CH2MHill, "Regional Groundwater Flow Model for the Santa Clarita Valley: Model Development and Calibration" (April 2004)

Final Report

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Development and Calibration

Prepared for

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Executive Summary

The water purveyors in the Santa Clarita Valley of Southern California have constructed a regional-scale numerical groundwater flow model of the valley. The model, which is called the Santa Clarita Valley Groundwater Model (Regional Model), simulates the occurrence and flow of groundwater, including its interaction with streams in the area. Figure ES-1 shows the study area, including the Regional Model's boundaries. Figure ES-2 shows the extent of the watershed that the valley occupies, and shows the sub-watersheds that drain into the study area covered by the Regional Model.

The Regional Model has been developed as part of the work scope contained in a Memorandum of Understanding (MOU) that was entered into in August 2001 by the Upper Basin Water Purveyors in the Santa Clarita Valley and the United Water Conservation District in Ventura County. This report documents the construction and calibration of the Regional Model, including presenting the conceptual hydrogeologic model on which the Regional Model is based.

ES.1 Model Development Objectives and Approach

The Regional Model is intended to become an evolving tool for managing the local groundwater resource. Specific objectives that are identified for the model are:

a. To be able to evaluate the long-term sustainability (yield) of the two aquifer systems that are present in the valley, the Alluvial Aquifer and the Saugus Formation, under a range of existing and potential future water resource management conditions

b. To be able to evaluate artificial recharge to increase the long-term sustainability of the aquifer system, particularly in conjunction with the availability of imported surface water supplies

c. To evaluate the influences of future water management plans and alternatives on groundwater conditions within the valley and on the flows of water into the downstream basins in Ventura County

d. To facilitate general management of water quantity and water quality issues

The approach to developing the Regional Model included the following steps:

1. Compiling information on the geology and hydrogeology of the valley and developing a conceptual understanding of the groundwater flow system

2. Creating a variety of data sets to conduct steady-state and transient calibrations

3. Constructing the Regional Model using the MicroFEM® finite-element groundwater flow code, and also using the available database and geographic information system (GIS) for the Santa Clarita Valley

4. Calibrating the Regional Model
5. Performing sensitivity tests on the Regional Model

ES.2 Hydrogeology of the Santa Clarita Valley

Section 2 of the report describes the hydrogeology of the Santa Clarita Valley, including the geologic system; groundwater occurrence; groundwater recharge and discharge mechanisms; the relationship of surface hydrology to the valley's groundwater resources; historical trends in the valley's hydrology; the role of the State Water Project (SWP) in the valley's water resources and water supply; and key findings from prior studies conducted in the valley. This section of the report focuses particularly on information of specific relevance to development of the Regional Model. Figure ES-3 is a schematic representation of the regional-scale geology and hydrologic cycle in the Santa Clarita Valley. Figure ES-4 is a geologic map.

ES.2.1 Geology

The geology of the valley is defined in part by the non-water-bearing bedrock that underlies and surrounds the valley's aquifer systems. This bedrock forms a bowl-shaped aquifer system, which is thickest at the center of the valley and progressively thins outwards towards the margins of the valley. The deeper of the two aquifer systems is contained in the Saugus Formation, which consists of lenticular and interfingered beds of poorly- to well-consolidated sandstone, conglomerate, and siltstone that are at least 7,500 feet thick in the deepest part of the basin. The most productive portion of the Saugus Formation is thought to be the area southwest of the San Gabriel Fault. The deeper and older portion of the Saugus Formation, the Sunshine Ranch Member, was deposited in a marine environment and consists of fine-grained, low-permeability siltstone and sandstone that preclude development of municipal water supplies. Evidence from geophysical logs also indicates that the groundwater in much of the Sunshine Ranch Member may be somewhat brackish in quality.

Overlying the Saugus Formation is the Alluvial Aquifer, which consists of extensively interlayered and interfingered mixtures of gravel, sand, silt, and clay, with variable amounts of cobbles and boulders. In general, alluvium in the main river valley ranges from medium-grained sand to sandy gravel and cobbles. Due to its unconsolidated to poorly consolidated condition, and its lack of cementation, the alluvium has relatively high permeability and porosity.

ES.2.2 Groundwater Recharge

Average annual rainfall in the Santa Clarita Valley is approximately 18 inches per year, and higher (up to 30 inches per year or more) in the surrounding mountains. Natural groundwater recharge occurs from direct precipitation and from stormwater flowing in the Santa Clara River and its tributaries. Each of these streams have their headwaters in areas lying upstream of the Alluvial Aquifer and Saugus Formation. Consequently, stormwater that is generated in these upstream watersheds flows into the valley and is an important source of groundwater recharge. Because the climate is semi-arid, rainfall and stormwater runoff occur primarily between November and March and can vary considerably in magnitude from year to year. The direct precipitation in the valley and the recharge of stormwater generated in upstream watersheds together provide approximately 94 percent of the total groundwater recharge to the valley's groundwater resources. Irrigation on agricultural and urban lands represents another 4 percent, and underflow beneath Castaic Dam into the adjoining Alluvial Aquifer is estimated to represent approximately 2 percent of the total basinwide groundwater recharge.

ES.2.3 Groundwater Discharge

Groundwater discharge from the Alluvial Aquifer occurs primarily as discharge to the Santa Clara River and evapotranspiration (ET) by the riparian vegetation growing along the river corridor. The Alluvial Aquifer also discharges as subsurface outflow into the Piru Basin at Blue Cut, which is located just downstream of the Los Angeles-Ventura County line. Groundwater pumping occurs from both the Alluvial Aquifer and the Saugus Formation, and Saugus Formation groundwater also discharges to the Alluvial Aquifer.

ES.2.4 Aquifer Physical Properties

Specific capacity data from Alluvial Aquifer production wells indicates that the horizontal hydraulic conductivity is approximately 300 to 700 feet per day, and possibly higher, along the Santa Clara River. In the tributaries, the horizontal hydraulic conductivity is approximately 100 to 600 feet per day. The horizontal hydraulic conductivity in the Saugus Formation has been estimated to be approximately 6.5 feet per day, based on pumping and injection tests conducted on production wells with long screen intervals.

ES.2.5 Basin Hydrology

Long-term records of groundwater elevations and pumping exist for the Alluvial Aquifer throughout the valley. These records indicate that groundwater elevations can fluctuate significantly from year to year in the eastern part of the valley, in response to patterns of droughts and above-normal rainfall. In the western part of the valley, groundwater levels are stable, as this is the regional groundwater discharge area. Despite the variations in groundwater elevations in the eastern valley and the variations in pumping throughout the valley during the past five decades, groundwater elevations in the Alluvial Aquifer have shown no permanent long-term declines. In addition, the availability of SWP water has allowed the valley to become increasingly urbanized, and the resulting gradual increase in urbanization and SWP water imports have resulted in a gradual increase in flows in the Santa Clara River.

Similar conditions are seen in the Saugus Formation. From the late 1980s through the early to mid-1990s, groundwater elevations declined in response to drought conditions and increased pumping. However, starting in the mid-1990s, Saugus groundwater elevations increased notably as pumping decreased and rainfall increased. As with the Alluvial Aquifer, the Saugus Formation showed groundwater elevation recovery to levels seen prior to the drought.

ES.2.6 Water Supply

The Santa Clarita Valley obtains its water supply from local groundwater sources and from SWP water that is delivered to the Castaic Lake Water Agency by the California Department of Water Resources (DWR) via the California Aqueduct. Water use includes municipal and agricultural uses.

Before 1970, agriculture was the predominant land use in the valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during the 1950s and early 1960s ranged from 35,000 to 44,000 acre-feet per year (AF/yr). Pumping from the Alluvial Aquifer dropped gradually from 40,000 AF/yr in 1967 to less than 30,000 AF/yr by 1983, and did not rise above 30,000 AF/yr until 1993. In the Saugus Formation, very little pumping occurred before 1960. From 1960 through 1990, total pumping from the Saugus Formation ranged from approximately 2,500 AF/yr to approximately 8,500 AF/yr. In response to statewide drought conditions, pumping from the Saugus Formation ranged between 10,000 and 15,000 AF/yr from 1991 through 1994. Saugus pumping was reduced beginning in 1995, as the drought ended and additional water supplies became available. The water management practices of the purveyors call for maximizing the use of Alluvial Aquifer and SWP water. Groundwater pumping is minimized from the Saugus Formation, except during years when SWP water allocations are below normal. Consequently, since 1995, Saugus pumping has ranged between approximately 4,000 and 8,500 AF/yr.

The Castaic Lake Water Agency (CLWA) has a contract amount of SWP Table A water of 95,200 AF/yr. Modeling by DWR has indicated that actual SWP water imports, based on the current CLWA Table A contract amount, will be 66,300 AF/yr in wet years, 56,800 AF/yr in average years, and 37,900 AF/yr in multiple dry years. The occurrences of drought years in the SWP system is based on the hydrology of Northern California, and hence only occasionally coincides with the occurrence of drought locally. In addition to the above entitlements, DWR occasionally releases flood flows into Castaic Creek from Castaic Dam. These flows averaged 15,700 AF/yr during the 24-year period of water years 1977 through 2000. However, no flood flows were stored or delivered in five of those years, and the median flow was 2,800 AF/yr (only 18 percent of the average flow).

ES.3 Model Construction

The Regional Model was constructed using the three-dimensional finite-element groundwater modeling software called MicroFEM® (Hemker and de Boer, 2003). The Regional Model covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. The model area largely coincides with the Santa Clara River Valley East Groundwater Subbasin, extending from the Lang stream gage at the eastern end of the valley to the County Line gage area in the west. The Regional Model is based on a finite-element mesh consisting of 7 layers, with 17,103 nodes and 32,496 elements in each layer. The upper model layer simulates the Alluvial Aquifer, or the upper portion of the Saugus Formation wherever the Alluvial Aquifer is not present. The underlying layers simulate the underlying freshwater Saugus Formation and the Sunshine Ranch Member.

The boundary conditions in the model consist of specified flux boundaries for precipitation; irrigation; recharge from ephemeral streams; pumping; and underflow from beneath Castaic Dam. Head-dependent flux boundaries are used in the perennial reach of the Santa Clara River, and to model any residual drainage of groundwater that might occur in the ephemeral reach under high water table conditions. A head-dependent flux boundary is also used for ET. A constant-head boundary was used in the Alluvial Aquifer at the downgradient (western) end of the valley, at the County Line gage.

Groundwater recharge rates were estimated using precipitation records; streamflow records; watershed maps; topographic maps; and aerial photography. These recharge rates were calculated using a detailed Surface Water Routing Model that was written specifically for the construction and calibration of the Regional Model. Pumping rates and pumping depths were defined from groundwater pumping and well construction records.

ES.4 Model Calibration Process

Calibration of the Regional Model involved matching both steady-state and transient conditions in the Alluvial Aquifer and the Saugus Formation. The steady-state calibration was performed for calendar years 1980 through 1985, and the transient calibration was performed for calendar years 1980 through 1999. The goals of the calibration process were generally to match groundwater flow directions, groundwater gradients, and groundwater elevations that were measured throughout the 20-year simulation period at wells across the valley. Figures ES-5 and ES-6 show the locations of wells that were used to evaluate calibration in the Alluvial Aquifer and the Saugus Formation, respectively. The figures also show how each aquifer was subdivided into zones to facilitate parameter selection and model calibration. An additional calibration goal was to match the patterns of total flow in the Santa Clara River and estimated groundwater discharge rates to the river. Model variables were adjusted in a manner that sought to honor independent estimates of parameter values while resulting in the best possible calibration.

ES.5 Model Calibration and Sensitivity

The Regional Model meets most of the qualitative and quantitative goals that were established for the calibration process. For the steady-state model, statistical goals for the head residuals, which are equal to the modeled minus measured groundwater elevations, were easily met for the Alluvial Aquifer and adequately met for the Saugus Formation. For the transient model, trends in groundwater elevations were generally well matched. However, during the mid- and late 1990s, the model tended to simulate too much decline in Alluvial Aquifer groundwater elevations in the eastern-most portion of the valley and water level fluctuations that were too variable in Castaic Creek. Groundwater discharges to the river were simulated well for both the steady-state and transient models.

The groundwater budget for the 20-year transient calibration period showed that recharge from precipitation and streamflows varied considerably from year to year, ranging from less than 15,000 AF/yr in the driest years to as much as 270,000 AF/yr in the wettest years (see Figure ES-7). In contrast, total groundwater discharges were less variable, ranging from approximately 61,000 AF/yr at the end of the late 1980s/early 1990s drought to 116,000 AF/yr during 1998 (see Figure ES-8). This variability in groundwater discharge did not follow the year-to-year pumping patterns, but instead was caused by year-to-year fluctuations in ET and groundwater discharges to the river. These fluctuations, in turn, correlated well with groundwater recharge patterns. During the 20-year transient calibration period, changes in the volume of groundwater stored in the combined Alluvial-Saugus aquifer system varied primarily according to year-to-year variations in regional rainfall. No long-term decline in groundwater storage was observed in the field or simulated by the model (see Figure ES-9) during this period. As Section 2.6.2 of this report will discuss, available data dating back to the 1950s also show that no long-term water level declines have occurred in the valley, despite past periods of significant pumping (particularly during the 1950s) and drought cycles.

Sensitivity analyses were performed to evaluate whether further changes in the values of key model parameters would improve the calibration quality of the Regional Model. Variables that were tested were the hydraulic properties (horizontal and vertical hydraulic conductivities and storage coefficients) for the Alluvial Aquifer and the Saugus Formation; the riverbed leakage terms for the Santa Clara River and Castaic Creek; and the ET parameters. The sensitivity analysis indicated that the model is calibrated well and that it is sensitive to the choices of horizontal hydraulic conductivity in both aquifers and vertical hydraulic conductivity in the Saugus Formation. The Regional Model was also sensitive to the riverbed leakage terms in both groundwater recharge and groundwater discharge areas. However, the model was insensitive to the choice of ET parameters.

The process of calibrating the Regional Model to a 20-year period of groundwater elevation and streamflow data has resulted in a model that is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies. The primary attributes of the model's calibration that makes this tool appropriate for its intended uses are:

a. Its ability to simulate historical trends in groundwater elevations and river flows during a 2-decade period that reflects increased urbanization, increased SWP water imports (from outside the valley), and associated changes in land use and water use

b. Its ability to simulate trends in smaller geographic areas of interest within the valley (for example, near the Whittaker-Bermite property)

c. Its use of an integrated model of the watershed, the Surface Water Routing Model, to define the amount of rainfall and stormwater that is potentially available to recharge the groundwater system

The calibration process has resulted in a Regional Model that closely simulates, on a monthly basis, total flows in the river and estimated volumes of groundwater discharging to the river. The calibration process has also resulted in a Regional Model that closely simulates the short-term and long-term time-varying trends in groundwater elevations throughout the valley, which is necessary for evaluating groundwater management strategies. The close calibration of the groundwater elevation trends and absolute groundwater elevations in both the Alluvial Aquifer and the Saugus Formation near the Whittaker-Bermite property also renders the Regional Model suitable for particle-tracking analyses, to support the design of a long-term pumping and groundwater treatment plan that will restore impaired water supplies while also preventing contamination in unimpacted portions of the aquifer.

ES.6 Model Use and Recommendations

The Regional Model is generally well-calibrated and therefore can be applied to meet the objectives for which it was developed. Nonetheless, because no model is perfect, it should be used with care, and all model results should be examined by qualified and experienced hydrogeologists and water resource managers. It is recommended that future applications of the model include sensitivity analyses on key variables and that the Regional Model and the Surface Water Routing Model be updated as water use conditions change in the future. Additionally, data gathering efforts should continue or resume, to facilitate updates of the Regional Model. In particular, controlled pumping tests should be conducted to provide quantitative estimates of aquifer properties at the locations of new Saugus Formation wells and streamflow monitoring should resume at the Lang gage, in order to better understand the magnitudes and timing of Santa Clara River flows into the valley.

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Figures

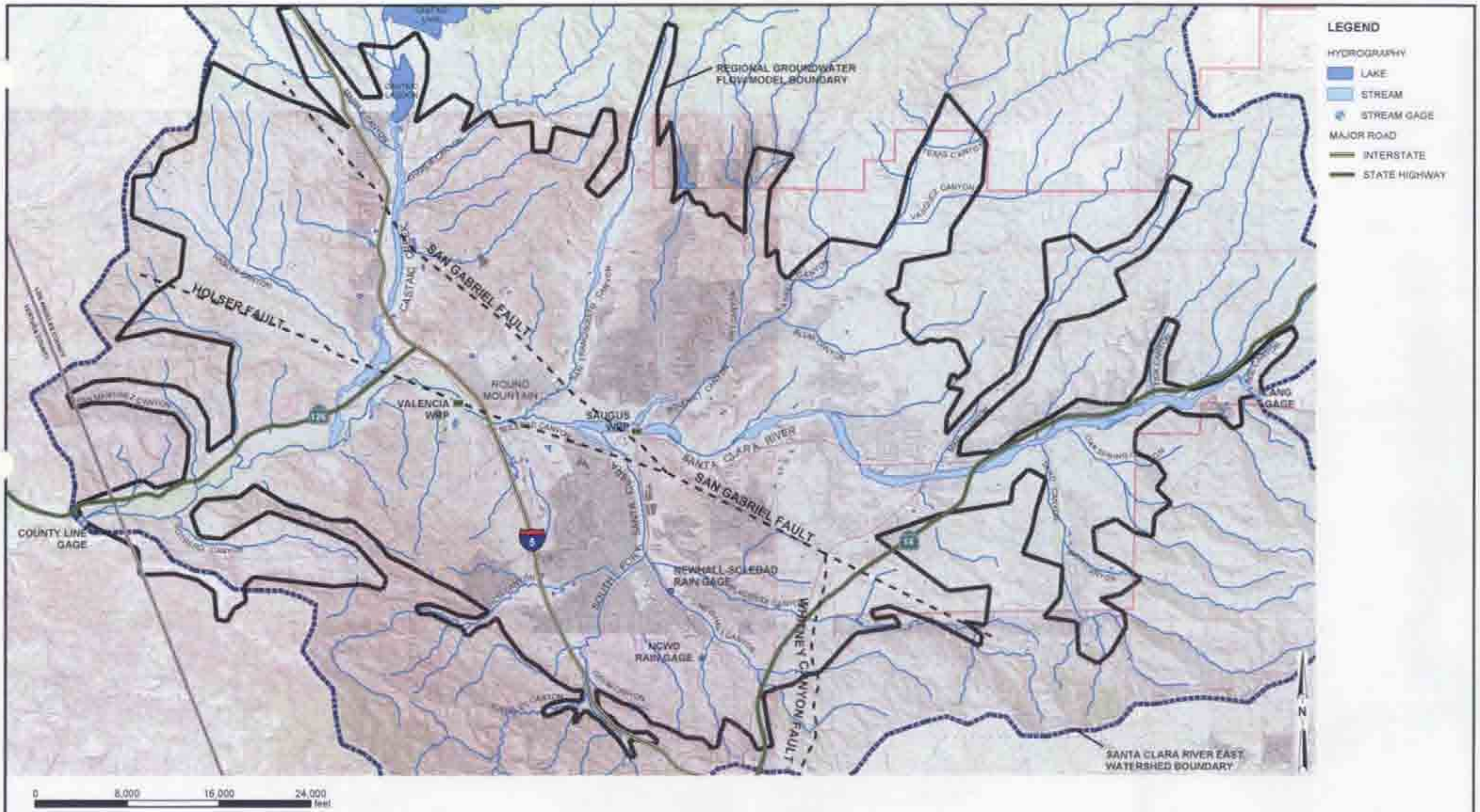

FIGURE ES-1
MAP OF STUDY AREA
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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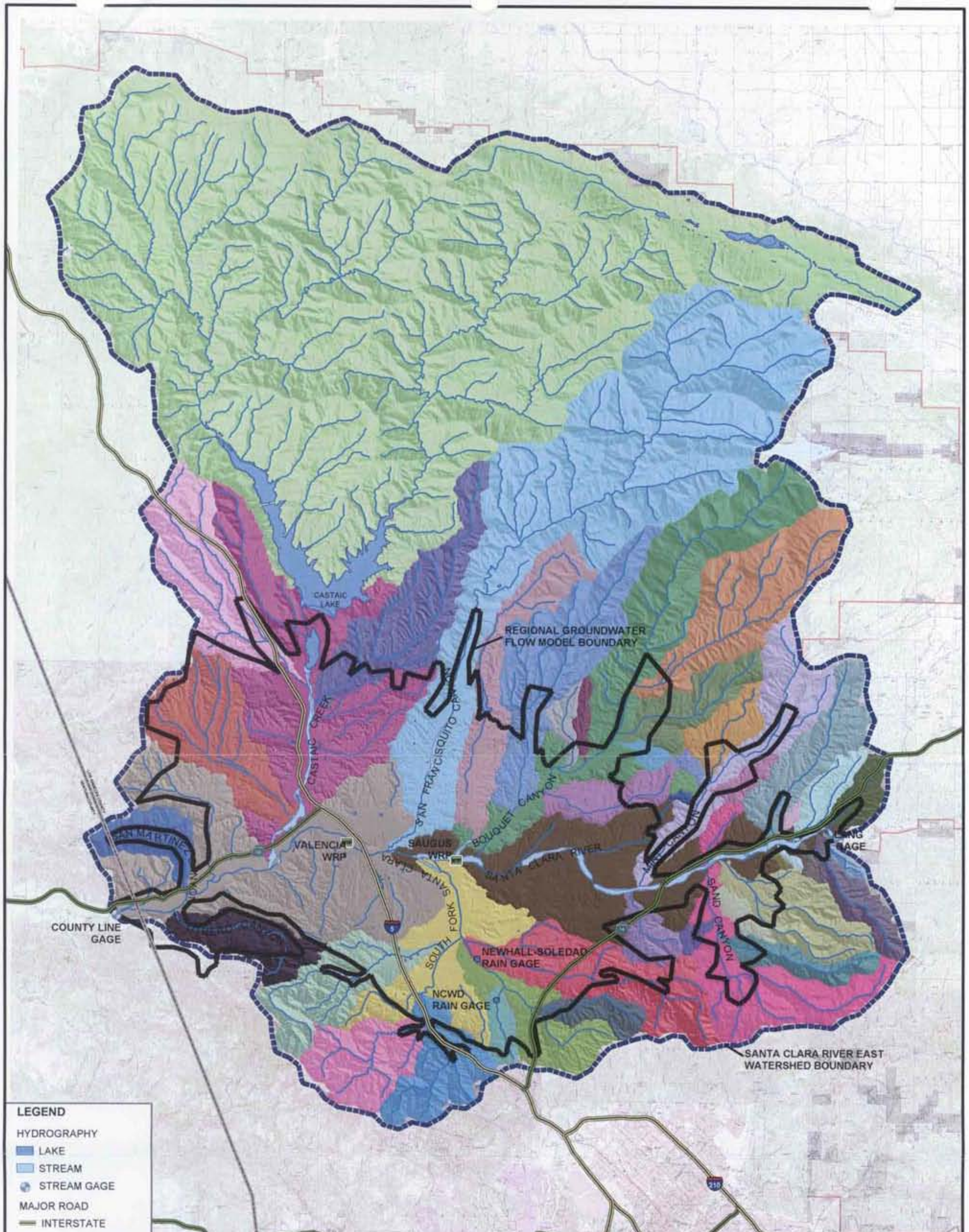

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FIGURE ES-2
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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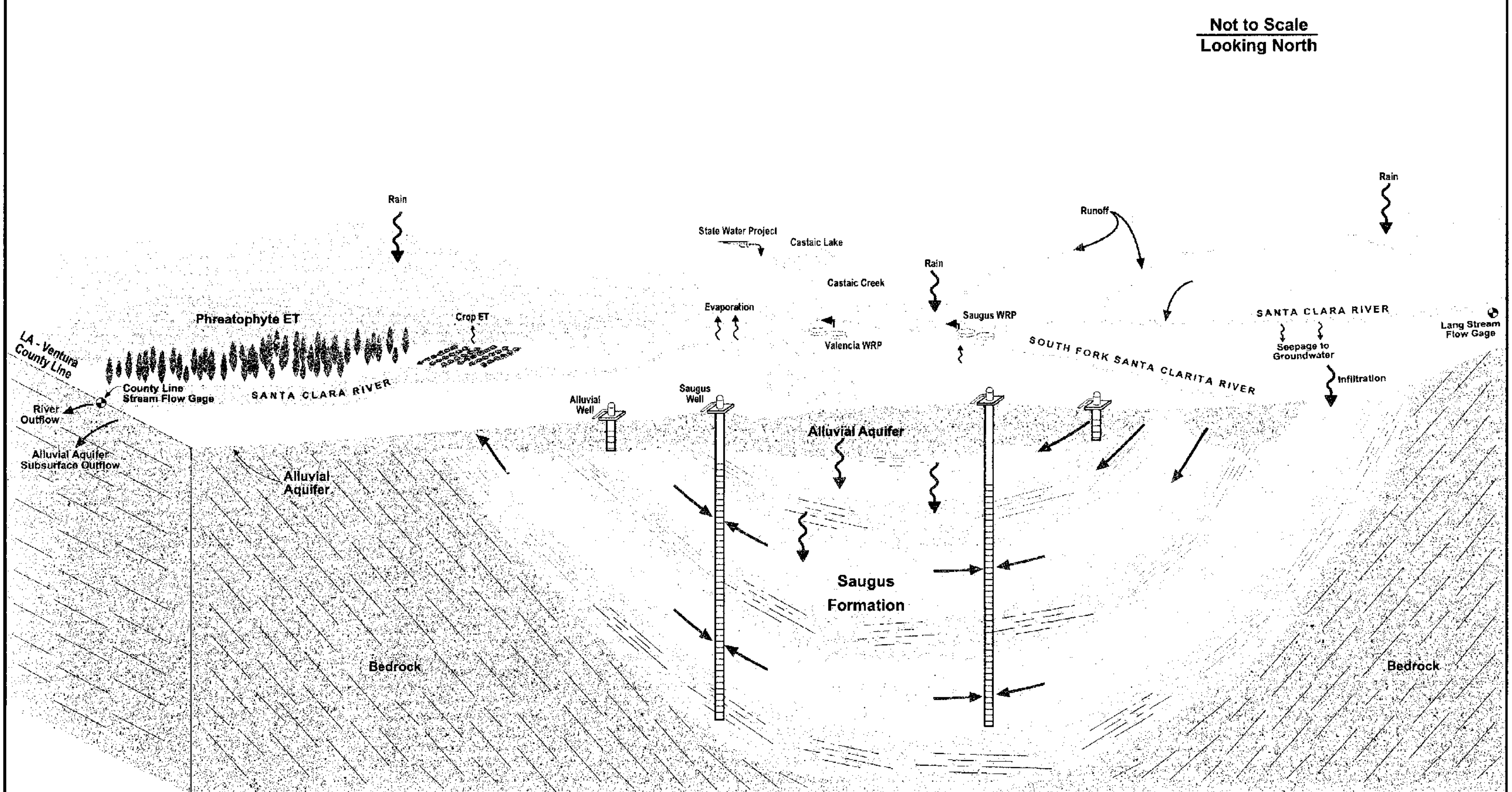

FIGURE ES-3
SANTA CLARITA VALLEY HYDROLOGY
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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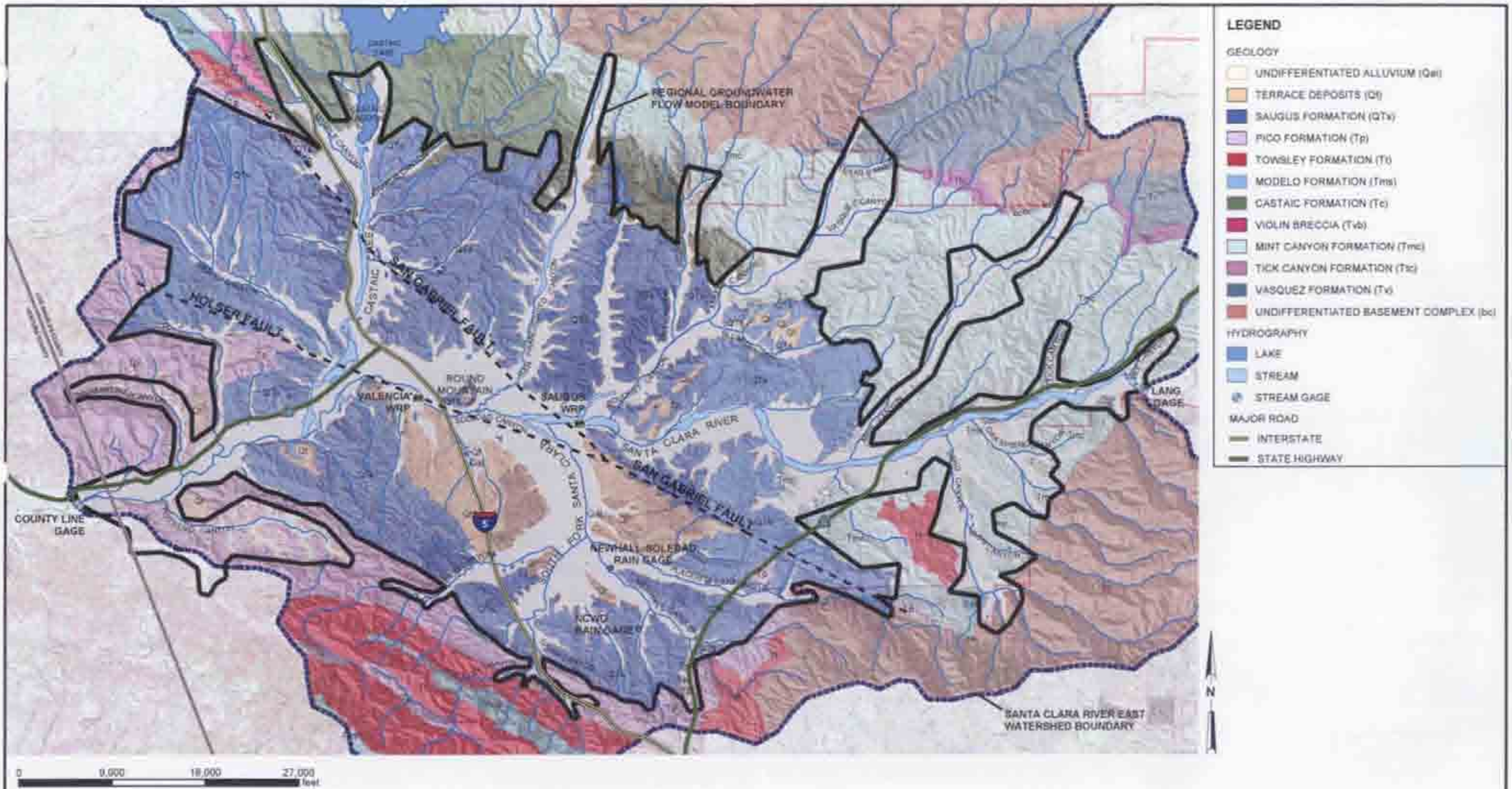

FIGURE ES-4
BASIN GEOLOGIC MAP
REGIONAL GROUNDWATER FLOW MODEL REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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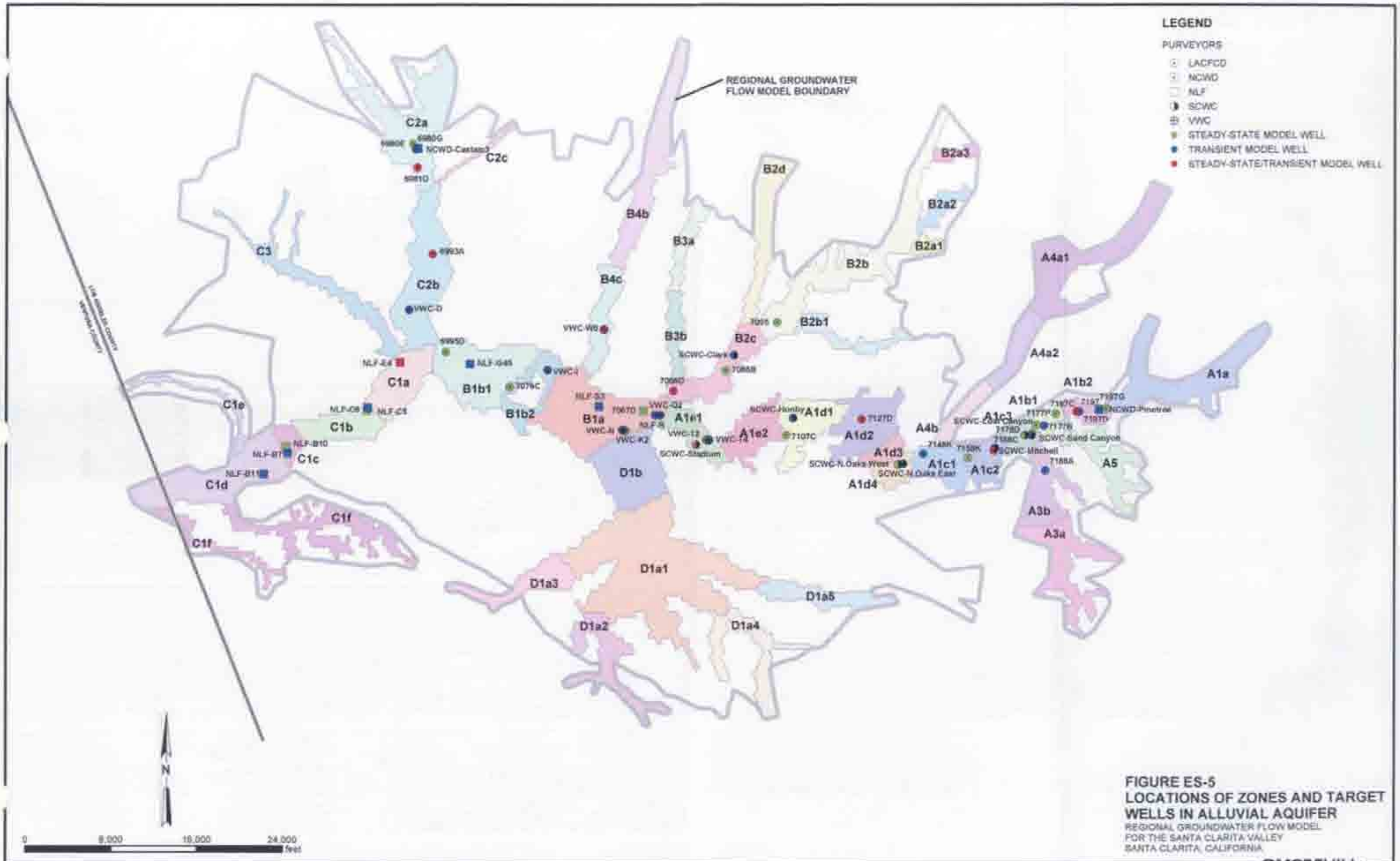

FIGURE ES-5
LOCATIONS OF ZONES AND TARGET WELLS IN ALLUVIAL AQUIFER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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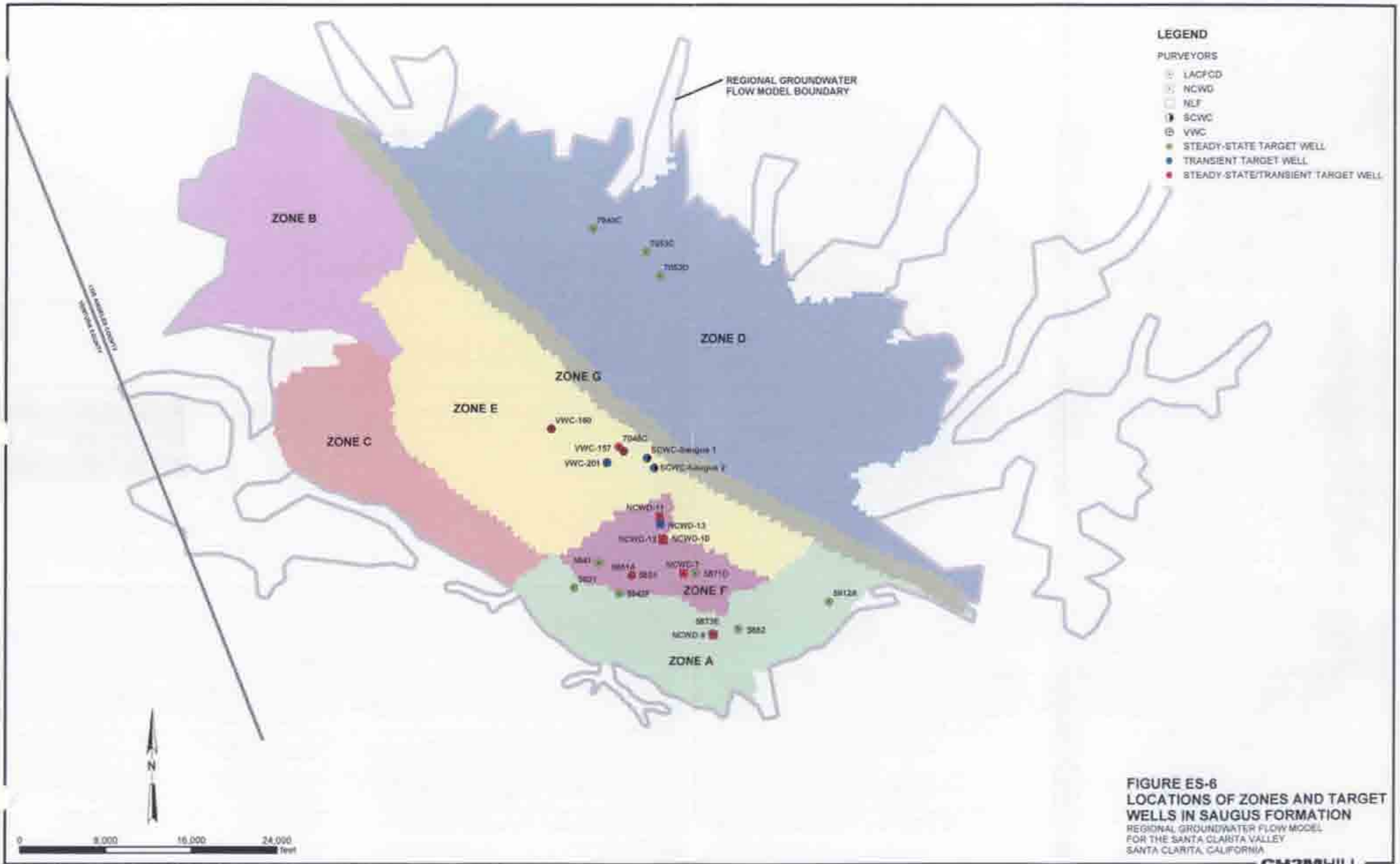

FIGURE ES-6
LOCATIONS OF ZONES AND TARGET WELLS IN SAUGUS FORMATION
REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
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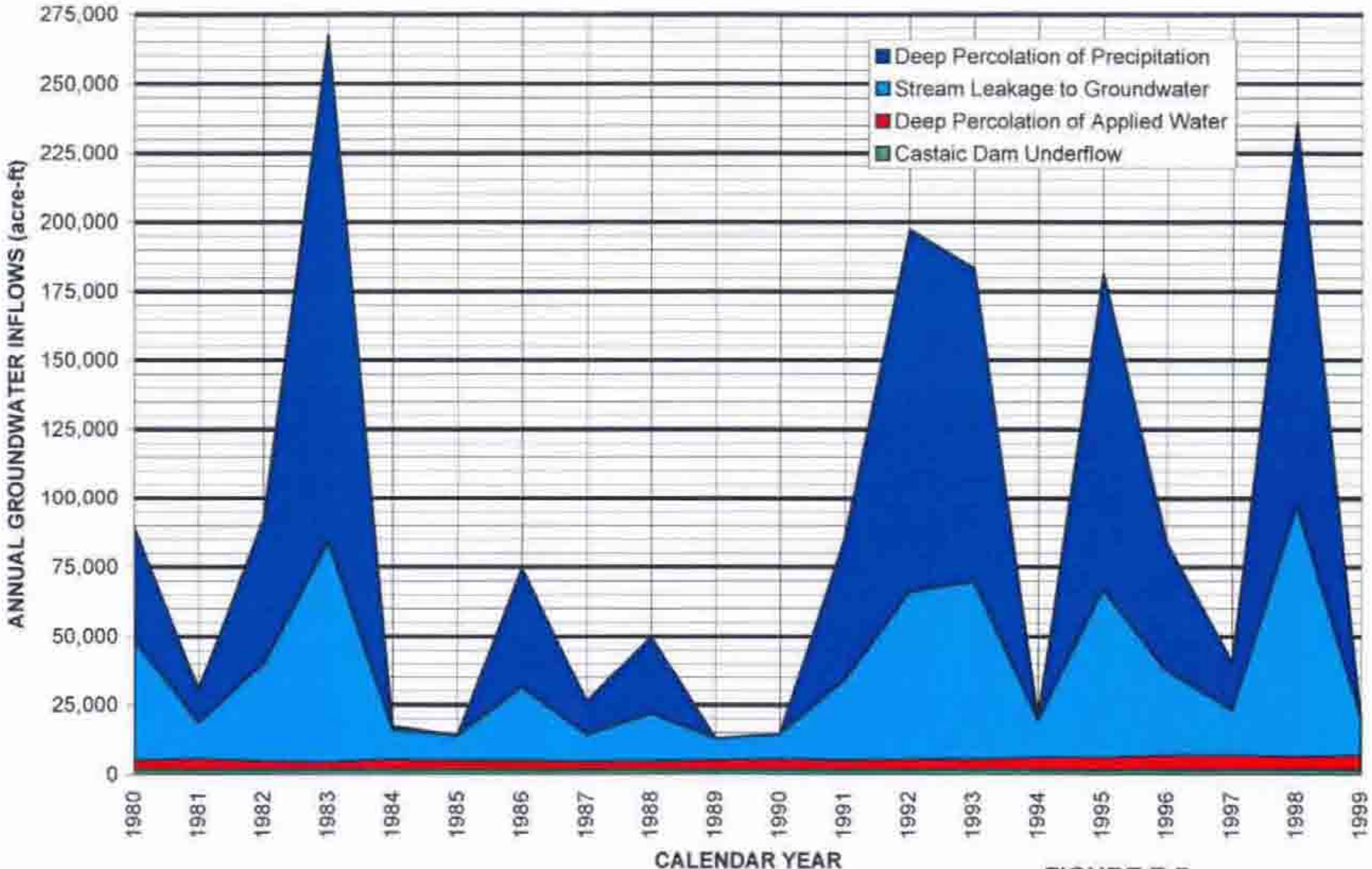

FIGURE E-7
ANNUAL GROUNDWATER INFLOWS
REGIONAL GROUNDWATER FLOW MODEL REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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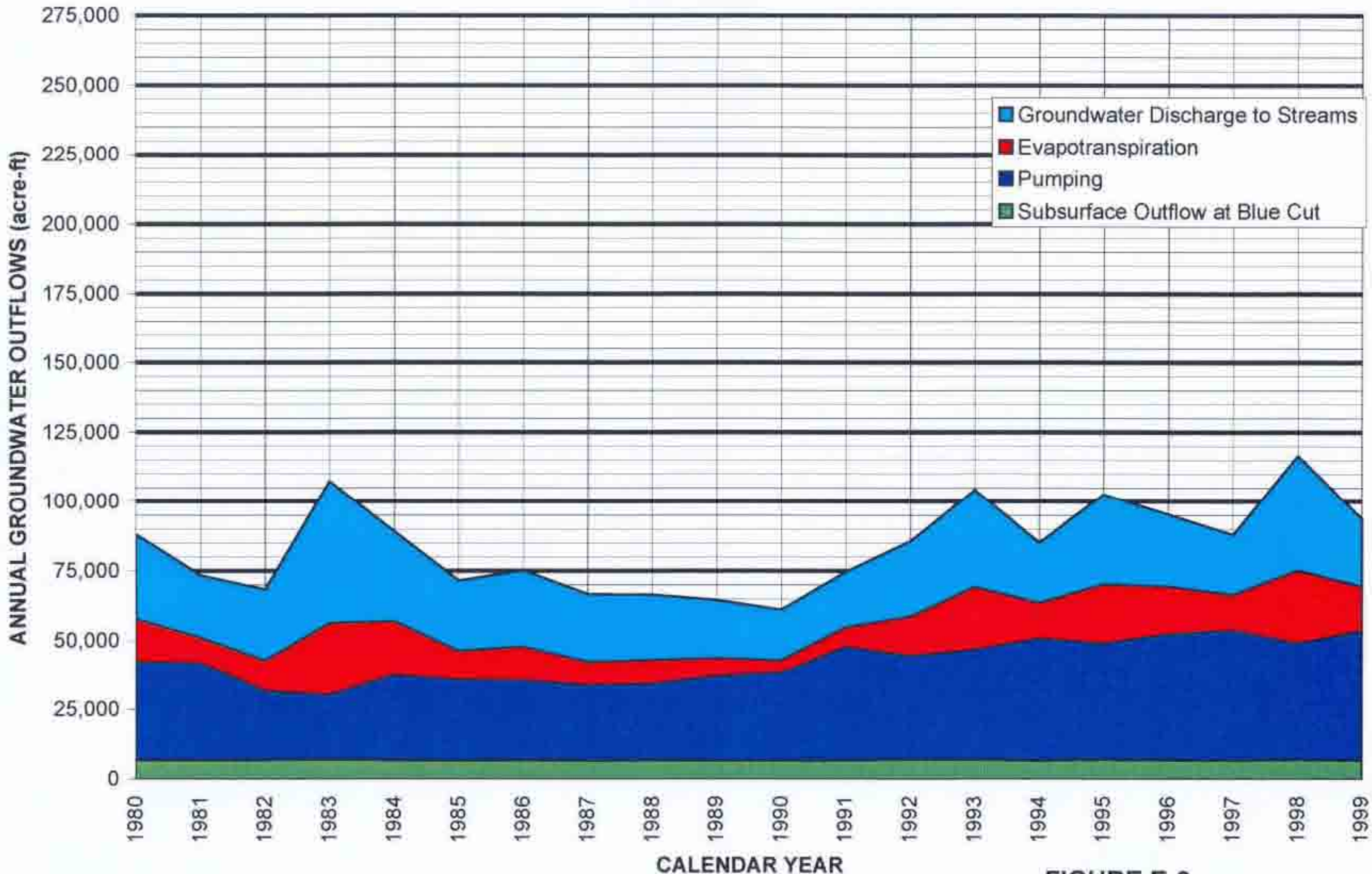

FIGURE E-8
ANNUAL GROUNDWATER OUTFLOWS

REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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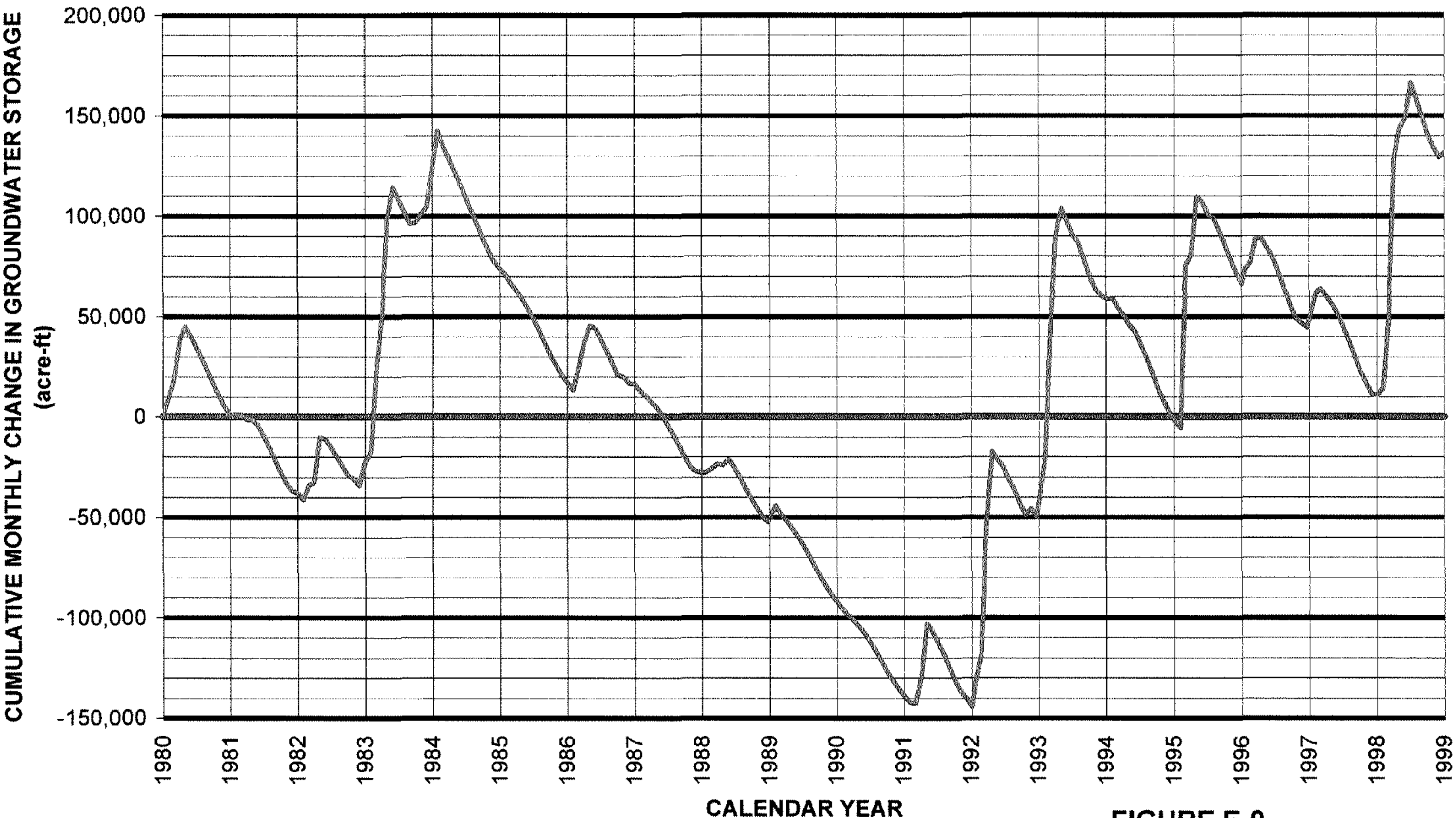

FIGURE E-9
CUMULATIVE CHANGE IN GROUNDWATER STORAGE
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Acronyms and Abbreviations

°F	degrees Fahrenheit
AF	acre-feet
AF/yr	acre-feet per year
ASR	aquifer storage and recovery
bgs	below ground surface
cfs	cubic feet per second
CLWA	Castaic Lake Water Agency
cm/sec	centimeters per second
county line	Los Angeles-Ventura County line
Downstream Water Users	Los Angeles County Waterworks District, Newhall Land & Farming Company, Newhall County Water District, and United Water Conservation District
DWR	California Department of Water Resources
ET	evapotranspiration
ft/day	feet per day
ft^2/day	square feet per day
ft/yr	feet per year
GIS	geographic information system
gpd	gallons per day
gpd/ft	gallons per day per foot
gpm	gallons per minute
gpm/ft	gallons per minute per foot
GPS	global positioning system
I-5	Interstate 5
in/yr	inches per year
K	hydraulic conductivity
Kh	horizontal hydraulic conductivity
Kv	vertical hydraulic conductivity
LACFCD	Los Angeles County Flood Control District
LACSD	Los Angeles County Sanitation District

LACWWD	Los Angeles County Waterworks District
LADPW	Los Angeles County Department of Public Works
MOU	Memorandum of Understanding
NCDC	National Climate Data Center
NCWD	Newhall County Water District
NLF	Newhall Land & Farming Company
Purveyors	Upper Basin Water Purveyors
R	vertical anisotropy ratio (Kh:Kv)
RCS	Richard C. Slade and Associates, LLC
Regional Model	Santa Clarita Valley Groundwater Model
residual	residual error
RMS	root-mean-square
SCWC	Santa Clarita Water Company
SWP	State Water Project
SWRM	Surface Water Routing Model
Sy	aquifer specific yield
T	transmissivity
UWCD	United Water Conservation District
USGS	U.S. Geological Survey
VWC	Valencia Water Company
WHR	Wayside Honor Rancho
WRP	water reclamation plant
WY	water year

SECTION 1

Introduction

This report describes the development of a regional groundwater flow model for the Santa Clarita Valley, located in northwestern Los Angeles County, California. The model, called the Santa Clarita Valley Groundwater Model (Regional Model), simulates the occurrence and flow of groundwater, including its interaction with streams in the area. It has been developed for the water purveyors in the valley as a tool for the analysis of groundwater management options in the context of future water demands and water supply conditions in the valley. Figure 1-1 is a map showing the study area.

1.1 Model Use Objectives

The Regional Model has been developed as part of the work scope contained in a Memorandum of Understanding (MOU) that was entered into in August 2001 by the water purveyors in the Santa Clarita Valley (the Purveyors) and the United Water Conservation District (UWCD), located downstream in Ventura County. The MOU, which is contained in Appendix A, is a commitment by the Purveyors to expand the analysis of groundwater conditions such that the adequacy of the local water supply is well understood and questions about surface water and groundwater resources can be more readily addressed. The MOU contained a number of technical components, including the development and calibration of a regional-scale groundwater flow model and the preparation of technical reports on topics such as groundwater model development. This report and the model described herein reflect the accomplishment of two of the MOU technical components.

The Regional Model is intended to become a tool for managing the local groundwater resource, including the relationship of surface water to groundwater in the valley. The model has been designed to be an evolving tool that will analyze groundwater development, natural and artificial recharge (particularly in conjunction with the availability of imported surface water supplies), and the resultant impacts of these activities on groundwater conditions within the valley and on the flows of water into the downstream basins in Ventura County. As discussed in the MOU, one use will be to evaluate the long-term sustainability, or operational yield, of the shallow Alluvial Aquifer and the deeper groundwater resources that are present in the underlying Saugus Formation. Specifically, this assessment will look at basin operations over a multi-year wet/dry cycle, with operational yield defined as a basin operating plan that allows continued pumping from these aquifers while assuring that groundwater supplies are adequately replenished from one wet/dry cycle to the next. The parties to the MOU agreed to use the Regional Model for this assessment because (1) data show no long-term lowering of the water table or degradation of water quality has occurred during the 50 to 60 years of historical groundwater development in the valley, and (2) current planning places future pumping of the Alluvial Aquifer in the same range as historical pumping. At this time, the primary question of interest to the MOU parties is the effect of pumping the Saugus Formation during short-term dry periods at rates that are higher than have been historically pumped from that formation. An additional planned application of the model will be to evaluate the restoration of pumping capacity that has been impacted by perchlorate contamination in the vicinity of the Whittaker-Bermite property in the central part of the valley.

Based on these objectives, the MOU specified that a model would be constructed that covers the entire area within the Santa Clarita Valley where Alluvial and Saugus groundwater resources are present, and that the model should be subjected to a transient calibration.

1.2 Model Development

The approach to developing the model included:

a. Compiling information on the geology and hydrogeology of the valley and developing a conceptual understanding of the groundwater flow system.

b. Creating a variety of data sets to conduct steady-state and transient calibrations.

c. Constructing the groundwater flow model using the MicroFEM® finite-element groundwater flow code, and also using the available database and geographic information system (GIS) for the Santa Clarita Valley.

d. Calibrating the flow model.

e. Performing sensitivity tests on the flow model.

This project was conducted for the parties to the MOU, who are the United Water Conservation District (UCWD) in Ventura County and the Upper Basin Water Purveyors, the water providers in the Santa Clarita Valley. The Upper Basin Water Purveyors consist of four retail purveyors of municipal water and the Castaic Lake Water Agency (CLWA), which has a contract with the State of California to obtain water from the State Water Project (SWP), and which furnishes SWP water to the four retail purveyors. The four retail purveyors are Los Angeles County Waterworks District (LACWWD) No. 36, the Newhall County Water District (NCWD), Santa Clarita Water Company (SCWC, a division of CLWA), and the Valencia Water Company (VWC).

1.3 Previous Studies

There are several previous studies of the groundwater system in the Santa Clarita Valley that were used to help develop the conceptual and numerical models of the hydrogeologic system. These studies include reports on the regional geology and hydrogeology, and a previous modeling analysis of the feasibility of constructing an aquifer storage and recovery (ASR) system. These studies are listed below and are described in more detail in Section 2.7 of this report.

a. *Hydrogeologic Investigation: Perennial Yield and Artificial Recharge Potential of the Alluvial Sediments in the Santa Clarita River Valley of Los Angeles County, California* (Richard C. Slade and Associates, LLC [RCS], 1986). This report was the first comprehensive study of the geology and hydrology of the Alluvial Aquifer.

b. *Hydrogeologic Assessment of the Saugus Formation in the Santa Clara Valley of Los Angeles County, California* (RCS, 1988). This report was the first comprehensive study of the geology and hydrology of the Saugus Formation.

c. *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001). This report documented the results of ASR field tests in the Saugus Formation that evaluated the feasibility of injecting water into, and recovering water from, deep Saugus Formation wells.

d. *2001 Update Report: Hydrogeologic Conditions in the Alluvial and Saugus Formation Aquifer Systems* (RCS, 2002). This report was a summary and update of the 1986 and 1988 RCS reports.

e. *Newhall Ranch ASR Impact Evaluation* (CH2M HILL, 2001). This document evaluated the longer-term basinwide influences that would occur for an ASR program that was proposed as part of the water supply for the planned Newhall Ranch community.

f. *Newhall Ranch Updated Water Resources Impact Evaluation* (CH2M HILL, 2002). This document updated the ASR impact evaluation, including analyzing the effects of all aspects of the Newhall Ranch community (not just ASR) on the valley's water resources.

1.4 Report Organization

The remainder of this report is organized as follows:

Section 2 describes the hydrogeology of the Santa Clarita Valley, including the geologic system; groundwater occurrence; groundwater recharge and discharge mechanisms; the relationship of surface hydrology to the valley's groundwater resources; historical trends in the valley's hydrology; the role of the SWP on the valley's water resources and water supply; and key findings from prior studies conducted in the valley. This section of the report (along with Appendix B) focuses on information of specific relevance to development of the regional flow model.

Section 3 discusses the construction of the model, including the modeling software; the grid design; the layer-by-layer representation of the aquifers; the boundary conditions; the estimation of groundwater recharge rates; and the assignment of pumping rates in the model. Appendix C describes the design, operation, and data for a surface water routing model that was developed to provide the Regional Model with recharge rates from urban irrigation, agricultural irrigation, direct precipitation, streamflows entering the model domain, and discharges from water reclamation plants (WRP).

Section 4 describes the calibration conditions; the calibration goals; the model variables that were adjusted during calibration; the calibration procedure; and the measured (target) data that were used to evaluate calibration quality.

Section 5 presents quantitative and semi-quantitative evaluations of the calibration results, with a focus on the assessment of the model's calibration quality compared with the calibration goals presented in Section 4. Section 5 then concludes with a sensitivity analysis that further evaluates calibration quality and demonstrates the sensitivity of simulated groundwater elevations and water budget terms to changes in model parameter values.

Section 6 summarizes the applicability of the model for use in managing local groundwater resources, including the key attributes of the model and recommendations for further data collection and future model updates.

Section 7 is the reference list.

Figures

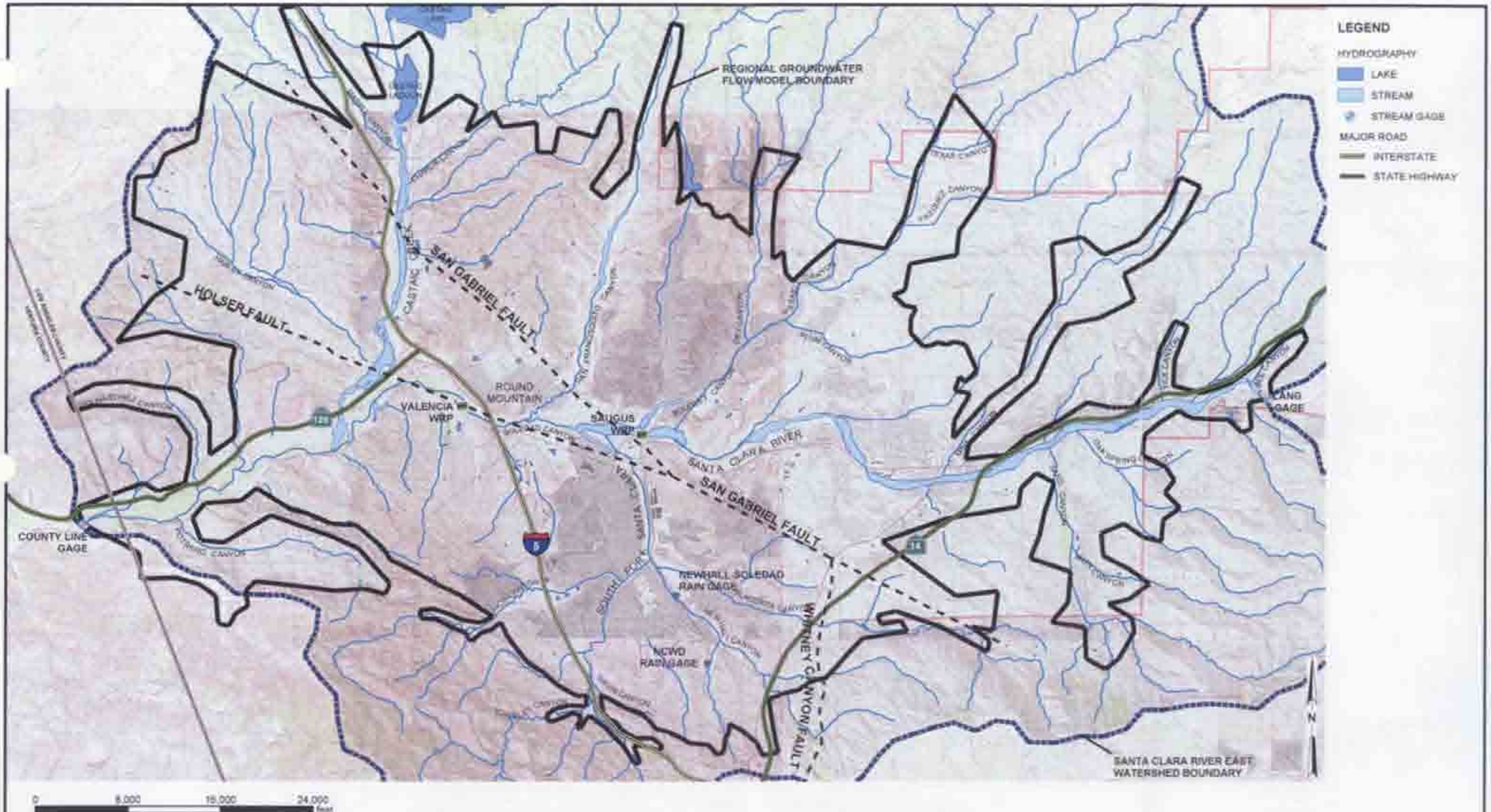

FIGURE 1-1
MAP OF STUDY AREA
REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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SECTION 2

Hydrogeology of the Santa Clarita Valley

The geology and hydrogeology of the Santa Clarita Valley are described in this section, which is derived primarily from the reports described in Section 1.3 and Section 2.7. Figure 2-1 is a schematic representation of the regional scale geology and hydrologic cycle in the Santa Clarita Valley. As shown on Figure 2-1, the two aquifer systems in the Santa Clarita Valley are the Alluvial Aquifer and the Saugus Formation. Groundwater is exchanged between these two units. Additionally, the aquifer systems are affected by direct rainfall; streamflows in the Santa Clara River and its tributaries; evapotranspiration (ET) by riparian vegetation along portions of the river; and human influences which consist of pumping, agricultural and urban irrigation, discharge of treated water into the Santa Clara River from two water reclamation plants, and occasional releases of water into Castaic Creek from Castaic Lake and Castaic Lagoon.

Figure 2-2 shows the location of the Santa Clarita Valley groundwater basin. This groundwater basin is identified by the California Department of Water Resources (DWR) as the Santa Clara River Valley East Groundwater Subbasin and lies within the DWR-designated Upper Santa Clara River Hydrologic Area. Figure 2-3 is a map of the Santa Clarita Valley, showing the locations of production wells completed in the Alluvial Aquifer and Saugus Formation.

2.1 Setting

The study area comprises the relatively flat-lying Santa Clarita Valley and portions of the surrounding hills and mountains. The study area extends from approximately the Los Angeles-Ventura County line (county line) on the west to the community of Lang on the east, and from the southern end of Castaic Lake on the north to the intersection of the Golden State Freeway (Interstate 5 [I-5]) and the Antelope Valley Freeway (State Highway 14) on the south. The mountains that surround the Santa Clarita Valley include the Santa Susana and San Gabriel Mountains to the south and the Sierra Pelona and Leibre-Sawmill Mountains to the north. Elevations range from approximately 800 feet on the valley floor to approximately 6,500 feet in the San Gabriel Mountains. The headwaters of the Santa Clara River are at an elevation of approximately 3,200 feet at the topographic divide separating the Upper Santa Clara River Hydrologic Area from the Mojave Desert.

The largest community in the study area is the City of Santa Clarita, which was formed in 1987 through the amalgamation of the communities of Newhall, Valencia, Saugus, and Canyon Country. Other smaller unincorporated communities in the study area include Stevenson Ranch and Val Verde in the west, Castaic in the northwest, and Lang in the east. The population of the City of Santa Clarita was estimated to be approximately 151,260 in the 2000 U.S. Census. In 2001, the Southern California Association of Governments estimated the population of the surrounding unincorporated Santa Clarita Valley at 48,237. Hence, the total current population of the Santa Clarita Valley is approximately 200,000 (RCS, 2002).

Prior to the 1960s, the predominant land use in the Santa Clarita Valley was agricultural, with much of the valley undeveloped. Urbanization began gradually in the 1960s, with a rapid increase beginning in the late 1970s and early 1980s and continuing to the present. Accompanying the rapid population increase has been a gradual change in valley land use patterns, from largely agricultural to urban and suburban developments. Nevertheless, a considerable portion of the hills and low mountains bordering the main river valley remain in a natural, undeveloped condition (RCS, 2002).

2.2 Climate

The study area has a semi-arid Mediterranean-type climate, characterized by long, dry summers and relatively short, wet winters. Temperatures in the Santa Clarita Valley range from a minimum of 20 degrees Fahrenheit (°F) to 30°F in the winter to a maximum of approximately 100 to 110°F during the summer. Mean monthly temperatures range between approximately 48°F in the winter and 77°F in the summer.

Rainfall data have been recorded since 1883 at the Newhall-Soledad gage (Station No. FC32CE), located at the Los Angeles County Department of Public Works (LADPW) Newhall-Soledad Division Headquarters office, on San Fernando Road in the community of Newhall. The average rainfall at this gage was 17.95 inches from 1883 through 2000 and 17.84 inches from 1950 through 2000.[1] A second rain gage is located approximately 1.3 miles to the south, at the NCWD office. Figure 2-4 shows the annual rainfall at the Newhall-Soledad and NCWD gages for calendar years 1950 through 2000. As shown in the figure, annual rainfall is highly variable from year to year. During this period, the highest calendar-year rainfall was 42.17 inches in 1978 at the Newhall-Soledad gage, and 48.33 inches in 1983 at the NCWD gage. The lowest amount of annual rainfall from 1950 through 2000 was 4.15 inches in 1972 at the Newhall-Soledad gage, and 8.47 inches in 1989 at the NCWD gage. Average annual rainfall from 1979 through 2000 was 18.67 inches at the Newhall-Soledad gage and 22.88 inches at the NCWD gage. Rainfall at the NCWD gage is usually greater than at the Newhall-Soledad gage, because the NCWD gage is located closer to the hills that form the southern boundary of the watershed and receive a greater amount of orographic precipitation.

Rainfall is not only variable on an annual basis, but is also highly seasonal. Approximately 80 percent of the annual precipitation in the Santa Clarita Valley falls between November and March. Most of the precipitation comes from winter storms that last only a few days and are separated by relatively long periods of clear weather.

As shown by the difference in rainfall values between the Newhall-Soledad and NCWD rain gages, rainfall varies across the basin according to elevation differences and the locations of surrounding mountain ranges. Figure 2-5 shows lines of equal precipitation (rainfall isohyets), based on long-term mean annual precipitation data compiled from the U.S. Geological Survey (USGS), DWR, and California Division of Mines maps and data. The source maps consist primarily of U.S. Weather Service data for approximately 800 precipitation stations, but in the Los Angeles and San Francisco Bay areas the

[1] Annual rainfall values for the Newhall-Soledad gage are based on monthly records reported by the National Climate Data Center (NCDC) and LADPW.

U.S. Weather Service data have been supplemented by county and local agency precipitation data. The precipitation isohyets shown on Figure 2-5 display the average annual rainfall during the period from 1900 through 1960. (See the internet site http://gis.ca.gov/meta.epl?oid=286 for more information.)

2.3 Geology

Figure 2-6 presents a geologic map of the Santa Clarita Valley, as reported by RCS (2002). The geologic units shown on the map include water-bearing sediments and non-water-bearing bedrock.

The Santa Clarita Valley is underlain and bounded by non-water-bearing bedrock units that are Miocene, Oligocene, and pre-Tertiary in geologic age. These units yield little water and are not considered viable for groundwater development.

Where the bedrock units are not exposed at the ground surface, they are overlain by younger geologic units. The Pliocene-age to Pleistocene-age Saugus Formation (map symbol, QTs) overlies the bedrock in much of the basin. At the far western and eastern ends of the basin, and in the upper reaches of some of the canyons, the Saugus Formation is absent and the bedrock units are overlain by a blanket of unconsolidated alluvium of Quaternary geologic age (map symbol, Qal). Where present, the alluvium overlies the Saugus Formation within much of the Santa Clarita Valley. In some areas where the alluvium is absent, the Saugus Formation is overlain by scattered outcrops of Quaternary-age Terrace deposits (map symbol, Qt). Groundwater is present in much of the alluvium and the Saugus Formation. However, the terrace deposits do not contain significant water resources because they are typically situated at elevations above the regional water table.

2.3.1 Non-Water-Bearing Bedrock

Underlying the water-bearing sediments in the Santa Clarita Valley are a series of consolidated, older, cemented sedimentary and crystalline rocks of Tertiary geologic age or older. For the most part, the sedimentary rocks are exposed along the flanks of the hills and mountains that border the Santa Clarita Valley, while the geologically older crystalline metamorphic and igneous rocks crop out in the upper watershed areas of the Sierra Pelona and San Gabriel Mountains.

Geologically older sedimentary rocks underlie the base of the Saugus Formation and are exposed in the hills beyond the exterior boundary line for the mapped surface limits of the Saugus Formation. The older rocks lying immediately below the Saugus Formation are: (1) the Pico Formation, composed of siltstone and shale, which underlies the Saugus Formation in the region southwest of the San Gabriel fault; and (2) the Castaic Formation and the Mint Canyon Formation, mainly siltstone and shale, which underlie the Saugus Formation in areas northeast of the San Gabriel fault. These sedimentary rock formations are generally fine grained, have low permeability, and do not yield substantial quantities of water to wells. In the project area, these rocks are considered barriers to groundwater flow.

2.3.2 Water-Bearing Sediments

Water-bearing sediments in the Santa Clarita Valley consist of:

a. Alluvial and valley fill deposits that underlie the Santa Clara River and its tributaries

b. Partially consolidated, older sediments of the Saugus Formation, including the Sunshine Ranch Member, that underlie the alluvium and are also exposed in the hillsides surrounding the main portion of the valley

2.3.2.1 Alluvium

The alluvial sediments are composed of extensively interlayered and interfingered mixtures of gravel, sand, silt, and clay, with variable amounts of cobbles and boulders. In general, alluvium in the main river valley ranges from medium-grained sand to sandy gravel and cobbles. Drillers' logs indicate the presence of discrete sand zones and discrete gravel zones in many areas of the alluvium. Due to its unconsolidated to poorly consolidated condition, and its lack of cementation, the alluvium has relatively high permeability and porosity.

The alluvial sediments lie within and along the course of the Santa Clara River and its main tributaries. The maximum thickness of the alluvium varies along the Santa Clara River, but generally is considered to be 200 feet. Typically, the alluvium tends to be thickest near the central portion of the river, and thins or pinches out near the flanks of the adjoining hills.

The alluvium overlies the Saugus Formation in much of the valley. However, in the eastern part of Soledad Canyon, the Saugus Formation is absent, and instead the alluvium overlies Miocene-age terrestrial sediments of the Tick Canyon and Mint Canyon Formations. In the upper reaches of some tributaries to the Santa Clara River, the alluvium overlies these or other Miocene-age sediments, such as the Pico and Castaic Formations. At the west end of the valley, the alluvium overlies the Pico Formation.

2.3.2.2 Saugus Formation

The Saugus Formation is present throughout the main portion of the Santa Clarita Valley and extends to the surrounding foothills. The Saugus Formation contains lenticular and interfingered beds of poorly- to well-consolidated sandstone, conglomerate, and siltstone that are at least 7,500 feet thick in the deepest part of the basin. These terrestrial sediments were deposited in stream channels, floodplains, and alluvial fans by the ancestral drainage system in the valley. The coarser-grained materials in the Saugus Formation were deposited in the main channels of the ancestral drainage system, and the locations of these channels changed throughout the approximately 3-million-year period of deposition of the Saugus Formation. Recent interpretations of geophysical electric log data indicate that the coarse-grained channel deposits (the primary water-bearing strata) are thicker and more numerous in some areas than in other locations in the valley. Although the Saugus Formation displays a considerable amount of lateral variability in lithology and grain size, some thicker stratigraphic packages can be traced through portions of the valley, primarily on the west (downthrown) side of the San Gabriel Fault (RCS, 2002).

The deeper and older portion of the Saugus Formation, the Sunshine Ranch Member, was deposited in a marine environment and consists of fine-grained, low-permeability siltstone and sandstone. The Sunshine Ranch Member has a maximum thickness of approximately 3,500 feet in the central part of the valley. It is present at or very close to ground surface at the margins of the valley. Geophysical (electric) logging indicates that the groundwater in much of the Sunshine Ranch Member may be somewhat brackish in quality and is not useful for municipal water supply purposes.

2.3.3 Geologic Structure

Faulting and folding of the rocks in the region have caused the sedimentary rocks, including the Saugus Formation, to form a bowl-shaped structure. The Saugus Formation and the underlying bedrock dip generally toward the center of the "bowl" from all locations along the bottom (basal) contact of the Saugus Formation.

Dominating the geologic structure in the valley is the southeast-northwest-trending San Gabriel fault. The fault is a northeast-dipping reverse fault. The vertical displacement of the Saugus Formation on each side of the fault varies along the length of the fault and ranges from 100 feet to 2,600 feet within the valley (RCS, 1988). The Saugus Formation is thickest south of the fault, and this is the area where all significant Saugus production wells are located. North of the San Gabriel fault, the Saugus Formation is older, thinner, and finer grained than south of the fault. Little groundwater development has occurred north of the San Gabriel Fault.

A spur from this fault, referred to as the Holser fault, trends west through the valley. Cross sections prepared by RCS (1988, 2002) show that marker beds are offset by approximately 100 to 200 feet across the Holser Fault, which is substantially less than the offset across the San Gabriel Fault. Another spur fault called the Whitney Canyon fault extends south from the San Gabriel Fault in the southeastern corner of the valley.

2.4 Groundwater Occurrence, Recharge, and Discharge

Groundwater is present in the alluvium under generally unconfined conditions. Saugus Formation groundwater is thought to be present under unconfined conditions in the shallowest water-bearing zones where the Alluvial Aquifer is absent, and under semi-confined and confined conditions at greater depths. Figure 2-1 is a schematic cross-sectional representation of the groundwater flow patterns in the Santa Clarita Valley, including the predominant recharge and discharge mechanisms for the two aquifer systems. These are discussed in detail below.

2.4.1 Alluvium

Natural sources of recharge to the alluvium include deep percolation (infiltration) of direct precipitation within the valley; percolation of stream runoff flowing into the valley along the Santa Clara River and its tributaries; subsurface inflow from the adjoining (upgradient) portions of the Alluvial Aquifer to the north and east of the valley; and discharge of groundwater from the Saugus Formation to the Alluvial Aquifer, primarily on the west side of the Santa Clarita Valley.

Manmade sources of recharge to the Alluvial Aquifer include infiltration of irrigation water; infiltration of stormwater runoff from urban areas; infiltration of surface flow and underflow from Castaic Dam within the Castaic Creek area; infiltration of water released by the Los Angeles Department of Water and Power from its reservoir facilities in upper San Francisquito Canyon and upper Bouquet Canyon; and infiltration of water reclamation plant (WRP) discharges to the Santa Clara River from two Los Angeles County Sanitation District (LACSD) WRPs in the valley (Plant No. 26 near Bouquet Canyon and Plant No. 32 near Valencia).

Groundwater discharge is significant in the western portion of the Alluvial Aquifer, where it occurs primarily as discharge to the Santa Clara River and ET by the riparian vegetation growing along the river corridor. Groundwater discharge from the west end of the basin also occurs as subsurface outflow through the Alluvial Aquifer to the downstream Piru Basin. Other groundwater discharge mechanisms in the Santa Clarita Valley are pumping for agricultural and municipal uses and seepage to underlying permeable portions of the Saugus Formation, particularly in the eastern portion of the basin.

According to RCS (1986), groundwater present within the Alluvial Aquifer flows from east to west roughly coincident with the direction of surface water flow. Figure 2-7 displays a groundwater elevation contour map for the Alluvial Aquifer, using water level data collected during the spring of 2000.

RCS (2002) estimated that the amount of groundwater in storage in the Alluvial Aquifer has historically fluctuated between approximately 100,000 and 200,000 acre-feet. Table 2-1 summarizes the well-by-well historical annual groundwater pumping from the Alluvial Aquifer from 1980 through 2000. Historical groundwater production rates during this period averaged 29,700 acre-feet per year (AF/yr) and ranged from approximately 20,300 to 43,500 AF/yr. As discussed later in Section 2.6.2, these pumping rates are at or below pumping rates during the 1950s and 1960s, when groundwater was used primarily for agricultural purposes.

2.4.2 Saugus Formation

The Saugus Formation is recharged by two principal sources: (1) infiltration of precipitation in the exposed portions of the Saugus in the highlands surrounding the valley, and (2) seepage from the Alluvial Aquifer along the Santa Clara River and its tributaries, particularly in the eastern and central portions of the Santa Clarita Valley. Minor recharge may also occur in limited areas through irrigation seepage, where the land overlying the Saugus is cultivated. In the eastern part of the Santa Clarita Valley, the Saugus Formation is underlain by older rocks of the Castaic Formation and Mint Canyon Formation, which surround the bowl-shaped Saugus structure. Little, if any, groundwater exchange occurs between these formations and the Saugus Formation.

Discharge from the Saugus Formation occurs in part as groundwater pumping from wells as deep as 2,000 feet. Discharge from the Saugus Formation also occurs at the west end of the valley, west of the I-5 bridge, where Saugus groundwater is thought to discharge to the Alluvial Aquifer. The older and relatively impermeable rocks of the Pico Formation, that underlie and form the western boundary of the Saugus Formation, form a barrier to groundwater flow and force Saugus groundwater to discharge upwards into the Alluvial Aquifer in the area extending between two miles and six miles upstream of the county line (refer to Figure 2-1). The Saugus is not present at Blue Cut, which is approximately three miles downstream of the Saugus/Pico Formation contact and approximately one mile downstream of the county line.

Because the Saugus Formation and underlying bedrock units tilt downward from the edges of the valley to the center of the valley, the permeable sand layers within the Saugus Formation near the margins of the valley are thought to be oriented so that they are in direct connection with the overlying Alluvial Aquifer. Consequently, recharge to the Saugus Formation from the Alluvial Aquifer is thought to be greatest in these areas, particularly on the east side of the valley. Also, discharge from the Saugus Formation to the Alluvial Aquifer is thought to be enhanced where permeable sand layers of the Saugus are contacting the Alluvial Aquifer on the western end of the valley where the Saugus Formation discharges.

The available water level data, which are concentrated in localized areas, indicate that the direction of groundwater flow in the Saugus is toward the center of the valley from the highlands. The data indicate that Saugus groundwater flows toward the western end of the Santa Clara Valley where it discharges naturally into the Alluvial Aquifer. Figure 2-8 displays a groundwater elevation contour map for the Saugus Formation, using water level data collected during the fall of 2000 (RCS, 2002).

Although few wells have been drilled into the Saugus Formation at or north/northeast of the San Gabriel fault, there is evidence of limited Saugus groundwater flow across the fault. Data that suggest this limited hydraulic connection between the two fault blocks are as follows:

a. Geologic and geophysical logging of former exploratory oil wells indicates that the Saugus Formation is much thinner north of the San Gabriel Fault than south of it (see geologic cross section E-E′ in RCS, 1988). Preliminary interpretations of recent geologic and geophysical logging at multi-port monitoring wells on the Whittaker-Bermite property also suggest the Sunshine Ranch Member is present at much shallower depths on the upthrown fault block, north/northeast of the fault, than on the downthrown block, south/southwest of the fault. Together, these data indicate that the older and fine-grained Sunshine Ranch Member of the Saugus Formation predominates in the area north of the fault.

b. Water level monitoring on the Whittaker-Bermite property shows groundwater elevations in multi-port monitoring well MP-3, on the upthrown side of the fault, are approximately 100 to 150 feet higher than in the other multi-port wells, which are on the downthrown side of the fault. Additionally, the three monitoring wells on the downthrown side (MP-1, MP-2, and MP-4) that have been monitored since January 2003, show responses to seasonal pumping of nearby water supply wells, whereas the monitoring well on the upthrown side (MP-3) shows no such response. (See Figure 2-3 for the locations of these wells, and Figure 2-9 for plots of groundwater elevations over time at each of these wells.)

In contrast, recent drilling, well construction, and pump testing work has indicated that the Holser Fault does not act as a barrier to groundwater flow. In early 2003, well MP-5 was installed in the Saugus Formation, located just north of the fault. This is a multi-port monitoring well that measures water levels at four discrete depths as great as 965 feet in the Saugus Formation. During March 2004, a deep Saugus production well south of the Holser Fault (VWC-205, located 4,700 feet away) was pumped for 72 hours under controlled conditions that included allowing no pumping to occur from other Saugus wells in the area.

The test was performed in part to evaluate the Holser Fault's hydraulic influence in the Saugus Formation. During pumping at VWC-205, measurable drawdown was observed at the two deepest ports at MP-5, which are situated at depths (795 feet and 965 feet) that correspond with the depths of the upper portion of the screen of VWC-205. Water level recovery monitoring conducted when VWC-205 was shut down showed rising water levels in these same two ports at MP-5. These observations are consistent with previous indications that the Holser Fault is not a significant barrier to groundwater flow in the Saugus Formation.

RCS (2002) estimated that the amount of groundwater in storage in the freshwater-portion of the Saugus Formation is approximately 1.65 million acre-feet. Historical groundwater production rates since 1980 have ranged from approximately 3,000 to nearly 15,000 AF/yr. Table 2-2 summarizes the well-by-well historical annual groundwater pumping from the Saugus Formation from 1980 through 2000.

2.5 Aquifer Physical Properties

2.5.1 Alluvium

Available groundwater elevation data and aquifer test data from Alluvial wells indicate that the Alluvial Aquifer is unconfined (i.e., is under water table conditions). Transmissivity values range from 4,700 square feet per day (ft^2/day), or 35,000 gallons per day (gpd) per foot (gpd/ft) to over 100,000 ft^2/day, or 750,000 gpd/ft. Specific yield values range from approximately 0.09 to 0.16 (RCS, 1986, 2002).

The transmissivity values are estimated (indirectly calculated) from pumping plant efficiency (specific capacity) tests conducted on a number of alluvial water wells over the years by the Southern California Edison Company. The transmissivity estimates that are calculated from these tests vary widely over short distances, and in some cases they vary substantially over time at individual wells. This is because the drawdown data that are collected during these tests are solely from the pumping wells themselves. Consequently, the use of water level drawdown data from pumping wells may provide transmissivity estimates that are strongly influenced (potentially biased low) by the condition of the well's screen or perforations and the gravel pack, particularly in the case of older wells. Nonetheless, these estimates can be useful for identifying substantial spatial variations in aquifer permeability if one selects the highest transmissivity values that are calculated for each given well (those values least impacted by well structure or well-related issues). Table 2-3 summarizes the results of the interpretations of the specific capacity data. Appendix B contains detailed tables of the testing data and the calculations of transmissivity and hydraulic conductivity, along with a comparison of these values to parameter values used in the regional model.

2.5.2 Saugus Formation

Available aquifer test data from Saugus wells located near the center of the valley where the Saugus is thickest indicate that the Saugus is semi-confined to confined (under pressure). In areas where the Saugus crops out, the uppermost saturated zones are partially unconfined because the permeable beds are folded upwards. In the highlands, the Saugus beds are exposed at the ground surface, and in the valley the Saugus beds are in contact with the Alluvial Aquifer.

Transmissivity values range from approximately 400 to 25,000 ft^2/day (3,000 to 180,000 gpd/ft), but are typically between 5,500 and 11,000 ft^2/day (40,000 and 80,000 gpd/ft). Storativity values are on the order of 10^{-3} to 10^{-4}. These aquifer parameter values have been estimated from well performance tests and from the Saugus Formation ASR study conducted in 2000 (RCS, 2001, 2002). Table 2-4 summarizes this parameter data.

The ASR study consisted of a three-phase field test:

a. Phase 1: Injection of approximately 24 million gallons of treated drinking water into well VWC-205 at three injection rates (500, 800, and 1,100 gallons per minute [gpm]). Injection at each rate was performed for 7 days, for a total injection period of 21 days.

b. Phase 2: Recovery of 33 million gallons of water by pumping well VWC-205 at an average rate of 2,300 gpm for a period of 10 days. This pumping began 13 days after injection had ended.

c. Phase 3: Pumping 35 million gallons of water from nearby well VWC-201 at an average rate of 2,400 gpm for a period of 10 days. This pumping began 24 days after pumping had stopped at well VWC-205.

Water levels were monitored in nearby non-pumping Saugus Formation wells, including a Saugus monitoring well located 35 feet from well VWC-205, and in a newly installed Alluvial Aquifer monitoring well located 40 feet from well VWC-201. Monitoring began 22 days prior to Phase 1 and continued 3 days beyond the completion of Phase 3. Testing and monitoring details are provided in the report titled *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001). The ASR test indicated that it is hydrogeologically feasible to inject and recover significant volumes of water from a well completed in the Saugus Formation. The data also indicated that there was no measurable effect on water levels at the alluvial monitoring well during the monitoring period.

The ASR testing data also indicated that wells VWC-201 and VWC-205 have specific capacities between 10 and 20 gpm per foot (gpm/ft), which is intermediate in value between those of nearby wells. NCWD's wells to the south have specific capacities ranging from approximately 2 to 10 gpm/ft. To the north, wells that are owned by VWC and SCWC show specific capacities ranging from approximately 25 to 50 gpm/ft. Although these data suggest the possible existence of slightly more permeable zones in the center of the basin than along the southern edge, the apparent difference may also be caused by differences in well construction and well efficiency. Analyses of the ASR test data, including numerical model calibration runs, indicate that the bulk permeability of the Saugus Formation at wells VWC-201 and VWC-205 is approximately 6.5 feet per day (ft/day) (CH2M HILL, 2001).

2.6 General Hydrology and Hydrologic Cycle

The major sources of surface water in the Santa Clarita Valley include precipitation, return flows of urban and agricultural irrigation water, and treatment plant discharges to the Santa Clara River from two WRPs which were built in 1962 and 1967. Another significant source of surface water is the increased importing of SWP water, which is stored in Castaic Lake and Castaic Lagoon, then treated and delivered by CLWA to the retail water purveyors in the Santa Clarita Valley. In some years, DWR releases flood flows from Castaic Dam/ Lagoon into Castaic Creek during the winter or spring months. Further details regarding the operation of the SWP system and its effect on the valley's hydrology and water supply are provided in Section 2.6.3 below.

Before 1970, agriculture was the predominant land use in the valley. Agricultural water was supplied by production wells, most of which were completed in the Alluvial Aquifer. Pumping from the Alluvial Aquifer during the 1950s and early 1960s ranged from 35,000 to 44,000 AF/yr. Pumping from the Alluvial Aquifer dropped gradually from 40,000 AF/yr in 1967 to less than 30,000 AF/yr by 1983, and did not rise above 30,000 AF/yr until 1993. In the Saugus Formation, very little pumping occurred before 1960. From 1960 through 1990, total pumping from the Saugus Formation ranged from approximately 2,500 AF/yr to approximately 8,500 AF/yr. In response to statewide drought conditions, pumping from the Saugus Formation ranged between 10,000 and 15,000 AF/yr from 1991 through 1994. Saugus pumping was reduced beginning in 1995, as the drought ended and additional water supplies became available. The water management practices of the purveyors call for maximizing the use of Alluvial Aquifer and SWP water. Groundwater pumping is minimized from the Saugus Formation, except during years when SWP water allocations are below normal. Consequently, since 1995, Saugus pumping has ranged between approximately 4,000 and 8,500 AF/yr.

The remainder of this section describes the hydrology of the Santa Clarita Valley, historical hydrologic trends, and the operation of the SWP system and its influence on local hydrology and water supplies.

2.6.1 Basin Hydrology

The natural surface water features in the basin are the Santa Clara River and the tributaries that flow into it from canyons lying north and south of the river (Figure 2-10). Flows in the tributary canyons, and in the reach of the Santa Clara River that lies upstream of San Francisquito Canyon, are ephemeral, or intermittent. In these ephemeral streams, flow is limited to short-term runoff periods during storm events. The reach of the Santa Clara River west of San Francisquito Canyon is a perennially flowing river that obtains its flow from natural discharge of Alluvial Aquifer groundwater and from discharge of treated water from two WRPs. The other significant surface water feature is Castaic Lake, an SWP reservoir that lies at the north end of Castaic Creek in the northwestern portion of the valley. Like other tributaries to the Santa Clara River, the flows in Castaic Creek are ephemeral.

Figure 2-1 is a schematic diagram showing the hydrologic cycle for the Santa Clarita Valley. Table 2-5 lists the components of the hydrologic cycle for the basin. The components are classified in the table as one or more of the following:

a. Surface water recharge
b. Surface water discharge

c. Groundwater recharge
d. Groundwater discharge

These four elements of the hydrologic cycle have an important influence on the availability of surface water and groundwater resources in the basin. Time-series plots were constructed to show the relative magnitudes and trends of the various components of the hydrologic cycle in recent years. The time-series plots also illustrate the interrelationships of the hydrologic system components and their relationships to trends in groundwater levels in the Alluvial Aquifer and the Saugus Formation. The time-series analyses are discussed below.

2.6.2 Historical Hydrologic Trends

Long-term water level data have been collected over the years at purveyor-owned wells in the City of Santa Clarita and along the South Fork Santa Clara River. The data have been collected in pumping wells, and the hydrographs of these wells are steep at certain times, suggesting that some water levels are influenced by pumping at the well. Nonetheless, the data show some general trends over time and are useful for assessing general relationships between groundwater elevation trends and changes in groundwater recharge and pumping over time. Following are discussions of the observed hydrologic trends in the basin during the 50-year period from 1950 through 1999, as well as a comparison of hydrologic trends locally and in the SWP system.

2.6.2.1 Historical Trends in Rainfall

Figure 2-11 shows the annual precipitation along with the cumulative departure from the average annual precipitation since 1950. Cumulative departure refers to the cumulative amount of rainfall that is greater than or less than the long-term average rainfall. The slope of the cumulative departure plot shows the temporal trends in rainfall over successive years. The figure shows the following trends in precipitation within the Santa Clarita Valley:

a. 1950 through 1964: Dry conditions except for single wet years in 1952, 1957, 1958, and 1962 (a nearly continual decrease in cumulative departure values)

b. 1965 through 1970: Wet conditions (increase in cumulative departure values)

c. 1971 through 1977: Average to dry conditions (flat or declining cumulative departure values)

d. 1978 through 1983: Wet conditions (increase in cumulative departure values)

e. 1984 through 1991: Dry conditions (decrease in cumulative departure values)

f. 1992 through 1999: Highly variable conditions from year to year, but overall increase in cumulative departure values

2.6.2.2 Historical Trends in Alluvial Groundwater Elevations

Figure 2-12 shows trends in groundwater elevations in two Alluvial Aquifer wells located near the mouth of the South Fork Santa Clara River (VWC-N and NLF-S) and two Alluvial Aquifer wells near the western end of the basin (NLF-C5 and NLF-C7). The figure also shows trends in the following other components of the hydrologic cycle:

a. Precipitation at the Newhall-Soledad rain gage (plotted as the cumulative departure from the average precipitation)

b. Annual pumping volumes from the Alluvial Aquifer and the Saugus Formation

c. Total discharges from the WRPs to the Santa Clara River

d. Measured flow volume in the Santa Clara River during the lowest flow month of each year

Observations from Figure 2-12 are as follows:

a. Alluvial Aquifer groundwater elevations show greater variability over time within the basin interior (wells VWC-N and NLF-S) than near the basin outlet (wells NLF-C5 and NLF-C7). The range in water levels during the 50-year period of record is approximately 100 feet at the interior wells but only 20 to 30 feet in the two wells near the basin outlet.

b. The effect of reduced pumping from the Alluvial Aquifer from 1967 through 1989 was to minimize seasonal fluctuations in Alluvial Aquifer water levels near the aquifer's regional discharge zone at the western end of the valley. In this area, fluctuations in Alluvial pumping over time affected Alluvial groundwater elevations only seasonally; year-to-year variations in groundwater elevations were small. This indicates that water levels in this area are controlled less by pumping than by the discharge of Alluvial Aquifer groundwater to the Santa Clara River in the area downstream of I-5.

c. As with the western portion of the Alluvial Aquifer, the central portion of the Alluvial Aquifer has not shown long-term water level declines. During the 1950s and early 1960s, total pumping from the Alluvial Aquifer ranged between 35,000 AF/yr and 44,000 AF/yr during all but one year, and long-term (year-to-year) groundwater elevations were relatively stable (see the hydrographs for wells VWC-N, and NLF-S). When pumping from the Alluvial Aquifer decreased beginning in 1967, Alluvial groundwater elevations in this area quickly rose and have been relatively stable since about 1970, despite an increase in Alluvial Aquifer pumping during the 1990s. The hydrographs indicate that after an extended drought and high rates of pumping, Alluvial Aquifer groundwater elevations recover very quickly when normal or above normal rainfall patterns return.

d. The seasonal low flow in the Santa Clara River at the County Line gage has shown a long-term increase since the mid-1970s and, to some degree, during the late 1960s. The figure shows that this increase in flow coincides with increases in the annual discharges of treated water to the Santa Clara River from the two WRPs. Although Alluvial Aquifer pumping increased during the 1980s and 1990s, the seasonal low river flow did not show a long-term decrease during this period. The increases in WRP and Santa Clara River flows and the fluctuations in Alluvial Aquifer pumping have not caused long-term changes in Alluvial Aquifer groundwater elevations at the two wells near the basin outlet.

2.6.2.3 Historical Trends in Saugus Groundwater Elevations

Figures 2-13 and 2-14 compare groundwater elevation trends in the Saugus near the Santa Clara River, below the mouth of the South Fork Santa Clara River, with the same hydrologic components displayed on Figure 2-12. Figure 2-13 shows this information for the period 1950 through 1999, and Figure 2-14 shows this information during the 1990s, when groundwater levels rose in the Saugus Formation. Figures 2-15 and 2-16 show the same information, but for groundwater elevations at Saugus Formation wells located farther away from the Santa Clara River, along the tributary valley containing the South Fork Santa Clara River.

In examining the four Saugus figures, it is difficult to distinguish between the influences of precipitation and pumping trends on changes in Saugus water levels. Although a slight rise in water levels may have occurred at VWC-157 and VWC-160 during the late 1960s and early 1970s, it appears to follow the trends in Saugus pumping volumes more closely than the precipitation trends. The data at VWC-157 also suggest that a succession of above-normal precipitation years (e.g., 1978 through 1983) or a year of precipitation that is substantially above normal (e.g., 1983) may have some influence on Saugus water levels. However, the data are limited, and the periods of increased precipitation tend to coincide with periods of decreased pumping, making it difficult to identify the effect of precipitation or pumping on Saugus water levels.

Another observation is that the rise in Saugus water levels in the late 1960s and early 1970s occurred despite an increase in annual pumping volumes from the Alluvial Aquifer. This indicates that Saugus water levels are controlled by precipitation and/or Saugus pumping trends, and not by Alluvial pumping trends.

2.6.2.4 Comparison of Historical Trends in Alluvial and Saugus Groundwater Elevations

Figure 2-17 compares groundwater elevations at Alluvial and Saugus wells located near each other along the Santa Clara River, just below the mouth of the South Fork Santa Clara River. At this location, the trends in Alluvial groundwater elevations show no clear relationship with the trends in Saugus groundwater elevations. A moderate overall increase in groundwater elevations is observed in both the Alluvial Aquifer and the Saugus Formation during the late 1960s. However, this similarity in the water level trends may be a coincidence arising from reduced pumping in both aquifers. During the early 1970s, water levels in Saugus well VWC-157 decreased while water levels in the nearby Alluvial Aquifer well (VWC-N) generally increased. During the 1990s, the Alluvial Aquifer groundwater elevations at well VWC-N were generally stable despite (1) increased basinwide alluvial pumping and (2) a sharp decrease, then increase, in Saugus groundwater elevations, which correlated with the trends in Saugus pumping. In summary, although there may be a relationship between Alluvial and Saugus groundwater elevations near the margins of the Santa Clara Valley, where folding of Saugus beds has brought permeable zones in contact with the alluvium, Figure 2-17 indicates that there is general independence between the Alluvial and Saugus water level trends at this location, which is near the center of the bowl-shaped Saugus Formation structure discussed in Section 2.3.3.

2.6.2.5 Historical Trends in Santa Clara River Baseflow

Hydrograph separation techniques were applied to the daily streamflow data for the County Line gage to estimate historical groundwater discharges (baseflow) to the Santa Clara River within the Santa Clarita Valley. The hydrograph separation was performed for calendar years 1953 through 1999 using the following five steps:

1. For each day, the average daily flow at the County Line gage in cubic feet per second (cfs) was converted to acre-feet of volumetric flow for the day.
2. The daily flows from Castaic Dam and at the Castaic Creek South gage (located near the mouth of Castaic Creek) were subtracted from the flow at the County Line gage. These data reflect surface water flow from tributaries. Data from the Castaic Creek South gage were used through June 1977. Beginning in July 1977, operational data for Castaic Lagoon, presented in annual reports by DWR, were used to estimate surface flow contributions from Castaic Creek.
3. The discharges of treated effluent from WRPs owned by LACSD were subtracted. This was performed for calendar years 1975 and later, as 1975 was the first year that such records were available.
4. The resulting day-to-day trends in streamflows were scrutinized for days when notably elevated flows occurred suddenly. These days were assumed to be dominated by storm flow. In some cases, the elevated flows lasted for only 2 to 5 days. In other cases, flows remained elevated for several days but showed steady declines, indicating that only the beginning of the elevated-flow period was dominated by surface runoff.
5. On all other days, storm flow was considered to be minimal or zero, and the flow values calculated for days not dominated by storm flow were assumed to represent river base-flow (that is, groundwater discharge to the river). For each month, an average flow was calculated for these non-storm days. The average flow was then converted to a total flow for the month, and the monthly flow volumes were summed to come up with the total flow for each year.

Table 2-6 presents the annual calculations from the hydrograph separation analysis. Table 2-7 presents summary statistics for the entire 47-year period that was analyzed, as well as for shorter time frames. Tables 2-8 and 2-9 show dry-year, normal-year, and wet-year statistics for the entire period of record and the shorter time frames. The shorter time frames are:

a. Calendar years 1953 through 1965, which were years of primarily agricultural water use prior to urbanization and construction of WRPs. This 13-year period was also characterized by 5 years of below-normal rainfall.

b. Calendar years 1975 through 1999, which represent 25 years of significant urbanization, including SWP water importation and WRP operations. This 25-year period was characterized by 6 years of below-normal rainfall, though rainfall volumes in general were somewhat higher (19.4 inches per year [in/yr] average, versus 15.5 in/yr average for 1953 through 1965).

c. Calendar years 1953 through 1999, but excluding 8 years (1966 through 1974) when WRP discharges occurred but were not recorded.

The daily streamflow data and the hydrograph separation technique indicate the following:

a. Summary statistics in Table 2-7 for all types of rainfall years (dry, normal, and wet) show that average groundwater discharges to the river from 1953 through 1965 were approximately 2,500 AF/yr (3.5 cfs). Groundwater discharges to the river were typically

14,000 to 22,000 AF/yr (19 to 31 cfs) from 1975 through 1999 because of more rainfall, increasing urbanization, and increasing importation of water from outside the valley.

b. For normal rainfall years only, median and average groundwater discharges to the river were approximately 12,500 and 14,300 AF/yr (17 and 20 cfs), respectively, during 1975 through 1999 (Table 2-8); approximately 8,600 and 10,000 AF/yr (12 and 14 cfs), respectively, for the entire historical record (Table 2-9); and approximately 4,000 and 3,600 AF/yr (5.5 and 5.0 cfs), respectively, from 1953 through 1965 (Table 2-8).

c. For drought years only, Table 2-8 shows that groundwater discharges to the river ranged from 400 to 4,900 AF/yr (0.5 to 7 cfs) between 1953 and 1965, and from 5,200 to 14,500 AF/yr (7 to 20 cfs) between 1975 and 1999. Table 2-8 also shows that median and average groundwater discharges to the river during drought years were 600 and 1,700 AF/yr (1 and 2 cfs), respectively, from 1953 through 1965, and typically 9,600 and 10,200 AF/yr (13 and 14 cfs), respectively, from 1975 through 1999.

2.6.3 State Water Project Operations and Hydrology

The import of SWP water is an important aspect of the local hydrologic system, particularly for water supplies. Following is a summary of the SWP system's operations and history in the Santa Clarita Valley, the amount of SWP water available to the valley, and a comparison of the timing of wet-dry rainfall cycles in the SWP system and in the Santa Clarita Valley.

2.6.3.1 State Water Project Operations and History

SWP water is transported to the Santa Clarita Valley by the California Aqueduct and is stored in Castaic Lake prior to use. Castaic Lake is one of several facilities that store SWP water that is transported to Southern California by the California Aqueduct and other aqueducts. The designated uses of Castaic Lake are recreation and storage of SWP water intended for eventual municipal use.

The stored SWP water is delivered by CLWA, which was formed in 1962 to provide a supplemental supply of imported water to the retail water purveyors in the valley. CLWA treats this water at two facilities, the Earl Schmidt Filtration Plant and the Rio Vista Water Treatment Plant, then wholesales this water to each of the retail water purveyors through an extensive transmission pipeline system. The CLWA service area covers approximately 195 square miles (124,800 acres), including the City of Santa Clarita and the surrounding unincorporated communities.

In 1966, CLWA signed a contract with DWR that established a contract amount of 41,500 acre-feet of SWP water. CLWA subsequently purchased 12,700 AF/yr from a Kern County water district during the 1980s, and recently purchased an additional 41,000 AF/yr from a member agency of the Kern County Water Agency, for a current total of 95,200 AF/yr of Table A SWP water. From 1980, when SWP water was first imported into the Santa Clarita Valley, through 1999, the total amount of SWP water delivered to the CLWA service area was approximately 298,972 acre-feet.

The SWP water is combined with local groundwater to meet both residential and non-residential interior and exterior water demands. Ultimately, a substantial portion of the municipal water supply reaches the local existing WRPs in the valley. Historically, the treated water has been discharged from these WRPs to the Santa Clara River, where it contributes significantly to the natural surface water and groundwater flows reaching Ventura County. As discussed previously, stream gage data at the county line (USGS Gage No. 11108500)[2] demonstrate an increase in annual flow since the import of SWP water and the operation of the WRPs began, even during dry years. This is expected to continue in the future because increased urbanization will increase CLWA water deliveries, which in turn will increase inflows and outflows at LACSD's two WRPs (LACSD, 1998; CH2M HILL, 2002). However, over time, a portion (up to 17,000 AF/yr) of the future increases in flows into the WRPs will become reclaimed water that is used for outdoor irrigation, rather than being discharged into the river.

2.6.3.2 State Water Project Water Availability

The current CLWA Table A contract amount of 95,200 AF/yr of SWP water is affected by a number of factors, including hydrologic conditions; the status of SWP facilities construction; environmental requirements; and evolving policies for water resources management in the San Francisco Bay and Sacramento Delta system, which help route SWP water. While several programs may improve the reliability of SWP water imports to Southern California, such as Interim Delta Improvements and future improvements called the Full Delta Fix and South of Delta Storage, water planning efforts in the Santa Clarita Valley have conservatively assumed that future SWP water supplies will be equal to the SWP supply available under existing conditions. (See the Urban Water Management Plan 2000 [S.A. Associates et al., 2000] for details.)

The DWR has created a model of the SWP system and its allocations. The results from the model, called the DWRSIM model, are used by water agencies in the Santa Clarita Valley as planning numbers for SWP deliveries. The planning numbers for annual SWP water imports to the Santa Clarita Valley, based on CLWA's current Table A contract amount, are as follows:

a. Average years = 56,800 AF/yr (59.7 percent of the 95,200 AF/yr Table A contract amount)

b. Wet years = 66,300 AF/yr (69.6 percent of the 95,200 AF/yr Table A contract amount)

c. Multiple dry years = 37,900 AF/yr (39.8 percent of the 95,200 AF/yr Table A contract amount)

d. Multiple critical years = 19,000 AF/yr (20.0 percent of the 95,200 AF/yr Table A contract amount)

The DWRSIM model also indicates that a dry year allocation occurs, on average, once every 10 years, and that 3 consecutive years of drought occur, on average, once every 20 years. A separate DWR study (Roos, 1992) also concluded that droughts in excess of 3 years are rare in Northern California. Consequently, because of the availability of storage in the SWP

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[2] Until October 1996, this gage was located just downstream of the county line at Blue Cut, an area where the valley becomes substantially narrower in width and the river begins to bend toward the southern side of the valley. See Figure 1-1 for this location. This gage continued operation through October 21, 1996, at which time it was permanently taken out of service. A new gage (USGS Gage No. 11109000) was put into service beginning on October 1, 1996 approximately 2.5 miles downstream, near Piru Junction, at the Las Brisas Bridge.

system, DWR and the water agencies in the Santa Clarita Valley use the dry year allocation of 37,900 AF/yr to plan for single dry years, and also for droughts lasting up to 3 years.

2.6.3.3 Local and State Water Project Historical Hydrology

Table 2-10 compares the historical hydrologic pattern for the SWP system with the local basin hydrology since 1944. The SWP hydrologic pattern is affected by the hydrology of Northern and Central California and is specifically mentioned in the Sacramento Four Rivers Unimpaired Runoff Index in Volume 1 of *Bulletin 160-98: The California Water Plan Update* (DWR, 1998). This index provides a general indication of SWP water delivery patterns, though it only describes runoff into the SWP system and does not account for system storage and other factors that affect actual SWP deliveries. The local hydrologic pattern shown in Table 2-10 is based on the long-term rainfall record at the Newhall-Soledad rain gage. Table 2-10 shows the following:

a. Critically low runoff years occurred in the SWP system during the 2-year period 1976 through 1977; during 1988; during the 3-year period 1990 through 1992; and again during 1994.

b. The period 1980 through 1999 shows primarily extreme hydrologic conditions (wet, dry, or critical), with moderate hydrologic conditions occurring only twice, above-normal years in 1980 and 1993.

c. Hydrologic conditions in the SWP system are often different from local hydrologic conditions. Below-normal years in the SWP system often do not coincide with local droughts, and only some critical SWP years, 1990 and 1994, coincide with local drought. Likewise, historical SWP hydrology has varied considerably during years of local droughts.

The Regional Model was calibrated to time-varying hydrologic conditions for the historical time period 1980 through 1999 (see Section 4 for more details on Regional Model calibration). Table 2-11 compares SWP hydrology, SWP allocations, and local hydrology for the period 1980 through 1999. Based on the historical cycle and the goals listed above, the hydrologic cycle relating to the availability of SWP water during that period was as follows:

a. Years 1 through 5 (water years [WY] 1980 through 1984): normal or above-normal availability

b. Year 6 (WY 1985): 1-year drought (below-normal availability)

c. Years 7 through 10 (WYs 1986 through 1989): normal or above-normal availability

d. Years 11 through 13 (WYs 1990 through 1992): 3-year drought (below-normal availability)

e. Year 14 (WY 1993): normal or above-normal availability

f. Year 15 (WY 1994): 1-year drought (below-normal availability)

g. Years 16 through 20 (WYs 1995 through 1999): normal or above-normal availability

Although SWP hydrology was dry or critical during water years 1987 through 1989, the DWRSIM model indicates that the storage volume in the SWP would have provided normal water deliveries to the Santa Clarita Valley (S.A. Associates et al., 2000).

2.6.3.4 Availability of Castaic Creek Flood Flows

As provided through agreement with DWR, CLWA has access to approximately 4,700 acre-feet of storage in Castaic Lake. This water is stormwater that flows into Castaic Lake from its upstream watersheds. Prior to completion of Castaic Dam in 1972, the LACWWD, Newhall Land & Farming Company (NLF), NCWD, and UWCD, which together constitute the Downstream Water Users, had certain rights to the stormwater flowing in Castaic Creek. On October 24, 1978, DWR entered into agreements with the Downstream Water Users regarding their rights to this water. Under the terms of the agreement, DWR would release the first 100 cfs of inflow. At the time of the agreement, flows in excess of 100 cfs were believed to be wasted to the ocean. When the local inflow to Castaic Reservoir exceeds 100 cfs, the excess of 100 cfs inflow is retained in the reservoir. Until May 1 of each year, the Downstream Water Users can receive 75 percent of this retained water by paying specified storage charges. If the Downstream Water Users request this water, it is delivered by releasing water into Castaic Lagoon, and then Castaic Creek. These releases are called Castaic Creek Flood Flows. If the Downstream Water Users do not request this water on or before May 1, any retained water becomes the property of DWR.

The allocation of stored water among the Downstream Water Users is specified in a separate agreement. Under that agreement, UWCD receives 48 percent of the delivered flood flows, while the three Santa Clarita Valley entities, NLF, NCWD, and LACWWD, together receive 52 percent.

The Castaic Creek flood flows available to the group of four Downstream Water Users averaged 15,700 AF/yr during water years 1977 through 2000. (See Table 2-12.) However, the magnitudes of these flows varied greatly from year to year, as shown on Figure 2-18. No flood flows were stored or delivered in 5 of these years, and the median flow was 2,800 AF/yr (only 18 percent of the average flow). The highest flood flow was 67,400 AF/yr, in water year 1978, and the flood flow exceeded the average flow in only 7 of these 24 years. The Regional Model simulated these historical flows, as described in Appendix C.

2.7 Previous Studies

Several prior studies have been important in developing a general understanding of the valley's geology and hydrology and in developing and calibrating the Regional Model.

2.7.1 1986 Alluvial Aquifer Study

In 1986, RCS studied the alluvial sediments in the Santa Clarita Valley to estimate the amount of groundwater in storage and the amount of recharge that occurs over the long-term, and also to evaluate the feasibility of artificially recharging these sediments (RCS, 1986). This was the first published report detailing the hydrogeologic characteristics of the Alluvial Aquifer system, water well construction and testing information, and magnitudes and changes in groundwater elevation and groundwater quality. Prior studies in the Santa Clarita Valley focused on oil development, and therefore evaluated the regional geology with an emphasis on the subsurface geologic conditions in the hills and mountains surrounding the valley.

The 1986 study identified 650 water wells that had been drilled in the valley up to that time, all but 22 of which were drilled in the alluvium to depths less than 250 feet. The study examined geologic logs, well testing (specific capacity) records, long-term water level data, and water quality records. The study concluded that the coarse-grained, permeable sediments comprising this aquifer system are subjected to seasonal and year-to-year variations in water levels and groundwater in storage due to highly variable rainfall and streamflow patterns. In addition to describing the hydrogeology of the Alluvial Aquifer, the study mapped and identified the watersheds contributing to streamflows in the Santa Clara River and its tributaries, and estimated the amount of runoff from these watersheds that is potentially available as recharge to the Alluvial Aquifer. The study also concluded that it would be feasible to artificially recharge portions of the Alluvial Aquifer using spreading basins, primarily along the Santa Clara River in the area east of the mouth of Bouquet Canyon.

2.7.2 1988 Saugus Aquifer Study

In 1988, RCS conducted a study of the Saugus Formation that was similar in scope to the 1986 study of the Alluvial Aquifer (RCS, 1988). The scope of work included conducting 24-hour, constant discharge aquifer tests in five different Saugus Formation wells, including monitoring water level recovery rates. Six regional geologic cross-sections were also constructed from geologic and geophysical logs that had been compiled prior to this study at water wells and numerous oil wells within and around the Santa Clarita Valley.

The study concluded that the Saugus Formation is discretely layered, with groundwater production occurring from discrete sand and gravel zones that exist throughout much of the total thickness of the formation. The study also concluded that it is hydrogeologically feasible to develop additional groundwater supplies from the Saugus Formation as long as wells are properly sited and constructed, and that the groundwater-yielding capability of the Saugus Formation is likely greater south of the San Gabriel fault than north of the fault.

2.7.3 2002 Aquifer Study Update

In 2002, RCS updated the 1986 and 1988 studies with more recent data and prepared a report for both the Alluvial and Saugus Formation aquifers (RCS, 2002). As part of this work, a GIS and digital database were constructed. Field activities conducted during the study included surveying water well locations and elevations using a global positioning system (GPS) survey and water level data collected at Alluvial and Saugus wells.

The report concluded that groundwater levels in the Alluvial Aquifer and Saugus Formation have fluctuated over time, but have shown no long-term progressive declines in the amount of groundwater storage that could be considered indicative of overdraft conditions. From the long-term pumping and water level data, the report concluded that the Alluvial Aquifer can be pumped at rates between 30,000 and 40,000 AF/yr over the long-term, and suggested that pumping be between 30,000 and 35,000 AF/yr during dry years. For the Saugus Formation, the study concluded that pumping can occur at rates between 7,500 and 15,000 AF/yr on a long-term basis, with short-term increases to as much as

35,000 AF/yr during the end of a multi-year drought period. These pumping rates for the Alluvial and Saugus aquifer systems were referred to in the 2002 study as the operational yields of both aquifers.[3]

2.7.4 Newhall Ranch ASR Impact Evaluation

The Newhall Ranch Company performed analyses of potential impacts resulting from development of the proposed Newhall Ranch Specific Plan, including implementation of an ASR program. Findings were documented in the following reports:

a. *Assessment of the Hydrogeologic Feasibility of Aquifer Storage and Recovery, Saugus Formation, Santa Clarita Valley, California* (RCS, 2001).

b. *Newhall Ranch ASR Impact Evaluation* (CH2M HILL, 2001).

c. *Newhall Ranch Updated Water Resources Impact Evaluation* (CH2M HILL, 2002).

The study consisted of the following work:

a. An ASR field test was conducted by RCS in the Saugus Formation at VWC-205 in July 2000. The objective of the test was to determine the feasibility of injecting water into the Saugus Formation and later extracting the stored water. Approximately 24 million gallons of treated drinking water were injected into the well at a rate of up to 1,100 gpm for 21 days (RCS, 2001). The stored water was then recovered at a rate of 2,300 gpm for 10 days. Water levels were monitored in nearby Saugus Formation wells and in a newly installed Alluvial Aquifer monitoring well. This test demonstrated that ASR is indeed feasible in the Saugus Formation. Also, there was no measurable effect on water levels during the injection or pumping phase at the Alluvial monitoring well.

b. A pumping test was conducted by RCS in the Saugus Formation at VWC-201 to further demonstrate the limited hydraulic connection between the Saugus Formation and the Alluvial Aquifer. Well VWC-201 was pumped at 2,400 gpm for 10 days and water levels were monitored at an Alluvial Aquifer well located less than 50 feet away. Again, no response to Saugus Formation pumping was discernible at the Alluvial monitoring well.

While the ASR field test demonstrated that ASR is feasible in the Saugus Formation and that there is limited effect on the Alluvial Aquifer, it was necessary to conduct additional

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[3] The concept of operational yield was described in the RCS report as follows (RCS, 2002):

"One of the disadvantages of utilizing perennial yield as a basis for managing the pumpage from an aquifer system is that it represents a long-term average value for annual yield. There is a potential for the perennial yield value to be interpreted as a "not-to-exceed" volume, with a related potential for pumping above the perennial yield value in any give year to be incorrectly interpreted as "overdraft." A recently advanced concept intended to deal with such misinterpretations is that of operational yield. Operational yield can be defined as a fluctuating value of pumpage that may be above or below the perennial (or average) yield in any given year, and that varies as a function of the availability of other water supplies. The basic intent of the operational yield value is that it should not exceed the perennial yield of the groundwater basin over multi-year wet and dry cycles."

"The operational yield concept includes flexibility of groundwater use by allowing increased pumping during dry periods and increased recharge (direct or in-lieu) with supplemental water when it is available in wet/normal rainfall periods. The operational yield protects the aquifer by helping to assure that groundwater supplies are adequately replenished on a long-term basis from one wet/dry cycle to the next. In the Valley, historical groundwater data demonstrate that the alluvium has been, and continues to be, developed within its long-term sustainability (i.e., no continuous lowering of water levels, no notable trend toward degradation of groundwater quality, etc.)"

analysis to extrapolate the results of RCS's well field testing to a full-scale, long-term ASR operation. This additional analysis was designed to address the following questions:

a. Can 4,500 AF/yr of water be stored in the Saugus Formation for withdrawal during drought years?

b. Will storage of water in the Saugus Formation increase the rate of natural groundwater discharge to the Alluvial Aquifer and to the Santa Clara River, and, if so, by how much?

c. Will pumping Saugus Formation ASR wells during a drought period reduce groundwater elevations in the Alluvial Aquifer and, subsequently, flows in the Santa Clara River?

d. Will the ASR program result in water quality changes within the Saugus Formation, the Alluvial Aquifer, and the Santa Clara River?

e. Will the ASR program cause spreading of perchlorate that is present in the Saugus Formation?

To answer these questions, CH2M HILL prepared a numerical groundwater flow model of the western and central portions of the Santa Clarita Valley. The model simulated the groundwater flow in the Saugus Formation and the Alluvial Aquifer, accounting for the inflows and outflows to and from the Alluvial Aquifer, the Saugus Formation, and the Santa Clara River under historical conditions. The model was also used to simulate the changes in the groundwater flow system that would arise from operation of the ASR system. Of particular interest was the model's simulation of changes in subsurface groundwater flow out of the valley and changes in groundwater discharge into the Santa Clara River that would arise from ASR operations under a historical climatic cycle (wet and dry hydrologic conditions) observed during the 1980s and 1990s. These two groundwater discharge mechanisms were evaluated in detail with the model to estimate the potential changes in flow to Ventura County from the ASR system. The western limit of the model was placed at the county line, and the eastern limit of the Saugus Formation was established as the eastern limit of the model domain.

The primary findings from the analysis were:

a. On the basis of the historical timing of drought years, the proposed ASR system would provide long-term benefits to the river and the groundwater system. ASR pumping cycles would cause small (less than 1 foot) declines during drought years, and long-term operation of the ASR system would not cause long-term groundwater elevation declines in the Alluvial Aquifer, where riparian habitat is present along the river.

b. The combined influence of the proposed ASR program and the other water resource attributes[4] of Newhall Ranch would result in an overall increase in river flows over the long term.

c. The continued increase in water supplies to meet the water demands arising from a combination of growth outside Newhall Ranch and development of the Newhall Ranch

[4] Direct discharges of treated effluent into the river from the Newhall Ranch WRP, and the redistribution of irrigation demands (rates and locations) associated with conversion of water use from agricultural to municipal demands.

project would further enhance the long-term flows to the river, compared with present conditions. The occurrence of increased annual river flows during drought and nondrought years alike, compared with present conditions, is consistent with historical records, showing that continued urbanization and associated importation of water from areas outside the valley would increase river flows gradually over time.

Tables

TABLE 2-1

Annual Groundwater Pumping from the Alluvial Aquifer

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCWD	Castaic1	244	257	253	189	251	274	295	450	520	478	444	561	515	458	496	401	385	535	166	426	118
	Castaic2	124	48	0	0	0	0	380	535	324	678	0	0	0	477	518	380	327	268	257	331	289
	Castaic3	0	108	136	172	240	301	0	0	324	0	660	532	488	0	0	0	0	0	0	0	0
	Castaic4	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	95	57	6	7
	Pinetree1	346	326	355	242	148	273	8	0	2	152	0	47	16	247	154	79	64	89	227	403	245
	Pinetree2	58	84	209	112	154	113	206	309	351	348	31	0	283	326	218	165	70	0	0	0	0
	Pinetree3	398	527	225	432	753	655	719	756	758	672	801	724	682	450	607	595	624	812	716	505	494
	Pinetree4	0	0	0	0	3	28	234	77	4	0	0	0	10	19	232	55	333	510	338	5	355
NLF	161	317	370	271	223	314	220	170	0	0	0	120	82	401	753	791	0	0	0	0	123	106
	B10	0	0	0	0	0	0	0	0	0	0	0	291	1,225	452	1,406	894	1,045	930	1,244	1,155	990
	B11	186	217	159	133	184	138	60	0	0	127	445	311	0	136	51	127	151	30	250	212	182
	B5	1,218	1,423	1,041	858	1,208	772	1,178	1,002	1,481	1,928	1,893	1,880	860	989	1,950	1,921	1,649	1,756	1,273	1,748	1,500
	B6	858	1,002	733	604	850	543	946	788	165	96	137	263	615	283	808	1,359	1,421	1,602	1,572	2,133	1,830
	B7	0	0	0	0	0	0	60	0	0	127	0	0	400	180	581	373	56	286	176	444	381
	C	723	845	618	510	717	575	660	387	418	557	338	226	756	1,024	417	1,324	715	1,126	598	716	614
	C3	196	229	168	138	195	140	254	63	130	71	134	48	197	259	582	333	397	355	378	619	531
	C4	260	304	222	183	258	196	137	25	30	7	213	225	166	12	108	150	293	483	609	819	703
	C5	459	536	392	323	455	359	328	191	198	154	147	250	428	414	394	472	676	894	628	685	588
	C6	203	237	174	143	201	166	161	103	117	77	59	123	0	0	0	360	229	226	128	154	132
	C7	575	671	491	405	570	354	195	192	318	337	339	220	427	279	625	778	582	779	779	1,167	1,001
	C8	0	0	0	0	0	0	0	0	0	0	0	0	126	254	166	199	458	432	179	236	202
	E	2,067	2,416	1,767	1,457	2,051	3,342	1,842	1,180	812	624	965	498	1,325	1,513	1,022	1,366	2,542	1,949	1,522	2,506	2,150
	E2	174	203	149	123	173	138	103	0	0	251	1,284	830	560	584	555	115	669	525	426	138	118
	E3	0	0	0	0	0	0	0	0	0	0	0	0	0	15	138	0	0	0	0	0	0
	E4	1,011	1,181	864	712	1,003	639	716	83	566	392	553	284	376	16	0	381	140	339	80	281	241
	E5	0	0	0	0	0	0	0	0	0	0	0	0	65	274	0	142	514	598	42	0	0
	E7	0	0	0	0	0	0	0	0	0	0	0	0	116	80	105	88	79	2	0	0	0
	E9	96	113	82	68	96	78	117	288	476	411	339	596	252	187	435	319	12	142	170	42	36
	G45	324	378	277	228	321	179	153	98	123	99	143	146	165	82	144	137	159	180	144	231	198
	Q	441	515	377	311	438	159	360	382	312	185	15	0	0	0	0	0	0	0	0	0	0
	R	0	0	0	0	0	0	0	205	0	0	0	0	0	0	0	0	0	0	0	0	0
	R2	159	186	136	112	158	71	104	47	0	0	0	87	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	293	342	250	206	290	95	0	958	0	0	503	0	0	0	0	0	0	0	0	276	237
	S3	655	765	560	461	649	327	124	0	0	0	29	37	52	99	87	109	97	55	10	3	0
	Topco 1	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0
	Topco 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	W4	303	354	259	213	300	138	60	1	0	300	157	252	1	0	36	5	128	29	20	3	3
	W5	553	646	472	389	548	191	315	205	308	192	0	175	0	0	0	0	0	0	0	21	18
	X3	260	304	222	183	258	508	244	314	497	308	412	215	350	135	205	222	8	108	22	112	96
SCWC	Clark	303	228	131	137	194	200	208	342	248	301	407	542	662	635	572	662	1,027	873	697	878	747
	Guida	1,058	795	457	477	677	698	221	569	158	530	676	801	978	895	942	744	1,252	1,479	1,274	1,556	853
	Honby	594	447	257	268	381	392	193	391	462	216	930	893	731	1,393	476	553	352	814	532	1,162	815
	Lost Canyon 2	1,083	814	468	489	693	714	765	923	787	588	601	404	465	692	669	773	678	792	757	946	708
	Lost Canyon 2A	0	0	0	0	0	0	0	0	0	0	293	832	1,284	1,080	1,383	1,230	1,370	1,055	973	890	998
	Methodist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mitchell	1,189	893	515	537	761	785	444	582	485	435	264	3	474	663	564	610	598	633	482	913	439
	N.Oaks Central	488	367	211	220	313	322	304	361	153	329	525	704	701	1,403	1,313	965	851	870	1,490	1,682	1,145
	N.Oaks East	601	451	260	271	385	396	863	972	776	914	454	194	588	1,233	1,473	1,295	900	1,033	1,407	695	1,483
	N.Oaks West	643	483	278	290	412	424	874	465	842	413	275	78	634	866	972	795	663	952	934	1,894	1,663
	Sand Canyon	721	542	312	325	461	477	514	466	498	1,115	458	49	661	918	781	842	1,211	1,533	1,622	1,629	1,317
	Sierra	2,780	2,089	1,202	1,255	1,780	1,834	856	220	459	730	772	719	1,050	1,413	1,433	1,092	1,034	597	814	1,158	640
	Stadium	0	0	0	0	0	0	167	291	211	214	328	374	60	825	418	656	509	637	444	338	721

TABLE 2-1

Annual Groundwater Pumping from the Alluvial Aquifer

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
VWC	D	289	269	164	163	240	41	0	305	588	614	510	680	239	173	494	403	454	1,134	1,209	921	880
	I	214	200	122	121	177	181	95	0	91	132	73	108	1	0	1	0	0	0	0	0	0
	K2	0	0	0	0	0	0	0	0	0	0	0	982	1,134	1,708	2,089	1,155	1,305	1,076	1,489	1,420	861
	L2	9	8	5	5	7	91	0	0	0	0	0	838	526	996	1,236	818	961	308	190	532	494
	N	1,475	1,376	840	833	1,223	1,093	1,472	1,420	1,473	1,177	792	976	697	66	0	24	263	808	768	1,036	935
	N3	0	0	0	0	0	0	0	0	0	0	0	10	999	1,536	29	943	1,325	1,034	1,093	1,057	778
	N4	5	5	3	3	4	65	0	0	0	0	0	847	248	133	911	1,329	1,328	1,185	772	894	710
	Q2	440	411	251	248	367	461	838	893	512	1,483	1,398	1,783	335	548	1,348	1,126	1,385	1,462	1,655	1,288	1,387
	S6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	515
	S7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111
	S8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79
	T2	621	580	354	351	515	704	894	913	1,007	1,030	643	662	379	0	3	280	733	837	941	726	984
	T4	160	150	91	91	133	54	167	0	0	0	0	163	687	3	1	975	1,258	804	523	892	625
	U3	1,476	1,378	841	834	1,225	1,278	1,033	638	323	823	1,254	1,199	369	1	2	765	987	851	560	702	1,126
	U4	1,306	1,220	744	738	1,084	665	668	606	696	567	551	584	42	3	2	7	742	789	529	828	1,073
	W6	0	0	0	0	0	0	0	146	145	0	0	217	260	204	224	365	615	493	355	416	445
	W9	0	0	0	0	0	0	0	0	0	0	11	902	699	444	507	508	1,077	915	627	1,111	1,176
WHR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,842	1,229	1,376	772	1,104	1,204	1,352	760	614	1,229	1,131	1,010
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15	137	137	137	137	137	137	137	137	137	137	91	102	57	82	89	100	56	46	91	84	75
	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	1,021	680	762	427	612	666	748	421	340	680	627	559
	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Pumping (NCWD)		1,170	1,350	1,178	1,147	1,549	1,644	1,842	2,127	2,283	2,367	1,936	1,864	1,994	1,977	2,225	1,675	1,803	2,309	1,761	1,676	1,508
Total Pumping (NLF)		11,331	13,237	9,684	7,983	11,237	9,328	8,287	6,512	5,951	6,243	8,225	7,039	8,938	8,020	10,606	11,174	12,020	12,826	10,250	13,824	11,857
Total Pumping (SCWC)		9,460	7,109	4,091	4,269	6,057	6,242	5,409	5,582	5,079	5,785	5,983	5,593	8,288	12,016	10,996	10,217	10,445	11,268	11,426	13,741	11,529
Total Pumping (VWC)		5,995	5,597	3,415	3,387	4,975	4,633	5,167	4,921	4,835	5,826	5,232	9,951	6,615	5,815	6,847	8,698	12,433	11,696	10,711	11,823	12,179
Total Pumping (WHR)		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	2,000	2,240	1,256	1,798	1,959	2,200	1,237	1,000	2,000	1,842	1,644
Total Pumping (All Purveyors)		30,956	30,293	21,368	19,786	26,818	24,847	23,705	22,142	21,148	23,221	23,376	26,687	27,091	29,626	32,633	33,964	37,938	39,099	36,148	42,906	38,717
Total Pumping (Others)		500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	932	953	890
Total Alluvial Aquifer Pumping		31,456	30,793	21,868	20,286	27,318	25,347	24,205	22,642	21,648	23,721	23,876	27,187	27,591	30,126	33,133	34,464	38,438	39,599	37,080	43,859	39,607

Notes:
N. = north
WHR = Wayside Honor Rancho, owned by LACWWD
All pumping volumes are listed in acre-feet.

Data source: Luhdorff and Scalmanini, Consulting Engineers. April 2003. *Santa Clarita Valley Water Report 2002.* Prepared for the Castaic Lake Water Agency, Los Angeles County Waterworks District #36, Newhall County Water District, and Valencia Water Company.

TABLE 2-2

Annual Groundwater Pumping from the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Owner	Well Name	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NCWD	7	404	396	350	348	355	384	271	260	332	242	242	274	180	268	321	364	332	288	280	172	0
	4	440	449	319	385	315	369	222	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	119	227	115	138	1	0	5	1	1	0	4	1	1	0	1	0	0
	10	790	906	1,287	1,300	1,007	997	731	888	613	453	644	343	351	61	0	1	0	0	2	0	0
	11	729	870	716	754	1,159	1,278	2,209	2,371	1,265	1,280	1,252	1,034	428	730	614	522	353	81	14	0	0
	12	0	0	0	0	0	0	0	0	1,830	2,713	2,603	3,342	2,807	1,956	1,918	2,264	2,140	1,798	1,909	1,155	1,767
	13	0	0	0	0	0	0	0	0	0	0	0	0	1,393	2,053	2,246	1,623	2,045	3,001	2,351	1,295	419
NLF	156	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374
SCWC	Saugus1	0	0	0	0	0	0	0	0	31	0	0	1,690	437	1,226	1,333	0	410	451	0	0	0
	Saugus2	0	0	0	0	0	0	0	0	32	0	40	3,091	2,476	1,675	2,530	1,726	1,766	617	0	0	0
VWC	157	635	604	529	239	387	314	581	483	1,223	1,146	635	1,005	570	436	616	403	46	80	0	0	0
	159	0	0	0	0	0	0	0	0	0	0	3	63	65	74	147	68	3	0	0	0	0
	160	1,571	1,725	368	372	467	571	846	822	1,077	1,326	839	1,325	580	920	957	585	206	401	133	95	776
	201	0	0	0	0	0	0	0	0	0	57	2,039	2,249	1,170	752	845	530	71	35	16	11	172
	205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59
Total Pumping (NCWD)		2363	2621	2672	2787	2955	3255	3548	3657	4041	4688	4746	4994	5160	5068	5103	4775	4871	5168	4557	2622	2186
Total Pumping (NLF)		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	266	445	426	479	374
Total Pumping (SCWC)		0	0	0	0	0	0	0	0	63	0	40	4781	2913	2901	3863	1726	2176	1068	0	0	0
Total Pumping (VWC)		2206	2329	897	611	854	885	1427	1305	2300	2529	3516	4642	2385	2182	2565	1586	326	516	149	106	1007
Total Pumping (All Purveyors)		4,589	4,970	3,589	3,418	3,829	4,160	4,995	4,982	6,424	7,237	8,322	14,437	10,478	10,171	11,551	8,107	7,639	7,197	5,132	3,207	3,567
Total Pumping (Others)		0	0	501	434	620	555	490	579	504	522	539	480	446	439	474	453	547	548	423	509	513
Total Saugus Formation Pumping		4,589	4,970	4,090	3,852	4,449	4,715	5,485	5,561	6,928	7,759	8,861	14,917	10,924	10,610	12,025	8,560	8,186	7,745	5,555	3,716	4,080

Note:

All pumping volumes are listed in acre-feet.

Data source: Luhdorff and Scalmanini, 2003.

TABLE 2-3
Summary of Selected Tests and Estimated Parameter Values for the Alluvial Aquifer
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Area	Well Owner-Name	Estimated T (ft^2/day)	Model T (ft^2/day)	Estimated K (ft/day)	Model K (ft/day)	Model Zone
West of I-5	NLF-B5	80,000 to 150,000	60,500	750 to 1,400	550	C1c
	NLF-B6	40,000 to 70,000	60,500	100 to 600	550	C1c
	NLF-C4	20,000 to 35,000	60,500	100 to 300	550	C1b
	NLF-E5	40,000 to 55,000	71,500	100 to 400	550	C1a
Between I-5 and Soledad Canyon	VWC-I	30,000 to 45,000	22,500	250 to 350	375	B1b2
	VWC-K2	60,000 to 90,000	54,375	400 to 600	375	B1a
	VWC-N3	55,000 to 80,000	79,750	375 to 550	550	B1a
	VWC-N4	75,000 to 100,000	54,375	500 to 750	375	B1a
	VWC-Q2	35,000 to 50,000	79,750	250 to 350	550	B1a
	NLF-R2	50,000 to 105,000	22,050	600 to 1,200	245	B1a
	NLF-S	35,000 to 85,000	54,375	250 to 600	375	B1a
	NLF-S3	35,000 to 55,000	79,750	250 to 350	550	B1a
Lower Soledad Canyon	SCWC-Stadium	85,000 to 150,000	63,250	950 to 1,650	550	A1e1
	VWC-U3	90,000 to 170,000	63,250	800 to 1,500	550	A1e2
	VWC-U4	65,000 to 135,000	63,250	550 to 1,200	550	A1e2
	SCWC-Honby	30,000 to 50,000	49,500	300 to 550	550	A1d1
Upper Soledad Canyon	SCWC-N.Oaks West	35,000 to 55,000	49,500	400 to 600	550	A1d4
	SCWC-N.Oaks Central	85,000 to 120,000	49,500	900 to 1,350	550	A1d4
	SCWC-N.Oaks East	50,000 to 70,000	49,500	500 to 800	550	A1d4
	SCWC-Sierra	80,000 to 145,000	49,500	900 to 1,600	550	A1c1
	SCWC-Mitchell	40,000 to 60,000	49,500	450 to 650	550	A1c2
	SCWC-Sand Canyon	35,000 to 125,000	36,000	400 to 1,400	400	A1c3
	NCWD-Pinetree 3 and 4	30,000 to 50,000	31,500	300 to 550	350	A1b1
Castaic Valley	VWC-D	30,000 to 50,000	35,000	300 to 500	350	C2b
	NLF-E	60,000 to 90,000	35,000	600 to 900	350	C2b
	NLF-E2	45,000 to 100,000	35,000	450 to 1,000	350	C2b
	WHR Wellfield	40,000 to 75,000	35,000	400 to 750	350	C2a and C2b
Northern Canyons	NLF-W4	25,000 to 35,000	10,500	250 to 350	105	B4c
	VWC-W6	25,000 to 40,000	10,500	250 to 400	105	B4c
	SCWC-Guida	45,000 to 65,000	12,600	500 to 700	140	B2b
	SCWC-Clark	55,000 to 80,000	22,050	650 to 900	245	B2c

Note:
See Section 4.3.1 for a discussion of the model zones.

TABLE 2-4

Summary of Selected Tests and Estimated Parameter Values for the Saugus Formation

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Name	Date	Type of Test	Pumping or Injection Rates (gpm)	Length of Test (minutes)	Well Monitored	Specific Capacity (gpm/ft)[a]	T (gpd/ft)	T (ft^2/day)	Storativity	Model Zone
NCWD-7	03/04/1987	Drawdown	341	1,440	NCWD-7	3.1	26,400	3,530		F
NCWD-7	03/05/1987	Recovery		1,500	NCWD-7		23,300	3,110		F
NCWD-10	03/11/1987	Drawdown	364	1,440	NCWD-10	8.3	28,500	3,810		F
NCWD-10	03/11/1987	Drawdown	364	1,440	NCWD-12 (160 feet away)		57,700	7,710	9.10E-04	F
NCWD-10	03/11/1987	Recovery		1,480	NCWD-10		38,400	5,130		F
NCWD-10	03/11/1987	Recovery		1,490	NCWD-12 (160 feet away)		61,500	8,220	7.60E-04	F
NCWD-9	03/17/1987	Drawdown	256	1,460	NCWD-9	1.9	3,700	490		A
NCWD-9	03/17/1987	Recovery		1,500	NCWD-9		3,000	400		A
VWC-160	03/24/1987	Drawdown	2,562	720	VWC-160	49.8	163,000	21,790		E
VWC-160	03/24/1987	Recovery		850	VWC-160		182,000	24,330		E
VWC-205	07/01/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-205M (40 feet)	12.2	41,370	5,530	8.88E-04	E
VWC-205	07/02/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-201 (2,400 feet)		50,450	6,740	7.56E-04	E
VWC-205	07/03/2000	Injection + Recovery	500-800-1,100	30,240 / 12,960	VWC-157 (4,100 feet)		54,880	7,340	6.45E-04	E
VWC-205	08/01/2000	Pumping	2,273	12,960 / 14,440	VWC-205	18.7				E
VWC-205	08/01/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-205M (40 feet)	18.7	78,910	10,550	9.48E-04	E
VWC-205	08/02/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-201 (2,400 feet)		76,410	10,220	1.37E-03	E
VWC-205	08/03/2000	Pumping + Recovery	2,273	12,960 / 14,440	VWC-157 (4,100 feet)		65,880	8,810	1.36E-03	E
VWC-201	10/01/2000	Pumping	2,439	14,440 / 2,880	VWC-201	30	65,100	8,700	5.75E-04	E
VWC -201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-157 (1,900 feet)		44,230	5,910	1.17E-03	E
VWC-201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-205M (2,360 feet)		57,210	7,650	8.49E-04	E
VWC-201	10/01/2000	Pumping + Recovery	2,439	14,440 / 2,880	VWC-205 (2,400 feet)		47,890	6,400	6.75E-04	E
SCWC-Saugus1	07/01/1988	Pumping	2,941	1,440	SCWC-Saugus1	30.2	69,300	9,260		E
SCWC-Saugus1	07/01/1988	Recovery	2,941	480	SCWC-Saugus1		59,700	7,980		E
SCWC-Saugus2	09/01/1988	Pumping	2,531	2,880	SCWC-Saugus2	24.1	53,500	7,150		E
SCWC-Saugus2	09/01/1988	Recovery	2,531	1,320	SCWC-Saugus2		55,700	7,450		E
SCWC-Saugus2	09/01/1988	Pumping	2,531	2,880	SCWC-Saugus1		71,500	9,560	3.60E-04	E
SCWC-Saugus3	09/01/1988	Recovery	2,531	1,320	SCWC-Saugus1		60,200	8,050		E

[a] gpm/ft of drawdown

Note:

See Section 4.3.1 for a discussion of the model zones.

Data source: RCS, 2002 (except model zones)

TABLE 2-5
Recharge and Discharge Components of the Hydrologic Cycle in the Upper Santa Clara River Basin
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Recharge	Discharge
Surface Water	
Direct runoff of precipitation	Evapotranspiration of precipitation
Precipitation runoff from upstream watershed areas	Santa Clara River flow to Ventura County
Castaic Lake/Lagoon releases into Castaic Creek	Streamflow seepage to the Alluvial Aquifer
WRP discharges into the Santa Clara River	Evapotranspiration of applied irrigation water
Groundwater seepage into the Santa Clara River	
Irrigation return flows (agricultural and urban)	
Groundwater	
Infiltration of precipitation	Pumping
Infiltration of outdoor applied water (agricultural and urban)	Evapotranspiration of Alluvial Aquifer groundwater by riparian vegetation
Alluvial Aquifer subsurface inflow (Castaic Dam)	Alluvial Aquifer subsurface outflow (western study area boundary)
Streamflow seepage to Alluvial aquifer	Groundwater seepage into the Santa Clara River

Notes:

The two sources of water for agricultural and municipal water uses in the basin are groundwater pumping and imported water from the SWP.

Because SWP water is stored in Castaic Lake, which is outside the limits of the Alluvial and Saugus aquifers, it is not considered to be a part of the valley's hydrologic cycle while it is still in storage. However, SWP water that is land-applied or that is discharged from a WRP qualifies as a component of the hydrologic cycle. In addition, subsurface groundwater flow occurs into the Santa Clarita Valley beneath Castaic Creek due to water seepage beneath Castaic Dam.

TABLE 2-6
Estimated Annual Groundwater Discharge to the Santa Clara River
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Total Gaged Flow at Mouth of Castaic Creek (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[a]	Local Rainfall Condition[b]
1953	0	4,986	4,943	0	4,943	4.88	Dry
1954	977	7,316	5,554	0	5,554	15.82	Normal
1955	134	4,795	4,122	0	4,122	13.91	Normal
1956	311	5,429	3,803	0	3,803	14.21	Normal
1957	559	4,782	2,410	0	2,410	22.85	Wet
1958	21,204	38,756	5,344	0	5,344	23.14	Wet
1959	473	3,277	2,206	0	2,206	9.81	Dry
1960	1	777	586	0	586	11.64	Dry
1961	79	804	410	0	410	8.82	Dry
1962	5,101	28,460	2,433	0	2,433	21.22	Wet
1963	32	1,884	1,058	0	1,058	12.79	Normal
1964	1	1,030	646	0	646	10.09	Dry
1965	3,702	35,614	996	0	996	32.28	Wet
1966	5,780	10,101	2,332	No data	---	14.57	Normal
1967	27,819	40,480	8,640	No data	---	23.23	Wet
1968	4,381	7,216	3,895	No data	---	6.90	Dry
1969	46,461	258,660	29,395	No data	---	32.42	Wet
1970	6,597	31,066	14,924	No data	---	23.19	Wet
1971	2,310	15,883	10,843	No data	---	13.75	Normal
1972	2,205	16,027	12,975	No data	---	4.15	Dry
1973	12,671	52,631	26,115	No data	---	19.79	Wet
1974	7,288	25,265	11,918	No data	---	18.04	Wet
1975	2,027	14,770	10,806	5,534	5,272	10.92	Dry
1976	156	10,162	9,754	6,095	3,659	14.02	Normal
1977	1,380	13,454	9,359	6,004	3,355	20.87	Wet
1978	35,378	129,187	60,955	6,982	53,973	42.17	Wet
1979	13,626	57,594	42,448	7,397	35,051	21.47	Wet
1980	16,785	95,211	57,593	7,372	50,221	27.00	Wet
1981	6,519	24,232	21,172	7,949	13,223	13.42	Normal
1982	9,102	36,488	32,531	8,436	24,095	20.20	Wet
1983	67,058	131,236	55,878	9,420	46,458	39.07	Wet
1984	13,787	39,279	35,215	9,512	25,703	12.86	Normal
1985	2,619	24,466	24,089	9,614	14,475	8.37	Dry
1986	4,945	48,024	31,327	10,822	20,505	18.02	Wet

TABLE 2-6
Estimated Annual Groundwater Discharge to the Santa Clara River
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Total Gaged Flow at Mouth of Castaic Creek (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)[a]	Local Rainfall Condition[b]
1987	911	26,198	23,663	11,844	11,819	14.45	Normal
1988	2,415	36,611	24,934	12,363	12,571	16.92	Wet
1989	Unavailable	24,799	23,453	13,560	9,893	7.56	Dry
1990	0	23,472	21,772	14,006	7,766	6.98	Dry
1991	65	34,901	18,702	14,108	4,594	17.21	Wet
1992	4,450	68,577	23,601	15,703	7,898	32.03	Wet
1993	7,725	152,783	65,054	17,179	47,875	32.72	Wet
1994	Unavailable	32,039	31,239	16,946	14,293	10.27	Dry
1995	5,611	82,409	51,001	17,824	33,177	29.15	Wet
1996	5,632	47,930	36,366	16,831	19,535	15.88	Normal
1997	9,885	36,780	27,521	15,778	11,743	13.35	Normal
1998	47,803	205,139	81,744	17,695	64,049	30.73	Wet
1999	5,830	32,382	27,176	17,847	9,329	8.96	Dry

[a]Annual rainfall values are based on monthly records for this gage, as reported by NCDC and LADPW.

[b]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-7
Statistics on Annual Groundwater Discharge to the Santa Clara River, All Years
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	311	4,795	2,410	0	2,410	13.91
Average	2,506	10,608	2,655	0	2,655	15.50
Maximum	21,204	38,756	5,554	0	5,554	32.28
Statistics for 1975 through 1999						
Minimum	0	10,162	9,359	5,534	3,355	6.98
Median	5,632	36,611	27,521	11,844	14,293	16.92
Average	11,466	57,125	33,894	11,873	22,021	19.38
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	3,161	30,250	22,613	11,844	8,613	15.14
Average	8,230	41,211	23,207	11,873	15,396	18.05
Maximum	67,058	205,139	81,744	17,847	64,049	42.17
Statistics for 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	4,450	28,460	18,702	11,844	8,613	15.82
Average	9,151	43,050	21,338	11,873	15,396	17.92
Maximum	67,058	258,660	81,744	17,847	64,049	42.17

TABLE 2-8
Statistics on Annual Groundwater Discharge to the Santa Clara River, 1953 through 1965 vs. 1975 through 1999
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 5 Dry Years during 1953 through 1965						
Minimum	0	777	410	0	410	4.88
Median	1	1,030	646	0	646	9.81
Average	111	2,175	1,758	0	1,758	9.05
Maximum	473	4,986	4,943	0	4,943	11.64
Statistics for 4 Normal Years during 1953 through 1965						
Minimum	32	1,884	1,058	0	1,058	12.79
Median	222	5,112	3,963	0	3,963	14.06
Average	363	4,856	3,634	0	3,634	14.18
Maximum	977	7,316	5,554	0	5,554	15.82
Statistics for 4 Wet Years during 1953 through 1965						
Minimum	559	4,782	996	0	996	21.22
Median	4,402	32,037	2,421	0	2,421	23.00
Average	7,641	26,903	2,796	0	2,796	24.87
Maximum	21,204	38,756	5,344	0	5,344	32.28
Statistics for 6 Dry Years during 1975 through 1999						
Minimum	0	14,770	10,806	5,534	5,272	6.98
Median	2,323	24,633	23,771	13,783	9,611	8.67
Average	2,619	25,322	23,089	12,918	10,171	8.84
Maximum	5,830	32,382	31,239	17,847	14,475	10.92
Statistics for 6 Normal Years during 1975 through 1999						
Minimum	156	10,162	9,754	6,095	3,659	12.86
Median	6,076	31,489	25,592	10,678	12,521	13.72
Average	6,148	30,763	25,615	11,335	14,280	14.00
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 13 Wet Years during 1975 through 1999						
Minimum	65	13,454	9,359	6,004	3,355	16.92
Median	7,725	68,577	42,448	10,822	33,177	27.00
Average	16,642	83,970	42,702	11,639	31,063	26.74
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-9
Statistics on Annual Groundwater Discharge to the Santa Clara River, Including and Excluding 1966 through 1974
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	Castaic Creek Flows (acre-feet)	Total Gaged Flow at County Line (acre-feet)	Estimated Non-Storm Flow at County Line (acre-feet)	WRP Flows (acre-feet)	Estimated Groundwater Discharge to River (acre-feet)	Rainfall at Newhall-Soledad Gage (inches)
Statistics for 13 Dry Years during 1953 through 1999						
Minimum	0	777	410	5,534	410	4.15
Median	473	14,770	10,806	13,783	5,272	8.82
Average	1,601	14,311	12,630	12,918	6,347	8.41
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 12 Normal Years during 1953 through 1999						
Minimum	0	7,316	2,433	6,004	2,433	13.35
Median	5,101	26,198	21,172	11,844	11,743	16.92
Average	5,238	27,883	16,963	10,788	8,671	17.10
Maximum	12,671	52,631	27,521	15,778	13,223	21.22
Statistics for 22 Wet Years during 1953 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	7,507	44,252	25,525	10,822	20,505	23.17
Average	15,807	73,060	29,877	11,639	24,412	25.62
Maximum	67,058	258,660	81,744	17,824	64,049	42.17
Statistics for 11 Dry Years during 1953 through 1965 and 1975 through 1999						
Minimum	0	777	410	5,534	410	4.88
Median	79	14,770	10,806	13,783	5,272	8.96
Average	1,226	14,800	13,393	12,918	6,347	8.94
Maximum	5,830	32,382	31,239	17,847	14,475	11.64
Statistics for 10 Normal Years during 1953 through 1965 and 1975 through 1999						
Minimum	32	1,884	1,058	6,095	1,058	12.79
Median	944	17,197	15,463	10,678	8,649	13.97
Average	3,834	20,400	16,823	11,335	10,022	14.07
Maximum	13,787	47,930	36,366	16,831	25,703	15.88
Statistics for 17 Wet Years during 1953 through 1965 and 1975 through 1999						
Minimum	65	4,782	996	6,004	996	16.92
Median	5,611	48,024	31,327	10,822	20,505	23.14
Average	14,524	70,543	33,312	11,639	24,412	26.30
Maximum	67,058	205,139	81,744	17,824	64,049	42.17

TABLE 2-10
Historical Hydrology in Northern California and the Santa Clarita Valley
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Northern California Hydrology[a]	Local Hydrology[b]
1944	Dry	Wet
1945	Below Normal	Normal
1946	Below Normal	Wet
1947	Dry	Dry
1948	Below Normal	Dry
1949	Dry	Dry
1950	Below Normal	Dry
1951	Above Normal	Normal
1952	Wet	Wet
1953	Wet	Dry
1954	Above Normal	Normal
1955	Dry	Normal
1956	Wet	Normal
1957	Above Normal	Wet
1958	Wet	Wet
1959	Below Normal	Dry
1960	Dry	Dry
1961	Dry	Dry
1962	Below Normal	Wet
1963	Wet	Normal
1964	Dry	Dry
1965	Wet	Wet
1966	Below Normal	Normal
1967	Wet	Wet
1968	Below Normal	Dry
1969	Wet	Wet
1970	Wet	Wet
1971	Wet	Normal
1972	Below Normal	Dry
1973	Above Normal	Wet
1974	Wet	Wet
1975	Wet	Dry
1976	Critical	Normal
1977	Critical	Wet
1978	Above Normal	Wet
1979	Below Normal	Wet

TABLE 2-10
Historical Hydrology in Northern California and the Santa Clarita Valley
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	Northern California Hydrology[a]	Local Hydrology[b]
1980	Above Normal	Wet
1981	Dry	Normal
1982	Wet	Wet
1983	Wet	Wet
1984	Wet	Normal
1985	Dry	Dry
1986	Wet	Wet
1987	Dry	Normal
1988	Critical	Wet
1989	Dry	Dry
1990	Critical	Dry
1991	Critical	Wet
1992	Critical	Wet
1993	Above Normal	Wet
1994	Critical	Dry
1995	Wet	Wet
1996	Wet	Normal
1997	Wet	Normal
1998	Wet	Wet
1999	Wet	Dry

[a]Defined by water year, using the Sacramento Four Rivers Index (Figure 3-4 in Bulletin 160-98; DWR, 1998): wet = wettest; critical = driest.

[b]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-11
Historical State Water Project Allocations and Local Hydrology, 1980 through 1999
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Year	SWP Hydrology[a]	SWP Allocations[b]	Local Hydrology[c]
1980	Above Normal	100%	Wet
1981	Dry	100%	Normal
1982	Wet	100%	Wet
1983	Wet	100%	Wet
1984	Wet	100%	Normal
1985	Dry	100%	Dry
1986	Wet	100%	Wet
1987	Dry	85%	Normal
1988	Critical	100%	Wet
1989	Dry	100%	Dry
1990	Critical	100%	Dry
1991	Critical	30%	Wet
1992	Critical	45%	Wet
1993	Above Normal	85%	Wet
1994	Critical	50%	Dry
1995	Wet	80%	Wet
1996	Wet	100%	Normal
1997	Wet	100%	Normal
1998	Wet	100%	Wet
1999	Wet	100%	Dry

[a]Defined by water year, using the Sacramento Four Rivers Index (Figure 3-4 in Bulletin 160-98; DWR, 1998): wet = wettest; critical = driest. SWP = State Water Project.

[b]Contractor demands, and therefore requests for water, have been increasing through the time period shown. Water allocations in the earlier part of the time period reflect that 100% of contractor requests were met. Those requests were for amounts of water less than the full SWP contract (i.e., Table A) amounts totaling 4.1 million acre-feet. In recent years, SWP contractors have been requesting nearly all of the 4.1 million acre-foot Table A amount contained in the 29 SWP contracts.

[c]Defined from median rainfall (14.57 in/yr) from 1950 through 2000. Dry year < 12.38 in/yr (85 percent of median rainfall). Wet year > 16.75 in/yr (115 percent of median rainfall).

TABLE 2-12

Castaic Creek Flood Flows

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Water Year[a]	Natural Inflows	Flood Flows 10/1 - 4/30	Late Flood Flows[b] 5/1 - 9/30	Total Flood Flows	Net Flood Flows[c]	Flood Flow Shares UWCD 48%	NLF 44.867%	LACWWD 4.471%	NCWD 2.662%	Total NLF/LACWWD/ NCWD Flood Flows
1977	752	0	0	0	0	0	0	0	0	0
1978	92,780	89,592	325	89,917	67,438	32,370	30,257	3,015	1,795	35,068
1979	31,440	19,641	0	19,641	14,731	7,071	6,609	659	392	7,660
1980	54,158	47,625	101	47,726	35,794	17,181	16,060	1,600	953	18,613
1981	6,186	628	0	628	471	226	211	21	13	245
1982	8,930	3,544	0	3,544	2,658	1,276	1,193	119	71	1,382
1983	78,010	74,287	3,020	77,307	57,981	27,831	26,014	2,592	1,543	30,150
1984	10,582	2,106	0	2,106	1,580	758	709	71	42	822
1985	3,361	0	0	0	0	0	0	0	0	0
1986	20,005	13,867	0	13,867	10,400	4,992	4,666	465	277	5,408
1987	1,212	0	0	0	0	0	0	0	0	0
1988	4,401	807	0	807	605	290	272	27	16	315
1989	919	0	0	0	0	0	0	0	0	0
1990	540	0	0	0	0	0	0	0	0	0
1991	6,719	4,375	0	4,375	3,281	1,575	1,472	147	87	1,706
1992	29,409	22,631	0	22,631	16,973	8,147	7,615	759	452	8,826
1993	81,264	77,722	0	77,722	58,291	27,980	26,154	2,606	1,552	30,312
1994	6,424	502	0	502	377	181	169	17	10	196
1995	57,914	53,363	0	53,363	40,022	19,211	17,957	1,789	1,065	20,812
1996	7,105	1,654	0	1,654	1,241	596	557	55	33	645
1997	9,028	3,918	0	3,918	2,938	1,410	1,318	131	78	1,528
1998	68,846	66,597	11,639	78,236	58,677	28,165	26,327	2,623	1,562	30,512
1999	7,793	238	0	238	179	86	80	8	5	93
2000	7,212	4,118	0	4,118	3,088	1,482	1,386	138	82	1,606
Totals	**594,990**	**487,215**	**15,085**	**502,300**	**376,725**	**180,828**	**169,025**	**16,843**	**10,028**	**195,897**
Average	**24,791**	**20,301**	**629**	**20,929**	**15,697**	**7,535**	**7,043**	**702**	**418**	**8,162**
Median	**8,362**	**3,731**	**0**	**3,731**	**2,798**	**1,343**	**1,255**	**125**	**74**	**1,455**

[a]A water year is from October 1 to September 30, but the flood flow water is generally available only from October 1 through April 30.

[b]Late flood flows are from May 1 through September 30.

[c]Net flood flows are 75% of total flood flows.

Note:

All flows are listed in acre-feet.

Figures

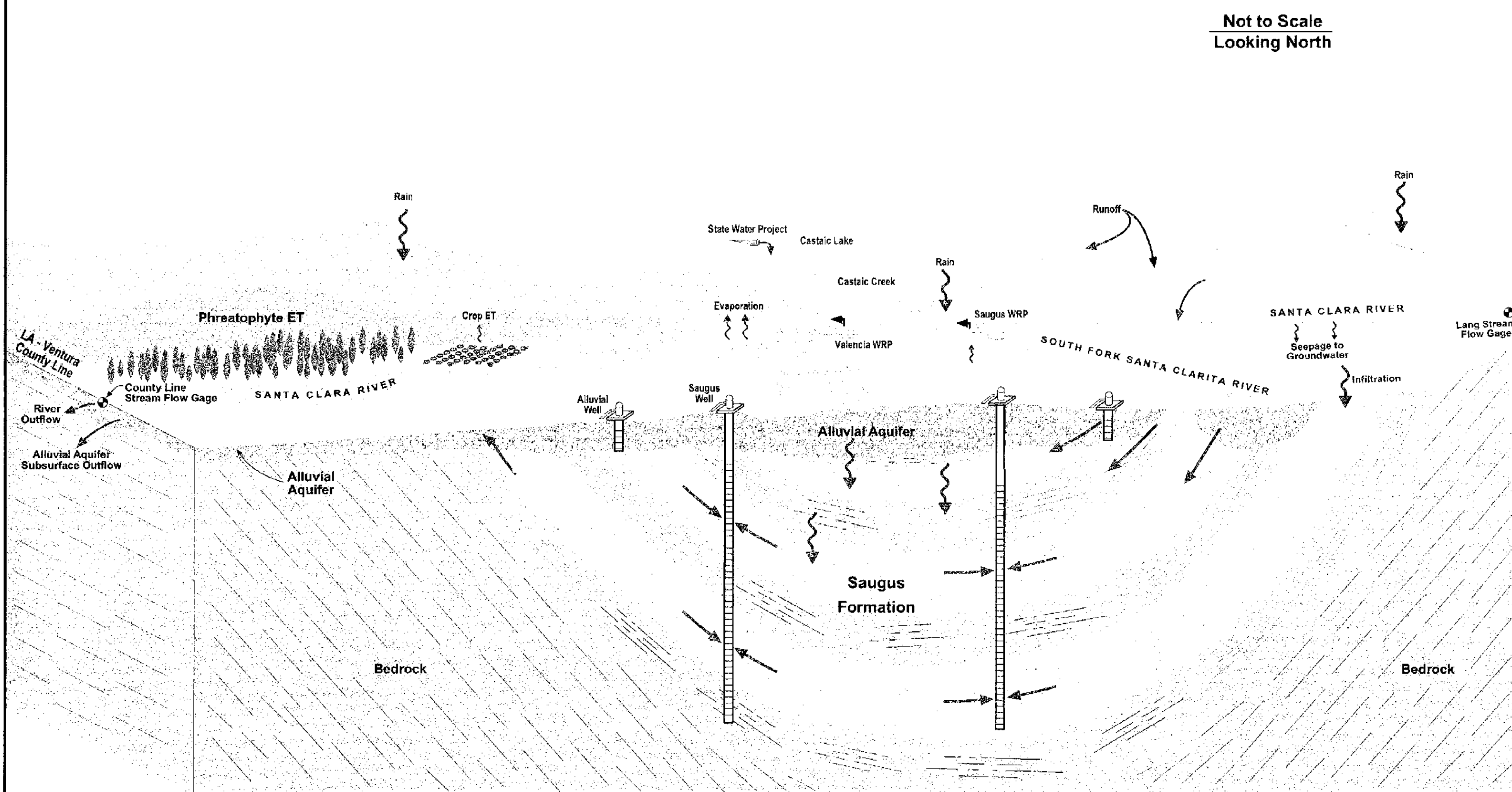

FIGURE 2-1
SANTA CLARITA VALLEY HYDROLOGY
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

ES12004006HDD_01 (1/20/04)

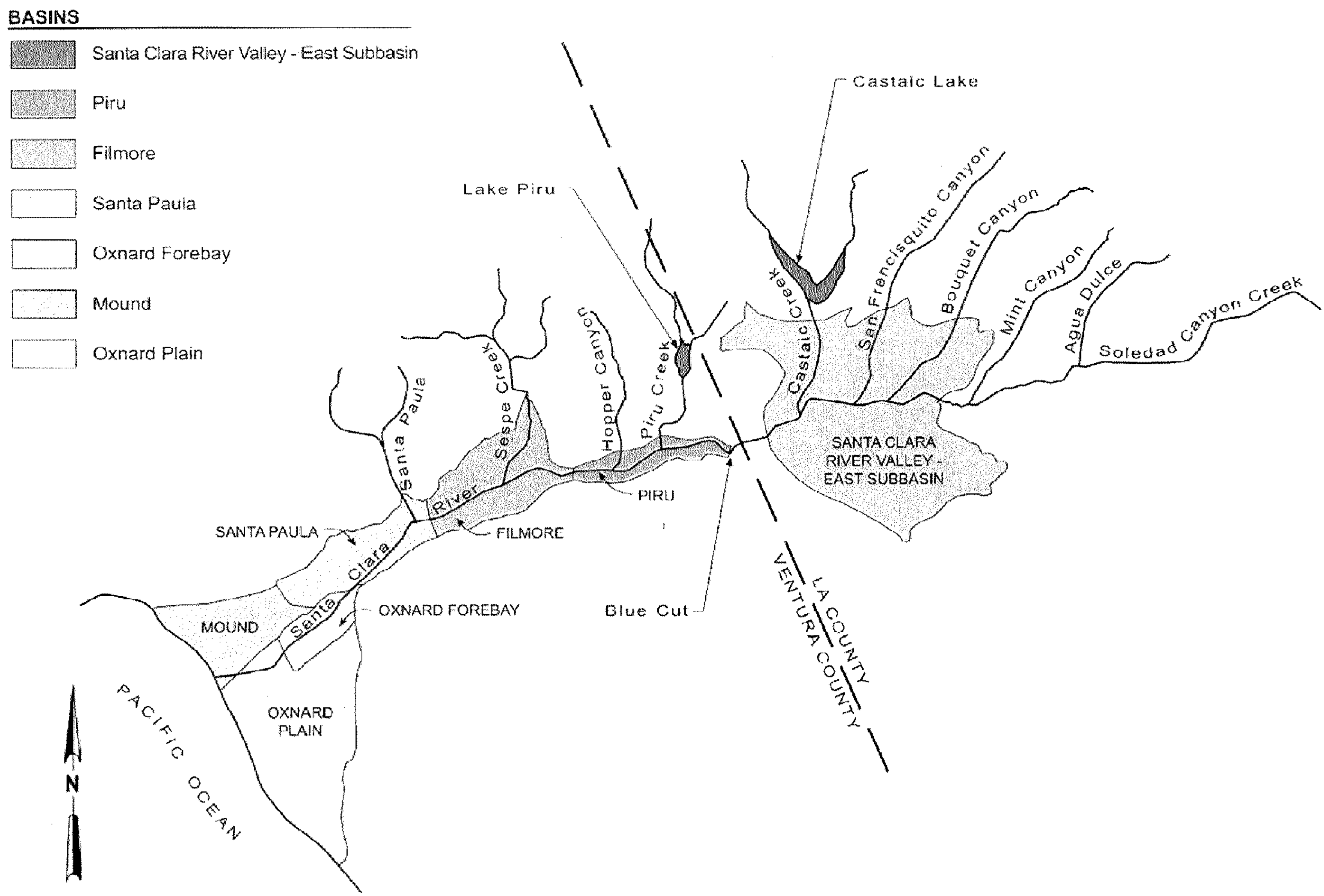

FIGURE 2-2
GROUNDWATER BASINS IN THE SANTA CLARA RIVER DRAINAGE
REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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FIGURE 2-3
WELL LOCATIONS AND FEATURES MAP

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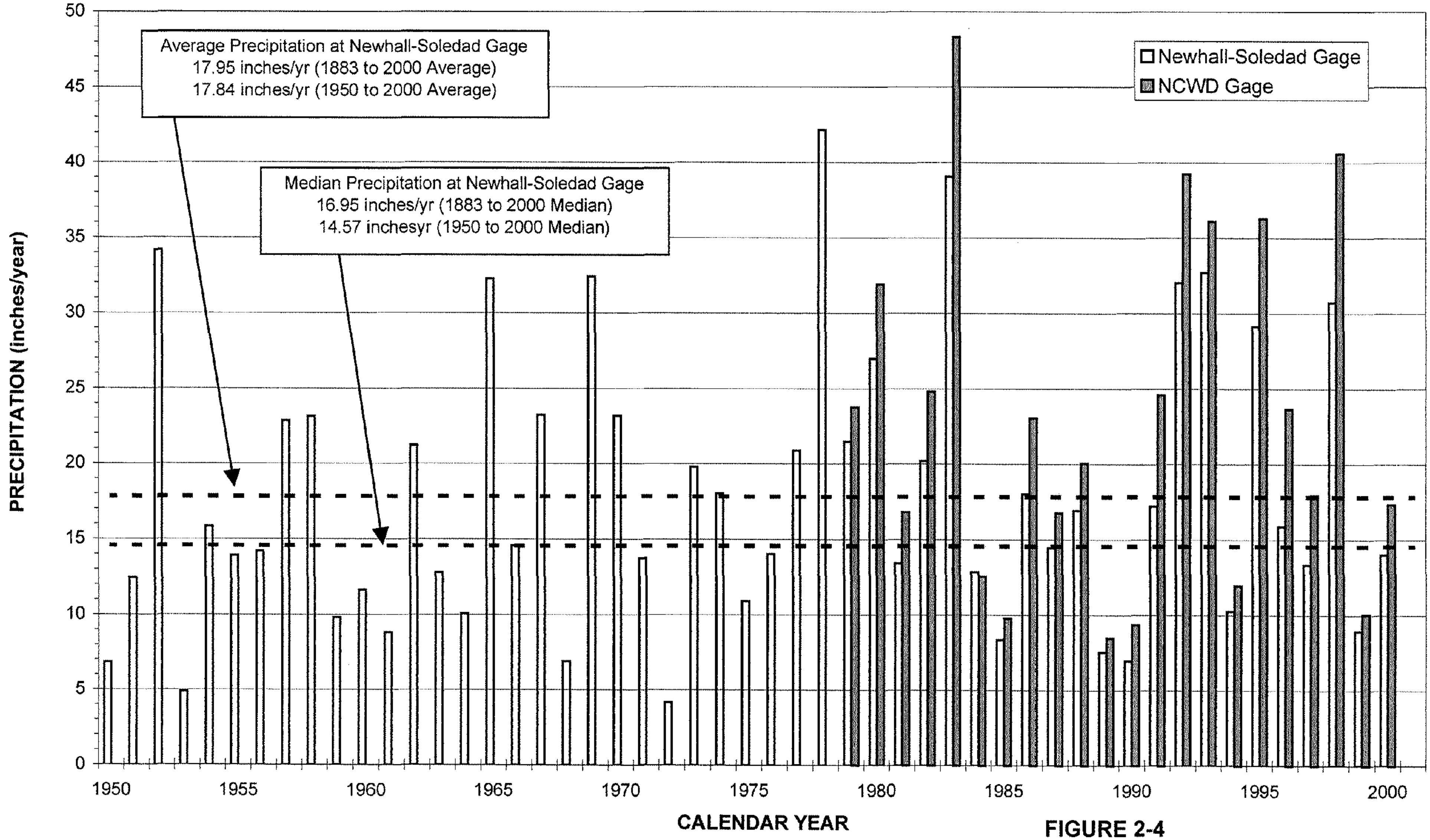

FIGURE 2-4
ANNUAL PRECIPITATION AT THE NEWHALL-SOLEDAD AND NCWD RAIN GAGES SINCE 1950
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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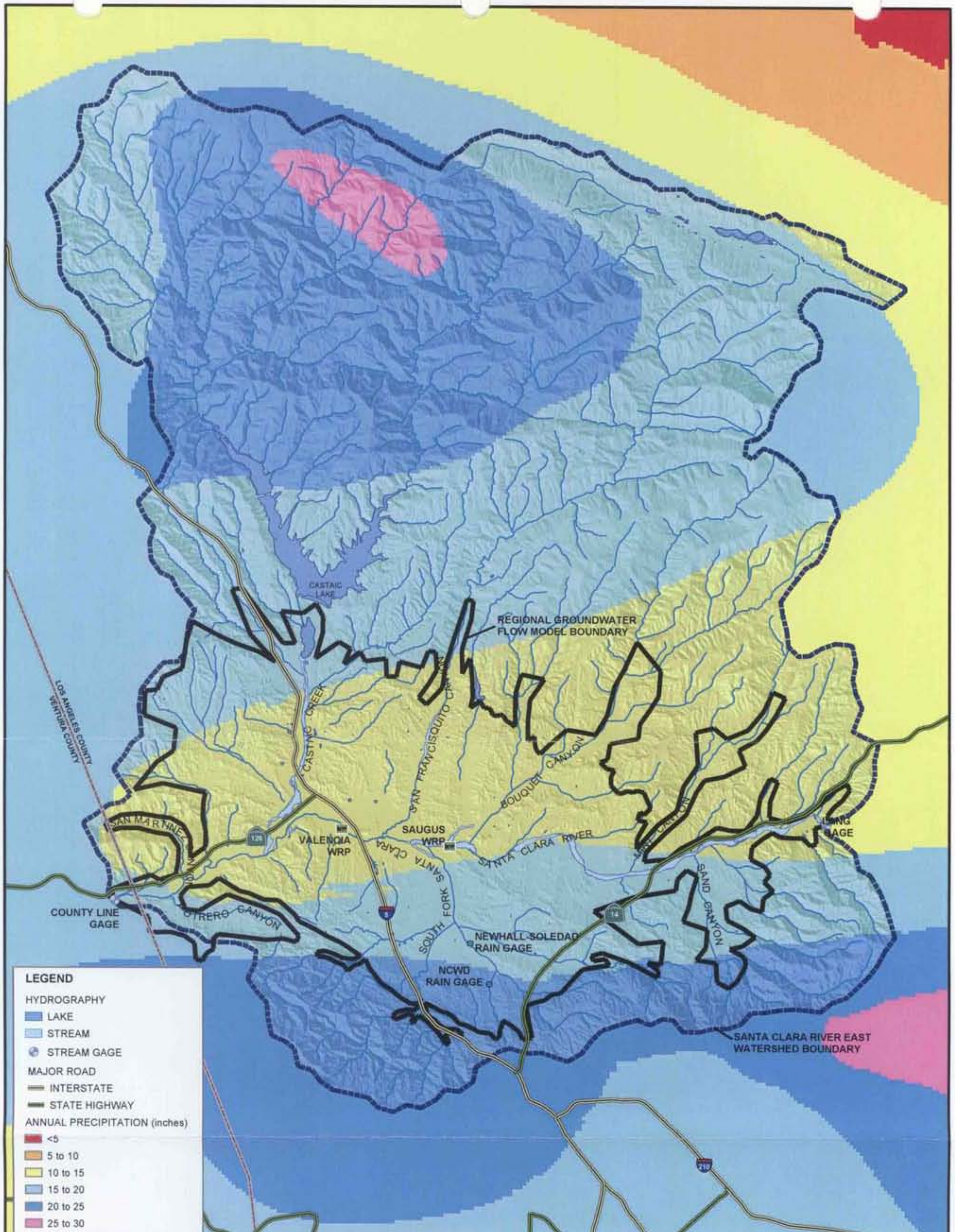
178973-401.xls\Fig 2-4



SOURCE: SEE THE INTERNET SITE HTTP://GIS.CA.GOV/META.EPL?OID=286 FOR MORE INFORMATION.

N

0 2.5 5 miles

FIGURE 2-5
ISOHYETAL MAP SHOWING AVERAGE ANNUAL PRECIPITATION PATTERN FROM 1900 TO 1960

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ\255\SANTACLARITA_MOU\FIGURES\MXD\FIG0205.MXD FIG0205.PDF

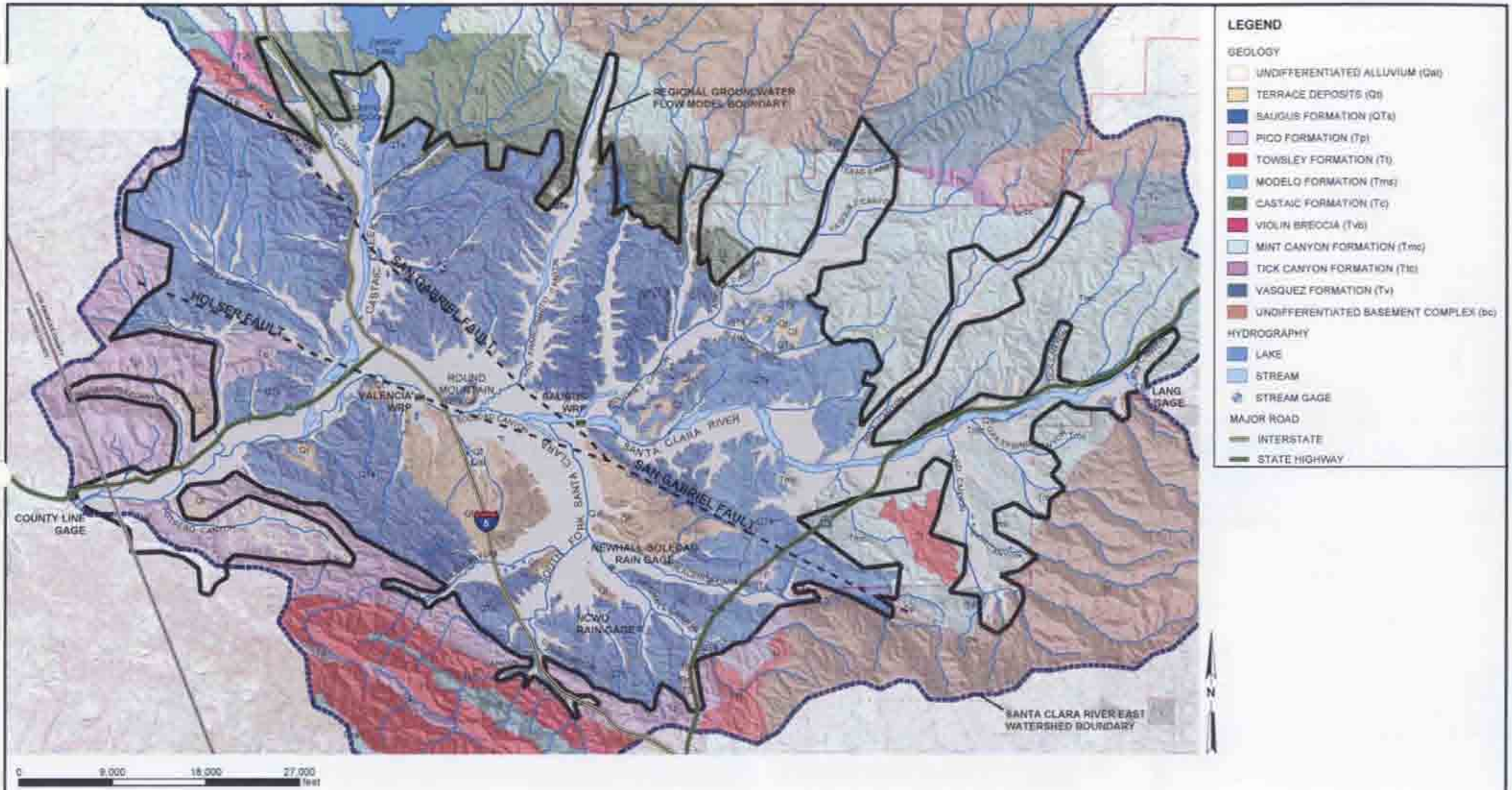
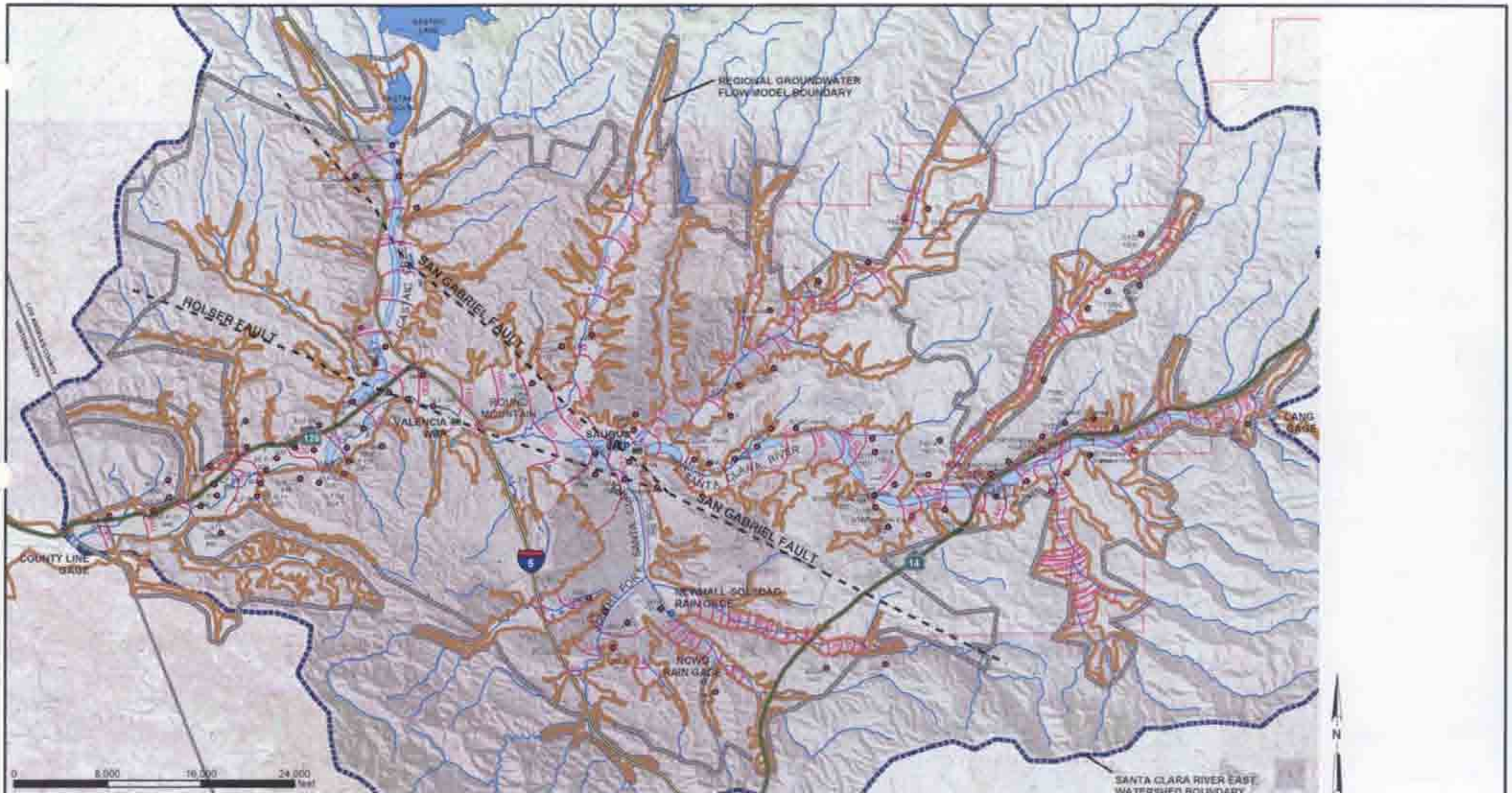


FIGURE 2-6
BASIN GEOLOGIC MAP
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA



NOTE: GROUNDWATER ELEVATION DATA TAKEN DIRECTLY FROM PLATE 4-3 OF RCS 2001 UPDATE REPORT. (RCS, 2002)

LEGEND

- CONTOUR OF SPRING 2000 GROUNDWATER ELEVATION (feet MSL)
- SPRING 2000 GROUNDWATER ELEVATION (feet MSL)
- EXTENT OF ALLUVIUM
- LAKE
- STREAM

FIGURE 2-7
GROUNDWATER ELEVATION CONTOUR MAP FOR THE ALLUVIUM – SPRING 2000
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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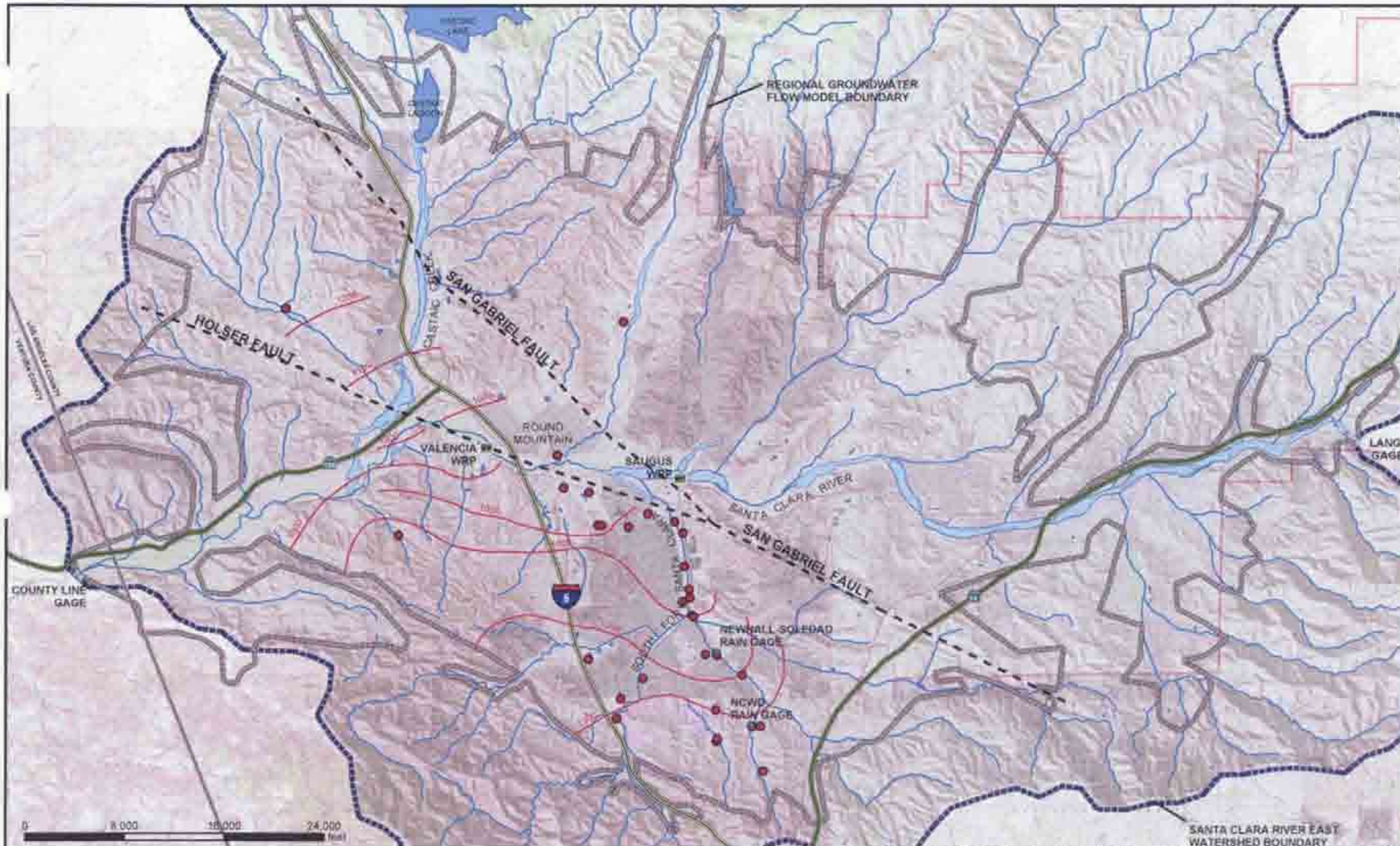
RDD \\ODIN\PROJ2\SS\SANTACLARITA_MOU\FIGURES\MXD\FIG0207.MXD FIG02-07.PDF 02/02/2004 12:27:27



NOTE: GROUNDWATER ELEVATION DATA TAKEN DIRECTLY FROM PLATE 5-3 OF RCS 2001 UPDATE REPORT. (RCS, 2002)

LEGEND

- SAUGUS WELLS
- CONTOUR OF FALL 2000 GROUNDWATER ELEVATION (feet MSL)
- LAKE
- STREAM

FIGURE 2-8
GROUNDWATER ELEVATION CONTOUR MAP FOR THE SAUGUS – FALL 2000
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\05\SANTACLARITA_MOU\FIGURES\MXD\FIG0208.MXD FIG02-08.PDF 02/04/2004 10:57:46

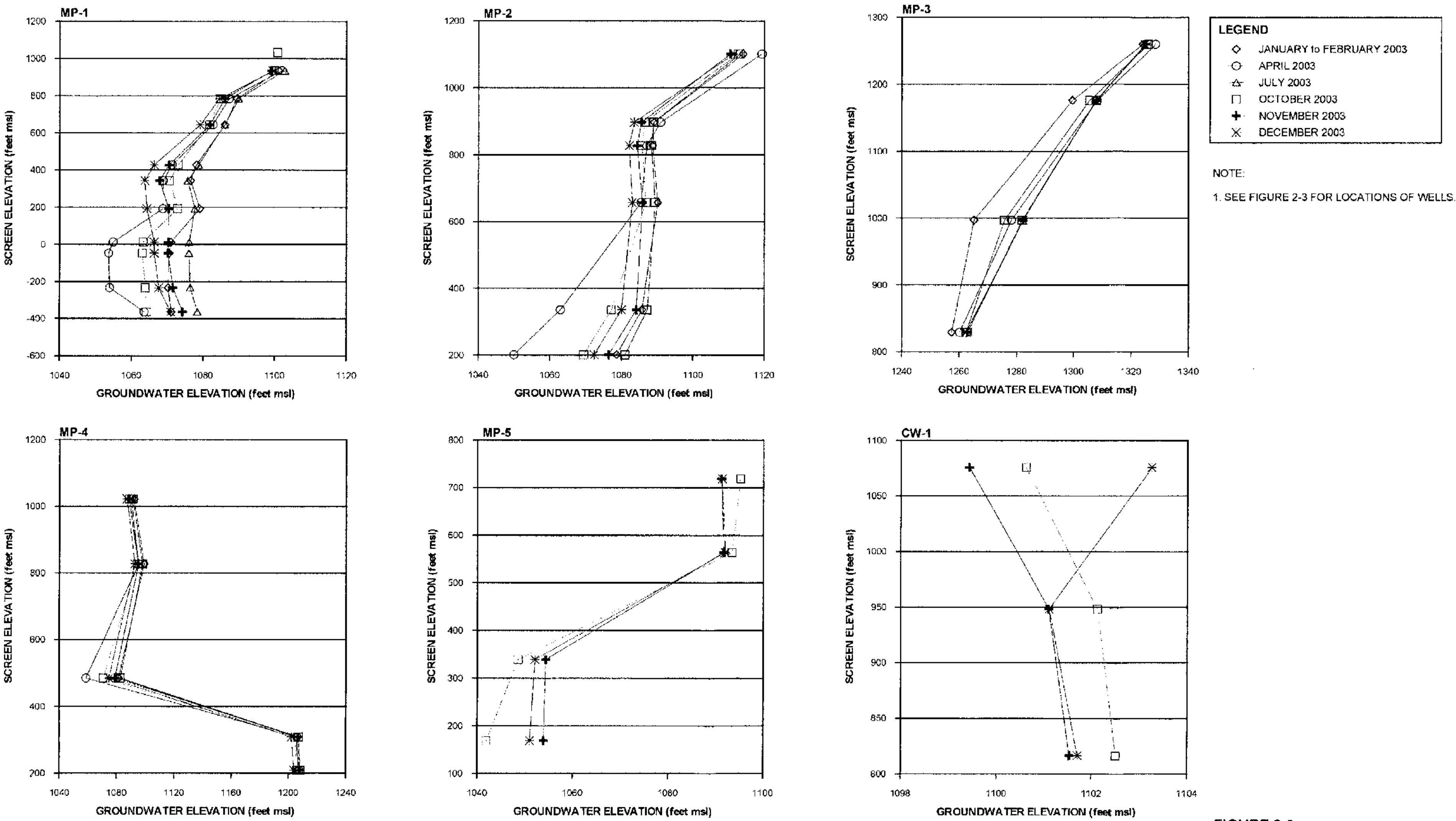

FIGURE 2-9
GROUNDWATER ELEVATIONS IN MULTI-PORT SAUGUS FORMATION MONITORING WELLS JANUARY 2003 THROUGH DECEMBER 2003
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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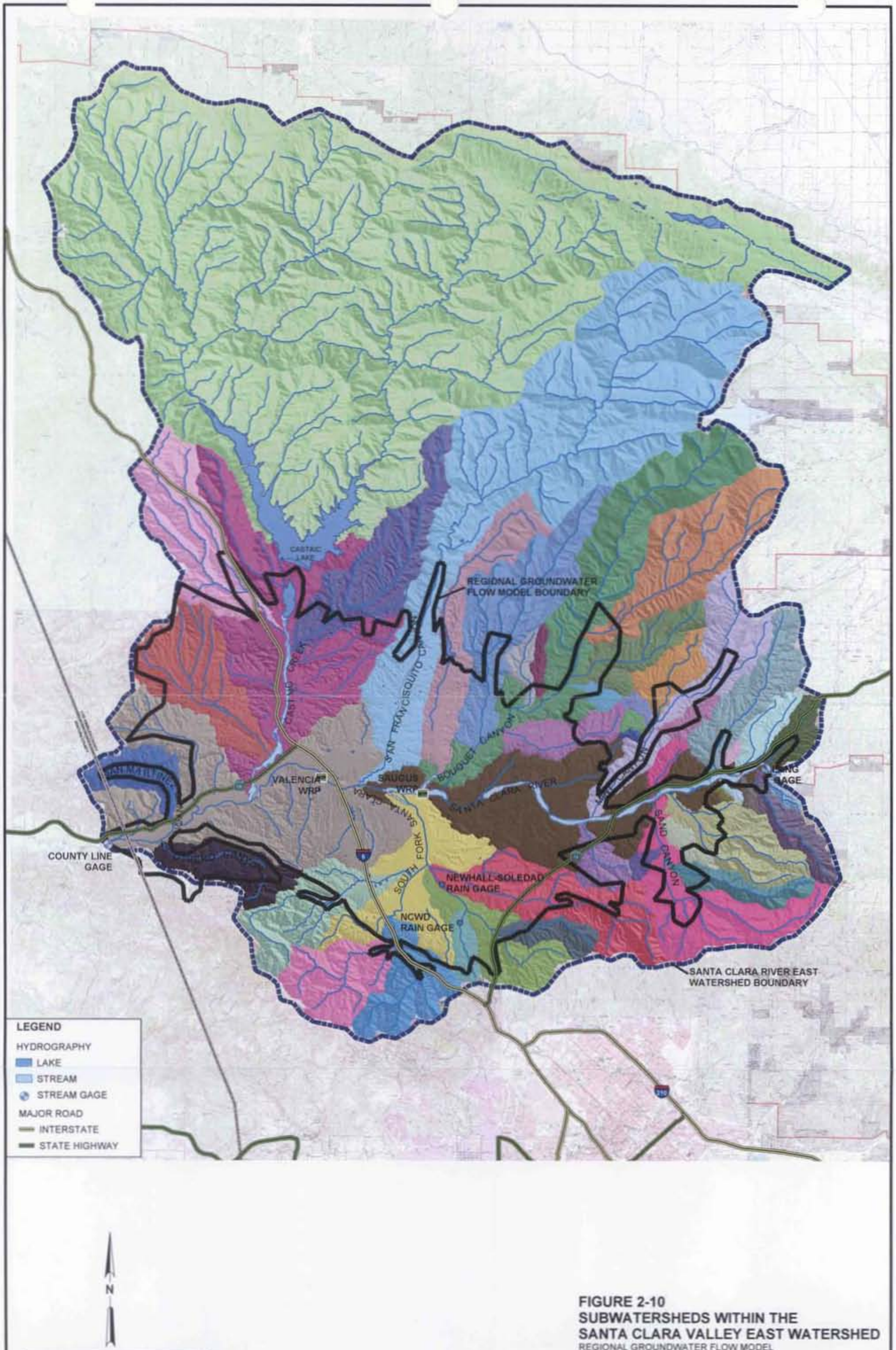

FIGURE 2-10
SUBWATERSHEDS WITHIN THE SANTA CLARA VALLEY EAST WATERSHED
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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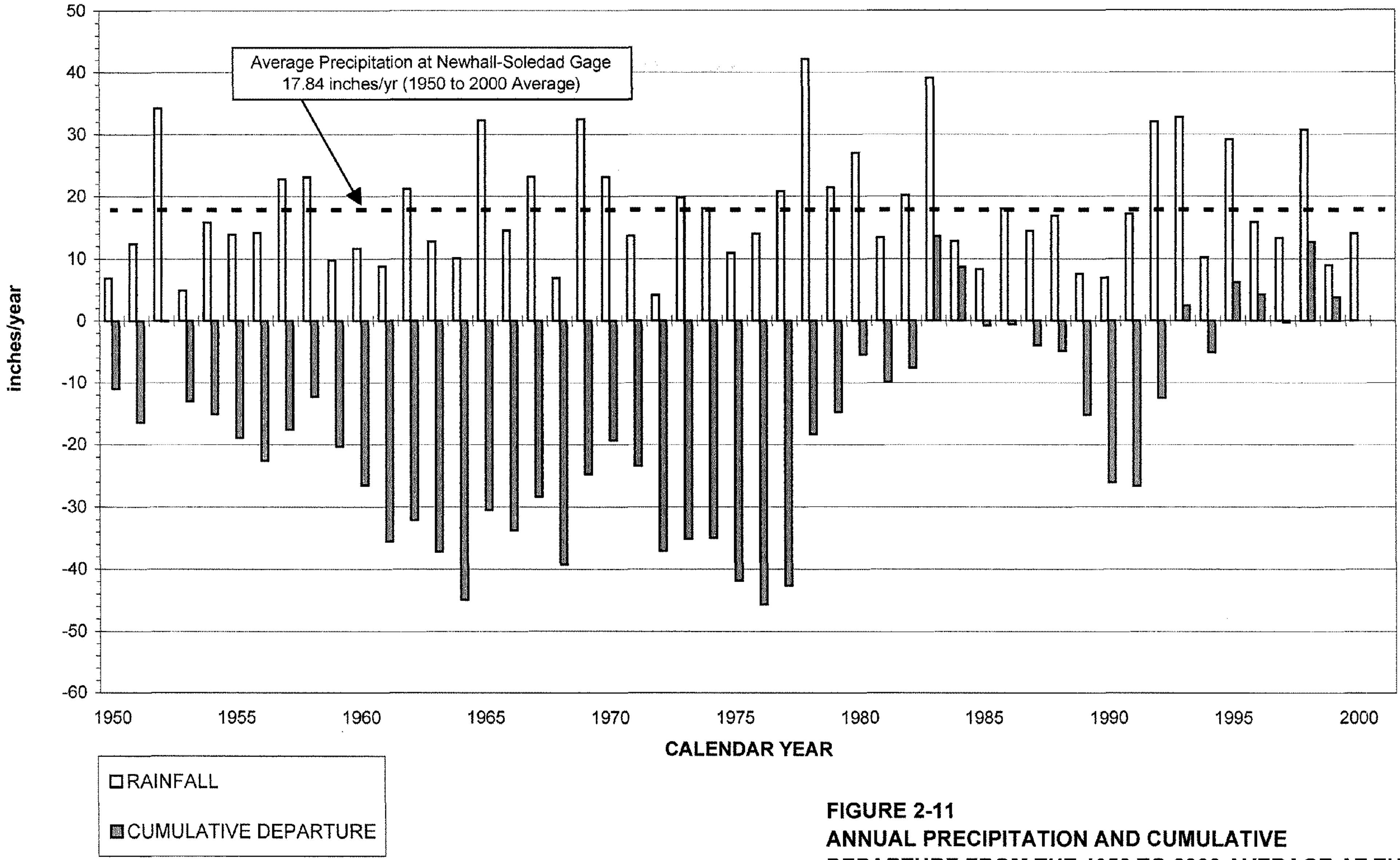

FIGURE 2-11
ANNUAL PRECIPITATION AND CUMULATIVE DEPARTURE FROM THE 1950 TO 2000 AVERAGE AT THE NEWHALL-SOLEDAD RAIN GAGE SINCE 1950
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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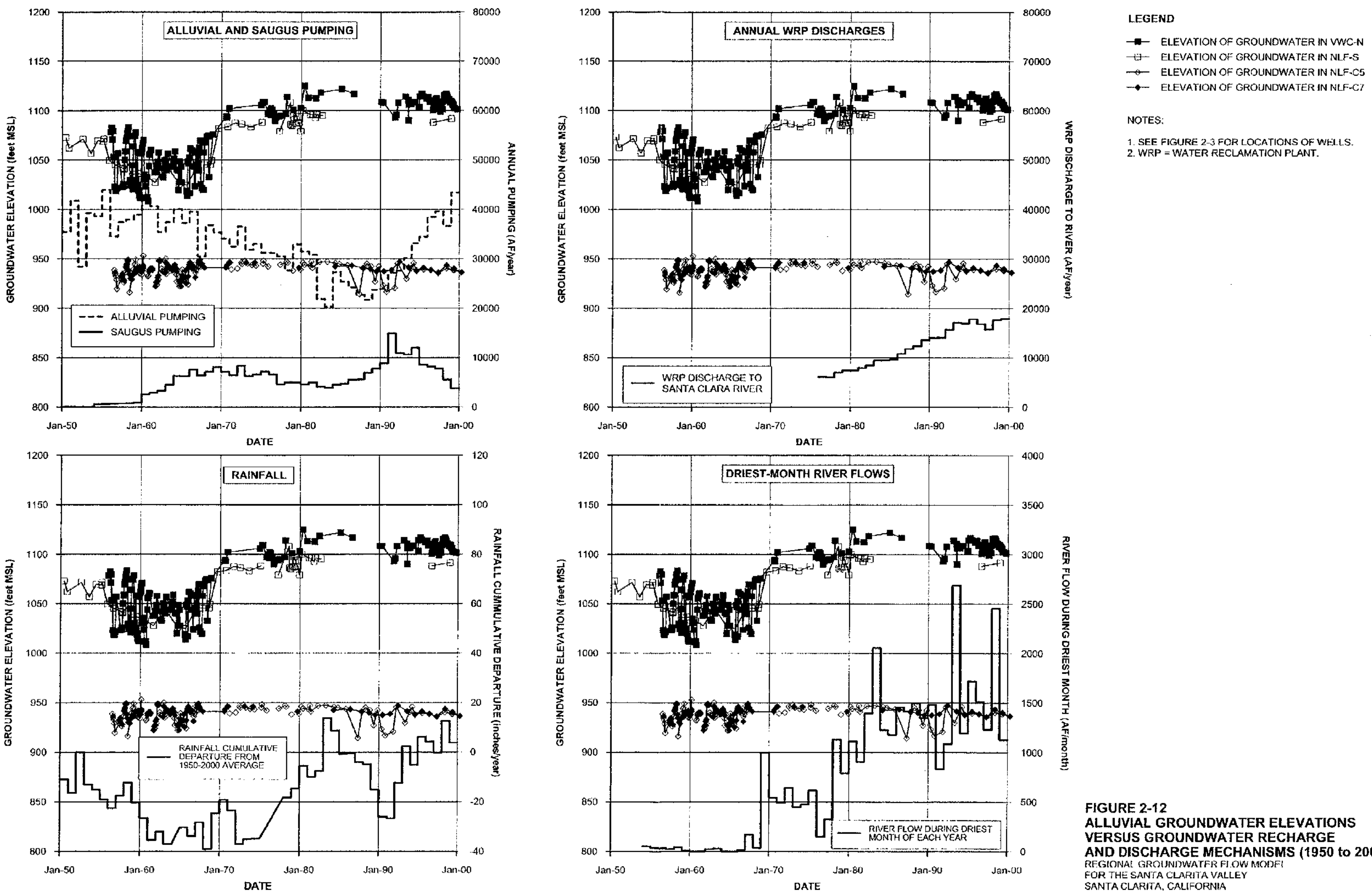

FIGURE 2-12
ALLUVIAL GROUNDWATER ELEVATIONS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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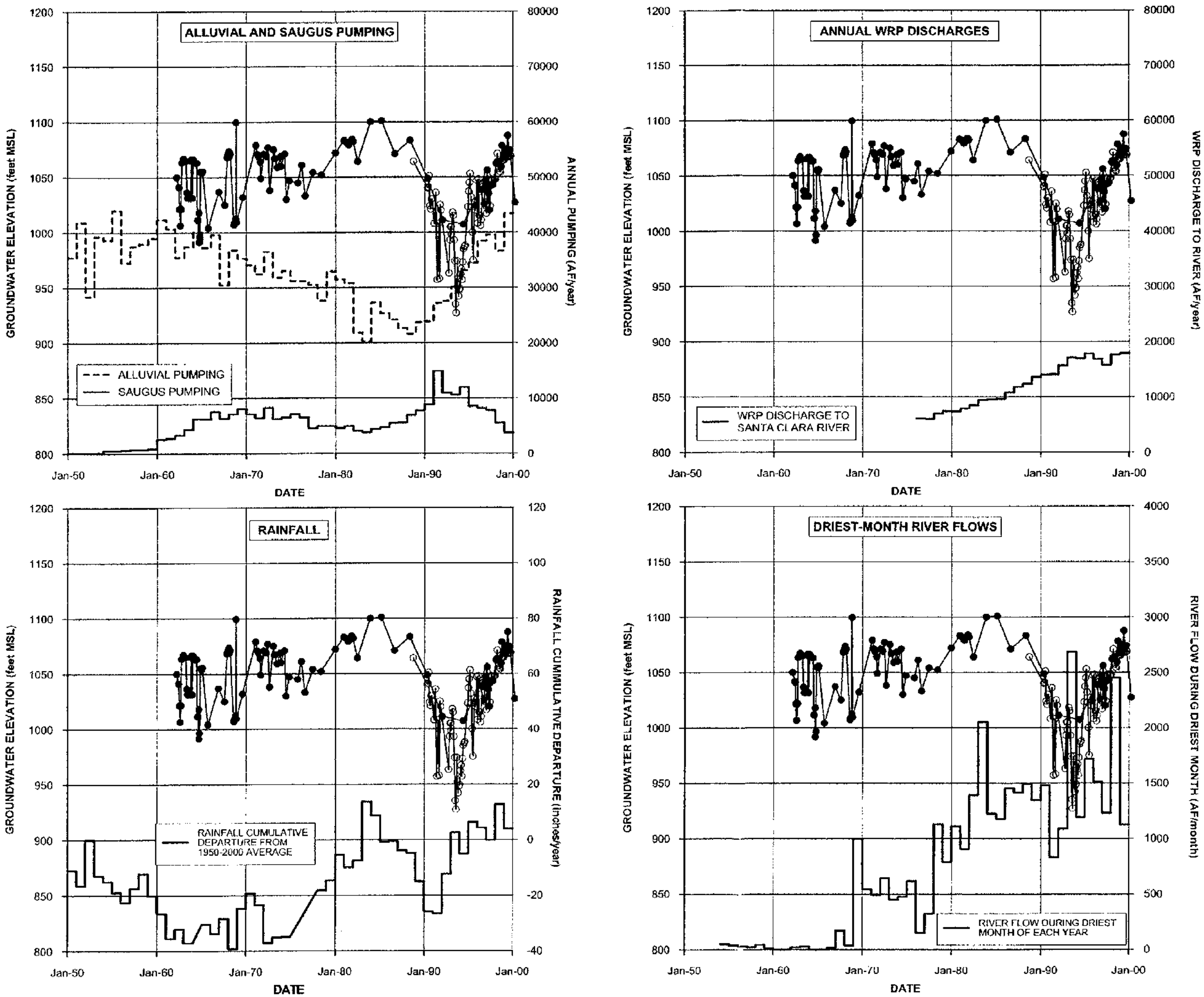

LEGEND

- ELEVATION OF GROUNDWATER IN VWC-157
- ELEVATION OF GROUNDWATER IN SCWC SAUGUS 2

NOTES:

1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

FIGURE 2-13
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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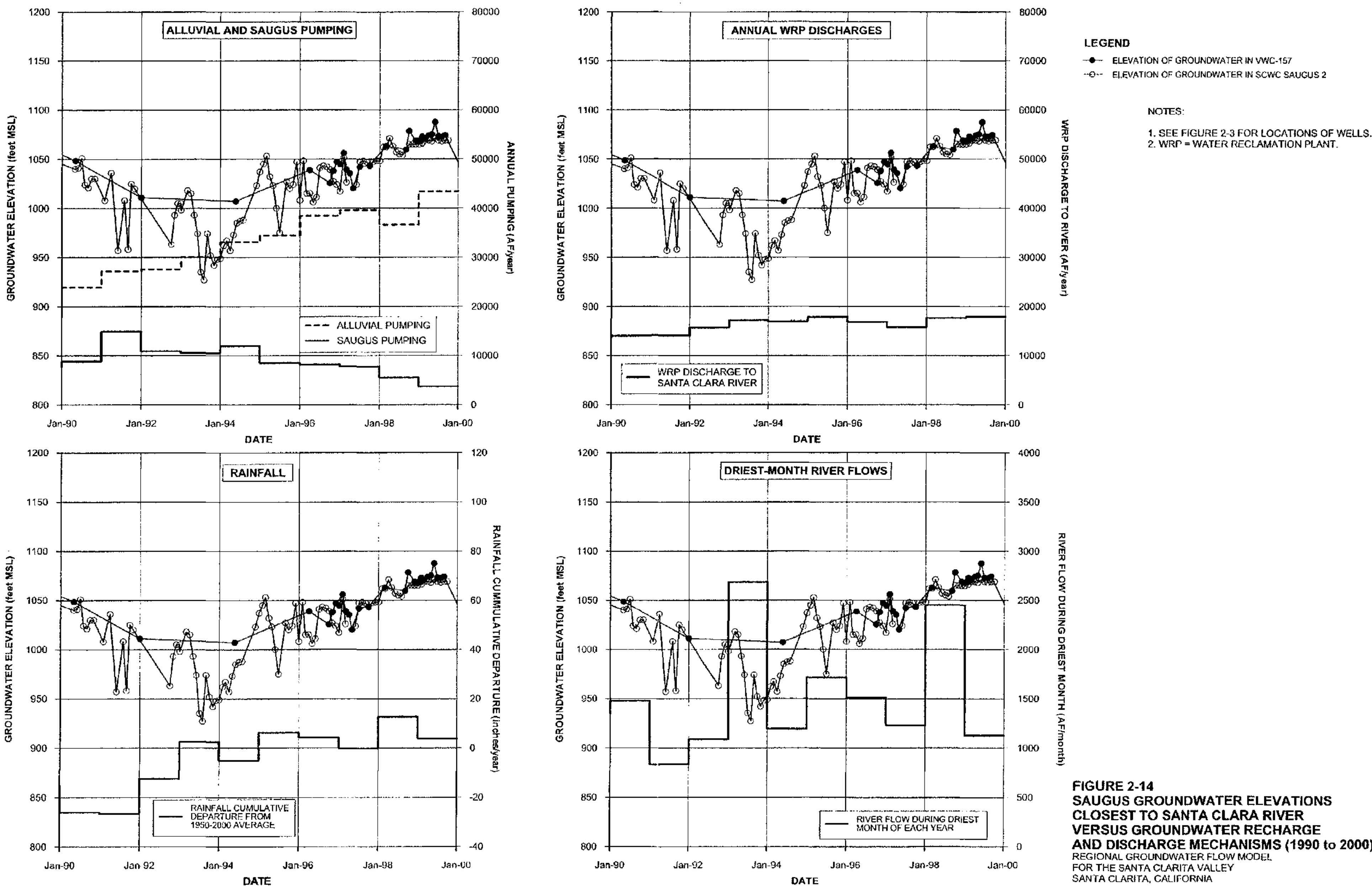

FIGURE 2-14
SAUGUS GROUNDWATER ELEVATIONS CLOSEST TO SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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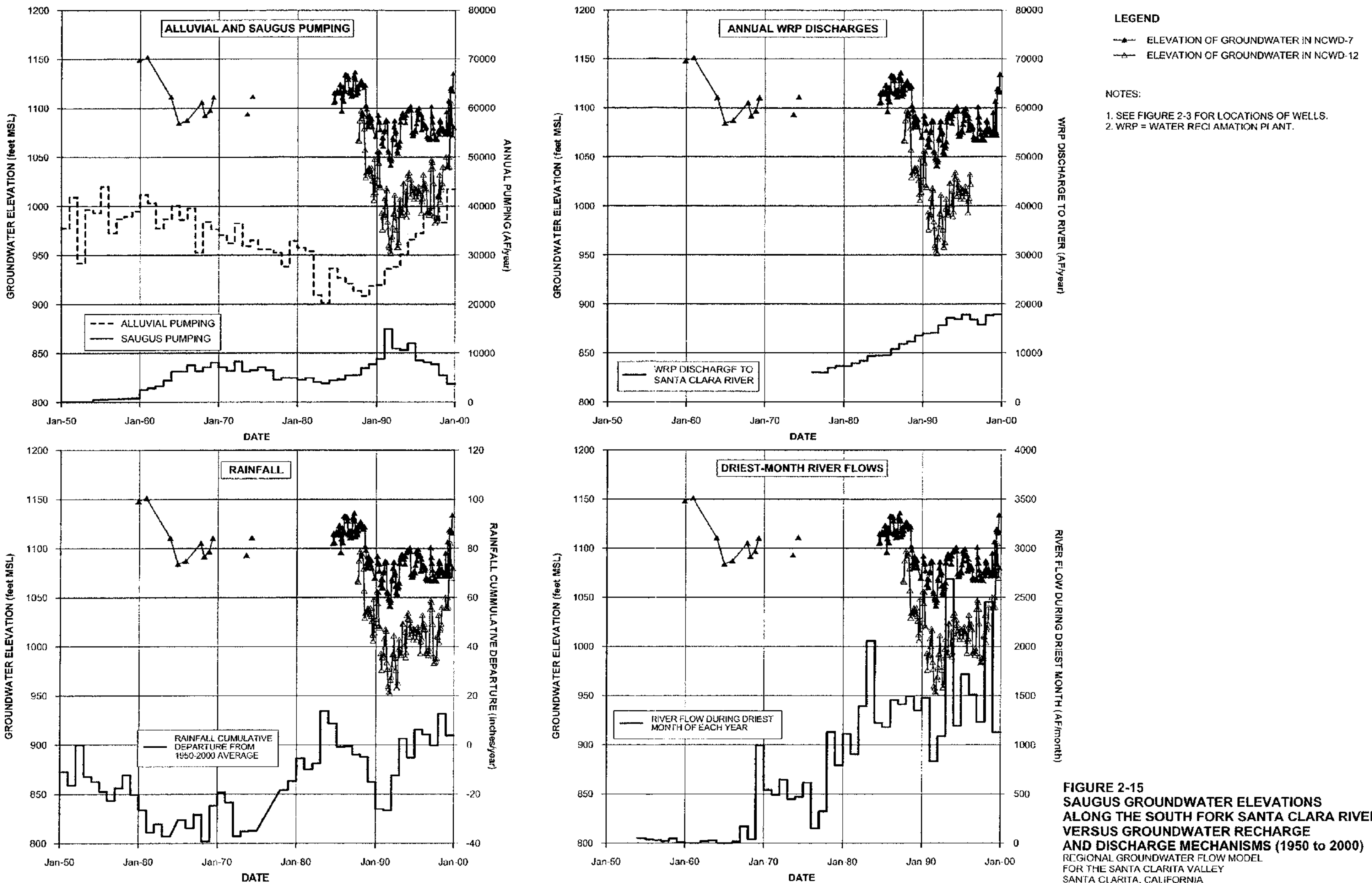

FIGURE 2-15
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

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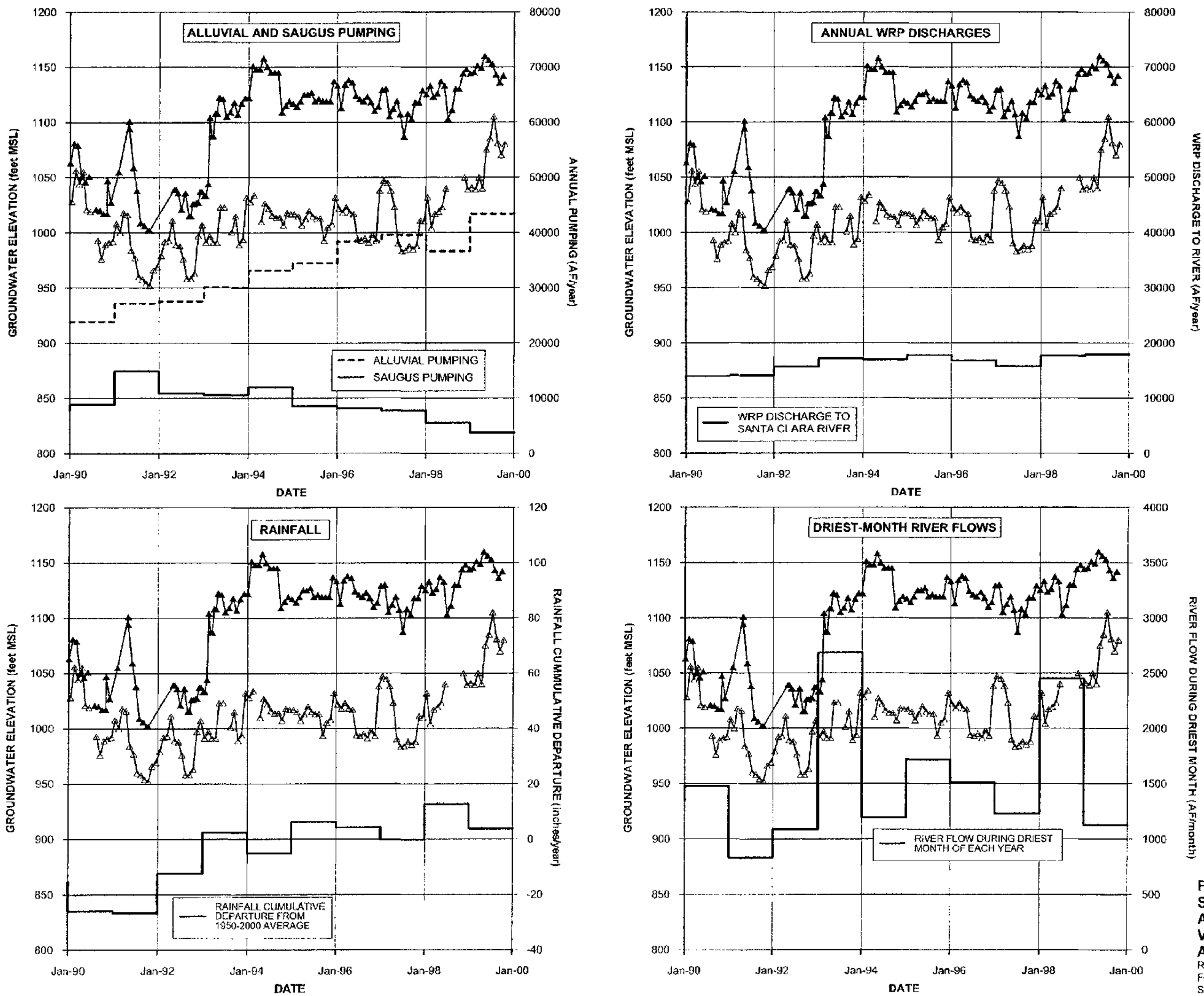

LEGEND

ELEVATION OF GROUNDWATER IN NCW-10

ELEVATION OF GROUNDWATER IN NCW-12

NOTES:

1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

FIGURE 2-16
SAUGUS GROUNDWATER ELEVATIONS ALONG THE SOUTH FORK SANTA CLARA RIVER VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1990 to 2000)

REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

CH2MHILL

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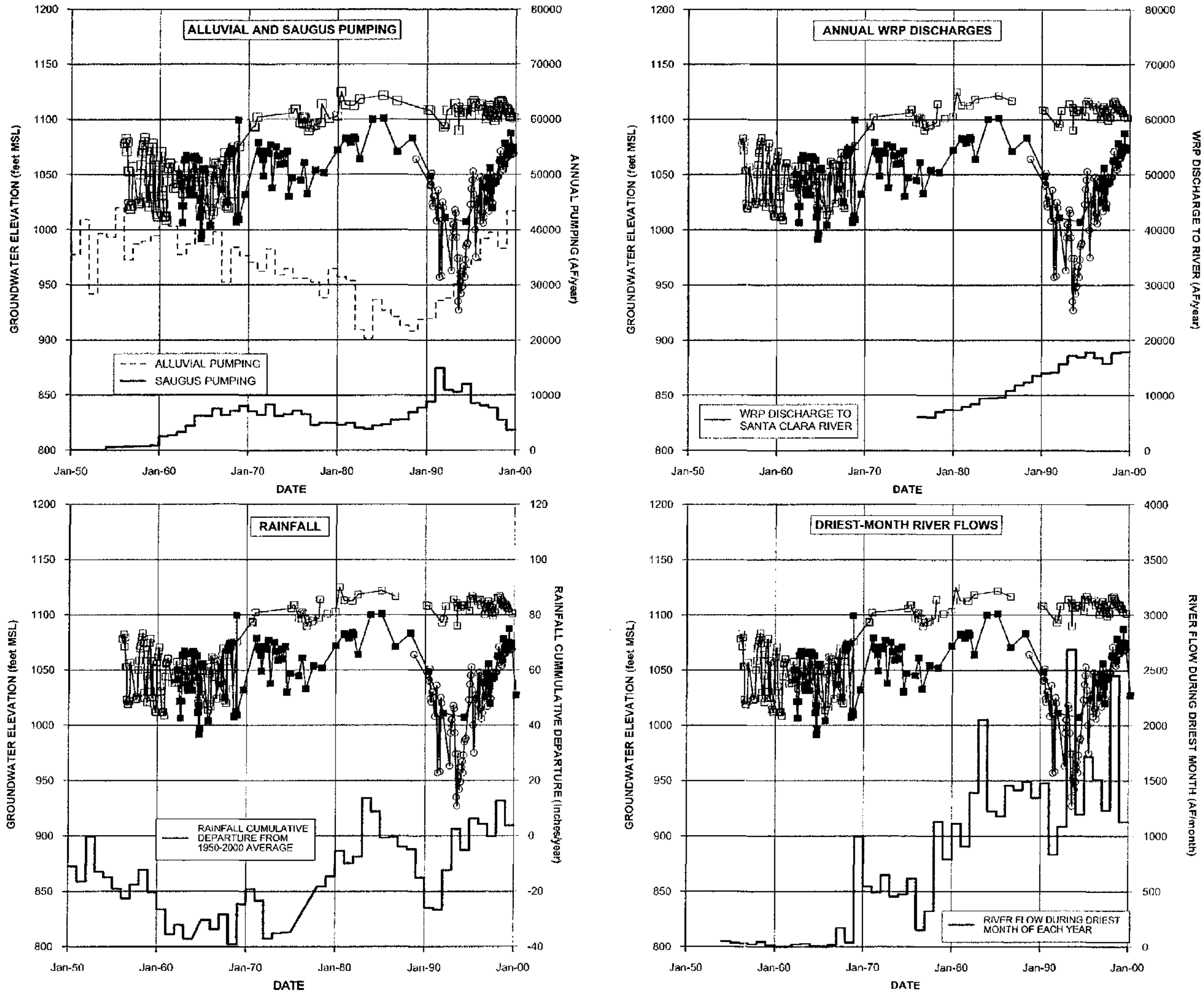

LEGEND

- ELEVATION OF GROUNDWATER IN VWC-N (ALLUVIUM)
- ELEVATION OF GROUNDWATER IN NVWC-157 (SAUGUS)
- ELEVATION OF GROUNDWATER IN SWC SAUGUS 2 (SAUGUS)

NOTES:

1. SEE FIGURE 2-3 FOR LOCATIONS OF WELLS.
2. WRP = WATER RECLAMATION PLANT.

FIGURE 2-17
GROUNDWATER ELEVATIONS IN ADJACENT ALLUVIAL AND SAUGUS WELLS VERSUS GROUNDWATER RECHARGE AND DISCHARGE MECHANISMS (1950 to 2000)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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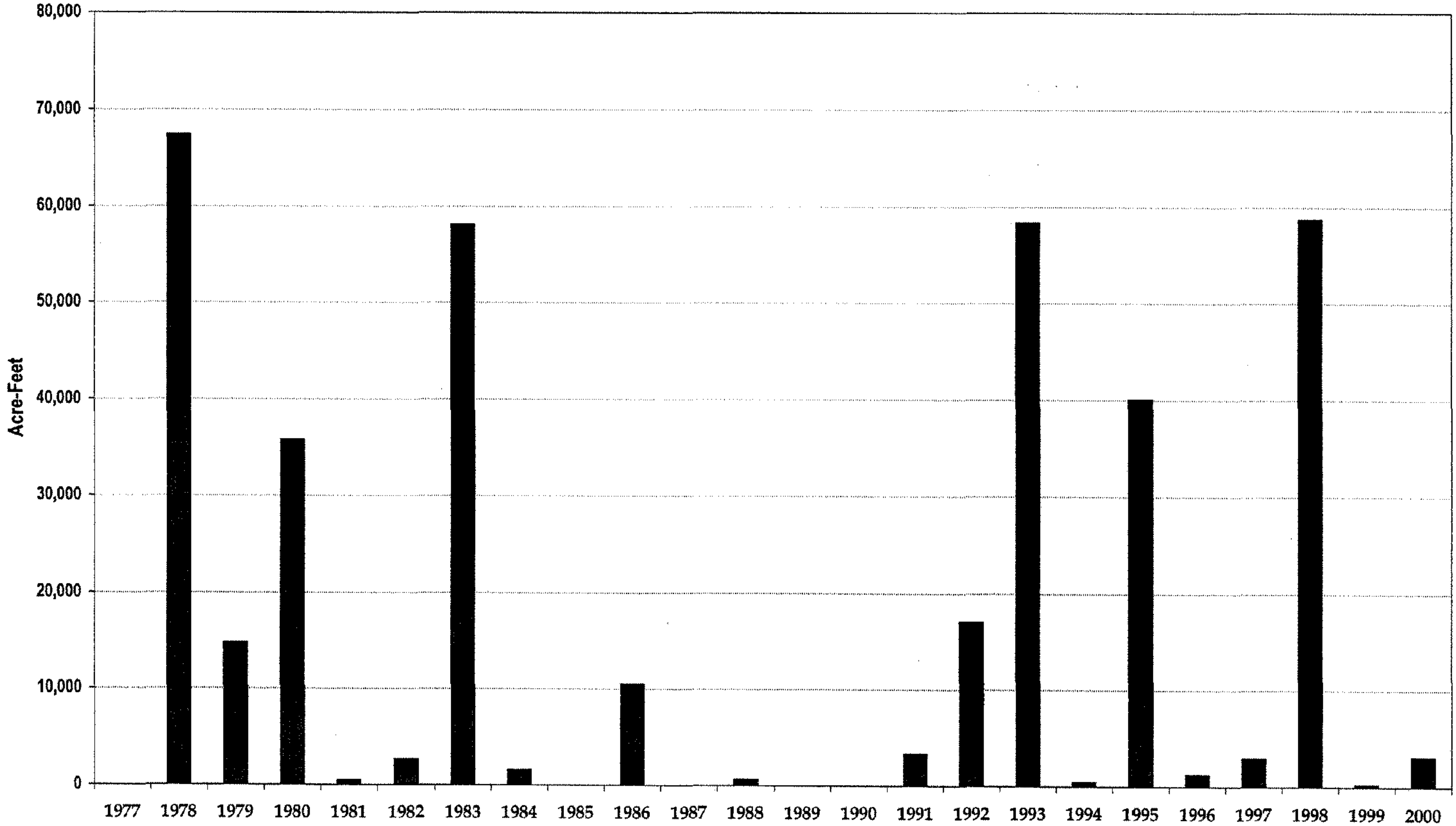
178973-306.GRF



This chart shows the potential Flood Flows available during water years 1977 through 2000. Water Year 1977 is defined as October 1, 1976 through September 30, but the water is generally available only from October 1 through April 30.

FIGURE 2-18
NET CASTAIC CREEK FLOOD FLOWS AVAILABLE TO DOWNSTREAM USERS
REGIONAL GROUNDWATER FLOW MODEL
REPORT FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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SECTION 3

Model Construction

The Regional Model is a three-dimensional numerical model of groundwater flow in the Alluvial Aquifer and the Saugus Formation. The model simulates changes in groundwater flow and storage during the recent 20-year period from 1980 through 1999. This section of the report presents the overall approach to the construction of the Regional Model including the model software; model domain; grid design; layering scheme; boundary conditions; designation of subareas within the model domain; and the process for estimating the magnitudes of groundwater recharge and pumping terms required by the model.

3.1 Modeling Software

The Regional Model was constructed using the three-dimensional finite-element groundwater modeling software called MicroFEM® (Hemker and de Boer, 2003). MicroFEM® operates in a Windows™ environment and can be used to solve groundwater flow problems for unconfined, semi-confined, or confined aquifer systems. This software simulates steady-state or transient flow conditions in up to a 20-layer aquifer system; the finite-element mesh may contain as many as 50,000 nodes in each model layer. The software contains several different methods for simulating groundwater/surface water interactions. MicroFEM® is based on software developed in the Netherlands during the 1980s for use in evaluating the effects of groundwater pumping in areas with complicated meandering rivers. Further details regarding this software's design, capabilities, and functionality can be found on the Internet at www.microfem.com and in two reviews of the software by Diodato (1997, 2000).

3.2 Extent of the Model Domain

A finite-element mesh was designed that covers the entire area underlain by the Saugus Formation, plus the portions of the Alluvial Aquifer that lie beyond the limits of the Saugus Formation. The model area largely coincides with the Santa Clara River Valley East Groundwater Subbasin, extending from the Lang stream gage at the eastern end of the valley to the County Line gage area in the west. The northern and southern edges of the model domain are defined by the geologic contacts mapped by RCS (2002) for the Alluvial Aquifer and the Saugus Formation. Figure 2-10 shows the model domain, along with its location relative to the upstream watersheds that contribute runoff into the model study area.

3.3 Model Grid

Figure 3-1 shows the spacing of the individual nodes that comprise the grid. The mesh contains 17,103 nodes in each model layer. The nodes are connected by segments, forming 32,496 triangular elements. Calculations of all flow components (recharge and discharge), groundwater storage, and groundwater elevations are performed by the model for each node and segment.

The nodes are 500 feet apart in the majority of the modeled area. However, a finer node spacing (150 feet) was used along the Santa Clara River and its tributaries to allow a more exact simulation of surface water/groundwater exchanges. Additionally, specific nodes were placed within this regional grid at the locations of production and monitoring wells.

3.4 Layering

The groundwater system was represented in the Regional Model with seven layers. The layer representation is summarized schematically on Figure 3-2. The Alluvial Aquifer, where present, was modeled with a single layer, and the Saugus Formation was modeled with multiple layers to its total depth, which was defined as the base of the Sunshine Ranch Member of the Saugus Formation. Figures 3-3 through 3-9 show the assigned thicknesses in model layers 1 through 7. Figure 3-10 shows the total modeled saturated thickness of the Saugus Formation. Figures 3-11 through 3-17 show the elevations of the base of each model layer. Figure 3-18 shows the model layering in three cross-sectional views. Further details regarding model layering are presented below.

3.4.1 Alluvial Aquifer Layer

In 2002, RCS compiled and geographically grouped hydrogeologic data from Alluvial Aquifer wells to estimate the aquifer's saturated thickness during various historical periods. The saturated thickness was defined from the average base elevation of the aquifer and the water level elevations measured during the fall of 1985 and the spring of 2000, then typical saturated thicknesses for geographic subareas were defined. The spatial distribution of the Alluvial Aquifer's typical saturated thickness is shown on Figure 3-3. Along the Santa Clara River, the typical saturated thickness ranges between 110 and 130 feet west of I-5; is less than 100 feet near Round Mountain; ranges between 100 and 150 feet between Round Mountain and Soledad Canyon; and ranges between 80 and 90 feet in Soledad Canyon. The typical saturated thickness ranges between 80 and 100 feet in the Castaic Creek Valley and in the lower reach of Bouquet Canyon. Other tributary canyons to the Santa Clara River have typical saturated thicknesses of 60 feet or less, and the saturated thickness decreases significantly in the upstream direction within each canyon, particularly along the South Fork Santa Clara River, where all production wells are constructed in the Saugus Formation, rather than the alluvium (RCS, 2002).

3.4.2 Saugus Formation Layers

The Saugus Formation was simulated using 500-foot-thick model layers through the freshwater-bearing deposits, which are present in the basin at depths up to 2,500 feet (RCS, 1988, 2002). The model layers were specified at each node by importing digitized contours of the total thickness of the Saugus Formation's freshwater-bearing deposits (Plate 5 in RCS, 1988). Figure 3-4 is a contour fill map showing the total thickness of the Saugus Formation's freshwater-bearing deposits that was programmed into the model. As shown in the individual thickness maps for each model layer, the Saugus is present in the model at progressively fewer nodes with depth, due to the bowl-shaped structure of the unit and the underlying bedrock.

3.5 Boundary Conditions

The boundary conditions used in the Regional Model were the following:

a. **Specified flux for precipitation within the model grid.** Deep percolation of precipitation was simulated using the precipitation top-system package contained in MicroFEM®.

b. **Specified flux for irrigation.** Deep percolation of agricultural irrigation and urban irrigation in developed areas was simulated using the precipitation top-system package contained in MicroFEM®.

c. **Specified flux and head-dependent flux along ephemeral streams**. With respect to groundwater discharges to streams, the Santa Clara River was modeled as an ephemeral, predominantly losing stream at and upstream of the mouth of San Francisquito Canyon, and as a perennial, predominantly gaining stream downstream of San Francisquito Canyon. Although flows in the river are currently perennial below the mouth of Bouquet Canyon, because of discharges from the Saugus WRP, the river was perennial only below the mouth of San Francisquito Canyon in the 1960s, prior to WRP operations. The tributaries to the Santa Clara River were modeled as ephemeral streams, using the precipitation top-system package to specify stream leakage to groundwater. Aerial photos and historical observations indicate that under high water table conditions, groundwater can locally discharge into Castaic Creek and the ephemeral reach of the Santa Clara River wherever Alluvial groundwater levels rise above the riverbed elevation. Consequently, the drain package in MicroFEM® was used in these streams to allow drainage of any groundwater that was calculated to be above the riverbed elevation at each river node.

d. **Specified flux and head-dependent flux along perennial Santa Clara River.** In the perennial reach of the Santa Clara River, the river was modeled using the wadi top-system package contained in MicroFEM®. The wadi package allows groundwater to discharge to the river whenever groundwater elevations are higher than the specified river stage. When groundwater levels are below the river stage, the river recharges the Alluvial Aquifer. The rate of recharge is proportional to the difference between the river stage elevation and the model-calculated groundwater elevation. However, once the groundwater elevation drops below the streambed sediments, the rate of leakage from the stream is constant (i.e., does not vary as the groundwater elevation fluctuates). For the Regional Model, each node along the perennial reach of the Santa Clara River was assigned a river stage 1 foot higher than the mapped bed elevation of the river. The riverbed permeability, or conductance, which helps control the model-calculated groundwater/surface water exchange rates, was adjusted during model calibration by calibrating to streamflow data collected at the county line. (See Section 4.3 for further details on the use of the streamflow data during model calibration.)

e. **Specified flux for pumping.** Pumping rates and locations for wells completed in the Alluvial Aquifer and the Saugus Formation were directly imported into the Regional

Model from the Upper Santa Clara River Groundwater Basin database. Further information on how pumping was specified in the model is contained in Section 3.7.

f. **Specified flux at upgradient Alluvial Aquifer boundaries.** Where there is Alluvial groundwater flow into the study area from beneath Castaic Dam, the magnitude of the specified flux was adjusted during the model calibration process, using groundwater elevations and gradients published by RCS (1986 and 2002).

g. **Specified groundwater elevation in the Alluvial Aquifer at the county line.** The groundwater elevation (805 feet) was obtained from water level contour maps for the Alluvial Aquifer prepared by RCS (1986, 2002). (See Figure 2-7 for groundwater elevation contours during Spring 2000, as mapped by RCS [2002].)

h. **Head-dependent flux for evapotranspiration.** ET from the water table by riparian vegetation was simulated using the evaporation top-system package contained in MicroFEM®. This package requires specification of the maximum rooting depth for the riparian vegetation, the maximum potential ET rate, and the ground surface elevation.

i. **No-flow**. In general, the outermost line of nodes that form the model boundary and the bottom of the model are no-flow boundaries. The exceptions are the western model boundary (specified head) and the specified-flux nodes representing underflow into the Alluvial Aquifer from beneath Castaic Dam. Also, all nodes on the model boundary are assigned specified fluxes due to precipitation and, in some cases, ephemeral streamflow.

3.6 Estimation of Groundwater Recharge Rates

The groundwater recharge rates required by the model were derived from the following information sources:

a. Precipitation records

b. Watershed maps and topographic maps

c. Aerial photography (to identify vegetation patterns and areas of agricultural and urban irrigation)

Groundwater recharge was defined on a month-to-month basis for the transient calibration process. Groundwater recharge rates were assigned at all model nodes using the GIS for the valley and a Surface Water Routing Model (SWRM), which was written specifically for the Regional Model using the Visual Basic Editor within Microsoft® Excel 97. For each month during the transient calibration period, the SWRM estimated the following:

a. The amount of water potentially available to recharge the aquifer, which consisted of:

   1. Infiltration of direct precipitation within the model grid area
   2. Infiltration of urban irrigation water
   3. Infiltration of agricultural irrigation water
   4. The amount of stormwater yielded by upstream watersheds in each tributary to the Santa Clara River
   5. The amount of water entering the valley in the Santa Clara River at the Lang gage

6. The amount of water released into Castaic Creek by DWR
7. The locations and volumes of flow discharged into the Santa Clara River from the two LACSD WRPs

b. The amount of water in each stream that actually infiltrates to the aquifer, based on an assigned streambed leakage rate at each model node

c. The amount of water in each stream that does not infiltrate and therefore remains as surface water in the Santa Clara River at the west end of the valley, at the County Line gage

During model calibration, the SWRM was used to adjust the streambed conductance terms for Castaic Creek and the ephemeral reach of the Santa Clara River. These adjustments were made by examining the differences between measured and modeled groundwater elevations at wells located in the valleys where these ephemeral streams are present. In addition, the streambed conductance terms were allowed to vary from month to month because the conductance implicitly incorporates the streambed area, which is large during high river flows and smaller during low-flow periods.

A detailed discussion of the SWRM's design, operations, and input data is contained in Appendix C.

3.7 Assignment of Pumping Rates

Pumping rates were assigned in the Regional Model using the following information:

a. Water use records maintained by the Purveyors and other agencies in the valley. These records were available in the form of AF/yr of water use at each well.

b. Estimates of monthly water demand for urban water use and agricultural water use.

c. Well construction records, which were needed to determine which model layers at each individual well should be assigned pumping.

Tables 2-1 and 2-2 summarize annual pumping rates at each well and for each year during the transient model calibration period. All production wells in the Alluvial Aquifer were assigned pumping rates in model layer 1. For each production well completed in the Saugus Formation, the pumping assignments in each model layer were based on the total pumping rate, the percentage of the model layer in which the well was open, and the thickness and hydraulic conductivity of each model layer. Table 3-1 summarizes this information and shows the percentage of the total well yield that was derived from each model layer.

Table 3-2 summarizes the monthly distribution of the annual pumping volumes. Separate distributions were used for agricultural demands, which are exclusively for outdoor uses, and for urban demands, which are for both indoor and outdoor uses. The monthly distribution of agricultural pumping was derived from crop consumptive use requirements published by the California Irrigation Management Information Service. The monthly distribution of urban demand was determined by examining monthly flow records for the two LACSD WRPs and monthly demand distributions recorded by VWC during the past several years.

Tables

TABLE 3-1
Allocation of Pumping by Layer for Wells Completed in the Saugus Formation
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
NCWD-7	3	520	974	454	2	908	100.0
NCWD-8	2	342	970	158	10	1,580	62.7
NCWD-8	3	342	970	470	2	940	37.3
NCWD-9	2	311	674	189	0.03371	6.37	59.4
NCWD-9	3	311	674	174	0.025	4.35	40.6
NCWD-10	3	780	1,544	220	2	440	28.8
NCWD-10	4	780	1,544	500	2	1,000	65.4
NCWD-10	5	780	1,544	44	2	88	5.8
NCWD-11	2	200	1,075	300	10	3,000	72.3
NCWD-11	3	200	1,075	500	2	1,000	24.1
NCWD-11	4	200	1,075	75	2	150	3.6
NCWD-12	2	485	1,280	15	10	150	8.8
NCWD-12	3	485	1,280	500	2	1,000	58.5
NCWD-12	4	485	1,280	280	2	560	32.7
NCWD-13	2	420	750	80	10	800	61.5
NCWD-13	3	420	750	250	2	500	38.5
NLF-156	2	320	1,800	180	10	1,800	21.8
NLF-156	3	320	1,800	500	6.5	3,250	39.4
NLF-156	4	320	1,800	500	4	2,000	24.2
NLF-156	5	320	1,800	300	4	1,200	14.5
SCWC-Saugus1	2	490	1,620	10	10	100	1.8
SCWC-Saugus1	3	490	1,620	500	6.5	3,250	59.9
SCWC-Saugus1	4	490	1,620	500	4	2,000	36.8
SCWC-Saugus1	5	490	1,620	20	4	80	1.5
SCWC-Saugus2	2	490	1,591	10	10	100	1.8
SCWC-Saugus2	3	490	1,591	500	6.5	3,250	56.9
SCWC-Saugus2	4	490	1,591	500	4	2,000	35.0
SCWC-Saugus2	5	490	1,591	91	4	364	6.4
VWC-157	3	586	2,008	414	6.5	2,691	40.2
VWC-157	4	586	2,008	500	4	2,000	29.9
VWC-157	5	586	2,008	500	4	2,000	29.9
VWC-159	3	662	1,900	338	0.025	8.45	27.3
VWC-159	4	662	1,900	500	0.025	12.5	40.4
VWC-159	5	662	1,900	400	0.025	10	32.3
VWC-160	3	950	2,000	50	6.5	325	7.5
VWC-160	4	950	2,000	500	4	2,000	46.2
VWC-160	5	950	2,000	500	4	2,000	46.2

TABLE 3-1
Allocation of Pumping by Layer for Wells Completed in the Saugus Formation
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner - Well Name	Model Layer	Depth to Open Interval (feet) Top	Bottom	Length of Open Interval in Model Layer (feet)	Kh (ft/day)	T in Open Interval (ft^2/day)	Percentage of Yield from Model Layer
VWC-201	3	540	1,670	460	6.5	2,990	52.7
VWC-201	4	540	1,670	500	4	2,000	35.3
VWC-201	5	540	1,670	170	4	680	12.0
VWC-205	3	820	1,930	180	6.5	1,170	23.9
VWC-205	4	820	1,930	500	4	2,000	40.9
VWC-205	5	820	1,930	430	4	1,720	35.2

TABLE 3-2
Allocation of Pumping by Month for Agricultural and Urban Production Wells
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Month	% of Annual Water Use, Agricultural	% of Annual Water Use, Urban	% of May through October Water Use, Urban
January	3.8	5.2	
February	5.1	3.7	
March	6.6	5.2	
April	9.1	6.6	
May	10.6	8.7	13.2
June	11.4	10.4	15.8
July	14.1	13.0	19.7
August	12.9	13.6	20.6
September	10.2	10.9	16.5
October	7.5	9.3	14.1
November	5.0	7.1	
December	3.8	6.3	
Total	**100.0**	**100.0**	**100.0**

Figures

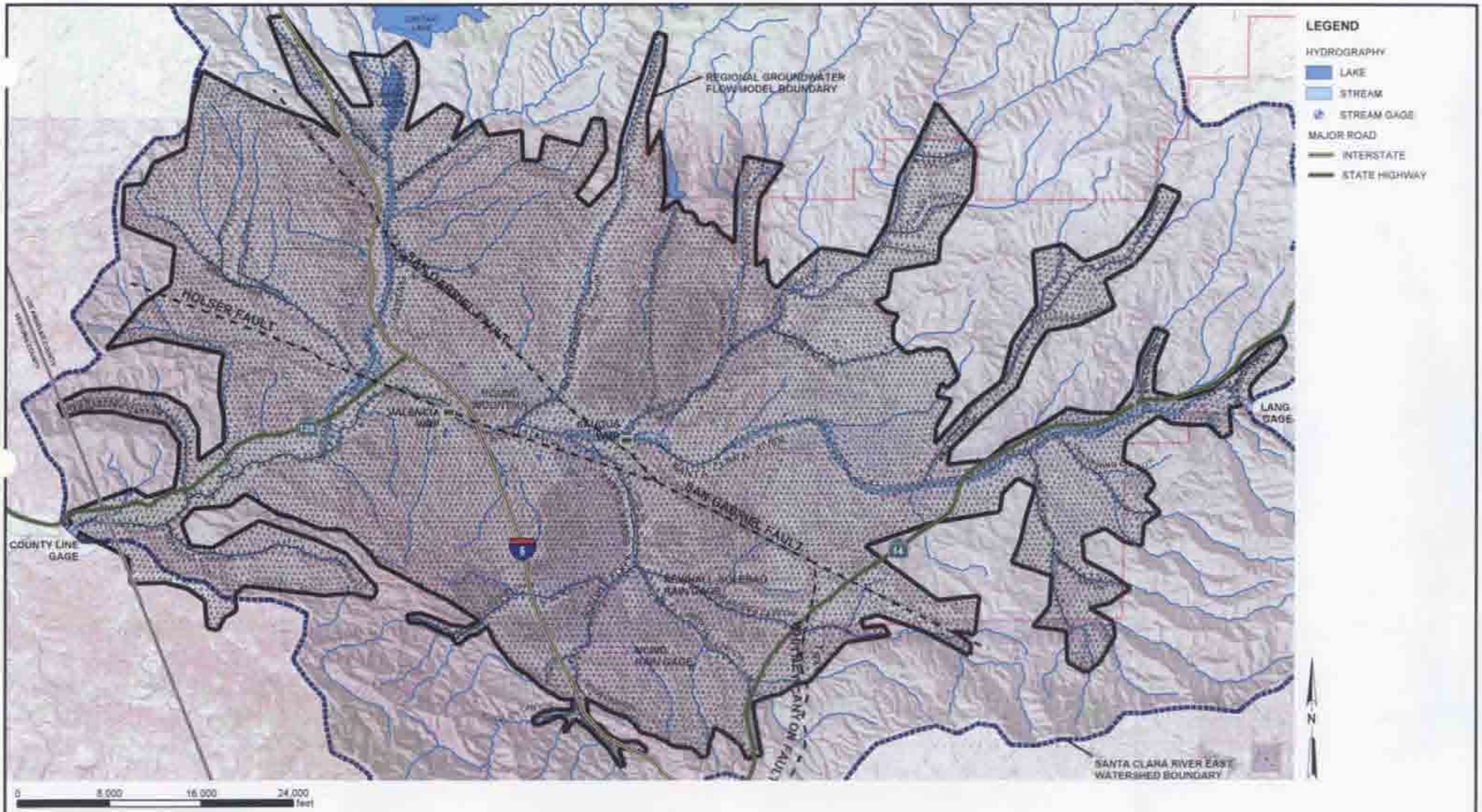

FIGURE 3-1
MODEL GRID
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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Stratigraphy			Model Layer	Thickness (feet)
Saugus	Alluvium	Saugus	1	500
Saugus	Saugus	Saugus	2	
Saugus	Saugus	Saugus	3	500
Saugus	Saugus	Saugus	4	500
Saugus	Saugus	Saugus	5	500
Saugus	Saugus	Saugus	6	500
Sunshine	Sunshine	Sunshine	7	Variable

FIGURE 3-2
SHEMATIC DIAGRAM OF THE MODEL'S REPRESENTATION OF STRATIGRAPHY IN THE MIDDLE OF THE BASIN
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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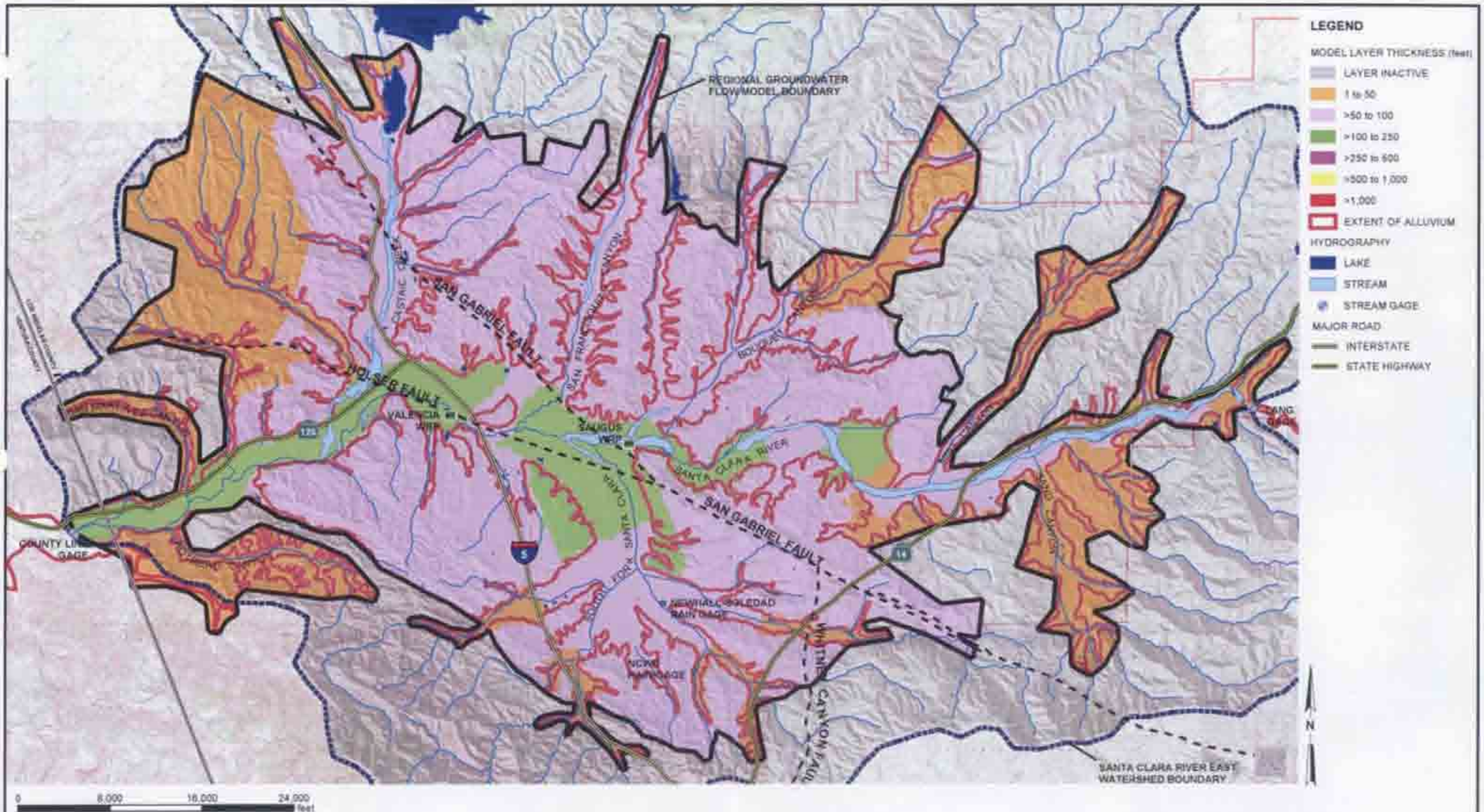

FIGURE 3-3
THICKNESS OF MODEL LAYER 1
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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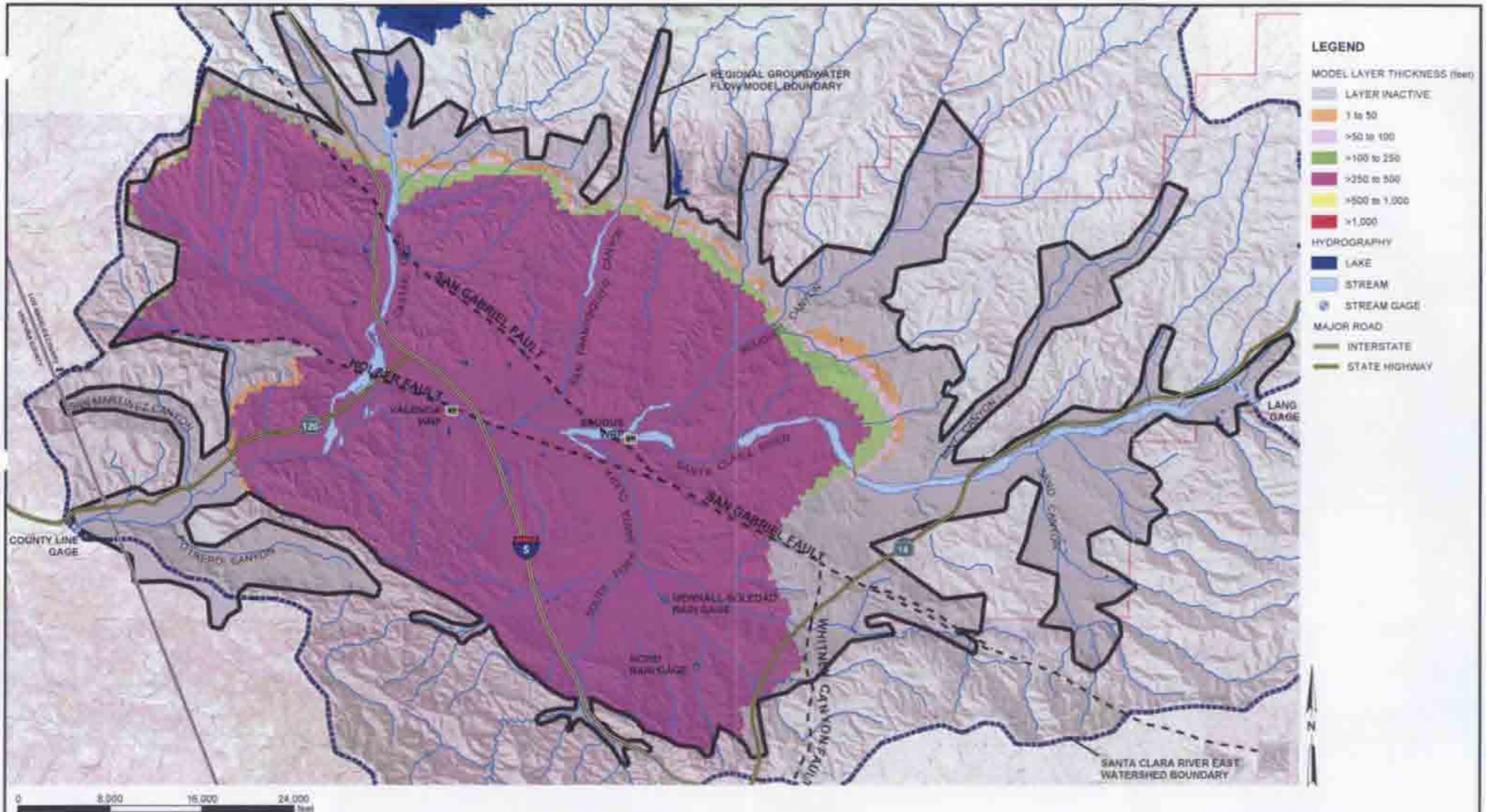

FIGURE 3-4
THICKNESS OF MODEL LAYER 2
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\SS\SANTACLARITA_MOU\FIGURES\MXD\FIG021.MXD FIG03-04.PDF 02/02/2004 13:21:28

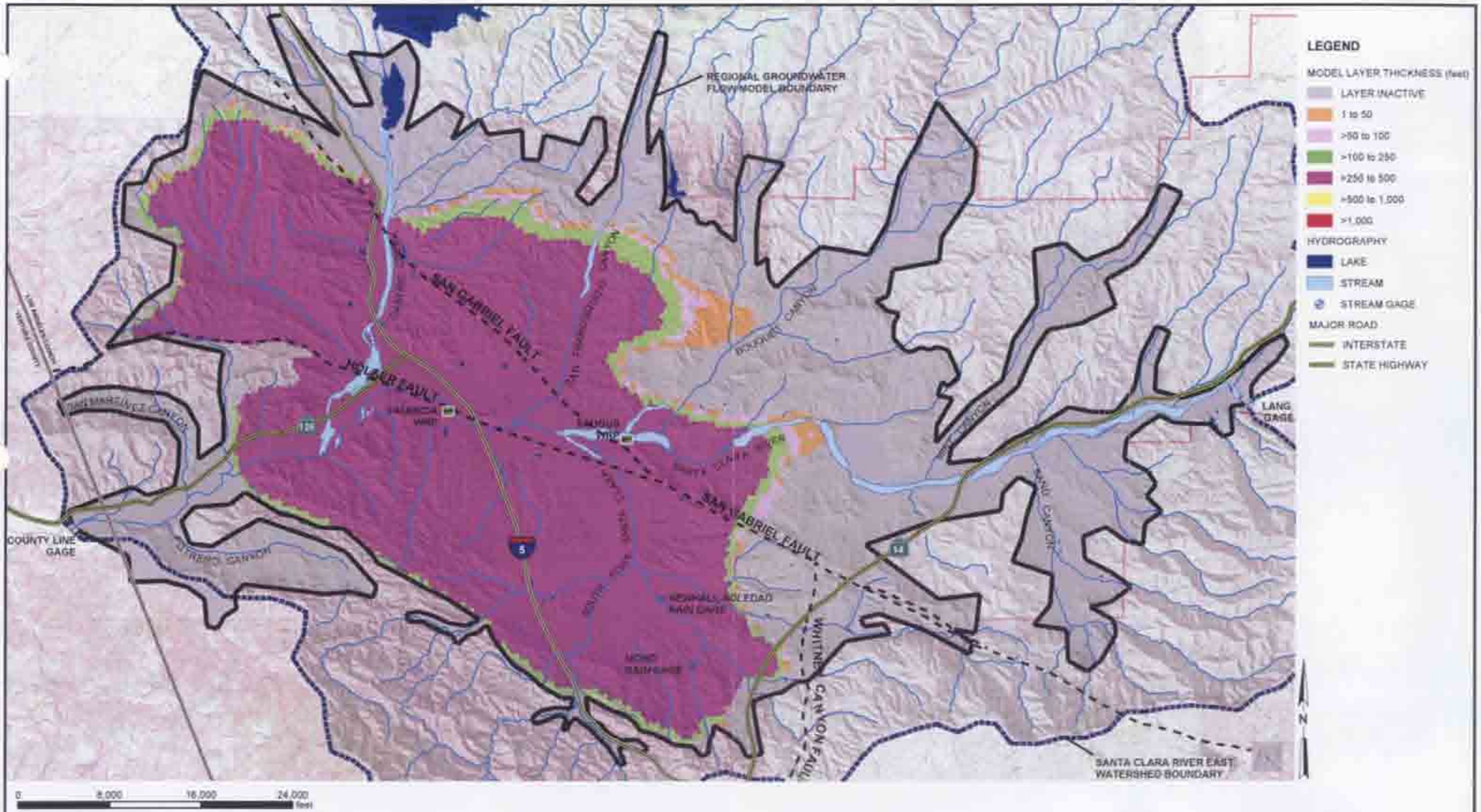

FIGURE 3-5
THICKNESS OF MODEL LAYER 3
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG022.MXD FIG03-05.PDF 02/04/2004 11:14:10

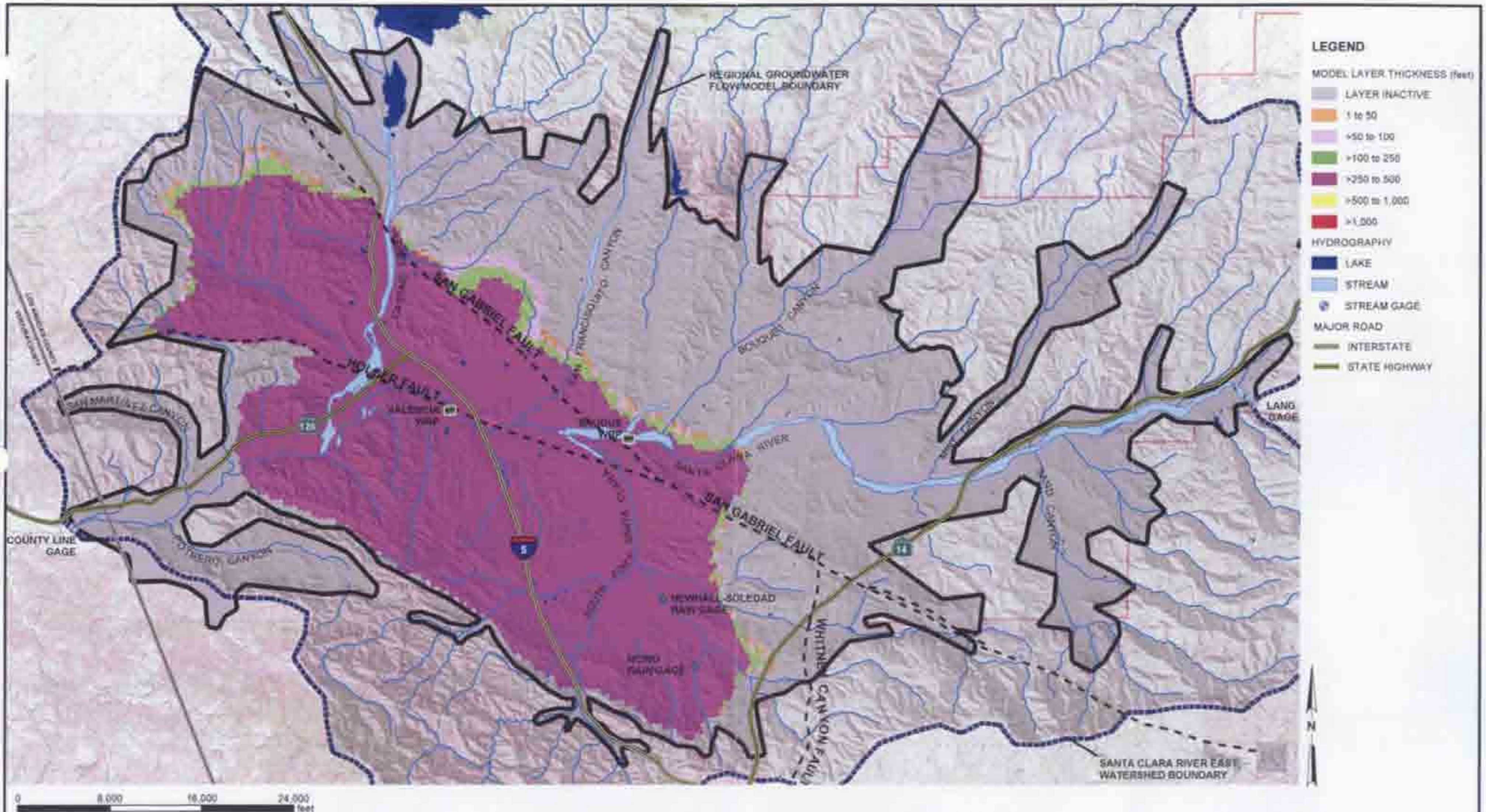

FIGURE 3-6
THICKNESS OF MODEL LAYER 4
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ\165\SANTACLARITA_MOU\FIGURES\MXD\FIG023.MXD FIG03-06.PDF 02/04/2004 11:19:11

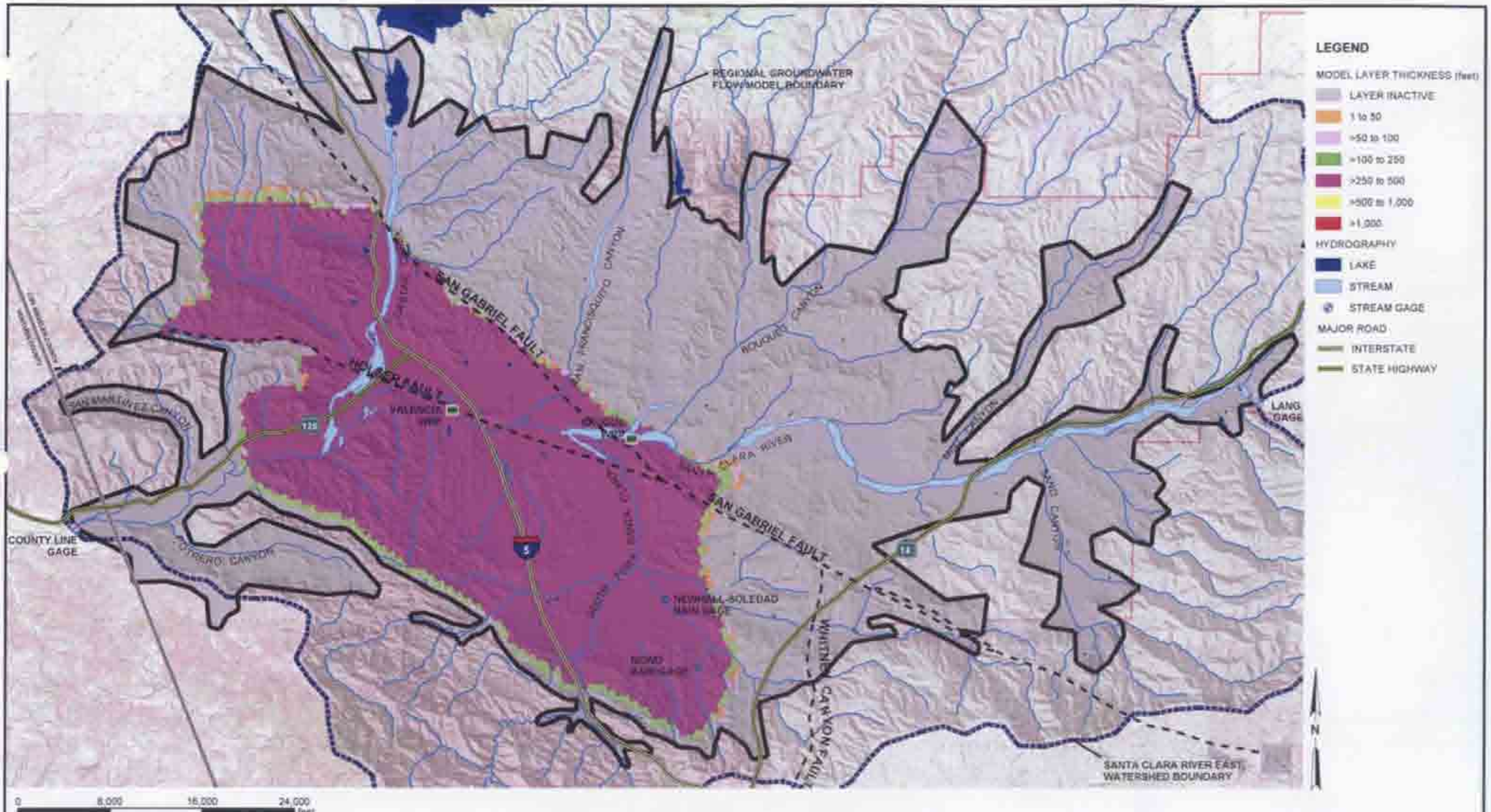

FIGURE 3-7
THICKNESS OF MODEL LAYER 5
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG024.MXD FIG03-07.PDF 02/04/2004 11:23:01

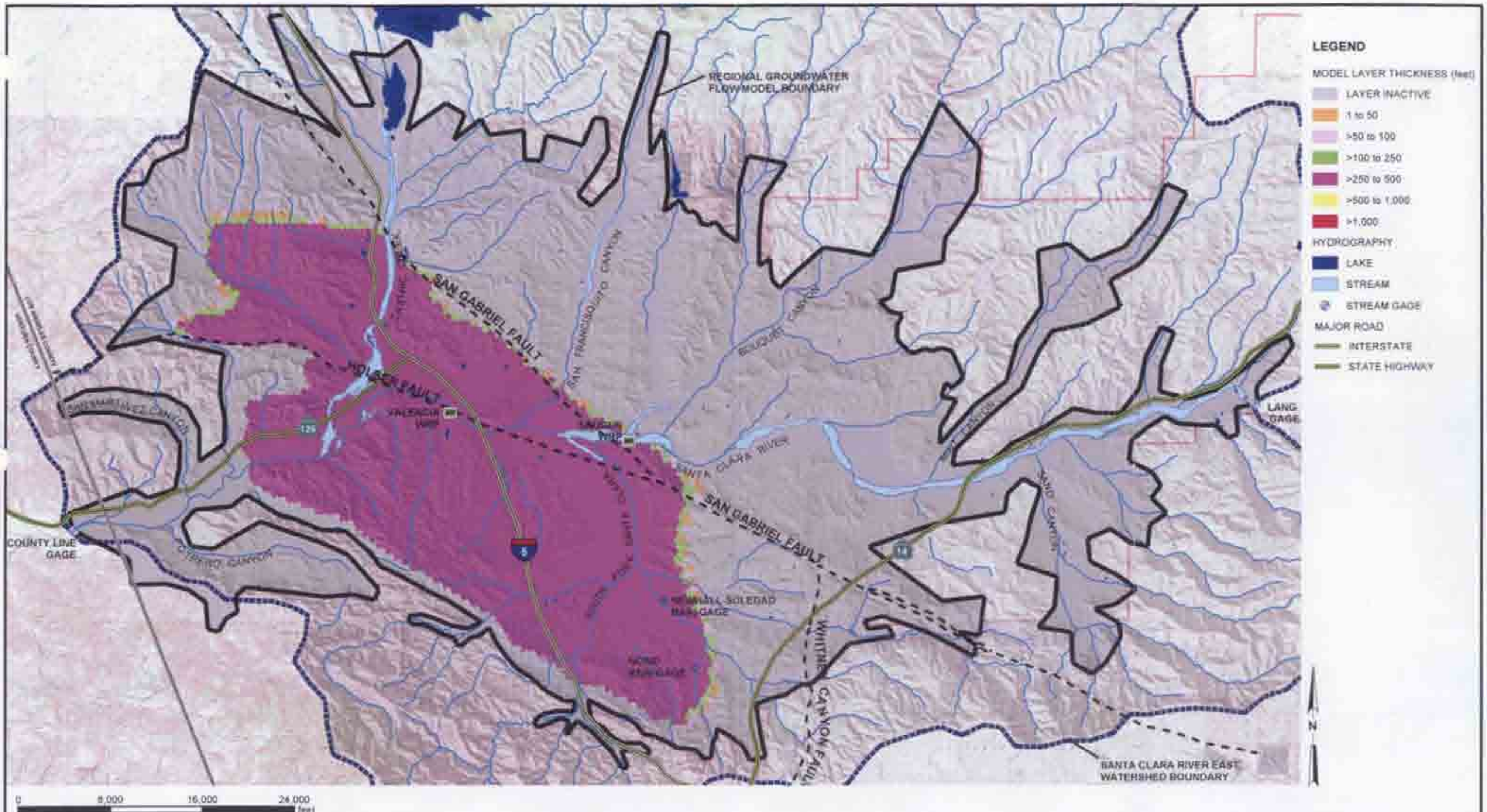

FIGURE 3-8
THICKNESS OF MODEL LAYER 6
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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ROD \\ODIN\PROJ2\66\SANTACLARITA_MOU\FIGURES\MXD\FIG025.MXD FIG03-08.PDF 02/04/2004 11:26:22

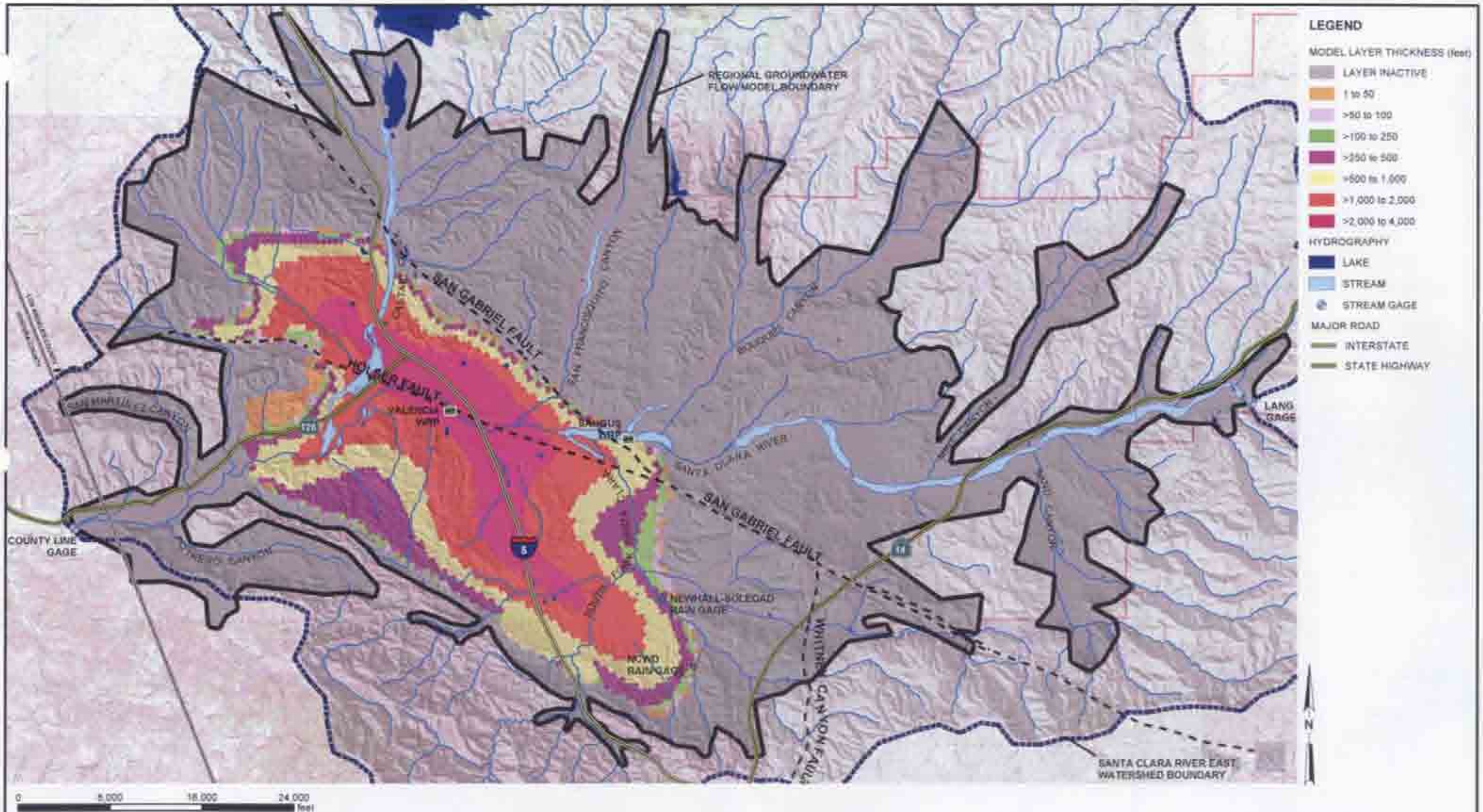

FIGURE 3-9
THICKNESS OF MODEL LAYER 7
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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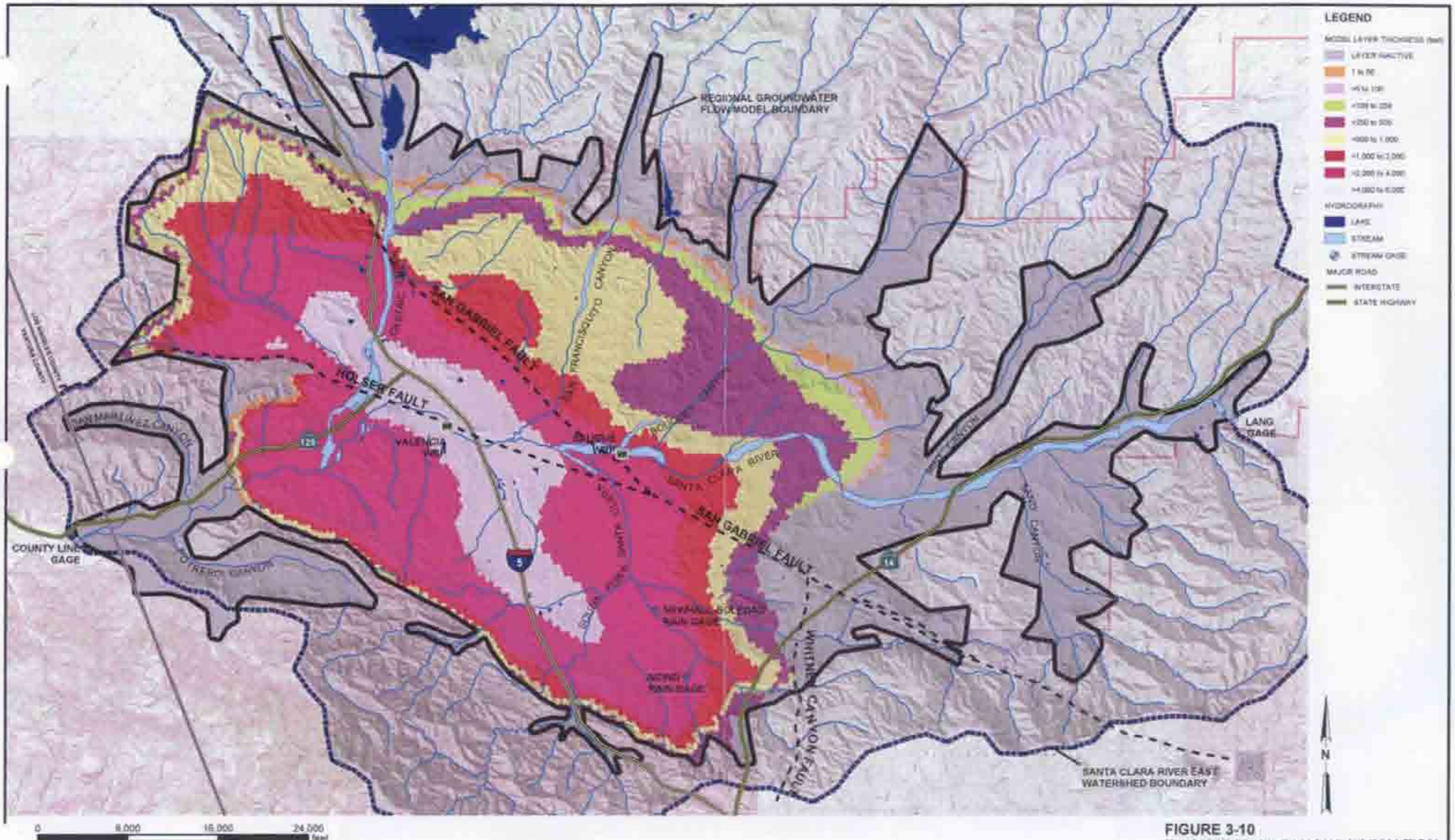

FIGURE 3-10
THICKNESS OF SAUGUS FORMATION
(MODEL LAYERS 1 THROUGH 7)
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\SANTACLARITA_MOU\FIGURES\MXD\FIG044.MXD FIG03-10.PDF 02/04/2004 14:19:00

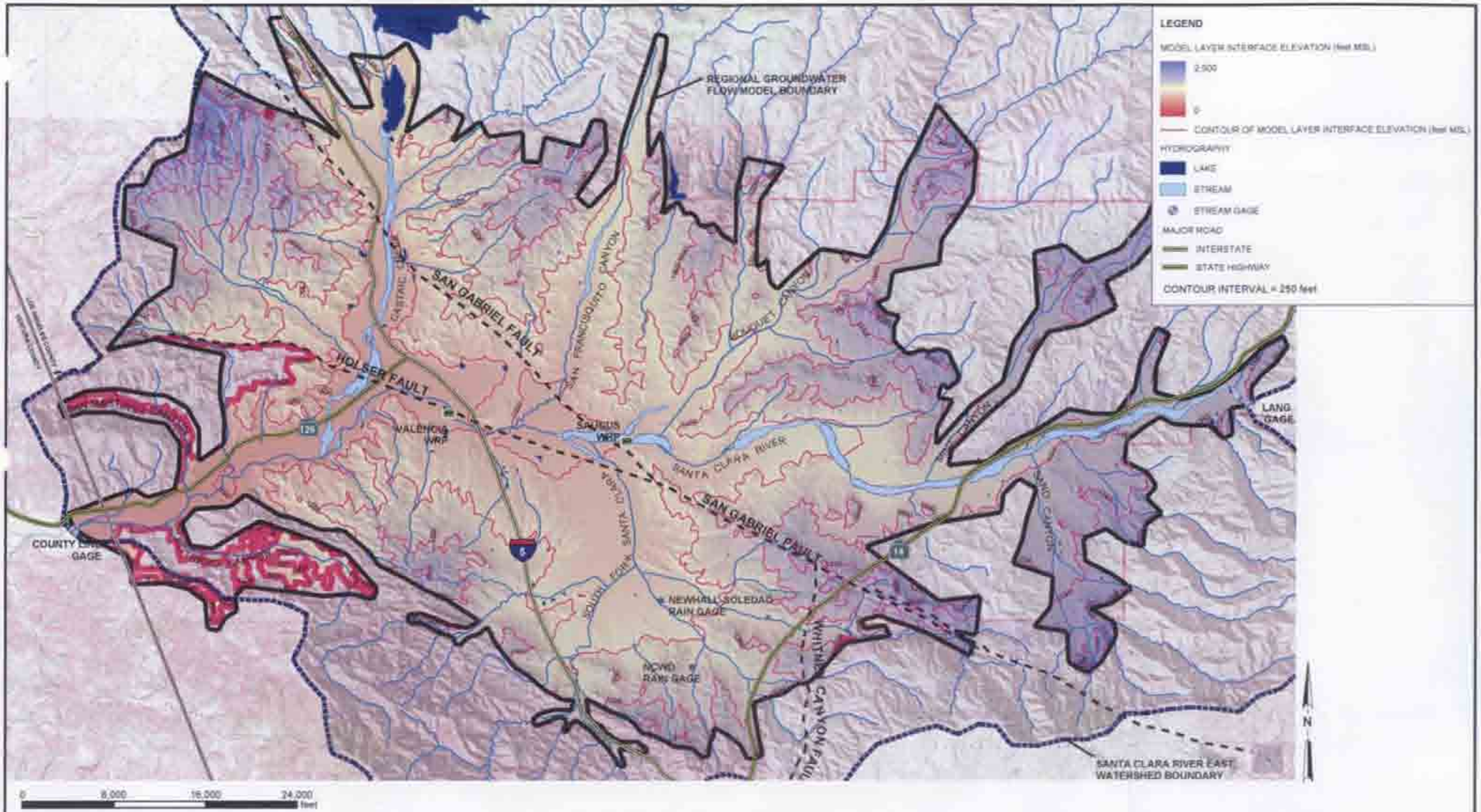

FIGURE 3-11
LAYER 1 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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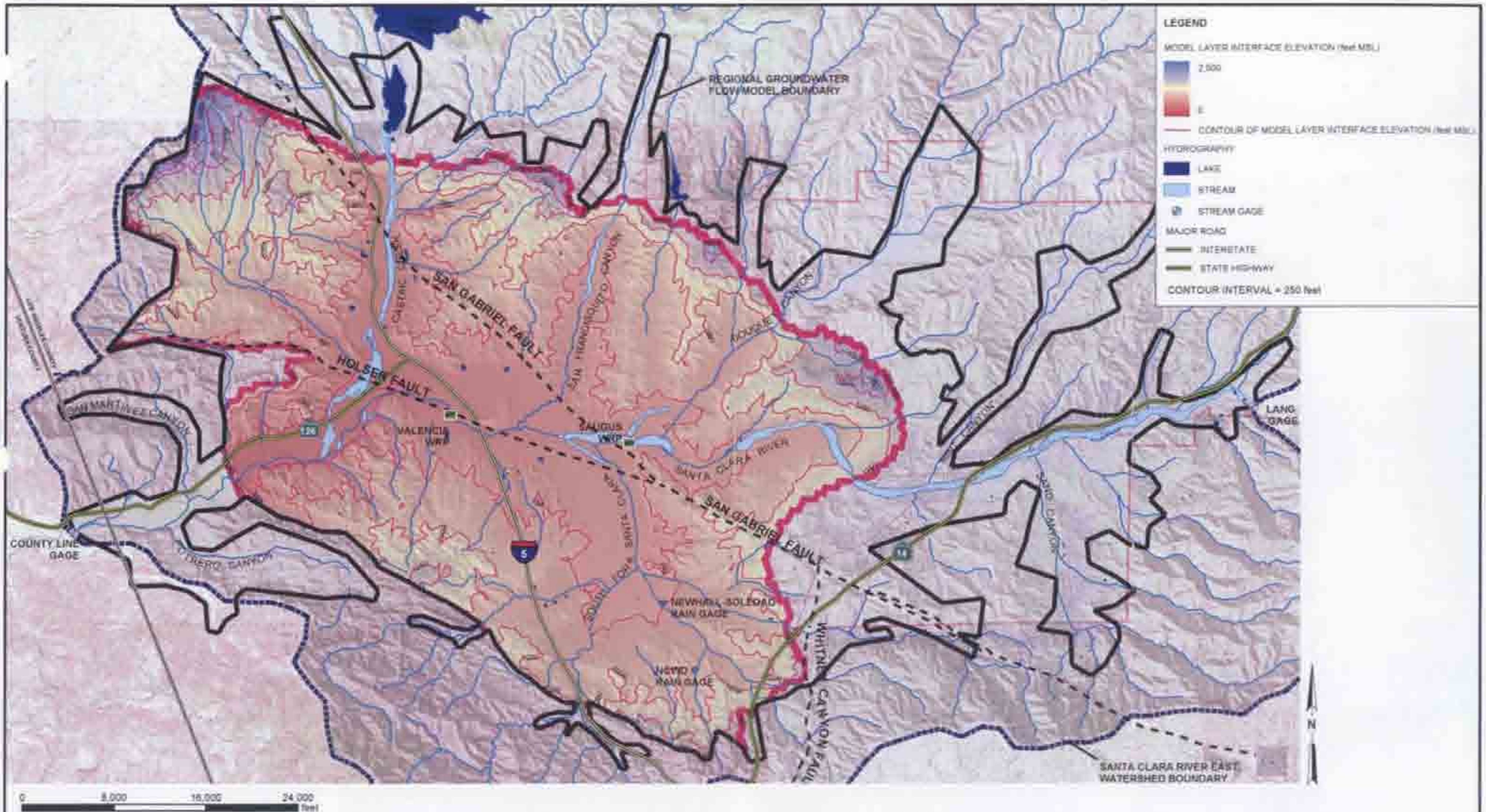

FIGURE 3-12
LAYER 2 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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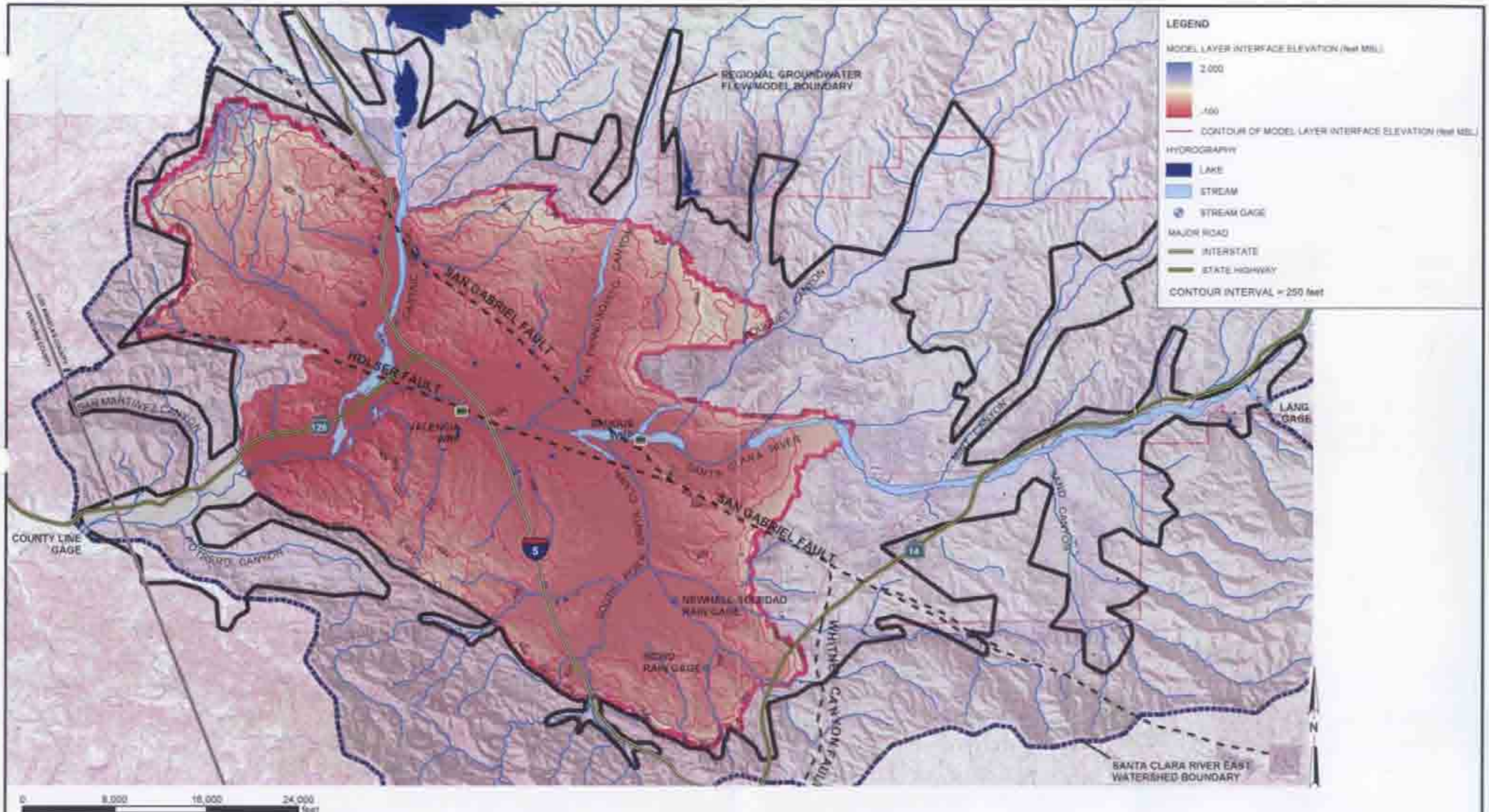

FIGURE 3-13
LAYER 3 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG029.MXD FIG03-13.PDF 02/04/2004 11:42:48

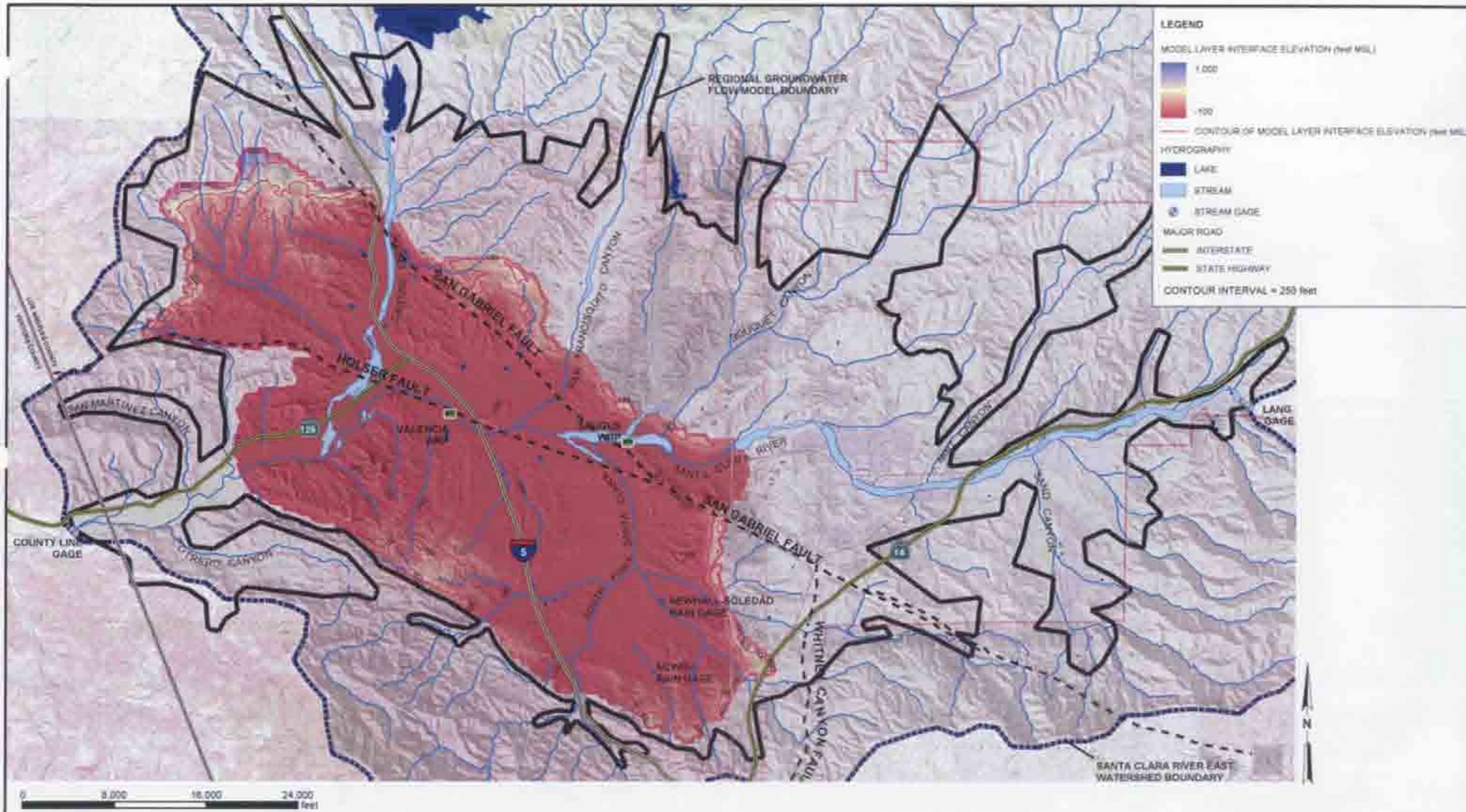

FIGURE 3-14
LAYER 4 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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ROD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG030.MXD FIG03-14.PDF 03/04/2004 11:53:17

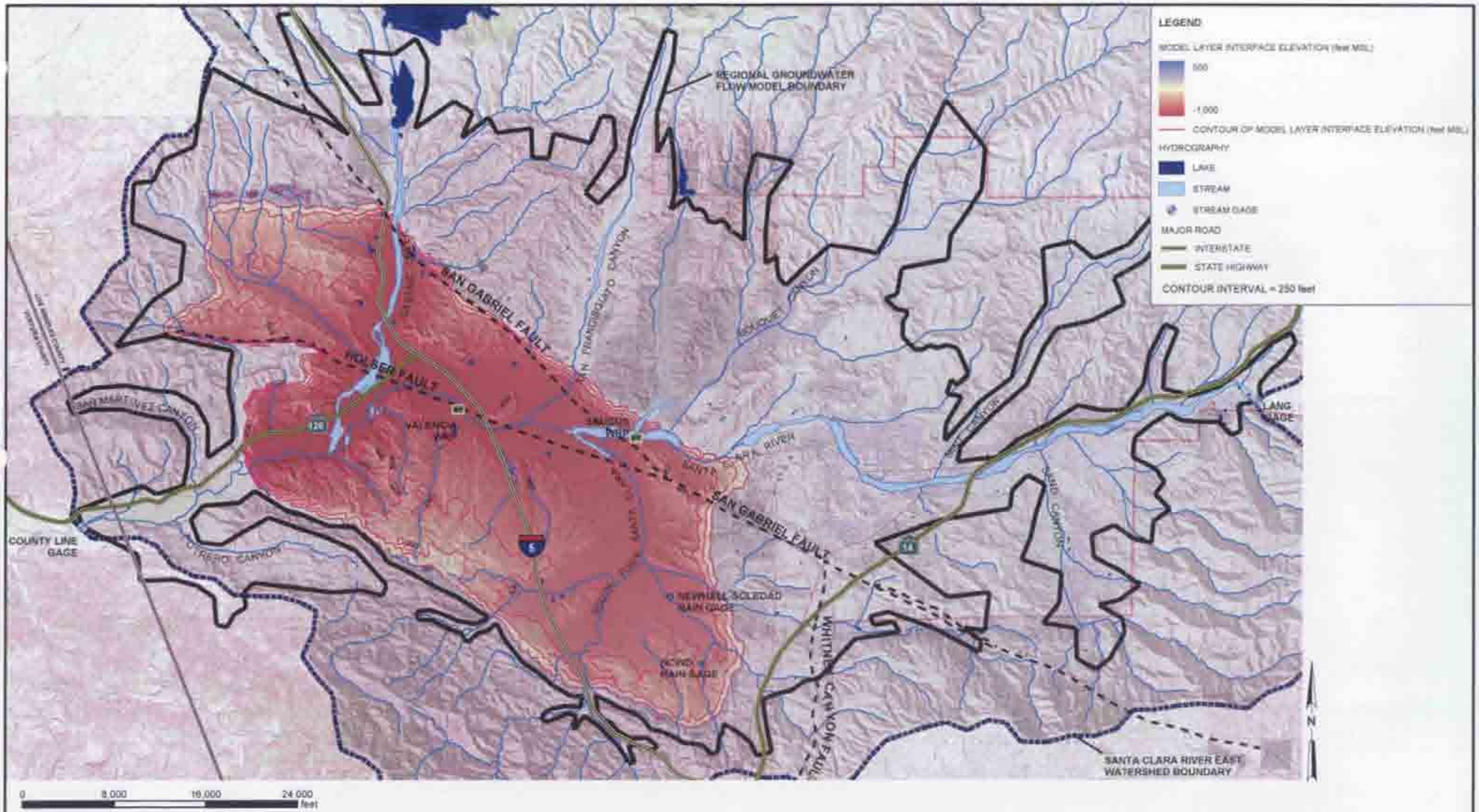

FIGURE 3-15
LAYER 5 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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RDD \\ODIN\PROJ2\56\SANTACLARITA_MOU\FIGURES\MXD\FIG031.MXD FIG03-15.PDF 02/04/2004 12:53:31

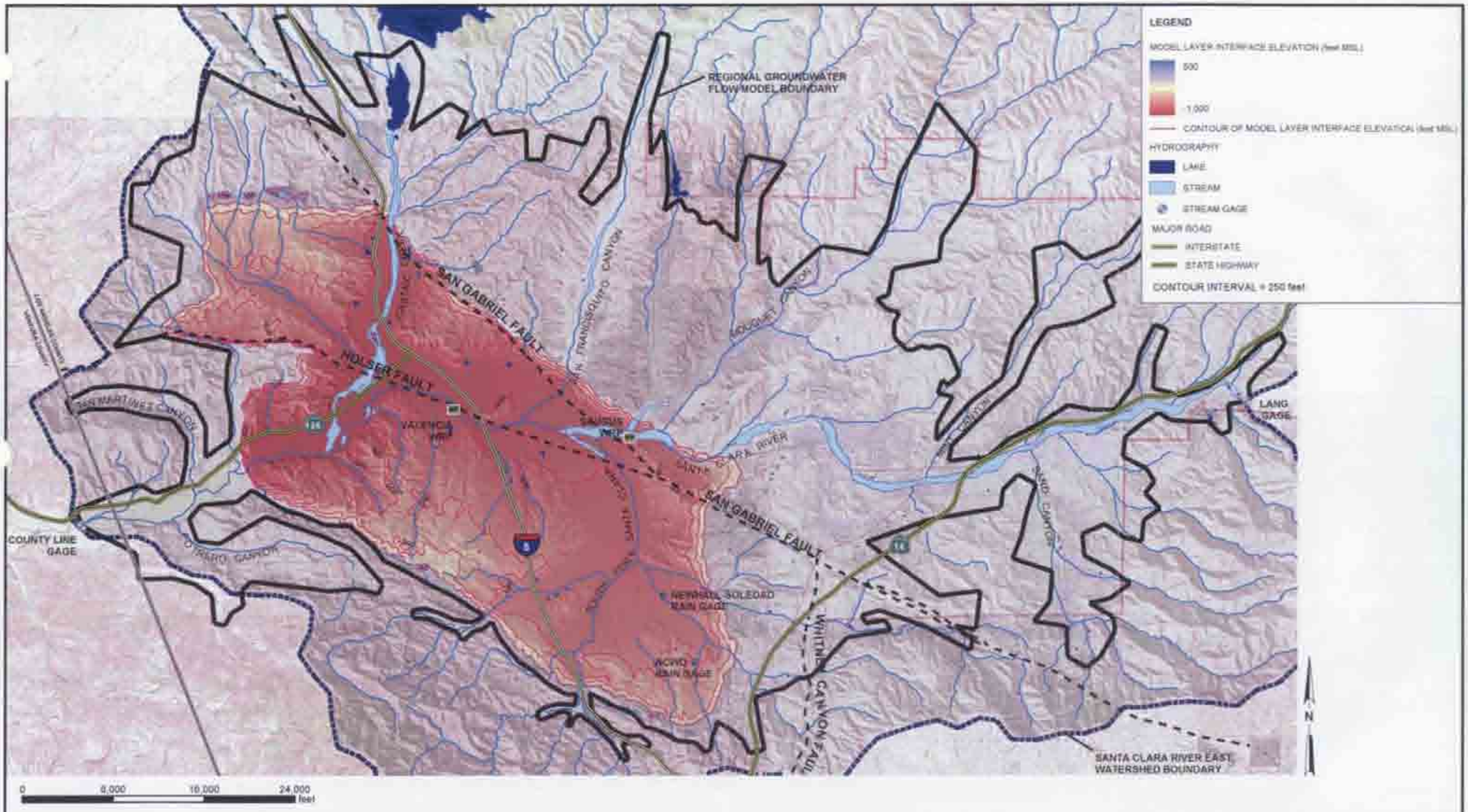

FIGURE 3-16
LAYER 6 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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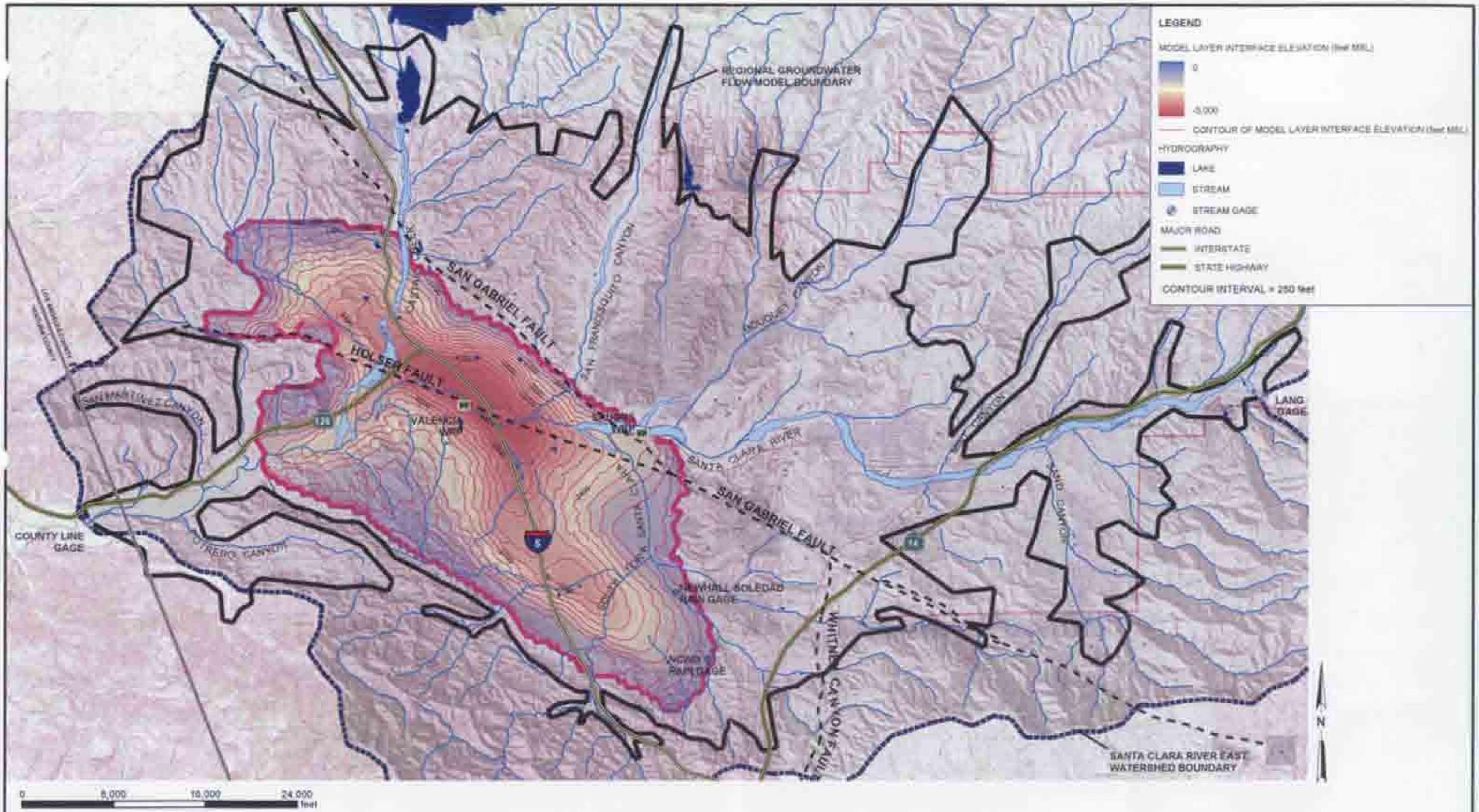

FIGURE 3-17
LAYER 7 BASE ELEVATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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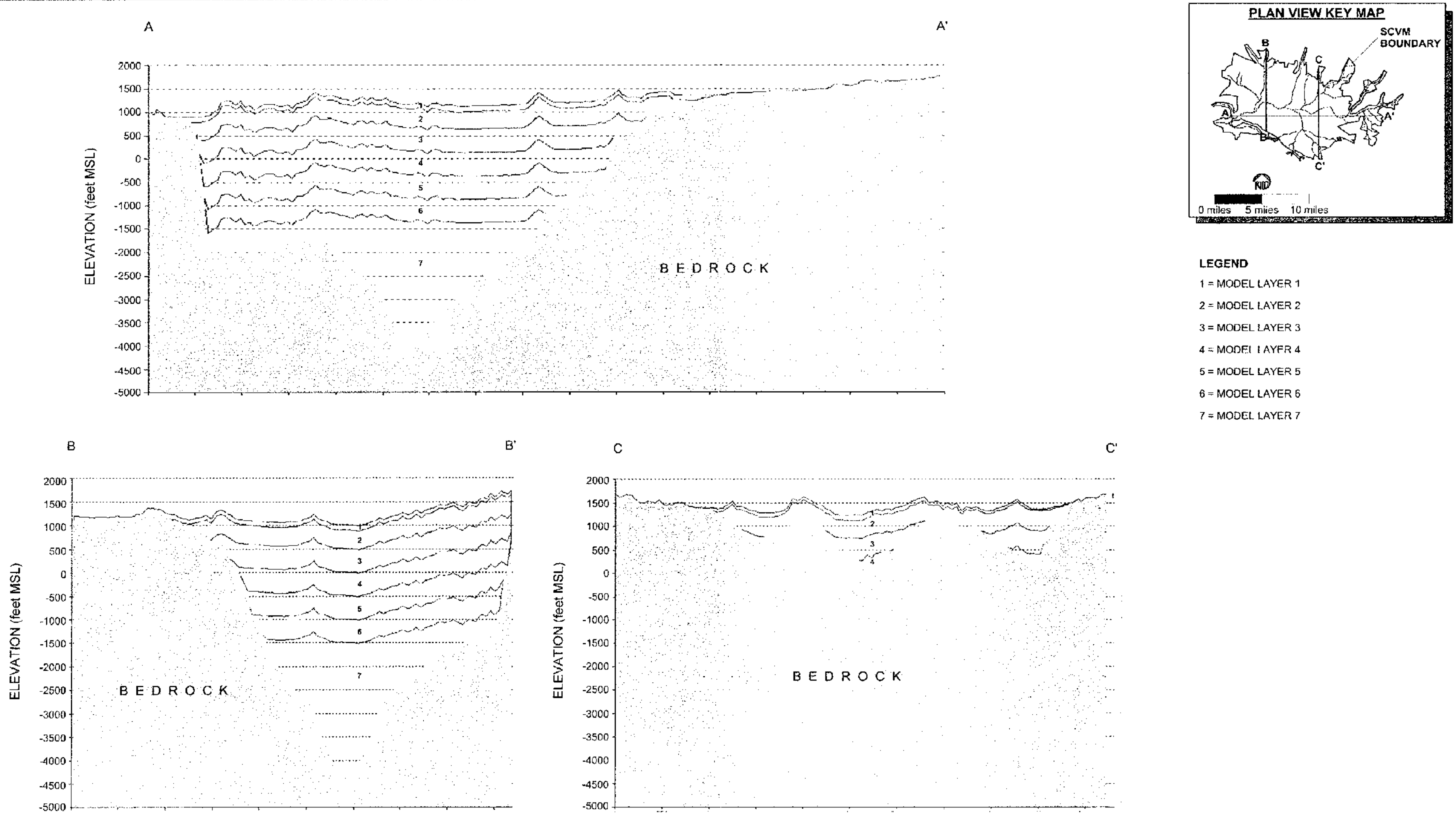
RDD \\ODIN\PROJ2\55\SANTACLARITA_MOU\FIGURES\MXD\FIG033.MXD FIG03-17.PDF 02/03/2004 13:13:34



LEGEND

1 = MODEL LAYER 1

2 = MODEL LAYER 2

3 = MODEL LAYER 3

4 = MODEL LAYER 4

5 = MODEL LAYER 5

6 = MODEL LAYER 6

7 = MODEL LAYER 7

HORIZONTAL CROSS SECTION SCALE

0 feet 10,000 feet 20,000 feet

5x VERTICAL EXAGGERATION

FIGURE 3-18
SCHEMATIC CROSS SECTIONS
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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SCHEMATICCROSSSECTIONS.SRF

SECTION 4

Model Calibration Process

This section describes the model calibration process. The Regional Model was calibrated according to the *Standard Guide for Calibrating a Ground-Water Flow Model Application*, published by the American Society for Testing and Materials (1996), which describes how to calibrate a model using historical data, including how to establish calibration target data, identify calibration parameters, and compare field data to model calibration results.

Following are discussions of the historical field conditions that were simulated during calibration; the goals of the calibration process; the model parameters (variables) that were adjusted during calibration; and the procedures and target data that were used to conduct the calibration process.

4.1 Calibration Conditions

Calibration of the Regional Model involved matching both steady-state and transient conditions in the Alluvial Aquifer and the Saugus Formation.

4.1.1 Steady-State Calibration

The steady-state calibration was performed for calendar years 1980 through 1985. The purpose of the steady-state model was to simulate average regional flow patterns, regional hydraulic gradients, and groundwater budgets during the initial time period to be modeled as part of the transient calibration effort. The steady-state model also provided initial groundwater elevations for the beginning of the transient model.

During the 1980 through 1985 period:

a. The average precipitation (20.15 in/yr) was approximately 2.5 inches higher than the 1950 through 2000 mean (17.35 in/yr).

b. Alluvial Aquifer pumping decreased slightly (see Table 2-1).

c. Saugus pumping remained relatively constant, between 3,800 and 5,000 AF/yr (see Table 2-2).

d. Importation of SWP water increased steadily, from 1,125 acre-feet in 1980 to 11,823 acre-feet in 1985.

e. WRP discharges into the Santa Clara River increased from approximately 7,400 AF in 1980 to approximately 9,600 AF in 1985.

f. Groundwater elevations in the Alluvial Aquifer remained relatively stable, except for a slight decline in the eastern part of the valley during 1984 and 1985, due to below-normal rainfall during those years.

g. Groundwater elevations in the Saugus Formation remained relatively stable.

Hence, even though SWP imports and WRP discharges increased during this period, groundwater elevations did not rise, instead remaining fairly stable or decreasing slightly due to the relatively stable natural hydrologic conditions during this 6-year period and the below-normal rainfall in 1984 and 1985. Consequently, this time period was deemed suitable for the steady-state portion of the model calibration effort.

4.1.2 Transient Calibration

The transient calibration was performed for calendar years 1980 through 1999 to create a model capable of simulating seasonal and long-term variations in groundwater elevations, groundwater recharge, and groundwater discharge for a historical period characterized by variable rainfall and recharge and changing land use and water use patterns. This 20-year period was chosen for the following reasons:

a. The volume of data is greater during this period than in previous years. In particular, SCWC and VWC installed several production wells in the Saugus Formation during this time period. Also, regular monitoring of groundwater levels was performed at more wells during this period than before.

b. Annual pumping volumes are well known before and after the 1970s, but are not as well known during that decade. Hence, it would be more difficult to calibrate a model during the 1970s because of the uncertainties in pumping volumes during that time.

c. Significant urban growth occurred in the valley between 1980 and 1999. This growth resulted in changes in land use and increased importation of SWP water, from 1,125 acre-feet in 1980 to 27,302 acre-feet in 1999.

d. The local hydrology and the hydrology of the SWP system varied considerably during this period, and included single-year and multi-year droughts both locally and in the SWP system. (See Section 2.6.3.3.) Specifically, the groundwater elevations in the Alluvial Aquifer and the Saugus Formation showed multi-year periods of water level decline followed by multi-year periods of water level recovery. Consequently, calibrating to this period would allow a model to predict basin conditions during and between future drought periods.

4.2 Calibration Goals

The success of the model calibration was determined by its ability to satisfy specific calibration goals that were established by the CH2M HILL project team and the Purveyors. Separate calibration goals were defined for the steady-state model and the transient model. The specific goals are given below, along with a discussion of how calibration success was measured. Calibration goals are comprised of quantitative (statistical) and qualitative criteria.

4.2.1 Calibration Goals for the Steady-State Model

a. **Groundwater Flow Directions.** Correctly simulate groundwater flow directions in the Alluvial Aquifer and Saugus Formation, as defined by regional groundwater elevation contour maps prepared by RCS (1985, 1986, 2002) for various periods in both aquifer systems. (See Figures 2-7 and 2-8.)

b. **Groundwater Elevation Residuals.** At each target well, simulate groundwater elevations to within 10 feet in the Alluvial Aquifer and 25 feet in the Saugus Formation, compared with observed average groundwater elevations during this period. The value of the modeled groundwater elevation minus the observed average groundwater elevation is called the residual error (residual). A positive residual at a given target well indicates that the model simulates too high a groundwater elevation. Conversely, a negative residual indicates that the model simulates too low a groundwater elevation.

c. **Statistics of Groundwater Elevation Residuals.** Achieve the following statistics for the residuals on a modelwide scale (i.e., for the combined group of calibration target wells):

   1. A mean residual as close to zero as possible.
   2. A mean residual that is less than 5 percent of the range in groundwater elevations measured at the target wells.
   3. A root-mean-square (RMS) error of less than 10 feet for the residuals at Alluvial Aquifer target wells and less than 25 feet for the residuals at Saugus target wells.
   4. A normalized RMS error of 10 percent or less. The normalized RMS error equals the modelwide RMS error divided by the range in groundwater elevations across the entire model domain.
   5. A normalized residual standard deviation of less than 10 percent. The normalized residual standard deviation equals the standard deviation of the residuals divided by the range in groundwater elevations across the entire model domain.
   6. Minimize the degree of spatial bias in the distribution of the residuals. Specifically, avoid creating large areas where the residuals are predominantly positive or predominantly negative. A well-calibrated model shows a scattering of negative and positive residuals within any given localized area.

d. **Groundwater Gradients.** Simulate the direction and magnitude of groundwater gradients across the model domain, including a significant horizontal gradient in the Saugus Formation that exists across the San Gabriel Fault (as measured at four multi-port monitoring wells located on the Whittaker-Bermite property, east of wells SCWC-Saugus1 and SCWC-Saugus2).

e. **Groundwater Below Ground Surface.** At nodes where streams are not present, maintain groundwater elevations below ground surface. At stream nodes, groundwater elevations should also be below ground surface in most ephemeral reaches, though a limited number of nodes can have higher groundwater elevations in the downstream ephemeral reaches, where the exact location of the transition from ephemeral to perennial conditions is variable over time and is only approximately known.

f. **Groundwater Discharge to River.** Simulate a groundwater discharge to the Santa Clara River on the order of 29,000 AF/yr, which is the estimated average baseflow during the steady-state model period (see Section 2.6.2.5).

4.2.2 Calibration Goals for the Transient Model

a. **Water Level Trends/Hydrographs.** Match observed fluctuations in groundwater elevations.

b. **Groundwater Below Ground Surface.** Maintain groundwater elevations below ground surface in the same general areas as previously discussed for the steady-state model.

c. **Total River Flow at County Line Gage.** Match the observed Santa Clara River flows measured at the County Line gage.

d. **Groundwater Discharge to River.** Match the estimated groundwater discharge rates to the Santa Clara River.

Discussions of how these calibration goals are met by the Regional Model are contained in Section 4.4.

4.3 Calibration Variables

The following variables were the subject of model calibration and testing:

a. The horizontal hydraulic conductivity (Kh) and the vertical anisotropy (R), which is the ratio of horizontal to vertical hydraulic conductivity

b. The storage coefficients

c. The relationship between rainfall and stormwater runoff in the tributary watersheds lying upstream of the groundwater basin

d. The riverbed permeabilities in gaining and losing reaches of stream systems, particularly in the ephemeral reach of the Santa Clara River and in Castaic Creek

e. ET parameters (primarily rooting depth and the maximum potential ET rate)

4.3.1 Horizontal Hydraulic Conductivity and Vertical Anisotropy

Because the Regional Model consists of over 17,000 active nodes in each of the seven model layers, the calibration process relied on the definition of zones of uniform hydraulic conductivity (K), spanning multiple nodes in a given layer and, in some areas, spanning multiple layers. Specifically, in a given layer, a geographic area was defined as a zone, and the Kh and R values were assigned to all model cells in that zone.

The number of zones and their locations were assigned in the model by primarily considering the hydrostratigraphy and the locations of target wells in the various calibration models, then considering the spatial variations in saturated thickness as summarized by RCS (2002). During the course of the calibration process, adjustments were made to the locations of the zone boundaries and the number of zones. Figures 4-1 and 4-2 show the geographic area designations for the Alluvial Aquifer and Saugus Formation, respectively. In the final calibrated Regional Model, 48 zones were used in the Alluvial Aquifer and 8 zones were used in the Saugus Formation, including a zone along the San Gabriel fault.

The values of Kh for each zone in the Alluvial Aquifer were specified at the beginning of the calibration process from the analyses of specific capacity tests (Table 2-3). In the Saugus Formation, Kh and R values were initially defined from the ASR test analysis (CH2M HILL, 2001) and, in the case of Kh values, also from slug test results on the Whittaker-Bermite property (CH2M HILL, 2003). During calibration, attempts were made to keep these values as close to the initial assigned values as possible. However, adjustments were made if changes to other parameter values were unable to bring the model into calibration.

4.3.2 Storage Coefficients

Model layer 1 was assigned a specific yield of 0.10 to simulate this layer as unconfined. The specific yield was allowed to range between values as low as 0.075 and as high as 0.15. The final Regional Model used a value of 0.10 at each node in layer 1 for both the Alluvial Aquifer and the Saugus Formation (see Section 5).

In model layers 2 through 7, which simulate portions of the Saugus Formation lying below the uppermost model layer, the storage coefficients were allowed to range between 10^{-4} and 10^{-3}, based on analyses of the ASR test results (RCS, 2001) and pumping tests at other Saugus wells (RCS, 2002).

4.3.3 Stormwater Runoff in Upstream Watersheds

See Section 3.6 and Appendix C for discussions of the SWRM, which determined the amount of stormwater generated in upstream watersheds that is available to recharge the Alluvial Aquifer.

4.3.4 Riverbed Permeabilities

The establishment of streambed permeabilities for perennial (gaining) and ephemeral (losing) stream reaches are discussed separately below.

4.3.4.1 Perennial (Gaining) Streams

The streambed conductance terms in the MicroFEM® drain and wadi packages regulate the rate of water exchange between groundwater and surface water along selected stream reaches in the valley. As discussed in Section 3.5, the wadi package is used along the perennial reach of the Santa Clara River, and the drain package is used in the river's ephemeral reach and along Castaic Creek to drain groundwater during periods of high water table conditions. For the drain and wadi packages, the streambed conductance at each node where these packages are used is defined from the following relationship:

$$C = (a/LW) * ([0.5*b_{aq}/Kv_{aq}] + [b_{stream}/Kv_{stream}]) \quad (1)$$

where at each stream node:

a = wetted area of the streambed

L = one-half of the combined lengths of the two grid segments (lines) that connect the stream node to the adjoining upstream and downstream stream nodes

W = the width of the streambed

b_{aq} = the thickness of the Alluvial Aquifer beneath the stream node

Kv_{aq} = the vertical hydraulic conductivity of the Alluvial Aquifer beneath the stream node

b_{stream} = the thickness of the riverbed sediments

Kv_{stream} = the vertical hydraulic conductivity of the riverbed sediments

The calibrated Regional Model uses values of 2 feet for b_{aq} and 10 ft/day (3.5×10^{-3} centimeters per second [cm/sec]) for Kv_{aq}.

4.3.4.2 Ephemeral (Losing) Streams

During the transient calibration phase of model development, the SWRM adjusted the streambed conductance terms for Castaic Creek and for the ephemeral reach of the Santa Clara River. Adjustments in streambed conductance values were made for the following reasons:

a. To integrate this term into the transient model calibration process

b. To account for the variations in streambed conductance that arise from:

   1. Variations in riverbed permeability along the length of the streambed

   2. Variations in riverbed permeability that can occur at a given location due to sediment scouring and redeposition processes that occur during storm runoff periods

   3. Variations in streambed conductance that arise from variations in the width of the river (greatest during storm runoff periods, smallest during low-flow periods)

The adjustment of streambed conductance values during calibration of the transient model was performed for each month and was conducted in an iterative manner by running both the SWRM and the Regional Model repeatedly until the streambed conductance terms or groundwater elevations showed no significant changes (see Appendix C).

4.3.5 Evapotranspiration Parameters

The ET rooting depth was set at 10 feet to correspond to typical rooting depths for phreatophytes such as the willow and cottonwood trees that are present in the riparian corridor along the perennial reach of the Santa Clara River. The maximum potential ET rate was set at 6 feet per year (ft/yr) during model calibration. Ground surface elevation was specified by importing USGS Digital Elevation Model files.

4.4 Calibration Procedure and Target Calibration Data

The steady-state and transient models were calibrated by running the Regional Model and comparing results to the calibration goals described in Section 4.2. The comparison of model results with calibration goals relied on the use of target data that consisted of groundwater elevation data, groundwater discharge to the river, and total flow in the river. Following are discussions of the target calibration data.

4.4.1 Groundwater Elevation Target Data

Alluvial Aquifer target wells were selected for each of the Alluvial zones shown in Figure 4-1. In the Saugus Formation, most wells were used as targets (Figure 4-2). Generally, the selected target wells were those with the greatest number of groundwater elevation measurements during the periods 1980 through 1985 for the steady-state model and 1980 through 1999 for the transient model. Some wells were measured routinely through 1985 but not through 1999, and some wells were not measured until after 1985. Therefore, the list of wells used as targets is different for the steady-state and transient models.

Figure 4-1 shows the target wells for the Alluvial Aquifer, and Figure 4-2 shows the target wells for the Saugus Formation. Table 4-1 provides location and construction information for each target well. The target wells include (1) purveyor-owned production wells; (2) production wells located at the Wayside Honor Rancho (WHR) facility; and (3) a network of non-pumping or low-pumping monitoring wells where water levels have been measured routinely by the Los Angeles County Flood Control District (LACFCD) for many years.

For the production wells, the available water level measurements have been recorded as pumping elevations and static elevations. Static elevations are collected when the well is not pumping. Model-simulated groundwater elevations at a pumping well will be higher than those measured under pumping conditions for the following reasons:

a. In the model, pumping is assigned at these wells, but the pumping nodes have much larger areas than the diameter of the borehole in which each well is completed.

b. The field measurements of groundwater elevations under pumping conditions measure lower groundwater elevations than exist in the aquifer adjacent to the borehole, due to well losses across the borehole wall and the screen or slotted pipe.

Therefore, for model calibration purposes, the calibration goal at target wells that pump was to simulate groundwater elevations as close to the static elevations as possible, while also ensuring that simulated elevations were higher than the pumping elevations. More importantly, the transient calibration effort focused on the periods with the greatest groundwater elevation changes, and the analysis specifically focused on the slopes of the hydrographs, not just the absolute magnitudes of the groundwater elevations.

In the tributary canyons east of I-5, geologic logs were unavailable for many of the LACFCD wells. The total depths and open intervals for many of these wells suggested that they were completed in the geologic units underlying the alluvium, probably due to limited saturated thickness in the alluvium, particularly in the upper reaches of each canyon. For this reason, no targets were selected in Mint Canyon or upstream of the SCWC-Clark production well in Bouquet Canyon. In Sand Canyon, only the well farthest downstream, 7188A, was deemed suitable for use as an Alluvial Aquifer target well. Along the South Fork Santa Clara River, geologic logs and well construction data indicate that all target wells are constructed in the Saugus Formation, not the alluvium. The geologic data indicate that there is very limited saturated thickness in the alluvium in this area.

4.4.2 Santa Clara River Baseflow and Total Flow

Target river flow data to which the Regional Model results were compared were the total gaged flow at the County Line gage and estimates of how much of the gaged flow consisted of groundwater discharge to the river (baseflow).

The simulated total flow at the County Line gage equaled the sum of:

a. The simulated groundwater discharge to the river as calculated by the groundwater model from all wadi and drain nodes

b. The volume of water in the streams that the Visual Basic program (described in Section 3.6 and Appendix C) calculated as surplus stream flow that would not infiltrate to the underlying Alluvial Aquifer

This simulated total flow was compared directly with County Line gage results. The simulated groundwater discharge to the river was compared with the estimated values of river baseflow described previously in Section 2.6.2.5 of this report and listed in Table 2-6. For the steady-state model, the average baseflow during the period 1980 through 1985 was approximately 29,000 AF/yr.

4.4.3 Adjustments to Model Parameters

The steady-state and transient calibration process involved the adjustment of multiple parameters. Initially, the calibration effort focused on the steady-state model, where adjustments were made to Kh and Kv values and streambed coefficients, particularly in the gaining reaches of streams, to establish groundwater elevations, gradients, and flow directions. Attention was then devoted to the transient model, where the parameters receiving adjustment were the storativity, Sy, and the stormwater infiltration rates. Adjustments to Kh and Kv values that had been established during steady-state calibration were considered during transient calibration, but adjustments to these parameters were found to be unnecessary.

Initially, these efforts to calibrate the steady-state and transient models used a fixed, specified relationship between precipitation and stormwater to define the amount of water available for potential infiltration to groundwater. As Appendix C discusses, this relationship was in the form of an empirical power-function equation developed by Turner (1986). The empirical equation uses power-function coefficients that Turner (1986) developed from measurements of the yields from 68 different watersheds throughout California. Although the equation was used throughout the calibration process, including in the final model, the steady-state and transient calibration processes indicated that the empirical power-function coefficients reported by Turner (1986) generated too much stormwater and groundwater recharge to the Santa Clarita Valley during dry years and too little stormwater and groundwater recharge during wet years. This was determined by comparing hydrographs of measured and modeled groundwater elevations and river flows. After many attempts to achieve calibration by adjusting other model parameters, it was concluded that a different set of power coefficients would need to be developed for the Santa Clarita Valley. Consequently, during the final stages of calibration, adjustments to the model focused primarily on the values of these coefficients and on the values of the streambed vertical hydraulic conductivity. Calibration was considered complete once it was determined that the calibration goals were achieved or that no further improvements to the model were possible.

Tables

TABLE 4-1
Target Wells for Calibration of the Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Well Name	Location	Model Zone	Well in Steady-State Model	Well in Transient Model	Year Drilled	Status 1986	Status 2001	Well Use	Easting (feet)[a]	Northing (feet)[a]	Measuring Point Elevation (feet MSL)	Total Depth (feet bgs)	Depth to Top of Open Interval (feet bgs)	Depth to Base of Open Interval (feet bgs)	Type of Open Interval	Drilling Method	Sanitary Seal Depth (feet bgs)	Depth of Pump Intake (feet bgs)
Alluvial Aquifer West of I-5																		
NLF-B11	Santa Clara River	C1c	No	Yes		Active	Active	Agricultural supply	6362161	1971971	886							
NLF-B10	Santa Clara River	C1c	Yes	No	1956	Active	Active	Agricultural supply	6364235	1974541	901.4	142	30	130	Knife cut			
NLF-B7	Santa Clara River	C1c	No	Yes	1946	Active	Active	Agricultural supply	6364397	1973939	901.6	102	19	88	Knife cut			
NLF-C5	Santa Clara River	C1b	Yes	No	1939	Active	Active	Agricultural supply	6371746	1977874	960.1	139	31	133	Knife cut			
NLF-C6	Santa Clara River	C1b	No	Yes	1939	Active	Active	Agricultural supply	6371835	1978154	966	103	26	93	Knife cut			
NLF-E4	Santa Clara River	C1a	Yes	Yes	1940	Active	Active	Agricultural supply	6374844	1982371	992.5	142	50	136	Knife cut			
6995D	Santa Clara River	C1a	Yes	No	1970	Active	Active	Water levels	6379091	1983329	1018						0	
NLF-G45	Santa Clara River	B1b1	No	Yes	---	Active	Active	Agricultural supply	6381356	1982222	1030	140	40	140				
7076C	Santa Clara River	B1b1	Yes	No	---	Active	Destroyed?	Water levels	6385042	1980084	1059						0	
Alluvial Aquifer between I-5 and Soledad Canyon																		
VWC-I	Santa Clara River	B1b2	No	Yes	1945	Active	Inactive	Municipal supply	6388567	1981657	1090	171	30	165			55	120
NLF-S3	Santa Clara River	B1a	No	Yes	---	Active	Destroyed	Agricultural supply	6393334	1976292	1129	250	95	205				
VWC-N	Santa Clara River	B1a	No	Yes	1936	Active	Active	Municipal supply	6395527	1976081	1130	260	76	237	Knife cut		50	140
VWC-K2	Santa Clara River	B1a	Yes	No	1945	Active	Active	Municipal supply	6395788	1976021	1132	242	62	230	Knife cut		50	63
NLF-R	Santa Clara River	B1a	Yes	No	---	Active	Destroyed	Agricultural supply	6397463	1977660	1157	160	40	140				
7067D	Santa Clara River	B1a	No	Yes	1964	Active	Destroyed?	Water levels	6398546	1977483	1157.5						0	
VWC-Q2	Santa Clara River	B1a	No	Yes	1954	Active	Active	Municipal supply	6399032	1977459	1158	170	76	126				100
Alluvial Aquifer in Soledad Canyon																		
SCWC-Stadium	Santa Clara River	A1e1	Yes	Yes	1946	Active	Active	Municipal supply	6402385	1974713	1197	130	33	130	Knife cut	Unknown		130
VWC-T4	Santa Clara River	A1e1	Yes	No	1953	Active	Active	Municipal supply	6403350	1975164	1191	150	50	135	Knife cut		50	100
VWC-T2	Santa Clara River	A1c1	No	Yes	1952	Active	Active	Municipal supply	6403623	1975127	1201	150	50	138	Knife cut			100
LACFCD-7107C	Santa Clara River	A1d1	Yes	No	---	Active	Destroyed?	Water levels	6410792	1975622	1276						0	
SCWC-Honby	Santa Clara River	A1d1	No	Yes	1959	Active	Active	Municipal supply	6411408	1977202	1282	226	50	202	Factory	Rotary	30	130
7127D	Santa Clara River	A1d2	Yes	Yes	1974	Active	Active	Water levels	6417808	1977062	1333	157					0	
SCWC-N Oaks West	Santa Clara River	A1d4	Yes	No	1940	Active	Active	Municipal supply	6421187	1972857	1392	136	80	118	Knife cut	Unknown		110
SCWC-N Oaks East	Santa Clara River	A1d4	No	Yes	1940	Active	Active	Municipal supply	6421651	1972936	1398	132	81	150	Knife cut	Unknown		130
7148K	Santa Clara River	A1c1	No	Yes	---	Active	Active	Water levels	6423523	1973851	1435						0	
7158K	Santa Clara River	A1c2	Yes	No	1965 or earlier	Active	Active	Water levels	6427699	1973490	1460						0	
7168C	Santa Clara River	A1c2	Yes	Yes	---	Active	Active	Water levels	6430088	1974149	1488						0	
SCWC-Mitchell	Santa Clara River	A1c2	No	Yes	1976	Active	Active	Municipal supply	6430168	1974420	1489	262	76	246	125 Mesh	Rotary	76	162
SCWC-Sand Canyon	Santa Clara River	A1c3	Yes	No	1973	Active	Active	Municipal supply	6432953	1975589	1523	127	60	140	Factory	Rotary	60	112
7178D	Santa Clara River	A1c3	Yes	No	1950 or earlier	Active	Active	Water levels	6433648	1975837	1528						0	
SCWC-Lost Canyon 2	Santa Clara River	A1c3	No	Yes	1965	Active	Active	Municipal supply	6433582	1975573	1530	310	95	125	Factory	Rotary	30	295
7177B	Santa Clara River	A1b1	No	Yes	1949 or earlier	Active	Active	Water levels	6434745	1976476	1542						0	
7177P	Santa Clara River	A1b1	Yes	No	---	Active	Active	Water levels	6434036	1976556	1542						0	
7187C	Santa Clara River	A1b2	Yes	No	---	Active	Active	Water levels	6435847	1977582	1548						0	
7197	Santa Clara River	A1b2	Yes	Yes	1945 or earlier	Active	Destroyed?	Water levels	6437790	1977821	1579						0	
7197D	Santa Clara River	A1b2	No	Yes	---	Active	Active	Water levels	6438053	1977798	1582						0	
NCWD-Pinetree1	Santa Clara River	A1b2	No	Yes	1966	Active	Active	Municipal supply	6439831	1977964	1588	235	50	210			20	160
7197G	Santa Clara River	A1b2	Yes	No	1974 or earlier	Active	Active	Water levels	6440544	1978061	1600						0	
Alluvial Aquifer along Castaic Creek																		
VWC-D	Castaic Creek	C2b	No	Yes	1950	Active	Active	Municipal supply	6375668	1987267	1036	142	60	136	Knife cut		50	100
6993A	Castaic Creek	C2b	Yes	Yes	1958 or earlier	Active	Active	Water levels	6377865	1992457	1067						0	
6981D	Castaic Creek	C2a	Yes	Yes	1972 or earlier	Active	Active	Water levels	6376437	2000534	1127						0	
NCWD-Castaic3	Castaic Creek	C2a	No	Yes	1961	Active	Active	Municipal supply	6376475	2002309	1141	135	55	136				100
6980E	Castaic Creek	C2a	No	Yes	1962 or earlier	Active	Active	Water levels	6376282	2002242	1144						0	
6980G	Castaic Creek	C2a	Yes	No	1962 or earlier	Active	Destroyed?	Water levels	6376020	2002731	1151						0	

TABLE 4-1
Target Wells for Calibration of the Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Well Owner-Well Name	Location	Model Zone	Well in Steady-State Model	Well in Transient Model	Year Drilled	Status 1986	Status 2001	Well Use	Easting (feet)[a]	Northing (feet)[a]	Measuring Point Elevation (feet MSL)	Total Depth (feet bgs)	Depth to Top of Open Interval (feet bgs)	Depth to Base of Open Interval (feet bgs)	Type of Open Interval	Drilling Method	Sanitary Seal Depth (feet bgs)	Depth of Pump Intake (feet bgs)
Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River																		
VWC-W6	San Francisquito Canyon	B4c	Yes	Yes	1952	Active	Active	Municipal supply	6393801	1985449	1159	158	90	153	Knife cut		50	100
7066D	Bouquet Canyon	B2c	Yes	Yes	---	Active	Active	Water levels	6400238	1979734	1182						0	
7086B	Bouquet Canyon	B2c	Yes	No	---	Active	Active	Water levels	6405151	1981611	1247						0	
SCWC-Clark	Bouquet Canyon	B2c	No	Yes	1946	Active	Active	Municipal supply	6405894	1983061	1257	160	20	120	Knife cut	Unknown		110
7095	Bouquet Canyon	B2b	Yes	No	1930 or earlier	Active	Active	Water levels	6409922	1986103	1323	146					0	
7188A	Sand Canyon	A3b	No	Yes	1952	Active	Active	Water levels	6434878	1972313	1568						0	
Saugus Formation																		
VWC-160	Santa Clara River	E	Yes	Yes	1964	Active	Active	Municipal supply	6388950	1976191	1101	2000	950	2000	Louvers	Rotary	65	260
7048C	Santa Clara River	E	Yes	Yes	1981	Active	Destroyed?	Water levels	6395222	1974491	1147						0	
VWC-157	S. Fork Santa Clara River	E	Yes	Yes	1962	Active	Active	Municipal supply	6395696	1974099	1151	2008	586	2008	Vertical slots	Rotary	15	340
VWC-201	S. Fork Santa Clara River	E	No	Yes	1989	Not Built	Active	Municipal supply	6394125	1973032	1152	1690	540	1670	Louvers	Mud rotary	460	360
SCWC-Saugus1	S. Fork Santa Clara River	E	No	Yes	1988	Not Built	Inactive	Municipal supply	6397847	1973452	1162	1640	490	1620	Wire wrap screen	Reverse	450	500
SCWC-Saugus2	S. Fork Santa Clara River	E	No	Yes	1988	Not Built	Inactive	Municipal supply	6398514	1972540	1158	1612	490	1591	Wire wrap screen	Reverse	460	500
NCWD-11	S. Fork Santa Clara River	F	Yes	Yes	1973	Active	Active	Municipal supply	6399004	1968019	1187	1136	200	1075	Louvers	Reverse rotary	150	340
NCWD-13	S. Fork Santa Clara River	F	No	Yes	1990	Not Built	Active	Municipal supply	6399098	1967327	1194	1300	420	750			50	445
NCWD-12	S. Fork Santa Clara River	F	Yes	Yes	1985	Inactive	Active	Municipal supply	6399282	1965920	1206	1340	485	1280	Louvers	Reverse rotary	420	400
NCWD-10	S. Fork Santa Clara River	F	Yes	Yes	1961	Active	Inactive	Municipal supply	6399388	1965803	1207	1555	780	1544	Louvers	Rotary	114	335
5851	S. Fork Santa Clara River	F	Yes	Yes	1968	Active	Active	Water levels	6396468	1962533	1233						0	
5851A	S. Fork Santa Clara River	F	Yes	No	1968	Active	Active	Water levels	6396432	1962504	1233						0	
5842F	S. Fork Santa Clara River	A	Yes	No	1974	Active	Active	Water levels	6395286	1960869	1248						0	
NCWD7	S. Fork Santa Clara River	F	Yes	Yes	1954	Active	Inactive	Municipal supply	6401264	1962732	1251	994	520	974	Knife cut	Cable tool		306
5841	S. Fork Santa Clara River	F	Yes	No	1973	Active	Active	Water levels	6393394	1963704	1256						0	
5871D	S. Fork Santa Clara River	F	Yes	No	1948 or earlier	Active	Active	Water levels	6402392	1962734	1262						0	
7053C	San Francisquito Canyon	D	Yes	No	---	Active	Destroyed?	Water levels	6397679	1992663	1291						0	
5882	S. Fork Santa Clara River	A	Yes	No	1931 or earlier	Active	Active	Water levels	6406409	1957586	1327						0	
5873E	S. Fork Santa Clara River	A	Yes	No	1957	Active	Active	Water levels	6403977	1957147	1353						0	
NCWD-9	S. Fork Santa Clara River	A	Yes	Yes	1958	Active	Inactive	Municipal supply	6404122	1956997	1354	675	311	674	Louvers	Rotary	75	230
5831	S. Fork Santa Clara River	A	Yes	No	1962	Active	Active	Water levels	6391103	1961398	1381						0	
7053D	San Francisquito Canyon	D	Yes	No	---	Active	Active	Water levels	6398984	1990433	1402						0	
5912A	S. Fork Santa Clara River	A	Yes	No	1948 or earlier	Active	Active	Water levels	6414810	1960110	1445						0	
7043C	San Francisquito Canyon	D	Yes	No	---	Active	Active	Water levels	6392762	1994816	1528						0	

[a]Coordinates are listed in California State Plane, NAD83 Datum, Zone V.

Notes:

Wells without owner designations belong to the Los Angeles County Flood Control District (LACFCD).

-- = No data available.

N. = north

S. = south.

Figures

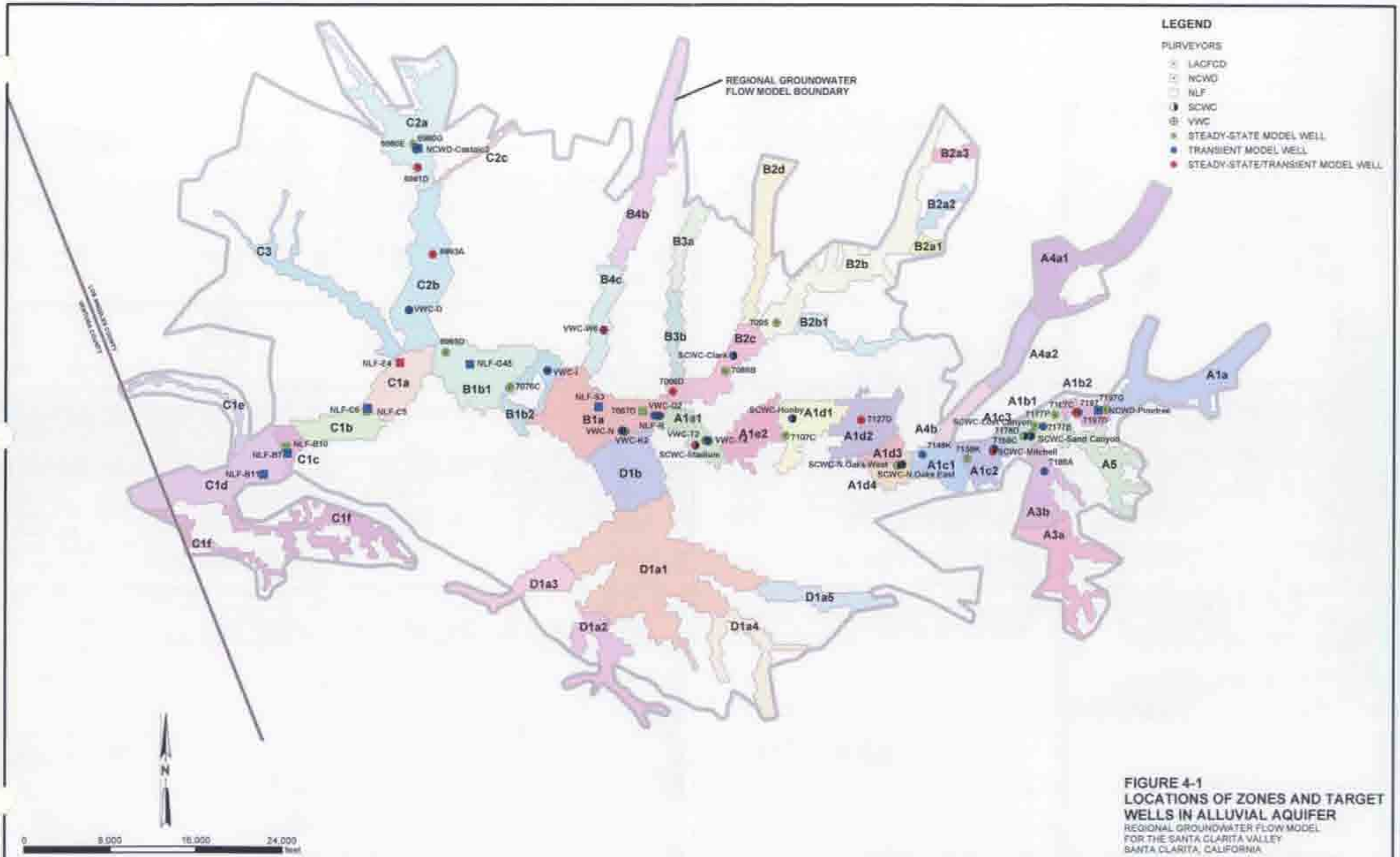

FIGURE 4-1
LOCATIONS OF ZONES AND TARGET WELLS IN ALLUVIAL AQUIFER
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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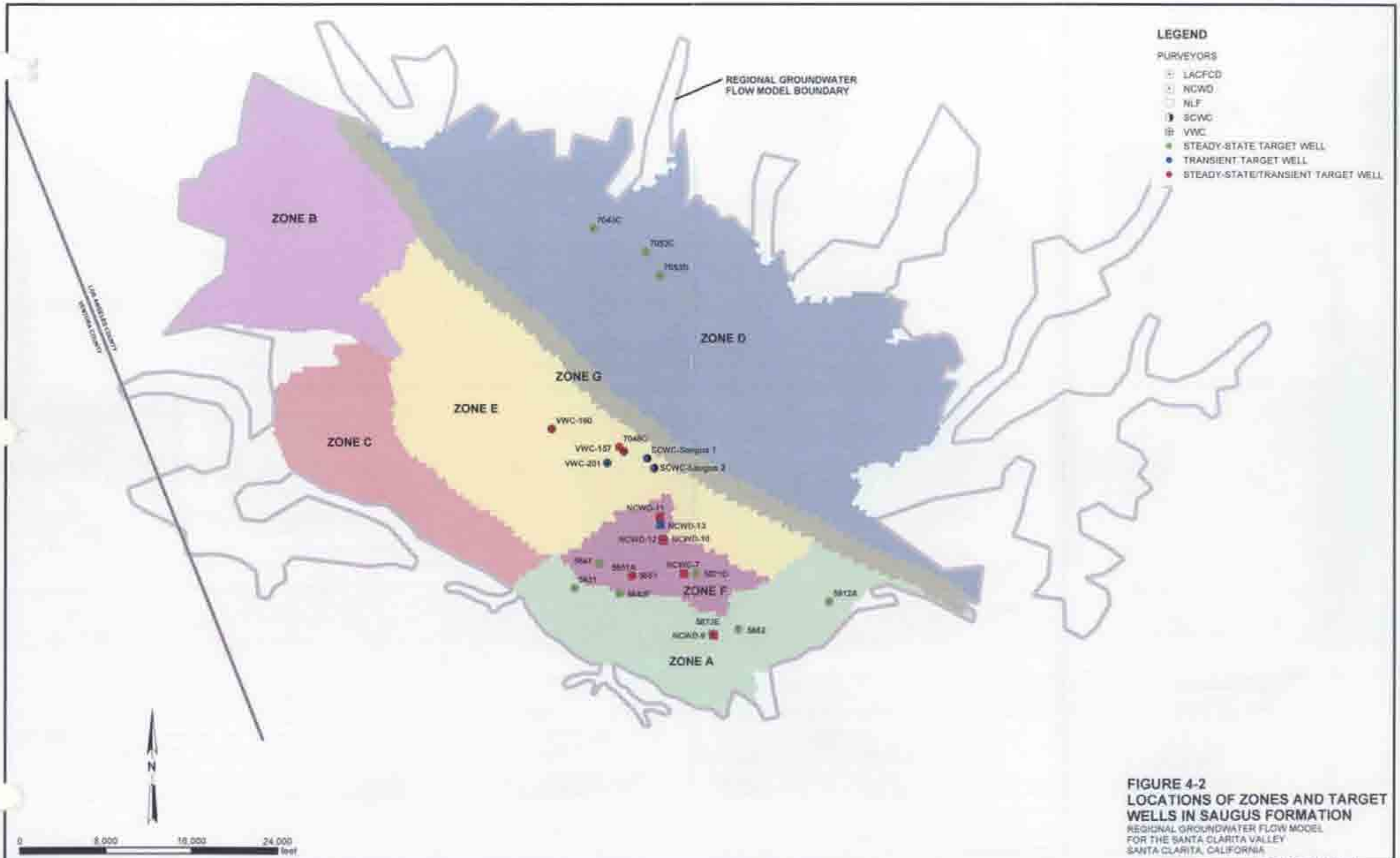

FIGURE 4-2
LOCATIONS OF ZONES AND TARGET WELLS IN SAUGUS FORMATION
REGIONAL GROUNDWATER FLOW MODEL
FOR THE SANTA CLARITA VALLEY
SANTA CLARITA, CALIFORNIA

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SECTION 5

Calibration Results and Sensitivity Analysis

This section of the report presents the calibrated Regional Model and a sensitivity analysis of the Regional Model. Sections 5.1 and 5.2 discuss the calibration quality of the steady-state and transient models (respectively) with reference to the calibration goals discussed in Section 4.2. Section 5.3 discusses the groundwater budgets for both models. Section 5.4 describes a sensitivity analysis that further evaluated calibration quality by comparing the sensitivity of the model-predicted groundwater elevations and river flows to the values of key model parameters.

The distribution of Kh in the calibrated model is presented on Figures 5-1 through 5-7 for model layers 1 through 7, respectively. Table 5-1 summarizes the values of transmissivity, thickness, and hydraulic conductivity in the 48 alluvial zones. Table 5-2 summarizes values of the other calibrated hydraulic properties that are used in the model.

5.1 Calibration Results for the Steady-State Model

Following are discussions of how the calibrated model compares with the six calibration goals established for the 1980 through 1985 steady-state model.

5.1.1 Groundwater Flow Directions – Calibration Goal 1

Figure 5-8 shows simulated groundwater elevations and flow directions in the Alluvial Aquifer as computed by the steady-state model. The groundwater flow directions are from east to west along the Santa Clara River, which is in agreement with published contour maps for the Alluvial Aquifer (see Figure 2-7). The contours show a very flat hydraulic gradient in the lower reach of the valley containing the South Fork Santa Clara River, which also agrees with published interpretations.

Figures 5-9 through 5-14 show groundwater elevation contour maps for layers 2 through 7 of the Regional Model, which represent the Saugus Formation. Layer 3 (Figure 5-10) is situated from 500 feet bgs to 1,000 bgs and is partially or fully screened by several of the Saugus production wells that are situated in the valley containing the South Fork Santa Clara River. In this area, the model-simulated flow directions in layer 3 are in good general agreement with published interpretations (see Figure 2-8).

5.1.2 Groundwater Elevation Residuals – Calibration Goal 2

Figure 5-15 is a scatter plot comparing simulated and observed average groundwater elevations for target wells in both the Alluvial Aquifer and the Saugus Formation. For a perfect simulation, each point shown on the figure would lie on the diagonal line. The figure shows that the Alluvial Aquifer target wells lie very close to the diagonal line, indicating a very good calibration to the observed average groundwater elevations from 1980 through 1985. For the Saugus Formation, there is greater variability. Some Saugus wells plot very close to the diagonal line, while one well (5882) lies 80 feet above the line and another well

(5831) lies 80 feet below the line. These two particular wells are near the southern model boundary, where the available water level data indicate that the groundwater gradients in the Saugus are very steep compared to areas closer to the Saugus production wells. Nonetheless, the Saugus wells are generally close to the diagonal line and do not plot consistently above or consistently below the line, indicating that the Saugus Formation is closely calibrated in the steady-state model.

Table 5-3 lists the residuals for Alluvial and Saugus wells. The residuals are also plotted on Figures 5-16 through 5-19. Positive residuals indicate that the Regional Model over-predicts the groundwater elevation, and negative residuals indicate that it under-predicts the groundwater elevation. Observations regarding the residuals are as follows:

a. Figure 5-16 shows the magnitudes of the groundwater elevation residuals for the 21 target wells in the Alluvial Aquifer that lie along the Santa Clara River. The plot shows the target wells in order from the downstream end of the valley (left side) to the upstream limit of the valley (right side). The plot shows that 13 of the 21 wells have residuals in the range of –5 to +5 feet, and that only one well (7158K) does not meet the 10-foot residual criterion for Goal 2. The plot also shows little, if any, spatial bias in the direction of the residuals; specifically, long reaches of the river do not show consistently positive or consistently negative residuals. Consequently, the groundwater elevations are very well calibrated along the Santa Clara River.

b. Figure 5-17 shows an equivalent plot for Alluvial Aquifer wells located in three of the tributary canyons. In these areas, where gradients are steep, the modeled groundwater elevations are generally within 10 to 11 feet of the average measured elevations. The plot indicates a tendency to slightly under-predict groundwater elevations, particularly in the upper-most reach of Bouquet Canyon, but the residuals generally meet the criterion for Goal 2.

c. Figures 5-18 and 5-19 show similar residual plots for production wells and for LACFCD monitoring wells, respectively, in the Saugus Formation. Three of the seven production wells meet the 25-foot residual criterion for Goal 2, and three of the monitoring wells meet this criterion. Both plots indicate a tendency to under-predict static groundwater elevations, particularly in four wells that are near the outer limits of the Saugus Formation (wells NCWD-9, 5831, 7043C, and 7053D). However, the water levels in these four wells appear to be anomalously high, compared with the water levels in surrounding wells. Consequently, the water level data indicate that these wells (particularly the three LACFCD wells) are constructed in perched Saugus zones lying above the regional Saugus aquifer system, and the negative residuals at these wells correspond to the anomalously high groundwater elevations. Excluding these four wells, three of the six production wells and five of the ten LACFCD monitoring wells meet the Goal 2 criterion, indicating that the steady-state calibration of the Saugus Formation is adequate, particularly because the focus of the model calibration effort is transient calibration, which is discussed in Section 5.2.

5.1.3 Statistics of Groundwater Elevation Residuals – Calibration Goal 3

Table 5-4 lists the residual statistics for target wells in both aquifer systems. The table shows statistics for the same wells listed in Table 5-3 and shown on Figures 5-16 through 5-19, except for Saugus wells 5831, 7043C, and 7053D. Table 5-4 shows that the residual statistics for the Alluvial Aquifer generally meet the criteria specified in Goal 3. For the Saugus Formation, the statistics meet the mean residual criterion, but the statistics for the square of the residuals are slightly above the criteria of (1) less than 25 feet for RMS error or (2) 10 percent or less for normalized RMS error. The Regional Model as a whole, however, with the Alluvial Aquifer and Saugus Formation combined, meets all Goal 3 criteria.

5.1.4 Groundwater Gradients – Calibration Goal 4

In the Alluvial Aquifer, the results for the first three calibration goals indicate that the steady-state model simulates groundwater gradients quite well, and therefore meets Goal 4.

For the Saugus Formation, the residuals for the NCWD wellfield in the South Fork Santa Clara River are consistently negative. However, the residual at the upgradient end of the wellfield at NCWD-7[5] is similar in magnitude to the average residual at the downgradient end of the wellfield at NCWD-10 and NCWD-11. Consequently, the gradients in this area are simulated reasonably well. Simulated gradients from the NCWD wellfield to the downgradient well VWC-160 are slightly low, as suggested by the more negative residuals in the NCWD wellfield and the less negative residual at VWC-160.

Additionally, recent water level data from the Whittaker-Bermite property indicate that the gradients are well simulated within the Saugus Formation in that area, which lies east and northeast of NCWD's wellfield. Table 5-5 shows the calculations of the model-simulated and measured groundwater gradients between wells MP-1 and MP-2, which are both on the downthrown side of the San Gabriel fault, and between MP-2 and MP-3, which are located on the downthrown side and upthrown side of the fault, respectively. These calculations are based on three rounds of manual water level measurements that were taken from January through October in 2003. Between wells MP-1 and MP-2, the gradients are almost perfectly matched. However, across the San Gabriel fault, the modeled gradient is approximately half as large as the measured gradient because the simulated groundwater elevation is low at MP-3.

Several attempts were made during model calibration to reduce the Saugus permeability to very low levels across the fault, but no further increases in MP-3 water levels could be obtained. The calibrated Regional Model uses a permeability along the fault that is between 100 and 1,000 times lower than the permeability of adjoining Saugus areas. Although the Regional Model was unable to simulate as high a groundwater elevation as has been measured recently at MP-3, it does simulate a substantial drop in groundwater elevations across the San Gabriel fault, which is consistent with the understanding of the limited hydraulic connection across the fault (see Section 2.4.2 and Figure 2-9). Therefore, the Regional Model is well calibrated across the fault because it simulates the permeability differences that exist on each side of the fault and also simulates the very limited movement of groundwater across the fault that is indicated by the significant difference in groundwater elevations that has been measured in the multi-port wells on each side of the fault.

[5] Well NCWD-9 is located farther upgradient, but has been used only sparingly since 1987.

5.1.5 Groundwater Below Ground Surface – Calibration Goal 5

Groundwater elevations simulated by the steady-state model are below ground surface at all non-stream nodes and in each tributary stream. Along the Santa Clara River, a small number of nodes showed groundwater elevations above the streambed in the western portion of Soledad Canyon, and also at and immediately upstream of Round Mountain, a Saugus outcrop that likely lies at shallow depths beneath the river itself. The reach of the river west of I-5 was calculated to be predominantly gaining (groundwater above ground surface). However, the Regional Model predicts that the river is losing over a reach extending between approximately 0.75 mile upstream to 0.5 mile downstream of the location where the river crosses over the western limit of the Saugus Formation. In this area, the riverbed has a gentler slope than in adjoining areas, and the riverbed does not lie beneath the water table in this particular reach.

5.1.6 Groundwater Discharge to River – Calibration Goal 6

The model-simulated groundwater discharge to the river was 28,600 AF/yr, which closely agrees with the 29,000 AF/yr value estimated from the hydrograph separation process described in Section 2.6.2.5.

5.2 Calibration Results for the Transient Model

Following are discussions of how the calibrated Regional Model compares with the four calibration goals established for the 1980 through 1999 transient model.

5.2.1 Groundwater Elevation Trends/Hydrographs – Calibration Goal 1

Trends in groundwater elevations are discussed for the following areas:

a. The Alluvial Aquifer along the Santa Clara River, west of I-5, as shown on Figure 5-20

b. The Alluvial Aquifer along the Santa Clara River, between I-5 and Soledad Canyon, as shown on Figure 5-21

c. The Alluvial Aquifer along the Santa Clara River in Soledad Canyon, as shown on Figure 5-22

d. The Alluvial Aquifer along Castaic Creek, as shown on Figure 5-23

e. The Alluvial Aquifer in other tributary canyons to the Santa Clara River, as shown on Figure 5-24

f. The Saugus Formation, where targets are located along the South Fork Santa Clara River, as shown on Figure 5-25

As discussed in Section 4.4.1, the calibration goal at target production wells was to simulate groundwater elevations that were higher than the pumping elevations and as close as possible to the static elevations. Therefore, the hydrographs show the model-simulated groundwater elevations, the measured static groundwater elevations, and, for production wells, the measured pumping groundwater elevations.

5.2.1.1 Alluvial Aquifer West of I-5

Modeled and measured groundwater elevations both show long-term stability, with no significant increases or decreases during the 1980 through 1999 transient calibration period. The Regional Model simulates somewhat greater seasonal variation in groundwater elevations than is suggested by the field measurements. However, the field measurements were collected infrequently. In general, the Regional Model is well calibrated in this area because of the close match between simulated and measured groundwater elevations and because it simulates the long-term stability of groundwater elevations in this area.

5.2.1.2 Alluvial Aquifer Between I-5 and Soledad Canyon

North of the Santa Clara River, near the mouth of San Francisquito Canyon, the Regional Model simulates the observed trends in static groundwater elevations at wells NLF-S3 and VWC-I during the period that data are available. The groundwater elevation trends are particularly well simulated at VWC-I starting in mid-1996, when the water level measurement frequency increased at this well.

Just upstream and along the south side of the river, the Regional Model simulates the trends in static water levels at well VWC-N very closely throughout the 20-year simulation period. The Regional Model also simulates the trends in static water levels quite well at well VWC-Q2, near the mouth of Soledad Canyon. In this same area, monitoring well 7067D simulates groundwater elevations that are somewhat lower than measured elevations, and the 40-foot fluctuation in simulated water levels at this well is of a generally similar magnitude as the observed fluctuation of 50 feet.

5.2.1.3 Alluvial Aquifer In Soledad Canyon

At wells throughout Soledad Canyon, the Regional Model closely simulates the regional decline in groundwater elevations during the late 1980s and early 1990s. The simulated and measured declines are especially close for wells in the eastern portion of this area, such as SCWC-North Oaks, SCWC-Mitchell, SCWC-Lost Canyon 2, and NCWD-Pinetree1.

Although the sharp increases in groundwater elevations in 1992 and 1993 are modeled well, these same wells (in the eastern half of Soledad Canyon) are unable to maintain high enough groundwater elevations during short dry periods that occur intermittently from 1993 through 1999. During this period, wells further to the west, such as SCWC-Stadium, VWC-T2, SCWC-Honby, and 7127D show better matches between modeled and measured groundwater elevations. Many model runs were performed to try to maintain higher water levels in eastern Soledad Canyon, but no substantial improvements could be made, suggesting that the lack of stream gage data at the Lang gage during this period may be responsible for the discrepancies.

A visual inspection of the former Lang gage station was conducted on July 17, 2003 during the model calibration process. The equipment that records the depth of water in the river was observed to be approximately 3 to 4 feet above the bed of the river at the time of the inspection. Although high river flows are known to have occurred since the time the gage was abandoned, it is unlikely that the bed elevation would have been lowered 3 or 4 feet by the net sediment scouring and redeposition processes that occur during high river flows. This observation means there likely was more flow occurring in the river prior to October

1989 than was recorded by this gage. This in turn means that measured and estimated flows during the period 1980 through 1999 are likely too low in the Regional Model, which would explain the model's simulation of too rapid a decline in water levels after high river flows recharge the aquifer. In summary, the design of the gage and the absence of data after October 1989 are the likely reasons that the Regional Model has difficulty maintaining sufficiently high groundwater elevations during dry periods in the eastern portion of the Alluvial Aquifer.

5.2.1.4 Alluvial Aquifer Along Castaic Creek

In the upper reaches of the Castaic Creek valley, the Regional Model simulates the measured groundwater elevation trends very well during the drought at wells NCWD-Castaic3, 6980E, and 6980G, though this evaluation is somewhat uncertain during the early 1980s due to infrequent data collection. However, these same wells show too much recovery during the initial post-drought recovery period in 1992, and they also show a small rise in groundwater elevations from 1993 through 1999 that is not indicated by the field measurements.

Farther downstream, the Regional Model closely matches the measured groundwater elevation trends at well 6993A well until the last few years of the drought, when groundwater elevations do not drop sufficiently. Well VWC-D (farther downstream) is modeled even better, but also shows a bit too much fluctuation during the mid- and late 1990s.

5.2.1.5 Alluvial Aquifer in Other Tributary Canyons to the Santa Clara River

At production well VWC-W6 in the lower reaches of San Francisquito Canyon, the Regional Model appears to simulate the measured groundwater elevations well, except for a possibly insufficient decline in early 1992 at the conclusion of the regional drought.

In Bouquet Canyon, the Regional Model closely simulates the measured groundwater elevation changes at the SCWC-Clark production well, although the groundwater elevations are a bit high throughout the simulation. The groundwater elevation trends are also well simulated farther downstream at monitoring well 7066D, though the groundwater elevations are somewhat under-predicted throughout the simulation.

In Sand Canyon, the simulation at monitoring well 7188A is good, although there is some uncertainty at the end of the drought due to the lack of data collection during 1990 and 1991.

5.2.1.6 Saugus Formation

In general, the Regional Model simulates the trends in groundwater elevations quite well at each Saugus production and monitoring well. Simulated and measured static groundwater elevations agree particularly well in the NCWD wellfield at the observation well (5851) and each NCWD production well.

Farther downgradient, the model tends to slightly over-predict groundwater elevations in the VWC and SCWC production wells (VWC-157, VWC-201, SCWC-Saugus1, and SCWC-Saugus2) and slightly under-predict groundwater elevations in the lone monitoring well (7048-C). However, the Regional Model closely simulates the groundwater elevation trends at each of these locations, which is the primary consideration for evaluating the quality of the transient calibration process in the Saugus Formation.

5.2.2 Groundwater Below Ground Surface – Calibration Goal 2

This goal was met at each target in the transient model. Of the 44 transient model target wells, 11 had simulated groundwater elevations within 5 feet of ground surface during the wettest periods of the model simulation. Three of these wells were located in the Castaic Valley (6980E, 6981D, and NCWD-Castaic3), one was in lower Sand Canyon (7188A), one was in Bouquet Canyon (SCWC-Clark), and six were in Soledad Canyon (VWC-T2, 7127D, SCWC-Mitchell, SCWC-Lost Canyon 2, 7177B, and NCWD-Pinetree1).

5.2.3 Total River Flow at County Line Gage – Calibration Goal 3

Figure 5-26 compares the modeled and measured total flows of the Santa Clara River at the County Line gage. The figure contains both a linear plot and a semi-logarithmic plot to better illustrate how the modeled and measured flows compare during low flow periods in the river.

Figure 5-26 also shows that the Regional Model adequately replicates seasonal cycles of low and high river flows. Prior to 1992, peak flows during the wettest months tend to be somewhat underestimated, probably because of under-predicted flow in the streams rather than insufficient groundwater discharge to the river. From 1992 through 1997, peak flows match well, but they are again underestimated in 1998 and 1999.

Seasonal low flows, during the summer months, are slightly over-predicted. In years such as 1990, the model over-estimates river flows by approximately 100 to 200 acre-feet per month. In other years, the Regional Model over-estimates the river flows by as much as 1,000 acre-feet per month. To evaluate this further, the estimated and model-simulated groundwater discharges to the river were compared, as discussed below.

5.2.4 Groundwater Discharge to River – Calibration Goal 4

Figure 5-27 compares the model-simulated groundwater discharges to the river with the discharges that have been estimated from hydrograph separation techniques (see Section 2.6.2.5). Because of uncertainty in the amount of treated water that infiltrates the streambed, Figure 5-27 displays a range for the estimated values, varying according to how much of the Saugus WRP treated water is estimated to infiltrate to groundwater as it travels down the Santa Clara River. For the purposes of this comparison, it was estimated that the infiltration could be negligible (blue line) and would be unlikely to exceed 75 percent of the Saugus WRP discharge (green line).

Figure 5-27 shows that the Regional Model simulates the patterns of groundwater discharges well. The Regional Model predicts lower groundwater discharge rates during high flow/high water table periods than were estimated from the hydrograph separation technique, but model uncertainty may not be the cause of this difference. It is equally, if not more, likely that the difference is due to the significant uncertainties associated with the hydrograph separation process during periods of high river flows. Specifically, as discussed in Section 2.6.2.5, it is difficult to determine how much of the receding flow after peak flow events is due to groundwater discharges versus continued stormwater drainage from within the basin or from upstream watersheds.

Figure 5-27 also shows that the Regional Model tends to predict higher rates of groundwater discharge during dry periods than estimated from the County Line gage. This is consistent with the Regional Model's over-prediction of total river flows, but anecdotal observations at the former gaging station site during low flow periods indicate that the river sometimes carved small channels that diverted a portion of the flow away from the gage, where it could not be measured. Consequently, the differences between modeled and measured total river flows and measured versus estimated groundwater discharges result from uncertainties in both the Regional Model and the gage data.

5.3 Groundwater Budget

Table 5-6 summarizes the groundwater budget for the 1980 through 1985 steady-state model. The values in the table are the average groundwater recharge and discharge rates in AF/yr during this period. As shown in the table, the majority of the recharge occurs from direct rainfall and stormwater flows, with irrigation and Castaic Lake underflow each comprising a very small portion of the total basin recharge. Groundwater discharge during this time period was approximately one-third pumping and one-third discharge to the Santa Clara River, with the rest consisting of subsurface outflow and ET. The table shows that ET is an important part of the groundwater budget, 15 percent of the total groundwater discharge in the basin.

Table 5-7 summarizes the groundwater budget for each year of the 20-year transient model simulation period (1980 through 1999). Figures 5-28 and 5-29 show the annual groundwater recharge and groundwater discharge rates, respectively. Figure 5-30 shows the change in groundwater storage each year, and Figure 5-31 shows the cumulative change in groundwater storage during the simulation period.

As is evident from Figure 5-28, recharge from precipitation and streamflows varies considerably from year to year, ranging from less than 15,000 AF/yr in the driest years to over 100,000 AF/yr in wetter years. In fact, for the five wettest years during this period, the model estimates that groundwater recharge ranged between 175,000 AF/yr and 270,000 AF/yr. In contrast, total groundwater discharges have been less variable (Figure 5-29), ranging from approximately 61,000 AF/yr at the end of the drought in the late 1980s through early 1990s to 116,000 acre-feet during 1998. Table 5-7 and Figure 5-29 together show that this variability in groundwater discharge does not follow the year-to-year pumping patterns, but instead is caused by year-to-year fluctuations in ET and groundwater discharges to the river. These fluctuations, in turn, correlate well with groundwater recharge patterns. For example, groundwater discharge rates increase during or immediately after significant rainfall years in 1983, 1992 through 1993, 1995, and 1998, and subsequently decrease in response to below-normal precipitation in the ensuing 1 to 2 years. This indicates that the predominant factors influencing changes in storage and groundwater discharge are the local rainfall recharge and stream recharge patterns from year to year, with anthropogenic influences (pumping and irrigation) having a smaller effect on the groundwater system. This is reinforced by Figures 5-30 and 5-31, which show that changes in groundwater storage volumes reflect year-to-year variations in regional rainfall.

5.4 Sensitivity Analysis

Sensitivity analyses were performed on the calibrated Regional Model to evaluate whether further changes in the values of key model parameters would improve the calibration quality of the model. The sensitivity analyses focused on the transient model. Following is a description of the design of the analyses and the findings.

5.4.1 Method of Sensitivity Analysis

Analysis focused on identifying the sensitivity of the transient model to Kh and Kv for both aquifer systems, the permeability of the bed of the Santa Clara River, and, to a lesser degree, the ET parameters.

To perform the analysis, one model variable, or group of variables, was varied upward or downward, and the model was run again. The amount by which each model variable was adjusted upward or downward was based on the range of values that was considered to be plausible for the variable, according to the data analysis that was conducted in support of development of the hydrogeologic conceptual model for the valley, which is described in Section 2 of this report. The following pairs of sensitivity runs were performed:

a. Adjusting the Kh. This parameter was multiplied and divided by a factor of 1.5 in all model layers. The R (Kh:Kv) was left unchanged for these runs, but the change in Kh caused a change in Kv values.

b. Adjusting the R upward or downward by a factor of 4.0. This caused changes to Kv, but not to Kh.

c. Adjusting the storage parameters. In model layer 1, the Sy was adjusted from the calibrated model value of 0.10 to 0.075 and 0.15. In model layers 2 through 7, the storativity was adjusted from the calibrated model value of 5×10^{-4} to values of 1×10^{-4} and 1×10^{-3}. The reductions to Sy and storativity were run simultaneously in a single model run, and the increases in Sy and storativity were run simultaneously in a single model run.

d. Adjusting the riverbed leakage terms at drain and wadi nodes in the Santa Clara River and Castaic Creek. These terms were multiplied and divided by a factor of 10.

e. Adjusting the ET parameters in a way that produced less ET. In one run, the maximum evaporation depth was changed from 10 feet to 5 feet. In another run, the maximum evaporation rate was changed from 6 ft/yr to 3 ft/yr.

5.4.2 Sensitivity Analysis Results

The results of the focused sensitivity analysis are presented as time-series plots of water levels and groundwater discharges to the river. Results are first presented for the aquifer hydraulic parameters (Kh, R, Sy, and storativity), then for the riverbed permeability and ET terms.

5.4.2.1 Sensitivity of Groundwater Elevation Trends to Aquifer Parameters

Figures 5-32 through 5-38 show the sensitivity of Alluvial Aquifer groundwater elevations in the transient model to variations in Kh, R, and Sy. Figures 5-39 through 5-43 show the same information for three Saugus production wells and two Saugus monitoring wells. The results and the conclusions that can be drawn from them are:

a. Alluvial wells in the western part of the basin (NLF-B7 and NLF-G45) show slight sensitivity to the choice of Kh, and little sensitivity to R and Sy. Lower Kh values would degrade the calibration quality of the Regional Model, whereas the tested ranges of the other parameters would have little effect on calibration quality.

b. Further east, VWC-N shows greater sensitivity to each parameter, though it is relatively insensitive to lower Kh values. Lower Kh values or changes to R values would not degrade calibration quality, whereas other parameter changes could potentially degrade the calibration.

c. Results are similar in Soledad Canyon at SCWC-Stadium, SCWC-North Oaks East, and NCWD-Pinetree1. Higher Kh values substantially degrade the calibration quality of the transient model at each of these wells.

d. The transient model was slightly to moderately sensitive to the choice of Alluvial Aquifer Kh in Castaic Creek at well VWC-D. In this area, it showed little sensitivity to R or Sy in the Alluvial Aquifer. The results suggest that higher K values could slightly improve the calibration.

e. Water levels at Saugus production wells along the lower reaches of the South Fork Santa Clara River (VWC-201 and SCWC-Saugus2) are sensitive to the choice of R, moderately sensitive to the choice of Kh, and comparatively insensitive to storativity. The transient model is more sensitive to Kh and storativity at nearby monitoring well 7048C than at the pumping wells. The plots generally indicate the model is well calibrated, although small decreases in Kh might slightly improve the calibration quality.

f. Similar results are seen for production well NCWD-11 and monitoring well 5851 farther upstream in the South Fork Santa Clara River valley. At NCWD-11, the R appears to be particularly well calibrated, as lower values cause groundwater elevations to fluctuate insufficiently, and higher values cause too much fluctuation, and in some cases, model-simulated water levels that are below pumping levels. Changes to Kh would not improve the model, and could in fact degrade it at the monitoring well.

5.4.2.2 Sensitivity of Groundwater Elevation Trends to River and Evapotranspiration Parameters

Figures 5-44 through 5-50 show the sensitivity of Alluvial Aquifer groundwater elevations in the transient model to variations in the riverbed K for drain and wadi nodes and to decreases in the two ET parameters, extinction depth and maximum potential ET rate. Figures 5-51 through 5-55 show the same information for the three Saugus production wells and two Saugus monitoring wells discussed in Section 5.4.2.1. The results and the conclusions that can be drawn from them are:

a. Alluvial wells in the western and central parts of the basin (NLF-B7, NLF-G45, and VWC-N) and along Castaic Creek (VWC-D) are sensitive to the choice of the riverbed K for the drain and wadi nodes. Reduced conductivity values notably increase the groundwater elevations at some wells, while higher values somewhat decrease groundwater elevations. The plots suggest that changes to this term would not improve calibration quality and could substantially degrade the calibration at some of these wells. Further east, in Soledad Canyon, the Regional Model is relatively insensitive to riverbed K in the gaining reaches of the Santa Clara River.

b. Reductions in drain and wadi riverbed K increase groundwater elevations by raising groundwater elevations in the Alluvial Aquifer, to which the Saugus discharges. Decreased riverbed permeability backs up water in the Alluvial Aquifer, and hence in the Saugus Formation. Changes to riverbed permeability do not improve Saugus calibration.

c. Groundwater levels in both the Alluvial Aquifer and the Saugus Formation are insensitive to the choice of ET parameters.

5.4.2.3 Sensitivity of Groundwater Discharge to the River to Changes in Aquifer Parameters

Figures 5-56 shows the sensitivity of discharges of Alluvial Aquifer groundwater to the river to changes in K, R, and Sy. The plots show that the model-calculated discharge to the river is sensitive to Kh, but not to R or Sy. A reduction in Alluvial Aquifer Kh would improve the calibration quality during seasonal or longer dry periods, but at the expense of degrading the calibration during the rainfall season for all but the wettest years. Increasing the Kh would slightly increase the predicted discharges during seasonal or longer dry periods.

5.4.2.4 Sensitivity of Groundwater Discharge to the River to Changes in River and Evapotranspiration Parameters

Figure 5-56 also shows the sensitivity of discharges of Alluvial Aquifer groundwater to the river to changes in riverbed K for drain and wadi nodes and to decreases in the two ET parameters, extinction depth and maximum potential ET rate. Figure 5-56 shows that a lower riverbed permeability would improve calibration during seasonal and longer dry periods, but notably degrade calibration during all rainfall periods. Figure 5-56 shows that reducing the ET extinction depth from 10 feet to 5 feet has little effect on model-calculated discharge to the river, while reducing the maximum ET rate slightly increases the model-calculated discharge.

5.5 Conclusion

The process of calibrating the Regional Model to a 20-year period of groundwater elevation and streamflow data has resulted in a model that is suitable for its intended applications, which are evaluating groundwater management strategies, groundwater sustainability, artificial recharge options, and restoration of contaminated water supplies. The primary attributes of the model's calibration that makes this tool appropriate for its intended uses are:

a. Its ability to simulate historical trends in groundwater elevations and river flows during a 2-decade period that reflects increased urbanization, increased SWP water imports (from outside the valley), and associated changes in land use and water use.

b. Its ability to simulate trends in smaller geographic areas of interest within the valley (for example, near the Whittaker-Bermite property).

c. Its use of an integrated model of the watershed (the SWRM) to define the amount of rainfall and stormwater that is potentially available to recharge the groundwater system.

The calibration process has resulted in a Regional Model that closely simulates, on a monthly basis, total flows in the river and estimated volumes of groundwater discharging to the river. The calibration process has also resulted in a Regional Model that closely simulates the short-term and long-term time-varying trends in groundwater elevations throughout the valley, which is necessary for evaluating groundwater management strategies. The close calibration of the groundwater elevation trends and absolute groundwater elevations in both the Alluvial Aquifer and the Saugus Formation near the Whittaker-Bermite property also renders the Regional Model suitable for particle-tracking analyses, to support the design of a long-term pumping and groundwater treatment plan that will restore impaired water supplies while also preventing contamination in unimpacted portions of the aquifer.

Tables

TABLE 5-1
Alluvial Aquifer Parameters in Calibrated Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Zone	Location	T (ft^2/day)	Kh (ft/day)	Average Alluvium Thickness (feet)
A1a	Santa Clara River below Lang gage	9,000 to 25,500	300	30 to 85
A1b2	Santa Clara River below A1a	31,500	350	90
A1b1	Santa Clara River below A1b2	31,500	350	90
A1c3	Santa Clara River below A1b1	36,000	400	90
A1c2	Santa Clara River below A1c3	49,500	550	90
A1c1	Santa Clara River below A1c2	49,500	550	90
A1d4	Santa Clara River below A1c1	49,500	550	90
A1d3	Santa Clara River below A1d4	16,500	550	30
A1d2	Santa Clara River below A1d3	60,500	550	110
A1d1	Santa Clara River below A1d2	49,500	550	90
A1e2	Santa Clara River below A1d1	63,250	550	115
A1e1	Santa Clara River below A1e2	63,250	550	115
B1a	Santa Clara River at South Fork mouth	54,375 to 79,750	375 to 550	145
B1b2	Santa Clara River below B1a	22,500	375	60
B1b1	Santa Clara River below Bb2	63,250	550	115
C1a	Santa Clara River below B1b1	71,500	550	130
C1b	Santa Clara River below C1a	60,500	550	110
C1c	Santa Clara River below C1b	60,500	550	110
C1d	Santa Clara River below C1c	60,500	550	110
D1b	Lower South Fork Santa Clara River	12,600	105	120
D1a1	Upper South Fork Santa Clara River	5,775	105	55
D1a2	Gavin Canyon	15	0.75	20
D1a3	Pico Canyon	15	0.75	20
D1a4	Newhall Canyon	15	0.75	20
D1a5	Placerita Canyon	200	10	20
A3a	Upper Sand Canyon	1,750	175	10
A3b	Lower Sand Canyon	5,250	105	50
A4a1	Upper Mint Canyon	2,800	140	20
A4a2	Central Mint Canyon	2,100	105	20
A4b	Lower Mint Canyon	13,125	175	75
A5	Oak Spring Canyon	8,750	175	50
B2a1	Unnamed tributary canyon	10,500	105	100
B2a2	Vasquer Canyon	10,500	105	100
B2a3	Texas Canyon	10,500	105	100

TABLE 5-1
Alluvial Aquifer Parameters in Calibrated Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Model Zone	Location	T (ft^2/day)	Kh (ft/day)	Average Alluvium Thickness (feet)
B2b1	Plum Canyon	10,500	105	100
B2b	Upper Bouquet Canyon	2,625 to 12,600	25 to 90	105
B2c	Lower Bouquet Canyon	22,050	245	90
B2d	Haskell Canyon	6,825	105	65
B3a	Lower Dry Canyon	6,300	105	60
B3b	Upper Dry Canyon	6,300	105	60
B4b	Upper San Francisquito Canyon	6,300	105	60
B4c	Lower San Francisquito Canyon	10,500	105	100
C1e	San Martinez Canyon	5,250	105	50
C1f	Potrero and Salt Canyons	5,250	105	50
C2a	Upper Castaic Creek valley	25,200	315	80
C2b	Lower Castaic Creek valley	35,000	350	100
C2c	Charlie Canyon	10,500 to 17,500	175	60 to 100
C3	Hasley Canyon	3,150	30	105

Notes:

The zones are based on alluvial storage units defined by RCS (1986, 2002).
However, they have been further subdivided in certain areas to facilitate model calibration.

See Figure 4-1 for the locations of the alluvial storage units.

TABLE 5-2
Aquifer Hydraulic Parameters Used in the Regional Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Parameter	Aquifer	Value	Comment
Kh	Alluvium	Variable	See Figure 5-1 and Table 5-1.
	Saugus	Variable	See Figures 5-2 through 5-7.
R (Kh:Kv)	Alluvium	10:1	Derived during model calibration process.
	Saugus	50:1 to 100:1	
Sy	Alluvium and Saugus outcrops	0.10	Derived during model calibration process.
Storativity	Saugus below model layer 1	5×10^{-4}	Derived during model calibration process.
Santa Clara River and Castaic Creek streambed thicknesses	Alluvium	2 feet	Assumed thickness of streambed sediments in gaining river reaches.
Santa Clara River and Castaic Creek streambed Kv	Alluvium	10 ft/day (3.5×10^{-3} cm/sec)	Derived during model calibration process.
ET extinction depth	Alluvium and Saugus	10 feet	Corresponds to typical rooting depth for phreatophytes along Santa Clara River.
Potential ET rate	Alluvium and Saugus	6 ft/yr	Estimated maximum water use by phreatophytes along Santa Clara River.

Notes:

cm/sec = centimeters per second

ET = evapotranspiration

TABLE 5-3
Residual Errors for 1980 through 1985 Steady-State Calibration Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Aquifer	Owner	Well Name	Number of Measurements	Measured Groundwater Elevation (feet msl)	Modeled Groundwater Elevation (feet msl)	Residual (Modeled - Measured) (feet)	Residual^2 (ft^2)
Alluvium	NLF	B10	5	890.70	889.51	-1.19	1.42E+00
	NLF	C5	14	940.61	945.04	4.44	1.97E+01
	NLF	E4	4	977.18	977.84	0.67	4.45E-01
	LACFCD	6995D	17	1003.04	998.75	-4.29	1.84E+01
	LACFCD	7076C	5	1037.16	1027.58	-9.58	9.18E+01
	VWC	K2	2	1113.00	1114.36	1.36	1.84E+00
	NLF	R	4	1137.50	1129.94	-7.56	5.72E+01
	VWC	T4	14	1180.20	1187.69	7.49	5.61E+01
	SCWC	Stadium	15	1186.27	1184.41	-1.86	3.44E+00
	LACFCD	7107C	51	1258.45	1256.45	-2.00	4.00E+00
	LACFCD	7127D	66	1315.83	1320.11	4.28	1.83E+01
	SCWC	N.Oaks West	45	1378.61	1373.49	-5.12	2.62E+01
	LACFCD	7158K	13	1427.48	1444.48	17.00	2.89E+02
	LACFCD	7168C	13	1464.85	1465.79	0.94	8.85E-01
	LACFCD	7178B	12	1495.78	1493.56	-2.21	4.90E+00
	SCWC	Sand Canyon	60	1504.32	1503.73	-0.59	3.47E-01
	LACFCD	7178D	12	1499.21	1509.63	10.42	1.09E+02
	LACFCD	7177P	11	1523.64	1514.99	-8.65	7.47E+01
	LACFCD	7187C	16	1526.06	1534.57	8.51	7.24E+01
	LACFCD	7197	13	1560.34	1556.41	-3.93	1.55E+01
	LACFCD	7197G	3	1577.00	1584.72	7.72	5.96E+01
	LACFCD	6993A	12	1042.95	1032.18	-10.77	1.16E+02
	LACFCD	6981D	3	1092.00	1092.24	0.24	5.66E-02
	LACFCD	6980G	10	1110.77	1107.87	-2.90	8.43E+00
	VWC	W6	5	1146.80	1139.03	-7.77	6.04E+01
	LACFCD	7066D	13	1154.92	1158.65	3.72	1.39E+01
	LACFCD	7086B	9	1227.33	1216.15	-11.19	1.25E+02
	LACFCD	7095	11	1297.96	1277.59	-20.38	4.15E+02
Saugus	LACFCD	5841	14	1114.98	1104.27	-10.71	1.15E+02
	LACFCD	5842F	13	1154.65	1111.16	-43.49	1.89E+03
	LACFCD	5851	45	1137.58	1109.08	-28.50	8.12E+02
	LACFCD	5851A	42	1140.77	1109.09	-31.68	1.00E+03
	LACFCD	5871D	13	1138.03	1117.18	-20.85	4.35E+02
	LACFCD	5873E	3	1286.67	1243.22	-43.44	1.89E+03
	LACFCD	5882	11	1251.99	1318.26	66.26	4.39E+03
	LACFCD	5912A	10	1424.13	1441.47	17.34	3.01E+02
	LACFCD	7048C	47	1110.32	1099.48	-10.84	1.17E+02
	LACFCD	7053C	9	1266.52	1267.60	1.08	1.16E+00

TABLE 5-4
Statistics of Residual Errors for 1980 through 1985 Steady-State Calibration Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Statistic	Alluvial Aquifer	Saugus Formation	Combined System	Criterion for Goal 3
Target Groundwater Elevations				
Number of Target Wells	28	10	38	---
Maximum Groundwater Elevation	1,577	1,424	1,577	---
Minimum Groundwater Elevation	891	1,110	891	---
Range in Groundwater Elevations	686	314	686	---
Statistics for Residuals				
Mean Residual	-1.19	-10.48	-3.63	As close to zero as possible
Mean Residual / Range in Groundwater Elevations	-0.2%	-3.3%	-0.5%	5%
Standard Deviation of Residuals	7.62	31.39	17.86	---
Standard Deviation of Residuals / Range in Groundwater Elevations	1.1%	10.0%	2.6%	10%
Statistics for Residual^2 Values				
Sum of Residual^2 Values	1,664	10,954	12,617	---
Average of Residual^2 Values	59	1,095	332	---
Root-Mean-Square Error (RMS)	8	33	18	10 feet for Alluvial, 25 feet for Saugus
RMS / Range in GW Elevations	1.1%	10.5%	2.7%	10%

Note:
An entry of --- means no criterion was established.

TABLE 5-5

Comparison of Modeled and Measured Horizontal Hydraulic Gradients for Multi-Port Monitoring Wells Near the San Gabriel Fault

Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

	MP-3	MP-2	MP-1	MP-2
Modeled Groundwater Elevation (feet)	1,225.52	1,092.02	1,084.78	1,092.02
Measured Groundwater Elevation (feet)	1,304.46	1,074.28	1,066.99	1,074.28
Residual Error (feet)	-78.94	17.74	17.79	17.74
Easting (feet)	6,406,801	6,405,215	6,399,944	6,405,215
Northing (feet)	1,971,284	1,968,850	1,970,850	1,968,850
Distance Between Wells		2,905.13		5,637.68
Difference in Modeled Groundwater Elevations		133.50		-7.24
Difference in Measured Groundwater Elevations		230.18		-7.29
Modeled Horizontal Gradient		-4.60E-02		1.28E-03
Measured Horizontal Gradient		-7.92E-02		1.29E-03
Modeled Gradient / Measured Gradient		0.58		0.99

Notes:

Wells MP-1 and MP-2 are located on the west (downthrown) side of the fault.

Well MP-3 is located on the east (upthrown) side of the fault.

Measured groundwater elevations are the average of measurements from January through July of 2003.

Wells MP-1 and MP-2 are in model layer 4; well MP-3 is in model layer 2.

TABLE 5-6
Groundwater Budget for 1980 through 1985 Steady-State Model
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Total Recharge	**AF/yr**	**Percent**
Rainfall	35,000	44.8
Streams	38,200	48.8
Irrigation	3,300	4.2
Subsurface Inflow (Castaic)	1,700	2.2
Total	**78,200**	**100.0**

Total Discharge	**AF/yr**	**Percent**
Discharge to Santa Clara River	28,600	36.6
Evapotranspiration	12,000	15.3
Subsurface Outflow	6,600	8.4
Pumping	31,000	39.6
Total	**78,200**	**100.0**

TABLE 5-7
Annual Water Budgets Calculated by the Calibrated Regional Model for 1980 through 1999
Regional Groundwater Flow Model for the Santa Clarita Valley, Santa Clarita, California

Calendar Year	Precipitation Infiltration	Infiltration of Applied Water	Streambed Infiltration	Castaic Dam Underflow	Total Recharge	Pumping	Groundwater Discharge to Streams	ET	Subsurface Outflow at County Line	Total Discharge	Change in Groundwater Storage	Cumulative Change in Groundwater Storage
1980 to 1981	41,003	3,375	43,226	1,705	89,310	35,542	30,507	15,387	6,691	88,128	1,181	1,181
1981 to 1982	12,102	3,871	13,148	1,700	30,821	35,209	22,304	9,214	6,641	73,368	-42,547	-41,365
1982 to 1983	52,415	3,022	35,134	1,700	92,270	24,918	25,583	11,157	6,695	68,353	23,917	-17,448
1983 to 1984	183,342	2,657	79,681	1,700	267,380	23,169	51,128	26,020	7,017	107,333	160,047	142,598
1984 to 1985	1,316	3,606	10,714	1,705	17,341	30,645	32,258	19,609	6,647	89,158	-71,817	70,781
1985 to 1986	2	3,279	9,082	1,700	14,063	28,963	25,369	10,629	6,572	71,533	-57,470	13,311
1986 to 1987	43,258	3,211	26,471	1,700	74,641	28,658	27,557	12,354	6,668	75,236	-595	12,716
1987 to 1988	11,915	2,991	9,694	1,700	26,299	27,085	24,434	8,601	6,566	66,686	-40,386	-27,670
1988 to 1989	27,949	3,075	17,106	1,705	49,835	27,571	23,518	8,752	6,613	66,454	-16,619	-44,289
1989 to 1990	0	3,393	7,899	1,700	12,993	30,415	21,004	6,676	6,520	64,614	-51,621	-95,911
1990 to 1991	0	3,787	9,092	1,700	14,579	31,652	18,151	4,711	6,530	61,043	-46,464	-142,375
1991 to 1992	51,315	3,397	28,933	1,700	85,345	41,067	19,924	6,963	6,647	74,600	10,745	-131,630
1992 to 1993	131,293	3,850	60,449	1,705	197,296	37,567	27,043	14,114	6,906	85,629	111,666	-19,964
1993 to 1994	113,547	3,773	64,341	1,700	183,361	39,741	34,976	22,598	6,875	104,191	79,170	59,207
1994 to 1995	813	4,415	13,436	1,700	20,365	44,120	21,612	12,839	6,586	85,157	-64,793	-5,586
1995 to 1996	114,663	4,517	60,647	1,700	181,527	42,009	32,426	21,314	6,887	102,637	78,890	73,305
1996 to 1997	46,312	5,205	30,512	1,705	83,734	45,574	25,888	17,092	6,762	95,317	-11,583	61,721
1997 to 1998	17,485	5,267	16,277	1,700	40,729	47,051	21,488	12,791	6,667	87,997	-47,268	14,453
1998 to 1999	138,991	4,758	90,634	1,700	236,084	42,043	41,283	26,213	6,959	116,498	119,585	134,039
1999 to 2000	26	5,343	13,714	1,700	20,783	46,867	24,335	15,943	6,607	93,752	-72,969	61,070
Minimum	0	2,657	7,899	1,700	12,993	23,169	18,151	4,711	6,520	61,043	-72,969	-142,375
Maximum	183,342	5,343	90,634	1,705	267,380	47,051	51,128	26,213	7,017	116,498	160,047	142,598
Average	49,387	3,840	32,010	1,701	86,938	35,493	27,539	14,149	6,703	83,884	3,053	5,907
Median	34,476	3,689	21,789	1,700	62,238	35,376	25,476	12,815	6,657	85,393	-14,101	6,949

Note:
All flow volumes are listed in AF/yr.