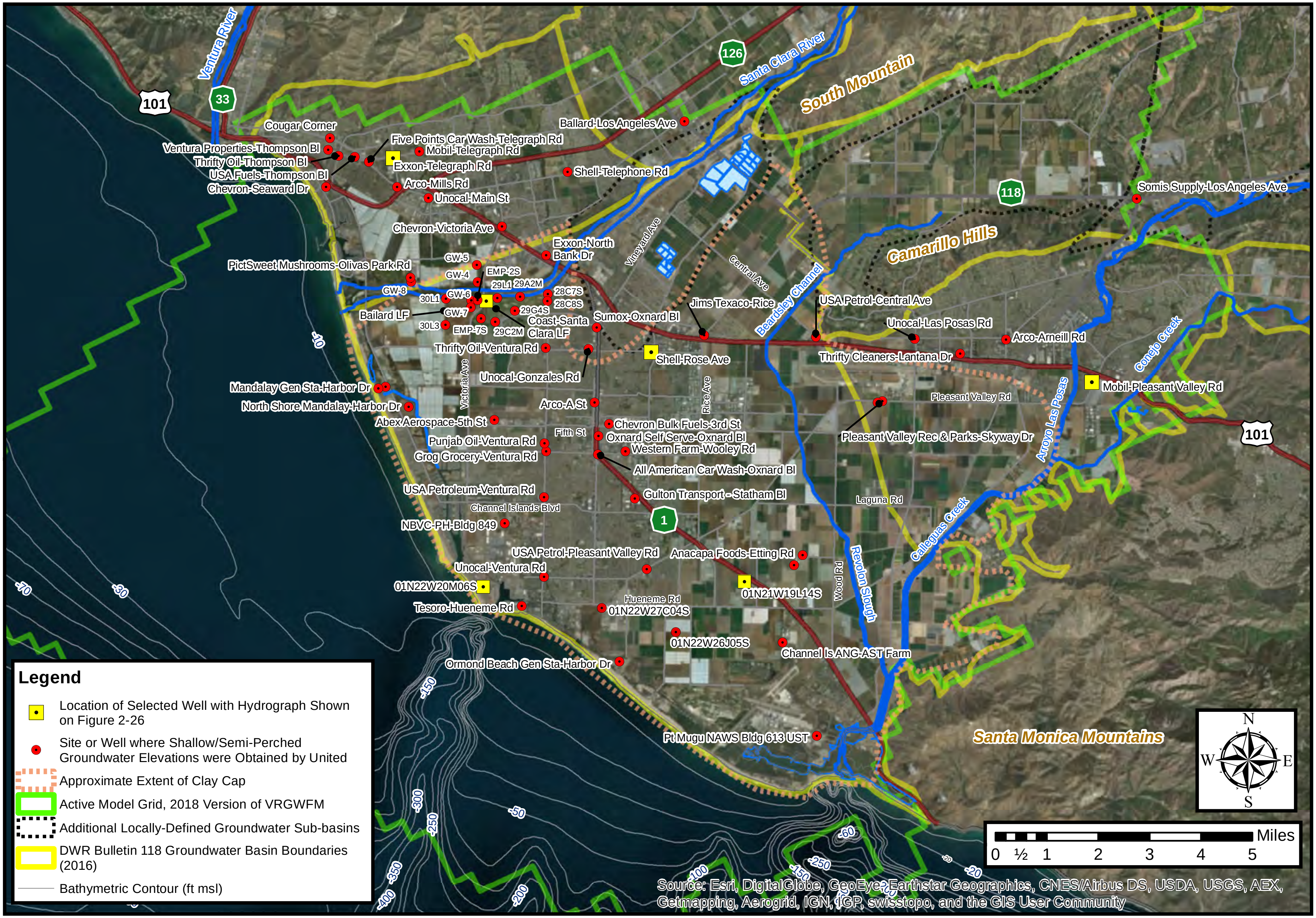


Figure 2-28. Locations of Selected Wells Screened in the Semi-perched Aquifer

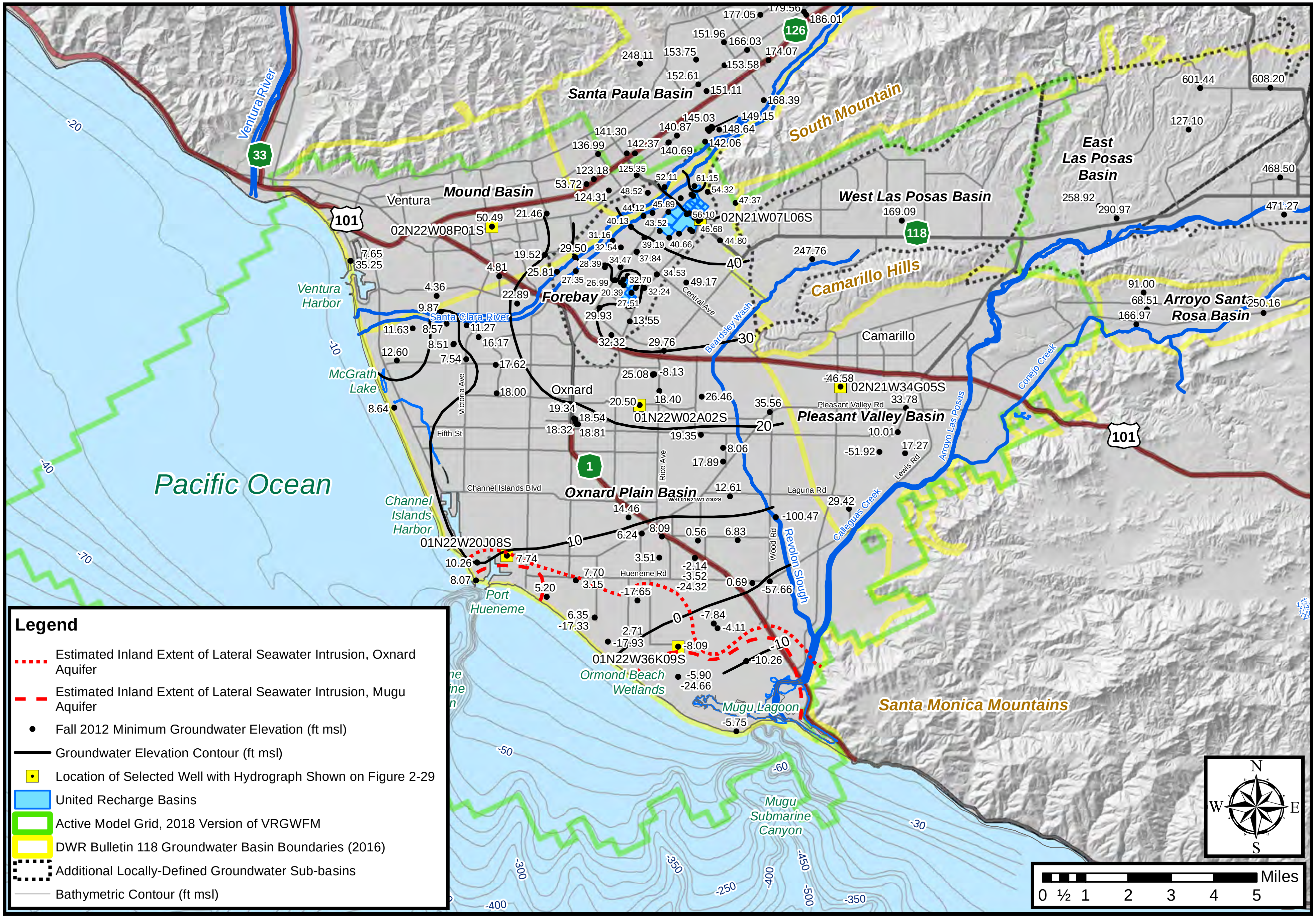


Figure 2-29. Groundwater Elevation Contours for UAS, Fall 2012

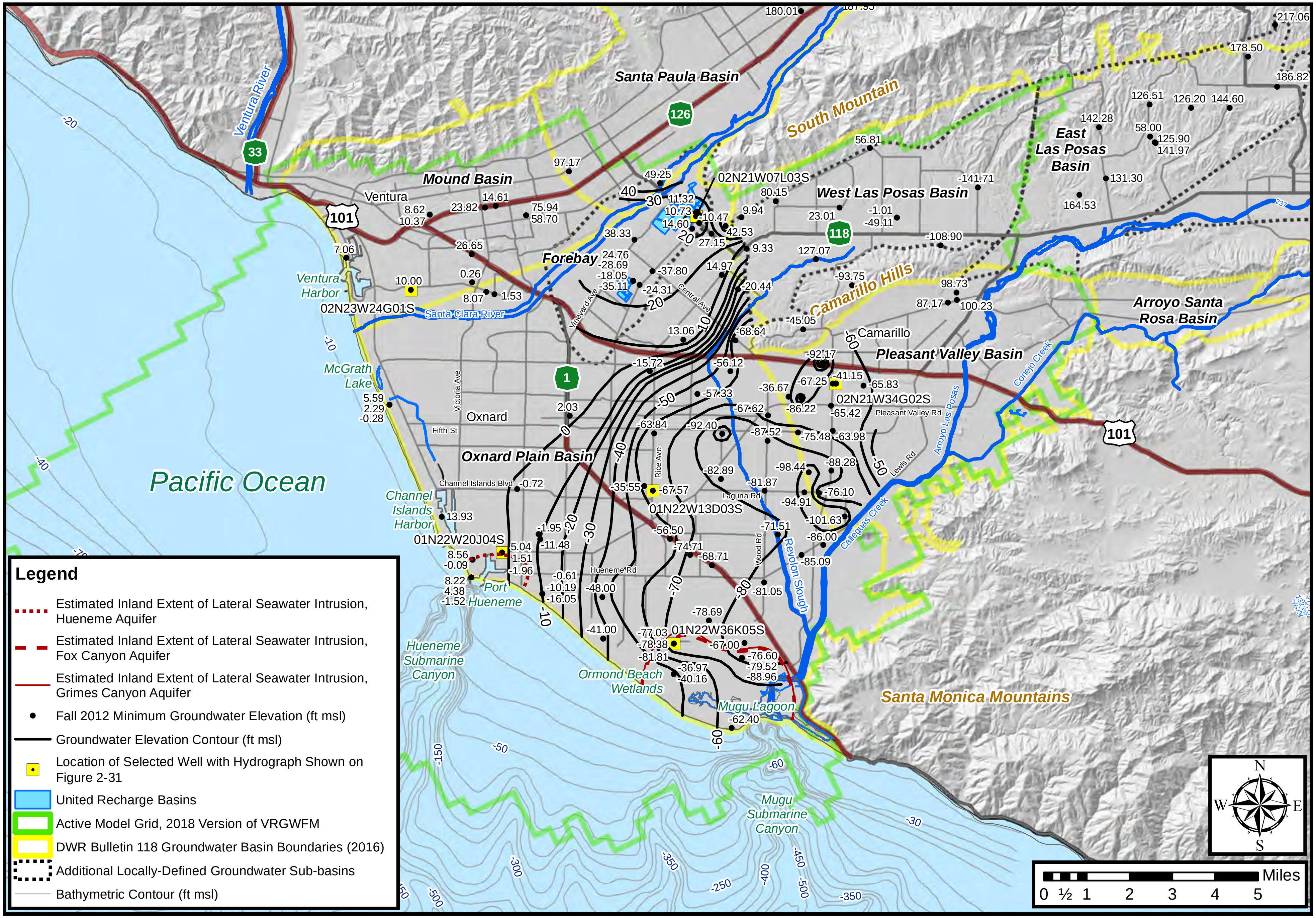


Figure 2-30. Groundwater Elevation Contours for LAS, Fall 2012

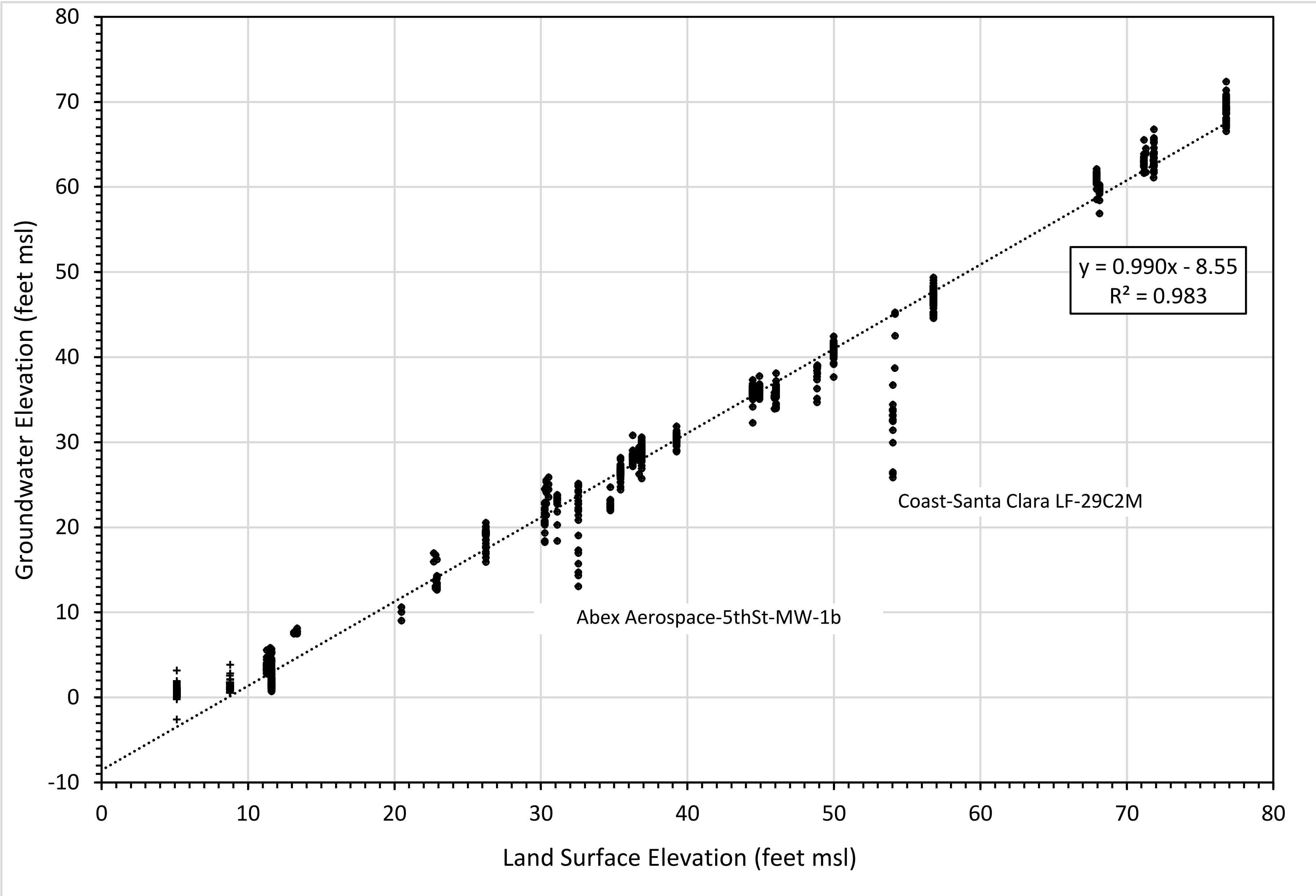


Figure 2-31. Groundwater Elevations in Semi-Perched Aquifer versus Land Surface Elevation

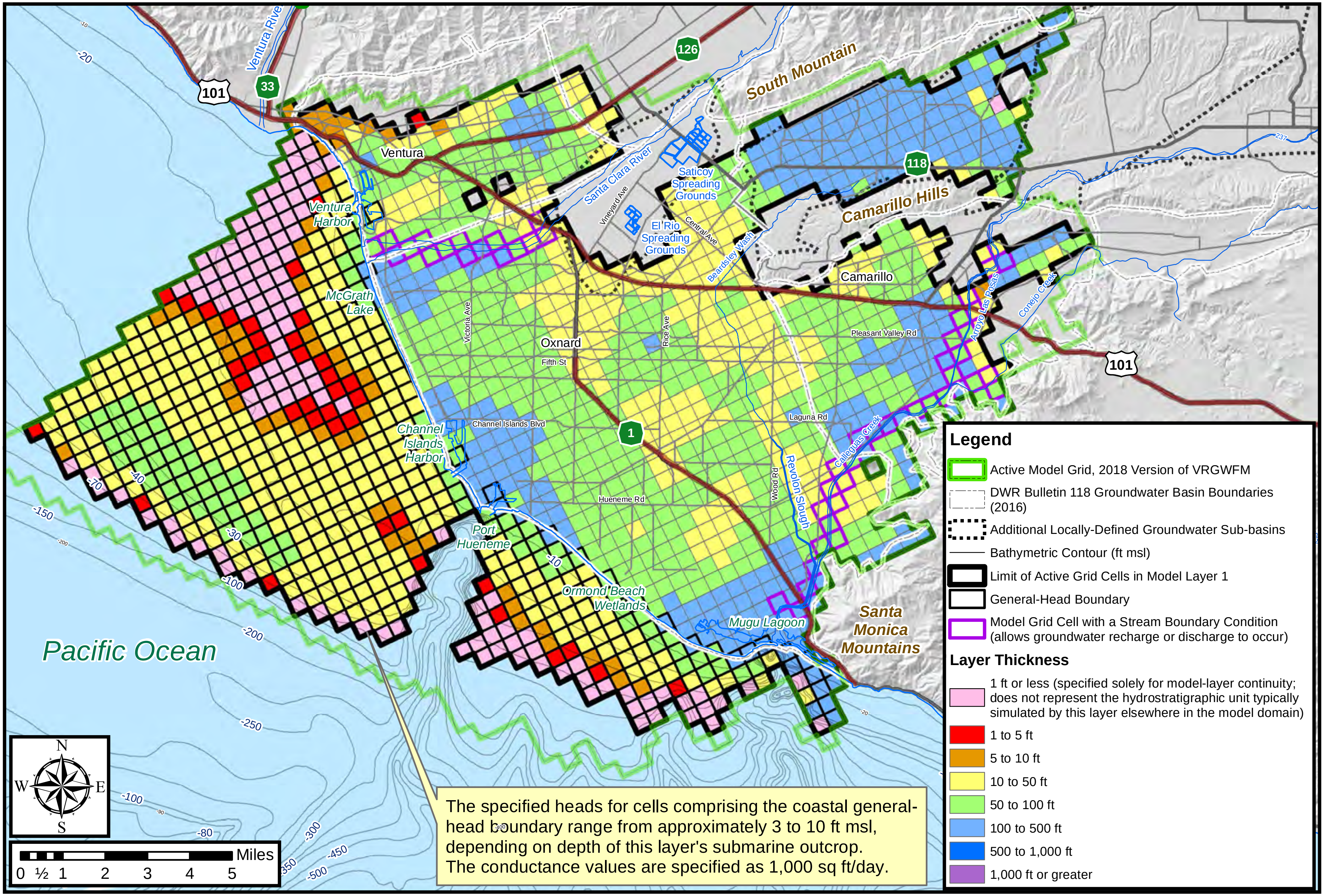


Figure 3-1. Boundary Conditions, Thickness, and Extent of Model Layer 1

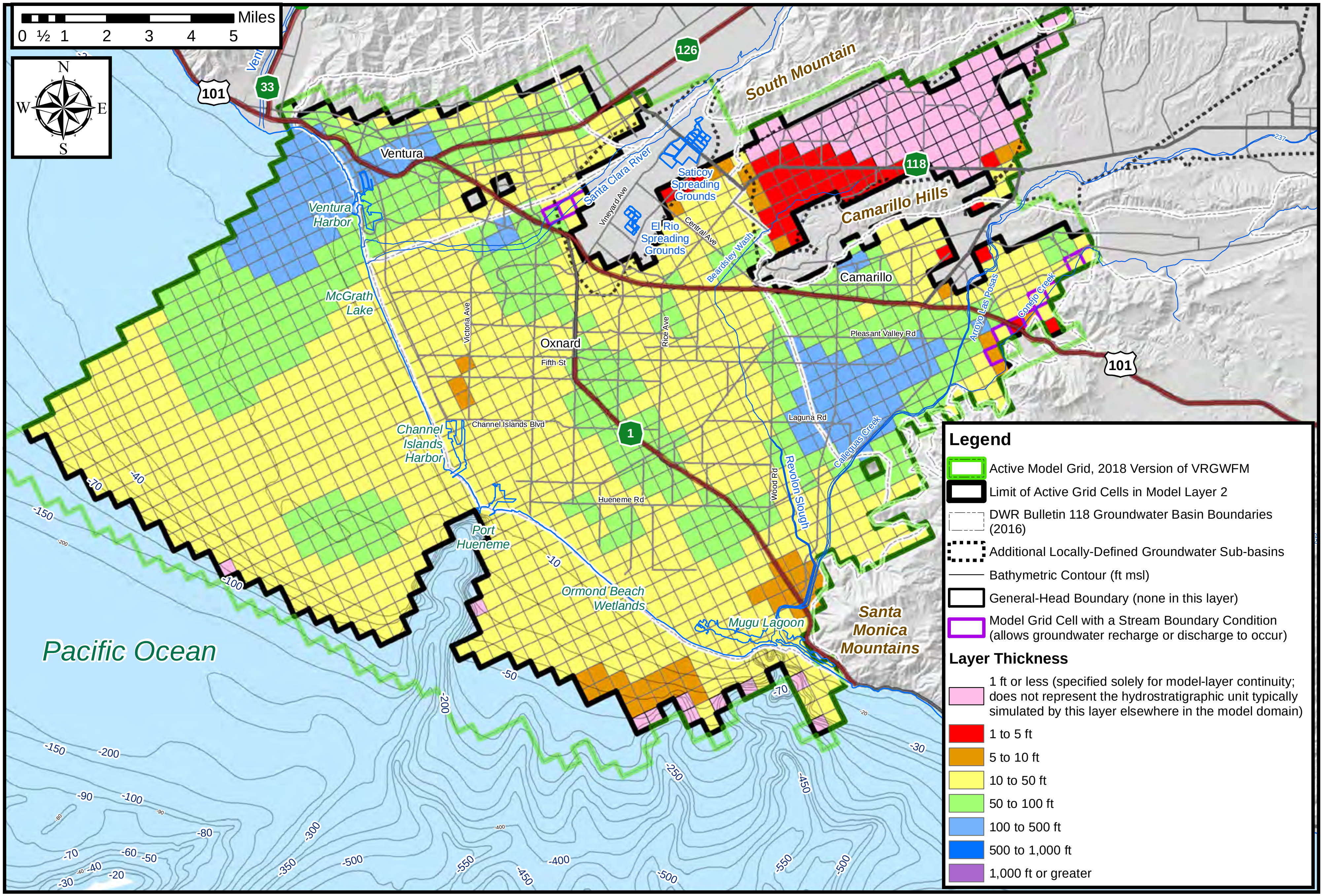


Figure 3-2. Boundary Conditions, Thickness, and Extent of Model Layer 2

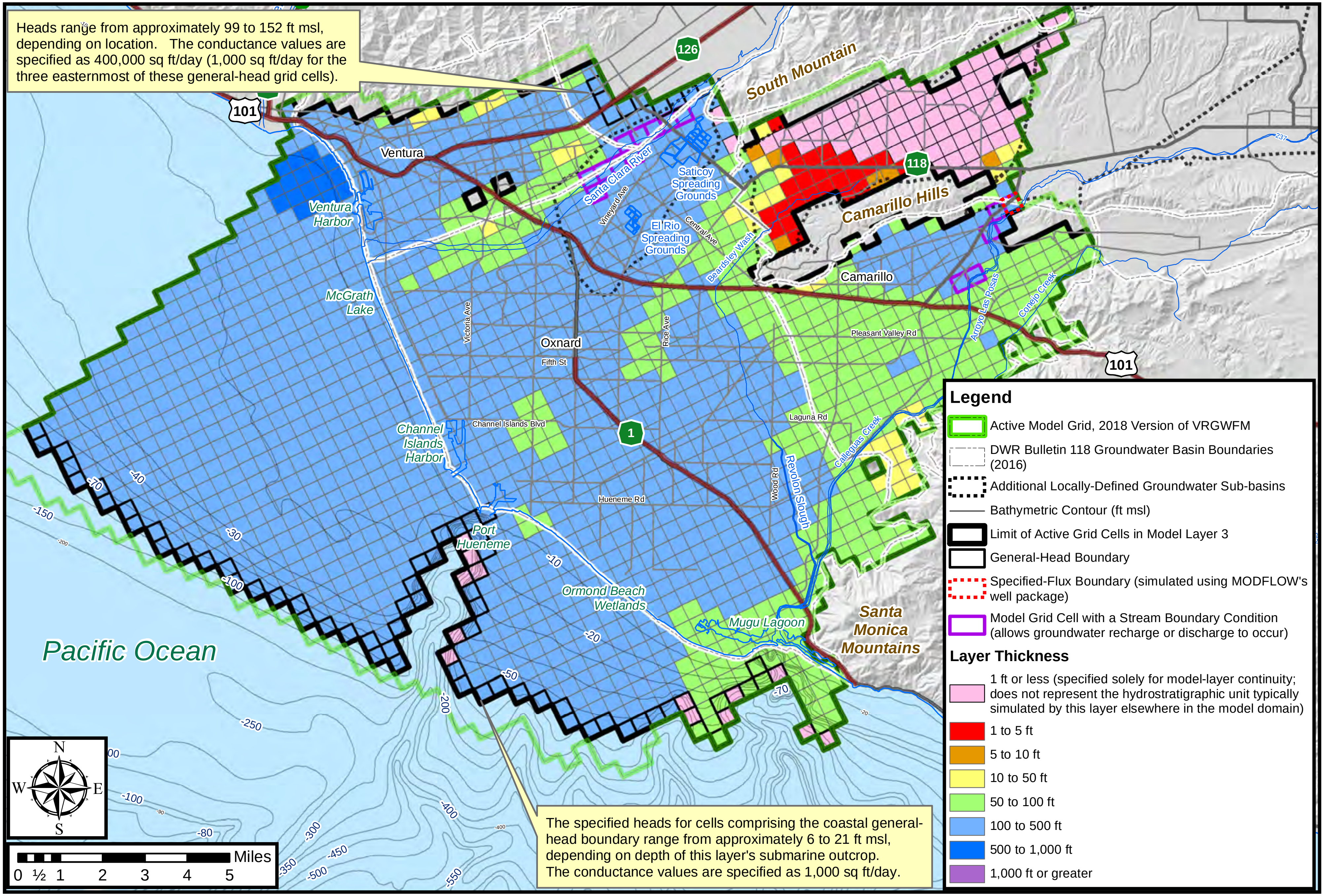


Figure 3-3. Boundary Conditions, Thickness, and Extent of Model Layer 3

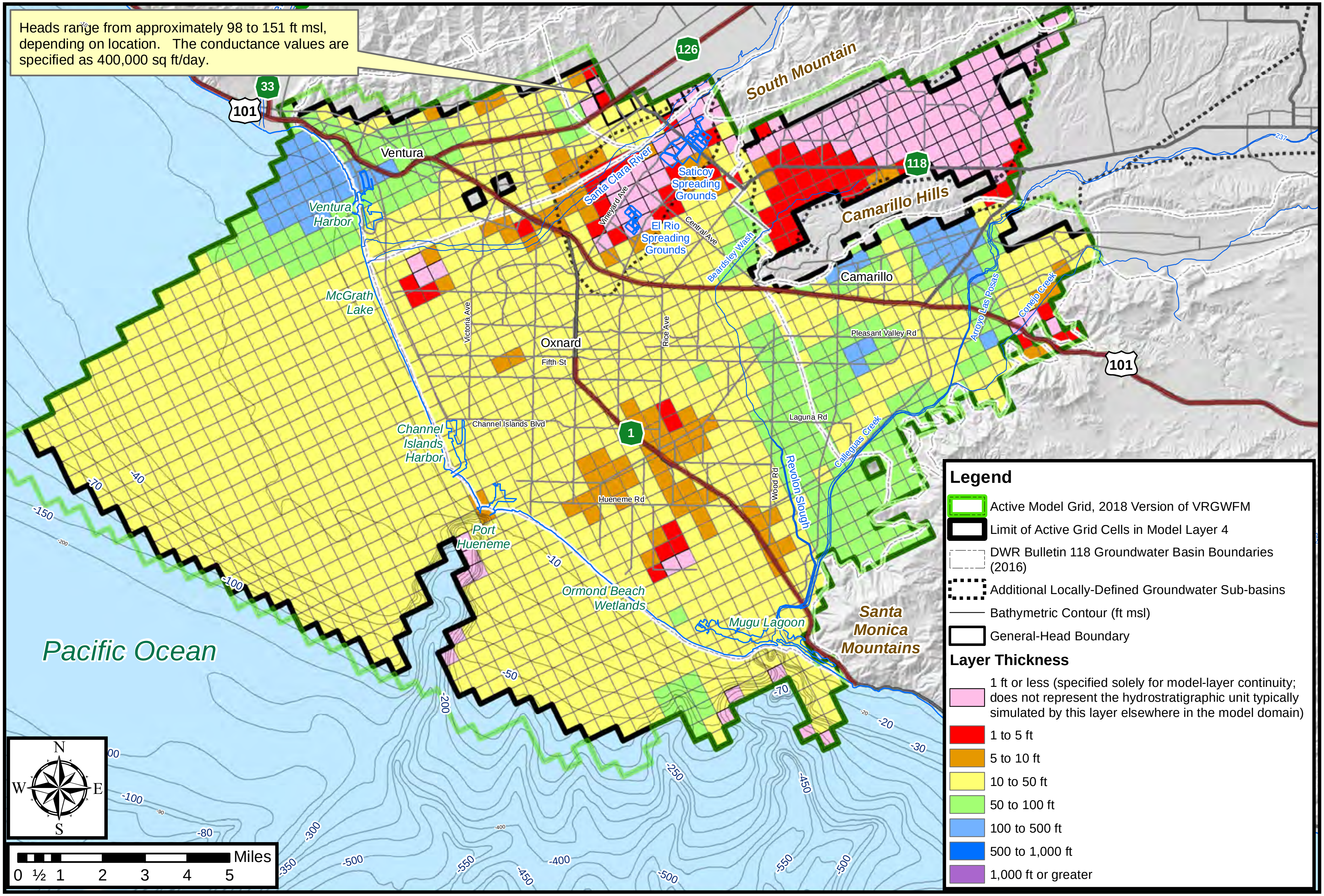


Figure 3-4. Boundary Conditions, Thickness, and Extent of Model Layer 4

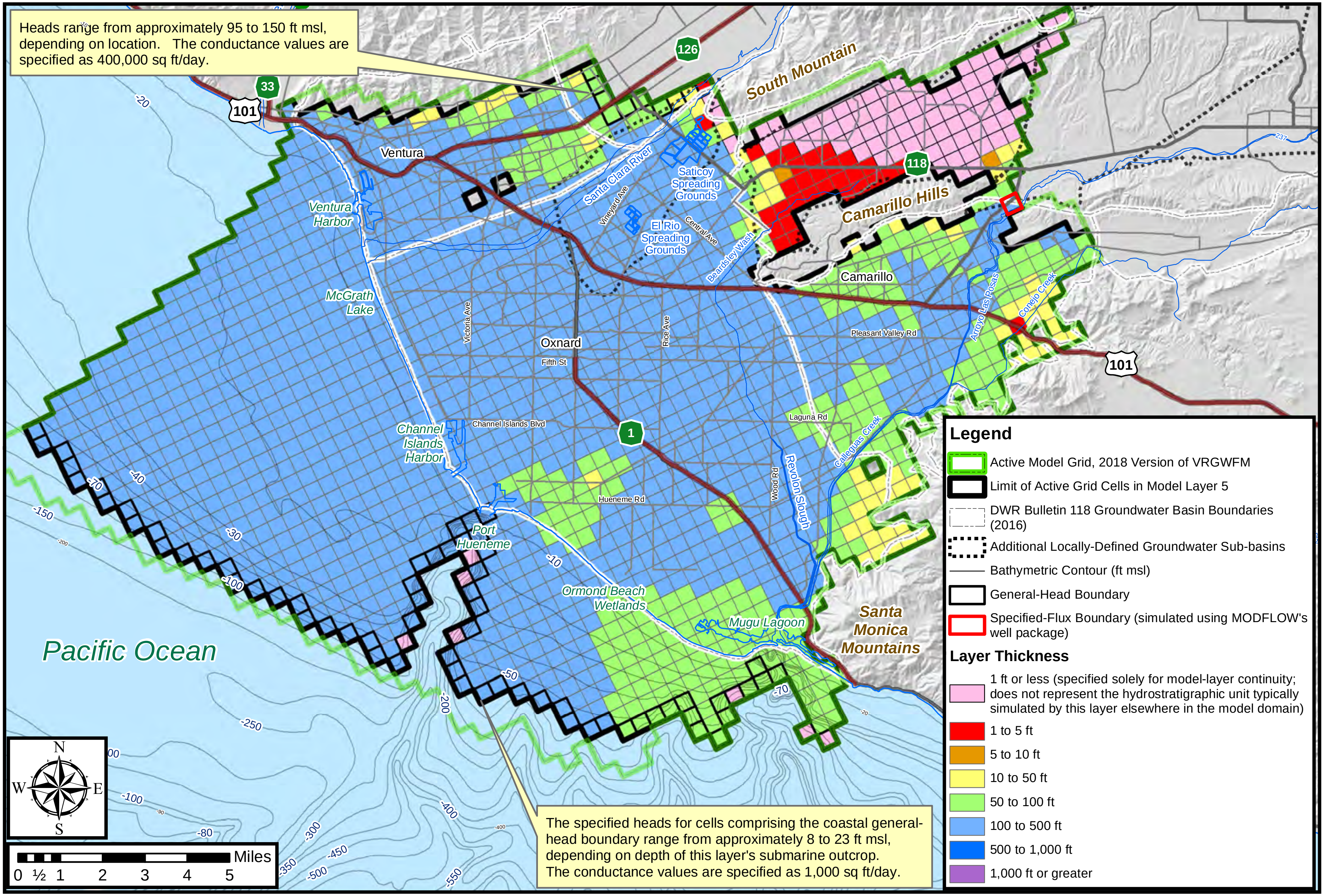


Figure 3-5. Boundary Conditions, Thickness, and Extent of Model Layer 5

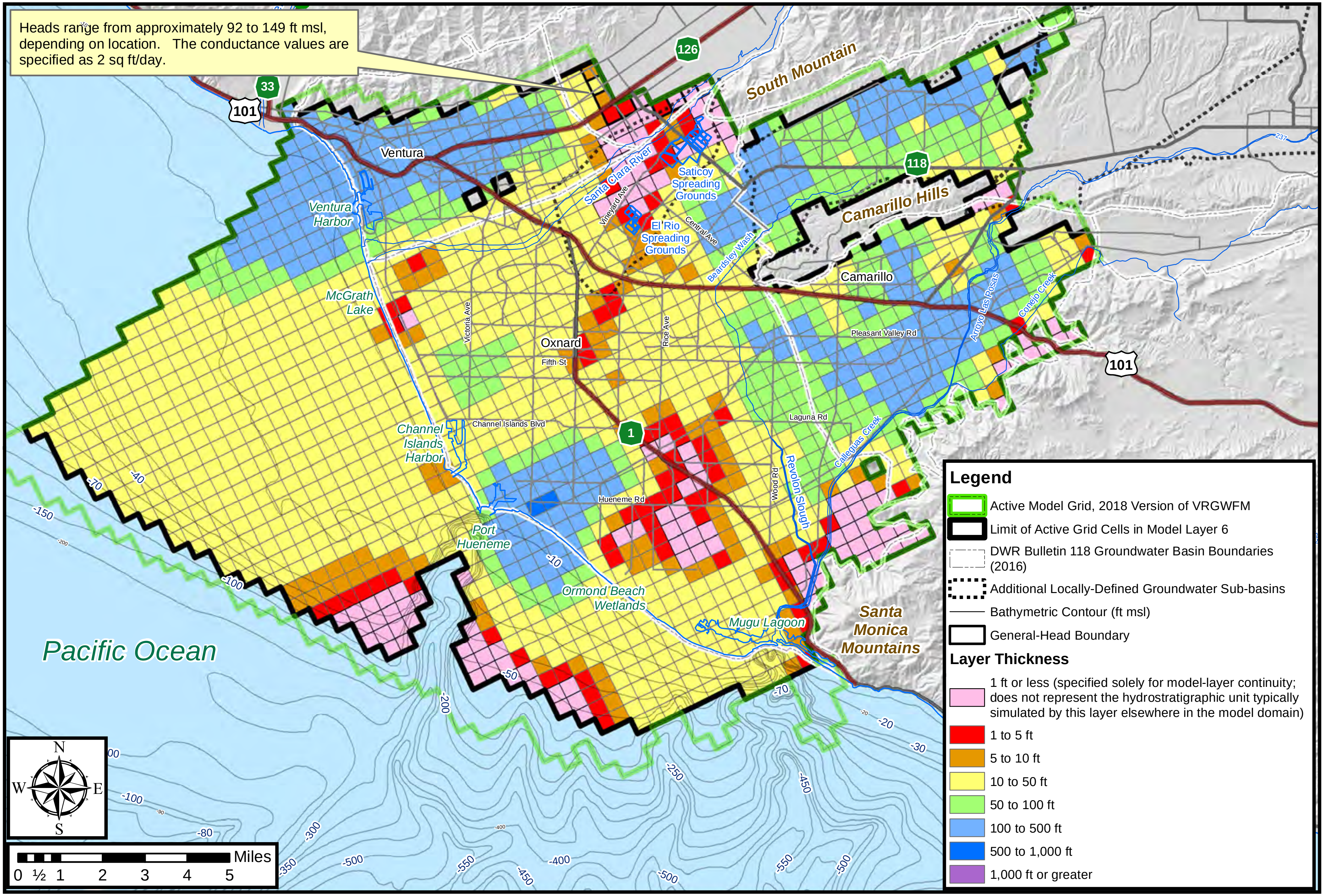


Figure 3-6. Boundary Conditions, Thickness, and Extent of Model Layer 6

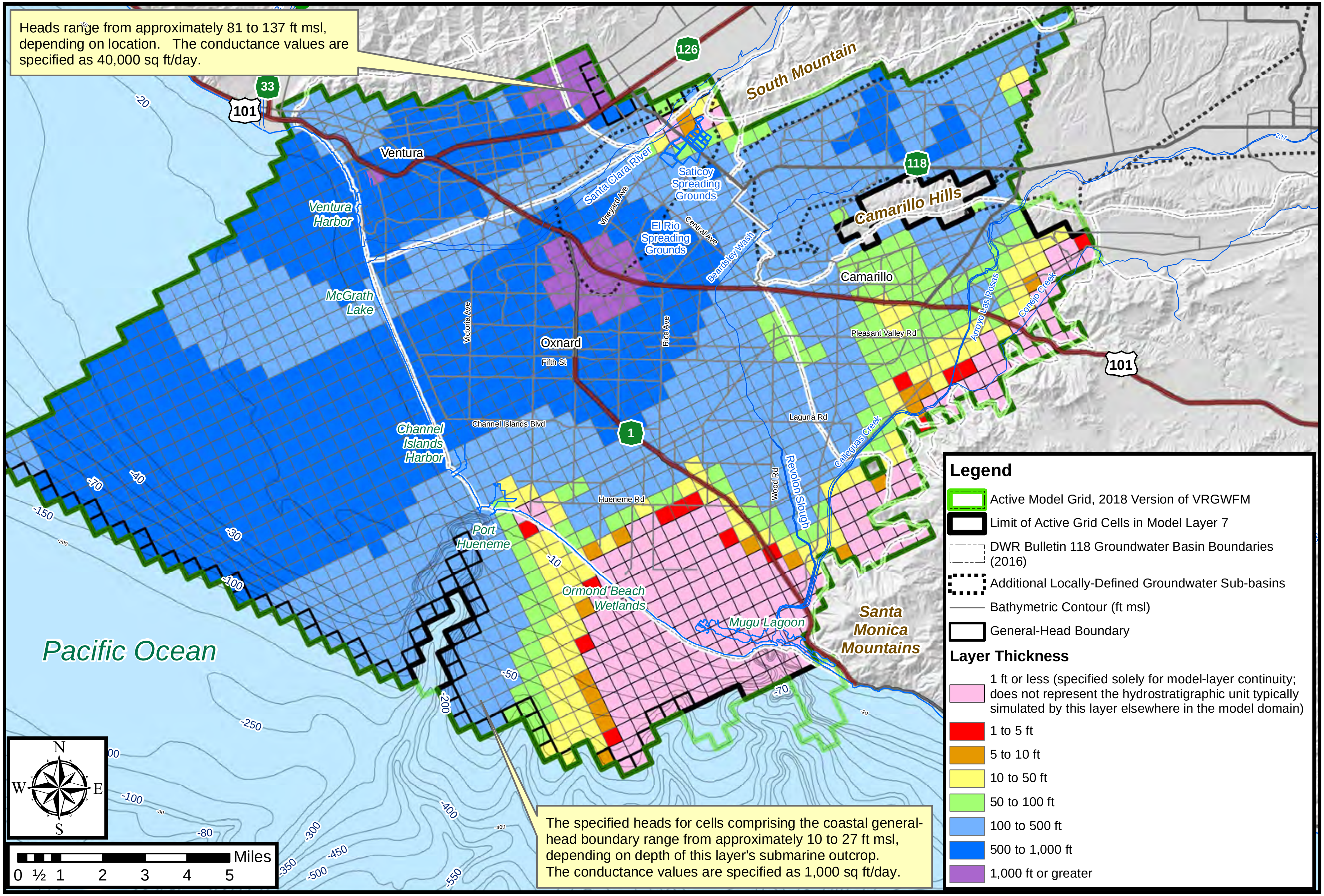


Figure 3-7. Boundary Conditions, Thickness, and Extent of Model Layer 7

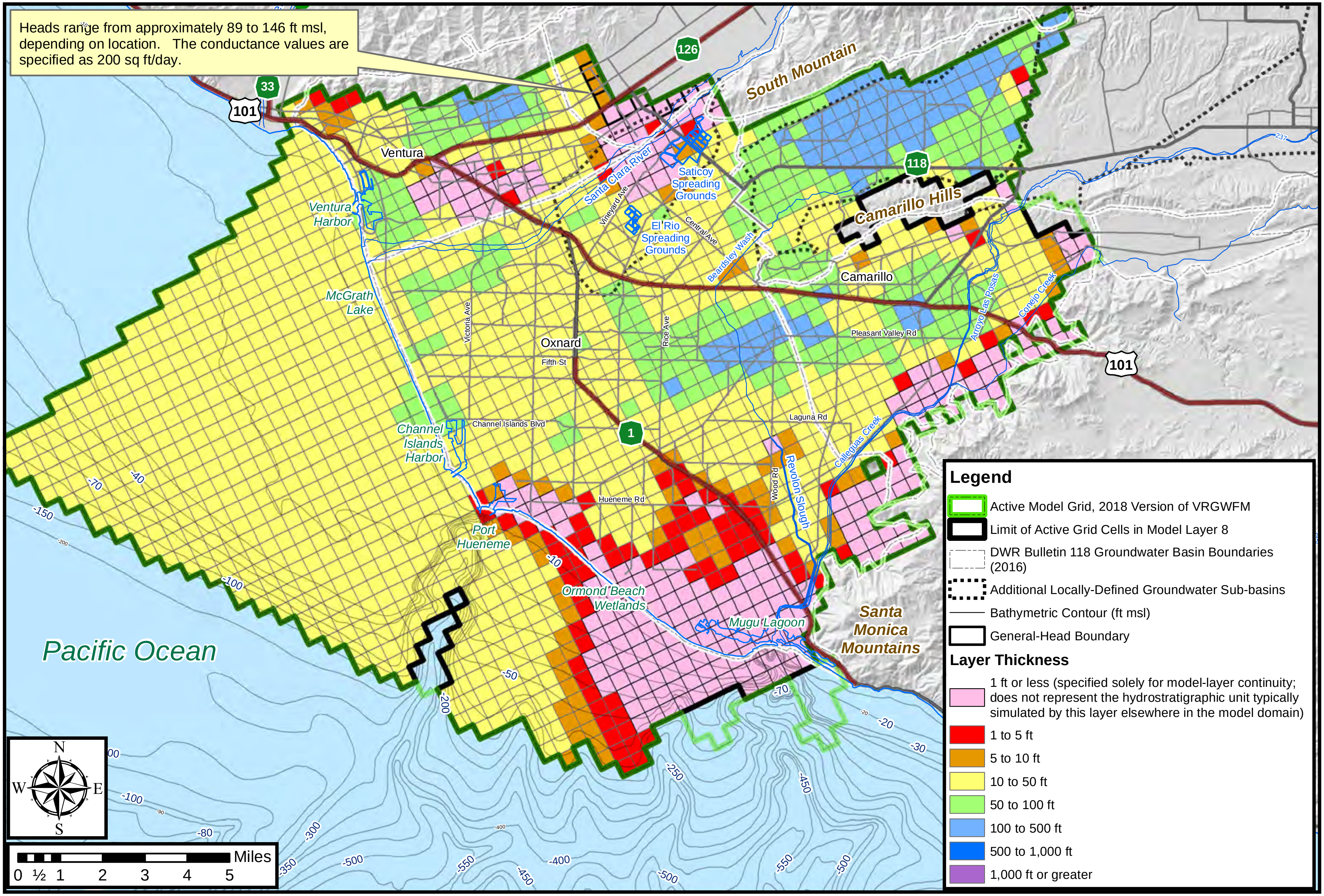


Figure 3-8. Boundary Conditions, Thickness, and Extent of Model Layer 8

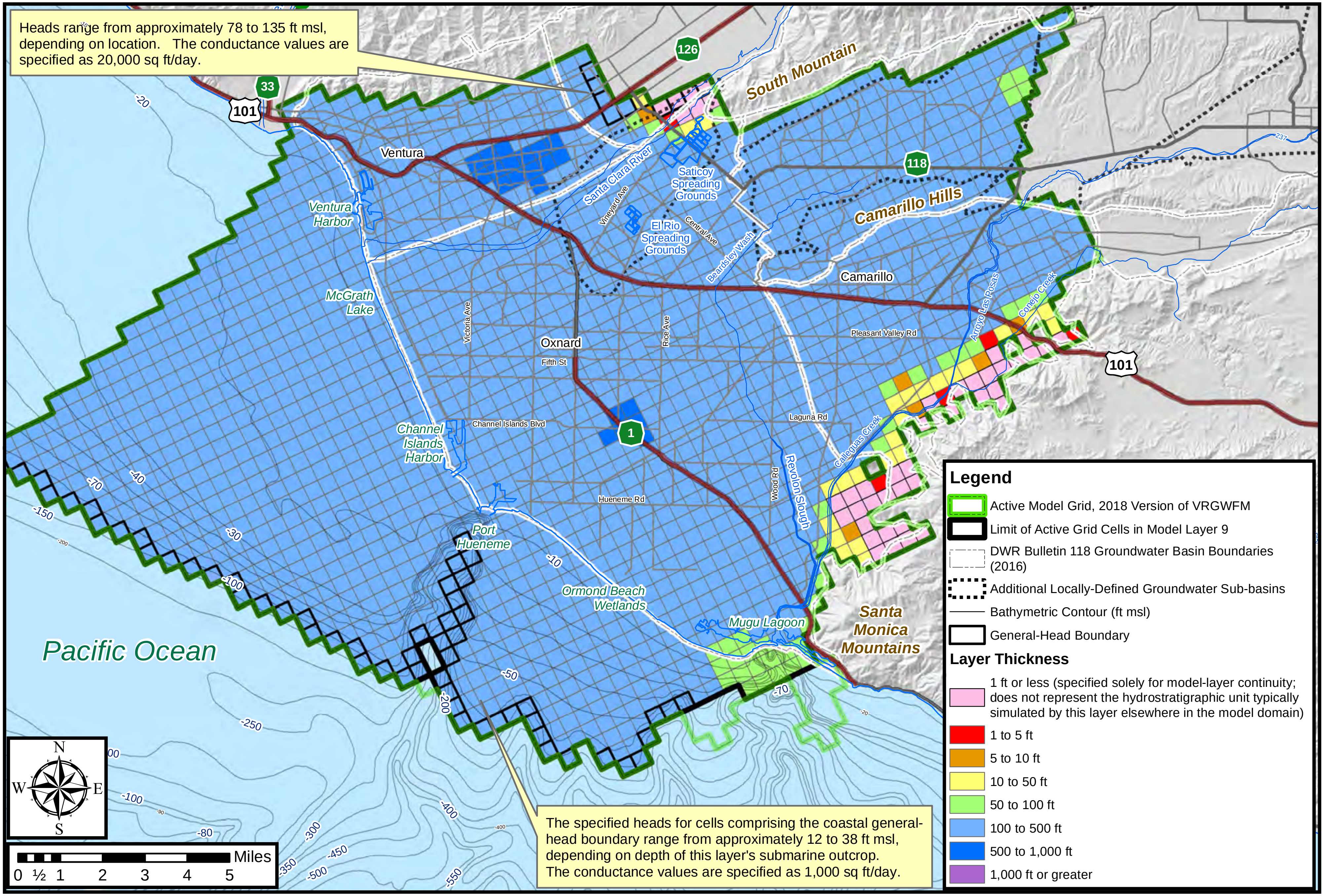


Figure 3-9. Boundary Conditions, Thickness, and Extent of Model Layer 9

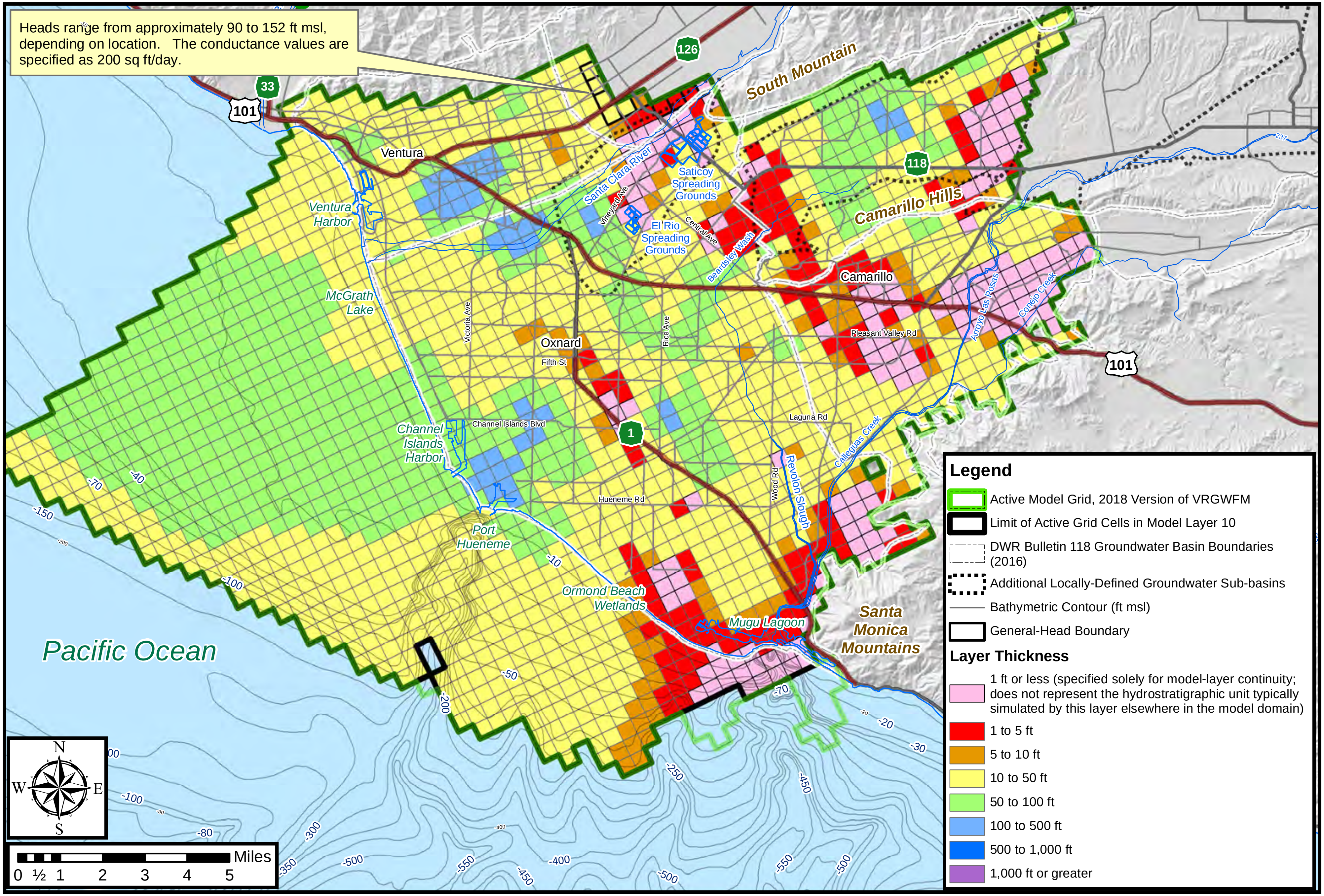


Figure 3-10. Boundary Conditions, Thickness, and Extent of Model Layer 10

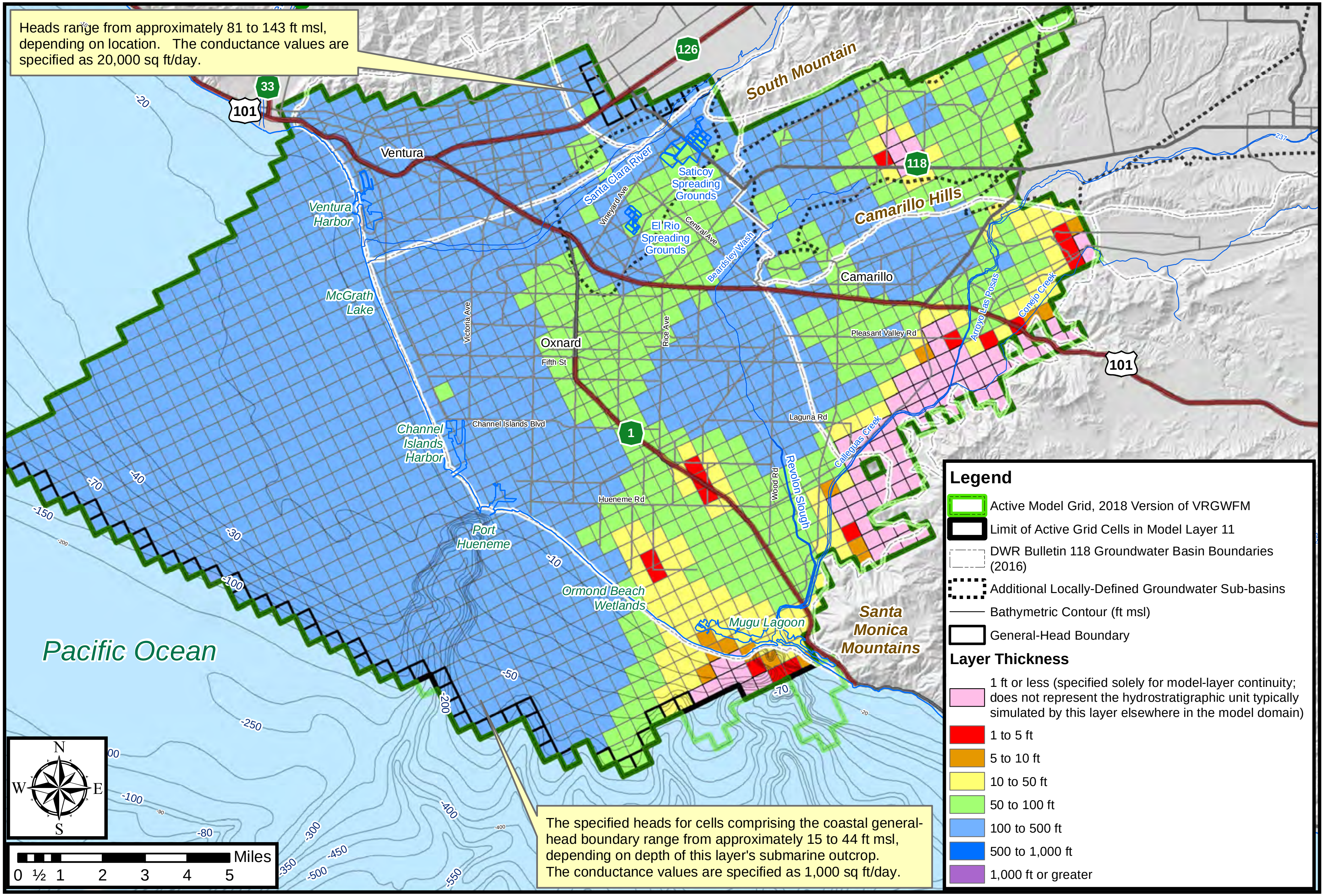


Figure 3-11. Boundary Conditions, Thickness, and Extent of Model Layer 11

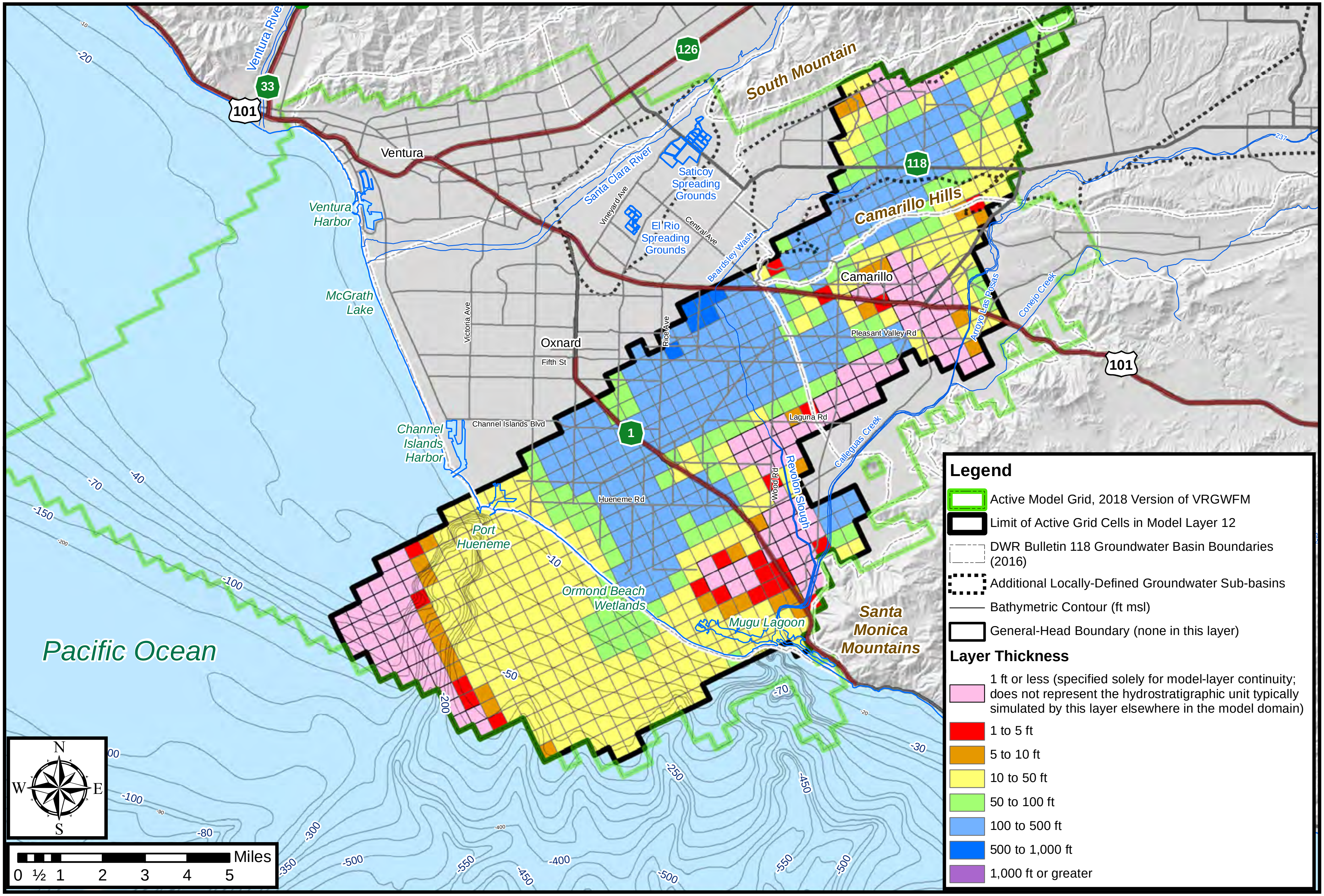


Figure 3-12. Boundary Conditions, Thickness, and Extent of Model Layer 12

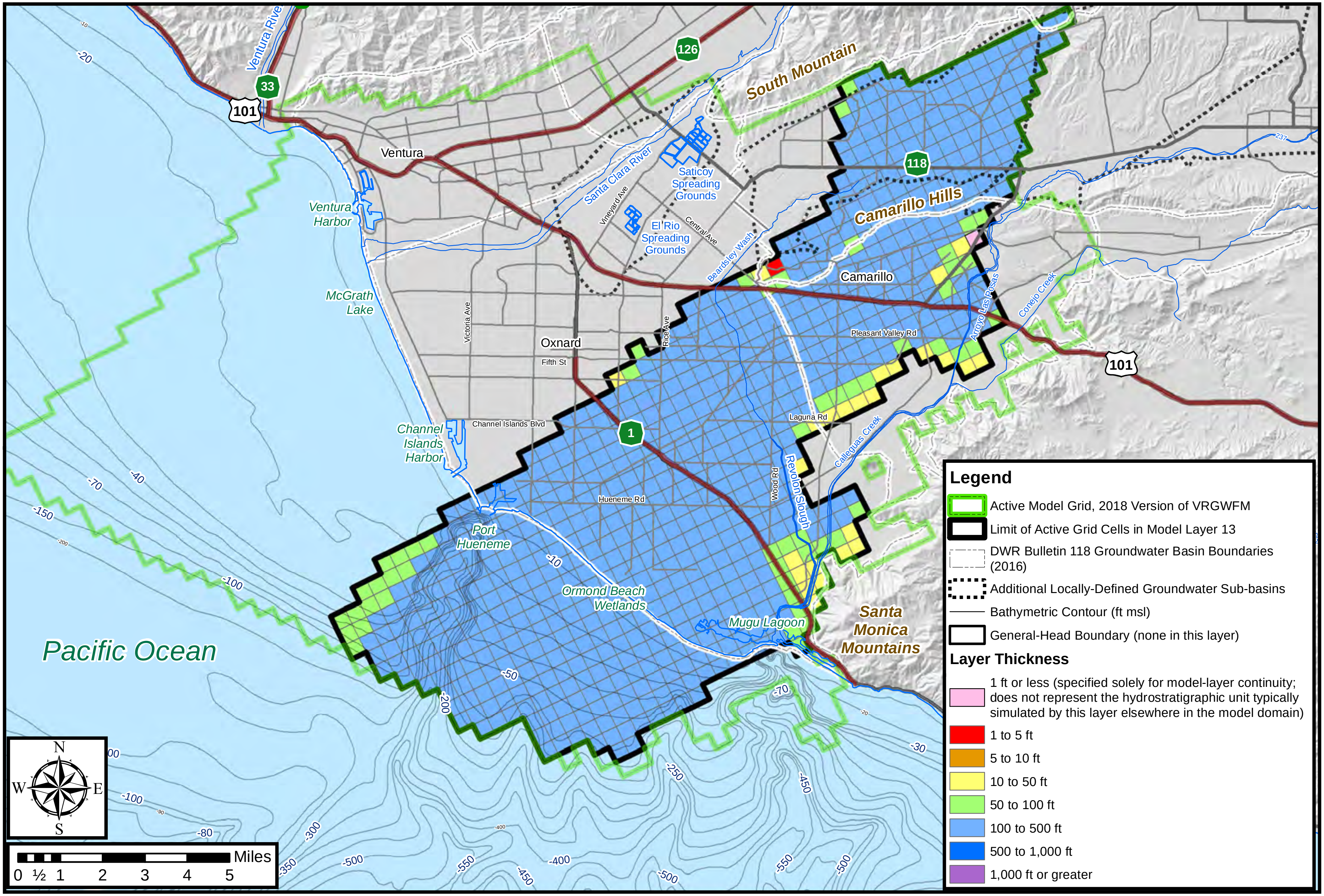


Figure 3-13. Boundary Conditions, Thickness, and Extent of Model Layer 13

Model Layer	Mound Basin	Forebay area	Oxnard Plain Basin	Pleasant Valley Basin	West Las Posas Sub-basin
1	Shallow alluvial aquifer	*layer inactive*	Semi-perched Aquifer	Semi-perched Aquifer	Shallow alluvial aquifer
2	Fine-grained Pleistocene deposits (Layers 2 through 4)	*layer inactive*	Clay Cap	Clay Cap	Layers 2 through 5 are each 1 foot thick in this basin, and assigned similar properties as the shallow alluvial aquifer
3		Oxnard Aquifer	Oxnard Aquifer	Oxnard Aquifer	
4		Oxnard-Mugu Aquitard	Oxnard-Mugu Aquitard	Oxnard-Mugu Aquitard	
5	Mugu Aquifer	Mugu Aquifer	Mugu Aquifer	Mugu Aquifer	
6	Mugu-Hueneme Aquitard	Mugu-Hueneme Aquitard	Mugu-Hueneme Aquitard	Mugu-Hueneme Aquitard	unnamed aquitard
7	Hueneme Aquifer	Hueneme Aquifer	Hueneme Aquifer	Hueneme Aquifer	Upper San Pedro Formation (Layers 7 and 8)
8	Hueneme-Fox Cyn Aquitard	Hueneme-Fox Cyn Aquitard	Hueneme-Fox Cyn Aquitard	Hueneme-Fox Cyn Aquitard	
9	Fox Cyn-main Aquifer	Fox Cyn-main Aquifer	Fox Cyn-main Aquifer	Fox Cyn-main Aquifer	Fox Cyn-main Aquifer
10	Mid-Fox Cyn Aquitard	Mid-Fox Cyn Aquitard	Mid-Fox Cyn Aquitard	Mid-Fox Cyn Aquitard	Mid-Fox Cyn Aquitard
11	Fox Cyn-basal Aquifer	Fox Cyn-basal Aquifer	Fox Cyn-basal Aquifer	Fox Cyn-basal Aquifer	Fox Cyn-basal Aquifer
12	*layer inactive*	*layer inactive*	Fox-Grimes Aquitard	Fox-Grimes Aquitard	Fox-Grimes Aquitard
13	*layer inactive*	*layer inactive*	Grimes Canyon Aquifer	Grimes Canyon Aquifer	Grimes Canyon Aquifer

Note: This diagram is conceptual, and does not reflect all of the details incorporated in the VRGWFM regarding changes in thickness or character of hydrostratigraphic units occurring in each basin or area.

Figure 3-14. Conceptual Diagram Illustrating Relationships between Model Layers and Hydrostratigraphic Units

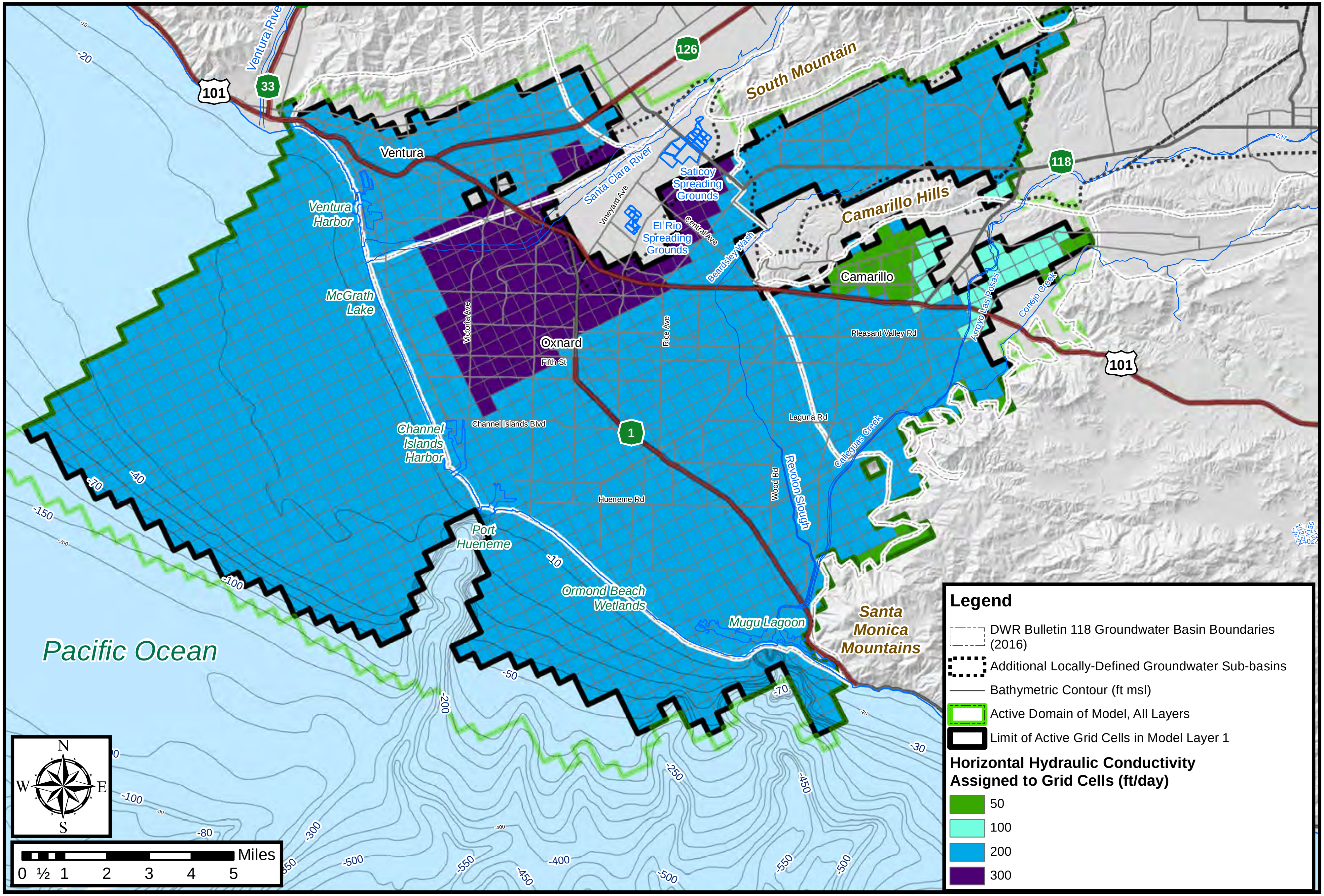


Figure 3-15. Horizontal Hydraulic Conductivity of Grid Cells in Model Layer 1

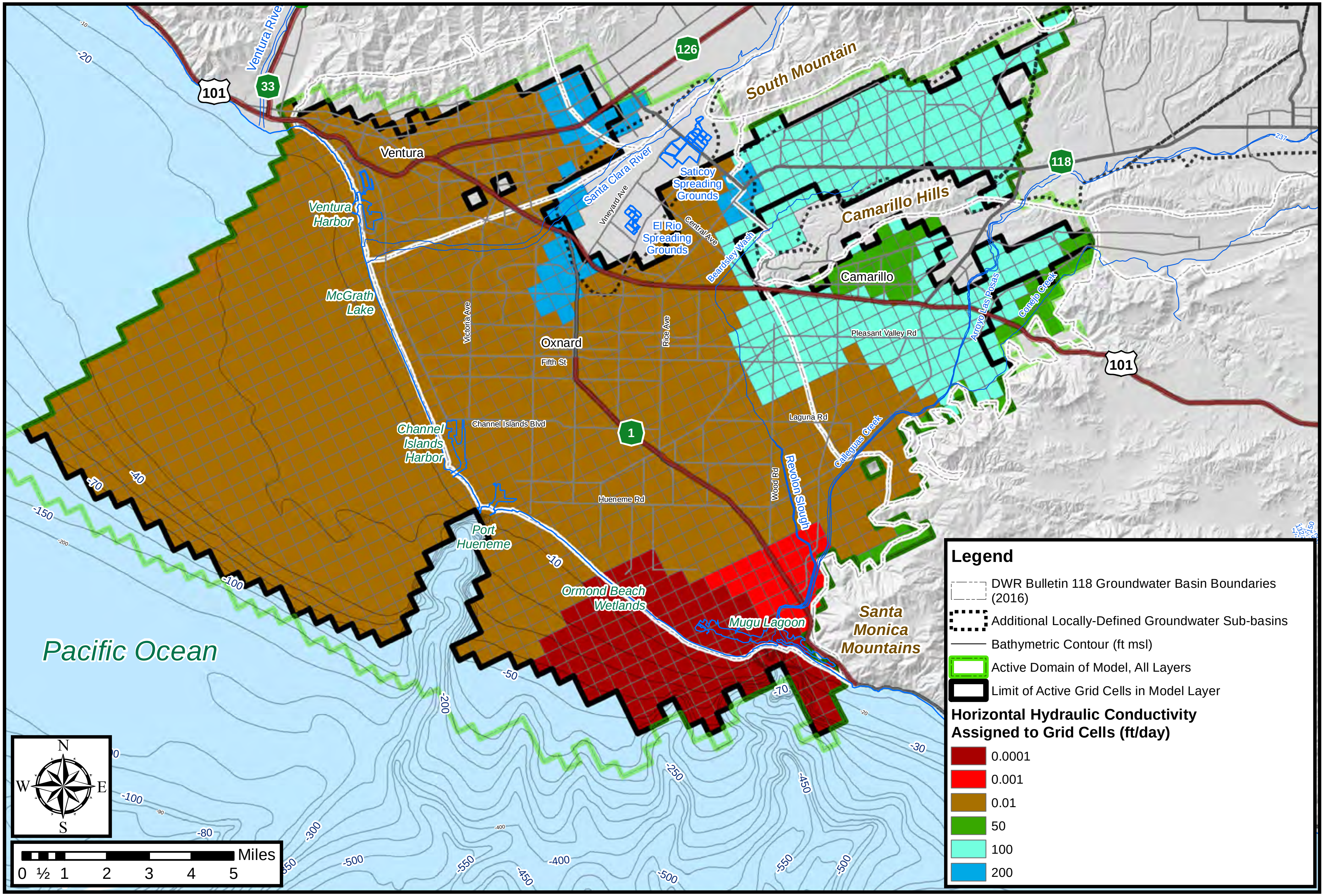


Figure 3-16. Horizontal Hydraulic Conductivity of Grid Cells in Model Layer 2

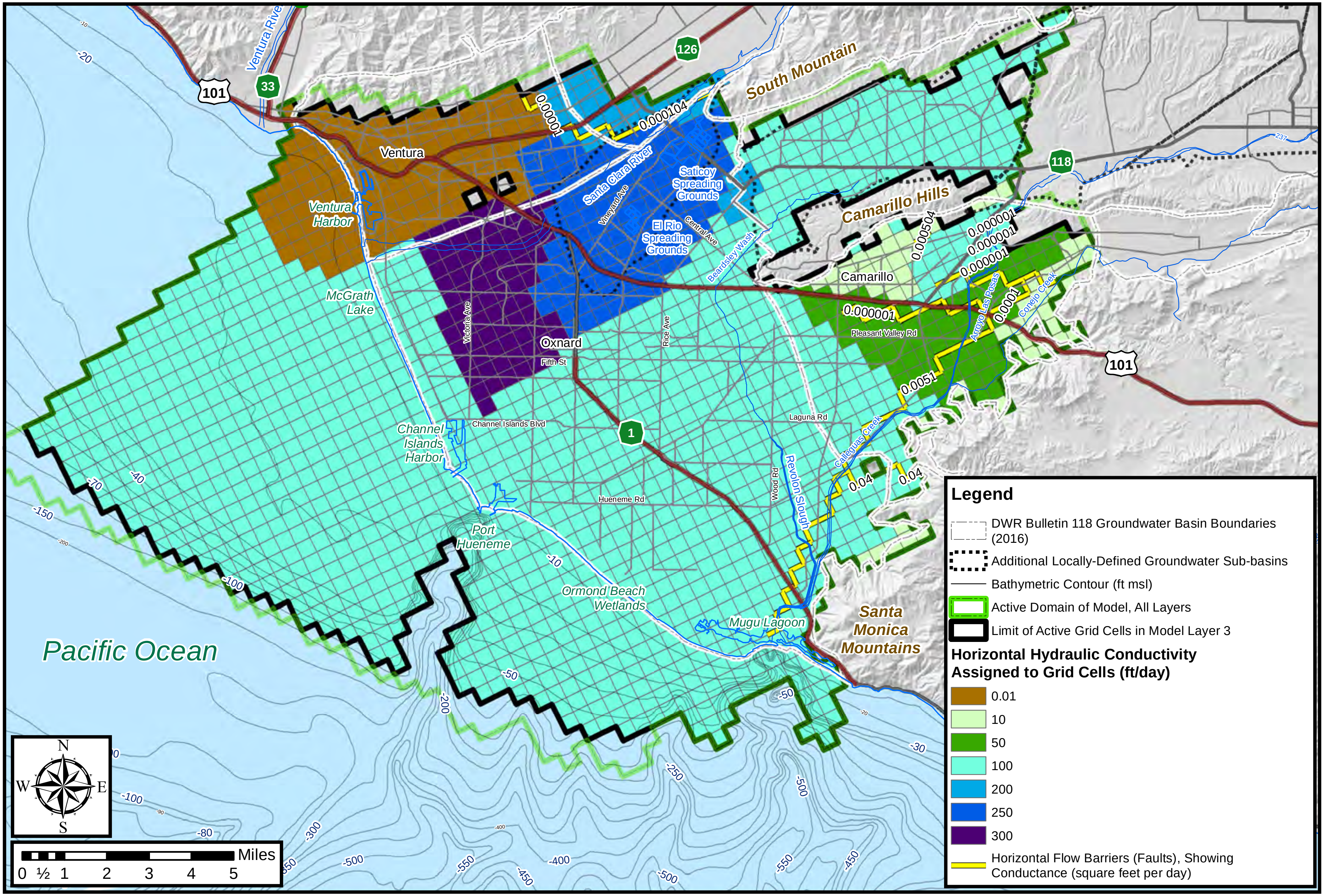


Figure 3-17. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 3

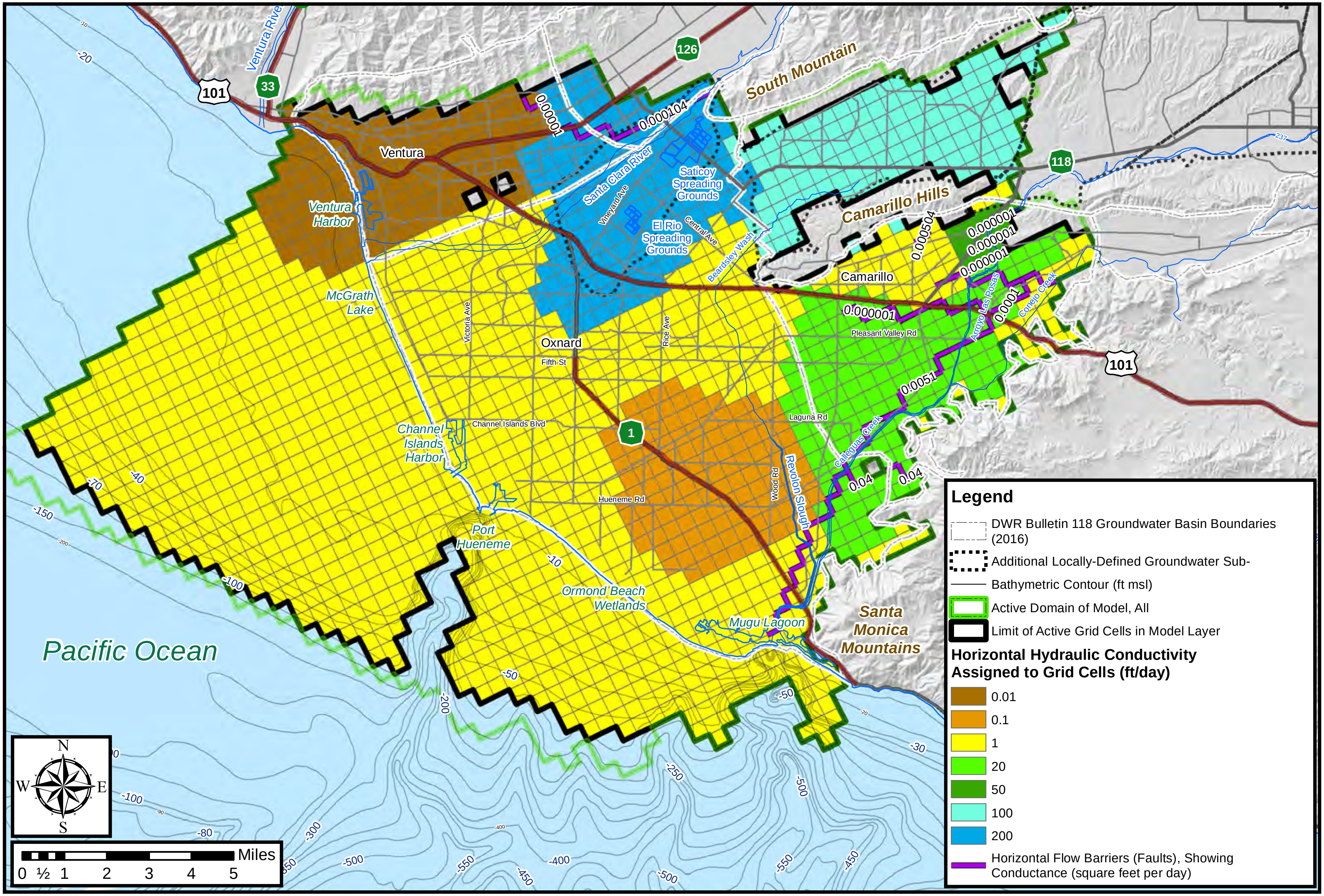


Figure 3-18. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 4

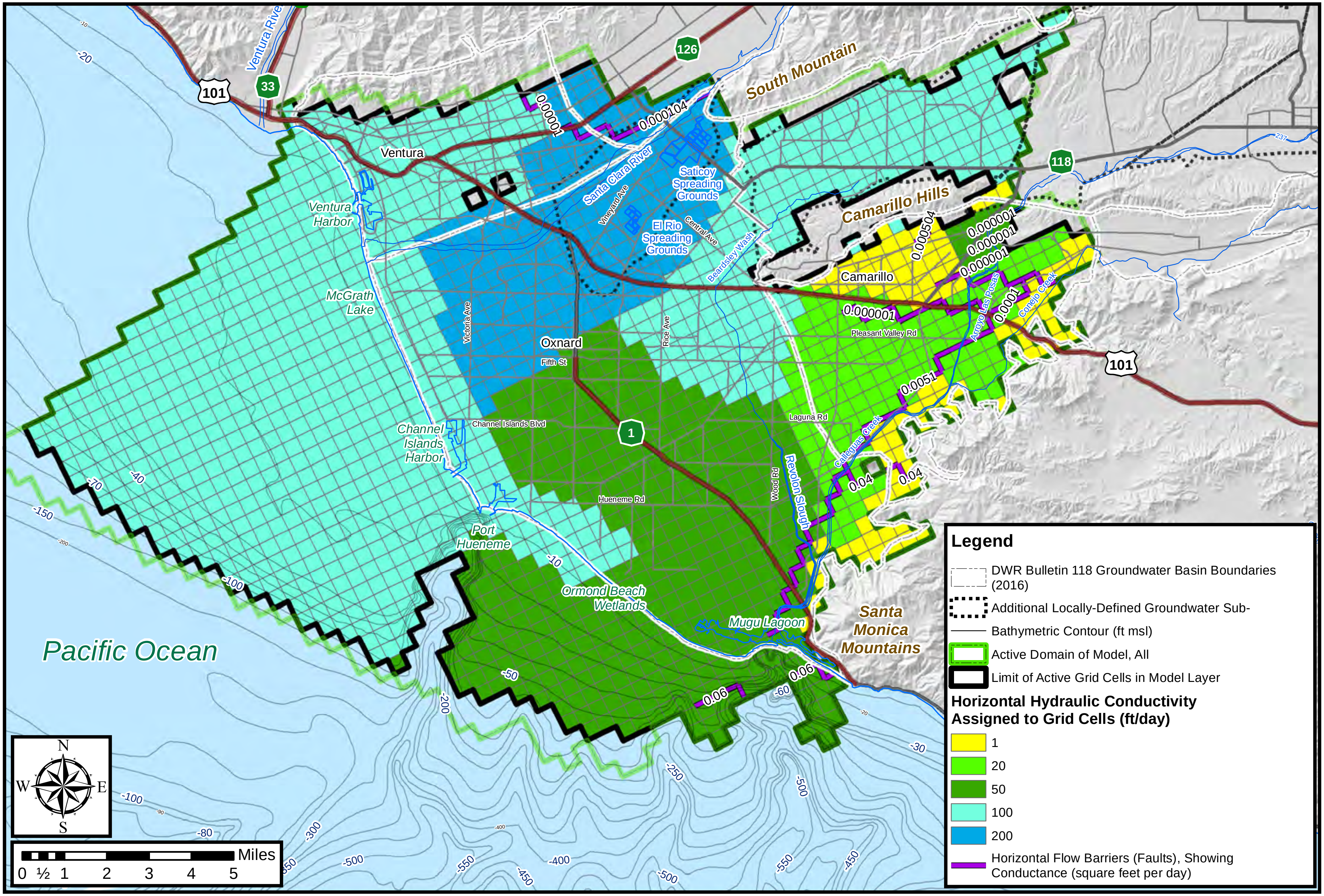


Figure 3-19. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 5

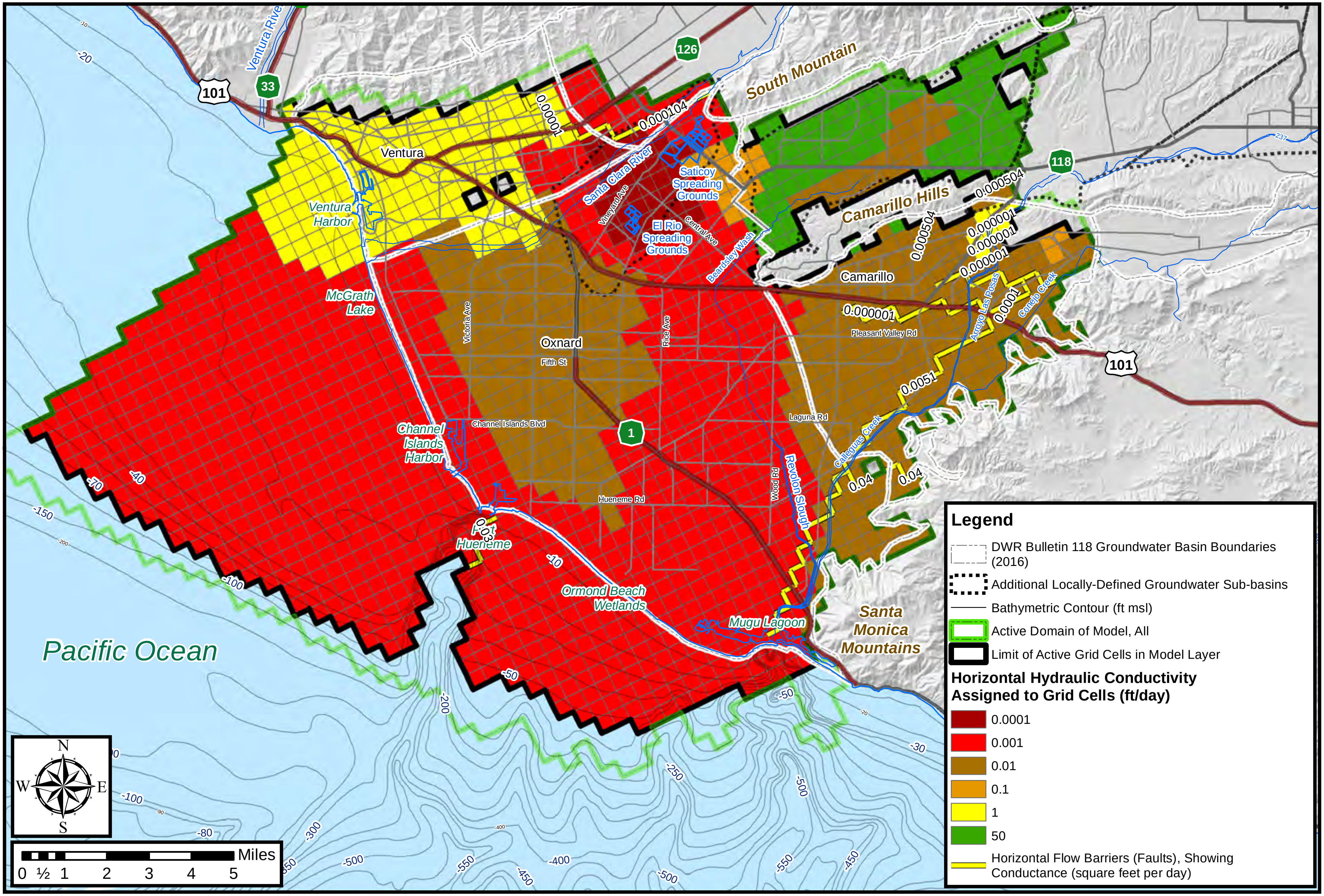


Figure 3-20. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 6

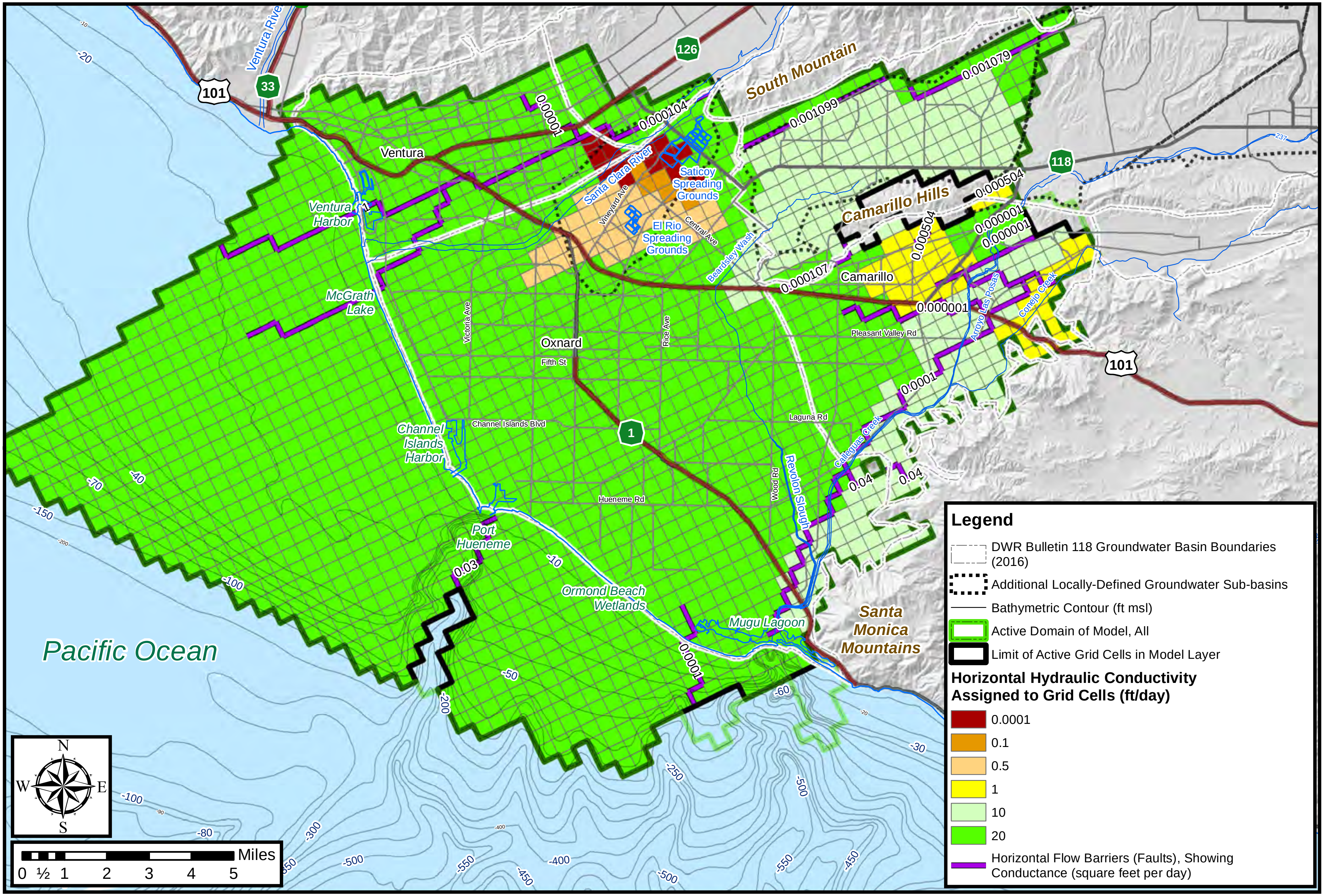


Figure 3-21. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 7

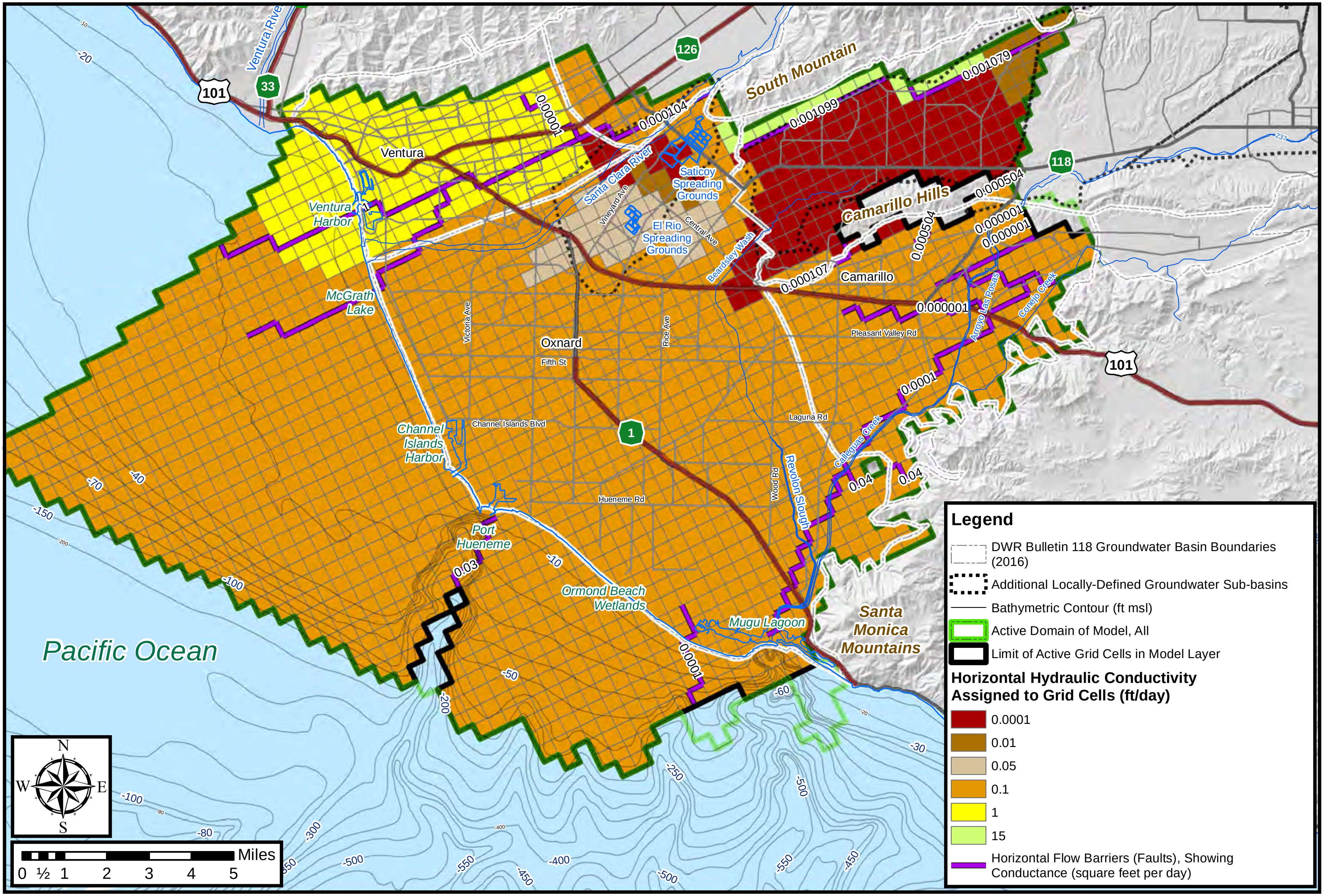


Figure 3-22. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 8

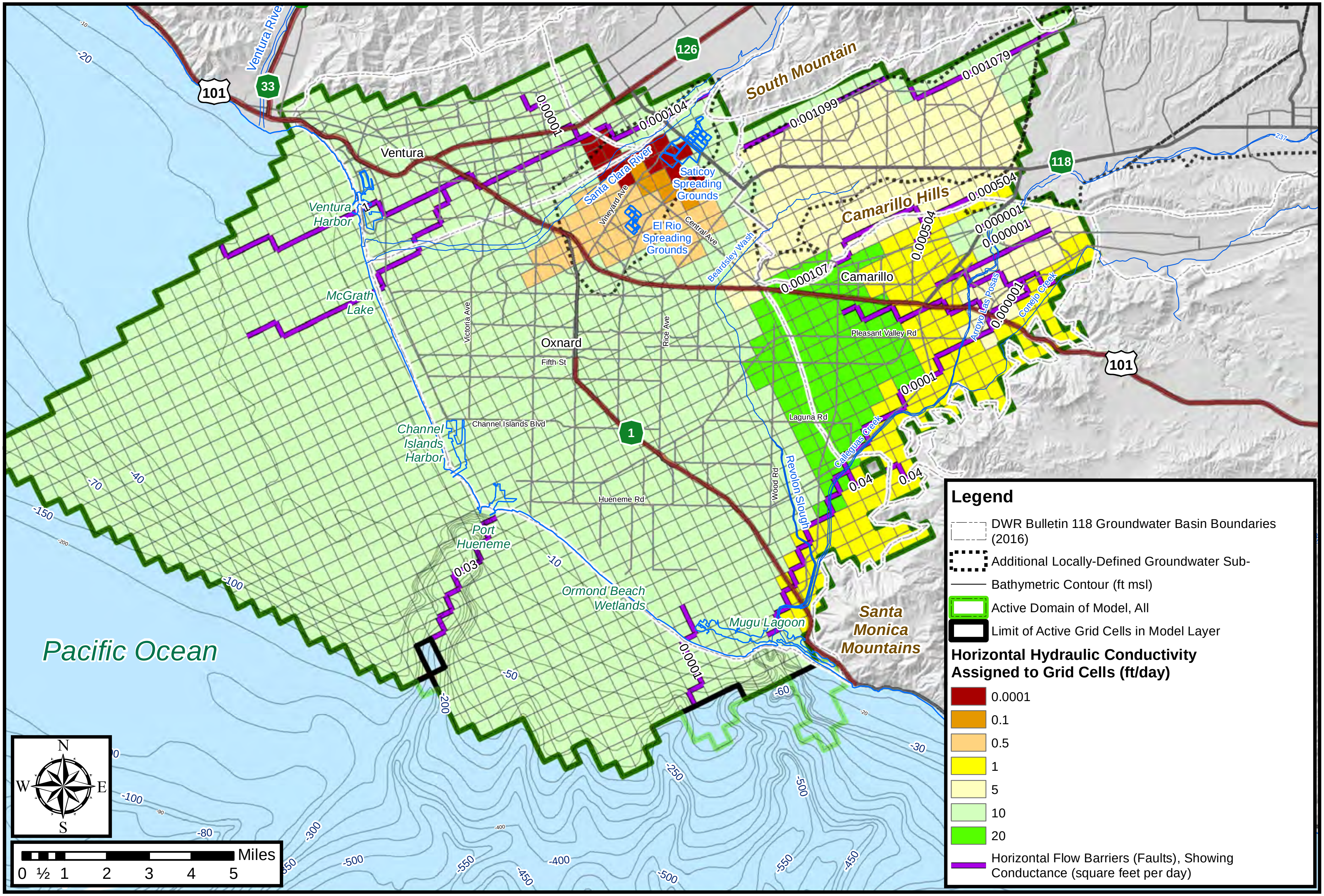


Figure 3-23. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 9

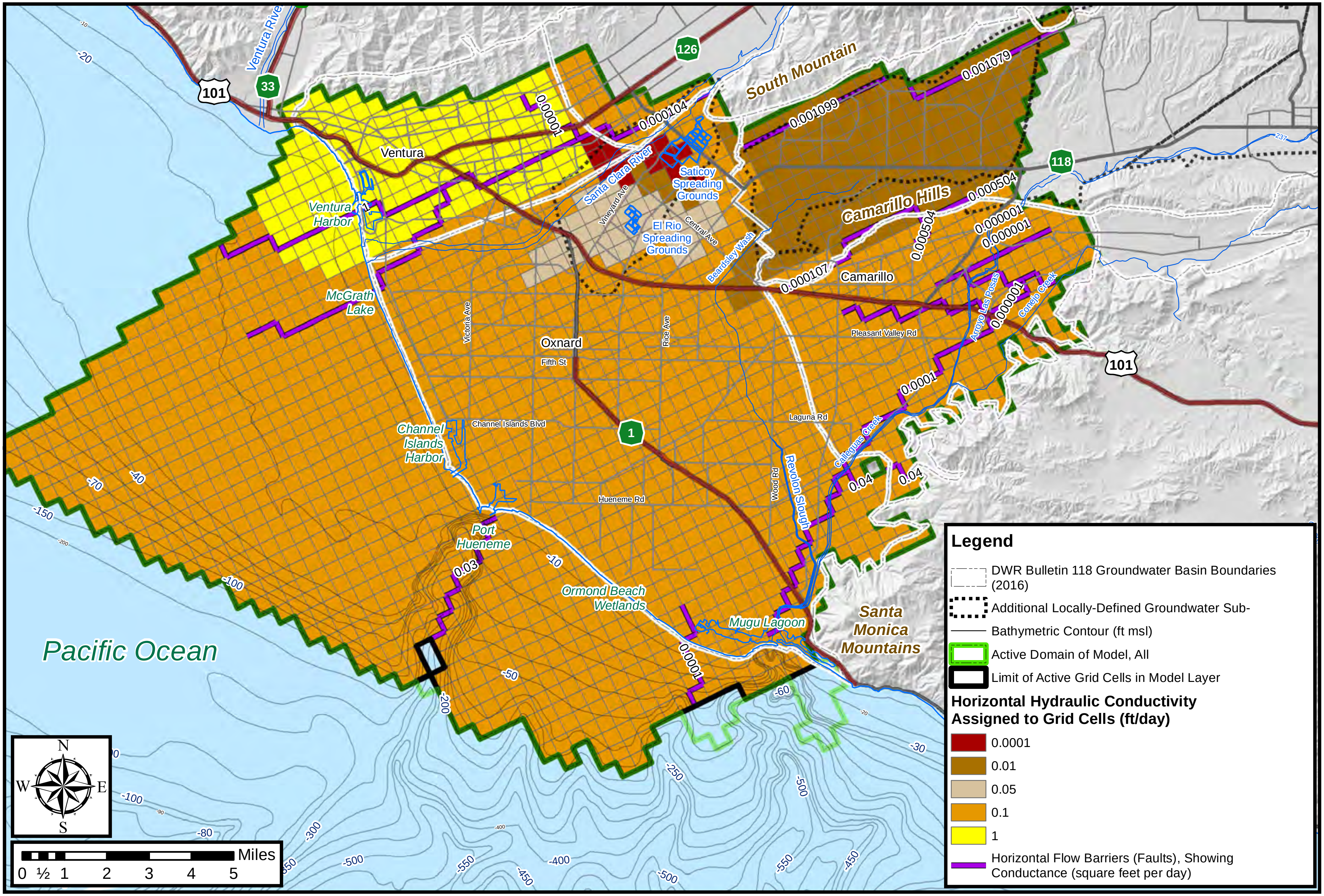


Figure 3-24. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 10

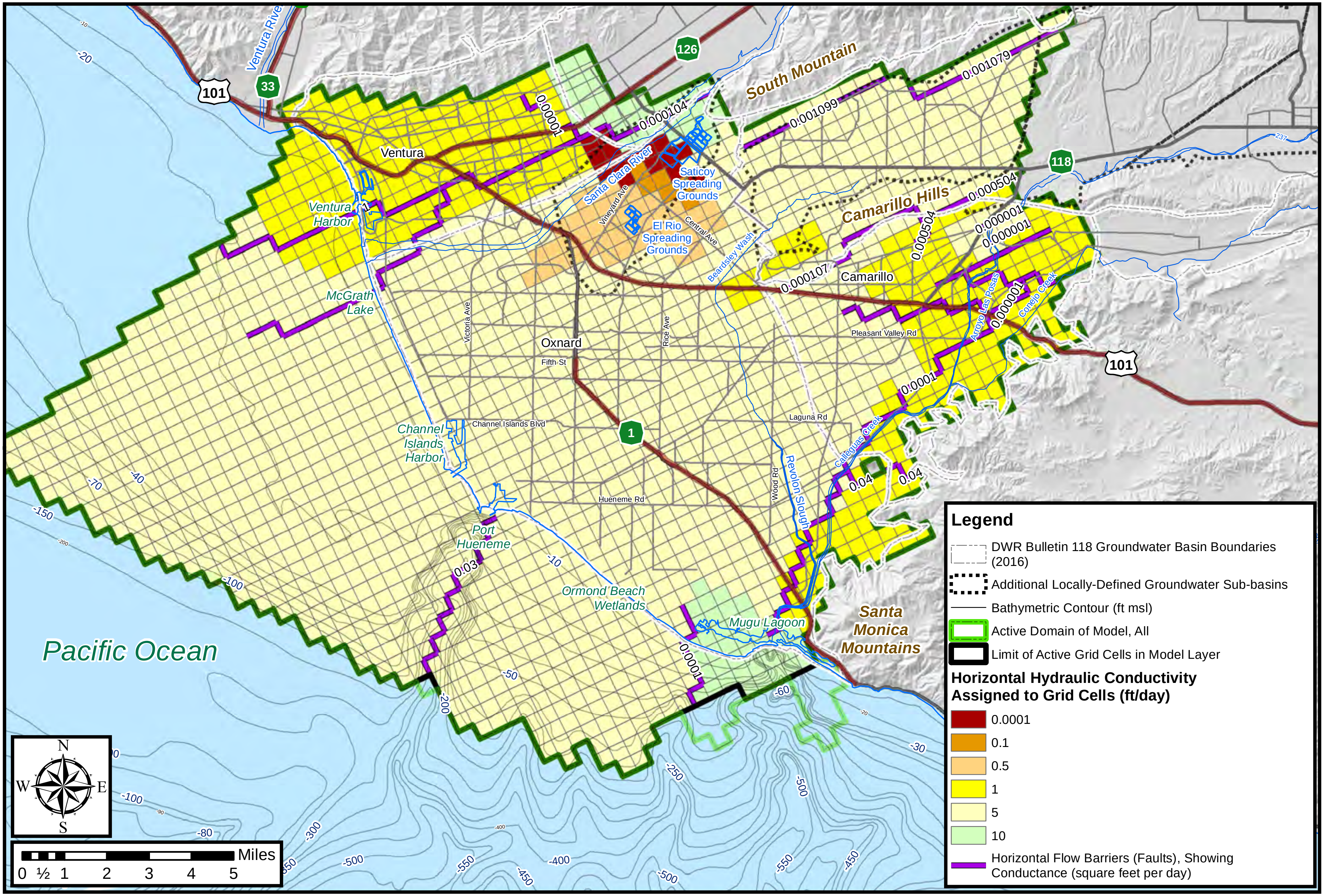


Figure 3-25. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 11

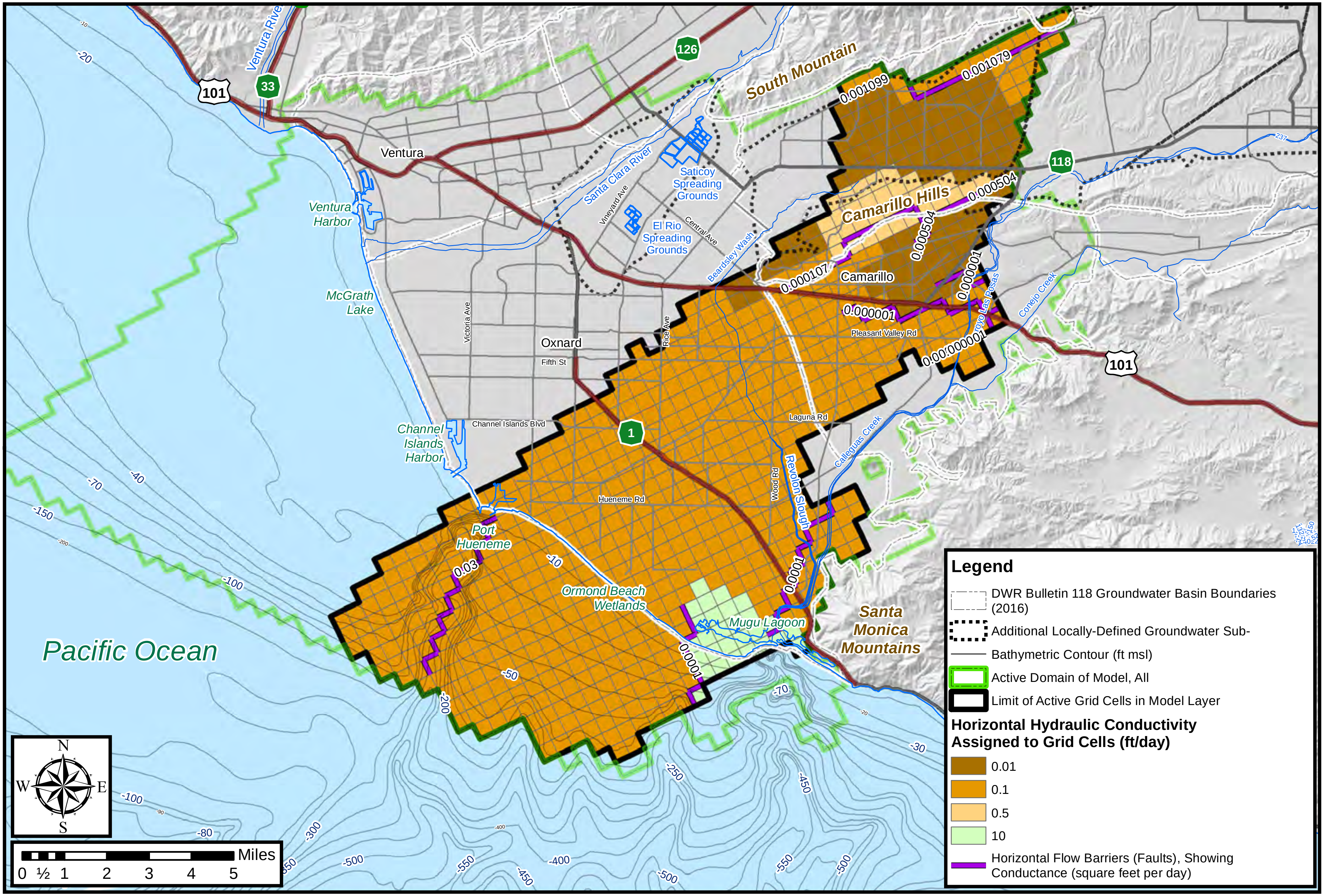


Figure 3-26. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 12

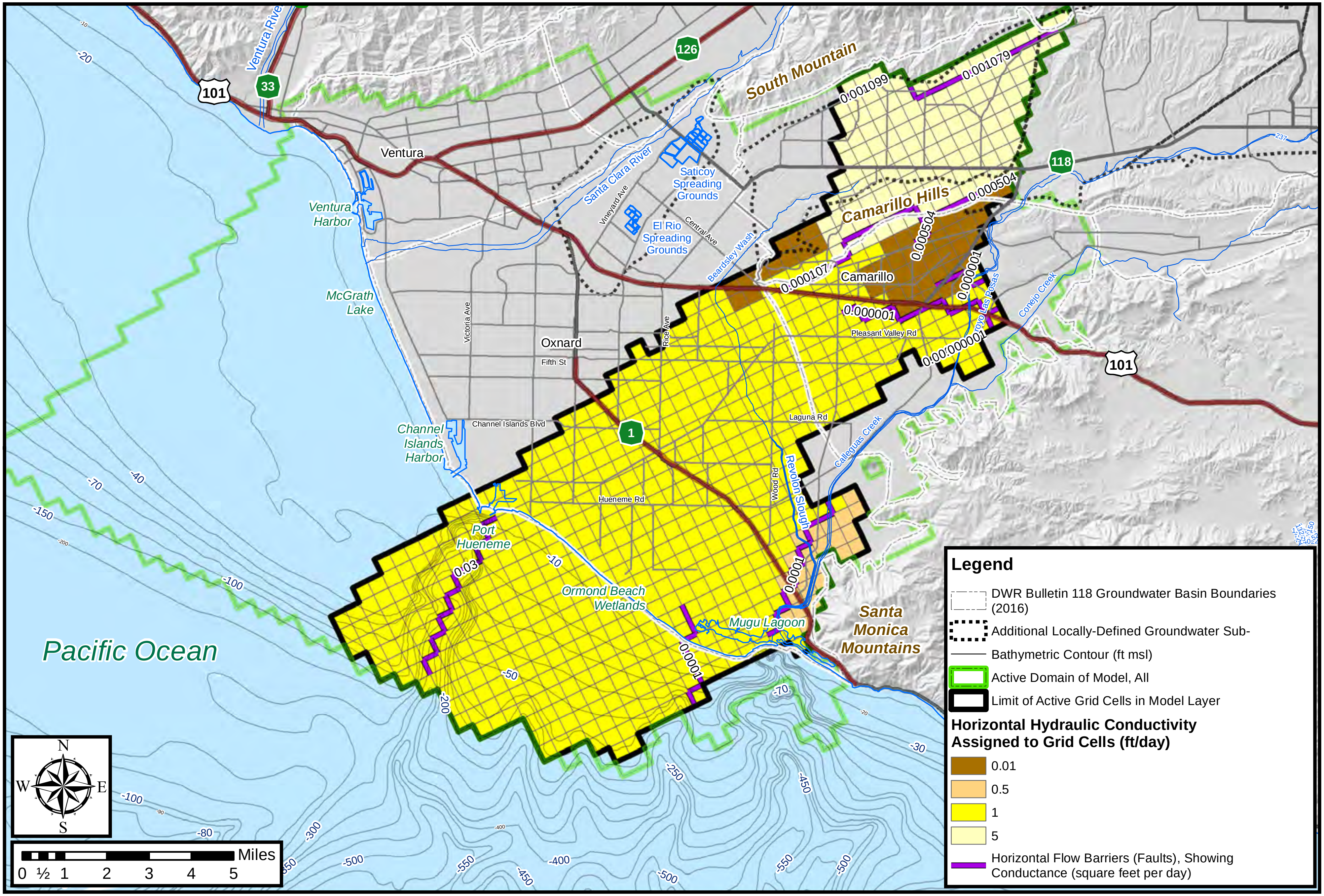


Figure 3-27. Horizontal Hydraulic Conductivity of Grid Cells and Conductance of Horizontal Flow Barriers in Model Layer 13

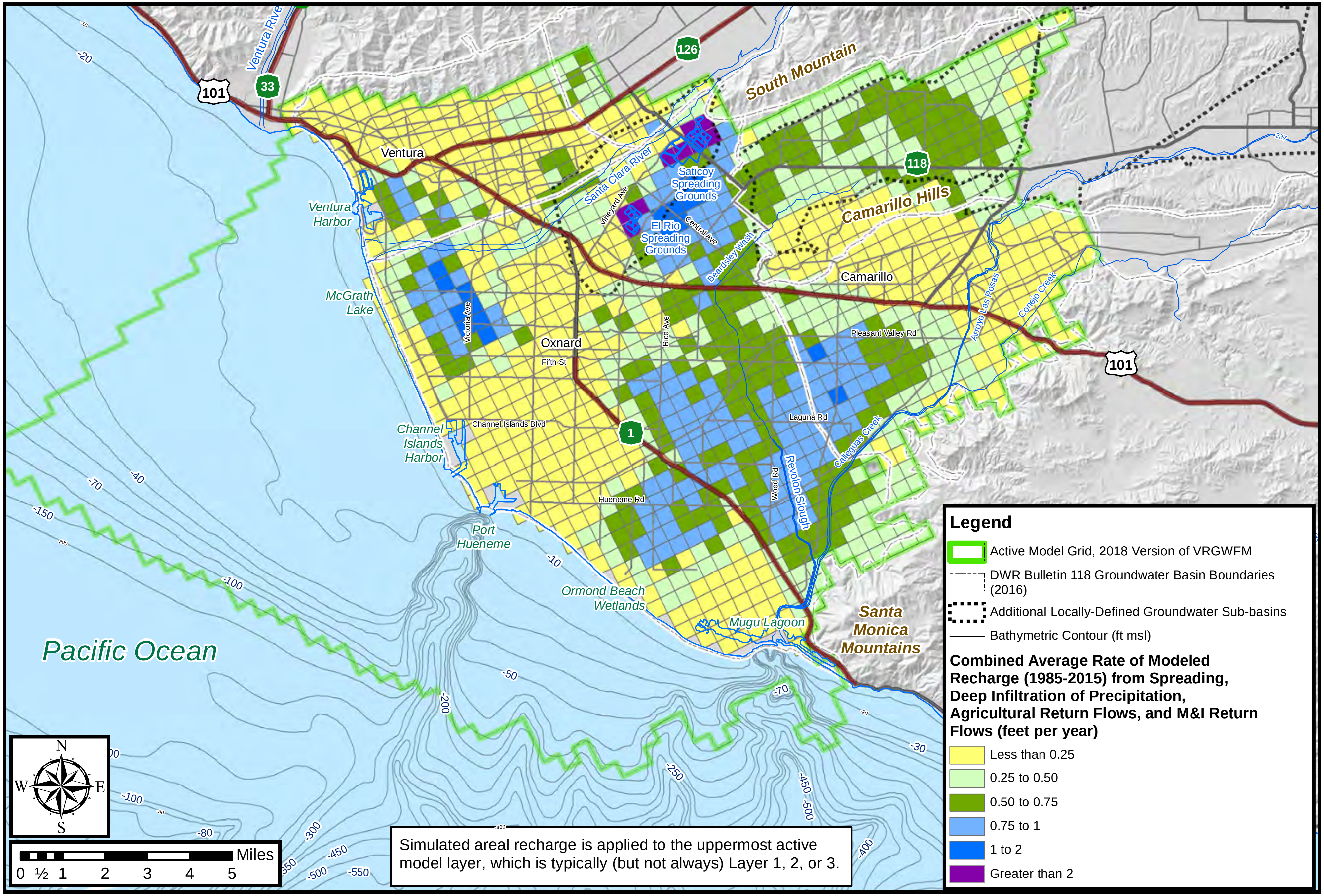


Figure 3-28. Simulated Average Areal Recharge Rates in Active Model Domain

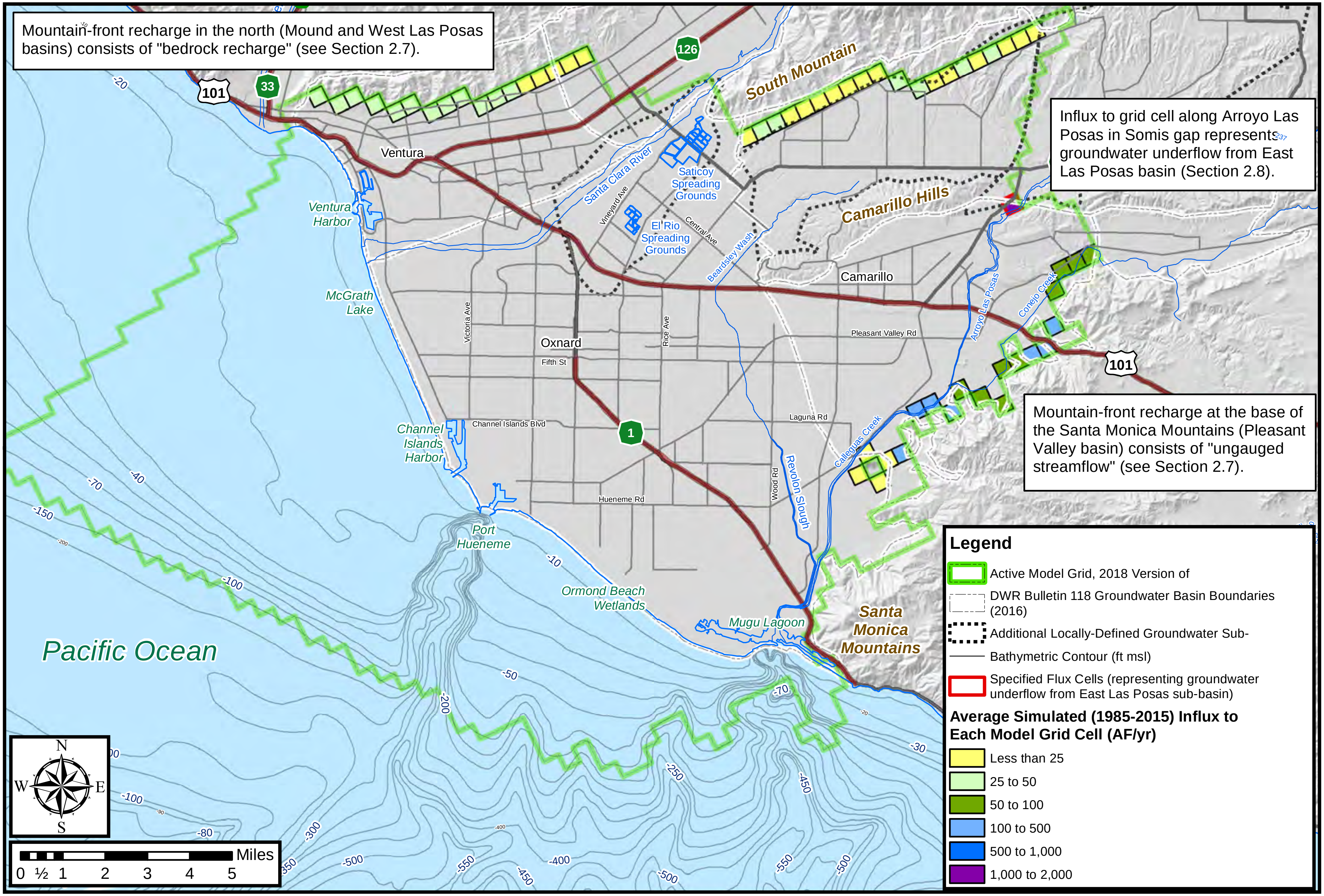


Figure 3-29. Simulated Average Mountain-Front Recharge Rate and Groundwater Underflow from Specified Flux Cells in Active Model Domain

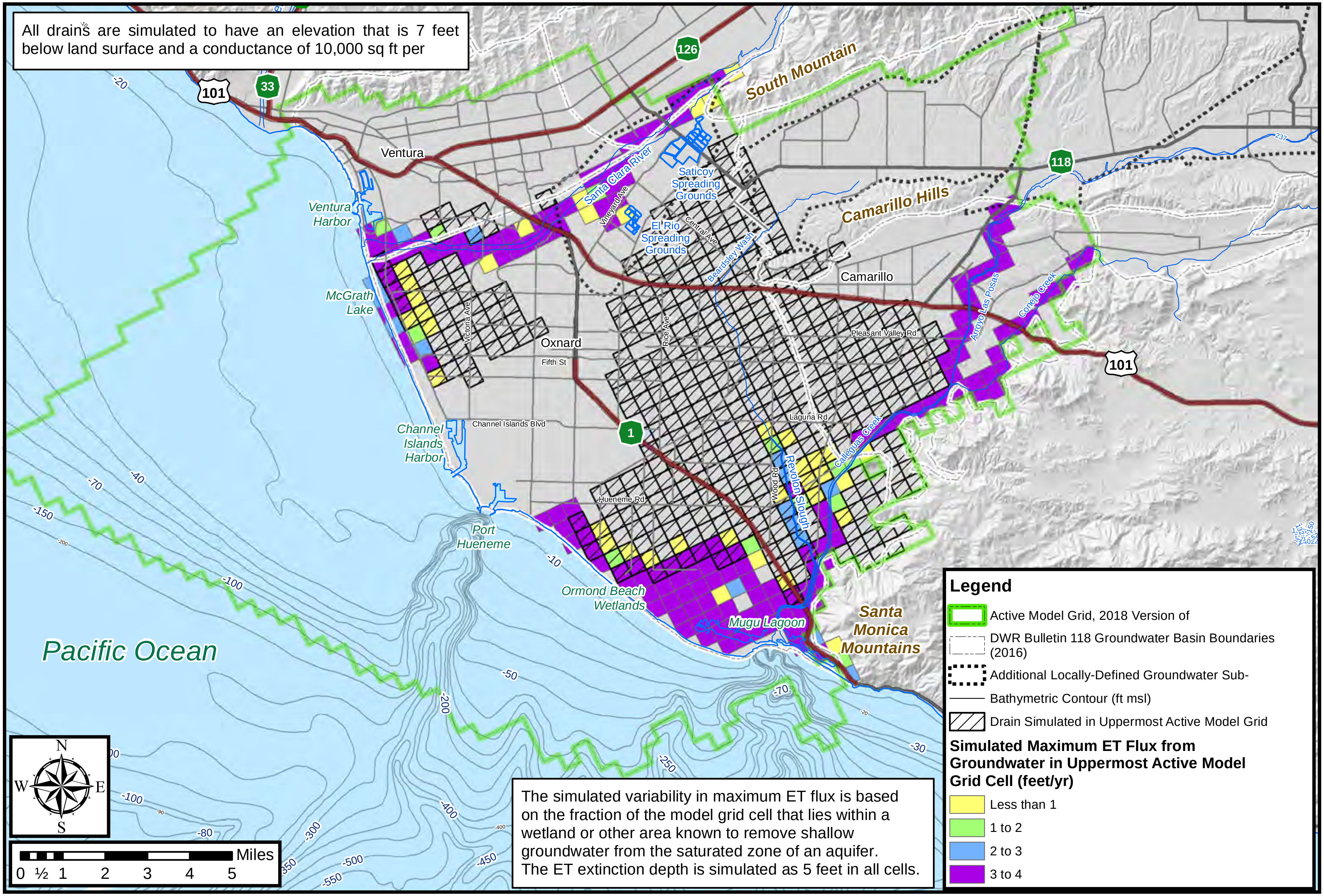


Figure 3-30. Model Grid Cells with Tile Drains or Evapotranspiration

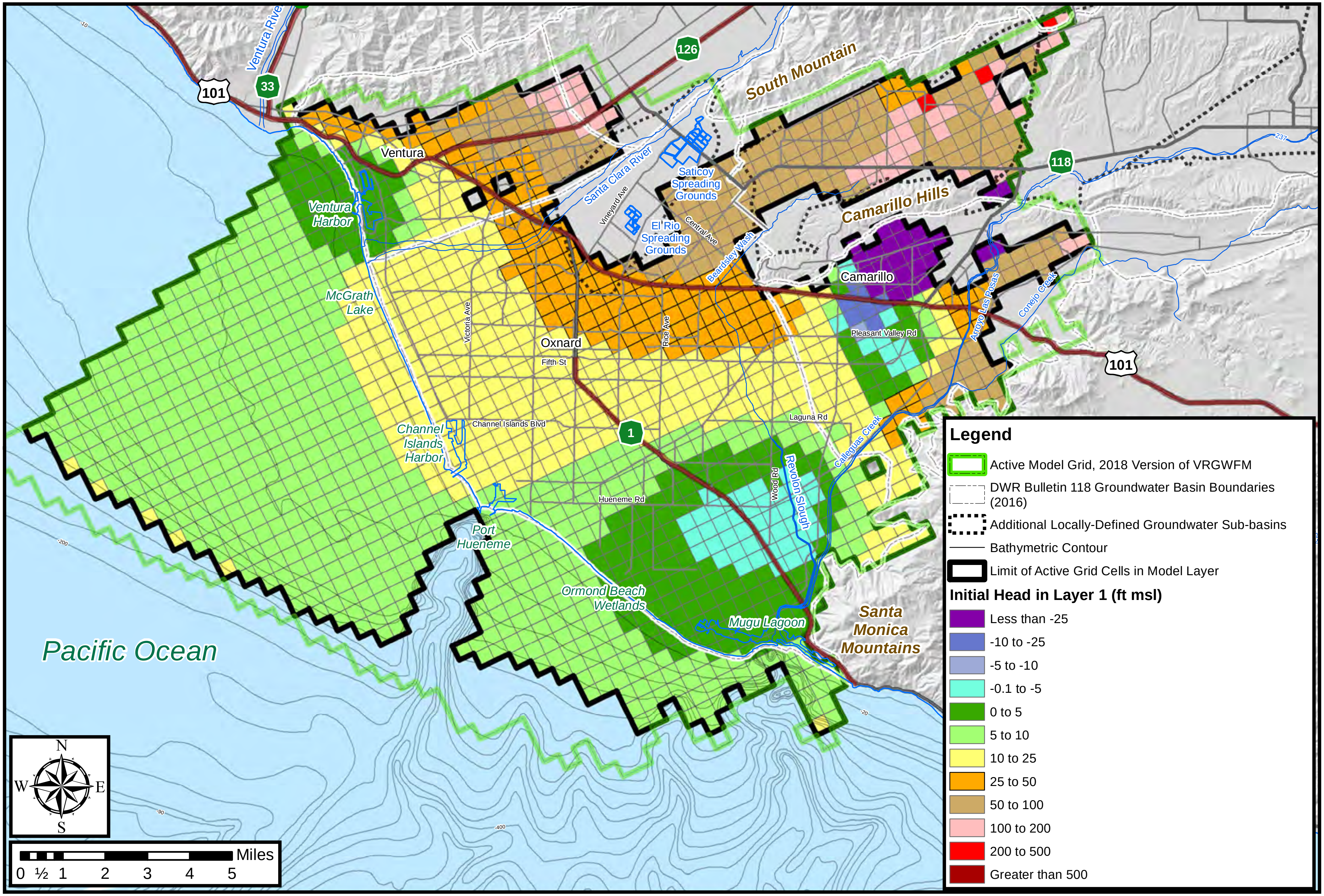


Figure 3-31. Initial Head in Model Layer 1, Representing the Shallow Groundwater System

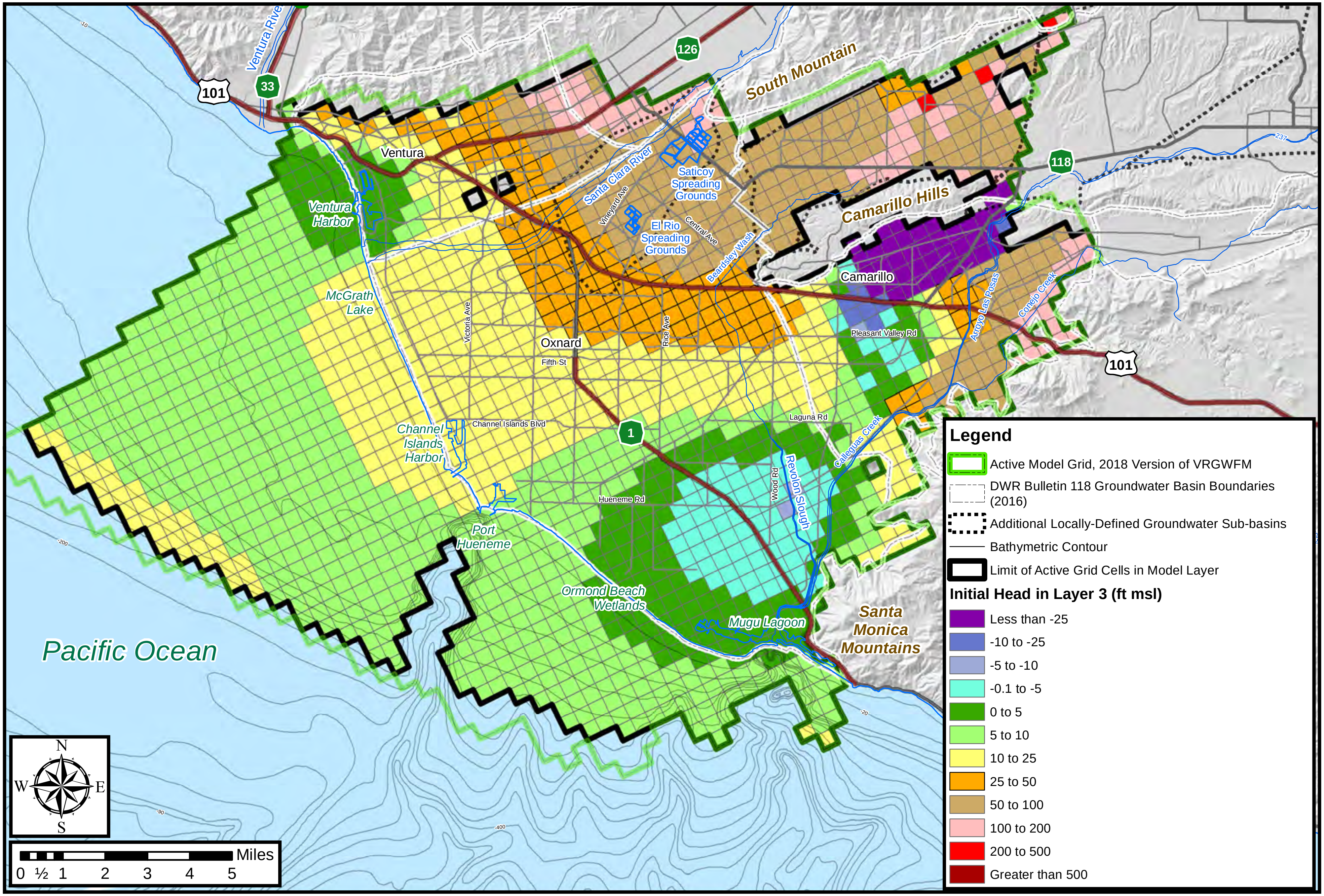


Figure 3-32. Initial Head in Model Layer 3, Representing the UAS

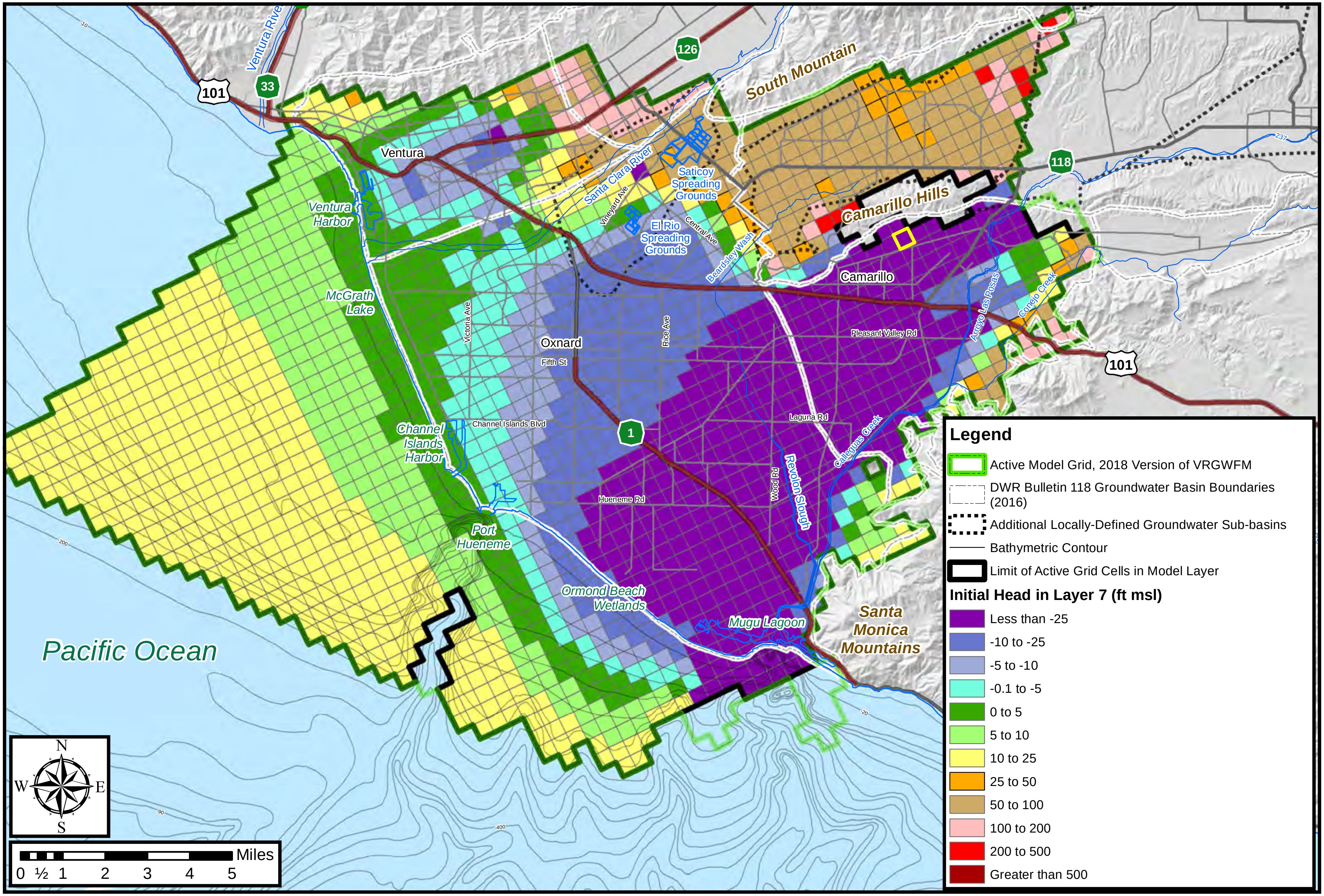


Figure 3-33. Initial Head in Model Layer 7, Representing the LAS

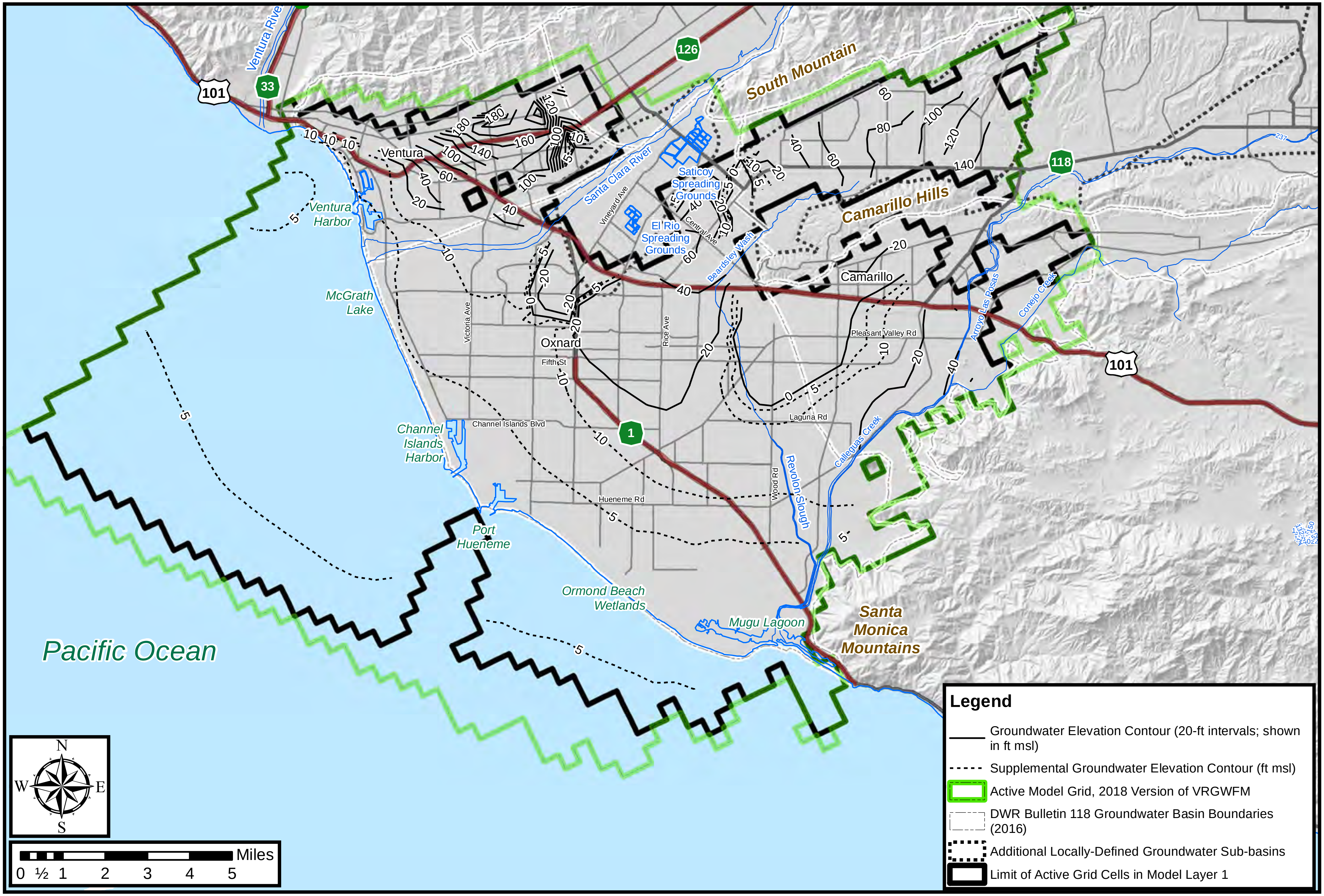


Figure 4-1. Simulated Groundwater Elevations in Layer 1, October 1991

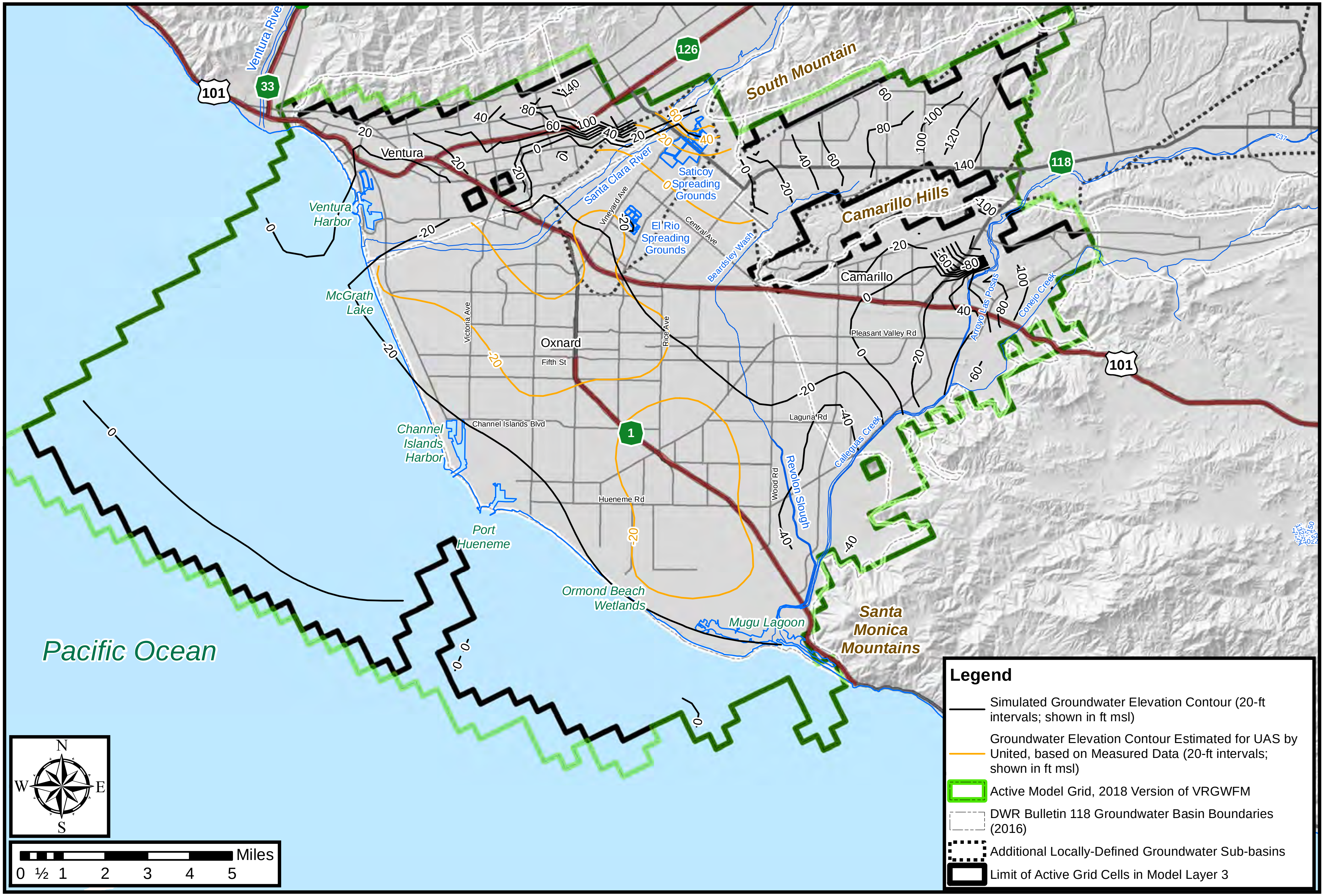


Figure 4-2. Simulated Groundwater Elevations in Layer 3, October 1991

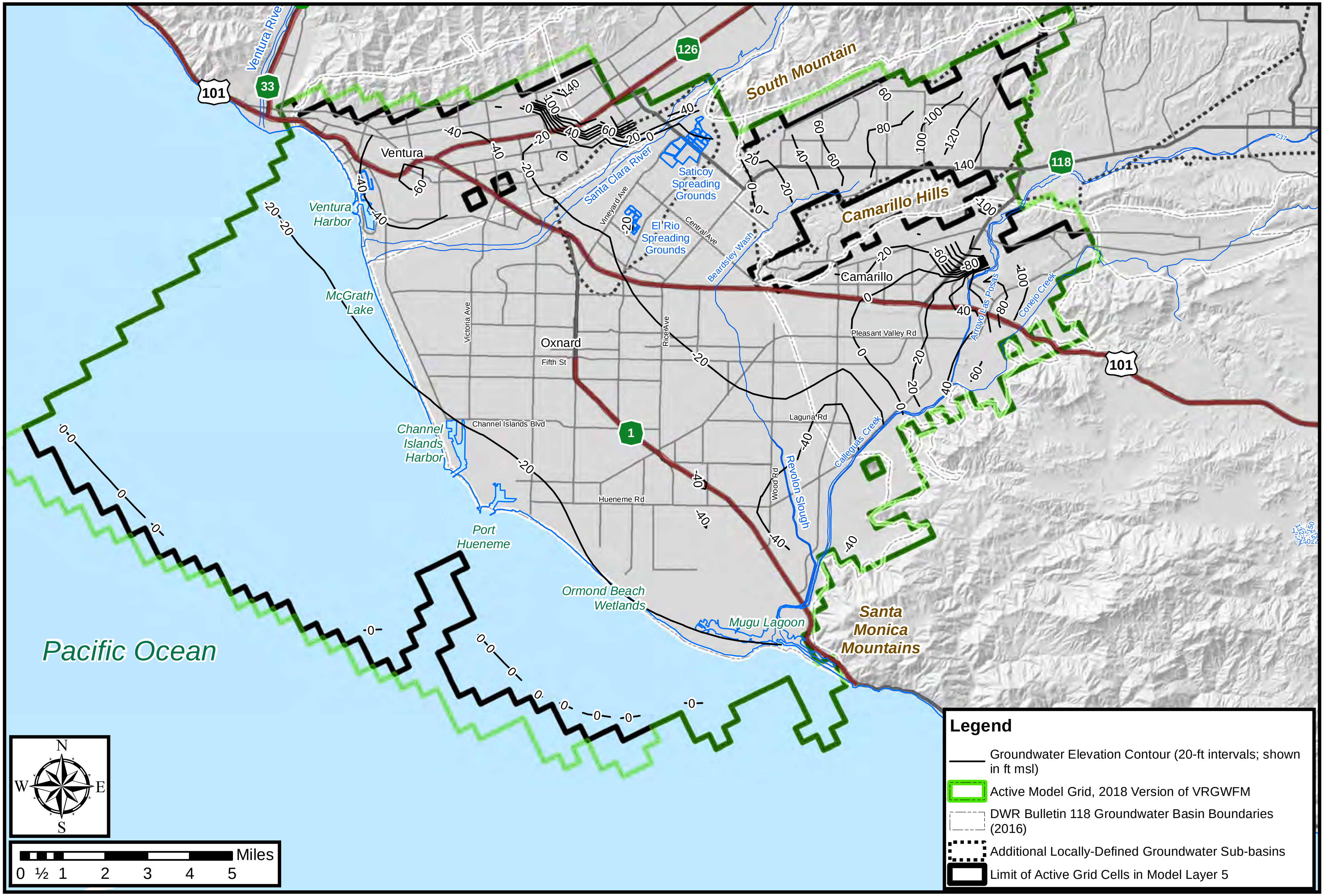


Figure 4-3. Simulated Groundwater Elevations in Layer 5, October 1991

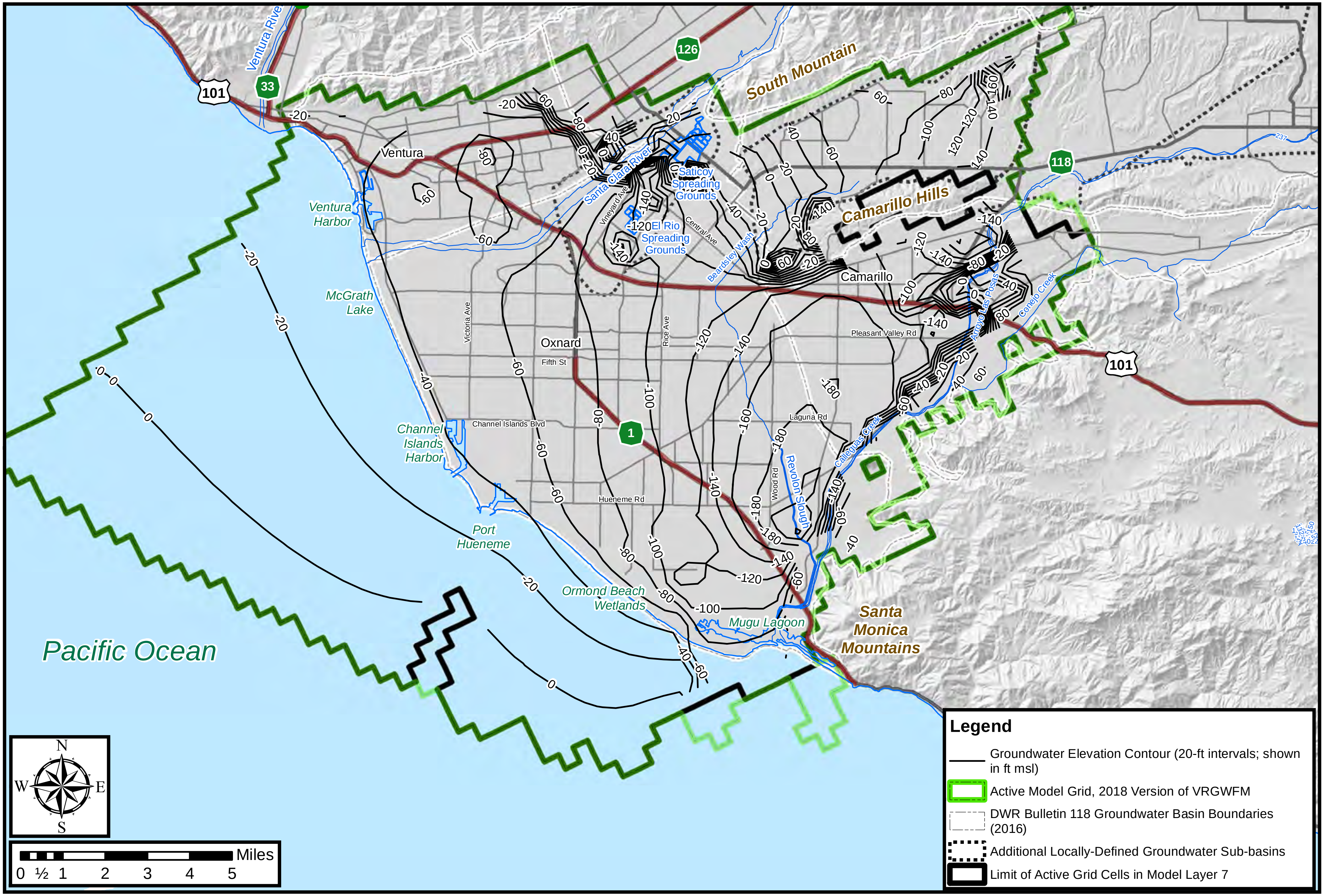


Figure 4-4. Simulated Groundwater Elevations in Layer 7, October 1991

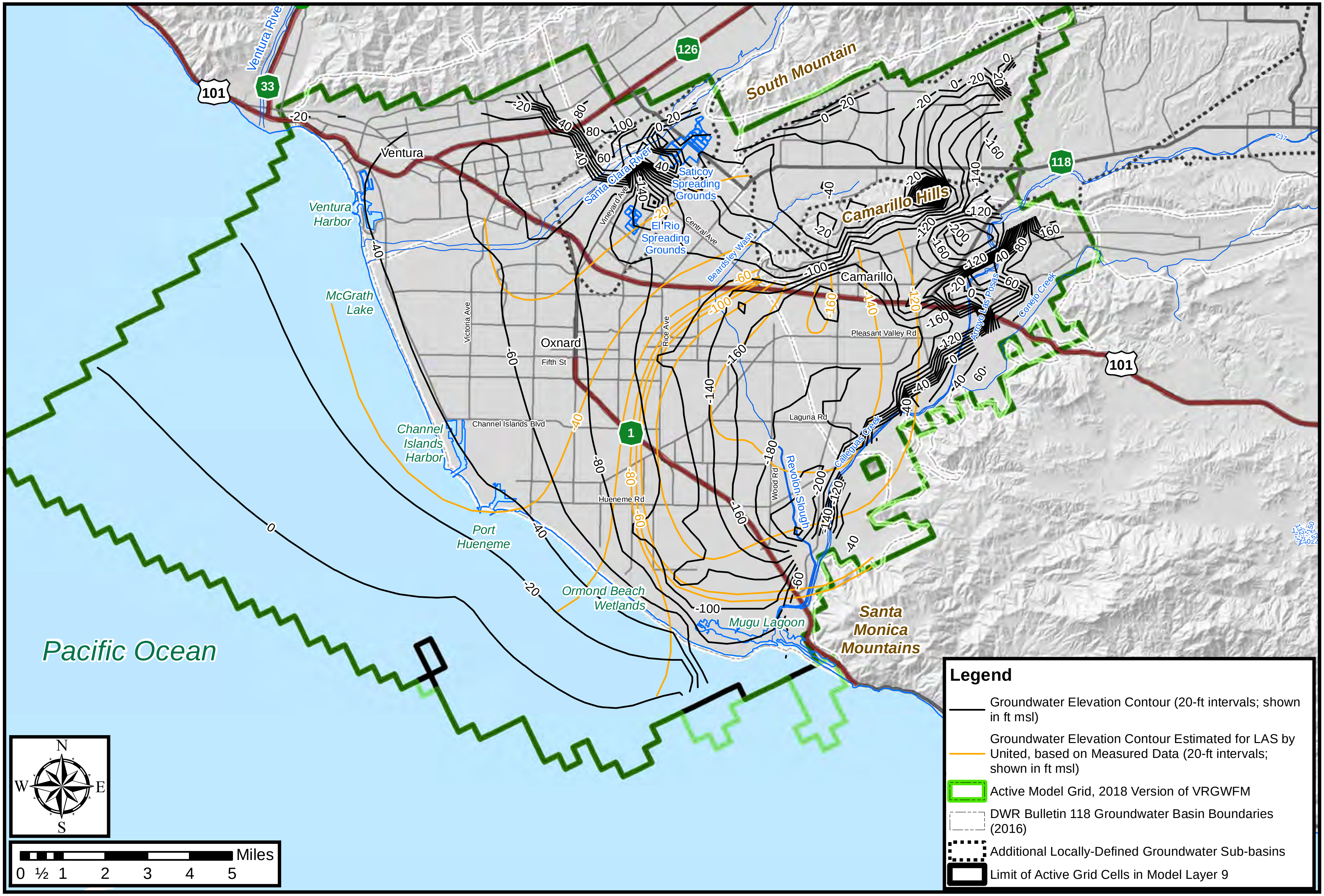


Figure 4-5. Simulated Groundwater Elevations in Layer 9, October 1991

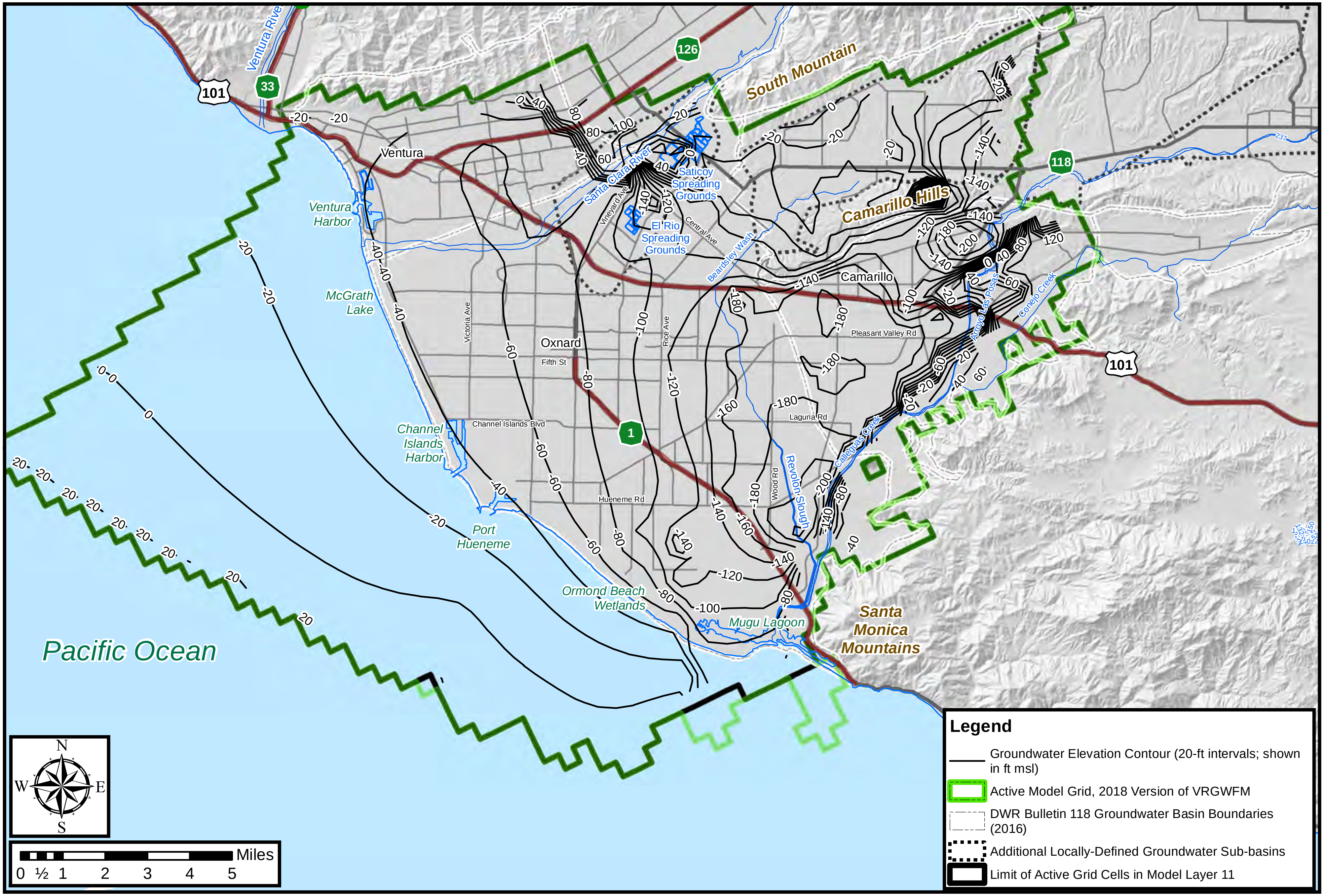


Figure 4-6. Simulated Groundwater Elevations in Layer 11, October 1991

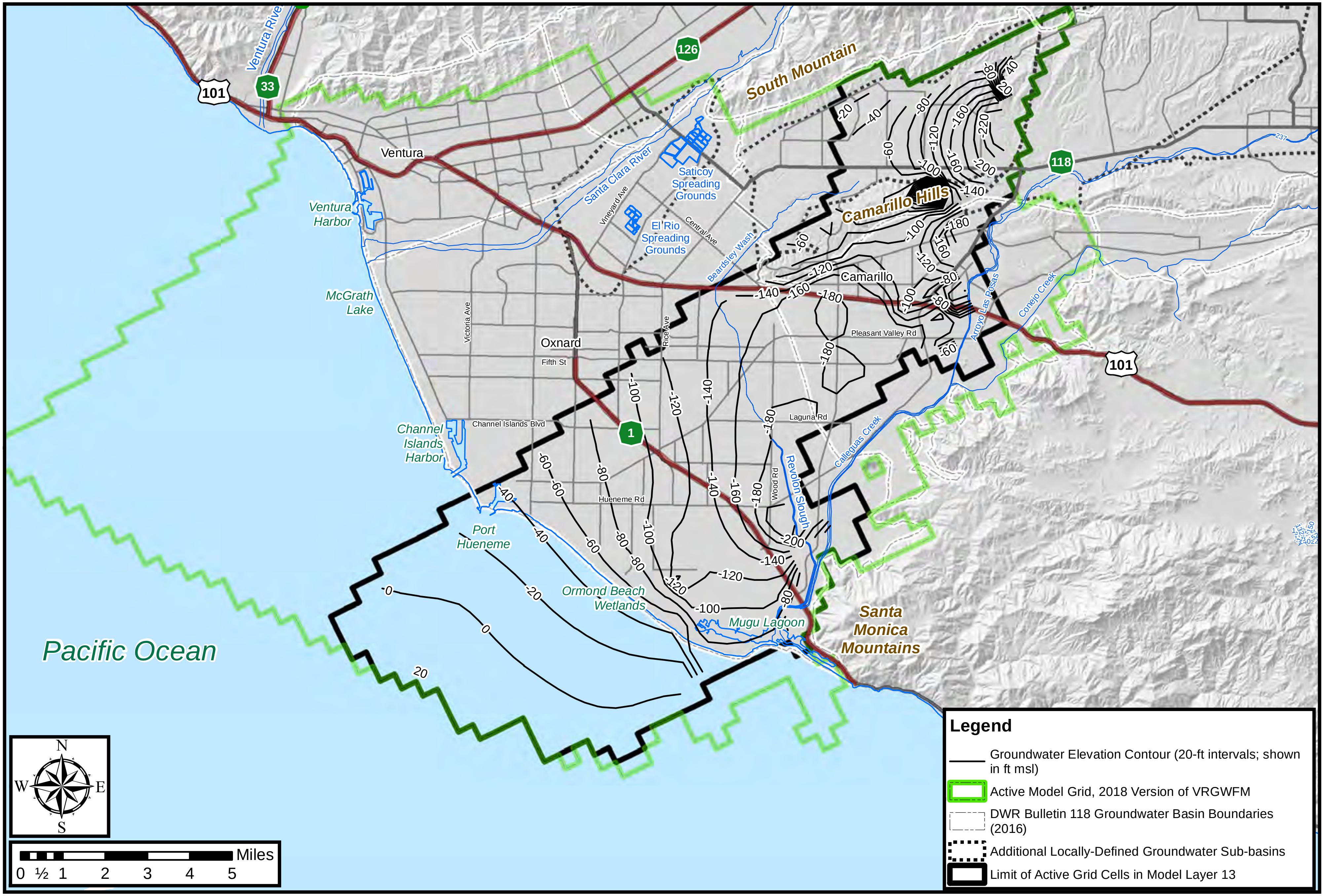


Figure 4-7. Simulated Groundwater Elevations in Layer 13, October 1991

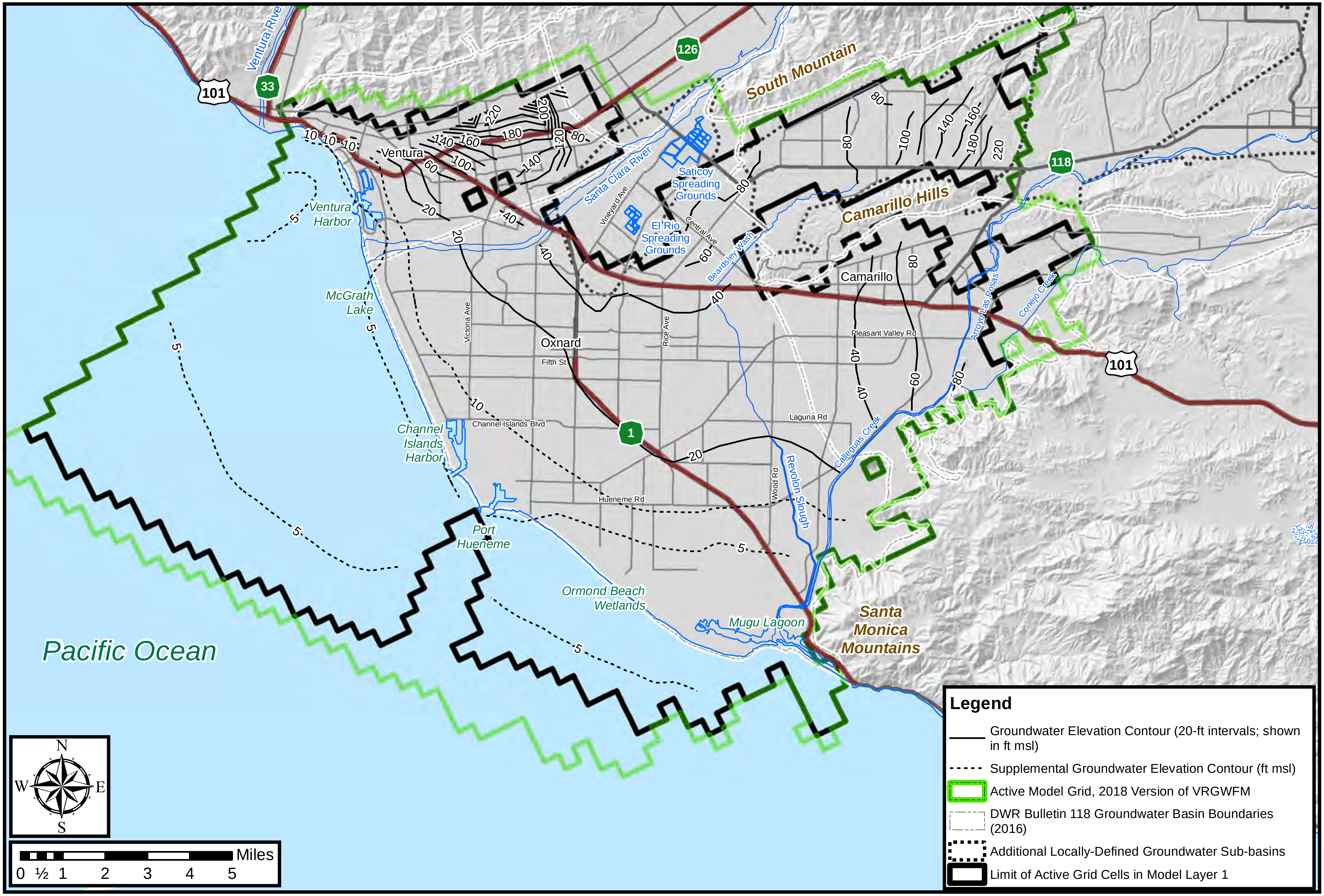


Figure 4-8. Simulated Groundwater Elevations in Layer 1, October 2006

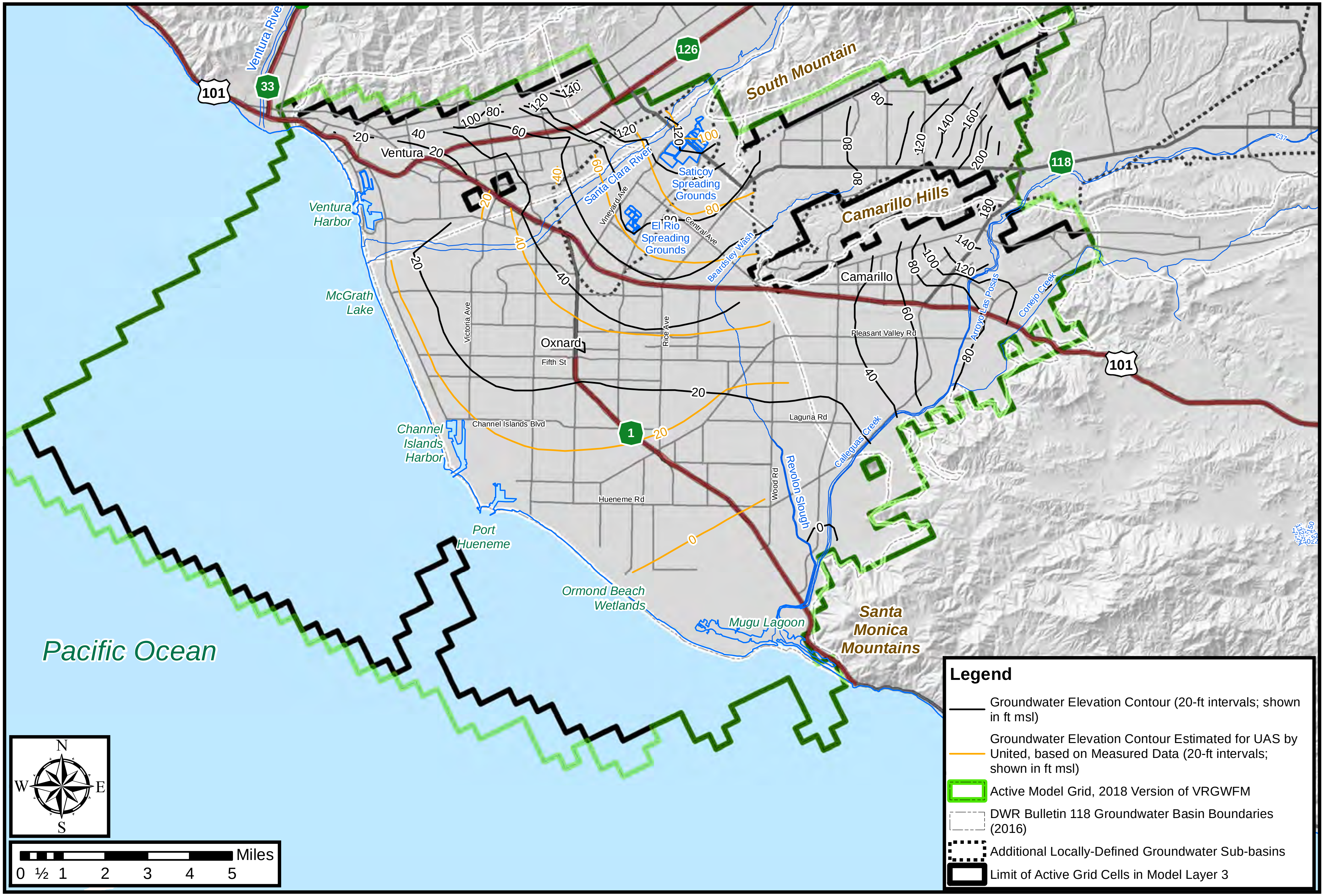


Figure 4-9. Simulated Groundwater Elevations in Layer 3, October 2006

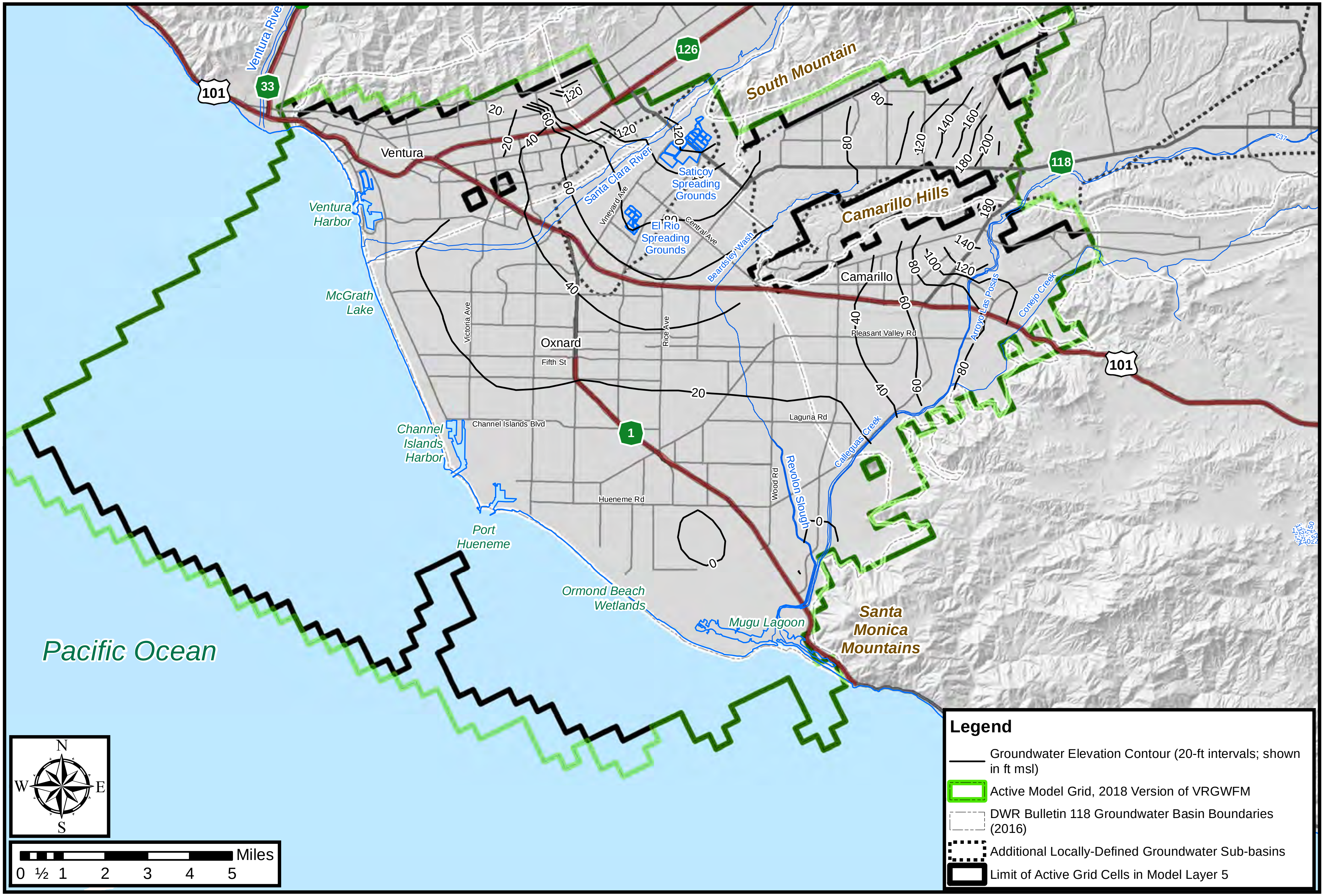


Figure 4-10. Simulated Groundwater Elevations in Layer 5, October 2006

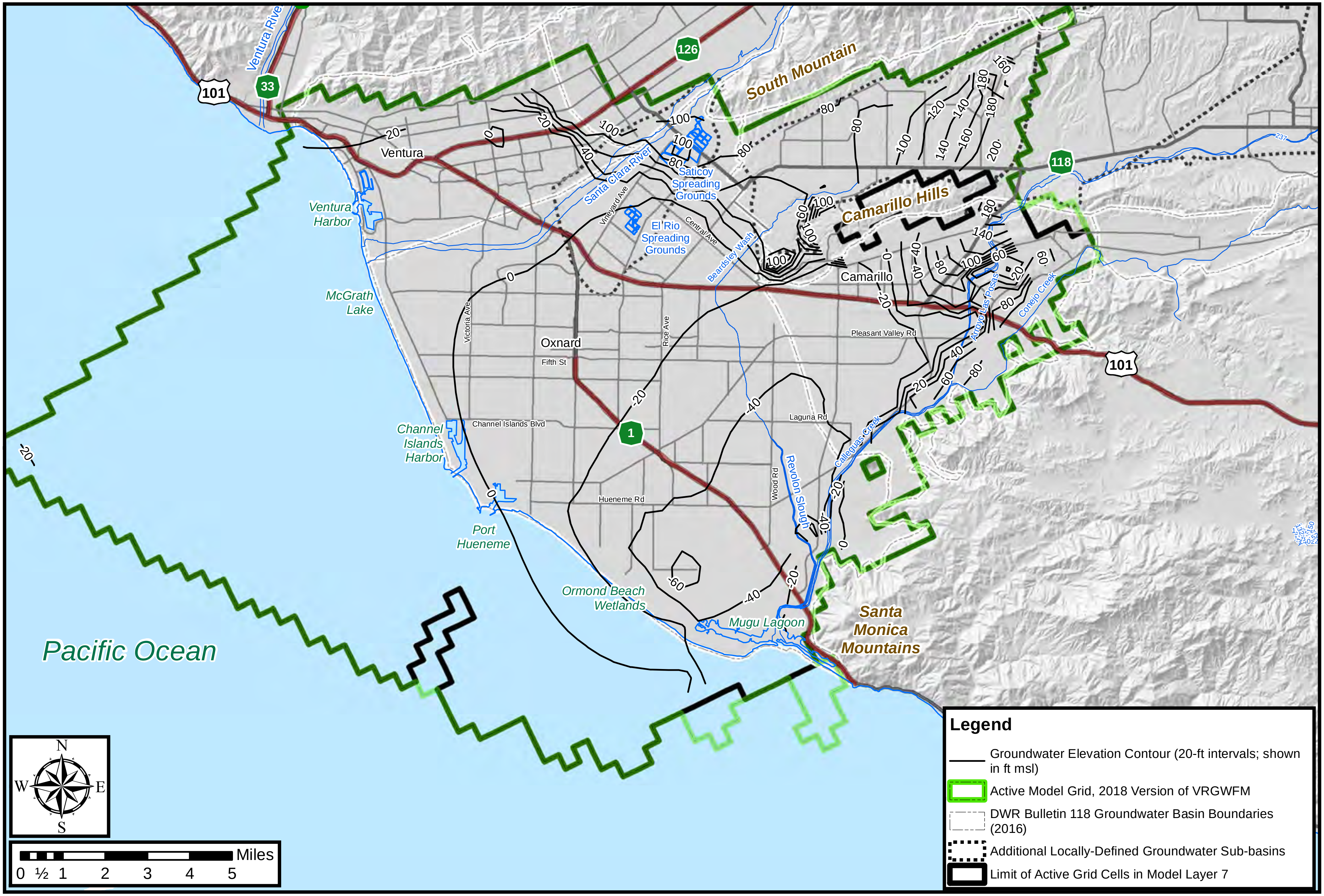


Figure 4-11. Simulated Groundwater Elevations in Layer 7, October 2006

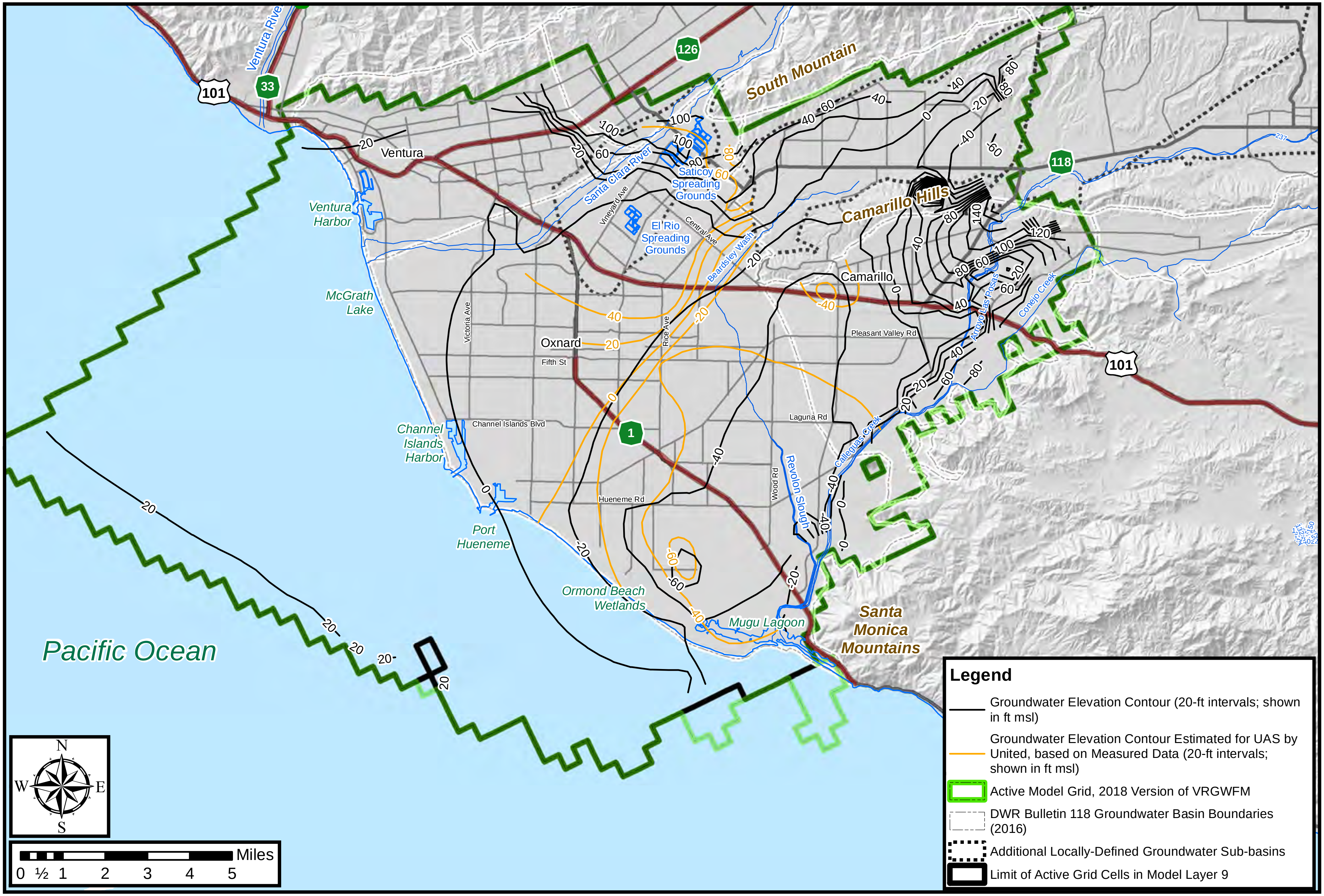


Figure 4-12. Simulated Groundwater Elevations in Layer 9, October 2006

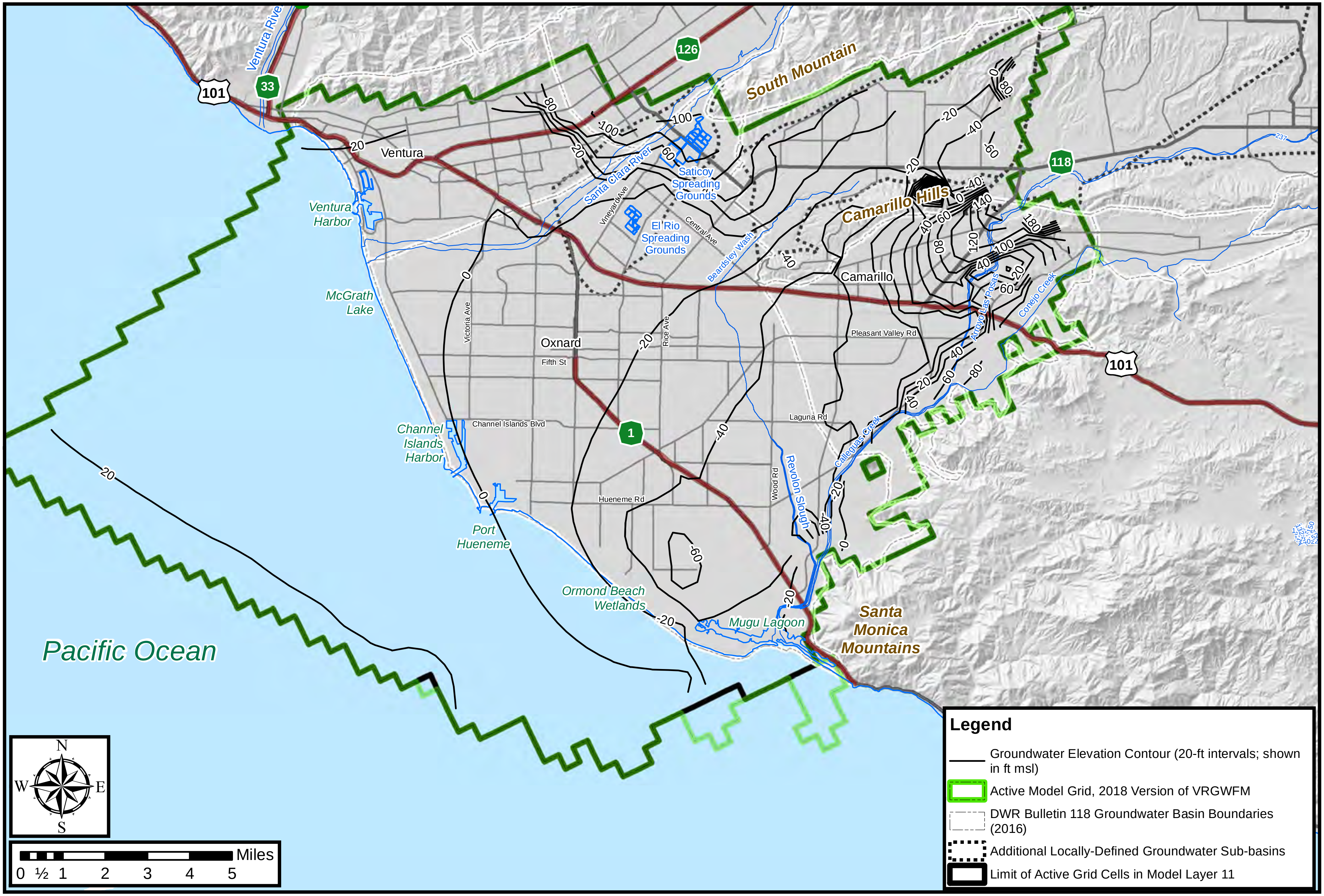


Figure 4-13. Simulated Groundwater Elevations in Layer 11, October 2006

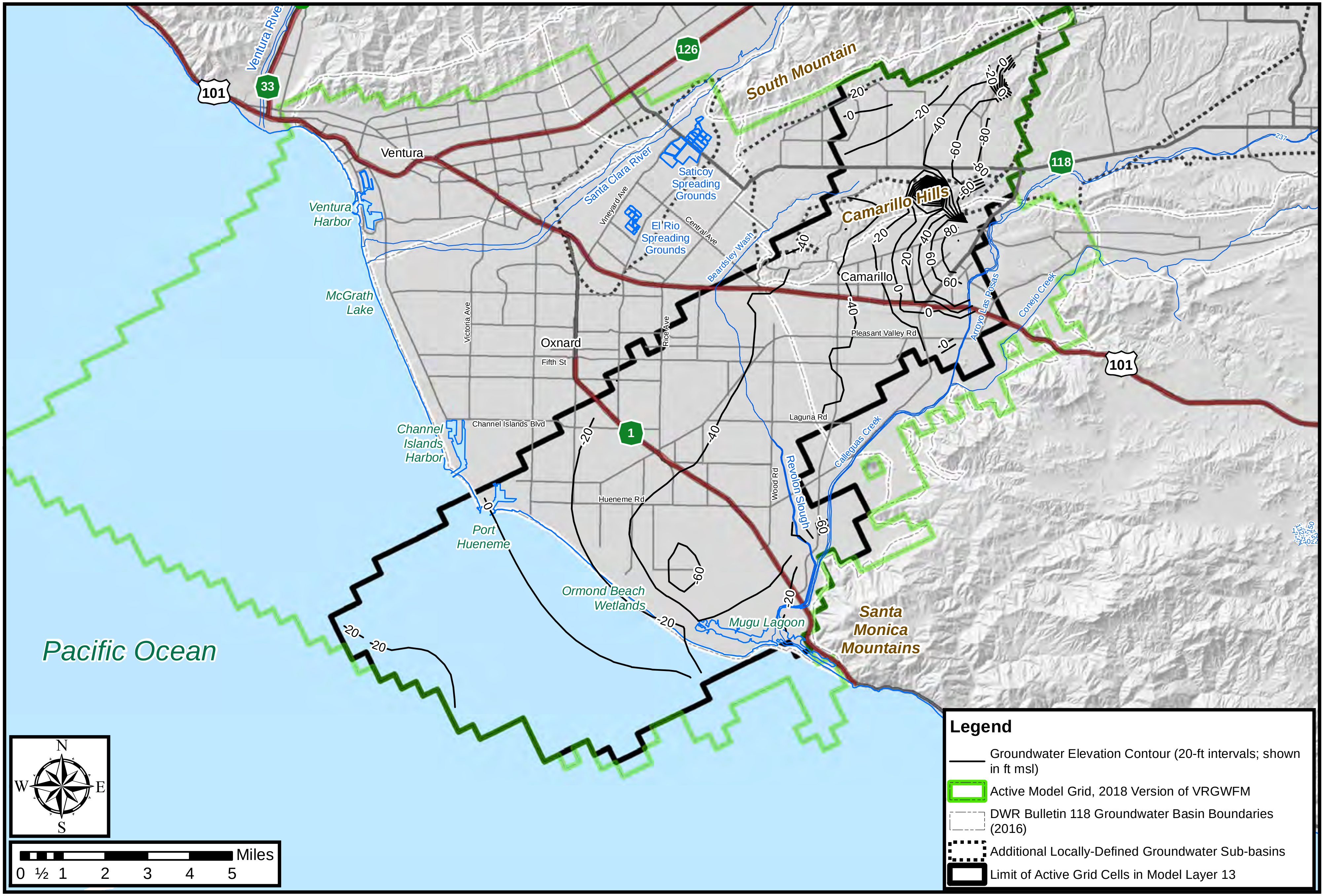


Figure 4-14. Simulated Groundwater Elevations in Layer 13, October 2006

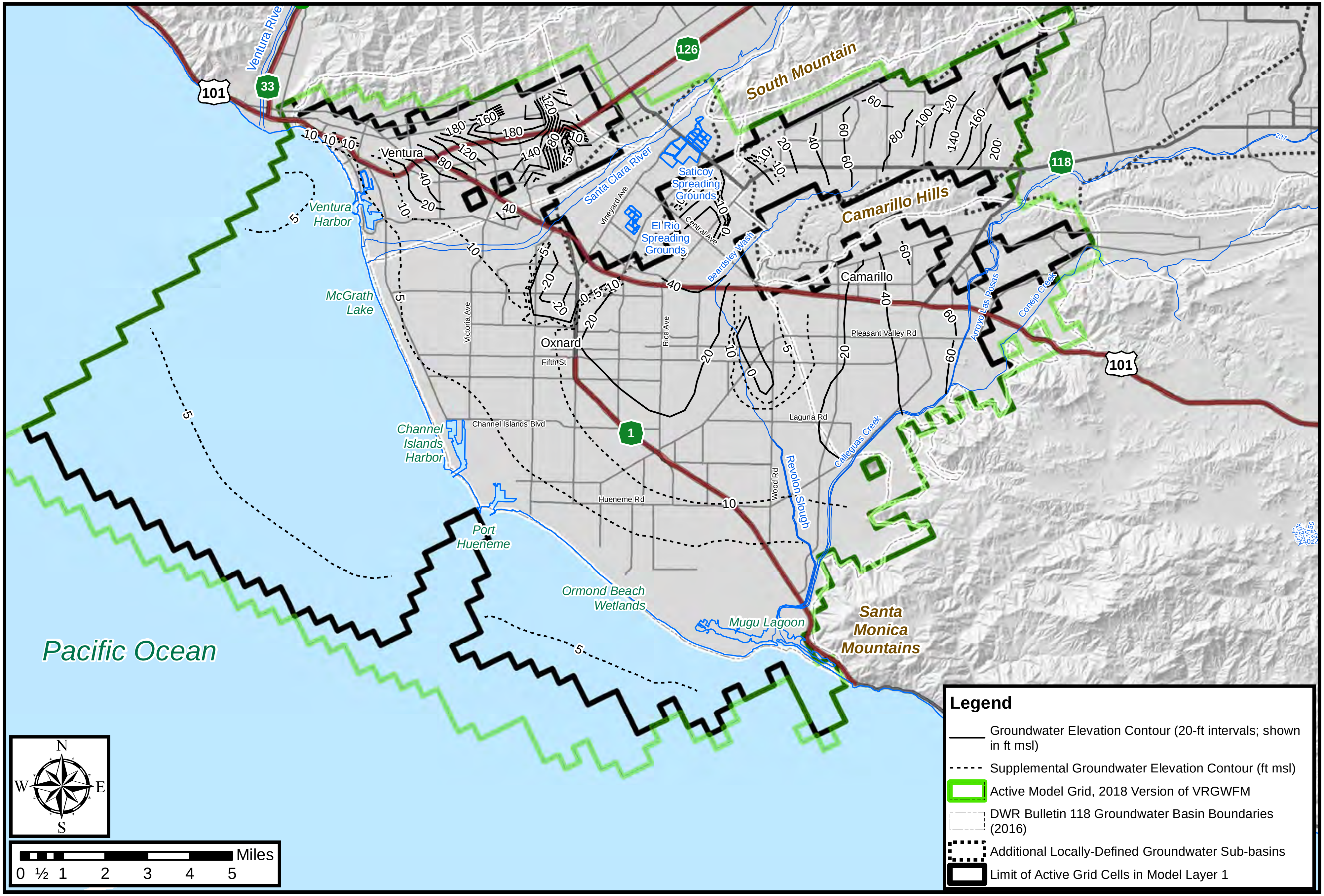


Figure 4-15. Simulated Groundwater Elevations in Layer 1, December 2015

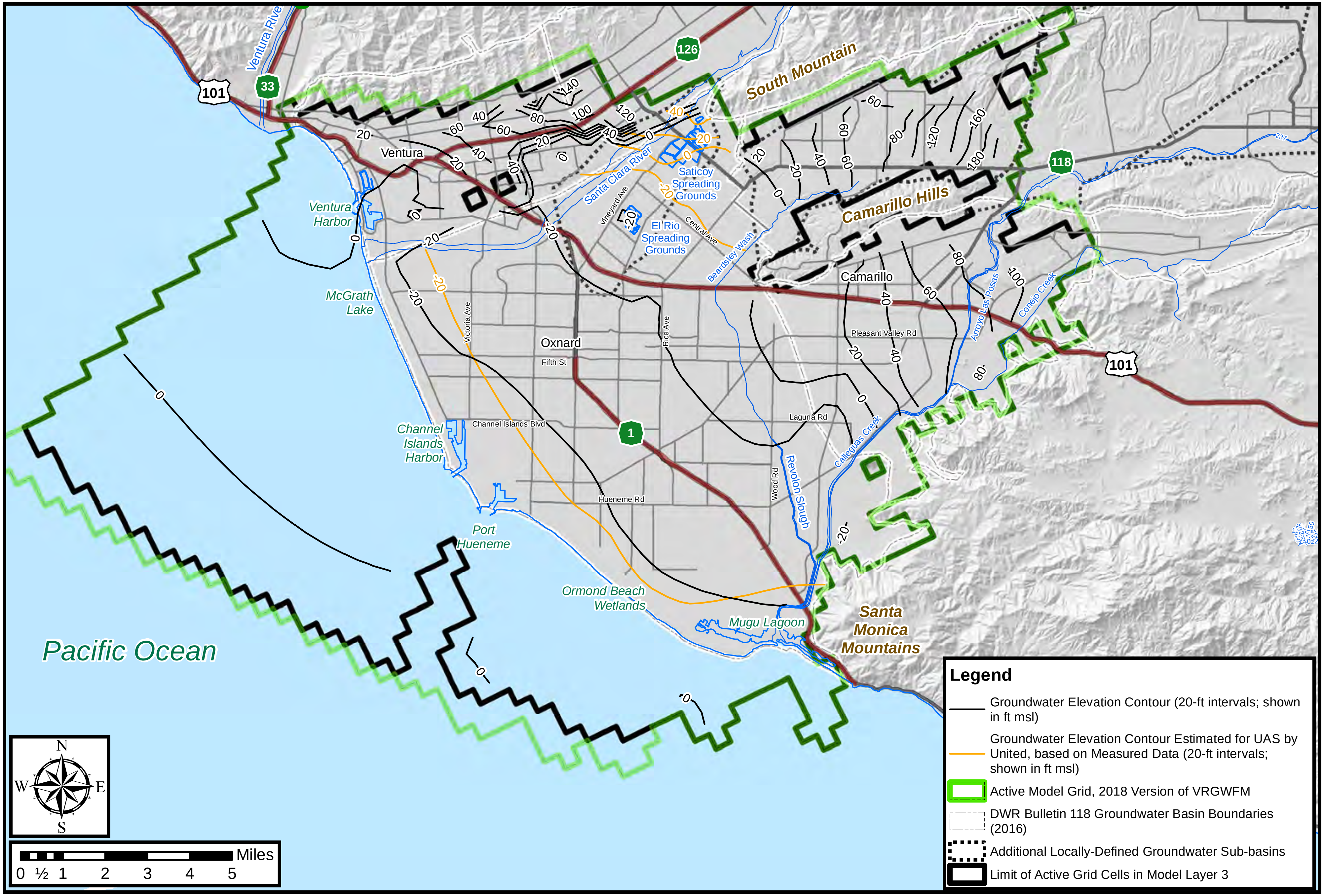


Figure 4-16. Simulated Groundwater Elevations in Layer 3, December 2015

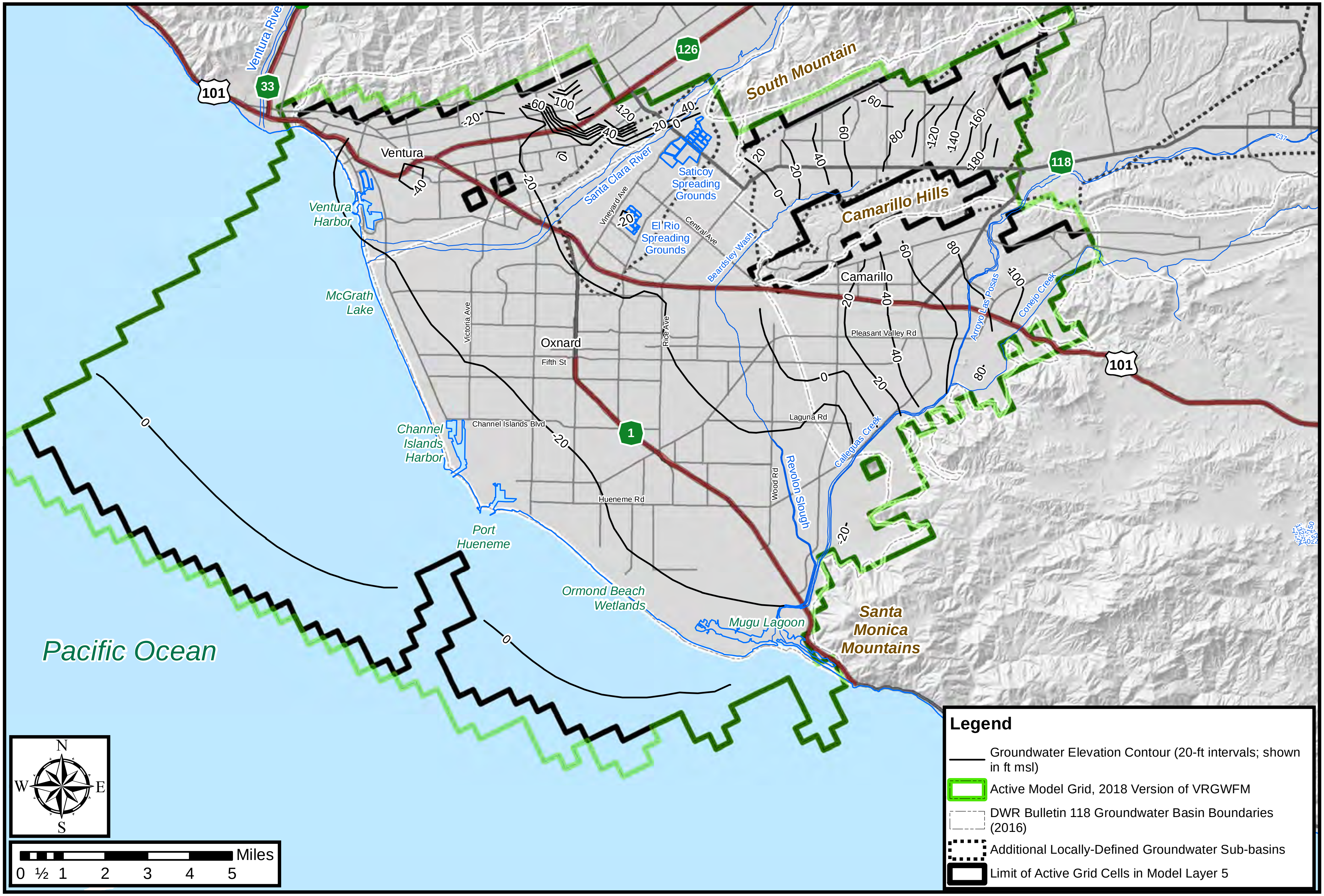


Figure 4-17. Simulated Groundwater Elevations in Layer 5, December 2015

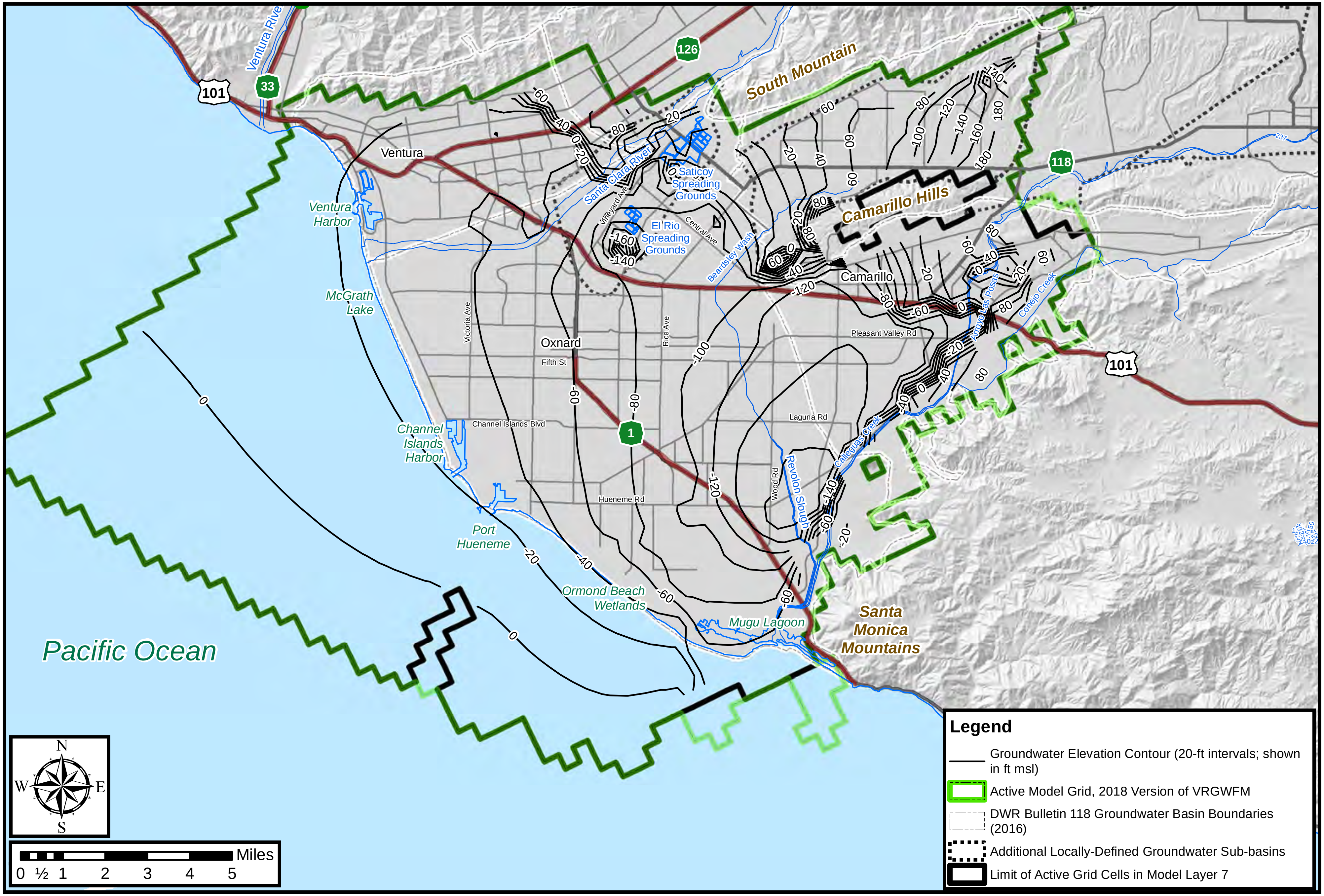


Figure 4-18. Simulated Groundwater Elevations in Layer 7, December 2015

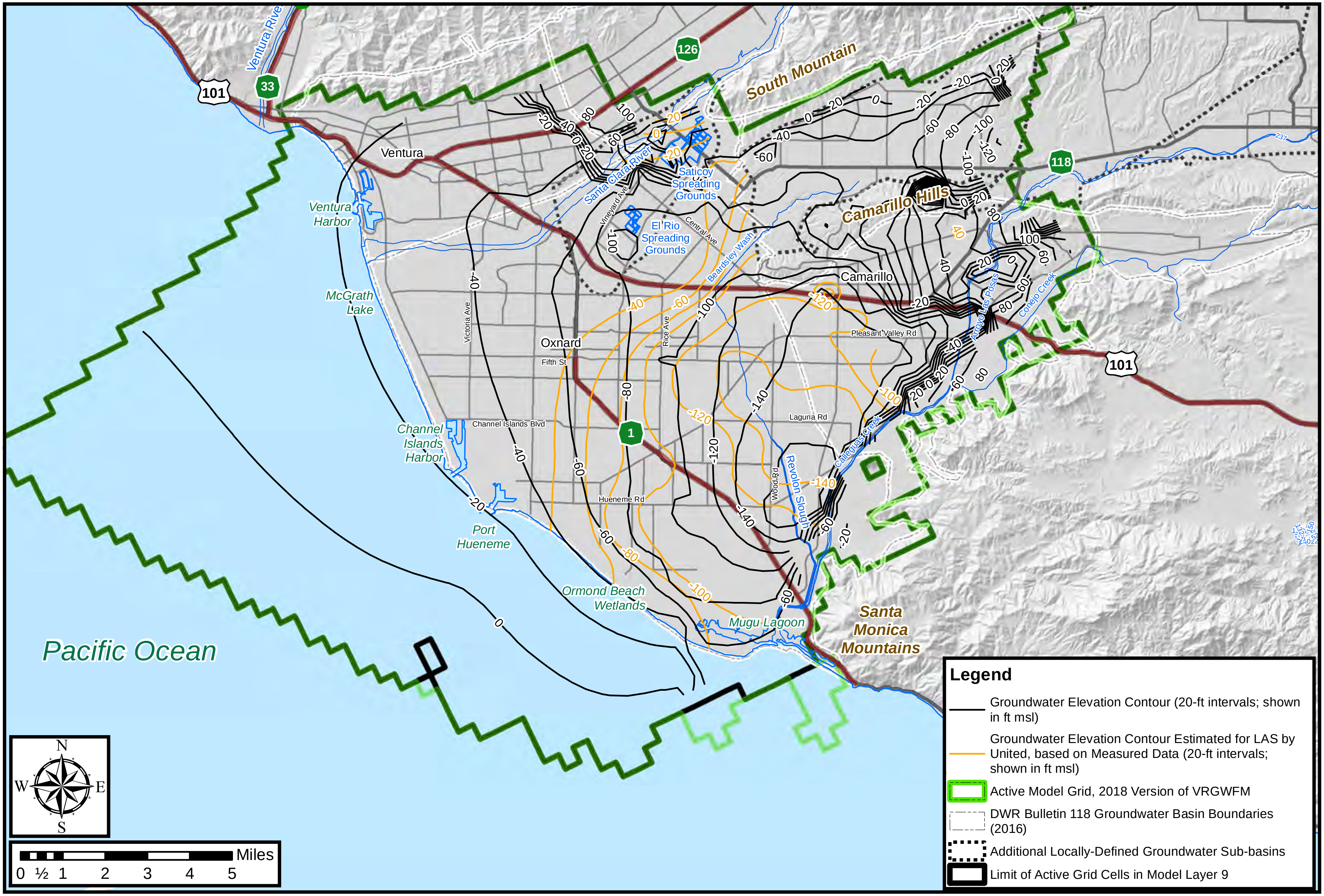


Figure 4-19. Simulated Groundwater Elevations in Layer 9, December 2015

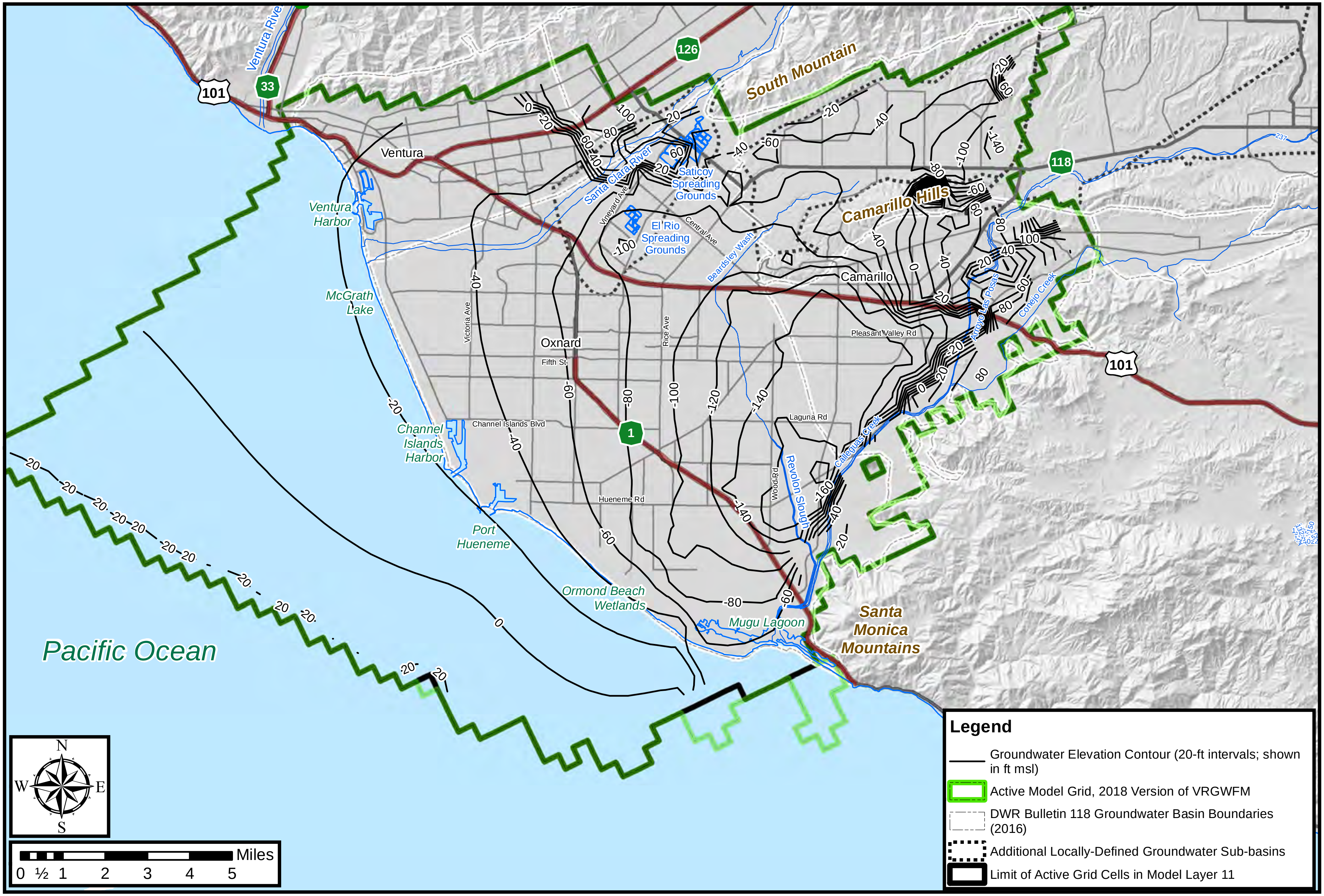


Figure 4-20. Simulated Groundwater Elevations in Layer 11, December 2015

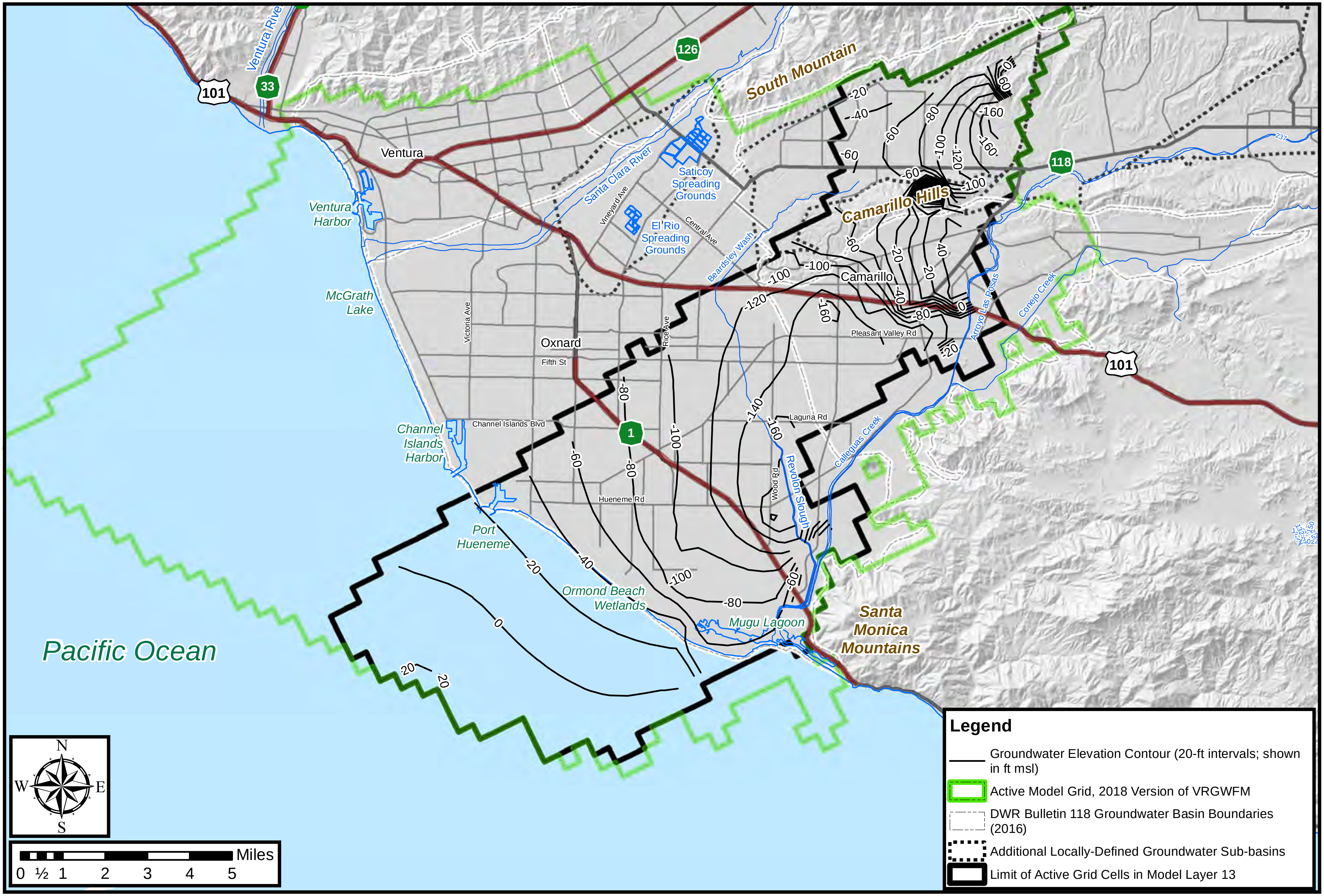


Figure 4-21. Simulated Groundwater Elevations in Layer 13, December 2015

Figure 4-22. Map of Wells Screened in the UAS that were used for Model Calibration

Figure 4-23. Map of Wells Screened in the LAS that were used for Model Calibration

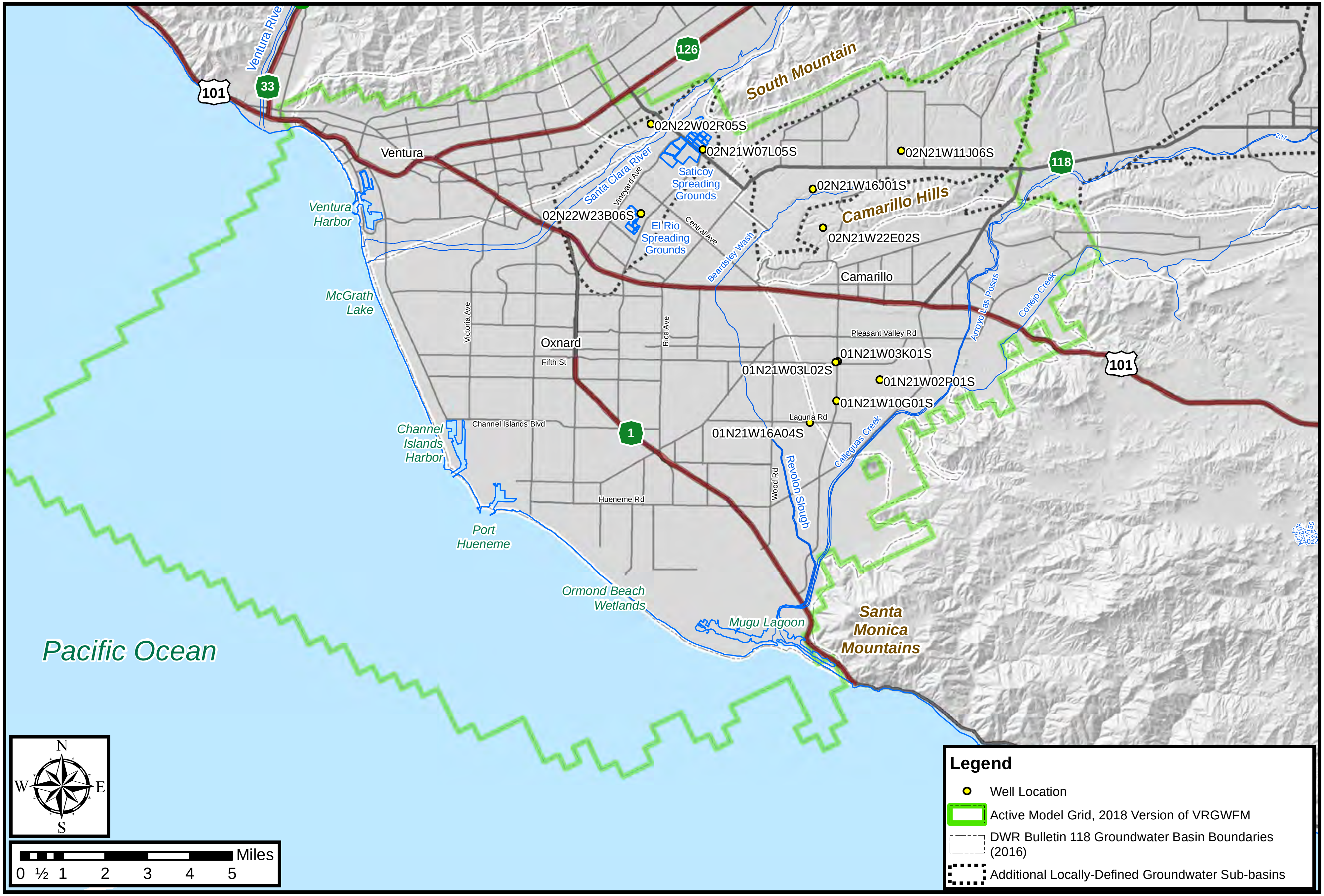


Figure 4-24. Map of Wells Screened in Both the UAS and LAS that were used for Model Calibration

Figure 4-25. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS in the Forebay.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

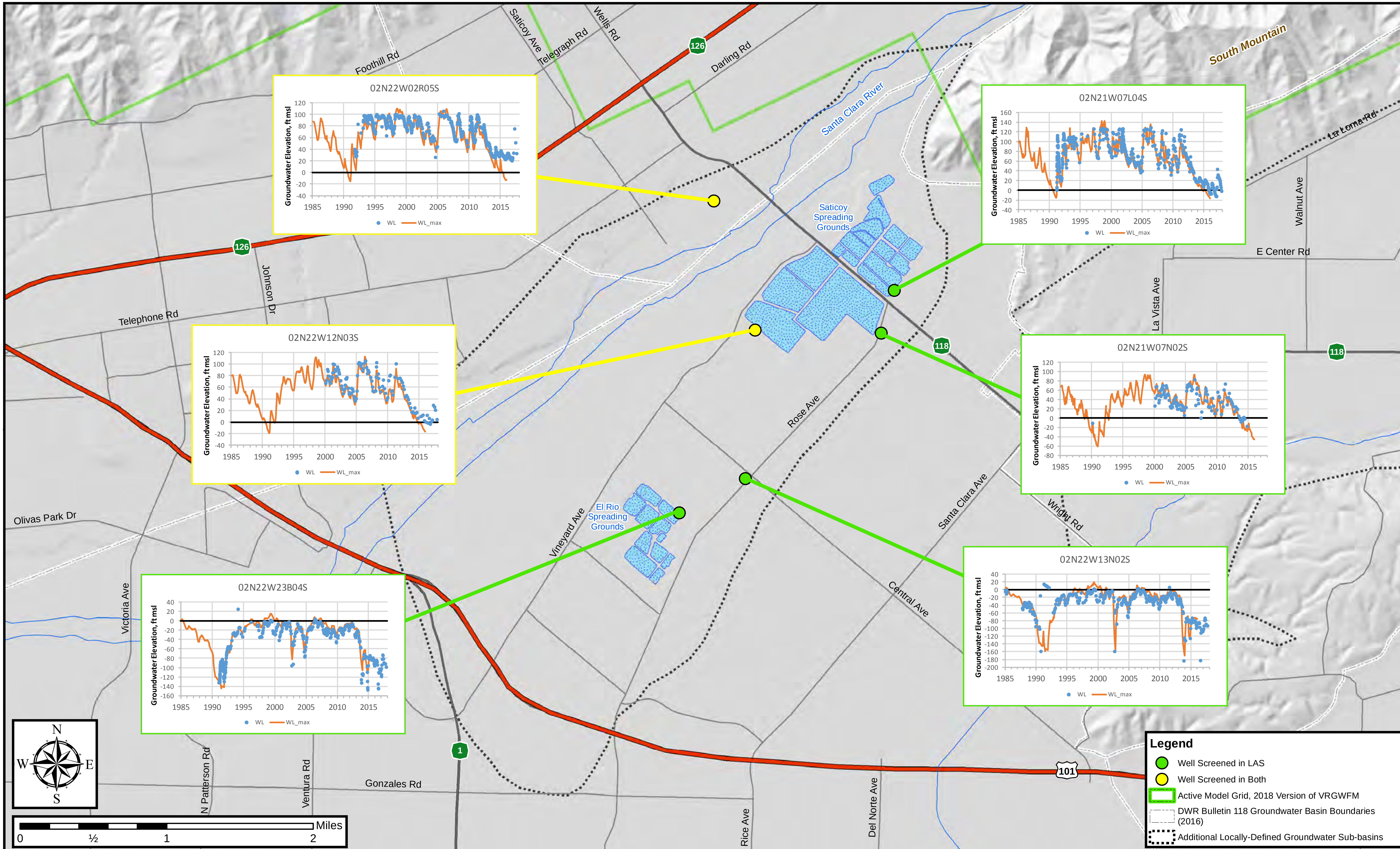


Figure 4-26. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the LAS & Both (screened across UAS & LAS) in the Forebay.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

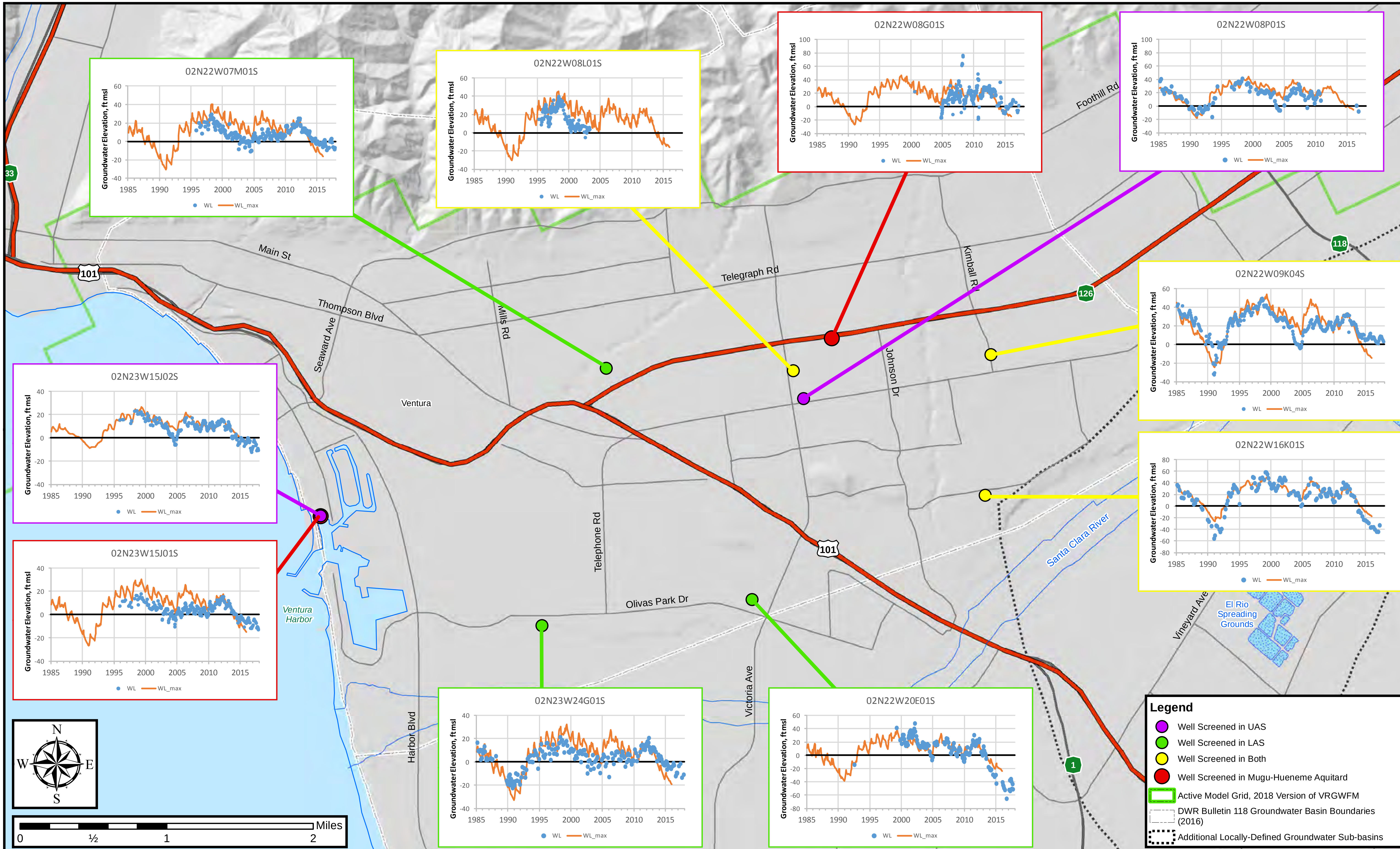


Figure 4-27. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS, LAS & Both (screened across UAS & LAS) in Mound Basin.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

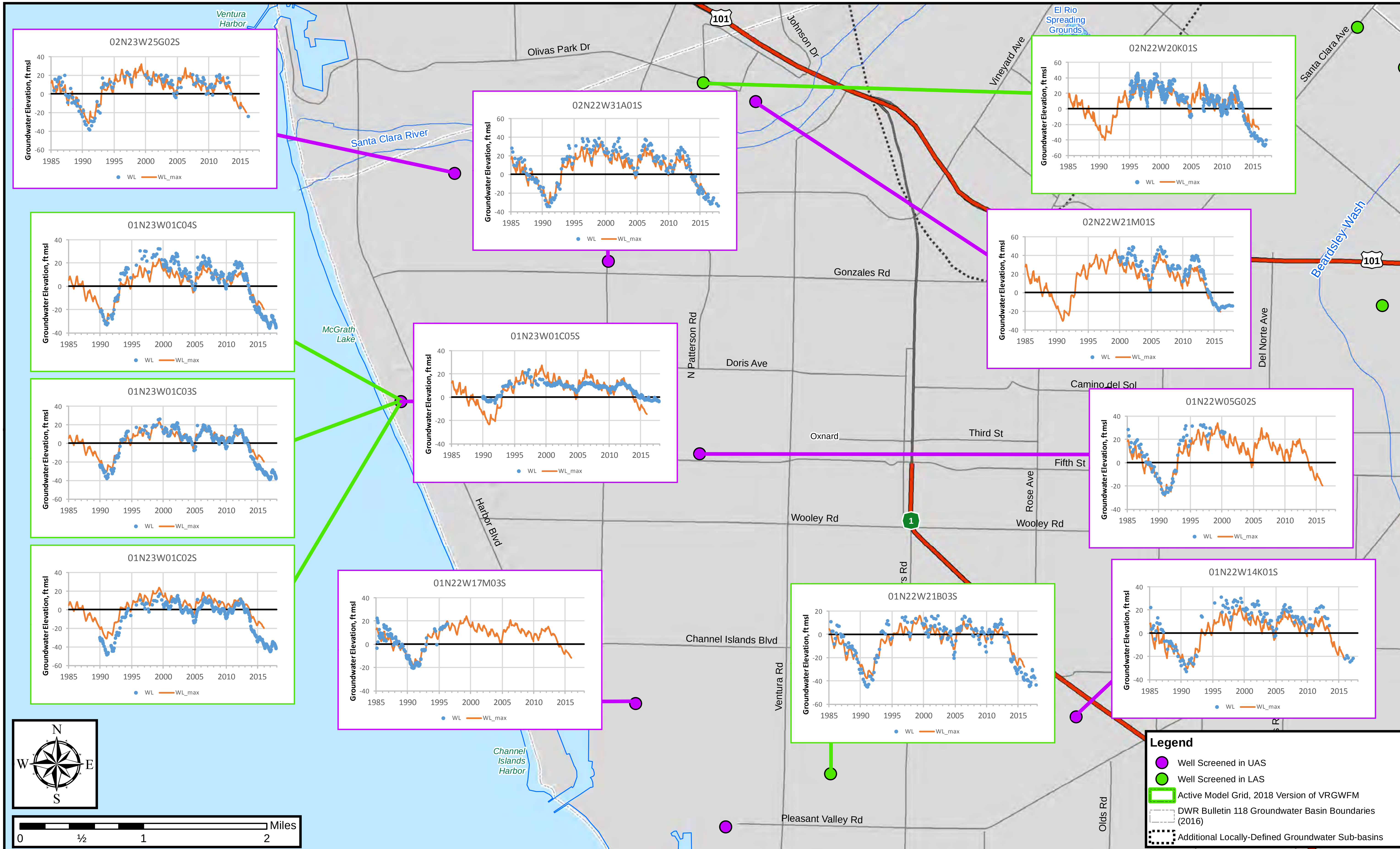


Figure 4-28. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS & LAS in the northwest portion of Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels. Orange line on hydrographs represent simulated groundwater levels.

Figure 4-29. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS & LAS in the northeast portion of Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

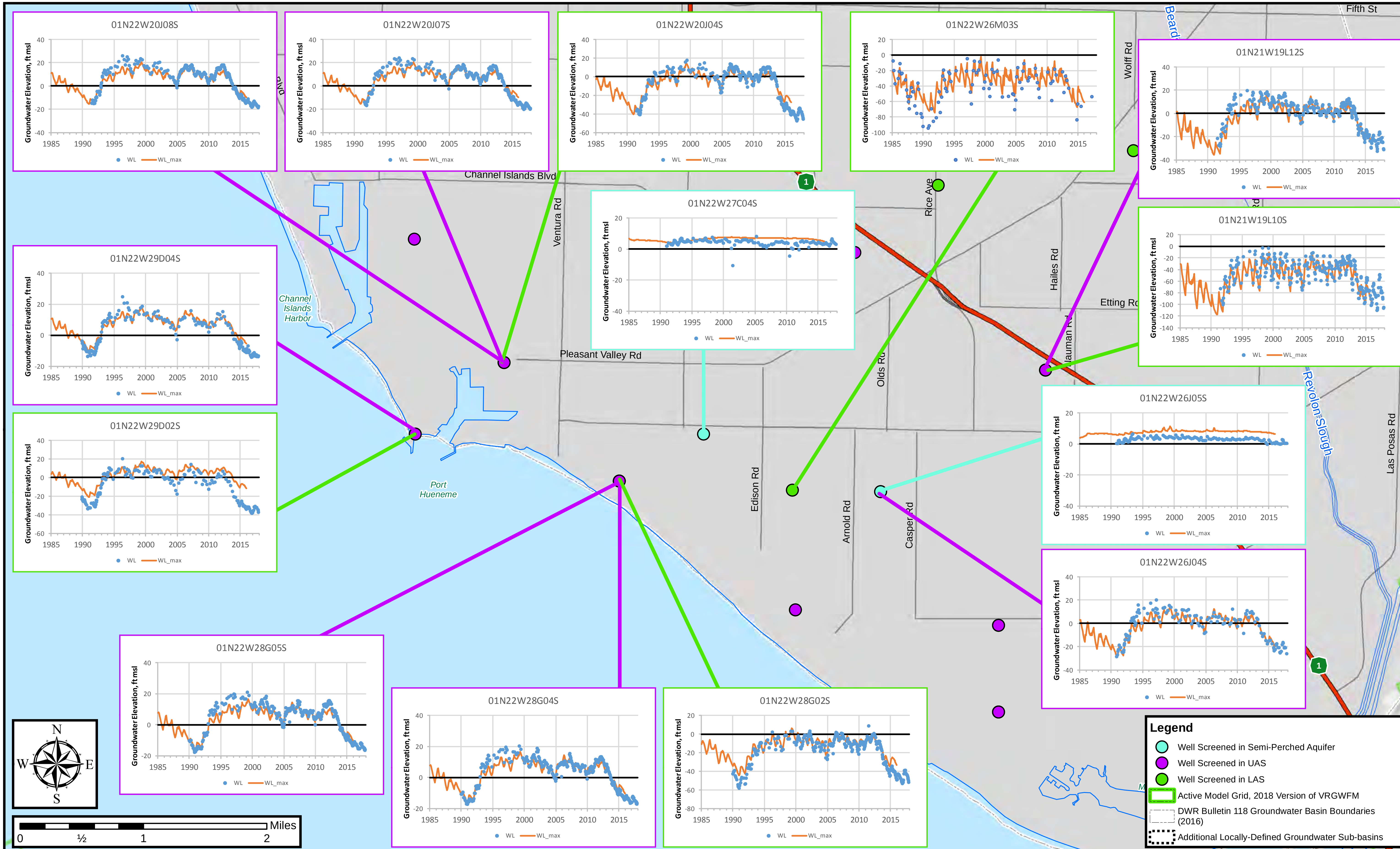


Figure 4-30. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the Semi-Perched Aquifer, UAS & LAS in the central portion of Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels. Orange line on hydrographs represent simulated groundwater levels.

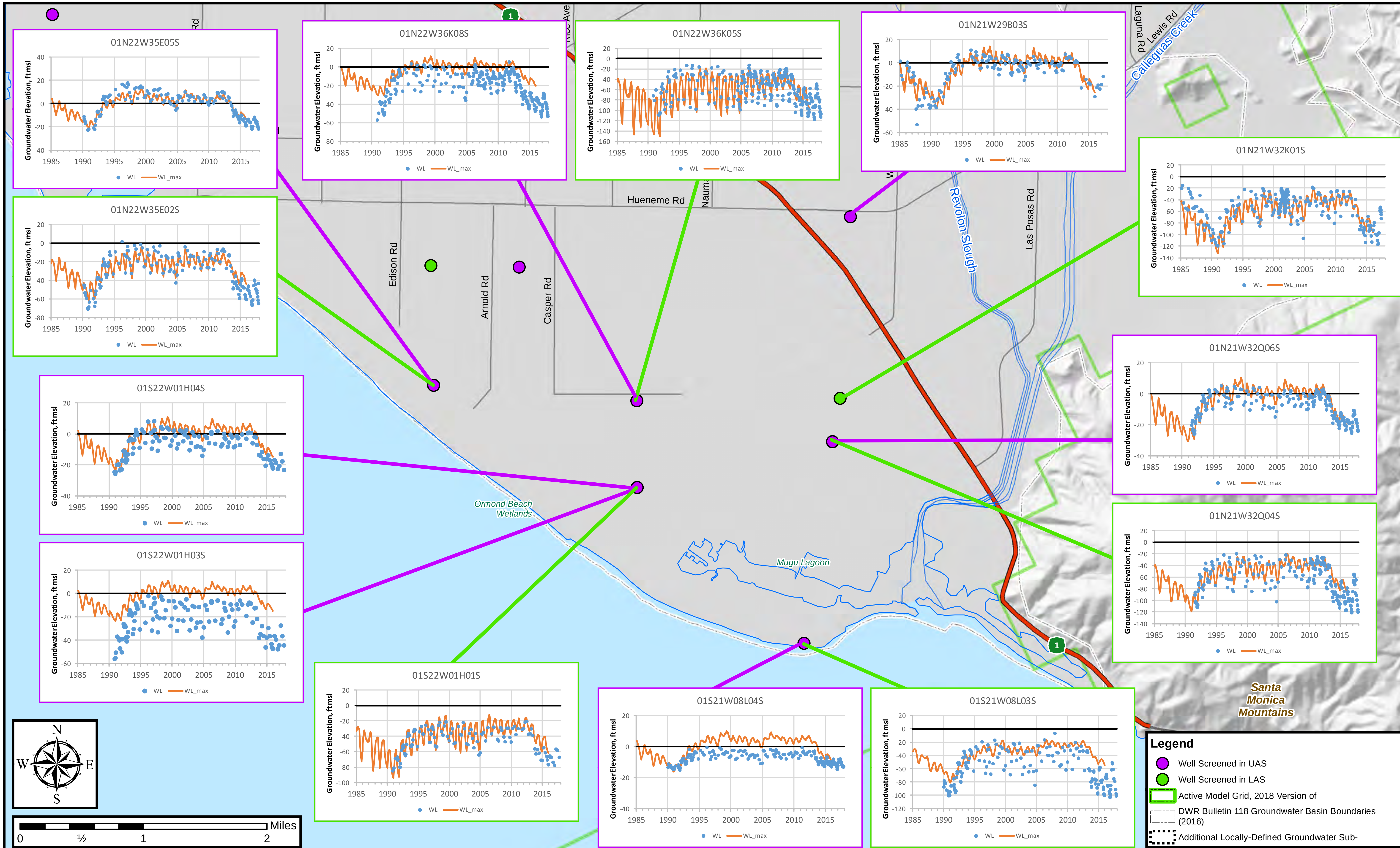


Figure 4-31. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS & LAS in the southern portion of Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

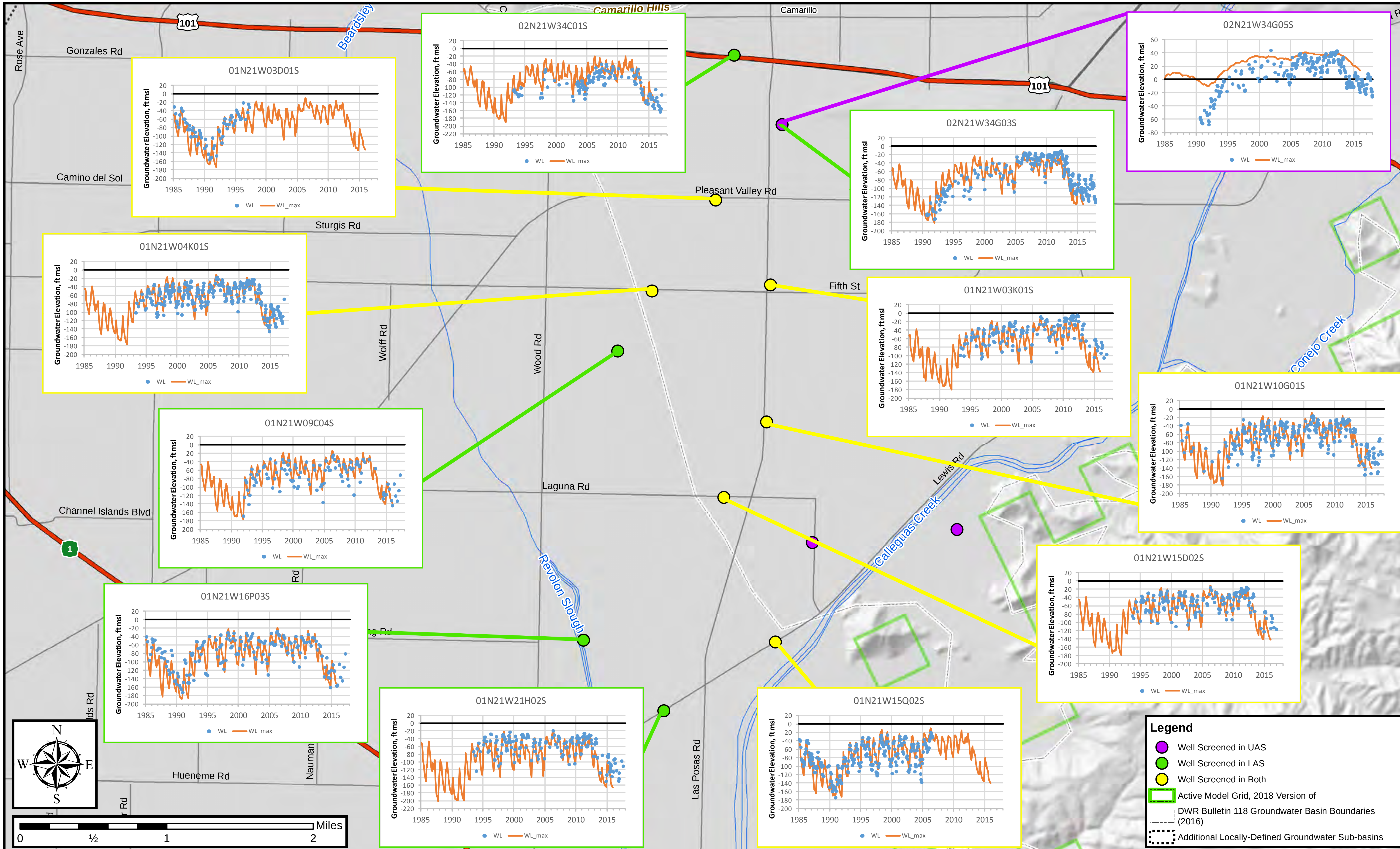


Figure 4-32. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS, LAS & Both (screened across UAS & LAS) in the western portion of Pleasant Valley Basin and eastern Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels. Orange line on hydrographs represent simulated groundwater levels.

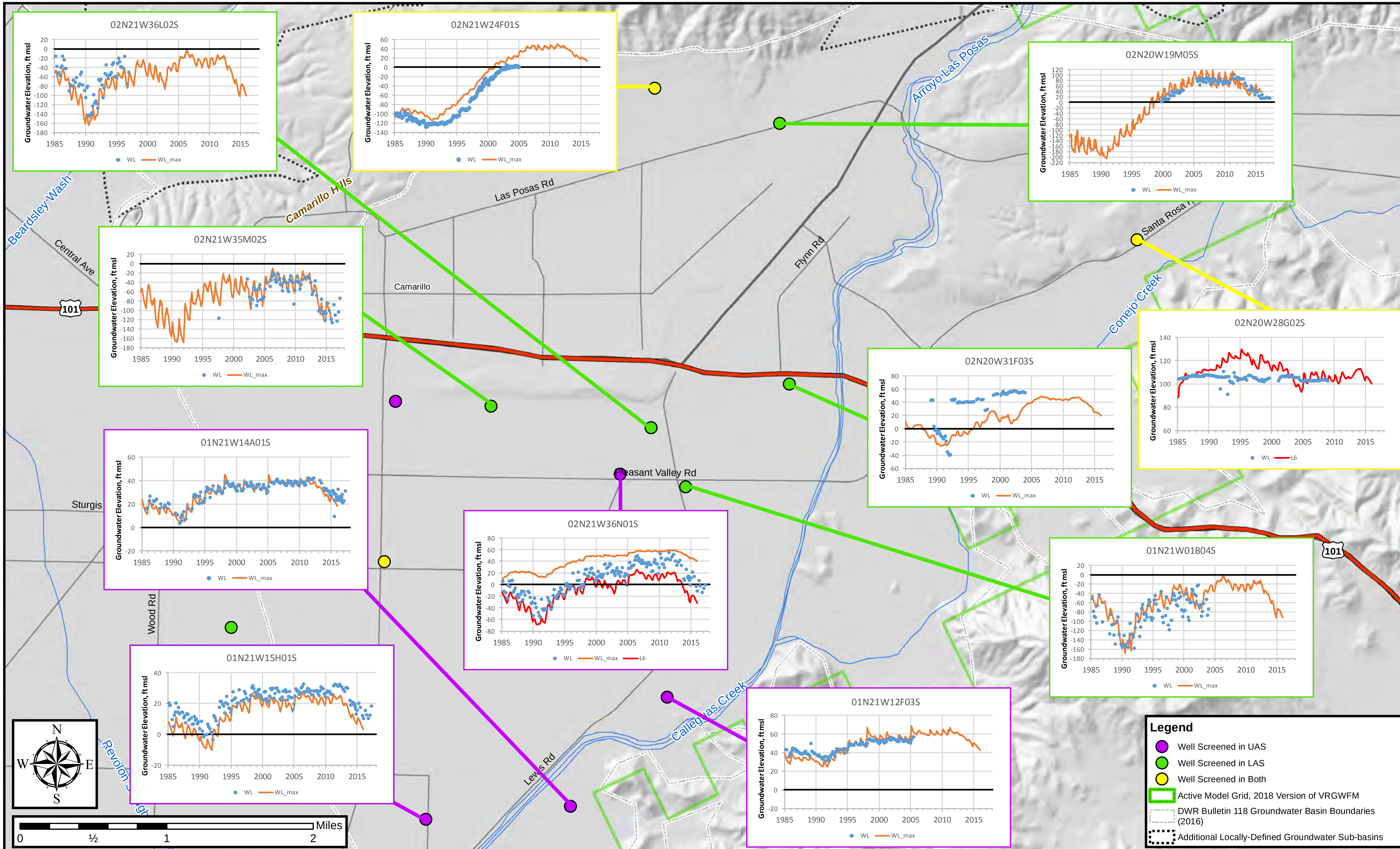


Figure 4-33. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS, LAS & Both (screened across UAS & LAS) in the eastern portion of Pleasant Valley Basin.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.

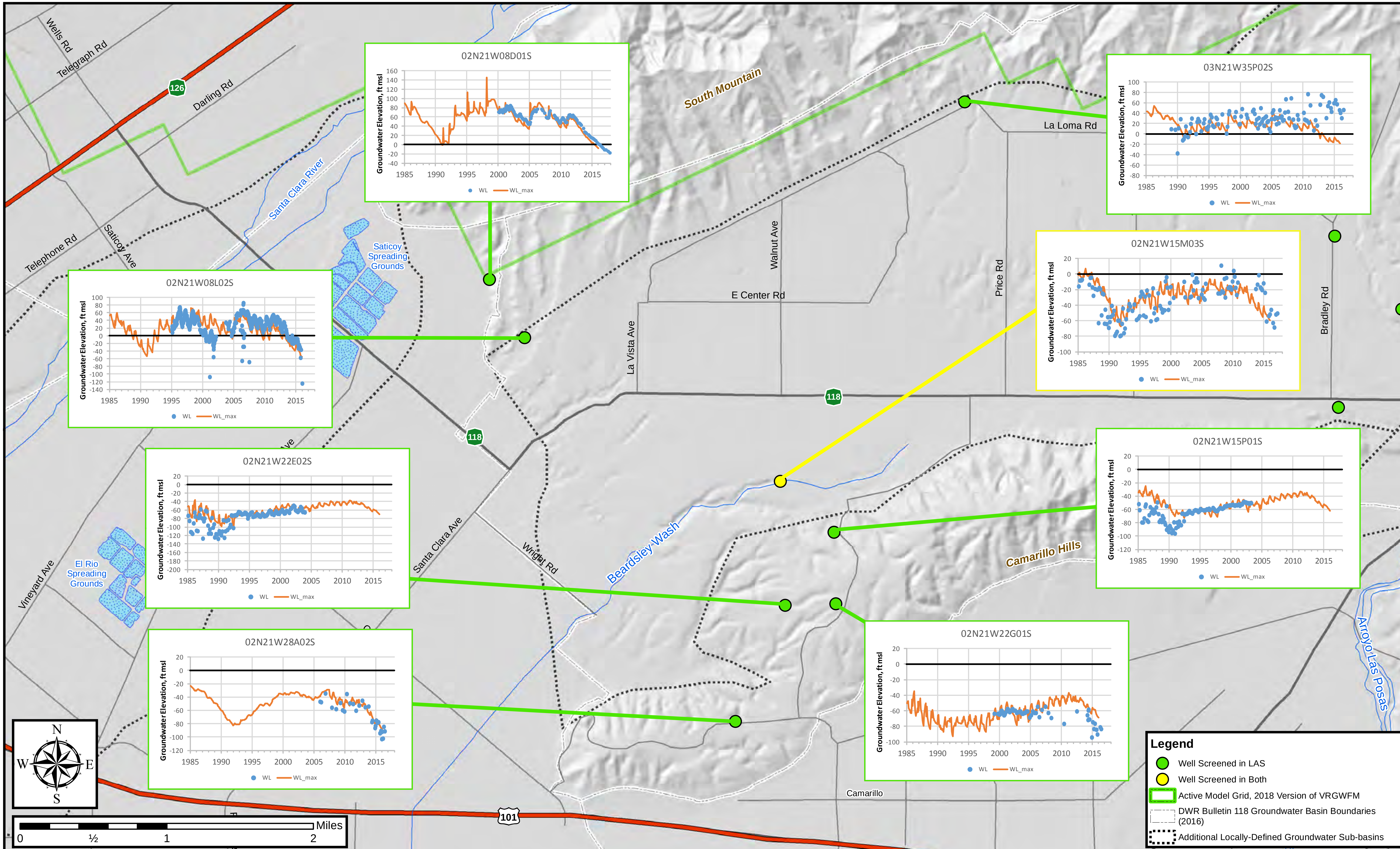


Figure 4-34. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the LAS & Both (screened across UAS & LAS) in the western portion of West Las Posas Basin, Camarillo Hills and northeast Oxnard Plain Basin.

Note: Blue dot on hydrographs represent measured groundwater levels. Orange line on hydrographs represent simulated groundwater levels.

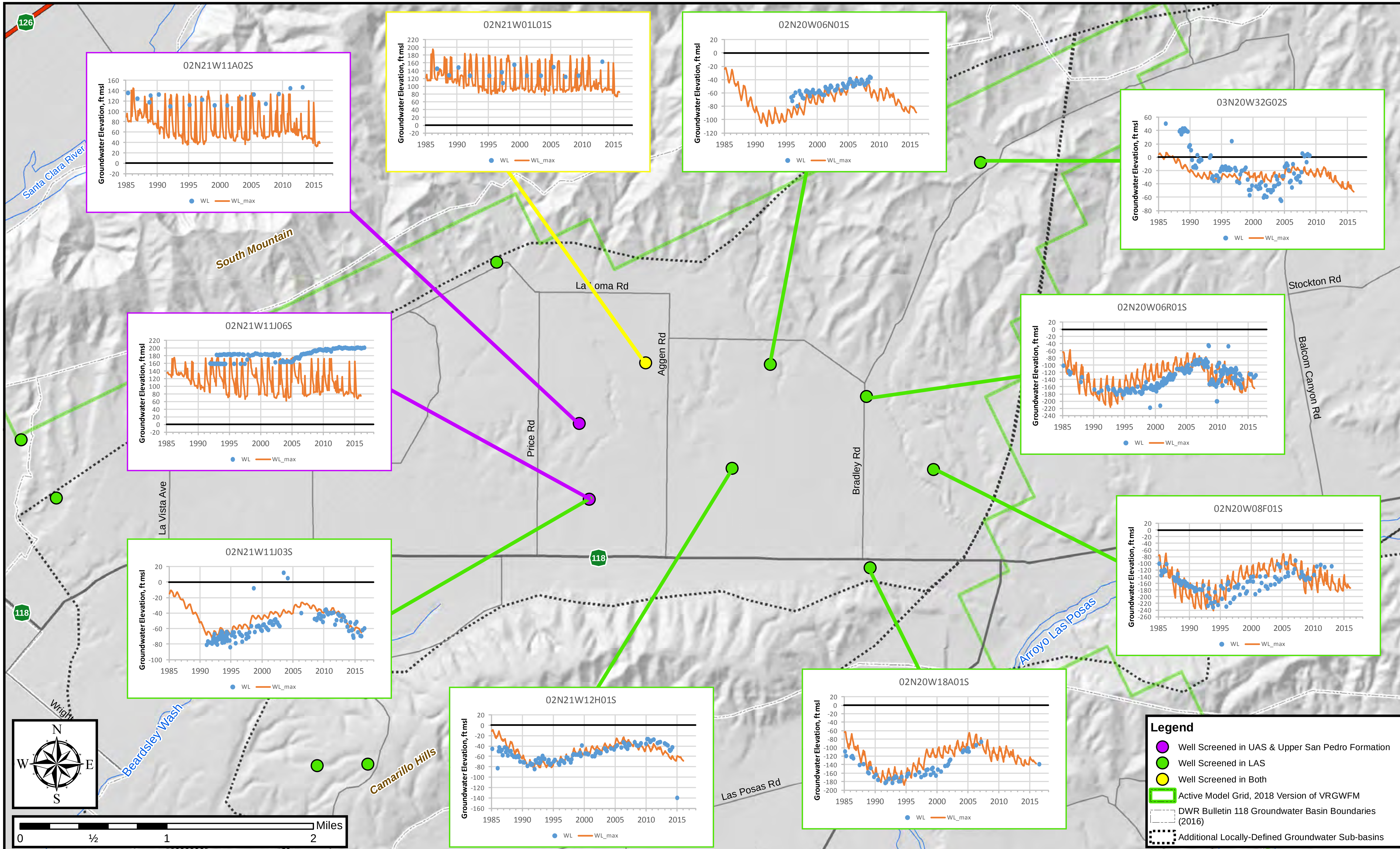
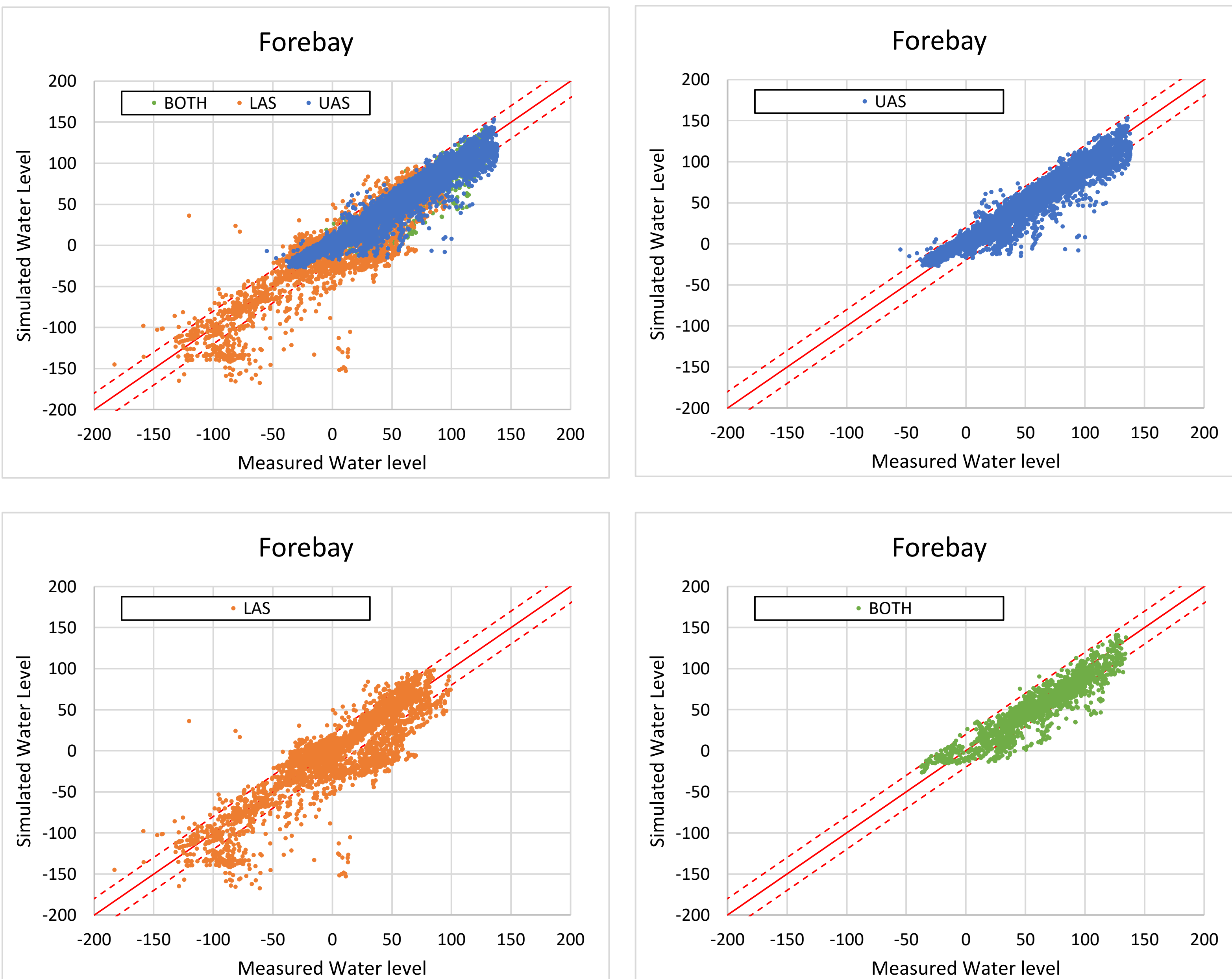


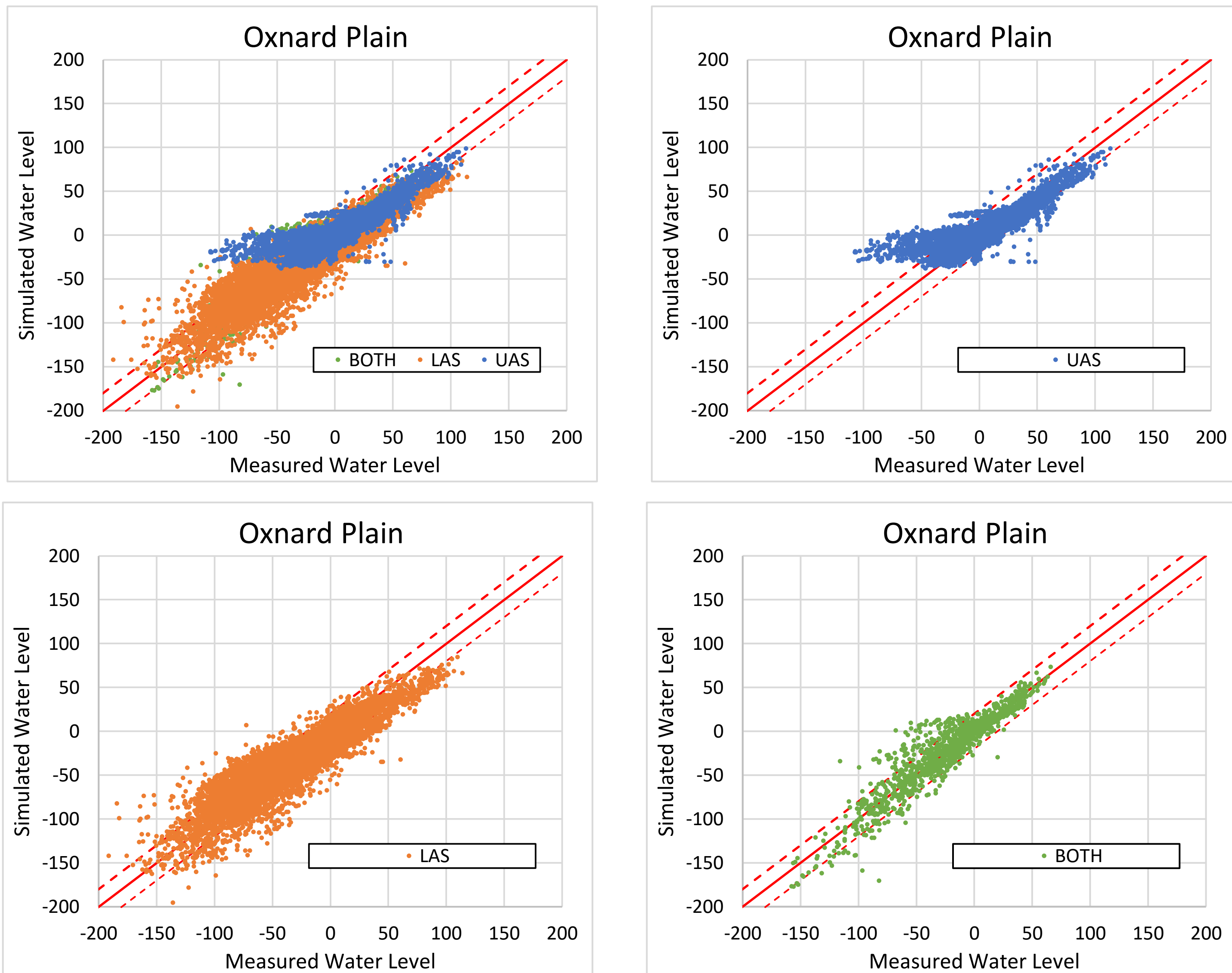
Figure 4-35. Selected Representative Hydrographs of Simulated and Measured Groundwater Elevations in the UAS, LAS & Both (screened across UAS & LAS) in the eastern portion of West Las Posas Basin.

Note: Blue dot on hydrographs represent measured groundwater levels.
Orange line on hydrographs represent simulated groundwater levels.



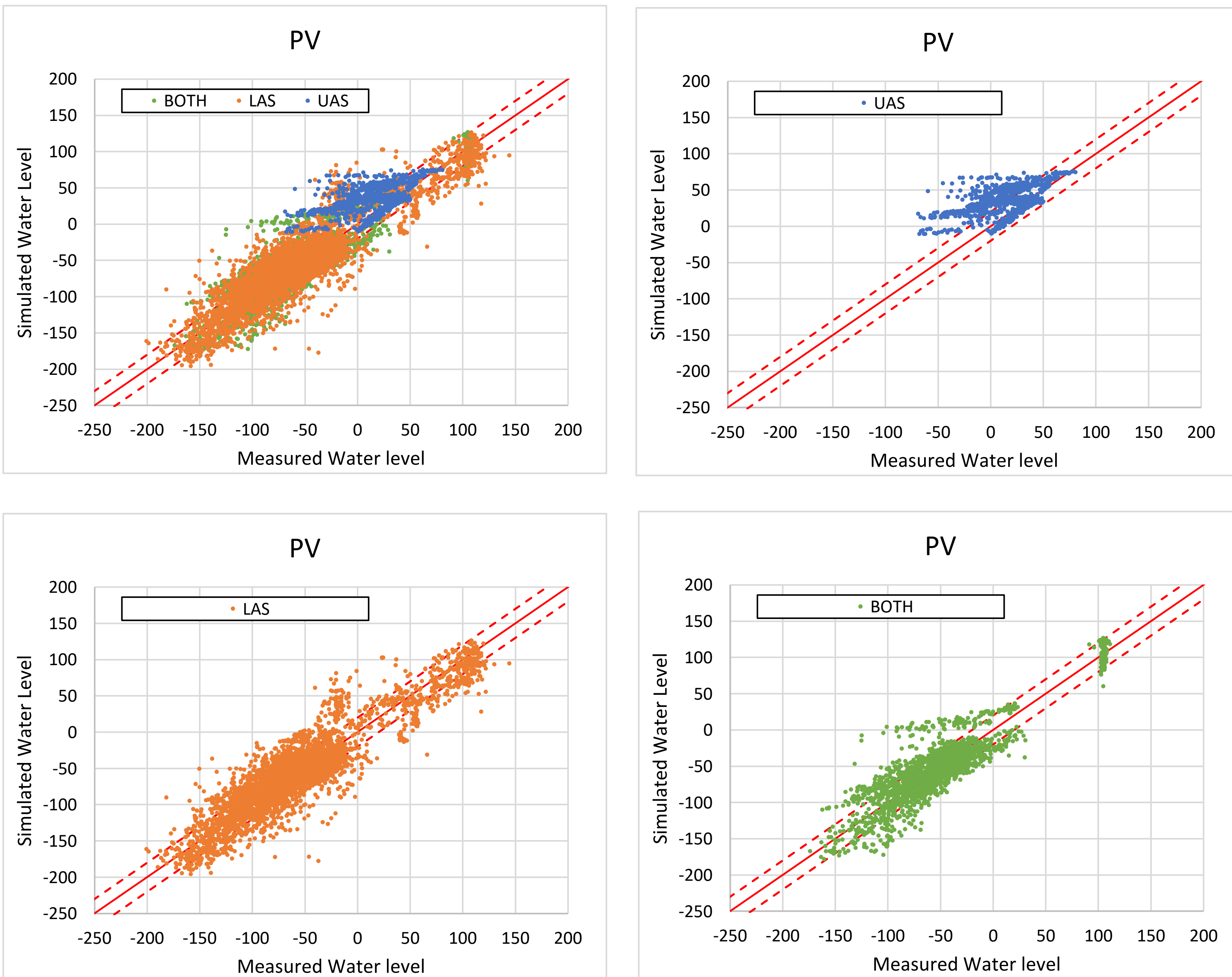
Note: Solid red line in each graph represents a 1 : 1 relationship between measured and simulated groundwater levels. Dashed red lines are offset 20 feet above and below the 1 : 1 (solid) line.

Figure 4-36. Scatterplots of Simulated versus Measured Groundwater Elevations in the Forebay



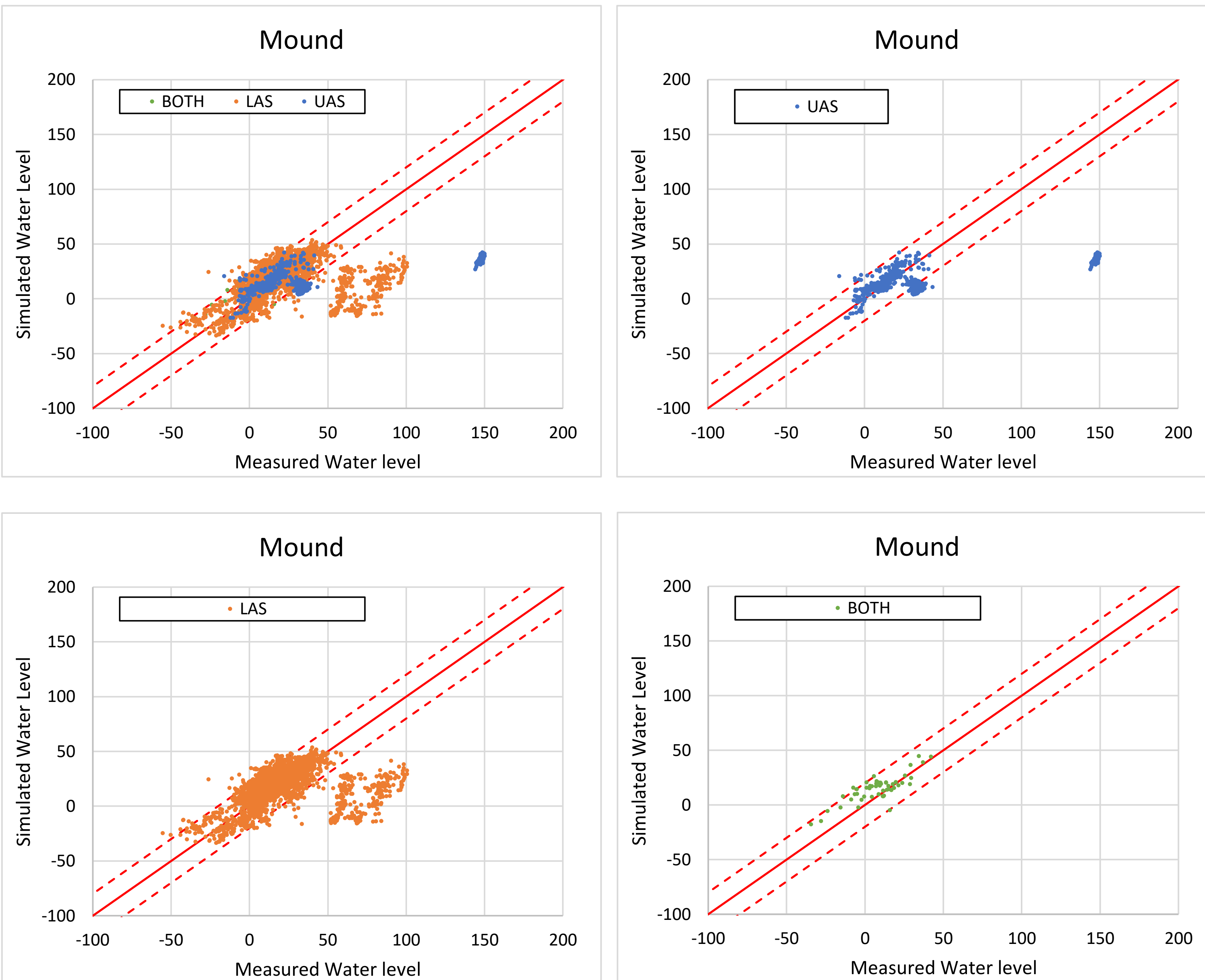
Note: Solid red line in each graph represents a 1 : 1 relationship between measured and simulated groundwater levels. Dashed red lines are offset 20 feet above and below the 1 : 1 (solid) line.

Figure 4-37. Scatterplots of Simulated versus Measured Groundwater Elevations in the Oxnard Plain Basin



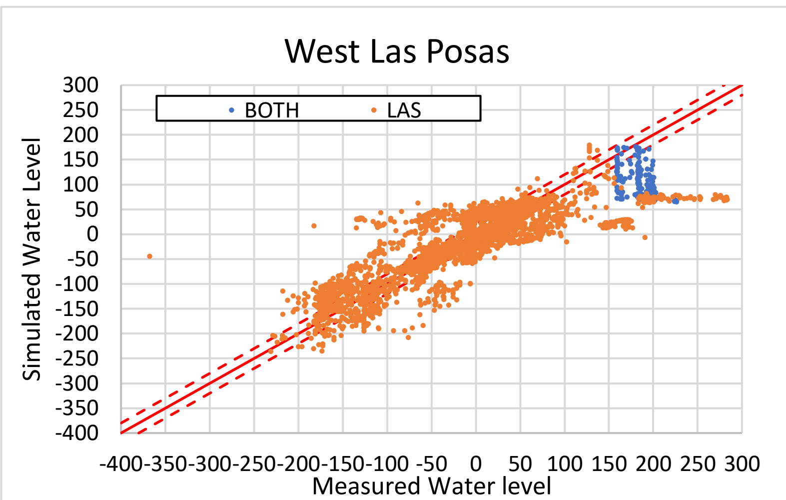
Note: Solid red line in each graph represents a 1 : 1 relationship between measured and simulated groundwater levels. Dashed red lines are offset 20 feet above and below the 1 : 1 (solid) line.

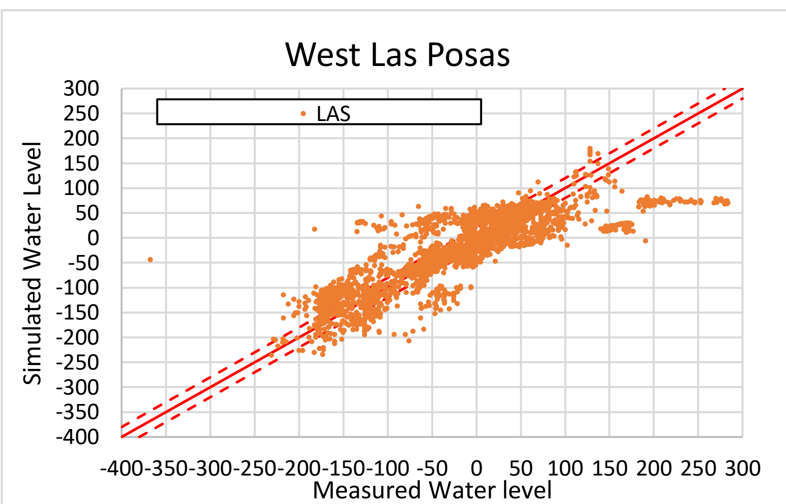
Figure 4-38. Scatterplots of Simulated versus Measured Groundwater Elevations in the Pleasant Valley Basin

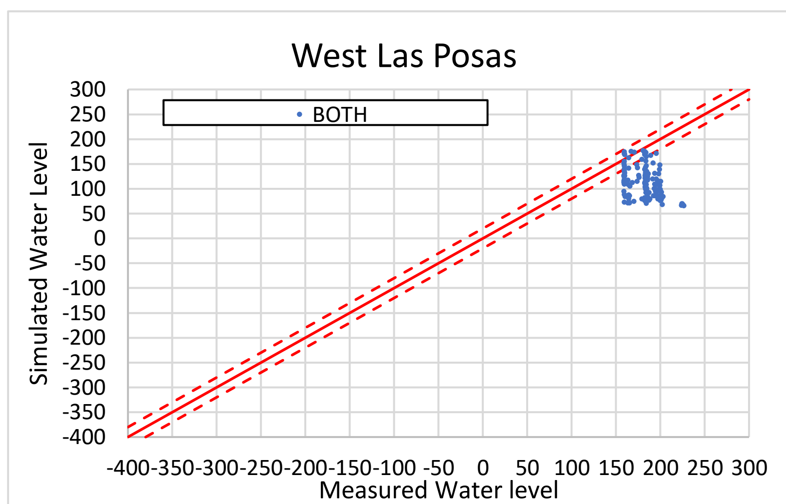


Note: Solid red line in each graph represents a 1 : 1 relationship between measured and simulated groundwater levels. Dashed red lines are offset 20 feet above and below the 1 : 1 (solid) line.

Figure 4-39. Scatterplots of Simulated versus Measured Groundwater Elevations in the Mound Basin







Note: Solid red line in each graph represents a 1 : 1 relationship between measured and simulated groundwater levels. Dashed red lines are offset 20 feet above and below the 1 : 1 (solid) line.

Figure 4-40. Scatterplots of Simulated versus Measured Groundwater Elevations in the West Las Posas Basin

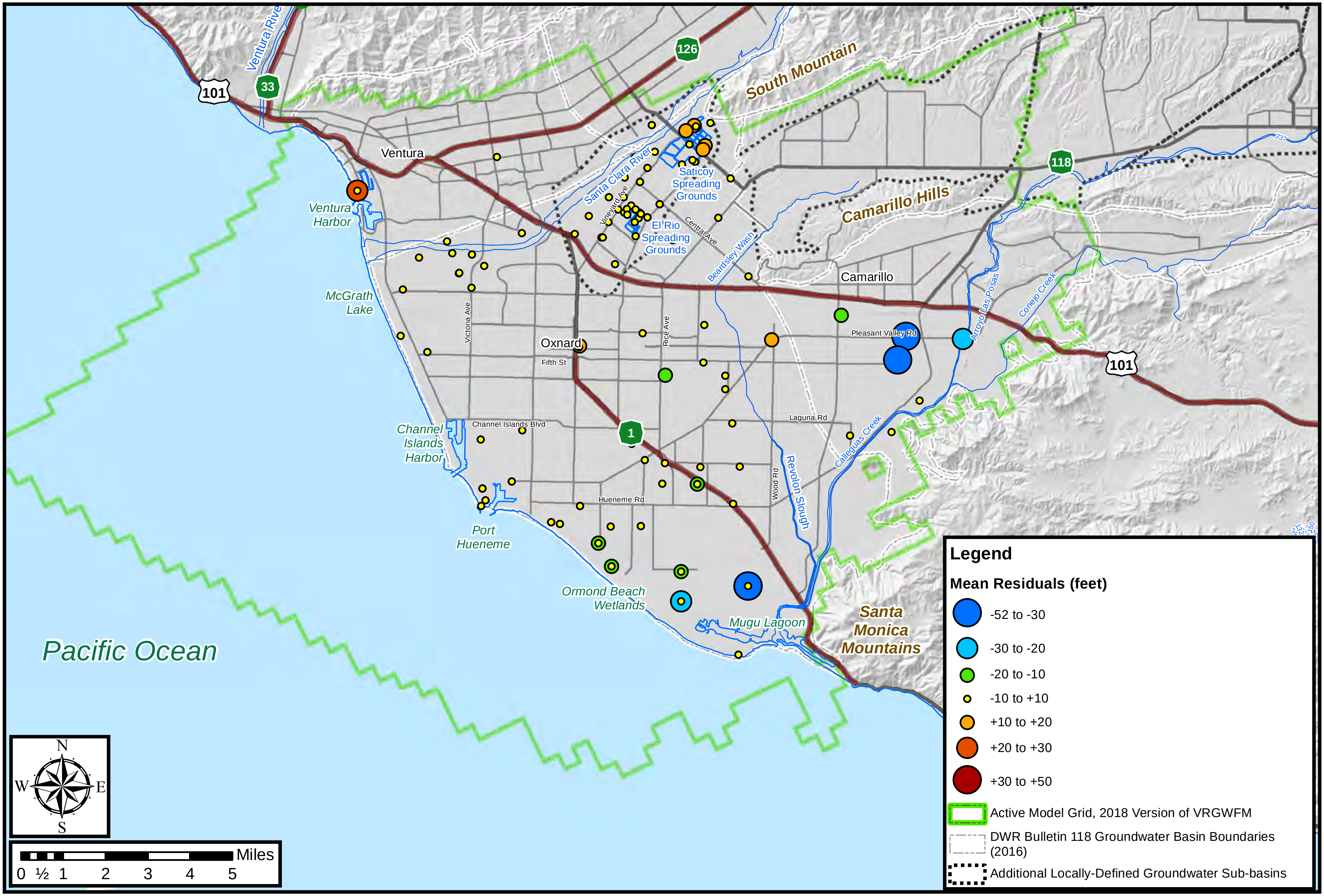


Figure 4-41. Mean Residuals for Groundwater Elevation in the UAS

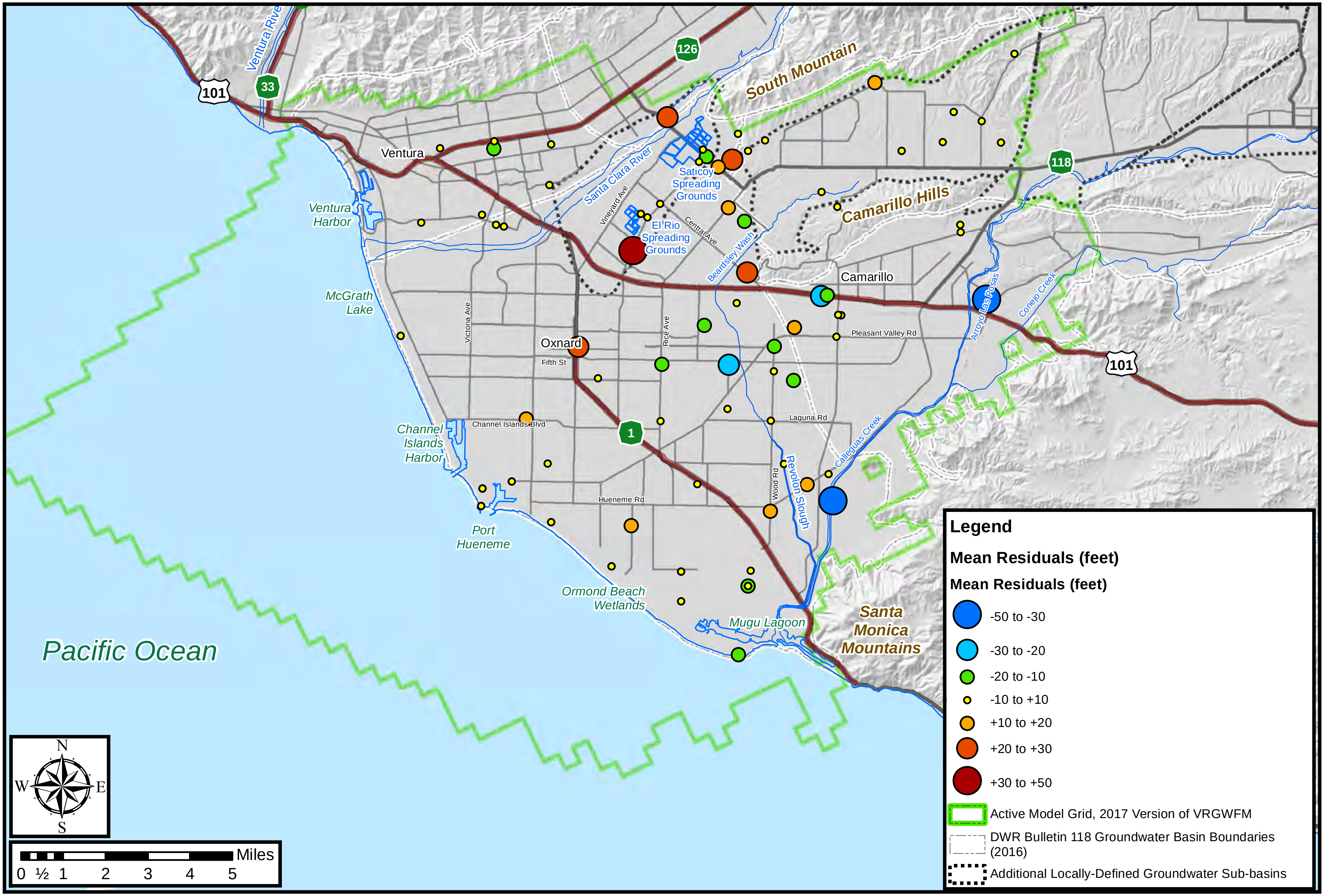


Figure 4-42. Mean Residuals for Groundwater Elevation in LAS

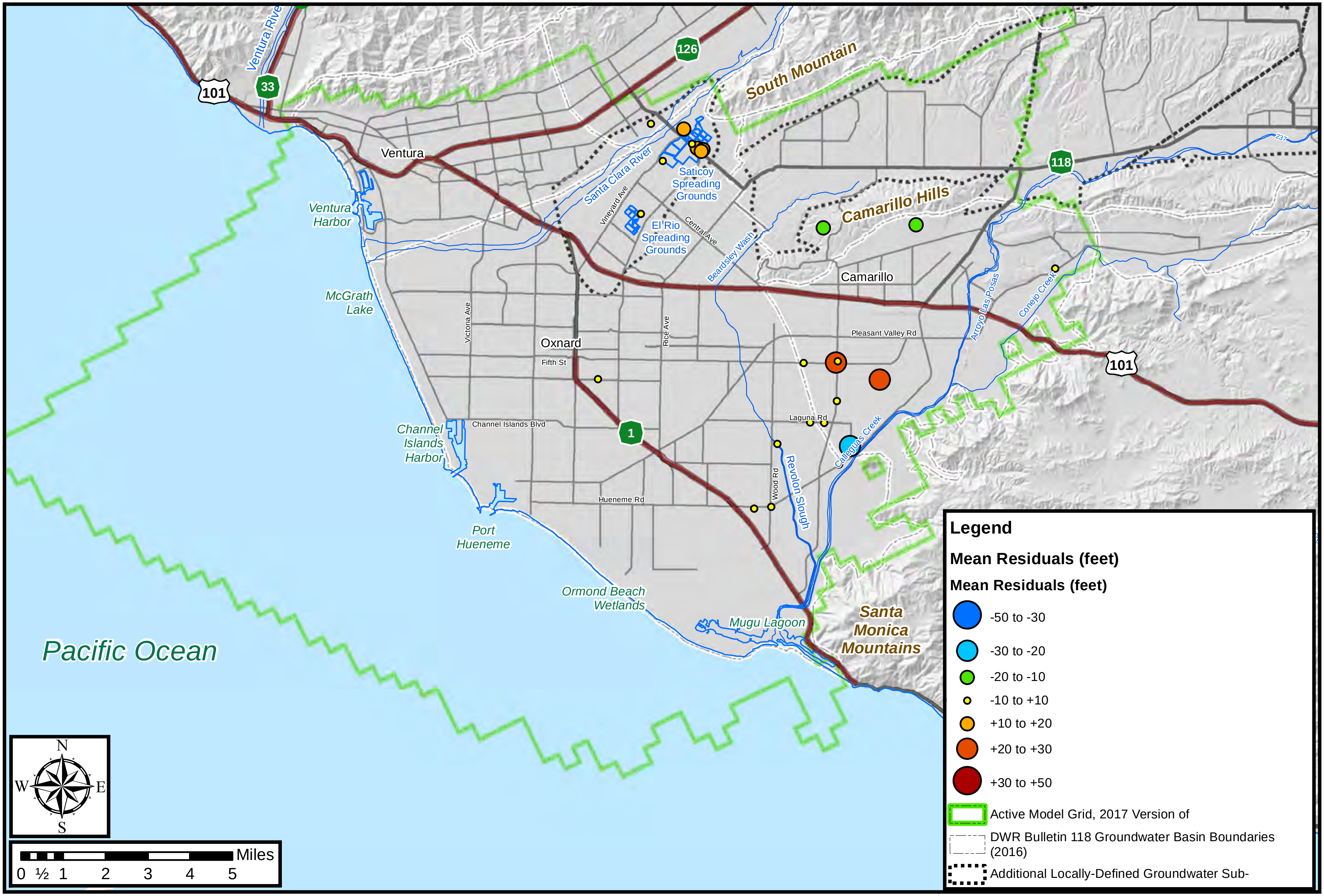


Figure 4-43. Mean Residuals for Groundwater Elevation at Wells Screened Across both the UAS and LAS

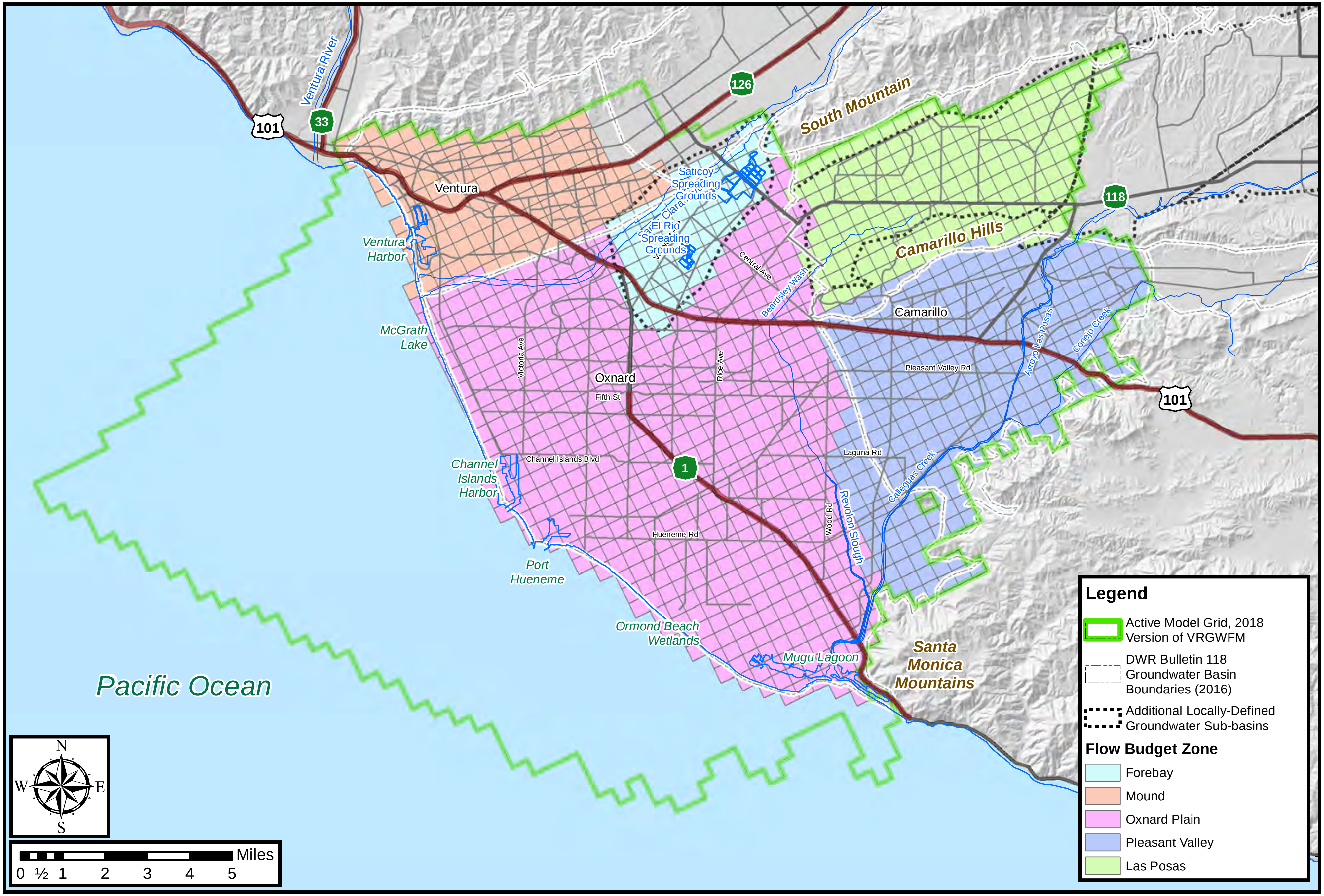


Figure 4-44. Flow Budget Zones Used for Review of VRGWFM Output from Historical Calibration Period

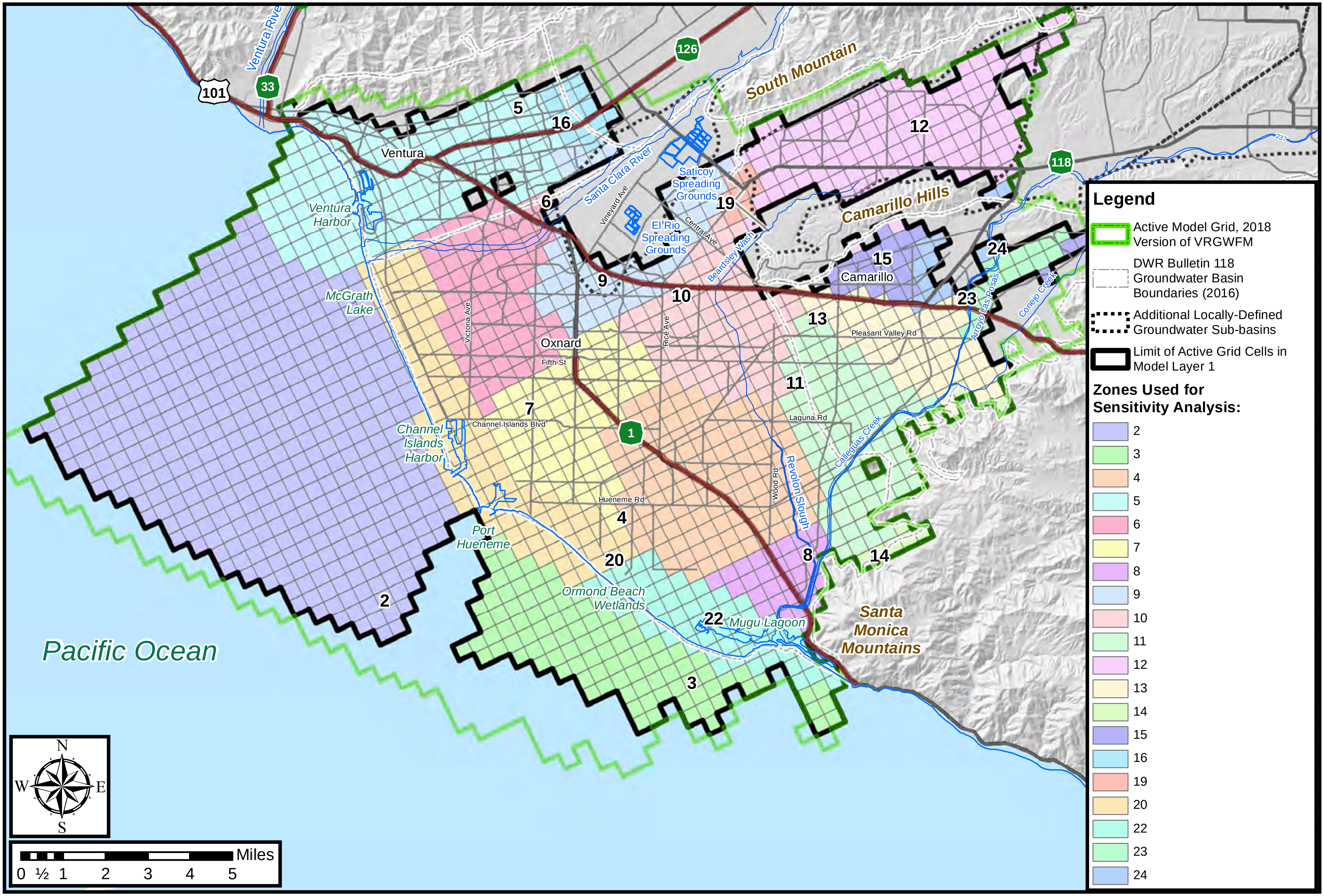


Figure 4-45. Zones Used for Sensitivity Analysis, Model Layer 1

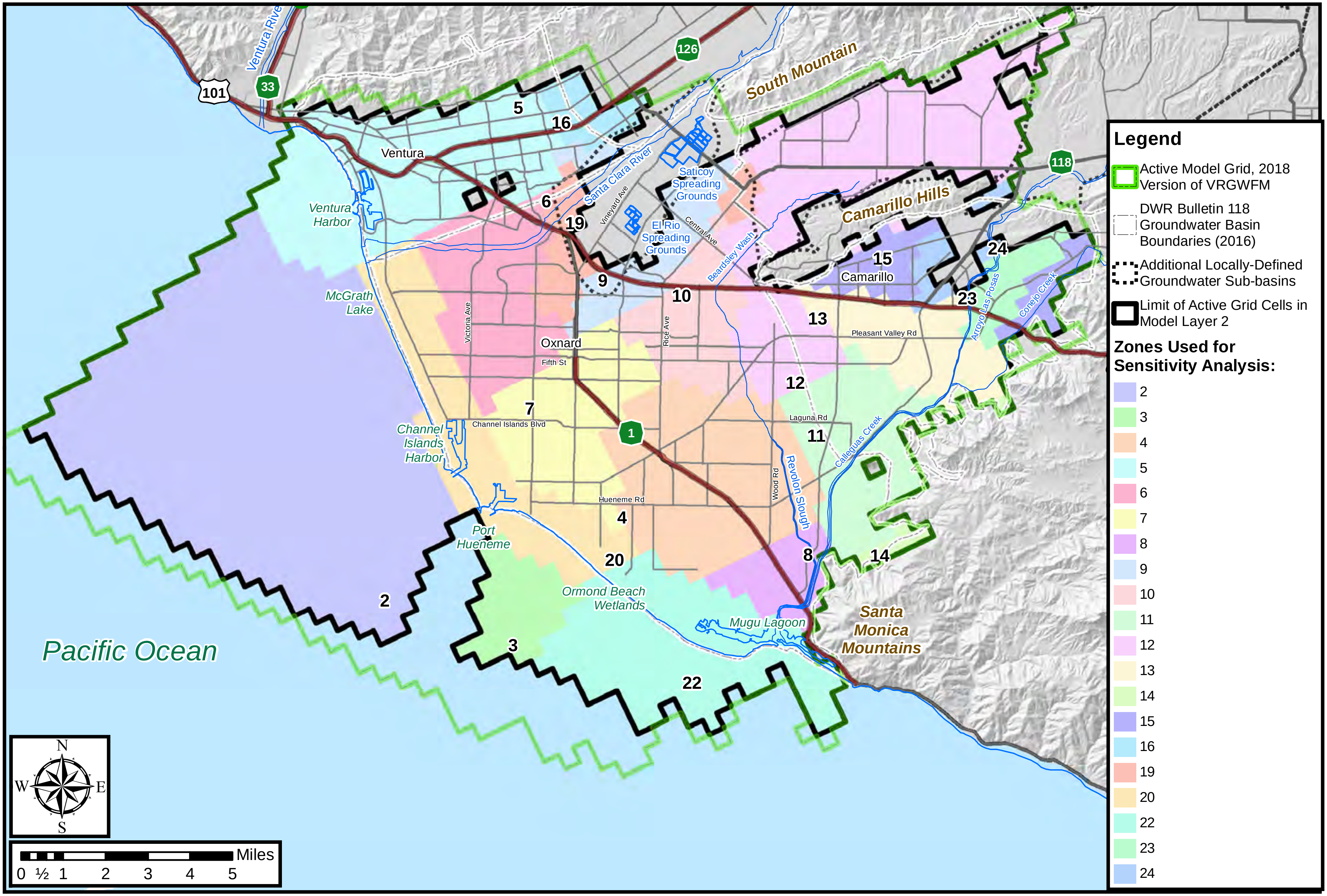


Figure 4-46. Zones Used for Sensitivity Analysis, Model Layer 2

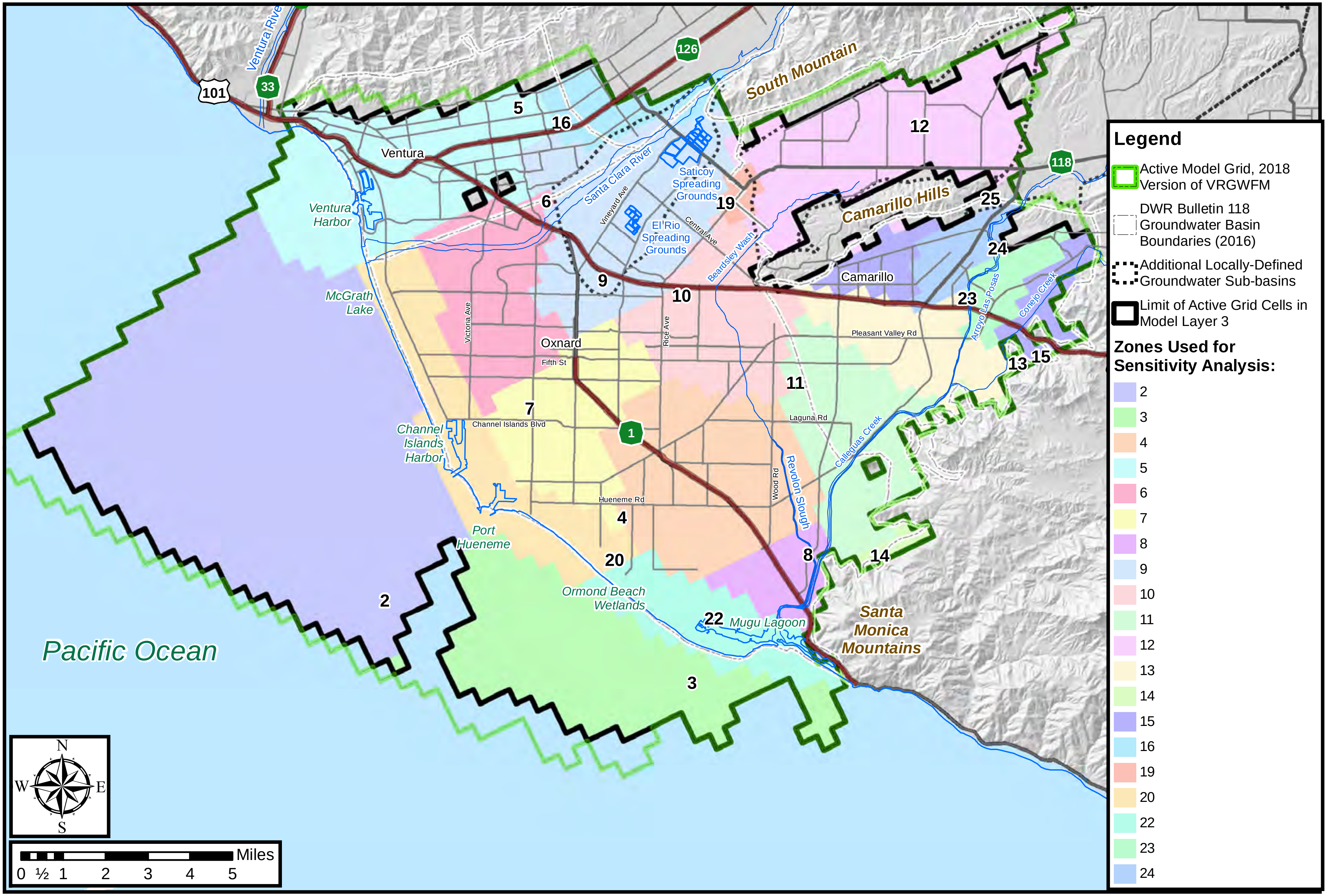


Figure 4-47. Zones Used for Sensitivity Analysis, Model Layer 3

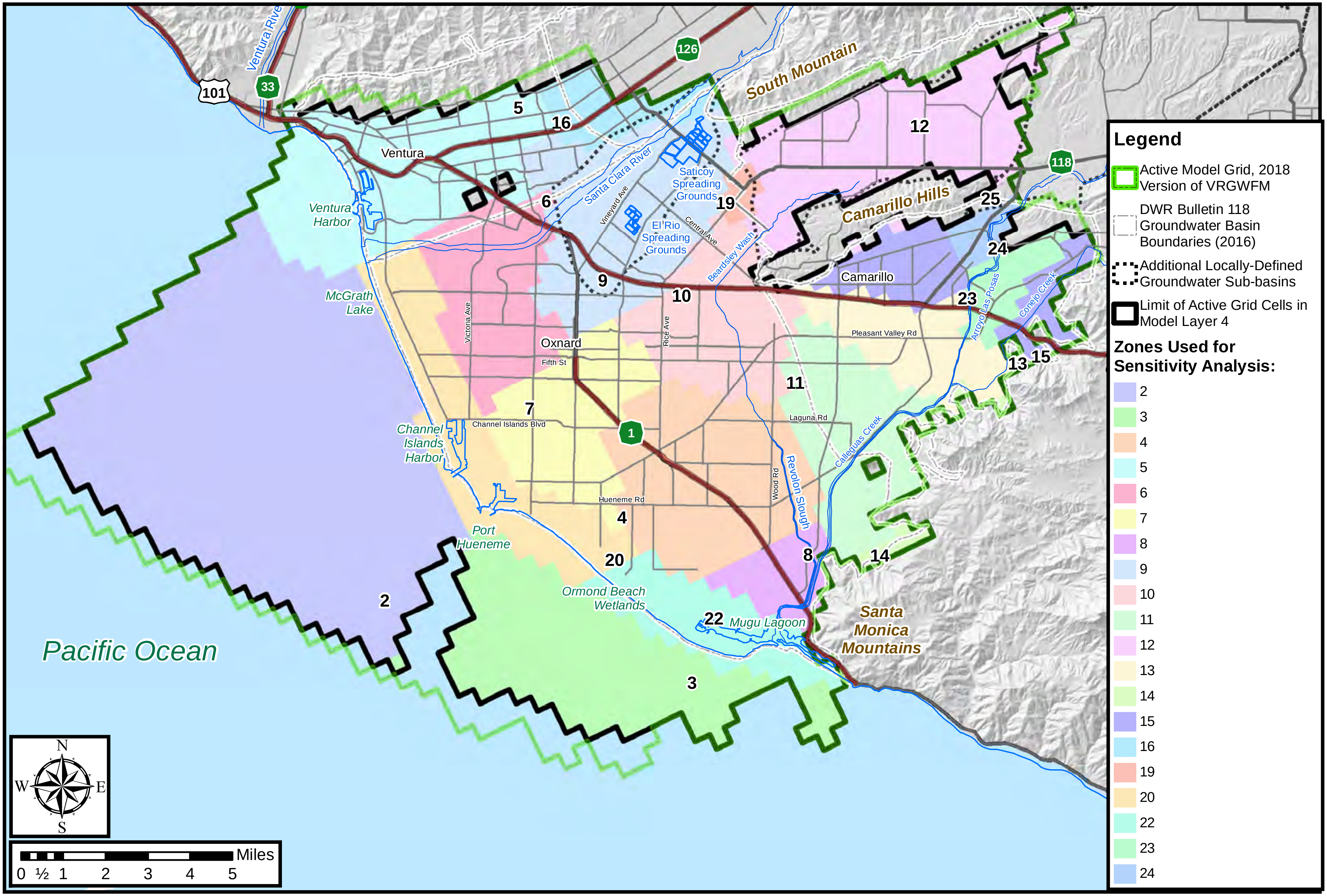


Figure 4-48. Zones Used for Sensitivity Analysis, Model Layer 4

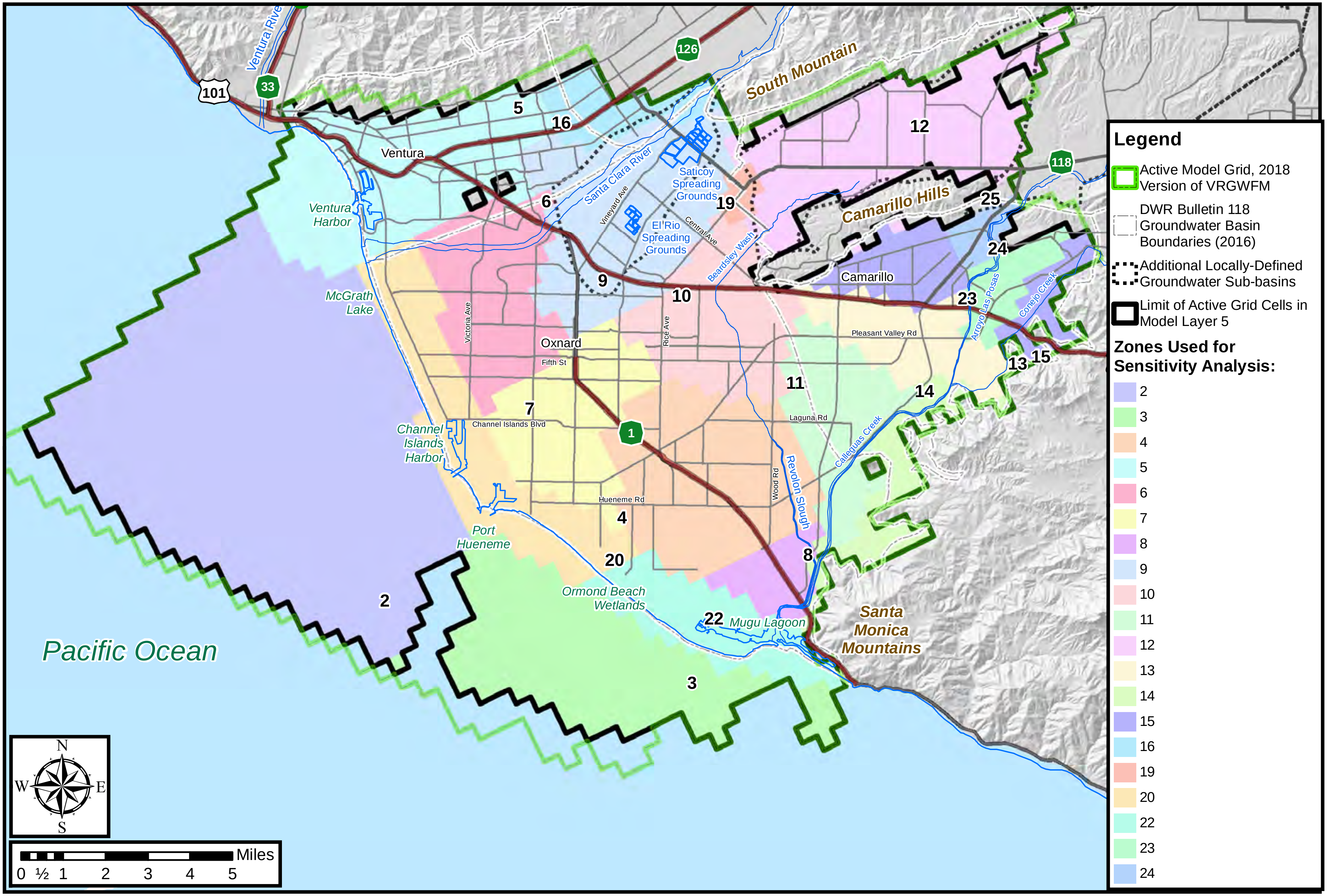


Figure 4-49. Zones Used for Sensitivity Analysis, Model Layer 5

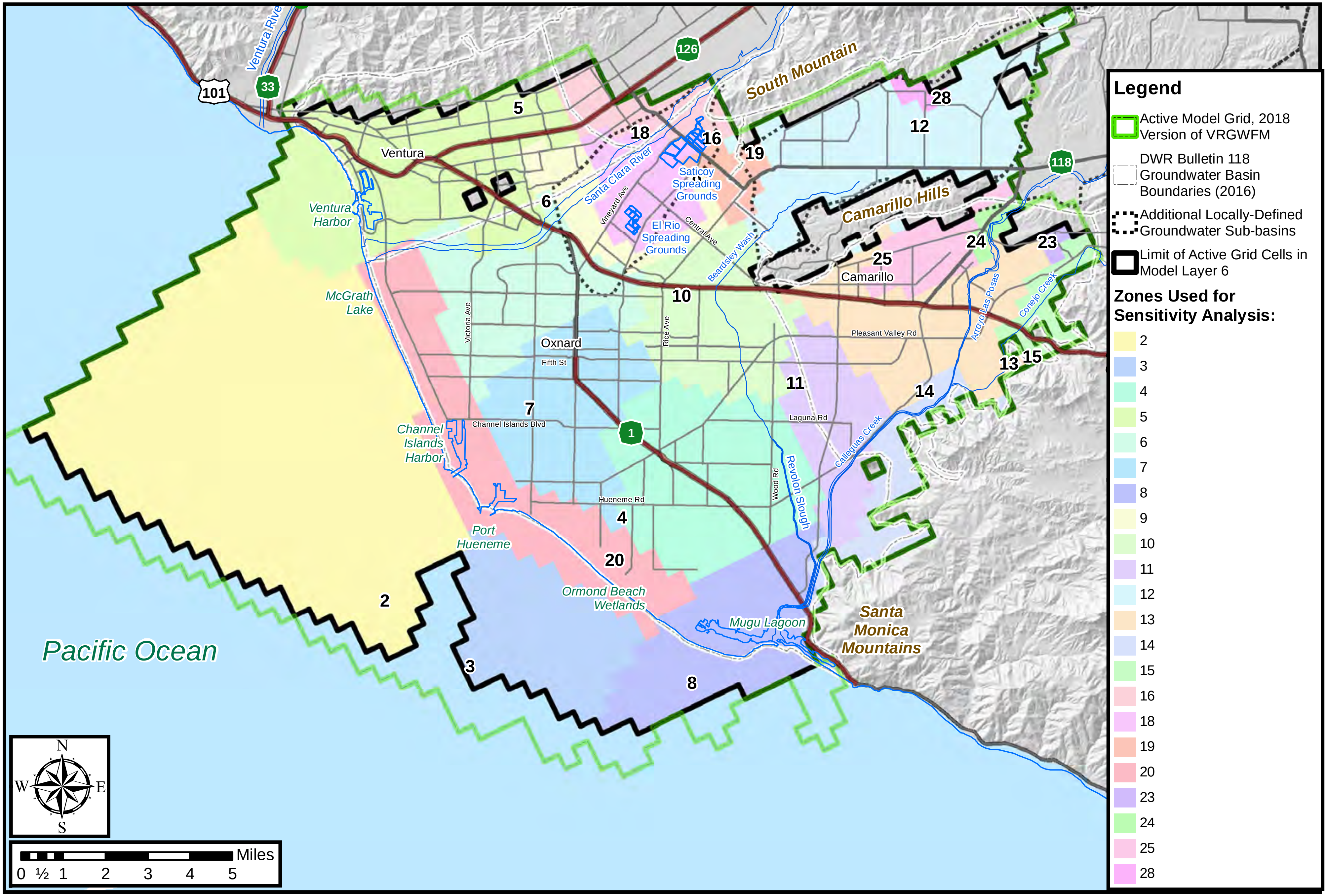


Figure 4-50. Zones Used for Sensitivity Analysis, Model Layer 6

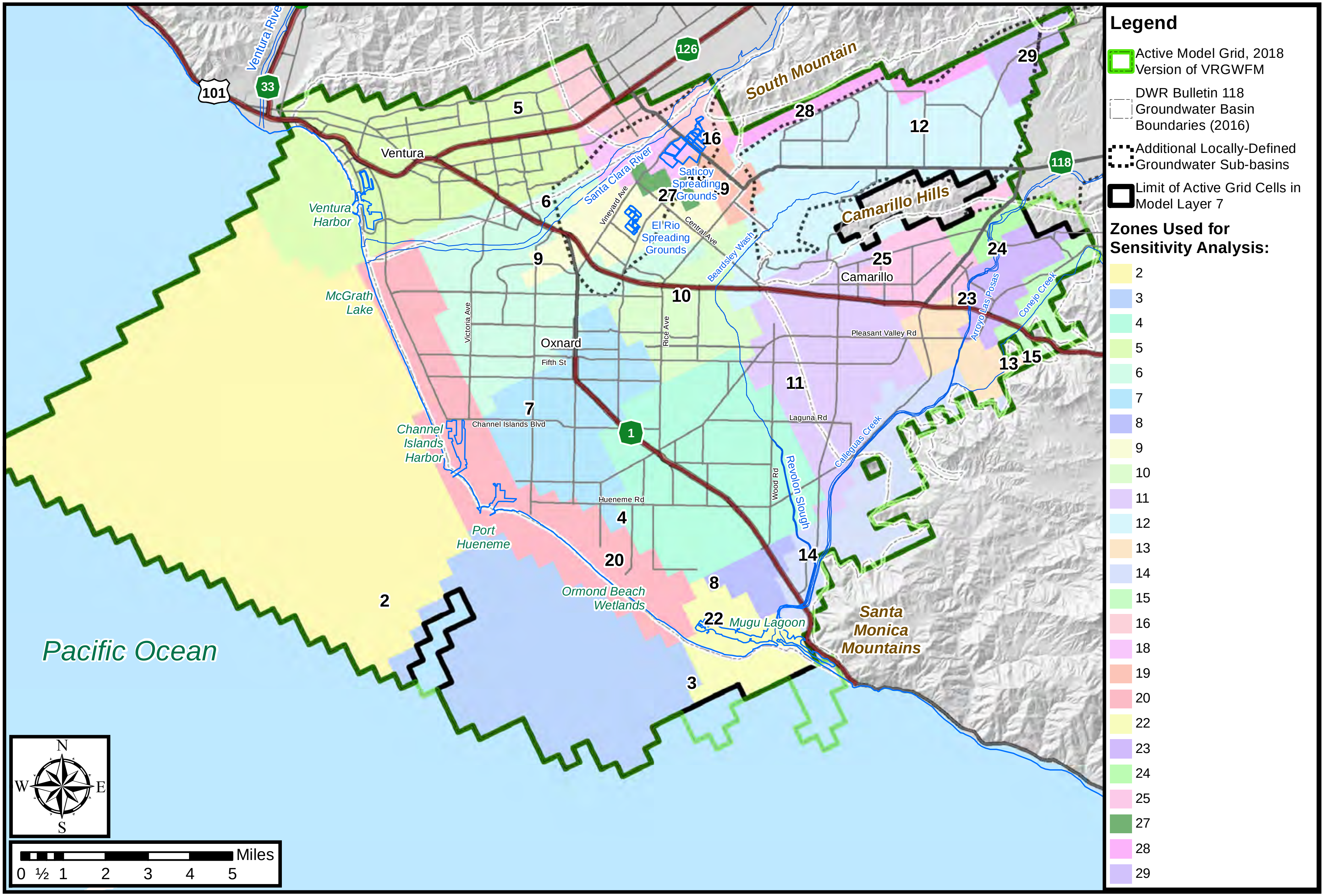


Figure 4-51. Zones Used for Sensitivity Analysis, Model Layer 7

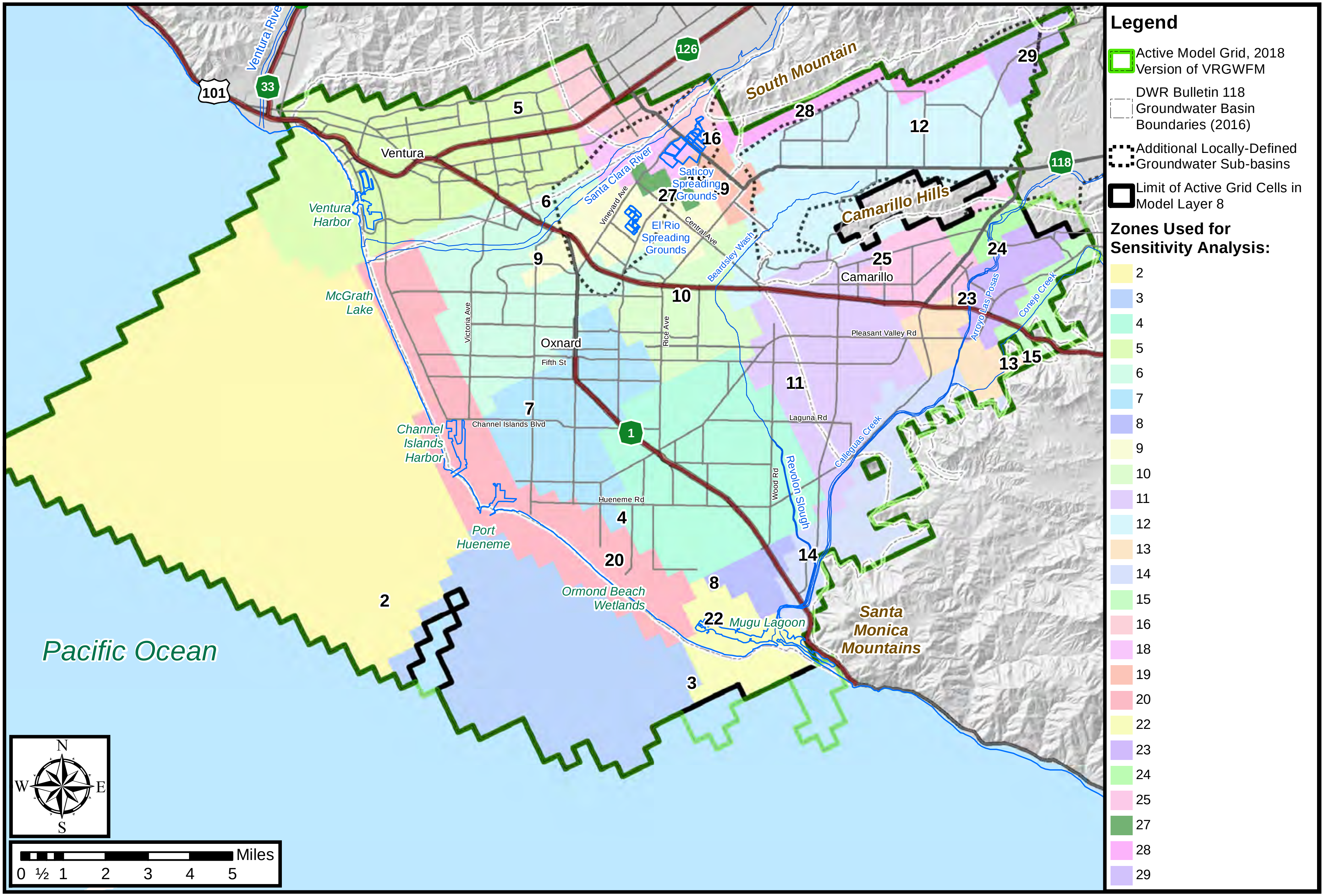


Figure 4-52. Zones Used for Sensitivity Analysis, Model Layer 8

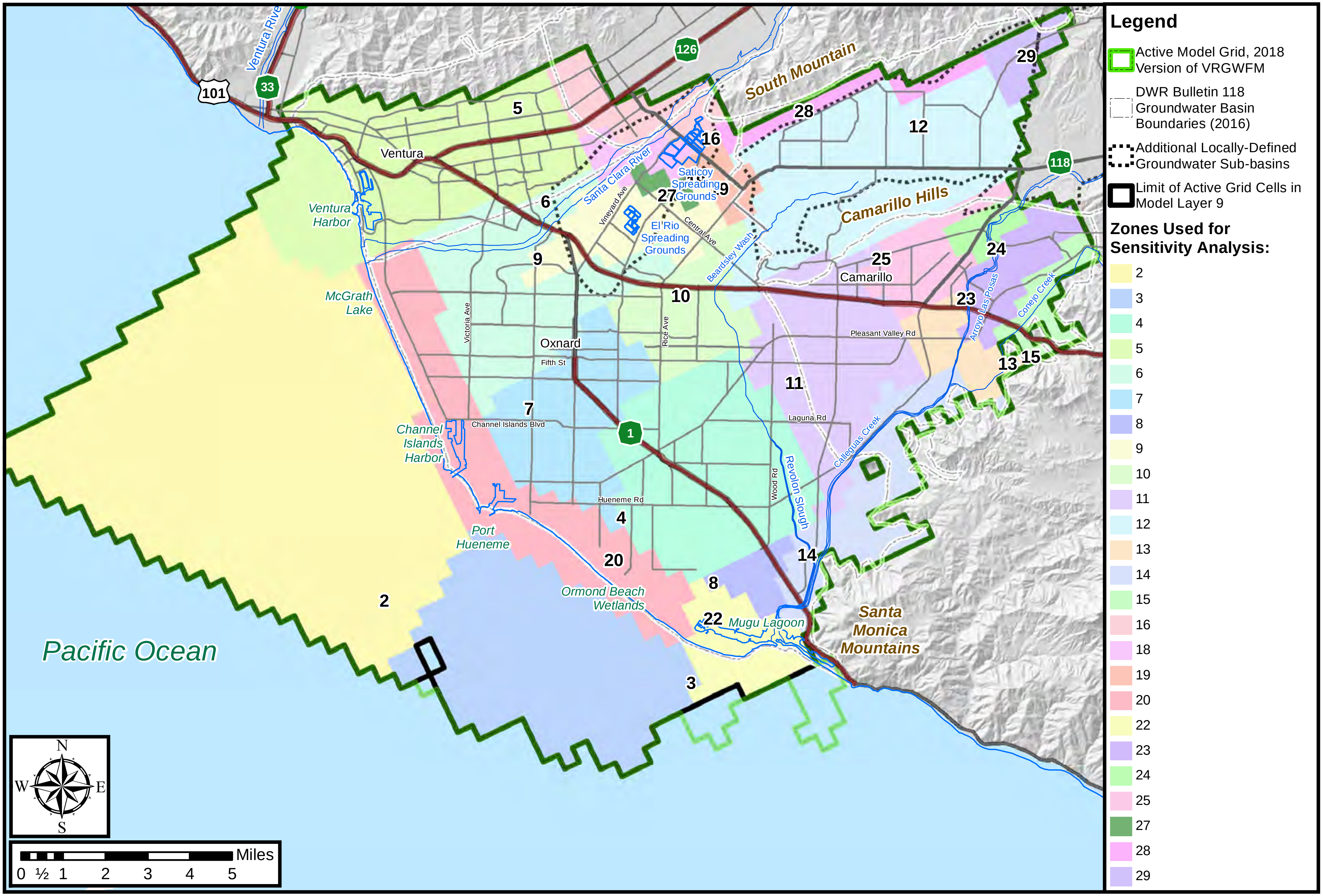


Figure 4-53. Zones Used for Sensitivity Analysis, Model Layer 9

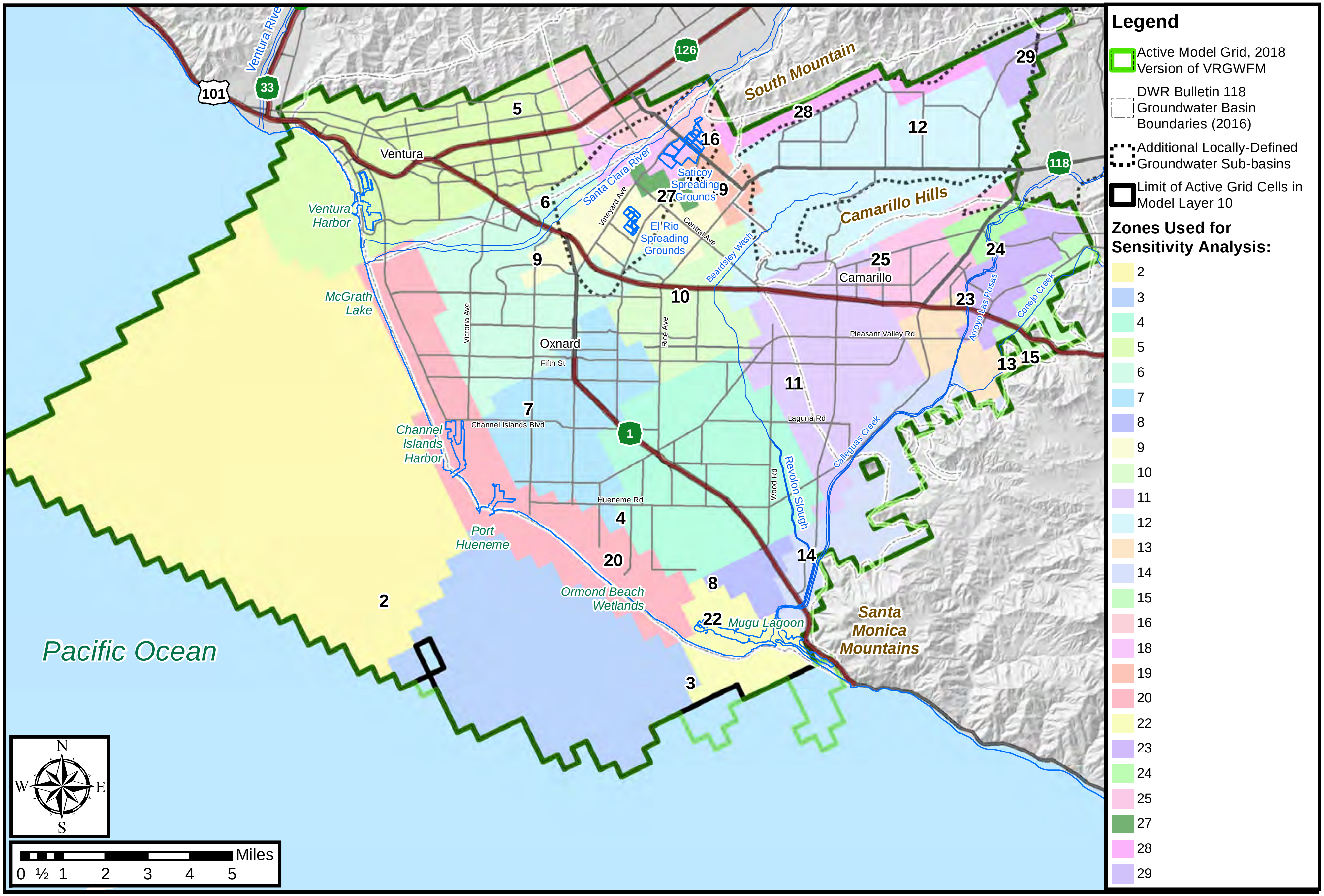


Figure 4-54. Zones Used for Sensitivity Analysis, Model Layer 10

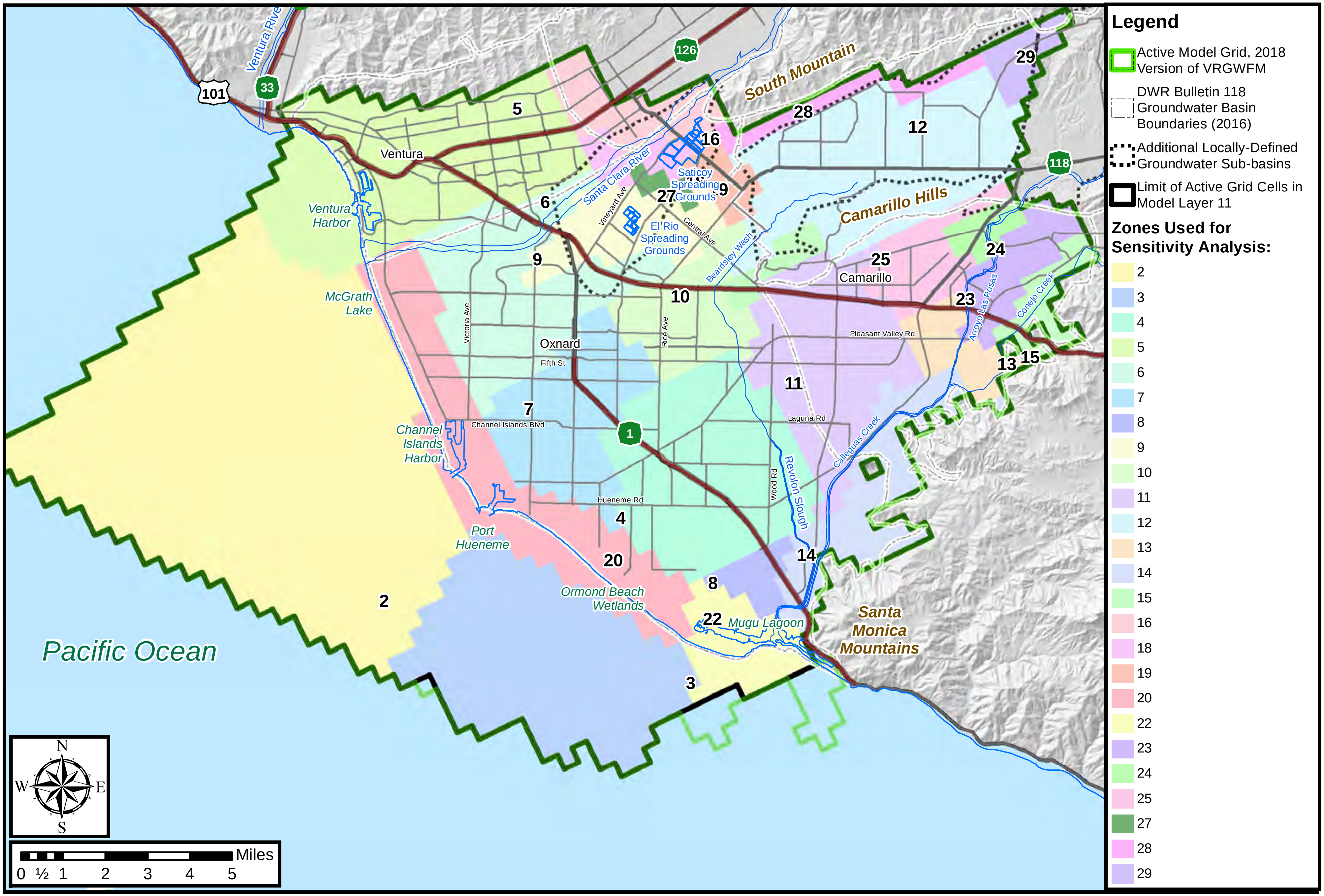


Figure 4-55. Zones Used for Sensitivity Analysis, Model Layer 11

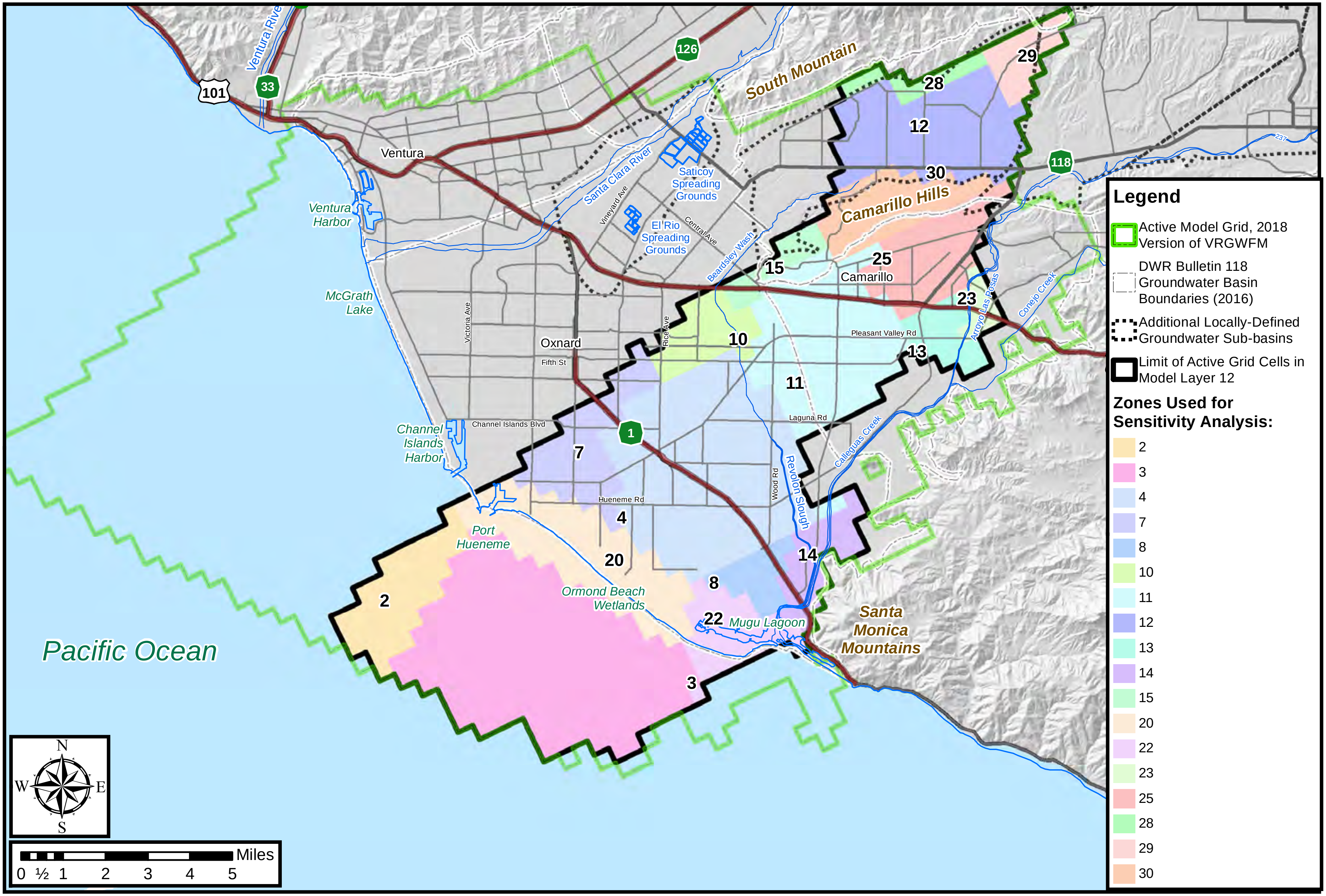


Figure 4-56. Zones Used for Sensitivity Analysis, Model Layer 12

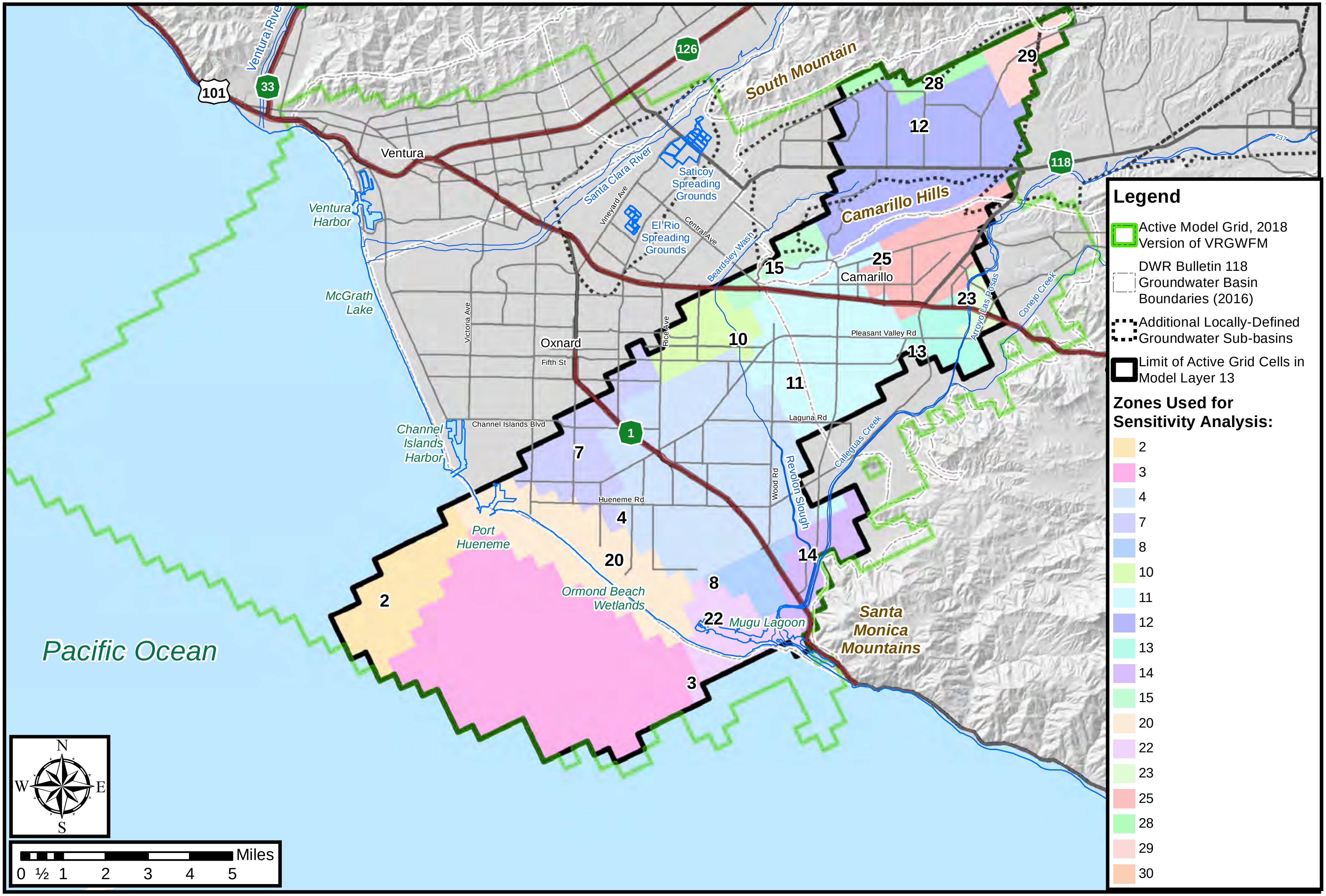


Figure 4-57. Zones Used for Sensitivity Analysis, Model Layer 13