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Santa Margarita Basin Groundwater Modeling Technical Study

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Prepared for

Scotts Valley Water District
2 Civic Center Drive
Scotts Valley, CA 95066

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List of Abbreviations

%	Percent
AF	Acre-feet
AFY	Acre-feet per year
AMBAG	Association of Monterey Bay Area Governments
C	Runoff coefficient

cfs	Cubic feet per second
CIMIS	California Irrigation Management Information System
COOP	Cooperative Observer Program
County	Santa Cruz County
ºF	Degrees Fahrenheit
DWR	California Department of Water Resources
ET	evapotranspiration
ET_o	reference evapotranspiration
ft	Feet
ft/day	Feet per day
tt^2/day	Feet squared per day
GIS	Geographic Information System
Gpd	Gallons per day
gpm	Gallons per minute
in	Inches
IRWM	Integrated Regional Water Management
K	Hydraulic conductivity
K_V/K_H	Ratio of horizontal to vertical hydraulic conductivity
LCWD	Lompico County Water District
MHA	Mount Hermon Association
MTBE	Methyl tert-butyl ether
mya	Million years ago
NAVD	North American Vertical Datum
NCDC	National Climate Data Center
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
NWS	National Weather Service
NOAA	National Oceanic and Atmospheric Administration
RMS	Root mean square
RWQCB	Regional Water Quality Control Board
SCWD	City of Santa Cruz Water Department
SLVWD	San Lorenzo Valley Water District
SMGB	Santa Margarita Groundwater Basin
SVWD	Scotts Valley Water District
S	Storativity
Sy	Specific yield
T	Transmissivity
UCSC	University of California at Santa Cruz
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UWMP	Urban Water Management Plan
WWTP	Wastewater treatment plant

Executive Summary

The objective of the Santa Margarita Groundwater Modeling Project is to update the Santa Margarita Groundwater Basin Model (SMGB Model) with new data and improve the calibration. The previous Model was originally completed in 2006 (ETIC, 2006) and included data through 2004.

The Santa Margarita Groundwater Modeling Project is one of the projects funded by a Proposition 84 Integrated Regional Water Management (IRWM) Program Planning Grant from the California Department of Water Resources (DWR Agreement No. 4600009400) to the Regional Water Management Foundation, a subsidiary of the Community Foundation Santa Cruz County, on behalf of the Santa Cruz IRWM Region.

The work was performed under the direction of the Scotts Valley Water District (SVWD). A Technical Advisory Committee composed of members from the SVWD, Santa Cruz County Environmental Health Services (County), San Lorenzo Valley Water District (SLVWD), Santa Cruz Water Department (SCWD), the University of California at Santa Cruz and others participated in this project and reviewed the work.

Santa Margarita Groundwater Basin

The Santa Margarita Groundwater Basin (SMGB or Basin) covers over 30 square miles in the Santa Cruz Mountains. The SMGB forms a roughly triangular area that extends from Scotts Valley to the east, Boulder Creek to the northwest and Felton to the southwest. Groundwater provides an important component of the water supply for residents living within the SMGB.

The SMGB consists of a sequence of sandstone, siltstone, and shale underlain by granite that lies within a geologic trough called the Scotts Valley Syncline. This sequence of sedimentary rocks is divided into several geologic formations. These units are defined on the basis of the type of rock and their relative geologic age based on studies by the United States Geological Survey (USGS). The SMGB contains several significant sandstone layers that form the primary water supply aquifers. These aquifers include:

- Santa Margarita Sandstone (Santa Margarita),
- Monterey Formation (Monterey),
- Lompico Sandstone (Lompico), and
- Butano Formation (Butano).

Over the past 25 years, groundwater levels in many parts of the SMGB, especially in the Lompico, have declined significantly (by over 200 feet in some areas). The decreases in groundwater levels have resulted in less groundwater available in aquifer storage for water supply. In addition, these declines have also reduced groundwater inflows that provide sustaining baseflows for the local streams that support an important fishery habitat especially in the summer months.

The understanding of the groundwater conditions in the SMGB has been developed over the years through regular data collection and reporting primarily from SVWD, SLVWD and the County. Several comprehensive studies by these agencies form the conceptual understanding of the hydrogeology and groundwater management in the SMGB. These data and reports form the basis of knowledge that was used to update the SMGB Model for this project.

Project Objectives

The SMGB Model updates focus on updating new hydrogeologic data and interpretations available since the 2006 report. The DWR grant agreement includes several scope-of-work elements that form the primary project objectives for the SMGB Model update. In summary, these include:

- Review new data from recently drilled wells to update the geologic correlations for definition of model layers;
- Incorporate updated groundwater and hydrologic data to extend the historical Model period from October 1984 to September 2012;
- Develop improved empirical methods for estimating streamflow inputs to the Model for use where actual data are not available;
- Incorporate recent MODFLOW code advancements to expand the Model's capabilities and improve performance;
- Conduct future-case scenarios using the updated Model to evaluate the effect of climatic and groundwater management conditions (e.g. conservation and conjunctive use programs) would affect groundwater levels and stream baseflows.

Conceptual Model Updates

The conceptual model represents our understanding of the key hydrogeological characteristics and features that control how groundwater moves through the SMGB. The basic components of the hydrogeological conceptual model include developing the geologic framework of the Basin aquifers, developing a water balance of recharge and outflows, and defining aquifer properties. The primary updates to the conceptual model involved the following:

- The geologic interpretation in the Scotts Valley area was revised based on data from new wells drilled in the vicinity as part of an environmental investigation that indicated that SVWD Well #9 was completed in the Monterey rather than the Santa Margarita. This resulted in a redefinition of the vertical thickness of the Santa Margarita and Monterey over a portion of the southern SMGB.
- To better simulate the aquifer structure, the Monterey was subdivided into two model layers to represent the presence of more permeable sandstone layers in the lower Monterey that are not present in the upper Monterey.
- The Butano was made thicker and more expansive in area to represent data from recent deep wells. To simulate this greater thickness, the Butano was split into three rather than one model layer. This change accounted for the presence of a thick shale unit separating the upper and lower Butano as mapped by the USGS. The lower Butano was separated into two layers to account for the large thickness of this formation, and was extended across the Basin to the Mount Hermon area.
- In the previous Model, minor internal faults were added to provide controls to groundwater flow and help with the calibration in some areas. As recommended by the TAC, all of these internal faults were removed from the updated Model. Since there was no direct physical evidence for these faults, their presence detracted from the overall defensibility of the Model.

- The model domain was extended to the northeast to include the Blackburn Gulch area that represents a key recharge area for the Lompico and Butano. This changed allowed for more direct simulation of groundwater-surface water interactions with Blackburn Gulch and the West Branch of Soquel Creek.

The water balance describes the amount and location where groundwater enters and exits the Basin. The primary changes were to improve the estimation of recharge and surface water runoff of precipitation in the SMGB. These changes include:

- A Rational Method approach (Chow *et al*, 1988) was developed based on defining a percentage of precipitation that goes to runoff or infiltration. The percentages vary by location based on the geology, vegetation and land use across the Basin.
- The model input files for the MODFLOW SFR package and Recharge packages are managed using a spreadsheet to create the necessary model input files.
- The updated approach provides the ability to develop scenarios to evaluate variable climatic conditions rather than relying solely on historical climatic conditions.

The aquifer properties describe the geologic factors that control the rate of groundwater movement within the aquifer. These were updated through model calibration within the potential range based on available hydrogeologic data available in the SMGB.

Model Setup and Calibration

The model setup included changes to incorporate recent MODFLOW code advancements. The advanced features incorporated into the updated Model include the following:

- The model was updated from MODFLOW 2000 to MODFLOW NWT to take advantage of new advanced features. MODFLOW-NWT (Niswonger *et al*, 2011) is a standalone version of MODFLOW-2005 that includes an advanced mathematical solver that provides a more robust solution to complex conditions such as rewetting of dry model cells, unconfined conditions and groundwater-surface water interactions. These features improve the ability of the Model to evaluate potential conjunctive use and recharge projects to increase groundwater levels in the SMGB.
- For improved simulation of the groundwater–surface water interactions, the Streamflow Routing (SFR) package was used to simulate streams. This package provides a more realistically means to simulate surface runoff by adding runoff along the length of the stream rather than only at the head of the stream. The SFR package (Prudic *et al*, 2004) also includes improved calculations methods of groundwater-surface water interactions.

Model calibration compares the ability of the model to simulate groundwater elevations over the historical period from October 1984 to September 2012. The calibration was evaluated using a statistical comparison of difference (or residual) between measured and simulated groundwater elevations. The primary performance measure is to improve upon the calibration from the previous Model.

Since the previous Model was updated by SVWD as part of the groundwater management program with data through 2012 (Kennedy/Jenks, 2013), improvement in the calibration can be measured by direct comparison of the performance of the two versions of the SMGB Model using the exact same data set. Table ES-1 provides a list of statistical measures to assess the calibration by comparing of the difference or residual between measured and simulated groundwater elevations. A brief summary of these measures includes:

- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. The closer this value is to zero, the better the calibration. The residual mean of -1.56 feet is an improvement of 69% over the previous Model.
- The absolute residual mean and Root Mean Square (RMS) Error are measures of the overall error in the model, and the calibration resulted in a 20% and 25% improvement over the previous Model.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation for the calibrated model is 21.70 feet, which is an improvement of 24%.
- The scaled absolute residual the ratio of the absolute residual mean is divided by the range of observed groundwater elevations. This ratio helps to put the calibration data into perspective for the scale of the groundwater basin. The ratio for the updated Model is 0.0224, which is an improvement of 20% over the previous Model.

The results of the calibration showed a general overall improvement in the calibration in the range of 20% to 25% over the previous model. This indicates that the changes implemented for the updated Model were successful and resulted in improved model performance.

TABLE ES-1
SUMMARY OF MODEL CALIBRATION
RELATIVE DIFFERENCE TO PREVIOUS MODEL

Calibration Measure	Previous Model	Updated Model	Percent Change
Units	Feet	Feet	Percent
Residual Mean	-5.1	0.7	86%
Residual Standard Deviation	28.5	19.4	32%
Absolute Residual Mean	19.3	13.3	31%
Root Mean Square (RMS) Error	29.0	19.4	33%
Scaled Absolute Residual Mean	0.028	0.019	31%
Number of Observations	16,344	16,344	same

Note: Previous Model is the ETIC (2006) version updated with data through 2012
Updated Model is the model version from this report with data through 2012.

The updated Model was evaluated to determine the historical change in aquifer storage in the SMGB since 1985. A summary of the change in groundwater storage by aquifer is provided in Table ES-2. The Model results demonstrate that the Lompico is the most impacted aquifer with a cumulative decline of nearly 16,000 acre-feet. The overall change in net aquifer storage is in line with previous estimates by Johnson (2009) and Kennedy/Jenks (2011).

TABLE ES-2
SUMMARY OF HISTORICAL MODEL RESULTS
CHANGE IN AQUIFER STORAGE 1985 TO 2012

Aquifer	Average Annual Storage Change	Cumulative Aquifer Storage Change
Units	AFY	AF
Santa Margarita	-111	-3,110
Monterey	-89	-2,490
Lompico	-486	-13,610
Butano	-305	-8,540
Locatelli	-4	-100
Total	-994	-27,850

Model Scenarios

Once the model is calibrated to historical conditions, it is capable of serving as a quantitative tool to forecast future groundwater conditions. The primary applications for the SMGB Model are to assess options for managing future water supplies and the effects of climate variations.

The SMGB can perform comprehensive scenarios of potential future conditions; however, varying a limited number of parameters allows for a more direct comparison to better understand cause-and-effect relationships. This latter approach was used for developing the scenarios for this study. Also, it is recommended to evaluate model scenario result by assessing overall trends using relative differences with a Base Case Scenario. The selected future-case scenarios were grouped together to meet the following objectives:

- Base Case Scenario – represent a continuation of current pumping and repeats historical hydrological conditions to serve as a basis of comparison for the other model scenarios.
- Groundwater management Scenarios – assess the effects of implementation of groundwater management actions to evaluate the effects of potential future groundwater pumping and/or recharge projects on aquifer storage and stream baseflow.
- Climate Variation Scenarios – provide an assessment of the effects of variations in the natural hydrology (precipitation and streamflow) on aquifer storage and stream baseflow.

Base Case Scenario

The Base Case Scenario is based on the 28-year calibrated historical model, but is setup to represent a potential future case condition. Since the future is not known, the scenario is based on applying assumptions for future conditions. For the Base Case scenario, the key assumptions include:

- Repeats the 28-year natural hydrology for 1985 to 2012 from the Calibrated Historical Simulation for determining precipitation and streamflow.

- The groundwater pumping assumes that the average quarterly groundwater pumping for each well over the 3-year period from 2010 to 2012.
- The initial groundwater elevations are the results of the Calibrated Historical Simulation representing September 2012.
- The representation of the physical groundwater basin and aquifer properties is left unchanged.

For the Base Case scenario, the pumping is set at a constant rate throughout the 28-year simulation period that represents recent pumping practices in the SMGB. This is considered an appropriate assumption for a Base Case scenario as it projects groundwater conditions if current practices were projected into the future, thus providing a reasonable basis of comparison for the other scenarios.

Table ES-3 provides a summary of the differences between the Calibrated Historical Simulation and the Base Case Scenario. Pumping in the Base Case Scenario is about 900 AFY less than in the Calibrated Historical Simulation. As a result, the aquifer storage increases 3,000 AF over the Base Case Scenario whereas it decreased by about 28,000 AF in the Calibrated Historical Simulation. This is due both to the difference in pumping, but also because the Base Case Scenario starts at a lower groundwater levels that account for the historical drawdown.

TABLE ES-3
SUMMARY OF MODEL SCENARIO RESULTS
COMPARISON OF HISTORICAL MODEL TO BASE CASE SCENARIO

Scenario	Groundwater Pumping		Change in Aquifer Storage		Average Stream Baseflow	
Condition	Average	Cumulative	Average	Cumulative	Total	Summer
Units	AFY	AF	AFY	AF	cfs	cfs
Calibrated Historical Simulation	3,700	104,000	-994	-27,850	8.2	6.9
Base Case Scenario	2,800	79,000	140	3,900	8.4	1.8

Note: 1 cfs is equivalent to 724 AFY

Groundwater Management Scenarios

The Groundwater Management (GW Mgmt) Scenarios are setup to assess the implementation of various water management plans by the local water districts. Since this study is not evaluating a specific project, the model scenarios are based on planned activities listed in published reports. These include:

- For SVWD, projected water demand from 2010 to 2035 including groundwater pumping, water exchanges and recycled water use is taken from the 2010 Urban Water Management Plan (Kennedy/Jenks, 2011).
- For SVWD, projected water demand including groundwater pumping, conservation and conjunctive use from the Water Supply Master Plan (Johnson, 2009).

- Potential future aquifer recharge projects are adapted from the Phase 1 Conjunctive Use Study by Santa Cruz County (Kennedy/Jenks, 2011).

These scenarios focus on variations on groundwater pumping and/or groundwater recharge projects on aquifer storage and stream baseflow. Four scenarios were defined to evaluate various groundwater-related issues and concerns in the basin. The assumptions included in the model scenarios include:

- GW Mgmt Scenario #1 – assumes past practices of higher reliance on groundwater pumping to meet water demand and is intended to provide a contrasting comparison to the planned groundwater management used in the other scenarios.
- GW Mgmt Scenario #2 – assumes implementation of the planned groundwater pumping from the UWMP and WSMP to meet the projected water.
- GW Mgmt Scenario #3 – assumes that 1,000 AFY of groundwater injection into the Lompico at Hanson Quarry area via injection wells. Other assumptions are the same as GW Mgmt Scenario #2.
- GW Mgmt Scenario #4 - assumes an annual average of 120 AFY of stormwater recharge from Low Impact Development (LID) projects in the Scotts Valley area. Other assumptions are the same as GW Mgmt Scenario #2.

TABLE ES-4
SUMMARY OF GROUNDWATER MANAGEMENT SCENARIO RESULTS
RELATIVE DIFFERENCE TO BASE CASE SCENARIO

Scenario	Change in Well Use		Change in Aquifer Storage		Change in Stream Baseflow	
Condition	**Injection**	**Extraction**	**Average**	**Cumulative**	**Total**	**Summer**
Units	**AFY**	**AFY**	**AFY**	**AF**	**cfs**	**cfs**
GW Mgmt Scenario #1 GW Pumping	0	+530	-195	-5,400	-0.20	-0.05
GW Mgmt Scenario #2 Conjunctive Use	0	-410	+130	+3,600	+0.15	+0.04
GW Mgmt Scenario #3 Active Recharge	+1,000	-410	+495	+13,800	+0.45	+0.11
GW Mgmt Scenario #4 LID Recharge	+120	-410	+165	+4,600	+0.25	+0.06

Note: 1 cfs is equivalent to 724 AFY

The results of the GW Mgmt Scenarios are summarized in Table ES-4 relative to the Base Case Scenario. In general, the following observations can be derived:

- The results from GW Mgmt Scenario #1 indicate that continuation of past practices of relying on groundwater pumping would result in continued long-term decline in aquifer storage and a decrease in stream baseflow.

- The GW Mgmt Scenario #2 results indicate that implementing the planned groundwater management would result in an increase in both aquifer storage and stream baseflow.
- The GW Mgmt Scenario #3 results indicate that implementing active groundwater injection into the Lompico at Hanson Quarry would result in a significant increase in aquifer storage and stream baseflows. The results indicate the recovery of about 65% of the aquifer storage loss from the Calibrated Historical Simulation. Because the recharge water is injected directly into the Lompico, a higher percentage of the recharge goes to aquifer storage rather than stream baseflows.
- The GW Mgmt Scenario #4 results indicate that LID recharge would produce increases in both aquifer storage and recharge. Because most of the recharge would be to the Santa Margarita, a higher percentage of the recharge goes to stream baseflows rather than aquifer storage.

Sustainable Yield Estimates

The sustainable yield is a concept that is applied to groundwater basins as a mechanism to define the natural limit of groundwater pumping. The sustainable yield represents the annual amount of water that can be taken from the existing wells in a basin over a period of years without "causing adverse impacts." Exceeding the sustainable yield for the basin may lead to perennial declines in groundwater levels which over time may result in widespread loss of well production. Any pumping will have an effect on the overall water balance so defining what an adverse impact is can be subjective and may differ among stakeholders.

For this study, the sustainable yield is defined as limiting further depletion of aquifer storage beyond the ability of the basin to be replenished naturally. For this, a linear regression was calculated comparing average annual groundwater pumping rate vs change in aquifer storage for the Base Case, GWMgmt #1 and GWMgmt #2. The result of this analysis is that the sustainable yield for the SMGB is in the range of 3,050 to 3,400 AFY. Looking at the results on an aquifer basis, the results are as follows:

- Santa Margarita Aquifer – 1,030 AFY
- Monterey Aquifer – 170 AFY
- Lompico Aquifer – 1,890 AFY
- Butano Aquifer – 320 AFY
- SMGB by summing aquifers – 3,410 AFY

Based on this analysis, the Santa Margarita may have additional pumping capacity, whereas the Lompico, Monterey and Butano are already near their pumping capacity. This estimate of sustainable yield is limited to an assessment of the existing well locations. An evaluation of new pumping sites located distant from existing locations to limit well interference has the potential to provide a higher sustainable yield estimate. The model provides a quantitative tool that could be used to further optimize groundwater pumping to maximize the sustainable yield while maintaining defined criteria for "adverse effects." In this manner, the SMGB Model could be used to locate additional pumping locations to supplement the water supply with little to no "adverse effects."

Climate Variation Scenarios

The Climate Variation Scenarios were developed to assess the effects of climatic variations on aquifer storage and stream baseflow. Two scenarios were developed that modify the natural hydrology inputs to assess the effect on aquifer storage and stream baseflow. The key assumptions and objectives of these scenarios include:

- Climate Scenario #1 assumes average precipitation conditions over the simulation period to assess the portion of aquifer storage and stream baseflow change that can be attributed to the rainfall deficit imbedded in the natural hydrology.
- Climate Scenario #2 assumes that the difference from average precipitation is increased by 20% for each model stress period to assess potential climate change characterized by more extreme precipitation conditions.
- All other conditions are the same as the Base Case Scenario.

Climate change is a growing concern to water managers in the SMGB. Although the understanding of what climate change will entail are evolving, especially for the California Coastal areas, a general consensus is that although average precipitation may remain similar, the year-to-year precipitation will become more extreme with wetter wet years and drier dry years.

Climate change is a complex subject that may potentially have multiple impacts on the SMGB. For Climate Scenario #2, the focus is on assessing the effects of more extreme variations in precipitation. To simulate this, the difference between the average and measured precipitation for each time period in the model was increased by 20%. This caused wet years to get wetter, dry years to get dryer and average years to remain about the same. Since these changes roughly balance out, the total precipitation for Climate Scenario #2 is about 1% less than for the Base Case.

The results of Climate Scenario #2 show that climate change would have limited effect on aquifer storage whereas stream baseflows would see a higher percentage change (Table ES-5). For stream baseflows, the average condition is similar to the Base Case, but shows that the extremes years have a 10% to 20% variation relative to the Base Case. This is again due to precipitation variations affection the Santa Margarita Sandstone rather than the Lompico. Because of the physical limitations for natural recharge reaching the Lompico, the climate variations have limited effect on changing the aquifer storage.

For the historical period from 1985 to 2012, the cumulative precipitation is about 40 inches below average precipitation over this period. Comparing the results of Climate Scenario #1 to the Base Case provides the approximate percentage of the change in aquifer storage that can be attributed to the historical rainfall deficit. Of the approximately 1,000 AFY of additional recharge, about 10% is attributed to an increase in aquifer storage, 50% to increased stream baseflows and the remainder to other groundwater discharges. Since most of the precipitation falls on the Santa Margarita Sandstone, most of the additional recharge is eventually discharged to streams or springs rather than adding to the aquifer storage. Most of the available aquifer storage is in the Lompico; however, the geology of the SMGB limits the recharge area for the Lompico, so it is less affected by variations in climate. Therefore, only about 10% of the historical decline in aquifer storage may be attributed to the rainfall deficit.

TABLE ES-5
SUMMARY OF CLIMATE SCENARIO RESULTS
RELATIVE DIFFERENCE TO BASE CASE SCENARIO

Scenario	Change in Natural Recharge		Change in Aquifer Storage		Change in Stream Baseflow		
Condition	**Average**	**Cumulative**	**Average**	**Cumulative**		**Total**	**Summer**
Units	**AFY**	**AF**	**AFY**	**AF**		**cfs**	**cfs**
Climate Scenario #1 Average Rainfall	900	25,000	75	+2,100	Avg	0.7	0.2
Climate Scenario #2 Climate Change	-215	-6,000	-25	-700	Avg Min Max	-0.1 -0.6 0.4	0.0 -0.2 0.1

Note: 1 cfs is equivalent to 724 AFY

Conclusions

The SMGB Model was updated to incorporate new hydrogeological data and interpretations within the Basin. The calibration of the model has been improved on the order of about 30%. These improvements have improved the model as a quantitative tool for assessing groundwater conditions in the SMGB to help the assessment of these potential future groundwater management projects.

The updated model was used to evaluate potential future groundwater conditions based on projected groundwater pumping and conjunctive use scenarios. The results indicate that continuing past groundwater pumping practices would likely result in reduced aquifer storage and stream baseflows. However, implementing conjunctive use as proposed in the SVWD UWMP and the SLVWD WMP would help reverse those trends. Implementing active groundwater recharge projects is shown to have the capability of restoring groundwater levels, aquifer storage and groundwater baseflow contributions to streams within the SMGB.

Section 1: Introduction

The Santa Margarita Groundwater Modeling Project is one of the projects funded by a Proposition 84 Integrated Regional Water Management (IRWM) Program Planning Grant from the California Department of Water Resources (DWR Agreement No. 4600009400) to the Regional Water Management Foundation, a subsidiary of the Community Foundation Santa Cruz County, on behalf of the Santa Cruz IRWM Region.

1.1 Santa Margarita Groundwater Basin

The Santa Margarita Groundwater Basin (SMGB or Basin) covers over 30 square miles in the Santa Cruz Mountains in the California Coast Ranges. The Basin forms a roughly triangular area that extends from Scotts Valley in the east, to Boulder Creek in the northwest, to Felton in the southwest (Figure 1-1). Groundwater is a key source of water supply for many of the residents living within the Basin.

The SMGB is situated within the San Lorenzo River Watershed that drains a 138 square-mile watershed that extends from the Santa Cruz Mountains south towards the River's mouth into Monterey Bay within the City of Santa Cruz. Key tributaries within the SMGB include Newell, Love, Zayante, Bean and Carbonera Creeks.

The SMGB lies in a geologically complex area formed by tectonic forces associated with the San Andreas Fault system. Within the SMGB, there consists of a sequence of sandstone, siltstone, and shale that are underlain by granite that lie within a geologic trough called the Scotts Valley Syncline. This sequence of sedimentary rocks is divided into several geologic formations. These units are defined on the basis of the type of rock and their relative geologic age based on studies by the United States Geological Survey (USGS) presented in reports by Clark (1966, 1981), Brabb et al. (1997), and McLaughlin et al. (2001). In the SMGB, the sandstone units serve as the primary aquifers that provide the majority of groundwater production for the local water supply. The main aquifers in the Basin include:

- Santa Margarita Sandstone (Santa Margarita),
- Monterey Formation (Monterey),
- Lompico Sandstone (Lompico), and
- Butano Formation (Butano).

Currently, DWR Bulletin 118 (DWR 2003) does not identify the SMGB as a groundwater basin. However, DWR does recognize three basins in the vicinity; however, these do not coincide with the SMGB. These include Scotts Valley Basin (DWR Basin 3-27); Felton Area Basin (DWR Basin 3-21), the Santa Cruz Purisima Formation (DWR Basin 3-21). The SMGB covers a significantly larger area than those depicted in Bulletin 118 (Figure 1-1). DWR Basins 3-27 and 3-50 cover a portion of the SMGB whereas DWR Basin 3-50 is limited to the Purisima Formation and is generally associated with the Soquel Creek Water District further to the south. This report will discuss the SMGB which represents the physical groundwater basin defined by the geology rather than the administrative boundaries represented by the three recognized DWR Basins.

1.2 Groundwater Issues

Over the past 25 years, groundwater levels in many parts of the SMGB, especially in the Santa Margarita and Lompico Aquifers in the Scotts Valley area, have experienced significant groundwater levels declines of over 200 feet in some areas. Groundwater level declines represent a loss in groundwater storage in the SMGB by an estimated 10,000 acre-feet or more in the Santa Margarita and Lompico (Johnson, 2009, Kennedy/Jenks, 2011b) resulting in less groundwater available for local water supply. In addition, these groundwater declines have also reduced sustaining baseflows to local streams that support an important fishery habitat, especially in the summer months. However, the areas of greatest historical decline in groundwater levels also provide aquifer storage potential that could be utilized by conjunctive use or other aquifer recharge projects.

1.3 Scope and Objectives

The scope of the Santa Margarita Groundwater Modeling Project is to update and improve the calibration of the Santa Margarita Groundwater Basin Model (SMGB Model) developed in 2006 (ETIC, 2006). The objectives of this project are to update, calibrate, and improve the existing SMGB Model, especially with respect to its ability to accurately evaluate groundwater-surface water interactions. This update of the SMGB Model emphasizes improved analysis of groundwater-surface water interactions and verification of the model's applicability across the entire basin, not just the Scotts Valley subareas. The update would include the following elements:

- Review new data from recently drilled wells to update the geologic for definition of model layers;
- Incorporate updated groundwater and hydrologic data to extend the historical Model period from October 1984 to September 2012;
- Develop improved empirical methods for estimating streamflow inputs to the Model for use where actual data are not available;
- Incorporate recent MODFLOW code advancements to expand the Model's capabilities and improve performance; and
- Conduct future-case scenarios using the updated Model to evaluate climatic and groundwater management conditions (e.g. conservation and conjunctive use programs) would affect groundwater levels and stream baseflows.

Based on review and analysis of the available data, the model parameters and boundary conditions will be update to better represent the current hydrogeological understanding of the SMGB. With these improvements, the updated SMGB model is intended to provide improved performance in assessing groundwater conditions to support ongoing groundwater management activities.

The work was performed under the direction of the Scotts Valley Water District (SVWD). A Technical Advisory Committee composed of members from the SVWD, Santa Cruz County Environmental Health Services (County), San Lorenzo Valley Water District (SLVWD), Santa Cruz Water Department (SCWD), the University of California at Santa Cruz (UCSC) and others participated in this project and reviewed the work.

1.4 Previous Modeling Studies

Much of the technical information and interpretations used for the Santa Margarita Groundwater Modeling Project are based on previous modeling and technical studies in the SMGB. Earlier modeling efforts built the foundation for subsequent modeling efforts.

The earliest modeling in the SMGB was done by Johnson (1988) who constructed a groundwater model of a portion of the Quail Hollow area to help evaluate the cause of elevated nitrate concentrations in groundwater produced from SLVWD's wells. The Johnson (1988) model and an earlier model of Scotts Valley (Jacobvitz, 1987) were incorporated into a regional groundwater flow model by the Association of Monterey Bay Area Governments (AMBAG) in 1992 as part of the draft Santa Margarita Groundwater Basin Management Plan (Watkins-Johnson Environmental, 1993) that was not adopted. Portions of the AMBAG model were later updated by SVWD (Todd Engineers, 1997b). These models were all run under steady-state conditions that did not evaluate time-varying conditions.

Johnson (2001 and 2002) later updated the Quail Hollow model through a detailed data assessment and conceptual model interpretation that lead to the development of a transient model of the Santa Margarita and Monterey for the Quail Hollow area. Johnson (2003) provided a detailed data assessment and conceptual model interpretation of the Pasatiempo area west of Scotts Valley, but a numerical model was not constructed.

The Santa Margarita Groundwater Modeling Project is updating the SMGB Model developed in 2006 (ETIC, 2006) for SVWD with funding from the DWR Local Groundwater Assistance Grant Program. The numerical model was based on a conceptual model of the basin developed with input and oversight from a technical advisory committee representing interested local agencies. The model was also used as part of the Phase 1 Conjunctive Use Project (Kennedy/Jenks, 2011b) by Santa Cruz County to evaluate potential groundwater recharge projects in the SMGB.

SVWD has regularly updated the SMGB Model as part of their Groundwater Management Program to evaluate changes in groundwater storage. The most recent update of that previous version of the SMGB Model included data through 2012 (Kennedy/Jenks, 2013b).

1.5 Acknowledgments

Kennedy/Jenks would like to acknowledge the contributions of several people who provided technical and administrative support throughout this project. The following identifies several key individuals and acknowledge their contributions.

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The Santa Margarita Groundwater Modeling Project was overseen by SVWD who provided overall project management. Kennedy/Jenks would like to recognize the efforts of Charlie McNiesh of SVWD for initiating this project. We would like to also recognize the efforts of Piret Harmon of SVWD in helping guide this project to completion after the retirement of Mr. McNiesh.

A Technical Advisory Committee (TAC) of experts and stakeholders was formed to review the work as it progressed. Kennedy/Jenks would like to acknowledge the input and support of the TAC which included the following:

- Piret Harmon, General Manager, SVWD
- John Ricker, Water Resources Division Director, Santa Cruz County Environmental Health Services
- Mike Cloud, Geologist, Santa Cruz County Environmental Health Services (retired, now an independent consultant)
- Andy Fisher, Professor of Hydrogeology, University of California, Santa Cruz
- Nick Johnson, Principal Hydrogeologist with MWH Americas working for SLVWD
- Kim Adamson, General Manager, Soquel Creek Water District
- Brian Lockwood, Senior Water Resources Hydrologist, Pajaro Valley Water District
- Tim Carson, Program Director, Regional Water Management Foundation

Kennedy/Jenks was the prime consultant for this project and provided staff that performed the technical scope of work for this project. However, a modeling project relies on the accumulation of technical work performed in the SGMB over the years. This work is referenced throughout this report. Kennedy/Jenks would like to acknowledge the time and effort of several individuals who provided significant contributions in support of this project. These include:

- Mike Cloud shared insights and data from his long-time efforts in refining the complex geologic correlations within the SMGB. Mike was instrumental in helping to reinterpret the geology in several keys areas. The project benefited from his contributions and that data was incorporated into this update of the SMGB model.
- Nick Johnson shared his long-time insights and data from his previous work in developing the hydrogeology of the SMGB, especially for the Pasatiempo and Quail Hollow areas, as the hydrogeology consultant to SLVWD. These data were also incorporated into this update of the SMGB model.
- John Ricker, Andy Fisher, Nick Johnson, Mike Cloud and Tim Carson reviewed all or parts of the draft report. Their edits, comments and insights were valuable in improving the overall quality of this report.

Four of the original TAC members retired or changed jobs during the course of this project. The consultant team would like to acknowledge their input and support during their tenures on the TAC. These members include:

- Charlie McNiesh, General Manager, SVWD (retired)
- Bill O’Brien, Operations Manager, SVWD (retired)
- Jim Mueller, General Manager, SLVWD (retired)
- Chris Coburn, now Executive Director of the Resource Conservation District of Santa Cruz County (previously with Santa Cruz County Health Services Agency)

Section 2: Physical and Cultural Setting

This section provides a summary of the physical characteristics, land use and water use for the SMGB relevant to the development of the groundwater model.

2.1 Topography

The SMGB is situated on the southwestern slope of the central Santa Cruz Mountains in Santa Cruz County (Clark *et al*, 1989, Brabb *et al*, 1997). The Santa Cruz Mountains comprise a portion of the California Coast Ranges physiographic province (Clark, 1966). The relief in the SMGB is moderately rugged, with elevations ranging from less than 300 feet above mean sea level using the North American Vertical Datum (NAVD 1988) along the San Lorenzo River to over 1,800 feet on the flanks of Ben Lomond Mountain. The higher elevations range from ridges over 800 feet in the northern SMGB to ridges over 1,000 feet on the eastern side of the SMGB.

The general topography of the area consists of north-south trending, elongated steep-sided ridges alternating with V-shaped valleys (Figure 2-1). One of the largest of these valleys underlies the City of Scotts Valley, which is located on an area of generally level ground in the vicinity of Scotts Valley Drive and Highway 17 along Carbonera Creek (Figure 2-1).

2.2 Population

The majority of the population is concentrated in the Scotts Valley area and the Highway 9 corridor along the San Lorenzo River (Figure 2-1). The SMGB area was sparsely inhabited and dominated by summer homes through the 1950s. Early development in the area filled most of the flatter areas and lined most creeks before environmental regulations were in place. Steep slopes and rugged terrain have long been a significant constraint to commercial and residential development in all areas of Santa Cruz County.

Scotts Valley is the largest community in the study area (Figure 2-1). The 2010 census indicated a population of 11,580 people, which is a 1.7% increase relative to the 2000 census. The 2013 estimated population by the US Census Bureau (2014) is 11,755 (1.5% increase from 2010). Population growth in Scotts Valley was highest in the 1970’s to 1990’s. The population history for Scotts Valley indicates that growth with a population of 3,621 in 1970, 6,891 in 1980, 8,615 in 1990, 11,358 in 2000 and 11,580 in 2010 (CensusViewer, 2014, California Demographic Research Unit, 2013, Scotts Valley, 2007).

Along the San Lorenzo River, the majority of the population lives in the communities of Felton, Ben Lomond, Boulder Creek and other nearby unincorporated communities along State Highway 9 (Figure 2-1). From 2000 to 2010, the population for Felton and Boulder Creek has decreased by 23% and 11%, respectively, whereas the population for Ben Lomond has increased by 2% and 12%, respectively (CensusViewer, 2014). The 2010 census indicated a population of 41,538 people in the San Lorenzo Valley, which is 6% less than the population reported in the 2000 census (Kennedy/Jenks, 2011a).

2.3 Land Use

There are a variety of land uses in the SMGB area including communities, rural residential and quarrying as shown on Figure 2-2. Land use data were obtained using online the Santa Cruz County Geographic Information System (GIS). In the 1960's and 1970's, Santa Cruz County experienced rapid growth in both population and development. These land use changes have contributed to the SMGB's water supply issues.

2.3.1 Community Development

Community development is represented on the land use map (Figure 2-2) primarily by the commercial/industrial, suburban and small community land use categories.

Scotts Valley is the most highly developed area within the SMGB with most of the commercial/industrial and suburban land use areas concentrated within or adjacent to the City Limit (Figure 2-2). Scotts Valley experienced a significant increase in development from 1980 to 2000 including construction of large commercial and industrial complexes (Santa Cruz County, 2001). Much of the land along Scotts Valley Drive and Mt. Hermon Road, which form the primary corridors through the city, has been developed and covered with asphalt parking areas, roads, and buildings. A study based on satellite image analysis approximated that more than 60% of this area is now covered with impervious areas and much of this area is commercial property (Balance Hydrologics, 2010). The primary industry in Scotts Valley is light industrial uses for high tech, computer oriented businesses (Scotts Valley, 1999). The Skypark Airport was established in Scotts Valley and was operated from 1947 to 1983, and is currently under redevelopment commercial land use (Scotts Valley, 2007).

Much of the remainder of Scots Valley is residential development that has occurred over much of the City of Scotts Valley and several parts of the surrounding area shown mostly as suburban land use (Figure 2-2). Residential uses include both single and multiple-family residences, apartments and condominiums and mobile home parks (Scotts Valley, 1999). Within Scotts Valley, several areas are identified as irrigated land (Figure 2-2) that consist primarily of golf courses, large parks or institutional property that maintain a large area of grass with irrigation.

The communities for the Highway 9 corridor along the San Lorenzo River are shown primarily as small community land or rural residential land use (Figure 2-2), which are differentiated from suburban by lower population density and less development stormwater drainage. Commercial development was not specifically defined in the GIS data, but within the SGMB consists of small commercial areas primarily along Highway 9. However, much of the community development along Highway 9 is outside of the SMGB.

2.3.2 Rural Areas

Small unincorporated communities have developed along major tributaries to the San Lorenzo, including the areas along Zayante Creek and Lompico Creek shown as rural domestic land use areas on Figure 2-2. Several of these residential communities originated as "summer encampments". There are, in fact, relatively few valleys without a few clusters of homes, now typically occupied year-round. Residential land uses in the unincorporated areas is primarily single-family residential with the majority of the residences located on large lots (Scotts Valley, 1999).

The rural/native/undeveloped land use areas (Figure 2-2) represent areas of the basin with either widely spaced residences on large lots, undeveloped areas, or designated open space. Recent rural development has been in more remote, steeper areas, and more recently, stand-alone mountain residences have been arrayed along most ridgelines. Open space lands include areas used for outdoor recreation; designated for preservation of natural resources (wildlife habitat, rivers, watershed lands, etc.); managed production of resources (mineral resources, forest lands); and areas where public health and safety hazards exist (Johnson, 2009; Kennedy/Jenks, 2011a). Undeveloped parts in the SMGB are typically covered by redwood or pine forests. These include wildlife habitat, rivers, and watershed lands designated for preservation of natural resources or forest lands and mineral resource areas designated for reclamation. Other designated open space includes safety areas that define public health and safety hazards due to unstable soil areas, fault zones, floods, etc.

2.3.3 Mining

Sand mining is the major mineral extraction activity in the survey area, although a number of operations have been closed over the past decade. In addition, exploratory drilling for oil and gas has also been conducted throughout the survey area, principally during the 1950s and 1960s. The following is a summary of the large sand and aggregate mining operations located within the SMGB as listed by the Santa Cruz County Planning Department (2014) and shown on Figure 2-2:

- **Hanson Quarry** (*aka* Kaiser Quarry) mined sand from the Santa Margarita Sandstone for construction sand until 2003 on an approximately 200 acre site west of Scotts Valley. Disturbed areas are being reclaimed to open space with a native species vegetative cover similar to the naturally occurring Sandhills habitat.
- **Olympia Quarry** (*aka* Lonestar Quarry) mined sand from the Santa Margarita Sandstone until 2002 for construction sand on an approximately 70 acre site east of Ben Lomond. Disturbed areas are being reclaimed to open space with a native species vegetative cover similar to the naturally occurring Sandhills habitat.
- **Quail Hollow Quarry** currently mines sand from the Santa Margarita Sandstone for construction and industrial uses on an approximately 105 acre site east of Ben Lomond. The mine contains a sand processing plant and bulk sand dryer. Mining is permitted to continue until the permitted reserves are exhausted. The designated end use is open space. Concurrent reclamation is in progress as mining ceases in some areas.

2.3.4 Agriculture and Timber

Agricultural acreage in the SMGB is limited because of the steep topography and limited tillable land. Following the widespread initial logging of the late 1800's and early 1900's, apples and other orchard fruits were, however, planted on the flatter newly opened slopes throughout the subject watersheds. Much of this acreage has been abandoned and now supports chaparral, second growth redwood forests, and residential development. In the San Lorenzo River watershed, almost one-quarter of the land is now in public or private ownership for natural resource conservation (Kennedy/Jenks, 2011a).

Timber resources historically were the major industry in the Santa Cruz Mountains. Timber harvests continue in many parts of the San Lorenzo River watershed, and the average timber harvest size from 2006 to 2008 was about 400 acres. Both SLVWD and the City of Santa Cruz have stopped timber harvesting on their lands, instead managing their watersheds for the yield of water and for open-space uses. SLVWD ceased timber harvesting in the 1970s and adopted a prohibition on timber harvesting in 1986 (Johnson, 2009; Kennedy/Jenks, 2011a).

2.4 Water Purveyors

Groundwater usage is reported here to represent a water year that runs from October through September of the following year. The purpose of the water year is to better represent the typical groundwater cycle in the SMGB. The typical California climate pattern consists of a rainy season from November through April and a dry summer from May through September. Groundwater levels are typically highest in late spring and lowest in late summer and early fall.

Several public and private water purveyors operate within the SMGB. Figure 2-3 shows the jurisdictional boundaries of the water districts and the larger private water purveyors. A summary of groundwater production records for the SMGB are provided in Appendix A. The following provides an overview of the major groundwater producers in the SMGB.

2.4.1 Scotts Valley Water District

The Scotts Valley Water District (SVWD) provides water to a majority of the residential, commercial and industrial customers (about 3,650 connections) in the City of Scotts Valley and rural areas primarily to the north (Figure 2-3). SVWD serves primarily residential customers with some commercial and industrial connections as well (Kennedy/Jenks, 2011a).

Groundwater currently provides 100% of the SVWD's potable water supply. Annual groundwater production by SVWD in 2012 was 1,361 acre-feet. Groundwater pumping by SVWD peaked in 2003 at 2,078 acre-feet. Since then, the District's groundwater production has declined by more than 700 acre-feet per year (about 34%), and declines have occurred in seven of the past nine years (Kennedy/Jenks, 2013b).

SVWD's monthly water production is typically between 100 and 150 acre-feet per month during the wetter months of November through April and between 175 and 250 acre-feet per month during the drier months of May through October when water demand is higher primarily for outdoor uses. SVWD has actively worked to control growth of water supply demand primarily through implementing the Water Conservation and the Recycled Water Programs. In the past five years groundwater production has steadily declined by about 75 acre-feet per year (AFY), even though the number of service connections has continued to grow (Kennedy/Jenks, 2013b).

SVWD's Recycled Water Program augments the water supply and offsets groundwater pumping for non-potable uses, especially for landscape irrigation. The source of recycled water is the tertiary wastewater treatment plant operated by the City of Scotts Valley in conjunction with the SVWD. Recycled water deliveries have continuously increased since the program started in WY2002. In WY2012, recycled water deliveries were approximately 184 acre-feet. From September 2002 through the end of WY2012, approximately 1,230 acre-feet of recycled water had been delivered. The entire 1,230 acre-feet of recycled water usage represents an equivalent reduction in groundwater pumping (Kennedy/Jenks, 2013b).

In 1994, SVWD formally adopted its Groundwater Management Plan (Todd Engineers, 1994), and has been managing groundwater resources through a comprehensive monitoring program of groundwater conditions in the Scotts Valley area for over 20 years. Results, analysis and interpretation of the monitoring program are reported each year in the Annual Groundwater

Management Report (Todd, 2003b, ETIC, 2005, Kennedy/Jenks, 2008, 2010, 2012b, 2013b and 2014).

2.4.2 San Lorenzo Valley Water District

SLVWD supplies water to a large portion of the SMGB (Figure 2-3) and currently operates four standalone water systems with separate water supplies: The Northern System, the Southern System, the Mañana Woods System and the Felton System. Together, these water systems serve approximately 7,400 connections for 22,500 people (Johnson, 2009, SLVWD, 2009).

SLVWD provides both surface water and groundwater to provide the water supply in the Northern Systems serving the communities of Boulder Creek, Brookdale, Ben Lomond, and Zayante. SLVWD utilizes local surface water utilizing pre-1914 water rights from five creeks located west of the San Lorenzo River and outside of the SMGB. The volume of surface water produced varies due to year-to-year precipitation trends, but, in general, supplies approximately half of the total SLVWD water supply (SLVWD, 2009; Johnson, 2009). In 2012, surface water from the five streams provided 815 acre-feet to the water supply.

Groundwater supplements surface water supplies in the Northern System when necessary, especially in the summer, so groundwater production will vary with the availability of surface water supplies. The groundwater is obtained from the Quail Hollow and Olympia wellfields in the western portion of the SMGB (Figure 2-3). In 2012, 450 acre-feet was pumped from the Olympia wellfield and 219 acre-feet from the Quail Hollow wellfield. Total water production in the Northern System was 1,483 acre-feet in 2012. Since 1976, pumping at the Olympia wellfield has ranged from 51 acre-feet in 1980 to 552 acre-feet in 2007; pumping at the Quail Hollow wellfield has ranged from 101 acre-feet in 2011 to 545 acre-feet in 1988.

SLVWD annexed the Felton System in 2008. The Felton System currently relies on solely on surface water from creeks and springs west of the San Lorenzo River and outside of the SMGB. In 2012, the Felton System supplied 537 acre-feet of surface water.

The Southern System serves a large area of the western portion of the Scotts Valley (Figure 2-3) and relies solely on groundwater (Johnson, 2009, SLVWD, 2009). Groundwater production by SLVWD in the Southern System was 362 acre-feet in 2012. Annual groundwater production by SLVWD has been relatively constant with production rates fluctuating between 330 to 450 AFY from WY1995 to the present. SLVWD pumping is from the production wells Pasatiempo #6 and #7. SLVWD Pasatiempo #5A was put into production in June 2014.

SLVWD annexed the Mañana Woods Mutual Water Company in 2006 which services a small area outside the Scotts Valley city limits. SLVWD also now operates the Mañana Woods #2 well which produced 33 acre-feet in WY2012 as part of the Southern System.

2.4.3 Lompico County Water District

The Lompico County Water District (LCWD) is a small county water district located east of Boulder Creek (Figure 2-3). LCWD was issued a permit in 1966 to serve drinking water to the Lompico area which consists of mostly single-family homes with an estimated population of 1,500 people and about 500 service connections. The surface water sources are Lompico and Mills Creeks with a small diversion dam on Lompico Creek, a tributary to Zayante Creek (SLVWD, 2009). LCWD has an appropriative right to 26.9 AFY of surface water, with a requirement for a minimum release of 0.10 cfs at all times. The District also operates groundwater wells that can be used to supplement surface water supplies.

2.4.4 Mount Hermon Association

The Mount Hermon Association (MHA) is located near Bean Creek upstream from the confluence with the San Lorenzo River (Figure 2-3). MHA is a year-round conference center and camp that serves more than 60,000 guests each year. Groundwater is the sole source of potable water supply. The MHA water supply is provided from the Mount Hermon #2 and #3 wells located on the property. Pumping by MHA declined to 174 acre-feet in 2012, down from a high of 232 acre-feet in 2008. Records for MHA are available from 1990 to the present.

2.4.5 City of Santa Cruz

The Santa Cruz Water Department (SCWD) serves water to the City of Santa Cruz, unincorporated areas to the north and east of city limits and a small portion of the City of Capitola. An estimated population of 90,000 is served by the SCWD (2006, 2011). The City of Santa Cruz Water Department (SCWD) does not serve water in the SMGB area, but does operate a surface water diversion on the San Lorenzo River near Felton, and the Loch Lomond Reservoir on Newell Creek in the SMGB. On average, about 75% of the SCWD's annual water supply needs are met by surface water diversions from the San Lorenzo River and the North Coast streams (SCWD, 2006, 2011; EDAW, 2005). Withdrawals from the Loch Lomond Reservoir, approximately 20% of the SCWD average annual supply, are made mainly in the summer and fall months when flows drop off and additional supply is needed to meet higher daily demands. During the winter, this water is utilized when the North Coast and San Lorenzo River sources become untreatable due to excessive turbidity from storm runoff.

2.5 Regional Groundwater Pumping

Groundwater production in the SMGB consists of pumping by water purveyors and private wells. Table 2-1 provides a summary of annual groundwater production by user type in the SMGB, and Figure 2-4 illustrates the year-to-year change in pumping by water user type. In addition to the water purveyors discussed in Section 2.4, groundwater production in the SMGB includes pumping from wells private wells including the following:

- SVWD and SLVWD are the largest groundwater pumpers in the SMGB and are shown separately. Other public water suppliers that use groundwater include MHA and LCWD.
- Industrial Wells – Industrial pumping is primarily accounted for pumping by the Hanson Quarry before the quarry was closed in 2004. Currently, the Quail Hollow Quarry water supply wells are the primary industrial water user within the SMGB.
- Remediation – Groundwater pumped for the environmental remediation projects is primarily for the Watkins-Johnson Superfund Site and the Camp Evers MTBE plume remediation. Groundwater remediation in the SMGB began in 1987 with pumping at the Watkins-Johnson Superfund Site. Pumping was highest in the 1980's and has diminished since then to 39 acre-feet in 2012.
- Private Wells – Private domestic wells supply water to rural residents located throughout the SMGB. Total well production is based on available well permits in the area. An average water use of 0.28 AFY is assumed for each domestic well (Todd, 1998). Larger

private wells include wells used for irrigation and maintaining landscape ponds. Groundwater production for these wells is estimated based on limited available reported production data.

TABLE 2-1
GROUNDWATER PRODUCTION SUMMARY FOR THE SMGB
FROM 1976 TO 2012

Water User	Recent (2012)	Average (1976 to 2012)	Minimum (Year)	Maximum (Year)
Groundwater Production (acre-feet per year)				
SVWD	1,351	1,378	460 (1978)	2,077 (2003)
SLVWD	1,004	942	473 (1979)	1,452 (2007)
LCWD and MHA	217	173	45 (1990)	276 (2008)
Industrial	113	484	113 (2012)	788 (1984)
Remediation	39	134	39 (2012)	465 (1987)
Private Wells	198	282	198 (2012)	419 (1988)
SMGB Total	2,922	3,392	2,173 (1976)	4,485 (2003)

2.6 Wastewater

The City of Scotts Valley provides wastewater collection, treatment and disposal within the city limits and some adjoining areas. Suburban residential and commercial/industrial land use areas require service from a public water system to develop at the highest allowed density. The plant has a permitted capacity of 63,000 gpd but is currently operating at about 45,000 gpd (Kennedy/Jenks, 2013a).

The County of Santa Cruz Health Services Agency estimates that about 13,500 parcels in the San Lorenzo River watershed are served by individual on-site wastewater disposal systems, most of which meet current standards (Kennedy/Jenks, 2013a). The Mt. Hermon Association community has a large onsite wastewater disposal system that treats wastewater from a hotel, cabins and homes that is discharged within the SMGB. Return flow from these on-site wastewater disposal systems, especially septic tanks, provide a component to the groundwater recharge in the SMGB. A 1997 investigation of septic systems in the Scotts Valley area identified a large number of active septic systems within the City of Scotts Valley. The City currently requires any lands that are developed or will be developed within the sanitary sewer assessment district or within 200 feet of an existing sewer main to connect to the City sewer system (Baseline, 1997, Todd, 2003b).

Using GIS data provided by Santa Cruz County, about 4,700 parcels were identified within the SMGB that were permitted for septic tank use. Of these, about 65% of those parcels are in the small community land use areas that are primarily located along the Highway 9 corridor. Most of the remainder, about 18%, is in the rural domestic land use area; and 8% in the rural/native/undeveloped land use areas. About 9% are listed in the suburban and commercial/industrial areas of Scotts Valley and these are considered dated and are generally considered that these properties have been connected to the city's wastewater collection system.

The areas designated by the small community land use areas along Highway 9 have been developed at density levels typical of many urban areas despite their rural surroundings. County policies designate that these communities be limited to urban low density development unless community disposal systems are available. Santa Cruz County established CSA 12 in 1989 to promote better septic system management and maintenance and imposes an annual fee to fund the on-site wastewater management program.

The rural residential land use areas have the lowest density range, where minimal services are available. These areas include various open space and natural resource conservation areas unsuitable for more intense development. Rural residential areas are the next highest density range, requiring access from roads maintained to rural road standards.

During the period of rapid growth, year-round residential occupancy increased which resulted in adding more on-site disposal systems in the San Lorenzo River watershed. More recently the rate of new septic system addition has decreased to about 15 systems per year in 2007 and four systems per year in 2009 (Kennedy/Jenks, 2013a).

2.7 Applied Water

Without large scale agriculture, irrigation is primarily associated with maintaining turf in commercial and suburban areas, especially in Scotts Valley. Todd (1998) estimated that of the water applied outside, 85% is assumed to be lost to evapotranspiration and only 15% is assumed to return to the groundwater basin.

Valley Gardens golf course and the Spring Lakes, Vista del Lago, and Montevalle mobile home parks maintain landscaping ponds. The ponds are maintained by a combination of surface water runoff (and may discharge surface water following storm events), groundwater from wells, and, more recently, recycled water. The ponds are not lined, and losses from the ponds occur through pond evaporation, occasional pond overflow, and percolation to groundwater. Todd Engineers (1998) estimated that about 14 AFY of return flow from the landscaping ponds.

Another form of applied water in urban areas is associated with pipe leakage, which is water that leaks from water and sewer pipes that percolates to groundwater. Studies of pipe leakage range from 5% to 30%of the total water use in an area (Lerner, 1986; Leauber, 1997; HydroFocus, 2007; DWR, 2011). Recent water conservation efforts by the water districts have included accelerated repair and maintenance of water pipes to reduce pipe leakage. Therefore, an estimate of 5% of the total water use is a conservative estimate of recharge from pipe leakage for the SMGB.

Section 3: Geology, Soils and Vegetation

Groundwater flow through the SMGB is strongly influenced by the type of rock and the stratigraphic relationships of the various geologic units, and much of the work in developing the SMGB Model goes to capturing this complex geology. This section summarizes the geology of the SMGB.

3.1 Previous Studies

Subsurface data on the geology of the SMGB has been developed through the efforts of multiple parties for different purposes. The regional geology is based on previous studies by the USGS in reports by Stanley (1985), Clark (1966, 1981), Clark *et al* (1989), Brabb *et al* (1997), Akers and Jackson (1977), Muir (1981), McLaughlin and Clark (2004) and McLaughlin *et al* (2001). The work by the USGS was for basic scientific research followed by detailed investigations of the 1989 Loma Prieta Earthquake.

The local water districts have conducted several technical studies regarding groundwater management that include additional geological assessment especially as related to water supply wells. Relevant technical reports prepared for the Scotts Valley Water District include Todd Engineers (1997a, 1998a, 2003a, 2003b) ETIC (2005, 2006) and Kennedy/Jenks (2008, 2010, 2013b, 2013c), for San Lorenzo Valley Water District include Johnson (1988, 2001, 2002, 2003 and 2009) and for Santa Cruz County include Kennedy/Jenks (2011b) and Ramlit (2002).

Environmental remediation investigations have contributed detailed subsurface information especially in the Scotts Valley area associated with the Watkins-Johnson Superfund site (R.L. Stollar & Associates,1988; Arcadis, 2011, 2012, 2014), Camp Evers regional MTBE plume (Cambria, 2000), and Ben Lomond Landfill (Geosyntec, 2004, 2013), Scotts Valley Dry Cleaners (Secor, 2007; Stantec, 2009). The discussion of the regional geology provided below is a summary of the references listed above.

3.2 Regional Geology

The SMGB comprises a portion of the California Coast Ranges, and is a geologically complex area that was formed by the same tectonic forces that created the Santa Cruz Mountains. The geologic history discussed below is derived from the work of Stanley (1985) and Clark (1981). This brief summary of the geologic history is discussed here to provide context on the development of the complex geology of the SMGB.

3.2.1 Geologic Units

The geology of the SMGB is characterized by a sequence of sandstone, siltstone, and shale that rest upon the crystalline basement rocks. This sequence of sedimentary rocks is divided into several geologic formations that are defined on the basis of the type of rock and their relative geologic age. The physical descriptions of the geologic formations are defined on the basis of the type of rock and their relative geologic age based on studies by the USGS (Clark, 1966, 1981, Brabb *et al*, 1997, and McLaughlin *et al*, 2001).

The stratigraphic column for the region indicates a crystalline basement rock overlain by a Tertiary-aged sedimentary sequence (Figure 3-1). Areas outside of the SMGB have a different sequence of sedimentary units that are not all present within the SMGB. The geologic map (Figure 3-2), from Brabb *et al* (1997), shows regional surface outcrop distribution of these geologic units. Within the SMGB, the geologic formations from youngest to oldest include:

- **Alluvial Deposits** (alluvium) – Unconsolidated sands and silts typically less than 10 to 20 feet thick found in the Scotts Valley area and along the San Lorenzo River associated with existing and prehistoric streams.
- **Purisima Formation** (Purisima) – Siltstone and sandstone that forms the tops of some of the hills in the Scotts Valley area, but absent over most of the SMGB. It is a key aquifer in the coastal areas far outside the SMGB.
- **Santa Cruz Mudstone** – Dense shale that is found near the ground surface underlying much of the northern areas of Scotts Valley. The Santa Cruz Mudstone is an aquitard that forms a cap that limits recharge to the underlying aquifers where it is present.
- **Santa Margarita Sandstone** (Santa Margarita) – The Santa Margarita generally consists of massive, fine-to-medium-grained sandstone that forms a distinctive formation of white sand that can be observed in cliffs around Scotts Valley. The Santa Margarita forms an important aquifer in the SMGB.
- **Monterey Formation** (Monterey) – Thick shale with a few sandstone layers. It separates the Santa Margarita and Lompico, but is missing underneath parts of Scotts Valley. Generally, the Monterey is an aquitard that hydraulically separates the Santa Margarita and Lompico; however, thin sandstone layers are sufficient to support small local water supply and domestic water wells.
- **Lompico Sandstone** (Lompico) – A thick sandstone that looks similar to the Santa Margarita; however, this unit is primarily found in the subsurface with limited surface outcrops primarily along the basin margin both to the north and south of Scotts Valley. The Lompico is the most heavily pumped aquifer in the SMGB.
- **Butano Formation** (Butano) – The Butano is a thick sandstone unit that consists largely of sandstone and interbeds of mudstone, shale, and siltstone. Specifically, the Butano consists of three members that include the lower sandstone member, the middle siltstone member, and the upper sandstone member (Clark, 1981). It is found at depths greater than 1,000 feet below Scotts Valley, but it is found at the surface to the north. The Butano forms a significant aquifer in the SMGB.
- **Locatelli Formation** (Locatelli) – The Locatelli Formation is characteristically a gray, sandy siltstone with a basal sandstone bed typically found at the base of the unit found in the southwestern part of the SMGB. The basal sandstone layer supports some domestic water wells.
- **Crystalline Basement Rock** (crystalline basement) –The crystalline basement is primarily composed of quartz diorite of Cretaceous age that is best exposed upon Ben Lomond Mountain and along the lower portions of Carbonera Creek. The crystalline basement surface has been downwarped beneath the Scotts Valley syncline to form the base of the SMGB.

3.2.2 Faults

The SMGB is bounded by the two regional faults, the Ben Lomond Fault to the west and the Zayante Fault to the north (Figure 3-2). The Zayante fault zone is the most important geologic structure present between the San Andreas and San Gregorio faults. It is mapped for over 30 miles from west of Ben Lomond Mountain southeastward to the vicinity of Watsonville (Brabb, 1989). The area north of the Zayante Fault is composed of a sequence of Tertiary-aged sedimentary formations that are not present south of the Zayante Fault in the SMGB (Figure 3-2).

The Zayante Fault marks the boundary between two large crustal blocks that are defined by distinctly different underlying basement rocks. South of the Zayante Fault, including the SMGB, the crystalline basement rocks are composed principally of granitic rocks, representing continental crust, that occur at a relatively shallow depth. North of the Zayante Fault, the basement is not exposed but gravity and magnetic data (Jachens and Griscom, 2004) suggest it is composed gabbro representing oceanic crust. The juxtaposition of 90-mya continental basement with 165-mya oceanic gabbroic basement along the Zayante fault demonstrates that significant displacement, with several miles of “up-to-the-south dip-slip displacement” occurred along the Zayante fault (McLaughlin and Clark, 2004).

Although the Zayante fault is confined to a narrow zone, branching lineaments locally occupy a zone as much as 1 to 2 km wide (Clark, 1981, McLaughlin and others, 1988). The relatively straight course of this fault across canyons and ridges suggests that the shallow fault plane dips steeply, but the fault plane is interpreted to bend towards the southwest, underneath the SMGB, at depth. Aftershocks of the 1989 Loma Prieta earthquake associated with the Zayante fault occurred at depths of 4 to 6 miles (McLaughlin and Clark, 2004).

The Ben Lomond Fault extends southeastward from near Boulder Creek, through the community of Ben Lomond, to the vicinity of Felton (Clark 1981; Brabb *et al*, 1997). This fault forms the western boundary of the SMGB. The southeastward-flowing San Lorenzo River follows the trace of the Ben Lomond fault. The fault has brought the Monterey Formation into contact with the granitic rocks of Ben Lomond Mountain and to the south has locally juxtaposed the Monterey and Lompico Sandstone, suggesting a dip separation of less than 500 feet. Gravity studies in the Felton area suggest that the crystalline basement is vertically offset less than 1,000 feet by the Ben Lomond fault (Clark and Rietman, 1973). The youngest strata clearly displaced by this fault are of the Monterey Formation. The Quaternary alluvium along the San Lorenzo River does not appear to be affected.

3.2.3 Folds

The SMGB is defined by the Scotts Valley syncline that extends from Boulder Creek eastward underneath Scotts Valley, but appears to die out farther east into an area of shallow crystalline basement rock (Figure 3-2). The axis of the syncline has a northwest-southeast trend (Clark 1981; Brabb *et al*, 1997). The syncline is expressed at the surface by geologically younger geologic units outcropping in the center of the syncline, with progressively older units outcropping on the flanks of the syncline. The Scotts Valley Syncline is the primary geologic structure that defines the SMGB.

The deepest part of the Basin is located in northern Scotts Valley where the sedimentary rocks that form the basin aquifers are over 1,500 feet thick. The depth to the crystalline basement varies from near the surface along Carbonera Creek to over 2,000 feet in the area of SVWD

Wells #3B and #7A. These two wells are located in the axis of the Scotts Valley Syncline which is the deepest part of the SMGB.

3.3 Geologic History Summary

The sediments in the basin have been folded during deformation associated with the development of the Coast Ranges (Stanley, 1985; Clark 1981) during the time the geologic units of the SMGB were being deposited. Each episode of folding also further deforms the older formations. This history has created complex stratigraphic relationships where intervening geologic formations are removed by erosion creating pinchouts allowing different combinations of units in contact with one another.

A summary of the major events in the geologic history with estimated time of occurrence and geologic age, corresponding to the stratigraphic column in Figure 3-1) is summarized from USGS reports by Stanley (1985) and Clark (1981) include the following:

- *Pre-*Cretaceous - The metasedimentary rocks exposed on Ben Lomond Mountain represents a relic of the former overlying rock that covered this area with thousands of feet of overlying sedimentary rocks from earlier times that were subsequently metamorphosed into the quartzite, schist and marble seen on Ben Lomond Mountain.
- *Prior to 95 million years ago (mya)* (Cretaceous) - Granitic rock intruded into the metasedimentary rocks about 90 to 70 mya; however, this is interpreted as the last episode and that much of the emplacement occurred prior to 95 mya.
- *Between 95 and 61 mya* (Paleocene) – Regional uplift led to "unroofing" of the metasedimentary and granitic rock occurred where this overlying rock was removed by erosion (McLaughlin and Clark, 2004). After this "unroofing" event, the granitic rock formed the surface where subsequent deposition occurred.
- *Between 59 and 54 mya* (Paleocene) - The oldest sedimentary sequence in the SMGB is Locatelli Formation that lies nonconformably upon the crystalline basement rock. Deposition of the Locatelli is considered to have occurred in several small steep-sided basins that developed in the region during the Paleocene (Stanley, 1985).
- *Between 54 and 52 mya* (Eocene) - Following deposition of the Locatelli, uplift and erosion during the late Paleocene is recorded by the unconformity between the Locatelli and the Butano Sandstone suggesting a major regional tectonic event (McLaughlin and Clark, 2004; Graham, 1976; Clark, 1968). During this time, almost all of the Locatelli was removed by erosion leaving only isolated exposures.
- *Between 52 and 44 mya* (Eocene) - The Butano Sandstone is interpreted to have been deposited in very deep water on a submarine fan with sediment supplied by an uplifted granitic highland located several miles to the south (Stanley, 1985). The area including the SMGB is interpreted as one of several small and very deep basins that were separated from each other by uplifted ridges of granitic basement. Relatively rapid rates of sediment accumulation indicated by the thickness of the lower Butano and presence of conglomerates of large granitic gravel to boulders suggest a continuation of active tectonism (Stanley, 1985).
- *Between 52 and 44 mya* (Eocene) - During the late middle Eocene, deposition of coarse sediment on the Butano submarine fan slowed considerably that is reflected in the

general lithologic change to the sandstone in the middle and upper members becoming thinner bedded and finer grained upward (Stanley, 1985; Clark, 1981).

- *Between 44 and 14 mya* (Eocene, Oligocene and Miocene) - Deposition continued after the Butano with the deposition of the San Lorenzo Formation, Zayante Sandstone, Vaqueros Sandstone, and Lambert Shale. These units are no longer present in the SMGB, but over 6,000 feet of stratigraphic interval is present in the basin north of the Zayante Fault. It is interpreted that these units were deposited, but were eroded by concurrent uplift along the Zayante Fault during this time (Stanley, 1985; Clark, 1981).
- *Between 44 and 14 mya* (Eocene, Oligocene and Miocene) - A period of geologic deformation preceded the deposition of the Lompico Sandstone as evidenced by the pronounced angular unconformity of the Lompico with the crystalline basement, Locatelli and Butano Formations in different portions of the basin (Stanley, 1985; Clark, 1981).
- *Between 18 and 14 mya* (Miocene) - Subsidence resumed in the SMGB leading to renewed marine transgression resulting in the deposition of the shallow-marine Lompico Sandstone and the deeper-water deposits of the Monterey Formation. The Lompico and Monterey represent a marine fining-upward transgressive cycle representing a change from shallow, basal sandstone to deeper organic mudstone deposition (Stanley, 1985; Clark, 1981).
- *Between 14 and 12 mya* (Miocene) - Subsequent geologic deformation of the Lompico and Monterey led to an angular unconformity with the overlying Santa Margarita Sandstone. Erosion removed Monterey Formation in the Scotts Valley area forming areas where the Santa Margarita Sandstone was deposited directly on the Lompico Sandstone (Stanley, 1985).
- *Between 12 and 7 mya* (Pliocene) - Another marine sedimentary sequence consisting of a shallow-water transgressive sandstone unit, the Santa Margarita Sandstone, a deeper water siliceous organic mudstone unit, the Santa Cruz Mudstone was deposited during this time (Stanley, 1985; Clark, 1981).
- *Between 6 and 2 mya* (Pliocene) - A later and shallower phase of marine transgression is recorded by the Purisima Formation (Stanley, 1985; Clark, 1981). Abundant silicic glass and dark andesitic fragments representing influence of nearby volcanism serve to differentiate the Purisima Formation from all older sedimentary rock units in the area. The Purisima Formation rests unconformably upon the Santa Cruz Mudstone indicting continued deformation during this time. In the SMGB, the Purisima is discontinuously exposed along ridge tops with a maximum thickness of about 200 feet.
- *After 2 mya (Quaternary)* – The Purisima has relatively uniform dip towards the southwest indicating continued uplift of the region has occurred causing the erosion of the overlying sedimentary rock developing the current landscape (Clark, 1981). Over most of the region, the Purisima is eroded or unconformably overlain by marine terrace, alluvial and landslide deposits (Stanley, 1985).

3.4 Geology of the SMGB

The SMGB is a roughly triangular area that is bounded by the Ben Lomond Fault to the west and the Zayante Fault to the north (Figure 3-2). To the southeast, the basin is bounded by the granitic crystalline rock which rises steeply in this area. Ben Lomond Mountain, which is primarily composed of crystalline basement rock, is located west of the SMGB. The area north of the Zayante Fault is composed of a sequence of Tertiary-aged sedimentary formations that are not present south of the Zayante Fault in the SMGB (Figure 3-2). There is a significant displacement along both of these faults, and there is not considered to be appreciable groundwater flow across either the Ben Lomond or Zayante Faults.

Figures 3-3 and 3-4 present representative geological cross sections across the SMGB to show the stratigraphic relationships that have developed from the complex geologic history described above. Additional cross sections are provided in Appendix B to provide additional detailed data on the correlation of geologic units across the SMGB. Geologic structure map showing the elevation of a geologic horizon, such as the base of the Santa Margarita Sandstone, are also provided in Appendix B. These data were used to develop the geologic structure of the SMGB that was incorporated into the SMGB Model. The following provides a summary of key observations from these data.

The different geologic formations in the SMGB represent different depositional environments that control whether the unit is composed mostly of sandstone or mudstone. The following lists a series of observations from review of Figures 3-3 and 3-4 and the Appendix B figures:

- The crystalline basement rocks are the oldest rocks and define the base of the SMGB and the overlying sedimentary rocks represent the groundwater basin. In the SMGB, the depth to the crystalline basement rock varies less than 30 feet in the southern parts of the study area to over 1,500 feet north of Scotts Valley. The uneven surface of the crystalline basement rocks reflects the effects primarily of tectonic folding and, to a lesser degree, erosion. The geologic structure map of the base of the SMGB is included in Appendix B.
- An erosional remnant of the Locatelli remains along the axis of a tight fold the southwestern SMGB where it outcrops in the hillside along Eagle Creek and the San Lorenzo River. A pronounced angular unconformity separates the Locatelli from the overlying units, principally the Lompico. Previous studies by the USGS have not found an instance where the Butano and Locatelli are in contact.
- The Butano has been mapped in surface outcrop along the northern SMGB margin (Clark, 1981). The Butano Formation occurs as a wedge shaped that is thickest along the Zayante Fault and has been eroded by subsequent deposition of the Lompico to a pinchout about halfway across the SMGB with a pronounced angular unconformity with the overlying Lompico. The Butano ranges in thickness from zero at the pinchouts to over 2,000 feet along the Zayante Fault. The upper and middle members are only present in the northeastern portion of the SMGB.
- The San Lorenzo Formation, Zayante Sandstone, Vaqueros Sandstone, and Lambert Shale are present between the Butano and Lompico north of the Zayante Fault, but as shown on Figures 3-3 and 3-4, these units are missing in the SMGB.
- The Lompico forms a relatively uniform sandstone layer across the SMGB that typically ranges between 300 and 400 feet. The Lompico is thickest and coarsest in the southwestern SMGB, and gradually becomes thinner and less sandy in the northern SMGB. The base of the Lompico is a distinct erosional surface that is easily recognizable in geologic logs. The geologic structure map of the base of the Lompico is included in Appendix B.

- The Monterey Formation is primarily a thick mudstone and shale that forms a hydraulic barrier between the Santa Margarita and Lompico. However, In the Scotts Valley area along the SMGB margin, the Monterey has been completely eroded so that the Santa Margarita rests upon the Lompico, creating a window for groundwater direct exchange. The Monterey Formation contains sandstone interbeds, especially closer to the base, that have been used for water supply.
- The Santa Margarita is a distinctive white sandstone that crops out along bluffs in the SMGB. The Santa Margarita Sandstone is most extensively developed along the Scotts Valley syncline between the community of Ben Lomond and Scotts Valley, whereas to the northeast, the Santa Margarita thins and becomes more fine-grained (Clark, 1981). The geologic structure map of the base of the Santa Margarita is included in Appendix B.
- The Santa Cruz Mudstone is present along the axis of the Scotts Valley syncline east of Zayante Creeks. In the Bean Creek area, the Santa Cruz Mudstone forms the ridges; whereas near Carbonera Creek, It thickens and occurs more at depth.
- The Purisima Formation is discontinuously exposed along ridge tops with a maximum thickness of about 200 feet. The Purisima has eroded into the underlying layers in the eastern SMGB with a relatively uniform dip towards the southwest (Clark, 1981).

Groundwater flow through the SMGB is strongly influenced by the rock type and the stratigraphic relationships of the various geologic units, and much of the work in developing the SMGB Model goes towards capturing this complex geology.

3.5 Soils and Vegetation

The area is underlain by a complex mosaic of soils derived from underlying geologic formations, and influenced by others factors such as climate, aspect, vegetation cover, and local relief. Soil and vegetation influence how much precipitation infiltrates into the soil to recharge the groundwater aquifers.

3.5.1 Soil Types

In the most general terms, soils underlain by permeable sandstones, as well as igneous and metamorphic rocks, are deep and well-drained. These loamy and sandy loam soils are found throughout the heavily forested reaches of the survey area. Soils formed from the Santa Margarita and several other sandstone formations are also sandy, deep, and well drained as shown on Figure 3-5. Soils formed from mudstones and shales also tend to be deep, yet somewhat less well-drained. Overall, soil depth is often limited by shallow bedrock, steep slopes and the gradual loss of topsoil to erosion.

The U.S. Department of Agriculture (USDA) has compiled the soil survey for Santa Cruz County (USDA, 1980). In the soil survey report, the soils are classified throughout the country with respect to a variety of soil properties for a variety of hydrologic properties such as the permeability and available water capacity. Soil classifications have been grouped into four hydrologic groups according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms. These designations are useful for evaluating the recharge potential. The four hydrologic soil groups are:

- **Group A:** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high initial rate of infiltration, generally greater than 2.0 inches per hour.

- **Group B:** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well- or well-drained soils that have moderately fine to moderately coarse texture. These soils have a moderate initial rate of infiltration, generally 0.6 to 2.0 inches per hour.
- **Group C:** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine or fine texture. These soils have a slow initial rate of infiltration, generally 0.2 to 0.6 inches per hour.
- **Group D:** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow and overlie impervious material. These soils have a very slow initial rate of infiltration, generally 0.06 to 0.2 inches per hour.

3.5.2 Vegetation

Much of the SMGB is dominated by dense forests consisting of a mix of deciduous and evergreen trees and hardy shrubs. A map of typical vegetation derived from the USDA (1980) soil survey for Santa Cruz County is shown on Figure 3-6. Second growth coast redwood is the dominant forest species in the steep canyons, particularly where coastal fog can supply summer moisture. Several species of oak, as well as Douglas fir, tanoak, and madrone form mixed stands on drier slopes and aspects. Some ridges are covered by dense chaparral, composed mainly of manzanita and chamise. Ponderosa pine, a forest species not generally found in the Coast Range, forms a distinct community in the locations where the coarse sands of the Santa Margarita formation are exposed.

While scattered grasslands can still be seen in the San Lorenzo River watershed, most have been converted to residential uses or have reverted to chaparral and second growth forests. The coastal terraces support larger grasslands, but are also subject to the same sorts of residential development pressures and conversion to chaparral and coastal scrub. Within the area grasslands, few native bunchgrasses are found, having long ago been replaced by the exotic annual grasses introduced by early European settlers.

Riparian plant communities are established along all streams in the watershed, although human activity or debris from unstable slopes often encroaches in these areas. These riparian zones are thought to play vital roles in protecting and maintaining water quality in most of the water supply watersheds.

3.5.3 Soil and Vegetation Distribution

Soils in the SMGB fall into these groups, and their distribution is mostly controlled by the parent material derived from the underlying geologic formations. Also, the vegetation is strongly controlled by the soil type. Comparing the geologic map (Figure 3-2), soil map (Figure 3-5) and the vegetation map (Figure 3-6) shows these relationships.

Soils of Group A (the most permeable) occur along the western and southern parts of the SMGB. These soils mostly overlie, and are derived from, outcrops of the Santa Margarita and

Lompico Sandstones. Group A soils also occur in areas underlain by alluvium along Bean and Carbonera Creeks and the San Lorenzo River. The vegetation on these soils is primarily grasses and pine trees.

Soils of Group B are limited within the SMGB, but are mostly associated with the Butano Formation in the Boulder Creek area, but scattered occurrences are found across the SMGB. The vegetation on these soils is primarily redwood trees. An area of Group B soils in Scotts Valley is associated with the alluvium and the vegetation is primarily grassland.

Group C soils are generally associated with the Purisima, Monterey and Locatelli Formations throughout much of the SMGB. The vegetation on these soils is primarily redwood and Douglas fir forest with open areas of grasses, brush and chaparral.

Group D soils generally coincide with limited areas underlain by the Monterey Formation, Santa Cruz Mudstone and Purisima Formation scattered across the SMGB. The vegetation on these soils is more varied and can include grasses, brush, chaparral, and trees including oak and redwood.

Section 4: Regional Hydrology

Since most of the groundwater recharge in the SMGB is ultimately derived from precipitation, above-average rainfall years tend to produce increased groundwater recharge, sustaining long-term groundwater levels, whereas below-average rainfall years produced decreased groundwater recharge. In addition, stream flows are fed by runoff from both the mountainous and lower elevation areas; therefore, the variation in rainfall due to the orographic effects is important for understanding streamflows in the San Lorenzo River and its tributaries. This section summarizes the hydrology of the SMGB.

4.1 Climate

The climate pattern is Mediterranean with distinct rainy and dry seasons with a general pattern of warm summers and mild winters. In inland areas that have a sunny exposure, the mean maximum daily temperature is often more than 80 degrees Fahrenheit (ºF). The elevated inland areas are approximately 3ºF to 5 ºF cooler per 1,000-foot rise above sea level (USDA 1980).

4.1.1 Precipitation

Precipitation varies across Santa Cruz County primarily due to the orographic effects of topography. Three key precipitation measurement stations in the SMGB that have relatively long records include the SVWD station at the El Pueblo Yard, Ben Lomond 4 NOAA stations, and the SLVWD station at Boulder Creek.

Table 4-1 provides a summary of monthly precipitation data for SVWD (data from 1947 to present), SLVWD (data from 1981 to present) and Ben Lomond 4 (data from 1937 to present) rain gauges. In the driest years, which occur every 20 years on average, the Santa Cruz Mountains receive only 30 to 35 inches of precipitation. In the wettest years, precipitation totals more than 90 inches in parts of the Santa Cruz Mountains (USDA, 1980). A prolonged 19-year drought occurred in water years 1917-1935, with 80% or less of average rainfall. Significant droughts also occurred in water years 1975-77, 1987-94, and 2007-14 with approximately 60, 75 and 80% of average rainfall, respectively. A histogram of annual precipitation for the Scotts Valley and Boulder Creek stations is shown on Figure 4-1, and precipitation records are included in Appendix C.

For the SVWD El Pueblo station, the highest annual rainfall was 86.25 inches in 1983, and the lowest annual rainfall was 19.30 inches in 2014. Annual precipitation is reported by "water year," which begins 1 October and ends 30 September (of the identified year). The period from February 2013 through January 2014 was the driest 12-month recorded in Scotts Valley with a total of 6.1 inches, which is more than 35 inches below average for the preceding 67 years. This corresponds to a period extreme drought throughout California that prompted Governor Jerry Brown to issue a Drought Emergency Proclamation on January 17, 2014 (Kennedy/Jenks, 2014).

During the typical rainy season from November through March, the long-term average precipitation is over 35 inches representing about 84% of the average annual rainfall. During the typical dry season from June through September, the long-term average precipitation is less than one inch representing about 2% of the average annual rainfall. During the shoulder months that represent the transition from the rainy to the dry season, (typically October, April and May), the long-term average precipitation is less than 6 inches representing about 14% of the average annual rainfall. The difference in precipitation between the SVWD and SLVWD/Ben Lomond 4 rain gauges is greatest during December through March; however, the difference in rainfall is slight during April through November.

Several versions of isohytel (contours of equal rainfall) maps have been developed over the years by Watkins-Johnson (1993), Geomatrix (1999), ETIC (2006), Balance Hydrologic (2009) and Johnson (2009). Precipitation is heaviest in the mountains, such as Ben Lomond Mountain, where seasonal precipitation totals average 60 inches whereas mean annual precipitation along the coast is approximately 30 inches. To provide consistency, the version developed by Johnson (2009) is used for this study and shown on Figure 4-2. The distribution of rainfall shows higher precipitation on the western side of the SMGB associated with the orographic effect of Ben Lomond Mountain. Average annual precipitation generally declines towards the southwest reflecting the lower elevations approaching the coast.

TABLE 4-1
LOCAL CLIMATE SUMMARY FOR THE SMGB

	Jan	Feb	Mar	Apr	May	June
[1]Scotts Valley Average Rainfall (in.)	8.58	7.57	5.99	2.96	0.93	0.26
[2]Boulder Creek Average Rainfall (in.)	10.30	9.60	7.66	2.86	1.25	0.29
[3]Ben Lomond Average Rainfall `(in.)	10.01	9.96	7.12	3.13	1.05	0.21
[3]Average Max Temp (ºF)	62.0	63.7	66.8	71.6	76.8	82.1
[3]Average Min Temp (ºF)	36.9	38.8	40.3	41.7	45.2	48.3
[4]Reference ETo (in.)	1.86	2.24	3.41	4.50	5.27	5.70
	July	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
[1]Scotts Valley Average Rainfall (in.)	0.08	0.08	0.45	2.12	5.22	7.95
[2]Boulder Creek Average Rainfall (in.)	0.01	0.07	0.17	2.19	5.76	9.35
[3]Ben Lomond Average Rainfall `(in.)	0.08	0.11	0.37	2.46	5.75	8.99
[3]Average Max Temp (ºF)	85.1	85.3	84.5	78.3	68.0	61.4
[3]Average Min Temp (ºF)	50.5	50.4	48.9	44.7	39.5	36.3
[4]Reference ETo (in.)	5.58	5.27	4.50	3.41	2.40	1.86

Source [1]SVWD El Pueblo Rain Gauge
[2]SLVWD Boulder Creek Rain Gauge
[3]Ben Lomond 4 NOAA weather station
[4]CIMIS database at http://wwwcimis.water.ca.gov/

4.1.2 Long-Term Precipitation Trend

To evaluate the long-term precipitation trend, Figure 4-3 shows the cumulative precipitation deficit from 1984 to 2012 determined by the cumulative difference between the measured and average rainfall for each year. For this analysis, the period since 1983 was chosen because 1983 represents the maximum rainfall year recorded at Scotts Valley and groundwater levels were relatively high at that time. Since 1983, the long-term trends in precipitation are described as follows:

- From 1983 through 1986, there was essentially no net deficit of rainfall.
- The extended drought period experienced in Scotts Valley from 1987 through 1994 resulted in a cumulative rainfall deficit of over 100 inches.
- From 1995 to 2000, above average rainfall resulted in 50 inch recovery of the deficit from the preceding drought, but the overall rainfall deficit was still about 48 inches.
- From 1999 to 2004, near normal rainfall resulted in a slight deficit of 10 inches over this period. The overall deficit increased to over 62 inches.
- 2005 and 2006 were well above average rainfall which reduced the deficit by 35 inches but still left an overall deficit of nearly 27 inches since 1983.
- From 2007 through 2009 resulted in over 41 inches below average. This negated the improvement from the previous two years and leaves an overall deficit of 68 inches.
- 2010 and 2011 were slightly above average rainfall that reduced the rainfall deficit by about 20 inches leaving an overall deficit of about 48 inches
- 2012 through 2014 have been another drought period with rainfall over 43 inches below average. This further increased the overall rainfall deficit since 1983 to 92 inches.

As shown on Figure 4-3, the sustained drought period from 1987 to 1994 had a profound effect in the Scotts Valley area. Because of the severity of this sustained drought period, the several years of above average rainfall were not sufficient for the SMGB to naturally make up the deficit. Another period of extended drought from 2007 through 2014 depleted the gains from the intervening period leaving the overall rainfall deficit since 1983 to 92 inches (Kennedy/Jenks, 2010, 2014)..

4.1.3 Evapotranspiration

Evapotranspiration accounts for the uptake of water by plants and losses to evaporation. These natural phenomena affect two major components of the major supply sources to the groundwater basin: groundwater recharge and stream flow. These losses can be quantified using evaporation pan data and evapotranspiration data. SVWD has maintained an evaporation pan since 1985 at the El Pueblo Yard.

Evapotranspiration data are provided by the De Laveaga Golf Course weather station in Santa Cruz. The De Laveaga Golf Course weather station has been operated by the DWR since 1990 and reports to the California Irrigation Management Information System (CIMIS) database. These data serve as a reference for SVWD evaporation pan data and are available on the web at http://wwwcimis.water.ca.gov/.

Reference evapotranspiration, denoted as ET_o. is a calculation that assumes a hypothetical grass reference crop that closely resembles an extensive surface of green, well-watered grass of uniform height, actively growing and completely shading the ground. This provides a reference value to estimate evapotranspiration for other types of vegetation and soil conditions. Average annual ET_o reported by the CIMIS database at http://wwwcimis.water.ca.gov/ for the SMGB area is 46.3 inches. ET_o varies over the year in response to temperature and sunlight. Table 4-1 provides an average monthly ET_o for the region. The highest ET_o occurs in June (5.70 inches) and the lowest is in December and January (1.86).

4.1.4 Potential Climate Change Summary

Climate change has become a topic of increasing concern for water managers throughout California. Several reports and studies have been undertaken to better understand the effects of climate change from the global, statewide and local scales.

- Johnson (2009) provided a summary of climate change in the SLVWD Water Supply Master Plan.
- DWR jointly developed the Climate Change Handbook for Regional Water Planning (DWR, 2012) that focused on California water issues.
- A technical study by Russo *et al* (2013) evaluated precipitation in the San Francisco Bay Area that assessed changes in precipitation patterns from 1890 to 2010.
- Flint and Flint (2012) conducted regional hydraulic modeling study focused on streamflow in the Santa Cruz Mountains that included the San Lorenzo River watershed area and the SMGB.

Studies looking at recent data suggest a general trend is for increasing long-term annual average precipitation in northern California whereas in southern California, the averages show a decreasing trend. For the Santa Cruz Mountains in central California, the trend is for the long-term annual average precipitation to remain similar to slightly increase (Russo *et al*, 2013).

The general result of these studies is that the long-term annual average precipitation may change only slightly. However, the most significant change is that the precipitation distribution from year to year and month-to-month within a single year will become increasingly more extreme. In short, dry years will be drier and wet years will be wetter. Also, individual storms within a single year would become greater whereas dry spells would be longer and more persistent. These potential changes in precipitation and stream runoff trends would potentially be reflected groundwater recharge to the SMGB.

4.2 San Lorenzo River Watershed

The San Lorenzo River drains a 138 square-mile watershed that extends from the Santa Cruz Mountains south towards the River's mouth into Monterey Bay within the City of Santa Cruz. Small, steep tributaries feed the river from the west at Ben Lomond Mountain, while wider, more gently sloping tributaries feed the river from the east and northeast (Santa Cruz County, 2001, SLVWD, 2009). Zayante Creek, Bean Creek and Carbonera Creek are all tributaries to the San Lorenzo River (Figure 4-4).

Key existing information sources include hydrologic and water quality studies conducted by the County of Santa Cruz, U.S. Geological Survey, U.S. Army Corps of Engineers, Central Coast Regional Water Quality Control Board (RWQCB), DWR, local water purveyors, and consulting specialists. Much of this work is considered and cited in several summary reports (Ricker, 1994; Hecht *et al*, 1991; Camp Dresser & McKee, 1994; Swanson, 2001; and the Santa Cruz County, 2001). Pertinent findings of the prior investigations are incorporated into this report. Technical studies by the local water districts include Johnson (2001, 2003, and 2009) for SLVWD, and Todd (1984, 1998) for SVWD. Balance Hydrologics (2010) performed an assessment of streamflow for the County. The summary provided below is a compilation of the results of these studies.

4.2.1 San Lorenzo River

The San Lorenzo River is the primary surface water feature, and most of the SMGB is situated within the San Lorenzo River Watershed. Surface water flows in the watershed vary with the season with highest flows in the rainy winter months and lowest flows occurring in late summer and early fall. The San Lorenzo River and its tributaries provide a source of surface water available for potential diversions especially during high wintertime flows.

The longest continuous period of record in the area is the USGS gage on the San Lorenzo at Big Trees located just south of Felton (USGS Station No. 11160500). This gage has operated since 1937 and measures discharge from about 85% of the watershed upstream of the Tait Street Diversion. Table 4-2 provides average, minimum and maximum monthly average streamflow data based on the USGS gauge from 1937 to 2012.

The maximum daily discharge was 30,400 cubic feet per second (cfs) on December 23, 1955. The minimum instantaneous daily discharge was 5.6 cfs (3.6 mgd) on July 27 and 28, 1977, during a hard two-year drought. The annual mean runoff for the period of water year 1937 to water year 2012 is 132 cfs. The minimum daily discharge for the period of record was a flow of 5.6 cfs which occurred on July 27 and 28, 1977, one of the most intense droughts in recent time. More typical values of dry season average daily baseflow are in the 20 to 30 cfs range (Balance Hydrologics, 2010).

TABLE 4-2
USGS STREAM GAUGE SUMMARY FOR THE SMGB

	Fall Oct-Dec	Winter Jan-Mar	Spring Apr-Jun	Summer Jul-Sep
USGS Gage 1160500 – San Lorenzo River at Big Trees – 1936 to 2009				
Average streamflow (cfs)	77.4	334.9	97.7	21.8
Maximum streamflow (cfs)	1,319.0	1,853.0	1,048.0	65.8
Minimum streamflow (cfs)	8.3	13.8	9.4	6.5
USGS Gage 1160430 – Bean Creek – 1989 to 2007				
Average streamflow (cfs)	8.0	37.4	6.4	2.3
Maximum streamflow (cfs)	35.1	223.7	22.6	3.3
Minimum streamflow (cfs)	1.8	4.9	2.3	1.7
USGS Gage 1161300 – Carbonera Creek – 1985 to 2007				
Average streamflow (cfs)	19.5	40.3	3.2	0.2
Maximum streamflow (cfs)	262.8	191.9	40.7	0.6
Minimum streamflow (cfs)	0.0	0.9	0.2	0.0
USGS Gage 1160300 – Zayante Creek – 1957 to 1992				
Average streamflow (cfs)	3.9	67.7	30.6	0.9
Maximum streamflow (cfs)	38.1	946.1	819.1	2.6
Minimum streamflow (cfs)	0.3	1.0	0.5	0.0

Source USGS NWIS database at http://waterdata.usgs.gov/nwis/sw/
cfs- cubic feet per second

Of the 74-year period of record reviewed, it is estimated that about one-third of all days in the five months with higher surface water flows (typically mid-November to mid-April) have daily mean discharge (flow) greater than 200 cfs. An analysis of Big Trees Gage data for daily mean discharge greater than 25 cfs indicate that 63% of all days of record have flows greater than 25 cfs. Initial studies on anadromous fish in the San Lorenzo River were performed in 1976 by the SWRCB and revised in the late 1980s as part the water rights process, and established a bypass flow requirement of up to 25 cfs.

4.2.2 Fishery

The San Lorenzo River historically supported the largest salmon and steelhead fishery south of San Francisco Bay; the fourth largest steelhead fishery in the state. Coho salmon and steelhead are now listed as threatened or endangered species (Santa Cruz County, 2001, SLVWD, 2009), which can limit the potential to divert water without significant study and resource agency negotiation. As a result of the presence of threatened or endangered species, SCWD has prepared a draft Habitat Conservation Plan (SCWD, 2010) for steelhead in support of their Incidental Take Permit under the Endangered Species Act for their routine operations and maintenance activities. In addition, the NOAA Fisheries recently issued a draft Coho Recovery Plan (NOAA, 2010) that proposes to limit any further diversions, even during the wet season, on the San Lorenzo River.

One aspect of supporting the fishery in the San Lorenzo River watershed is supporting summertime baseflows in the tributary streams that provide key rearing habitats for juvenile salmon and steelhead (Alley, 2010). Summertime baseflows are primarily supported by groundwater discharge to streams. These form good rearing habitats because of the relatively cool groundwater supporting the flow and sustaining stream flows and water depth to provide adequate habitat for supporting the juvenile fish. Depletion of groundwater levels may have an adverse effect on these streams by reducing groundwater discharge and summertime baseflows for these streams (Alley, 2010).

4.2.3 Bean Creek

Bean Creek parallels Zayante Creek to the south and east, flowing into Zayante Creek approximately 3,000 feet upstream of the San Lorenzo River confluence. The USGS streamflow gage No. 11160430 on Bean Creek is located approximately 1.2 miles upstream of the confluence of Bean and Zayante Creeks, 100 feet upstream of Mount Hermon Road. The period of record for the gage is from January 1989 through water year 2007, when the gage was discontinued (USGS, 2013). The drainage area above the gage is 9.0 square miles, which is 90% of the total watershed (above its Zayante Creek confluence).

According to Table 4-2, mean annual discharge at Bean Creek is 13.5 cfs (mean of the four periods listed, each of which represents 25% of the water year). This is equivalent to about 9,730 AFY and represents about 8% of the annual average streamflow at the San Lorenzo at Big Trees station. The highest stream flows are typically measured in February. The most rapid decline in stream flow typically occurs from March through May. Upper Bean Creek and its tributaries are typically losing streams that recharge the groundwater. By contrast, in much of the lower watershed where Bean Creek and its larger tributaries have eroded down to the Santa Margarita, streamflow is enhanced by baseflow from the Santa Margarita.

Table 4-2 provides a summary of the seasonal average variation in streamflow in Bean Creek. Flow measurements for Bean Creek are included in Appendix C. The highest measured flow occurs in the winter during January through March with average flows of 37 cfs and a maximum flow of 224 cfs. The lowest flows occur primarily in the summertime with average flow of 2.3 cfs with a range of 3.3 to 1.7 cfs with the minimum daily flow of 0.94 cfs (Balance Hydrologics, 2010).

The Bean Creek watershed contains large areas where the Santa Margarita is exposed at the ground surface where higher initial infiltration rates of precipitation are anticipated before runoff occurs. The low streamflow conditions measured at the USGS gauge are considered to be supported by groundwater discharge to Bean Creek primarily along the lower reaches where the stream flows across the Santa Margarita Sandstone. Downstream of the USGS gauge, Bean Creek flows over the shale and mudstone of the Monterey, but receives contributions to summertime baseflow from springs emanating from the base of the nearby Santa Margarita outcrops.

Conversely, the middle reach of Bean Creek typically goes dry during the summer months, and from various personal accounts has done so since the 1960s (Ricker, pers. comm., 2015). This is attributed to high infiltration in the Santa Margarita in an area where summer groundwater levels are commonly below the bottom of the stream. Further upstream, Bean Creek flows over the Butano Formation where summertime baseflows also appear to be supported by groundwater discharge based on recent data showing high groundwater level in this area of the Butano.

4.2.4 Zayante Creek

The Zayante Creek USGS Gage No. 1160300 was operated during water years 1958 to 1992 to collect background data for a proposed surface-water impoundment in the upper Zayante Watershed (USGS, 2013). It was located 3.5 miles upstream from the confluence of Zayante Creek with San Lorenzo River at the bridge near the Zayante Store. The gage monitored a drainage area of 11.1 square miles, which covers about 60% of the total Zayante Creek Watershed. The Zayante gage measured flow above the confluence with Lompico Creek, which has a drainage area of 3.4 square mile and supplies a substantial portion of the streamflow in Zayante Creek (RAMLIT, 2002). According to Table 4-2, mean annual discharge at Zayante Creek is 25.8 cfs (mean of the four periods listed, each of which represents 25% of the water year). This is equivalent to about 18,800 AFY.

Table 4-2 provides a summary of the seasonal variation in streamflow in Zayante Creek. The highest measured flow occurs in the Fall and Winter during November through March with average flows of 20 to 40 cfs and a maximum flow of 263 cfs. The lowest flows occur primarily in the summertime with average flow of 0.2 cfs with a range of 0.0 to 0.6 cfs (Balance Hydrologics, 2010).

The Zayante Creek watershed contributing to the USGS gauge is primarily outside the SMGB Zayante Creek flows over the San Lorenzo and Zayante Formations outside the SMGB, and the Butano Formation and Lompico Sandstone within the SMGB. The data suggest that these do not contribute significant groundwater discharge to support baseflow upstream of the USGS gauge. Downstream of the USGS gauge, Zayante Creek flows primarily over the Monterey, which contributes little to stream baseflow; however, springs emanating from the base of the nearby Santa Margarita outcrops do support baseflows (Balance Hydrologics, 2010).

4.2.5 Carbonera Creek

Carbonera Creek is south of Bean Creek and is a tributary to Branciforte Creek, which flows into the San Lorenzo River in the City of Santa Cruz. Carbonera Creek USGS Gage No. 11161300 is located 4.1 miles upstream of its confluence with Branciforte Creek and 1.1 miles upstream of Glen Canyon Road. The drainage area to the gage is 3.60 square miles, which is 50% of the total watershed above the confluence with Branciforte Creek. The period of record is from February 1985 through water year 2007, when the gage was discontinued (USGS, 2013).

Table 4-2 provides a summary of the seasonal variation in streamflow in Carbonera Creek. Flow measurements for Carbonera Creek are included in Appendix C. The highest measured flow occurs in the winter during January through March with average flows of 68 cfs and a maximum flow of 946 cfs. The lowest flows occur primarily in the summertime with average flow of 0.9 cfs with a range of 0.0 to 2.6 cfs. The gage was located in a losing reach of Carbonera Creek where the stream transitions from flowing over Santa Cruz Mudstone to Santa Margarita and alluvial stream terrace deposits (Balance Hydrologics, 2010).

The gauge was located in a losing reach of Carbonera Creek where the stream transitions from flowing over Santa Cruz Mudstone to Santa Margarita and alluvial stream terrace deposits. The high maximum flow is considered to represent stormwater flow from the large paved areas within Scotts Valley which are conveyed to Carbonera Creek via storm drains. This flashy nature of has resulted in hydromodification of the stream channel leading to downcutting of the stream of several feet (Balance Hydrologics, 2010).

The gauge did not measure flows from Camp Evers Creek or the unnamed creek that joins Carbonera Creek below Camp Evers which are both characterized as perennial. There is no flow for many days in each year because the flows are either lost before they can be recorded and/or do not occur because of declining groundwater levels (Balance Hydrologics, 2010).

4.2.6 Newell Creek and Loch Lomond

Loch Lomond Reservoir is an impoundment of Newell Creek that was developed by the city of Santa Cruz in the late 1950's (Figure 4-4). The reservoir, constructed in 1960, is a source of water supply for the city of Santa Cruz and currently has a maximum storage capacity of about 8,600 acre feet. Loch Lomond, the only major reservoir in the San Lorenzo River watershed, is about 2.5 miles long with a maximum width of about 1,500 feet. Newell Creek Dam is an earthfill dam, 190 feet high and 750 feet long at the crest with a spillway crest is at elevation 577 feet (Johnson, 2009).

Releases to Newell Creek from the reservoir are made through outlet works on the upstream face of the dam. The lowest outlet is at elevation 470 feet. The elevation of the spillway is 577.5 feet above sea level. The required minimum release to Newell Creek from Loch Lomond is 1 cfs; however, this requirement has been relaxed during the current drought, adding to the need for groundwater baseflows to help maintain habitat. Newell Creek flows into San Lorenzo River 2 miles downstream from Loch Lomond Dam and extends 3 miles upstream of the upper end of the reservoir (McPherson and Harmon, 2000). Water released from Loch Lomond for use by SCWD is conveyed to the Graham Hill WTP through the Newell Creek Pipeline. The water flows by gravity from the reservoir to the Felton Booster Station, approximately 4.3 miles downstream of the dam.

A comparison of the elevations from the 1982 and 1998 surveys, where location of the data points along the 1982 cross sections aligned, indicate that sediment deposition has occurred in the upstream reach of the reservoir. The results also indicate that between 1982 and 1998 storage capacity decreased by 55 acre-feet, which is 0.6% of the 1998 maximum reservoir capacity. Sedimentation rates in Loch Lomond are small relative to its capacity, perhaps because the watershed of the reservoir is maintained primarily in open space. Sedimentation is not expected to constrain the water supply functions of the reservoir for many years to come. The City has commissioned four separate sedimentation surveys of Loch Lomond by USGS, beginning in 1971 (Brown, 1973), followed by a 1982 survey by Fogelman and Johnson (1986), and then a 1998 survey by McPherson and Harmon (2000).

4.3 Groundwater – Surface Water Interactions

Groundwater-surface water interactions play an important role in controlling groundwater conditions in the SMGB. Below is a brief summary on groundwater-surface water interactions based on earlier reports (Todd, 1984, 1998; Johnson 2002, 2009; ETIC 2005, 2006; Balance Hydrologics, 2007, 2010; Kennedy/Jenks, 2011b, 2013a).

4.3.1 Streams

Groundwater–surface water interactions with streams, such as Carbonera and Bean Creeks, are important hydraulic features that influence groundwater levels and flow. Depending on several factors, the groundwater–surface water interaction may result in one or more of the following:

- a stream may recharge the groundwater ("losing reach"),
- the groundwater may discharge to the stream ("gaining reach"),
- stream locations that can vary seasonally between gaining reaches during the spring and losing reaches during the fall, or
- exchange between surface water an groundwater reservoirs within the bed of the stream ("hyporheic flow"), which can have an important influence on nutrient cycling and temperature regulation

Stream reaches flowing over higher permeable geologic units and soils such as the Santa Margarita and Lompico Sandstones will tend to be more interactive with the underlying groundwater aquifers, whereas stream reaches flowing over lower permeable geologic units and soils such as the Santa Cruz Mudstone and Monterey Formation will tend to have minimal interaction with the groundwater aquifers. Spatially variable units such Butano Formation will vary based on local conditions.

Understanding the groundwater-surface water interactions is necessary to demonstrate the degree to which the Conjunctive Use Project can meets its primary goals of increasing the volume of groundwater in aquifer storage and while also increasing the summertime baseflow in streams. Some of the key aspects for understanding the groundwater-surface water interactions in the SMGB include:

- The primary gaining reach in the SMGB is the Lower Bean Creek. This reach is a key discharge area for Santa Margarita groundwater. Lower Bean Creek flows are sustained by groundwater, especially in the summertime.

- Upper Bean Creek and its tributaries, and Carbonera Creek are typically losing streams throughout the year.
- Much of the groundwater discharge from the Santa Margarita is directed towards springs and/or discharge to Bean Creek. This characteristic limits its potential for aquifer storage but increases its benefit for increasing summertime baseflow.
- There is little to no groundwater-surface water interactions with the Lompico in the Scotts Valley area. This characteristic increases its potential for aquifer storage but limits its benefit for increasing summertime baseflow.

Historically, some of the groundwater-surface water interactions were likely different in the Scotts Valley area when groundwater levels in the SMGB were higher. Since Bean Creek generally flows over areas where groundwater levels have remained stable, flows have varied little from historical conditions. There has been concern that declining groundwater levels away from Bean Creek in the Scotts Valley area has led to reduced groundwater discharge to Bean Creek.

Carbonera Creek is underlain along its route in Scotts Valley by the Santa Margarita and Lompico. Also, the Springs Lakes area has been described historically as a cranberry bog that likely represented shallow groundwater levels. During these high groundwater conditions, these areas were likely variable gaining and losing reaches depending on climatic conditions. Lower groundwater levels have also contributed to hydromodification along Carbonera Creek where the creek bed has been eroded deeper into the alluvium (Balance Hydrologics, 2010; ETIC 2005, 2006).

4.3.2 Springs

Springs represent another form of groundwater-surface water interaction where groundwater discharges to the surface. The SMGB contains numerous natural springs and seeps throughout the groundwater basin. In the SMGB, springs typically form at hydraulic low points along the base of the Santa Margarita overlying a lower permeability geologic unit such as the Monterey, Locatelli, or crystalline bedrock. Therefore, spring discharge will tend to remain relatively stable until the groundwater source feeding the spring is reduced.

The Redwood Springs, Ferndell Spring, and Eagle Creek represent large springs that have a history of flow measurements. For Redwood Springs and Ferndell Spring, located on the grounds of Mt. Hermon Conference Center, flows range from 0.33 to 0.17 cfs, respectively during the spring, and from 0.24 to 0.13 cfs during the fall (Kennedy/Jenks, 2013b). Eagle Creek is comprised of multiple springs and seeps in a small watershed that drains into the San Lorenzo River. Flow ranges from 0.66 cfs during the spring to 0.35 cfs during the fall. Flow measurements from these springs are presented in Appendix C. Several more springs exist that have not been measured, such as those along Camp Evers Creek and Dufour Springs; therefore, substantially more discharge by springs occurs than is documented.

Springs also occur at the contact of the Santa Cruz Mudstone and the Purisima. These units are typically found capping topographic highs in the Scotts Valley area. These springs drain precipitation recharge captured by the Purisima. The Purisima is generally unsaturated in the Scotts Valley area so these are small springs that flow during the rainy season that are termed wet-weather springs where it is generally lost to evapotranspiration; therefore, precipitation on the Purisima contributes little to groundwater recharge in the SMGB.

4.4 Stormwater

Stormwater is water that originates during precipitation events. Stormwater that does not soak into the ground becomes surface runoff, which either flows directly into surface waterways or is channeled into storm sewers, which eventually discharge to surface waters. Stormwater is of concern for two main issues related to the volume and timing of runoff water and to potential for contamination. Stormwater can also be a potential water resource that can potentially make urban environments more self-sustaining in terms of water with proper stormwater management. The City of Scotts Valley (2008) has a stormwater drainage system that conveys stormwater from developed areas along Scotts Valley Drive and Mount Hermon Road to Carbonera Creek.

Stormwater runoff in Scotts Valley has increased significantly as a result of increased urbanization and installation of a stormwater drainage system (Balance Hydrologics, 2010). The impervious area in Scotts Valley is approximately 300 acres, with a conservative estimate to account for landscape and unpaved areas of 250 acres. In urbanized areas, the increase in impervious surfaces from parking lots, roads, buildings, and compacted soil limit the ability for rain to infiltrate into the ground. Therefore, urbanized areas generate more runoff than the same areas in undeveloped condition. The reduced percentage of rainfall infiltrating into the soil results in less groundwater recharge. This has potential impacts to both the replenishment of groundwater supplies and the sustainability of stream baseflow in dry weather.

The runoff from the impervious surfaces occurs faster than on undeveloped land which leads to higher peak flows with higher flow velocities. Storm sewers collect runoff from these impervious surfaces and convey it to waterways. Therefore, even small storm events result in increased waterway flows. There is evidence that increased stormwater runoff resulting from urbanization has affected the local streams. Carbonera Creek shows signs of having been impacted by increasing peak stormwater flows from Scotts Valley. Stormwater runoff reaches the creek faster and has a higher and longer duration peak flow that is a result of urbanization. The increased stormwater flows have resulted in increased downcutting and erosion in the creek bed (i.e. hydro-modification) and has also contributed to flooding issues further downstream (Balance Hydrologics, 2010).

Section 5: Hydrogeology

Section 5 summarizes the hydrogeological data and conceptual model for each of the aquifers in the updated SMGB Model. This section summarizes these previous works as relevant to the development of the updated SMGB Model by identifying the major physical features of each of the aquifer in the SMGB.

5.1 Hydrogeological Conceptual Model

The conceptual model expands upon the aquifer characterization. Characterization is the physical description of the geological setting and groundwater conditions. The conceptual model expands upon this by adding an understanding of the hydraulic processes that control the movement of water and solutes through the aquifer and related systems.

5.1.1 Approach

The first step towards developing a sound, defensible numerical model is to ensure that consistency is maintained with the hydrogeological understanding or conceptual model of the basin. The conceptual model describes the geological setting and hydraulic processes for the basin based on a compilation and evaluation of the available data. It serves as the basis for constructing a numerical model. These basic components of the conceptual model necessary to construct a numerical model include the water balance and the aquifer characteristics.

The quality of the numerical model results is highly dependent upon the accuracy of the conceptual understanding of the hydrogeology and the quality and quantity of the available groundwater data. Although a model is a simplification of the natural system, the numerical model must be constructed in a manner that properly represents the key features of the groundwater basin in order to provide accurate and useful simulation results. Because of the complexity of a natural system, assumptions are necessary to define the aquifer properties and boundary conditions required for the numerical model. In support of numerical model development, a range of reasonable values are defined for aquifer properties and the water balance based on measured field data and hydrogeological analysis. Typically, these values are varied within the range prescribed by the conceptual model during calibration by applying the general procedure to define values for a representative elementary volume (REV) as described by Bear and Verruijt (1987).

The basic components of the conceptual model include the flowpath analysis, water balance and aquifer properties. The flowpath analysis describes the character and distribution of the aquifer to define the horizontal and vertical flowpaths of water and solutes through the system. The water balance describes the amount and location where groundwater enters and exits the aquifer. The aquifer properties describe the geologic factors that control the rate of groundwater movement within the aquifer.

5.1.2 Definition of Aquifers

The SMGB is made up of a series of geologic formations that act hydrologically as aquifers and aquitards. An aquifer is defined as a saturated permeable geologic unit that can both store and transmit significant quantities of water under ordinary conditions (Fetter 1994, Freeze and

Cherry, 1979). An aquitard, on the other hand, is defined as a saturated geologic unit that is incapable of transmitting significant quantities of water under ordinary conditions (Fetter 1994, Freeze and Cherry, 1979). However, the term "significant" is a relative term in the definition, so some formations may serve as a local, low producing aquifer, but also regionally act as an aquitard separating two more productive aquifers.

The primary aquifers in the SMGB area are the Santa Margarita, Lompico, and Butano Aquifers. The Santa Margarita and Lompico have long been recognized as the primary aquifers in the SMGB. The Santa Margarita has a long groundwater production history, with several production wells completed within this unit within the Scotts Valley area (Muir 1981). Similarly, the Lompico is currently the primary groundwater producing horizon in the Scotts Valley area, with several large production wells completed in this unit. Prior to the 2005, the role of the Butano Formation in providing water to SVWD had not been fully recognized (ETIC, 2005, 2006) when SVWD Wells #3B and #7A were reinterpreted as being mostly within the Butano Formation (Figure 3-3).

Regionally, the Santa Cruz Mudstone, Monterey and Locatelli act as aquitards that limit the flow of groundwater through the SMGB. However, the Monterey and Locatelli are considered minor aquifers. The sandstone interbeds and the fractured siltstones in the Monterey Formation can locally produce groundwater that is mostly used for small municipal and domestic wells. SVWD Well #9 and the LCWD water supply wells pumps from the Monterey. A few wells in the south of Scotts Valley area are completed within the basal sandstone layer in the Locatelli Formation.

Because of its limited distribution, the Purisima Formation is not a significant water producing unit in the SMGB; however, it is a significant aquifer farther to the southeast in the Soquel Creek area. The Quaternary alluvium located along Carbonera Creek is not considered a significant water producer because of its limited saturated thickness and lateral distribution.

5.2 Previous Studies

The updated SMGB Model relies on incorporating the findings of the previous hydrogeological investigations of the SMGB conceptual model for defining the numerical model. Considerable previous work has been performed characterizing the hydrogeology of the SMGB. Since many of these works build off of one another, later references are typically listed in the text; however, many of the earlier references contain valuable details, so were also reviewed for this study and can provide additional information regarding the hydrogeology of the SMGB for other future projects. Cited references are listed in the References section of this report. The following lists some of the more recent key references available on the hydrogeology of the SMGB used for this study include the following:

- The USGS has conducted numerous regional geological studies of the Santa Cruz Mountains including the SMGB as well as some of the earlier hydrogeology works. Many of these references are cited in Section 3. Some of the USGS's key works include:
    - Santa Margarita Sandstone as a Source of Drinking Water (Muir, 1981).
    - Regional geological studies (Clark *et al*, 1966, 1981, 1989; Brabb *et al,* 1997; and McLaughlin *et al*, 2001, 2004).
- Scotts Valley Water District relies solely on groundwater for their potable water supply, and utilizes groundwater wells completed in the Santa Margarita, Monterey, Lompico and Butano Aquifers. Some of the SVWD's key works include:

- Groundwater Management Plan (Todd Engineers, 1994)
- Annual Groundwater Management Reports (Kennedy/Jenks, 2014, 2013b, 2012b, 2011, 2010,2009, and 2008; ETIC, 2007, 2005, Todd Engineers, 2003b)
- 2006 Groundwater Modeling Study (ETIC, 2006)
- Butano Formation Groundwater Monitoring Project (Kennedy/Jenks, 2013c)
- Hydrogeologic investigation reports (Todd Engineers, 2003a, 1998, 1997a, 1997b, and 1984)

- San Lorenzo Valley Water District uses both surface water and groundwater or their potable water supply and utilizes groundwater wells completed in the Santa Margarita and Lompico Aquifers. Some of the SLVWD's key works include:
  - Quail Hollow hydrogeology (Johnson, 1988, 2001, and 2003)
  - Pasatiempo area hydrogeology (Johnson, 2002)
  - Regional hydrogeology (Johnson, 2009)
- Santa Cruz County has been involved in multiple projects and has personnel familiar with many aspects of SMGB hydrogeology. These include:
  - Conjunctive Use Project (Kennedy/Jenks, 2011b)
  - Mike Cloud, County hydrogeologist, personal communications on multiple aspects of the SMGB hydrogeology and stratigraphy.
- Association of Monterey Bay Area Governments conducted an early study that provided an initial definition of the SMGB.
  - Draft groundwater management plan (Watkins-Johnson, 1993)
- Regulatory compliance reports for operation of local sand quarries.
  - Woodward-Clyde, 1995
  - Weber, Hayes & Associates, 1999
- Environmental remediation investigations have contributed detailed subsurface information especially in the Scotts Valley area associated with the site investigation and remediation activities. These and other reports are available through the SWRCB GeoTracker web site (http://geotracker.waterboards.ca.gov/). Some of the more relevant references include:
  - Watkins-Johnson Superfund Site (R.L. Stollar,1988; Arcadis, 2011, 2012 and 2014)
  - Camp Evers regional MTBE plume (Cambria, 2000)
  - Ben Lomond Landfill (Geosyntec, 2013 and 2004)
  - Scotts Valley Dry Cleaners (Secor, 2007; Stantec, 2009)

The following discussion summarizes the key aspects of the hydrogeology conceptual model used for the development of the updated SMGB Model based on the references listed above.

5.3 Groundwater Data

Development of the hydrogeological conceptual model derived from an analysis of groundwater data. Section 2, 3 and 4 discuss groundwater data related to pumping operations, geology, climate and surface water flow. The following provides a summary of the groundwater level and aquifer test data that are not already discussed in previous sections.

5.3.1 Groundwater Level Data

Groundwater level data which includes groundwater elevation measurements collected by SVWD, other local agencies, private entities, and remediation sites. SVWD maintains a groundwater elevation database of historical groundwater elevations that have been collected over time. A summary table of groundwater level measurement data and locations are provided in Appendix D.

The groundwater elevation database data extends from 1968 to 2013 includes 208 wells; however, the amount of data can be quite variable for each well. For the SMGB Model Update, data from wells completed in the SMGB aquifers from 1985 to 2012 were used. Assignment of the geologic unit for each groundwater elevation location was based on the assessment by the source of the data. This geologic unit assignment was then re-evaluated during the in light of the geologic reinterpretations (see Section 3). Table 5-1 summarizes the amount of data and the distribution of groundwater elevation data by geologic unit.

The locations, aquifer and relative amount of data for the wells where groundwater elevation data are available are shown on Figure 5-1. Information about these wells is provided in Appendix D. Figure 5-2 presents representative hydrographs for each of the SMGB aquifers. These data will be discussed further later in this section.

TABLE 5-1
SMGB GROUNDWATER ELEVATION DATA AVAILABILITY BY AQUIFER FROM 1985 THROUGH 2012

Aquifer	Number of Wells	Number of Measurements
Santa Margarita	102	11,174
Monterey	10	744
Lompico	38	3,810
Butano	2	414
Locatelli	5	202
Total	**196**	**16,344**

5.3.2 Aquifer Test Data

The hydraulic properties of a hydrogeologic unit characterize its ability to store and transmit water. Values of these properties are used in analytical equations and numerical models to estimate the groundwater response to pumping and recharge.

These data can be derived from a number of methods. The most direct method is to collect field measurements during an aquifer test. Aquifer test data provide data on aquifer properties based on measuring the change in groundwater levels in response to changing pumping stresses. A representative summary of published aquifer data in the SMGB has been tabulated in a summary table is provided in Appendix D and an overall summary for aquifer or aquifer subarea is provided in Table 5-2.

Transmissivity (*T*) is the ability of an aquifer to transmit water through its entire saturated thickness (*b*) per unit width of aquifer perpendicular to the hydraulic gradient (Fetter 1994, Freeze and Cherry, 1979). This report uses transmissivity units of square feet per day (ft^2/d) and hydraulic conductivity (K) in feet per day (ft/day). Transmissivity equals the effective *K* of an aquifer multiplied by the aquifer's saturated thickness. Hydraulic conductivity is typically higher horizontally (parallel to the stratigraphy) than vertically (perpendicular to the stratigraphy), as expressed by the ratio K_V/K_H.

An aquifer's capacity to store water depends on the degree to which it is confined or unconfined. Under unconfined conditions, specific yield (*Sy*) is the volume of water that drains by gravity per unit volume of aquifer (Fetter 1994, Freeze and Cherry, 1979). Under confined conditions, storativity (*S*) is the volume of water released per unit area per unit decline in hydraulic head as a function of the compressibility of water and the aquifer matrix. Specific yield and storativity are both expressions of an aquifer's storage coefficient, and are dimensionless. An aquifer with a specific yield of 0.1 (i.e., 10 percent) may have a storativity of 0.0001 or less when fully confined. Under semi-confined conditions, leakage through an overlying (and/or underlying) aquitard results in an apparent storage coefficient of intermediate value (e.g., 0.02 to 0.005).

TABLE 5-2
RANGE OF AQUIFER PROPERTIES BY AQUIFER
BASED ON AVAILABLE AQUIFER TEST RESULTS

Aquifer	Transmissivity	Hydraulic Conductivity	Specific Yield	Storativity
Units	ft^2/d	ft/day	dimensionless	dimensionless
Santa Margarita – Entire SMGB	430 – 7,700	2 – 130	0.02 – 0.25	0.008 – 0.02
Santa Margarita - Quail Hollow/Olympia	430 – 6,200	2 – 50	0.12 – 0.25	0.008 – 0.02
Santa Margarita – Central SMGB	2,000 – 7,700	3 – 130	0.02 – 0.13	--
Santa Margarita – Scotts Valley Area	1,000 – 1,700	12 – 35	0.02 – 0.13	--
Monterey	170 – 1,000	0.05 – 6	0.01 – 0.03	$1e^{-3}$ – $1e^{-5}$
Lompico	500 – 3,200	0.5 – 7	0.02 – 0.07	$1e^{-3}$ – $1e^{-6}$
Butano	100 – 1,070	0.1 – 6		$1e^{-6}$ – $7e^{-4}$

Note: ft2/d – feet squared per day
Ft/day – feet per day

5.4 Conceptual SMGB Water Balance

The water balance describes the volume of water that enters and exits the basin. The difference between inflow and outflow is balanced by the change of groundwater in storage.

5.4.1 Water Balance Relationship

A water balance or water budget is a quantitative statement of the total water gains and losses from the basin over a period of time. The major components of the water balance evaluated for the SMGB can be expressed by the following relationship:

$$\mathbf{P_i + SW_i + Sb_i + RF_i + ER_i = Q_o + SW_o + Sb_o + ET_o \pm \Delta S}$$

where:

P_i	=	Percolation of Precipitation
SW_i	=	Percolation of Surface Water Recharge
Sb_i	=	Subsurface Inflow
RF_i	=	Percolation of Return Flows
ER_i	=	Enhanced Aquifer Recharge
Q_o	=	Groundwater Pumpage
SW_o	=	Groundwater Discharge to Surface Water
Sb_o	=	Subsurface Outflow
ET_o	=	Evapotranspiration
ΔS	=	Change in Groundwater Storage

The water balance is summarized by grouping the various inflow and outflows into four key components. These components include:

- **Precipitation Recharge (P_i) -** includes groundwater recharge from precipitation percolating through soil to the groundwater. The recharge rate varies across the area due to spatial variability in precipitation, soil conditions, geology, and land use. A more detailed discussion of precipitation recharge is provided in Section 6.7.
- **Groundwater-Surface Water Interactions (SW_i and SW_o) -** includes interactions between the aquifer and streams and springs. Streams have more complex interactions with the aquifer. The degree and direction of the exchange between streams and the aquifer can vary according to the relative difference between stream and groundwater levels. A more detailed discussion of groundwater-surface water interactions is provided in Sections 4.2 and 4.3.
- **Subsurface Inflow and Outflow (Sb_i and SW_o) -** includes the subsurface inflow and outflow of groundwater from outside the SMBG. The bounding faults to the SMGB are assumed to sufficiently block so that there is limited subsurface flow. A more detailed discussion of subsurface inflow and outflow is provided in Section 6.6.
- **Return Flows (RF_i) –** account for groundwater recharge derived from applied water at or near the ground surface from irrigation, wastewater disposal, or leaky pipes. A more detailed discussion of return flows is provided in Sections 2.6 and 2.7.
- **Enhanced Aquifer Recharge (ER_i) –** represents additional water beyond the natural recharge that is intentionally applied for the purpose of increasing the volume of groundwater in aquifer storage through an engineered project such as recharge basins, injections wells, enhanced stormwater percolation or other such project.

- **Wells (Q_o) -** includes groundwater pumping from wells that is extracted from the aquifer. The pumping rate for individual municipal wells and certain private wells is input into the model. Pumping from domestic and other wells is estimated based on past usage and/or approximated based on assumed usage. A more detailed discussion of groundwater pumping is provided in Section 2.4 and 2.5.
- **Evapotranspiration (ET_o) –** for the water balance, evapotranspiration is limited to the volume of groundwater removed directly from the saturated aquifer primarily by the uptake of plants. Evapotranspiration of precipitation prior to reaching the aquifer is accounted for elsewhere. A more detailed discussion of evapotranspiration is provided in Section 4.1.3.
- **Change in Groundwater Storage (ΔS) -** is a measure of the volume of groundwater present in the aquifer. The change in groundwater storage measures the increase or decrease in the volume of groundwater in the aquifer resulting from changes in groundwater levels.

5.4.2 General Character

In general terms, groundwater inflow to the SMGB is derived from percolation precipitation, streamflow, return flows, irrigation return flows, and subsurface inflow. Groundwater discharge or outflow from the SMGB is derived from well pumpage, subsurface outflow, stream discharge, and evapotranspiration.

The largest outflow is from groundwater-surface water interactions including discharge to streams and springs. Evapotranspiration is closely related to groundwater-surface water interactions because shallow groundwater affected by evapotranspiration typically occurs near streams and springs. Groundwater pumping generally increased from 1985 through 2001; but has generally decreased since 2001.

Precipitation is the ultimate form of natural groundwater recharge in the basin even though it can enter the aquifer either as direct infiltration through the soil or as infiltration from the creeks. Reductions in groundwater recharge can occur either naturally through reduced precipitation during a drought, or as a result of man-made effects such as urbanization cutting off or intercepting potential groundwater recharge. When the precipitation recharge is reduced, it results in a reduction in either the net outflow of the basin or the amount of water in storage. The latter is generally indicated by lower groundwater levels.

5.4.3 Previous Water Balance Estimates

Previous water balance estimates have been conducted in all or portions of the SMGB over the years. The following provides a summary of the previous work on the SMGB water balance.

Todd Engineers (1985) developed a water balance for the Scotts Valley area of the SMGB for SVWD. The report estimated a total groundwater in storage of 34,276 acre-feet in the Santa Margarita Aquifer, 232,530 acre-feet in the Lompico. The estimated change in groundwater storage from 1988 to 1998 was 3,281 acre-feet (328 AFY) with about 55% of the storage decline in the Santa Margarita Aquifer and 45% from the Lompico. Based on these estimates, the perennial yield of 4,200 AFY was derived for the SMGB. These estimates are now considered to have underestimated the change in groundwater storage. The report includes estimates of historical groundwater pumping and return flow that are included the updated SMGB Model. The report also included discussion on stream baseflows and aquifer properties.

SLVWD has conducted a number of groundwater studies focusing on their groundwater supply wells in the Quail Hollow, Olympia and Pasatiempo areas. The following is a brief summary of the detailed work by Johnson (2001, 2002, 2003, 2005, and 2009) on the water balance for the Santa Margarita Aquifer for SLVWD:

- In the Quail Hollow subarea, estimated total recharge as 3,900 AFY. Outflows include 3,500 AFY discharged to streams and 400 AFY to groundwater pumping. No long-term change in groundwater storage is noted in the Quail Hollow area, but may vary by 2,000 to 3,000 AFY due to year-to-year climatic variations (Johnson, 2001, 2003, 2009).
- In the Olympia subarea, estimated total recharge as 2,000 AFY. Outflows include 1,250 AFY discharged to streams, 570 AFY to groundwater pumping and 200 AFY to subsurface outflow. No long-term change in groundwater storage is noted in the Olympia subarea (Johnson, 2009).
- In the Mission Springs subarea near Bean Creek and its tributaries, estimated total recharge as 900 AFY plus 300 AFY of stream recharge. Outflows include 750 AFY discharged to streams, 150 AFY to groundwater pumping and 300 AFY to subsurface outflow. No long-term change in groundwater storage is noted in the Mission Springs subarea (Johnson, 2009).
- In the Pasatiempo subarea, estimated total recharge as 1,800 AFY. Outflows include 500 AFY discharged to streams and springs, 150 AFY to groundwater pumping and 300 AFY to subsurface outflow. Estimates of groundwater storage loss by Johnson (2002, 2009) suggest a cumulative loss of approximately 10,000 acre-feet in the Santa Margarita and Lompico Aquifers in the SMGB.
- In the Camp Evers subarea, estimated total recharge as 500 AFY and 500 AFY of subsurface inflow. Outflows include 200 AFY discharged to streams and subsurface outflow and 765 AFY to groundwater pumping. Estimated aquifer storage decline is noted as about 500 AFY for a long-term decline of 7,000 acre-feet (Johnson, 2002. 2009).

Water balance estimates were developed using the previous SMGB Model (ETIC, 2006) that were updated annually by SVWD (Kennedy/Jenks, 2013b). Based on the previous SMGB Model, the volume of lost groundwater storage is estimated to be approximately 12,000 acre-feet; however, over 60% of this storage decrease occurred before 1990 (Kennedy/Jenks 2008, 2009a, 2010, 2013). During this time, the annual change in aquifer storage has averaged about 1,080 AFY but varied from an increase of over 600 AFY to decreases of nearly 1,900 AFY. The decrease in groundwater levels have resulted in less groundwater available in aquifer storage for water supply, and may have reduced baseflow to local streams that support important fishery habitat, especially in the summer months.

Historically, the aquifers that have experienced the highest decline in storage are the Lompico and Santa Margarita. The initial large changes in groundwater storage were mostly in the Santa Margarita in the 1980's but the highest changes in the Lompico predominantly occurred during the 1990's to early 2000's. Over the past 10 years (2003 to 2012), aquifer storage has increased in the Santa Margarita and Butano, but decreased in the Lompico.

5.5 Santa Margarita Aquifer

The Santa Margarita Aquifer is the shallowest primary aquifer in the SMGB, so it was developed first by both municipal and domestic water users. Additional discussion of the geology of the Santa Margarita Sandstone is provided in Section 3.2.4. The following discussion provides a summary of the hydrogeological characteristics of the Santa Margarita Aquifer.

5.5.1 Hydrogeology of the Santa Margarita Aquifer

The Santa Margarita Aquifer is composed on the Santa Margarita Sandstone that has widespread surface exposures on the upland areas over a wide area of the portion of the central and southern SMGB (Figures 3-2 and 5-3). The Santa Margarita is described as a "clean sandstone" because of the low content of fine-grained sediments. The Santa Margarita Sandstone is typically composed of 85% to 90% fine-to-medium-grained sand, 7% to 8% silt, and 4% clay (Clark, 1981, USDA 1980). These geologic characteristics make the Santa Margarita a highly permeable aquifer.

The Santa Margarita is underlain by the less permeable Monterey Formation and capped with small remnants of Santa Cruz Mudstone. The Santa Margarita unconformably overlies the Monterey, and has completely eroded away the Monterey in the southeast and southern portions of the basin. The thickness of the Santa Margarita varies across the SMGB. It is thickest along the western side of the SMGB. It thins to and becomes finer grained to the east where it may grades conformably into the Santa Cruz Mudstone lateral (Clark, 1981).

Because of these widespread surface exposures, groundwater in the Santa Margarita is typically under unconfined conditions across the SMGB. In areas in northern Scotts Valley, the Santa Margarita occurs at depths of a few hundred feet and is overlain by the Santa Cruz Mudstone. In these areas, the aquifer is typically under confined conditions.

The Santa Margarita also acts as a key groundwater recharge area where it is exposed at the surface due to the relatively high soil infiltration rates of the sandy soils (USDA, 1980). These areas form significant groundwater recharge locations for both the Santa Margarita and Lompico. North of Scotts Valley, the Santa Cruz Mudstone conformably overlies the Santa Margarita Sandstone. Where the Santa Cruz Mudstone is present, it limits recharge from the precipitation and return flows and acts as an aquitard that limits groundwater flow where saturated.

Groundwater pumping is other major outflow component. Groundwater pumping from the Santa Margarita Aquifer is estimated at 836 acre-feet in 2012. About 75% of that pumping was from the SLVWD Quail Hollow and Olympic wellfields. From 2003 to 2012, groundwater pumping from these two wellfields ranged from 280 to 1,000 AFY accounting for 70% to 80% of total pumping from the Santa Margarita. Production from these wellfields varies inversely with SLVWD's surface water supplies so that in dry years, pumping is higher and conversely, pumping in lower in wet years. The remaining pumping is attributed to domestic, private and environmental remediation. About 60% of total domestic pumping in the SMGB is attributed to the Santa Margarita Aquifer owing to its shallow occurrence and high permeability.

In the 1980's, total groundwater pumping in the Santa Margarita ranged from 1,000 to 1,900 AFY. The increase is primarily attributed to higher industrial water use primarily by the sand quarries, higher environmental remediation pumping, and SLVWD pumping in the

Pasatiempo area that was later shifted to the Lompico. SLVWD Quail Hollow and Olympic wellfields operated within a similar pumping range.

5.5.2 Santa Margarita Aquifer Groundwater Flow

In general, groundwater flow in the Santa Margarita mimics the topography where groundwater flows from areas of higher elevation where the Santa Margarita is exposed at the surface and direct recharge occurs towards areas of lower elevations where groundwater is discharged at springs or creeks. Figure 5-3 shows groundwater elevations and flow directions for the Fall of 2012. The highest groundwater elevations in the Santa Margarita are found in the in the uplands south and northeast of Scotts Valley. The lowest groundwater elevations are found along Bean, Zayante and Newell Creeks, where groundwater discharges into the creek.

Groundwater flow in the Santa Margarita is characterized as “compartmentalized” where groundwater flows from a local recharge area toward a local discharge point. Groundwater recharge is primarily from precipitation falling on Santa Margarita outcrops. The upstream portions of Bean Creek and its tributaries act as recharge areas for the Santa Margarita Aquifer north of Scotts Valley area. This is evident when reaches of these streams intermittently become dry in summer months when all the upstream flow percolates into the underlying sandstone.

The largest outflow is from groundwater-surface water interactions as discharge to streams, springs and evapotranspiration. These natural outflows are controlled by the hydrologic cycle and physical characteristics of precipitation recharge flowing through the Santa Margarita to discharge points along the streams and springs. Bean, Zayante and Newell Creeks are a major discharge point for the Santa Margarita. The primary pumping centers in the Santa Margarita are currently SLVWD’s Quail Hollow and Olympic wellfields in the western portions of the Santa Margarita Aquifer.

Groundwater outflow from the Santa Margarita Aquifer also occurs in the Scotts Valley area where depressed groundwater levels from pumping in the Lompico induce downward groundwater flow where the Santa Margarita and Lompico are in direct contact (Figure 5-3). Percolating precipitation and surface water in this area passes through the Santa Margarita and into the Lompico.

In general, groundwater levels in the Santa Margarita have remained relatively steady since the 1980s (Fig. 5-2); however, declining groundwater levels in the Lompico have caused the Santa Margarita to become unsaturated in the vicinity where the Santa Margarita and Lompico are in direct contact (Figure 5-3). Because of the localized compartmentalization, the Santa Margarita Aquifer is also split into for subareas that can be used to evaluate more refined areas as shown on Figure 5-3. The subareas are defined in this case to evaluate groundwater-surface water interactions along the major stream systems, so the subarea boundaries are not defined along the creeks but either along surface water divides or other convenient boundary away from the streams. The following provides a summary of the groundwater conditions in these four subareas.

5.5.3 Quail Hollow/Olympia Subarea

Quail Hollow/Olympia subarea is an area where the Santa Margarita is exposed at the surface east of the town of Ben Lomond near the center of the SMGB. This subarea is generally defined as the portion of the Love, Newell, Zayante and Lompico Creek watersheds coinciding with the Santa Margarita outcrops. Zayante Creek has nearly eroded through the Santa Margarita leaving only a narrow area of Santa Margarita connecting exposures on the east and west sides of the creek. SLVWD has conducted several in-depth studies of this area (Johnson, 2001, 2003 and 2009) and the following is a brief summary of this work.

Groundwater occurs within the sandstone under unconfined conditions. The folded, eroded, irregular surface of the underlying Monterey forms the aquifer base. The sandstone has been removed by erosion along almost the entire area's perimeter, but is contiguous with permeable alluvial deposits along the San Lorenzo River.

The sandstone forms a small, distinct groundwater basin that provides water for municipal, domestic, and quarry needs, and baseflow to surrounding springs and streams (Johnson, 2001, 2003 and 2009). In general, streams in this area are generally gaining streams where groundwater discharges into the streams. Groundwater discharge also occurs from springs along the margins of the Santa Margarita outcrop area. Land use includes single-family homes with septic tanks; the Quail Hollow and Olympia quarries; the closed Ben Lomond Landfill; and a county park.

The water table mimics the topography as a result of mounded recharge beneath hills and ridges and groundwater discharge to downcut springs and streams. Perennial streams and springs are generally an expression of the water table. Under high water table conditions, the saturated thickness of the sandstone reaches 130 feet thick. During drought conditions, the groundwater surface partially flattens but maintains a similar shape. Groundwater flows toward the center of Quail Hollow from the north and south, toward adjacent streams to the east and west, and toward pumping wells. A groundwater divide separates flow east toward Zayante Creek from flow west toward Newell and Love creeks, the San Lorenzo River, and the District's wells.

Under drought conditions, some groundwater flows west under Newell Creek toward the river. Quail Hollow springs occur where the water table intersects the ground surface. Most area springs occur where the sandstone thickness diminishes toward Zayante Creek, forcing groundwater perched above the Monterey to emerge. During the recent drought cycle, Quail Hollow groundwater storage fluctuated by an estimated 5,000 ac-ft.

Groundwater inflows consist of rainfall and applied-water recharge. High rates of rainfall recharge are expected in areas of exposed Santa Margarita because of its high infiltration capacity and relatively low rates of runoff and evapotranspiration. Johnson (2001, 2003 and 2009) estimated the average rainfall recharge is about 20 inches per year on average. Water also enters the ground from excess landscape irrigation, wastewater leachfields, and quarry pond percolation. Water sources include locally pumped groundwater and water imported from the District's other sources. Applied-water recharge partially offsets reductions in rainfall recharge associated with development.

Outflows include springflow, stream baseflow, and pumping wells. SLVWD operates the Quail Hollow wellfield west of Zayante Creek and Olympia wellfield east of Zayante Creek. SLVWD pumps about 300 AFY on average from its Quail Hollow wells and about 400 AFY from the Olympic wells from 2003 to 2012. The amount of groundwater produced from other wells and springs is uncertain, but is estimated based on anticipated use. Quail Hollow Quarry relies on groundwater once it depletes its supply of captured winter runoff.

Groundwater-surface water interactions play a key role in this area. Newell and Zayante creeks and the San Lorenzo River gain baseflow where they pass along or through Quail Hollow. On average, Johnson (2001, 2003 and 2009) estimated that these three streams each gain roughly 1,000 AFY from groundwater discharge. Other potential groundwater outflows include leakage to the underlying Monterey Formation and phreatophyte evapotranspiration. Alluvium west of Quail Hollow joins the sandstone hydraulically to the San Lorenzo River. Because Zayante Creek cuts through the sandstone, Quail Hollow groundwater is hydraulically separate from the Santa Margarita Sandstone aquifer in the Olympia, Pasatiempo, and Scotts Valley areas.

5.5.4 Bean Creek Subarea

The Bean Creek subarea generally defined as the portion the Santa Margarita Aquifer within the Bean Creek watershed including its several tributaries. This is primarily a rural area with no large municipal wells; therefore, there is limited data or hydrogeologic studies conducted for this subarea. The following is a brief summary of the available information on this area by Johnson (2009), ETIC (2005), and Todd Engineers (1998, 2003).

The highest groundwater elevations are located in the upland areas in the northern part of the subarea (Figure 5-3). Groundwater recharge is primarily derived from precipitation and streambed percolation within the Santa Margarita exposures at the surface in these areas. The presence of the Santa Cruz Mudstone capping the higher elevations limits the amount of precipitation reaching the aquifer.

Groundwater is discharged through springs in the streambed where the streams have cut into the Santa Margarita, to the point that the groundwater elevations are higher than the stream stage. Springs are also located along the sides of the streams where the base of the Santa Margarita is exposed.

Groundwater flow is also directed toward the low groundwater elevations near the confluence of Lockhart Gulch and Ruins Creek with Bean Creek. The area west of Bean Creek shows a much wider spacing of the groundwater elevation contours, indicating a lower groundwater gradient.

Groundwater pumping is limited to domestic pumping as either individual wells or as small water companies serving a relatively small number of customers. Total groundwater pumping in his subarea is estimated to be less than 100 AFY. Available data indicates that groundwater levels have been even relatively stable over time (Figure 5-2), with variations generally ranging from 5 to 10 feet. Similarly, the observed variations in groundwater levels correspond to the climate pattern.

5.5.5 Scotts Valley Subarea

The Scotts Valley subarea is an area that includes both Santa Margarita outcrops and where it occurs at depth below the Santa Cruz Mudstone. This area consists of the Carbonera Creek watershed and includes most of the City of Scotts Valley. There have been several investigations of the Santa Margarita in the Scotts Valley area by both SVWD by Kennedy/Jenks (2008, 2010, 2011b, 2012b, 2013b and 2014); ETIC (2005 and 2006); and Todd Engineers (1994, 1998, 2003) and as part of the large environmental remediation projects in this area by Arcadis (2011, 2012, 2014), Stantec (2009), Secor (2007), Cambria (2000) and Stoller (1988). The following is a brief summary of the available information on this area.

As part of the revised geological interpretations in this area, the Santa Margarita is considered to be about 30 to 50 feet thick over much of the Scotts Valley area, but it thickens to the north and west towards the Bean Creek and Pasatiempo subareas. Figure 5-4 shows a detailed cross section illustrating the thinner interpretation of the Santa Margarita. The lower section is now attributed mostly to the Lompico, but also to sand interbeds in the lower Monterey.

In general, the highest groundwater elevations are located in the upland areas in the northeast of the Scotts Valley (Figure 5-3). Groundwater recharge is primarily derived from precipitation and streambed percolation within the Santa Margarita exposures at the surface in these areas. However much of the Santa Margarita Aquifer is overlain by the Santa Cruz Mudstone, thereby limits the amount of precipitation and return flows reaching the aquifer. Groundwater recharge also occurs along Carbonera Creek in Scotts Valley where the Carbonera Creek flows over the Santa Margarita or the alluvium directly overlie the Santa Margarita.

Groundwater flow is generally towards the south and west towards Bean Creek. Groundwater outflow is primarily as subsurface flow to adjoining subareas. The lowest groundwater elevations are found along the border with the Bean Creek subarea. Bean Creek is the primary groundwater discharge for groundwater in the Scotts Valley subarea (Figures 5-3).

Groundwater pumping in the Santa Margarita is limited to environmental remediation and domestic pumping in this subarea with the majority of the municipal and other pumping coming from deeper units. The revised geologic interpretation also reassigned wells previously considered to be completed in the Santa Margarita into deeper aquifers. Total groundwater pumping directly from the Santa Margarita is estimated to be less than 50 AFY in this subarea.

Over most of the Scotts Valley area, the Santa Margarita is underlain by the Monterey. However, in a portion of the Scotts Valley subarea, groundwater flow between the Lompico and Santa Margarita Aquifers occurs through a “window” where the Monterey Formation is absent (Figure 3-4). The window is an area where the Santa Margarita is underlain by the Lompico due to erosion prior to the deposition of the Santa Margarita completely removing the Monterey along the southern SMGB margin. North of this “window”, the intervening Monterey Formation effectively eliminated groundwater flow between the Lompico and Santa Margarita Aquifers. To the south of this “window”, the Lompico is absent and the Santa Margarita is underlain by the crystalline bedrock or the Locatelli Formation (Figure 3-4). Groundwater levels in the Santa Margarita tend to remain more stable in areas farther away from the “window” with the underlying Lompico.

Groundwater flowing from Carbonera Creek area south of the “window” flows downward as a result of the lowered groundwater levels in the Lompico, causing much of the Santa Margarita to be unsaturated in this area. Other factors that may contribute to these lower groundwater levels include paving of much of the area underlain by alluvium, which has cut off groundwater recharge from precipitation, and downcutting of Carbonera Creek due to higher stormwater flow directed there due to urbanization and/or changes in climate.

A detailed characterization of the perched zone was conducted at the Watkins-Johnson site (R.L. Stollar, 1988) which found that the perched zone was developed above a thin, moderately-cemented conglomerate within the Santa Margarita. The perched zone was noted as having holes that allowed for leakage between the perched zone and the regional Santa Margarita aquifer. At Watkins-Johnson, groundwater elevations are about 25 feet higher in the perched zone. The perched zone does not appear to have a significant impact on the groundwater supply, but it is locally important in influencing transport of contaminant plumes.

Data for OB-3 show that groundwater elevations declined about 20 feet in response to the pumping associated with the groundwater remediation at Watkins-Johnson (Figure 5-2).

Groundwater elevations increased by 8 to 10 feet by 2012, thereby recovering nearly 50% of the initial groundwater decline. Groundwater elevations at Watkins-Johnson show little to no change due to the declining groundwater levels in the Lompico.

5.5.6 Pasatiempo Subarea

The Pasatiempo subarea is generally defined as the portion the Santa Margarita Aquifer located south of Bean Creek and west of Mount Hermon Road and includes the Hanson Quarry site. There have been several investigations of the Santa Margarita in the Scotts Valley area for both SLVWD (Johnson, 2002, 2009) and SVWD by Kennedy/Jenks (2008, 2010, 2011b, 2012b, 2013b and 2014); ETIC (2005 and 2006); and Todd Engineers (1994, 1998, 2003). The following is a brief summary of the available information on this area.

The Santa Margarita in this area is several hundred feet thick and was extensively quarried until recently. The thickest sections are within the structural trough that extends north along the top of the Monterey Formation (Johnson 2002, 2009). The saturated sandstone is as much as 100 feet thick within this trough, making it an effective collector of recharge from across a large portion of the Pasatiempo subarea, where the saturated thickness is generally less than 50 ft. Johnson (2009) estimated volume of groundwater storage in the Pasatiempo Santa Margarita is less than 3,000 acre-feet.

The highest groundwater elevations occur south and southwest of Scotts Valley where the Santa Margarita caps these upland areas. Groundwater recharge is primarily from precipitation percolating into the sandy soil. Groundwater discharge occurs at numerous springs along the outcrop areas bordering Bean, Eagle and Camp Evers Creek. The largest of the include Ferndell, Redwood and Eagle Springs. Ferndell Spring discharges 20 to 150 gpm, Redwood Spring discharges 10 to 80 gpm, and Eagle Springs discharges 100 to 800 gpm. There are no measurements available for the numerous Camp Evers springs but these are likely in a similar range. The water discharged by these springs is sourced from the upland area adjacent to the springs (Figures 5-3).

Outflows primarily include springs and pumping wells. SLVWD operates the Pasatiempo wellfield west of Scotts Valley. Former SLVWD wells Pasatiempo #1 through #5 all produced at least partially from the Santa Margarita; however, SLVWD no longer produces from this aquifer because declining groundwater levels and elevated nitrates that led to a shifting of production into the underlying Lompico. SLVWD's pumping ranged from 200 to 260 AFY in the 1980s and early 1990's.

Other pumping includes landscape irrigation and pond maintenance by the Spring Lakes and Vista del Lago communities, and pumping for industrial uses at the Hanson Quarry. Similarly, pumping from the Santa Margarita was highest in the 1980s but then was replaced by pumping from wells in the Lompico. Combined pumping from Spring Lakes and Vista del Lago ranged from 150 to 200 AFY in the 1980s and early 1990's, and at Hanson Quarry pumping rates ranged from 250 to 350 AFY. However, several of these wells were completed across both the Santa Margarita and Lompico making it difficult to isolate the pumping from the Santa Margarita.

The variations in groundwater elevations of approximately 10 to 20 feet over this time show a pattern that more closely corresponds to the 1986 to 1994 drought period. This is followed by a recovery in groundwater levels during the higher rainfall years since WY1995. However, a portion of the Santa Margarita is directly underlain by the Lompico from the erosional "window" where the Monterey Formation is absent (Figure 5-3). Similar to the Scotts Valley subarea, groundwater flow from areas north of the “window” percolate into the underlying Lompico. Portions of the Santa Margarita in the vicinity of the “window” are unsaturated due to declining groundwater levels in the Lompico.

5.5.7 Santa Margarita Aquifer Properties

A review of past aquifer tests in the Pasatiempo and Scotts Valley area (Johnson, 2001), in conjunction with the recent reinterpretation of the hydrostratigraphy, indicates that few purely Santa Margarita aquifer tests have been conducted in the study area. Appendix D provides a representative summary of many of the aquifer tests conducted in the Santa Margarita.

Aquifer properties for the Santa Margarita in the SMGB are generally high but have a wide range. Transmissivities range over an order of magnitude from about 400 to 8,000 ft^2/d and specific yields of 0.02 to 0.18 (Table 5-2). Todd Engineers used uniform hydraulic conductivity of 5.3 ft/day and an assumed specific yield of 0.12 in early assessment of the Santa Margarita near Scotts Valley (Todd, 1997).

For the Quail Hollow/Olympia subarea, Johnson (2001) estimated hydraulic conductivities ranging from 2 to 40 ft/day, specific yield of 0.12 to 0.25, and storativity from 0.008 to 0.02. Johnson (2001) estimated hydraulic conductivities ranging from 6 to 16 ft/day in the Quail Hollow area. Johnson (2003) developed a model for the Quail Hollow area that used hydraulic conductivities ranging from 2.5 to 6.25 ft/day. For the Ben Lomond Landfill, Johnson (2001) reported data from earlier reports showing hydraulic conductivities ranging from 1.6 to 50 ft/day. Johnson (2001) analysis of aquifer tests at SLVWD's Olympia wellfield indicated hydraulic conductivities of 16 to 34 ft/day and specific yields of 0.17 to 0.25. The lower permeability of the sandstone near Quail Hollow is consistent with the interpreted paleo-depositional environment (Phillips, 1981). The ratio of vertical to horizontal hydraulic conductivities within the Santa Margarita ranged from 0.1 to 1 and average 0.3 to 0.8 (Johnson, 2001), which is consistent with the Santa Margarita being a clean sandstone.

The highest aquifer properties are noted at the Watkins-Johnson contaminant site south of Bean Creek. Estimates of hydraulic conductivity ranged from approximately 100 to 140 ft/day and estimates of specific yield varied from 0.02 to 0.18 based on several aquifer tests of the Santa Margarita (R.L. Stollar,1988).

5.6 Monterey Aquifer/Aquitard

The Monterey Formation primarily serves as a regional aquitard that separates the Santa Margarita and Lompico Aquifers. However, sandstone interbeds and the fractured siltstones in the Monterey can locally produce groundwater for small municipal and domestic wells. Additional discussion of the geology of the Monterey Formation is provided in Section 3.2.4. The following discussion provides a summary of the hydrogeological characteristics of the Monterey Aquifer/Aquitard.

5.6.1 Hydrogeology of the Monterey Aquifer/Aquitard

The Monterey Formation is primarily composed of mudstone, shale, and siltstone that represent a gradational change from the underlying Lompico Sandstone. Because of this conformable relationship, the lower Monterey also contains several sandstone interbeds in its lower sections. The thickness of the Monterey Formation varies widely across the area as a result of geologic deformation and erosion. The upper surface of the Monterey Formation has been eroded, and the Monterey Formation is missing along the southern and eastern margins of the groundwater basin. The Monterey Formation thickens towards the center of the basin to over 1,000 feet thick. Figure 5-5 shows the lateral extent of the Monterey.

Assumed rates of rainfall recharge to the Monterey range 1 to 3 inches per year (Johnson, 2001, 2009). Year-to-year variations in recharge are estimated from assumed relationships between rainfall, storm runoff, and evapotranspiration. Spatial variations in recharge are estimated from topography and land use.

In the southern Scotts Valley area, some of these sandstone interbeds are quite prominent that they have been mistaken for the Santa Margarita or Lompico in the past. Figure 5-6 shows two conceptual cross sections that illustrate the before and after geologic interpretations. Earlier interpretations had placed SVWD Well #9 and other similar wells in this area as Santa Margarita. However, their groundwater level histories were not similar to other Santa Margarita wells, but more closely matched the trends in the Lompico. Recent drilling for the Watkins-Johnson contaminant site provided new, detailed geologic information in this area (Arcadis, 2011, 2012, 2014). These data found Monterey shales at much higher elevations than had been recognized earlier. This led to a reinterpretation of SVWD Well #9 being completed in sandstone interbeds in the lower Monterey. The area along Mount Hermon Road is now interpreted to have a thinner Santa Margarita overlying the lower Monterey and Lompico. This reinterpretation helps to reconcile groundwater levels with the geologic interpretation.

Where present, the intervening Monterey Formation forms a significant regional aquitard, or confining unit, that significantly limits groundwater movement between the Santa Margarita and the Lompico. The Monterey is absent due to erosion prior to the deposition of the Santa Margarita that allows for the direct contact between the Santa Margarita and Lompico. In an area roughly defined as along Scotts Valley Drive, the Monterey is absent. In this area, the Santa Margarita directly overlies the Lompico, and this geologic configuration allows groundwater flow to occur between the Santa Margarita and Lompico. As discussed above, this relationship is important in understanding the groundwater interactions between these two primary aquifers.

The Monterey also acts as a local aquifer. The sandstone interbeds and the fractured siltstones in the Monterey Formation can locally produce can provide sufficient water for small municipal, industrial and domestic wells. The SVWD Well #9 is currently producing from the lower well screen that is completed within the Monterey Formation, and the LCWD has supplemental groundwater wells that are completed in the Monterey. Because of the widespread surface exposures, many domestic wells also produce from the Monterey.

Groundwater pumping from the Santa Margarita was estimated at 311 acre-feet in WY2004, up from 284 acre-feet in WY2003. Only a minor portion of the WY2004 pumping was for water supply, as both the water supply wells, SVWD Well #9 and Mañana Woods #2, also get a significant portion of their production from deeper zones. Over 50% of this production was for environmental remediation of contaminant plumes. The remainder is for irrigation and landscaping purposes by private users. The Santa Margarita and Monterey Aquifers account for only about 2% of the total production by SVWD.

Only a few wells have groundwater level data, and those are clustered around SVWD Well #9 so that a regional groundwater elevation map is not possible. Hydrographs on Figure 5-2 show that there are multiple groundwater levels even in this localized area. This is consistent with the interpretation of the Monterey as predominantly a regional aquitard that contains sandstone interbeds. These interbeds are not necessarily hydraulically interconnected, so represent the groundwater levels for their recharge area which may be at some distance from the location of the well. Therefore, it is likely that this pattern occurs throughout the region.

The lower Monterey, however, as represented by SVWD Well #9 does show a strong correlation with observed trends in the Lompico suggesting the interbeds intersected by this well have some hydraulic connection with the Lompico. Groundwater elevations have declined from about 490 feet above mean sea level (amsl) in 1983 to a low of 315 feet amsl in 1999. This steady decline in groundwater elevations averaging nearly 11 feet per year occurred during this period. A slight rise in groundwater elevations occurred from 1999 to 2002. Since 2002, the groundwater levels have remained relatively constant in SVWD Well #9.

5.6.2 Monterey Aquifer Properties

Few tests have been conducted on wells screened solely in the Monterey Formation. Analysis of SVWD's Plum Valley well site estimated a transmissivity of 174 ft^2/d for a 270-foot interval of Monterey Formation, suggesting a hydraulic conductivity of approximately 0.6 ft/day (Todd Engineers, 1984). Watkins-Johnson Environmental (1993) assumed transmissivities of 50 to 400 ft^2/d for the Monterey Formation, a specific yield of 0.02, and a storativity of 0.002. In the revised model, Todd Engineers (1997) assumed a hydraulic conductivity of 0.07 ft/day. Johnson (2002) reported aquifer property for the Monterey based on a review of earlier reports as follows:

- Hydraulic Conductivity ranging from 0.05 to 1 ft/day.
- Storativity ranging from 0.00001 to 0.005
- Specific Yield ranging from 0.01 to 0.03

5.7 Lompico Aquifer

The Lompico Aquifer is the primary water producing aquifer in the SMGB that provides a large percentage of the municipal water supply especially in the Scotts Valley area. Additional discussion of the geology of the Lompico Sandstone is provided in Section 3.2.6. There are several investigations of the Lompico for SVWD by Kennedy/Jenks (2008, 2010, 2011b, 2012b, 2013b and 2014); ETIC (2005 and 2006); and Todd Engineers (1994, 1998, 2003), for SLVWD (Johnson, 2002, 2009) and for the Camp Evers MTBE environmental remediation project Cambria (2000). The following discussion provides a summary of the hydrogeological characteristics of the Lompico Aquifer.

5.7.1 Hydrogeology of the Lompico Aquifer

The Lompico has a relatively uniform sandstone thickness but does appear to become slightly more finer-grained and thinner to the north and east across the SMGB. The lower third of the unit consists of thick beds of light-gray, medium-grained sandstone. The upper two-thirds of the unit are composed of massive yellowish-gray, fine-grained sandstone beds (Clark 1981). The Lompico is typically 300 to 400 feet thick (Clark, 1981, Brabb et al, 1997). The Lompico is found throughout most of the basin; however, the unit outcrops along the basin margins (Figure 3-2).

In the Scotts Valley area, the Lompico is primarily recharged from the Santa Margarita in the vicinity of the “window”. The limited amount of surface exposure of the Lompico within the groundwater basin significantly limits the potential for groundwater recharge from surface sources such as precipitation and streambed percolation. The overlying low-permeability Monterey Formation also significantly limits groundwater recharge by vertical flow from overlying units. Few natural points of groundwater discharge are noted for the Lompico in the SMGB. Currently, groundwater outflow is primarily through groundwater pumping wells.

Groundwater flow in the Lompico is primarily controlled by the large volume of groundwater pumping in this aquifer. Currently, groundwater elevations show a depression along the eastern margin of the basin at these pumping centers (Figure 5-7). The highest groundwater elevations are found both to the north and south of the main pumping centers. The higher groundwater elevations to the south are interpreted to represent recharge from the Santa Margarita. To the north, the higher groundwater elevations are interpreted to represent groundwater flow from the center of the basin. Groundwater flow is primarily through the Lompico from the north towards the pumping centers. The groundwater gradient is also generally on the order of 0.02 to 0.03; however, these gradients can steepen in the vicinity of large wells.

As noted above, wells are generally limited to the southern margin of the basin. The general pattern is a broad area of depressed groundwater levels forming a trough along the southern margin of the basin. The individual pumping wells are shown as isolated areas of increased drawdown. To the north, the higher groundwater elevations are interpreted to represent groundwater flow from the center of the basin towards the pumping centers in the south.

In the Pasatiempo area, groundwater flow within the Lompico is predominantly toward SLVWD and MHA production wells and east towards Scotts Valley (Johnson 2002, 2009). Groundwater levels in SLVWD's two SLVWD’s active Pasatiempo wells have declined about 130 feet since 1991, an average decline of about 8 feet per year (Figure 5-2). The Lompico Aquifer remains fully saturated at Pasatiempo #6, whereas at Pasatiempo #7 the Lompico’s saturated thickness appears to have diminished. The lowered groundwater levels result from reduced leakage from Santa Margarita and combined groundwater production of SLVWD, MHA, SVWD and other private pumpers.

The Lompico is a key groundwater aquifer for the area, but that has led to significant and widespread groundwater level declines. In Scotts Valley area, groundwater elevations have declined by 150 to 250 feet compared to the historic high levels. Figure 5-8 provides a cross section through Scotts Valley illustrating the relative changes in groundwater levels over time. Most of the groundwater pumping in the Scotts Valley area is from the Lompico (approximately 62% of SVWD’s groundwater production in WY2012). Groundwater levels in the Lompico have declined by 150 to 250 feet relative to pre-pumping groundwater levels. Groundwater pumping from the Lompico was estimated at 2,086 acre-feet in WY2004, down from 2,303 acre-feet in WY2003. Nearly all, over 97%, of the WY2004 Lompico production pumping was for water supply. Only a minor amount was for irrigation and landscaping purposes by private users.

Groundwater pumping from the Lompico was estimated at 2,086 acre-feet in WY2004, down from 2,303 acre-feet in WY2003. Pumping rates for large production wells in the Lompico typically range between 200 and 400 gpm.

5.7.2 Lompico Aquifer Properties

Various aquifer property analyses were conducted on data collected in 2012 and 2013 (Kennedy/Jenks, 2013c). The results of these analyses found a range of aquifer properties. These reflect differing conditions in the aquifer but also differences in test conditions and methods. Below is a summary of the aquifer property analyses for the Lompico

- Transmissivity – Two measurements ranging from 7,000 to 1,500 ft^2/d.
- Hydraulic Conductivity – Two measurements ranging from 4.1 to 17.3 ft/day.
- Storage Coefficient – Two measurements ranging from 0.00068 to 0.0017

Johnson (2002) analyzed 14 aquifer tests conducted on wells now interpreted to draw primarily from the Lompico that is summarized as follows:

- Transmissivity ranging from 2,000 to 2,400 ft^2/day.
- Hydraulic Conductivity ranging from 3 to 7 ft/dat.
- Storativity of 0.0005 for confined and 0.001 to 0.01 for semi-confined conditions
- Specific Yield ranging from 0.04 to 0.07

5.7.3 Lompico Groundwater Levels

As seen on the hydrographs, groundwater levels have declined in the Scotts Valley area – Camp Evers subarea. Groundwater elevations in SVWD Well #10 have declined from about 490 feet amsl in 1985 to a low of 350 feet amsl in 1995 (Figure 5-2). This steady decline in groundwater elevations averaged nearly 13 feet per year during this period. From 1995 to 2004, groundwater elevations had declined to about 320 feet amsl for an average three foot per year decline since 1995 (Figure 5-2). Declines in groundwater levels in other Lompico wells in the Scotts Valley area have ranged from 100 to 200 feet over the past 20 years (Figure 5-2). As shown on Figure 5-2, groundwater levels in Spring Lakes #4 and Pasatiempo MW-1 wells have shown similar decreases to those observed in the Lompico.

The groundwater elevations for Wells #11 Monitor have declined from a high of about 450 feet amsl in 1985 to a low of 300 feet amsl in 1994 (Figure 5-2). This steady decline in groundwater elevations averaged nearly 15 feet per year during this period. By 1999, groundwater elevations increased to about 360 feet amsl for an average 12 foot per year rise since 1995 (Figure 5-2). This rise is primarily the result of decreased pumping at SVWD's El Pueblo well field. Historical groundwater elevation data indicate that groundwater elevations in the El Pueblo Yard area were about 485 feet amsl in 1968. These data also show that groundwater elevations recovered from 385 to 430 feet amsl during 1982 through 1985 in response to reduced pumping.

5.8 Butano Aquifer

The Butano Aquifer is a significant water producing aquifer in the SMGB for SVWD, but is geologically complex and typically occurs at depths greater than 1,000 feet over much of the SMGB. Additional discussion of the geology of the Butano Formation is provided in Section 3.2.7. The following discussion provides a summary of the hydrogeological characteristics of the Butano Aquifer.

5.8.1 Hydrogeology of the Butano Formation

The geologic understanding of the Butano Aquifer is derived primarily from regional studies by the USGS by Clark (1966, 1981), Brabb et al (1997); and McLaughlin et al (2001). Municipal groundwater pumping from the Butano is conducted only by SVWD. Earlier reports (Todd Engineers, 1994, 2003a, 2003b) had attributed this pumping to the Lompico Aquifer; however, the ETIC (2006) report reinterpreted the geology of this deep portion of the SMGB based on correlations with the USGS regional stratigraphy and demonstrated that this deep pumping should be attributed to the Butano rather than the Lompico.

The Butano is a thick sedimentary unit that consists largely of sandstone with interbeds of mudstone, shale, and siltstone as described in Section 3. The Butano forms a wedge along the northern portion of the SMGB and has been mapped in surface outcrop along the northern SMGB margin (Figure 5-9). Specifically, the Butano consists of three members: the lower sandstone member, the middle siltstone member, and the upper sandstone member (Clark, 1981). The Butano has a total stratigraphic thickness of up to 5,000 feet; however, due to structural deformation and erosional history, the thickness of the Butano ranges from several hundred to a thousand feet thick (Figure 5-10).

Groundwater recharge to the Butano is primarily from infiltration of precipitation and streamflow in areas where the Butano is exposed at the surface. The Butano has a limited outcrop area at the surface situated along the northern fringe of the SMGB north of Scotts Valley. The limited surface exposures and overlying fine-grained layers limit the potential for surface recharge to the Butano. Groundwater recharge is primarily derived from infiltration of precipitation and from the streams that flow over the Butano Formation in these exposure areas north of Scotts Valley. Correspondingly, the Butano Aquifer appears to have few natural discharge points, so pumping is currently largest groundwater outflow from the Butano (ETIC, 2006). It is unclear if there is any subsurface inflow or outflows from the Butano Aquifer based on available data.

The production history of SVWD Wells #3B and #7A indicates that the Butano Formation is capable of producing significant volumes of groundwater. Annual groundwater production from the Butano is estimated to range from 500 to 1,000 acre-feet per year. Groundwater level declines in the Butano are not as well understood as those in the Lompico and the Santa Margarita due to a lack of monitoring wells completed entirely within the Butano. Static groundwater levels fluctuate about 100 feet seasonally due to pumping, but overall groundwater levels have maintained a relatively stable trend. This suggests that the Butano is actively recharged, allowing groundwater levels to recover each year in spite of the high volume of groundwater produced by these wells.

Groundwater pumping from the Butano has declined from over 700 AFY from WY2002 through WY2007 to an estimated 515 AFY in WY2012. Groundwater levels have increased by over 50 feet in SVWD #7A and about 40 feet in SVWD #3B since pumping began to decline in WY2007 (Figures 5-2). These trends in groundwater levels suggest that the Butano is a large aquifer system that is actively recharged, allowing water levels to recover each year in spite of the high volume of groundwater produced by these wells. This is in contrast to the Lompico, which is slow to recover.

5.8.2 Butano Groundwater Flow

In 2013, SVWD completed the "*Butano Formation Groundwater Monitoring Project*" (Kennedy/Jenks, 2013c) that included installation of two deep monitoring wells, aquifer tests and geologic characterization of the Butano Aquifer provides a key reference for the hydrogeology of the Butano. Tracking of groundwater levels and pumping are also tracked by the SVWD Annual Groundwater Management Reports (ETIC, 2005; Kennedy/Jenks, 2014, 2013b, 2012b, 2010, 2008). The following provides a summary of the information from these reports relevant to the SMGB Model update.

A groundwater elevation map was developed for the Butano using the limited number of wells completed within the Butano and shown in Figure 5-9. A well-developed drawdown cone is shown with groundwater elevations in the actively pumping SVWD Well #7A and SVWD Well #3B. Groundwater flow is interpreted to be mostly north to south towards the primary pumping center.

Groundwater elevation contours are interpreted to curve around to the east towards Blackburn Gulch where the Butano is partially exposed or covered with a thin layer of Lompico at elevations ranging from 600 to 800 feet along the creek. It is assumed that groundwater conditions in Blackburn Gulch are not artesian so groundwater levels are below the ground surface elevation at creek level. Groundwater flow is assumed to be more northeast to southwest along Blackburn Gulch due to the curvature of the contours to account for the ground surface elevations in Blackburn Gulch.

The hydraulic gradient was about 0.075 ft/ft between Stonewood and Canham Wells, but about 0.026 ft/ft between the Canham Well and SVWD #3B. This is a considered a steep groundwater gradient that suggests some limitation to groundwater flow. However, from the available data it is unclear what that limitation may be. It is interpreted to represent the effect of stratification within the geologically complex Butano Formation. This likely represents that the Stonewood Well is located at a higher stratigraphic level that is not in full hydraulic communication with the other wells.

5.8.3 Butano Groundwater Levels

Groundwater levels fluctuate seasonally due to pumping but overall groundwater levels have maintained a relatively stable year-to-year trend (Figure 5-2). These data suggest that the Butano is actively recharged, allowing groundwater levels to recover each year in spite of the high volume of groundwater produced by these wells. Since WY1996, static groundwater levels at Wells #3B and #7A have fluctuated seasonally within an elevation range of 200 to 300 feet msl, but have generally maintained a relatively stable trend. The response of groundwater levels to pumping in the Butano is not as well understood due to a lack of monitoring wells completed solely within the Butano (Kennedy/Jenks, 2008, 2009a, 2010, 2011b). Two deep monitoring wells were completed in the Butano in 2012 (Kennedy/Jenks, 2013c) that provide additional spatial groundwater elevation data.

Figure 5-10 is a hydrogeologic cross section that shows a relative difference in groundwater levels in the Butano from 1993 and 2008. Historically, the initial groundwater elevations for SVWD Well #7A were in the range of 430 feet msl in 1993 prior to pumping (Figure 5-2). From WY1993 to WY1995, groundwater levels in SVWD Well #7A declined nearly 200 feet relative to pre-pumping groundwater levels. However, since SVWD Well #7A is completed in both the Lompico and Butano it is unclear whether this drop in groundwater levels is reflective of conditions in the Butano or of observed decreases in the Lompico. It is unclear what the hydrogeologic relationship between the Lompico and the Butano is; however, it is thought that hydraulic communication between the two units is limited (ETIC, 2006).

Groundwater production from the Butano is primarily from SVWD Wells #3B and #7A, which have total depths of 1,740 and 1,680 feet bgs. Annual groundwater production from these wells typically ranges from 500 to 1,000 acre-feet per year. Based on the previous work done for the District (ETIC, 2006), the wells are screened across both the Lompico and Butano; however, most of the production is thought to be derived from the Butano.

SVWD #3B, #7A and #15 are considered to be screened across both the Lompico and Butano (Kennedy/Jenks, 2013c); however, measured groundwater elevations for SVWD #3B and #7A are considered representative of the Butano because a high percentage of the total screened interval is within the Butano. On the other hand, SVWD #15 has a shorter screened interval and the percentage of the screened interval in the Butano and Lompico is about equal. Therefore, the groundwater levels measured in SVWD #15 represent a composite of Lompico and Butano conditions, thus making the absolute measured groundwater elevation not representative of either the Lompico or Butano for use in groundwater elevation maps. However, as discussed above, the relative change in groundwater levels in SVWD #15 are considered to be generally representative of conditions in the Butano. Prior to the installation of the two monitoring wells in 2012, there were not sufficient data locations to attempt a groundwater elevation map. The locations of the these wells were selected with the intent of providing sufficient data to develop a groundwater elevation map even with only four wells.

5.8.4 Butano Aquifer Properties

Various aquifer property analyses were conducted on data collected in 2012 and 2013 (Kennedy/Jenks, 2013c). The results of these analyses found a range of aquifer properties. These reflect differing conditions in the aquifer but also differences in test conditions and methods. Below is a summary of the aquifer property analyses:

Aquifer Property Results Summary for the Butano:

- Transmissivity – Four measurements ranging from 100 to 850 ft^2/d.
- Hydraulic Conductivity – Six estimates based on four tests but using different thickness assumptions range from 0.1 to 6.0 ft/day.
- Storage Coefficient – Two measurements ranging from 0.000001 to 0.0007.

5.9 Locatelli Aquifer/Aquitard

The Locatelli Formation primarily serves as a local aquitard in the western Scotts Valley area; however, the basal sandstone layer can locally produce groundwater for domestic wells so it also acts as a minor aquifer. Additional discussion of the geology of the Locatelli Formation is provided in Section 3.2.8. The following is a summary of available information on the Locatelli from Johnson (2002, 2009) and ETIC (2005, 2006).

The Locatelli Formation is characteristically a gray, sandy siltstone with a basal sandstone bed typically found at the base of the unit. The Locatelli Formation lies nonconformably upon the crystalline basement rock. Within the study area, the Locatelli Formation is found only in the South Scotts Valley area where it outcrops in the hillside along Eagle Creek and the San Lorenzo River (Figure 5-11).

As mapped, it directly underlies the Lompico from the southwestern slopes of the Pasatiempo area eastward Scotts Valley. The eastern extent is considered to be near the intersection of Scotts Valley Drive and Mount Hermon Road in Scotts Valley. This indicates the complete absence of Butano beneath the southern limb of the Scotts Valley syncline in this area. Several wells in southern Scotts Valley have screened intervals at these depths. In north Scotts Valley, the Locatelli Formation has been inferred beneath about 600 feet of Butano Sandstone (ETIC, 2006).

A western boundary occurs where both sandstones are truncated by erosion along hillslopes above the San Lorenzo River. The sandstones dip away from this boundary, limiting the likelihood of springs. Limited amounts of groundwater may leak into the Locatelli Formation and migrate toward the San Lorenzo River. The Mount Hermon #3 well encountered additional sandstones beneath the Lompico. It is possible that the lowest of these is a near vertical section of the Locatelli basal sandstone; however, the data are insufficient make any definitive interpretation of this.

A few wells in the South Scotts Valley area have also been completed within the basal sandstone layer in the Locatelli Formation. No estimates of production, if any, are available for the Locatelli. The Vista del Lago well is considered to be completed across both the Santa Margarita and Locatelli; however, most of the groundwater production is assumed to be derived from the Santa Margarita. Deep aquifer zones within the Locatelli Formation appear confined, but have relatively little significance relative to the Santa Margarita and Lompico Aquifers.

No estimates of hydraulic properties are known for the Locatelli Formation or granitic basement. It may be assumed that the Locatelli Formation has properties similar to the Monterey Formation, or it may be less permeable. If and where the granitic rock is sufficiently fractured and/or has a weathered mantle, it may have moderate permeability within a limited depth.

Section 6: Numerical Model Development

The approach to develop a numerical model capable of simulating historical and future conditions depends upon properly incorporating the hydrogeological data from the basin. The following section describes the development of each of the components in the Model.

6.1 Approach

This objective of this project is to update the SMGB Model that was developed in 2006 (ETIC, 2006) for SVWD as a DWR grant project. The previous Model (ETIC, 2006) was setup for a 20-year base period from October 1985 to September 2004. SVWD has regularly updated the SMGB Model as part of their groundwater management activities to evaluate changes in groundwater storage. The most recent update of that previous version of the SMGB Model included data through 2012 (Kennedy/Jenks, 2013b).

The SMGB Model is a numerical groundwater model, which is a mathematical description of the hydrogeological conceptual model (Bear and Verruijt 1987). The advantage of a numerical model is that, once in a mathematical format, the model quantitatively combines data on basin geometry, aquifer properties, recharge, and discharge to simulate changes in groundwater elevations and calculate the water balance over time.

The SMGB Model is setup to represent the physical features that influence groundwater flow including the geology, hydrology and climate. Each of these features is mapped onto a model grid that represents the vertical and horizontal distribution of parameters over the SMGB based on the hydrogeological conceptual model. The parameters can also be varied through time over a defined base period to represent seasonal variations in precipitation, streamflow and groundwater pumping. A more detailed discussion of how each of these parameters was developed and entered into the SMGB model is summarized below.

When evaluating model results, it is important to consider the strengths and limitations of the numerical model. The horizontal and vertical resolution used to construct the model dictates the range of scales that the model can evaluate. The SMGB Model is designed as a regional or basin-wide model to evaluate long-term, regional trends and the overall groundwater inflow and outflow to the basin. Within that scale, conditions are averaged. However, this model may not contain the site-specific details necessary to evaluate some localized conditions due to geologic complexity or unique localized effects. For these areas, a more localized model may be required if such a detailed analysis is necessary. The regional model can provide a broader regional context to support the development of these localized models.

6.2 Model Setup

The model also incorporates spatial distribution of the physical features of the SMGB and the temporal distribution of time-varying parameters such as precipitation and recharge. The following describes

6.2.1 Model Code Selection

The model setup included changes to incorporate recent MODFLOW code advancements. For the SMGB Model, the computer code was updated from MODFLOW 2000 (Harbaugh *et al*,

2000) to MODFLOW NWT (Niswonger *et al*, 2011) to take advantage of new advanced features. Both variations of MODFLOW were developed by the United States Geological Survey (USGS). MODFLOW-NWT (Niswonger *et al*, 2011) is a standalone version of MODFLOW-2005 (Harbaugh, 2005) that includes an advanced mathematical solver that provides a more robust solution to complex conditions such as rewetting of dry model cells, unconfined conditions and groundwater-surface water interactions. These features improve the ability of the Model to evaluate potential conjunctive use and recharge projects increase future groundwater levels in the SMGB.

To facilitate model development, the MODFLOW processor Groundwater Vistas 6 (ESI, 2011) was used. Groundwater Vistas 6 is a widely used, industry-standard MODFLOW processor with many documented uses in support of basin management. The use of the industry standard modeling code MODFLOW-NWT along with a commercial processor supports future usability of the model.

6.2.2 Base Period

The update SMGB Model was constructed to simulate the 28-year base period from October 1985 through September 2012. The model is setup using water years that run from October through to the following September to capture the cause and effect relationship on groundwater levels of wintertime rain and subsequent summertime groundwater pumping. For each water year, the time steps represented the following seasonal periods.

- October through December (Fall period)
- January through March (Winter period)
- April through June (Spring period)
- July through September (Summer period)

To simulate this base period, the model is subdivided into time intervals termed stress periods. For the base period, a total of 112 stress periods were defined. To represent the marked seasonality of the climate of the area, the model was set up with quarterly (3 month) stress periods to allow the model to simulate seasonal variations.

The decision of the start date for the SMGB Model Base Period was influenced by data availability and groundwater conditions. The period starting in 1984 coincides with a marked increase amount of available groundwater data. In addition, groundwater levels in October 1984 where near their highest recorded levels. Static (non-pumping) depth to groundwater measurements at SVWD #10 were about 12 to 14 feet below ground surface and about 45 feet at SVWD #9. Groundwater level declines of more than 200 feet in these wells began in 1986, primarily coinciding with a regional increase in groundwater pumping in the Scotts Valley area. Therefore, the Base Period fully captures this critical period and is capable of evaluating the effects of the historic groundwater level declines observed in Scotts Valley on aquifer storage and streamflow in the SMGB.

Time-dependent parameters, such as groundwater pumping or precipitation recharge, are assigned to for each stress period. Conditions during the stress period are constant, but parameters can be varied from stress period to stress period. MODFLOW solves the groundwater elevations for the end of each stress period.

6.2.3 Model Domain and Grid

The SMGB covers over 30 square miles in the Santa Cruz Mountains. The SMGB forms a roughly triangular area that extends from Scotts Valley in the east, to Boulder Creek in the northwest, to Felton in the southwest. The area that is included in the SMGB Model is shown on Figure 6-1.

MODFLOW requires the application of a rectangular grid that encompasses the entire area, or domain, that will be modeled. The model grid forms the mathematical framework for the model. Each grid cell has to be populated with aquifer properties. Physical features such as streams and wells are mapped onto the model grid. Using this information, the MODFLOW model calculates a groundwater elevation at each model grid cell for each stress period. The density of model grid cells is what defines the resolution of the model in resolving drawdown and other hydrologic effects.

The updated SMGB Model consists of 346 rows, 434 columns, and 7 layers. The rows and columns have a uniform spacing of 110 feet. The total number of model cells is just over one million cells (1,051,148 cells), of which 352,269 are active cells where MODFLOW calculates a groundwater levels. Areas not in the SMGB are represented as no-flow cells where MODFLOW does not perform calculations. The high percentage of no-flow cells in the model grid is due to both the triangular shape of the SMGB and because the distribution of active cells varies from layer to layer because not all the formations have the same areal extent in the subsurface. The bottom of the lowest model layer is a no-flow boundary condition, representing the crystalline bedrock, which is assumed to be relatively impermeable.

For the updated SMGB Model, the model grid was expanded by about one mile to the east by adding 51 columns along the eastern margin of the grid. This allowed the SMGB Model include the Blackburn Gulch area within the active model area to include potential recharge areas for the Lompico and Lower Butano Aquifers and groundwater-surface water interactions with Blackburn Gulch, Branciforte Creek and the West Branch of Soquel Creek.

The previous SMGB Model consisted of 346 rows, 383 columns, and 4 layers using the same uniform 110-foot grid spacing. The total number of model cells was 530,072 cells, of which 180,503 were active. Thus the updated model nearly doubles the numbers of both the total and active cells. Much of that increase is due to the increase in the number of layers, eastward grid extension and revision on the distribution of the lower Butano. The updated SMGB Model has a higher grid resolution, which is especially useful for representing vertical flow through thick formations.

The SMGB Model covers the entire SGMB except for two small areas. The northwestern area is the narrow extension of the SMGB west of the San Lorenzo River in the vicinity of Boulder Creek formed by the intersection of the Ben Lomond and Zayante Faults (Figure 6-1). There is limited information from this small, geologically complex area, which is considered to be underlain by the upper Butano Aquifer with a thin cover of Lompico and alluvium. Groundwater in the Lompico west of the San Lorenzo River is considered to be hydraulically connected to San Lorenzo River and Boulder Creek, with little likelihood of groundwater flow to areas east of the River. The Butano is represented by a boundary condition to represent the influence from Boulder Creek

The eastern area is a portion of the lower Butano that extends eastward towards the West Branch of Soquel Creek (Figure 6-1). Available geologic data indicates that the Butano is a relatively thin layer overlying the crystalline bedrock in this area. The slope of the contact is down toward the Soquel Creek, which has nearly eroded through the entire remaining section of the Butano. Because of this geometry, groundwater is thought to flow towards and discharges into Soquel Creek, and is represented by a boundary condition that allows for groundwater flow towards Soquel Creek.

6.3 Model Structure

Model layers provide vertical resolution for the model to simulate variations in groundwater elevation, aquifer stresses, and water quality with depth.

6.3.1 Model Layer Definitions

The model layers are a representation of the geologic characteristics of the SMGB including the definition of the different aquifer layers. The model layers were developed based on the geology and site conceptual models presented in Section 2 and 5.

For the updated SMGB Model, the number of model layers was increased from four to seven layers to simulate hydrogeologic character of the primary water-bearing formations. The definition of the model layers SMGB Model is defined using seven layers that represent the following geologic units:

- Santa Margarita Sandstone (Santa Margarita) – Model Layer 1
- Monterey Formation (Monterey) – Model Layer 2 and 3
- Lompico Sandstone (Lompico) – Model Layer 4
- Butano Formation (Butano) – Model Layer 5, 6 and 7
- Locatelli Formation – incorporated into Model Layer 5 and 6.

The Santa Margarita Aquifer is represented by a single model layer (Model Layer 1). The distribution of the Santa Margarita is based on the geologic map of the SMGB as shown on Figure 6-2. The base of the Santa Margarita is derived from the interpretation of geologic logs and the geologic structure map included in Appendix B. The top of the Santa Margarita is the topographic surface in the outcrop areas and the base of the Santa Cruz Mudstone (see Appendix B) for the subsurface occurrences.

The Monterey Aquifer is simulated using two layers (Model Layers 2 and 3) as shown on Figures 6-3 and 6-4. The base of the lower Monterey is defined as the top of the Lompico Aquifer. The top of the Monterey is defined as either the topographic surface in the outcrop areas or the base of the Santa Margarita Aquifer where the top occurs in the subsurface. The lower Monterey is defined as a uniform 300 feet thickness across the SMGB. In areas where the total thickness of the Monterey is less than 300 feet, the available Monterey is assigned to the lower Monterey and the upper Monterey is absent. The available thickness on the Monterey Aquifer above the top of the lower Monterey is assigned to the upper Monterey so that it has a variable thickness across the SMGB.

The Lompico Aquifer is simulated using a single layer (Model Layer 4) as shown on Figure 6-5. The base of the Lompico is derived from the interpretation of geologic logs and the geologic structure map included in Appendix B. The Lompico is defined as a uniform over the majority of the SMGB, but is allowed to thin to 300 feet from the center of the Scotts Valley Syncline northwestward towards Boulder Creek. The top of the Lompico is defined as either adding the thickness from the base of the unit, the base of the Santa Margarita Aquifer, or the topographic surface, whichever is lower.

The Butano Aquifer is simulated using three layers (Model Layers 5, 6 and 7) as shown on Figures 6-6, 6-7 and 6-8. The base of the Butano is derived from the interpretation of geologic logs and the geologic structure map included in Appendix B. The lower Butano is defined as a uniform 900 feet thickness across the SMGB. In areas where the total thickness of the Butano is less than 900 feet, the available Butano is assigned to the lower Butano. The upper Butano is defined as 500 foot thickness below the base of the Lompico that represents the upper and middle members of the Butano. Model Layer 6 represents the remaining section of the lower Butano between Model Layers 5 and 7.

The Locatelli Aquifer is simulated using two layers (Model Layers 5 and 6) as shown on Figures 6-6 and 6-7. Although the Locatelli is stratigraphically below the Butano, these units are not considered to be in contact within the SMGB; therefore, for operational efficiency in running the MODFLOW model, the Locatelli is included with the Butano on Model Layer 5 and 6. The Locatelli is only present in small area in the southwestern SMGB. The Locatelli in Model Layer 5 represents the upper siltstone layer and Model Layer 6 represents the basal sandstone member.

6.3.2 Handling Geologic Pinchouts

To provide continuity for MODFLOW to calculate vertical groundwater flow, the vertical sequence of model cells must be active. In case of pinchouts, where intervening layers have been removed by erosion so that a higher stratigraphic interval is in contact with a lower one, poses a difficulty for MODFLOW simulations. By defining model layers as geologic units, we need to preserve vertical groundwater flow potential in MODFLOW by keeping the model cells in the intervening layer(s) active for the simulation.

MODFLOW requires that all model layers are continuous across the model domain, and that if models cells are inactive in one layer, they do not participate in vertical groundwater flow between layers. Therefore, the model layers representing the "pinched out" geologic formation need to remain active for vertical flow to occur. To handle pinchouts in the SMGB Model, the pinchout area is setup to simulate a thin portion of the underlying layer. To simulate the appropriate flow characteristics between the "pinch-out" area with the rest of that model layer, the horizontal flow barrier (HFB) package is used. Although the HFB package in commonly used to simulate faults, in this case, the HFB package is simulating the equivalent of the vertical conductance between adjacent aquifers currently being simulated within a single model layer.

The SMBG Model includes major geologic pinchouts that connection between overlying and underlying layers. The Monterey pinchout in the southern SMGB allows the following:

- Model Layer 2 includes two interlayer areas; one simulates Model Layer 3 where the lower Monterey is in contact with the Santa Margarita (Figure 6-3). The other simulates Model Layer 4 where the Lompico is in contact with the Santa Margarita.
- Model Layer 3 includes one interlayer connection to Model Layer 4, where the Lompico is in contact with the Santa Margarita (Figure 6-4).

The three model layers used to simulate the Butano Aquifer also use interlayers. These include the following:

- Model Layer 5 includes two interlayer areas (Figure 6-6); one simulates Model Layer 6 where it is in contact with the Lompico. The other simulates Model Layer 7 where it is in contact with the Lompico.

- Model Layer 6 includes one interlayer that Model Layer 7 where it is in contact with the Lompico (Figure 6-7).

6.3.3 Faults

The updated SMGB Model does not include any of the internal faults that were used for the previous Model (ETIC, 2006) as flow controlling features. The use of the HFB package in the updated Model is limited to helping to define the geologic pinchouts discussed above.

The primary reason faults were added to the previous model was to better simulate the groundwater level history for SVWD Well #9 and other nearby wells, which could not reconciled without adding a horizontal flow barrier under the previous geologic interpretation. Adding these flow barriers proved effective for matching the groundwater level history, but was not based on a well-defined geologic understanding. As discussed in Section 5, the revised geologic interpretation places the SVWD Well #9 area in the lower Monterey Aquifer while keeping the other nearby wells in the Santa Margarita. This provides a stratigraphic explanation for the distinct differences in the groundwater level history.

Other faults in the previous Model in the Lompico and Butano Aquifers were also removed because they were used primarily for controlling flow without having a clear geologic explanation. The presence of these faults limits the extent of drawdown in these aquifers, so there presence affects the assessment of changes in aquifer storage. The Butano Aquifer was subdivided into three model layers to provide a stratigraphic method based on observed geologic characteristics to simulate variations in groundwater conditions. In a geologically complex area such as the SMGB, it may well be possible that minor faults associated with the regional faulting along the San Andreas and Zayante Faults that affect groundwater flow may be present, but additional data is necessary to clearly define the location and influence of any such faults before they should be included in the SMGB Model.

6.3.4 Hydrostratigraphic Units

In addition to model layers, Groundwater Vistas allows for the definition of hydrostratigraphic units or subareas to provide options for grouping together parts of the model for calculation of the water balance. Each of the major aquifers was defined as a separate hydrostratigraphic unit. Interlayers representing the underlying aquifer were also included within the underlying hydrostratigraphic unit.

The Santa Margarita Aquifer is also split into for subareas that can be used to evaluate more refined areas, as shown on Figure 6-2. The subareas are defined in this case to evaluate groundwater-surface water interactions along the major stream systems, so the subarea boundaries are not defined along the creeks but either along surface water divides or other convenient boundary away from the streams. If different subareas are necessary for subsequent simulations, subareas can be easily redefined using the Groundwater Vistas processor or the USGS ZoneBudget (Harbaugh, 1990, 2008) program to evaluate other definitions of subareas as necessary.

6.4 Aquifer Properties

Aquifer properties represent the physical and hydrogeologic characteristics of the aquifers within the SMBG that control groundwater flow. Aquifer properties must be assigned to each active grid cell in the model. The conceptual model provides the framework necessary to define aquifer properties.

6.4.1 Groundwater Conditions

Groundwater conditions in the aquifers can be defined as unconfined or confined. Unconfined conditions exist when groundwater levels are below the top of the physical aquifer layer whereas confined conditions exist when groundwater levels are above the top of the physical aquifer layer.

Because of the complex geology in the SMGB, all seven model layers contain areas characterized as either confined or unconfined. Each of the aquifers has unconfined areas typically either in outcrop areas or areas where groundwater levels have been drawn below the top of the aquifer. Likewise, all of the aquifers have confined areas that exist at depth where groundwater levels are higher than the top of the physical aquifer layer. For the SMGB Model, MODFLOW was set up so that all the model layers are either saturated or unsaturated, as determined by model calculations. MODFLOW is able to automatically convert between unconfined and confined conditions through a comparison of the simulated groundwater elevation to the elevation of the top of the model layer.

6.4.2 Hydraulic Conductivity

Hydraulic conductivity represents the ability of the water to flow through the aquifer, and is defined horizontally within a model layer to represent groundwater flow through the aquifer and vertically between adjacent model layers to represent groundwater exchange between aquifers.

The definition of the horizontal hydraulic conductivity is based on an assessment of lithologic description and available aquifer test data (see Sections 2 and 5). Since each model layer represents a thick interval composed of varying degrees of gravel, sand, silt and clay, the horizontal hydraulic conductivity represents an average value over the entire vertical thickness that includes the finer-grained layers in addition to any specific sand and gravel zone. For the SMGB Model, horizontal hydraulic conductivity is defined using regionalized blocks based on the geologic character of the unit and refined during calibration.

The hydraulic conductivity used in the SMGB Model varies within a reasonable value range for the aquifer characteristics for each aquifer to achieve the model calibration. The hydraulic conductivities used in the SMGB Model are listed in Table 6-1 and are summarized as follows:

- The Santa Margarita Aquifer (Model Layer 1) has the highest horizontal hydraulic conductivities in the model, ranging from 2 to 25 ft/day, reflecting its character as a clean, weakly-consolidated sandstone (Figure 6-2).
- The Monterey Aquifer (Model Layer 2 and 3) has lower horizontal hydraulic conductivities that range from 0.1 to 1.5 ft/day that reflect its character as a predominantly fine-grained unit that contains sand layers (Figure 6-3 and 6-4). Higher values occur in Model Layer 3 representing the transitional nature of the contact with the underlying Lompico. The L3 Interlayer (Table 6-1) represents the Lower Monterey, and the L4 Interlayer represents the Lompico Aquifer.
- The Lompico Aquifer (Model Layer 4) has horizontal hydraulic conductivities ranging from 0.5 to 2.5 ft/day reflecting its character as a consolidated sandstone with thin clay and silt layers (Figure 6-5).

- The Upper Butano Aquifer (Model Layer 5), because of a lack of data, was assigned a uniform horizontal hydraulic conductivity of 1.0 ft/day based on the lithologic descriptions (Figure 6-6).
- The Lower Butano Aquifer (Model Layer 6 and 7) was also assigned uniform horizontal due to a general lack of data as listed in Table 6-1 and shown on Figures 6-7 and 6-8.
- The Locatelli Aquifer (Model Layer 5 and 6) was also assigned uniform horizontal due to a general lack of data as listed in Table 6-1 and shown on Figures 6-6 and 6-7.

TABLE 6-1
SUMMARY OF AQUIFER PROPERTIES APPLIED FOR SMGB
BY MODEL LAYER

Aquifer	Model Layer	Horizontal Hydraulic Conductivity	Storativity	Specific Yield
Units		feet per day	dimensionless	dimensionless
Santa Margarita Aquifer				
Scotts Valley	1	2 – 25	1.0E-04	0.06 – 0.10
Pasatiempo	1	4 – 12.5	1.0E-04	0.07 – 0.10
Bean Creek	1	2 – 25	1.0E-04	0.06 – 0.10
Quail Hollow	1	2.25 – 10	1.0E-04	0.06 – 0.10
Monterey Aquifer				
Upper Monterey	2	0.1	5.0E-06	0.02
Lower Monterey	3	0.25 – 1.5	1.5E-05 – 5.0E-06	0.02 – 0.06
L3 Interlayer	2	0.75	1.0E-05	0.04
L4 Interlayer	2,3	2.5	1.0E-05	0.05
Lompico Aquifer				
Lompico	4	0.5 – 2.5	1.5E-05 – 7.5E-06	0.04 – 0.06
Butano Aquifer				
Upper Butano	5	1.0	1.0E-05	0.04
Lower Butano	6	0.06	1.0E-07	0.02
Lower Butano	7	0.25	1.0E-06	0.06
L6 Interlayer	5	0.5	1.0E-07	0.02
L7 Interlayer	5,6	1.5	1.0E-06	0.04
Locatelli Aquifer				
Upper Locatelli	5	0.002	1.0E-07	0.01
Lower Locatelli	6	0.02	1.0E-05	0.04

6.4.3 Specific Yield and Storativity

Aquifer storage defines the ability of the aquifer to take in or release water. Under unconfined conditions, water released from or put into aquifer storage represents the physical draining of groundwater from interstitial pore space within the aquifer. Unconfined storage is defined by specific yield, which is typically consistent with the effective porosity of the aquifer. Under confined conditions, water released from or put into aquifer storage is derived from the compressibility of water as a result of changes in the aquifer pressure within the interstitial pore space. Confined storage is defined by specific storage or storativity.

MODFLOW 2005 requires the use of specific storage. The storativity, which is dimensionless, equals the specific storage (units of feet^{-1}) times the aquifer thickness. The previous Model (ETIC, 2006) used storativity to define the storage properties under confined conditions. Groundwater Vistas 6 developed an option that allows for the use of older storativity data sets by automatically performing the conversion to specific storage when developing the MODFLOW data sets. This option was used for the SMGB Model; therefore, the data is managed as storativity, but is input into MODFLOW as specific storage.

Reasonable ranges for the specific yield and storativity were varied within a reasonable range during the model calibration and the values are listed in Table 6-1. Storativity and specific yield numbers were updated during the calibration process. The specific yield is generally in the range of 0.01 to 0.25, whereas the storativity is generally in the range of 7.5×10^{-6} to 1.0×10^{-4}. For the Santa Margarita and Lompico Aquifers, storativity values ranged from 7.5×10^{-6} to 1.0×10^{-4} and correspond to the higher anticipated aquifer storage potential in the high hydraulic conductivity areas. In the Monterey and Locatelli, storativity values ranged from 1.5×10^{-5} to 1.0×10^{-7} representing the fine-grained nature of these formations. In the Butano storativity values ranged from 1.0×10^{-5} to 1.0×10^{-7}. The low range in the Butano is considered to represent the complex nature of the formation that is represented by relatively thick model layers that contain a heterogeneous mixture of coarse- to fine-grained materials. There is limited data available in the Butano, and the relatively low storativity used for the Butano may reflect adjustments in the SMGB Model to compensate for other data gaps.

6.4.4 Vertical Conductance

In general, groundwater flow within an aquifer is dominantly horizontal whereas flow between adjacent aquifers is essentially vertical. The application of vertical hydraulic conductivity recognizes the inherent isotropy present in natural geologic formations. Even within a highly-permeable sandy aquifer, the vertical hydraulic conductivity is typically lower than horizontal due to the original depositional layering and compaction of particles during the lithification process. Within a sandy aquifer, the ratio of vertical to horizontal hydraulic conductivity is typically is in the range of 1:5 to 1:10 (Bouwer, 1978). These are the values typically obtained from pumping tests as listed in Appendix D and discussed in Section 5.5.7. For lower-permeability layers with higher clay content, the alignment of platy crystal structure of clay minerals during compaction will lead to vertical to horizontal hydraulic conductivity ratios on the order of 1:100 to 1:1,000 or even lower (Freeze and Cheery, 1979).

Vertical groundwater flow is equivalent to Ohm's Law for serial electrical flow through different resistivity layers. Based on this analogy, vertical groundwater flow, similar to serial electrical flow, is limited by the lowest conductivity (or highest resistivity) layer encountered. Therefore, vertical groundwater flow is defined by the lowest-permeability, continuous layer that controls the exchange of groundwater between aquifer or model layers.

In a layered sedimentary groundwater basin such as the SMGB, vertical hydraulic conductivities can be several orders of magnitude lower than horizontal hydraulic conductivities because of the geologic heterogeneity. In the SMGB Model, specific low-permeability layers limiting vertical groundwater flow between the larger regional aquifers are not specifically defined using separate model layers. Vertical hydraulic conductivities are estimated based on lithologic descriptions of the different aquifer and/or model layers with emphasis given towards the lower conductivity units consistent with methods for determining the vertical hydraulic conductivity in a layered system (Bouwer, 1978, Freeze and Cherry, 1979). The vertical hydraulic conductivities defined for each model layer incorporate the presence of these low-permeability layers that limit vertical groundwater flow between the regional aquifers, so that they are represented by VCONT. For MODFLOW 2005, the vertical hydraulic conductivity can be defined on a cell-by-cell basis across the model domain. This approach is equivalent to the "Quasi Three-Dimensional" approach described in the MODFLOW manuals (Harbaugh, 2005).

In MODFLOW, vertical groundwater flow between model layers is calculated using vertical conductance (VCONT) that is the vertical hydraulic conductivity divided by the thickness from a layer to the layer below (Harbaugh, 2005). Because there is not a layer beneath the bottom layer, VCONT cannot be specified for the bottom layer. These values were updated during model calibration. The vertical hydraulic conductivity values used in the model to calculate the VCONT are summarized below:

- The Santa Margarita – Monterey Contact has relatively low values ranging from 0.00001 to 0.004 ft/day that represent the strong influence of the lower permeability shale layers within the Monterey on vertical flow between these units.
- The Santa Margarita – Lompico Contact has relatively higher values ranging from 0.006 to 0.05 ft/day that represent the unconformable contact areas between these two sandstone units.
- The Santa Margarita – Locatelli Contact has relatively low value of 0.00009 ft/day over the contact area within the model representing the influence of the upper siltstone member of the Locatelli.
- The Upper Monterey – Lower Monterey Contact has relatively low values ranging from 0.00001 to 0.00005 ft/day that reflect the influence of shale layers.
- The Lower Monterey – Lompico Contact has relatively low values ranging from 0.003 to 0.0002 ft/day representing the gradational geologic contact between the Lompico and the Lower Monterey.
- The Lompico – Upper Butano Contact has a vertical hydraulic conductivity range of 0.0002 to 0.000004 ft/day over the contact area within the model.
- The Lompico – Lower Butano Contact t has a vertical hydraulic conductivity range of 0.00002 to 0.00005 ft/day over the contact area within the model.
- The Lompico – Locatelli Contact has a vertical hydraulic conductivity range of 0.0001 to 0.000005 ft/day over the contact area within the model. The higher value represents the Lompico in contact with the basal sandstone member of the Locatelli.

- The Upper Butano – Lower Butano Contact the vertical hydraulic conductivity was a uniform 4.0E-06 ft/day to account for the thick middle siltstone member that separates the upper and lower members of the Butano.

6.5 Groundwater Pumping

Groundwater pumpage is the most significant groundwater outflow component for the basin. As discussed in Section 2, groundwater pumping was assessed in different water use categories including municipal, industrial, environmental remediation, landscaping water use and domestic use. Groundwater pumping is specified for each three-month stress period for each well location in the model. These locations are shown on Figure 6-9.

To import the pumpage data into the model, pumping records for all pumping wells within the domain were analyzed to produce pumping rates for each well for each of the seasonal, three-month stress periods. Model layer assignments were based on well screen intervals for each individual well. In the model, pumpage includes a combination of municipal, small commercial and community, and rural domestic pumping wells.

All pumping wells are included as either analytical elements of the MODFLOW well package in the model. The well listed in Appendix A where well pumping was defined either by records kept by well owners, or estimated based on the well type or water usage were input using analytical elements. For wells where measured pumping volume data was available, the data was summarized into seasonal, three-month intervals for input into the stress periods comprising the model base period. Through use of these monthly pumping records for municipal pumping wells, typical seasonal changes in municipal supply well pumping rates can be accurately represented in the model.

Several privately-owned wells that do not have pumping records, and for these wells values estimated volumes were used as discussed in Section 2. Larger wells are represented as analytical elements, and are assigned to model layers based on their actual screened intervals.

Domestic wells had an assumed pumping rate of about 0.28 acre-feet per year. Most small wells are screened within the uppermost active model layer at that location, and these are represented as boundary conditions. Locations were based on parcel locations with well permits from County records. These wells were assigned the SMGB Model using the MODFLOW well package and did not vary over time.

Table 6-2 present the overall trend in average annual groundwater pumping over time, and a further break down of pumping by subarea for the Santa Margarita (Figure 6-2). The major change is the decline in groundwater pumping in Santa Margarita and Monterey from 1984 to 2012. This is attributed to pumping in the Scotts Valley and Pasatiempo subareas being shifted to the deeper Lompico and Butano Aquifers as groundwater levels declined in these subareas. Groundwater pumping in the Quail Hollow and Olympia areas is variable because SLVWD uses groundwater when surface water supplies became insufficient. Pumping in the Butano increases sharply with the installation of the SVWD Wells #3B and #7A in the early 1990's. The recent decrease in pumping reflects significant decreases in environmental remediation and industrial pumping along with increased water conservation efforts by the water districts.

TABLE 6-2
SUMMARY OF AVERAGE ANNUAL GROUNDWATER PUMPING OVER TIME BY MODEL LAYER

Aquifer	Model Layer	1985-1991	1992-1998	1999-2005	2006-2012
Units		AFY	AFY	AFY	AFY
SMGB Total					
Santa Margarita	1	1,621	1,140	1,072	924
Monterey	2,3	484	324	234	178
Lompico	4	1,510	1,922	1,943	1,641
Butano	5,6,7	7	623	1,003	702
TOTAL	All	3,621	4,009	4,253	3,444
Santa Margarita Aquifer Subareas					
Scotts Valley	1	282	221	136	72
Pasatiempo	1	401	168	87	0
Bean Creek	1	64	64	60	54
Quail Hollow	1	777	589	692	701
Domestic	1	97	97	97	97

6.6 Subsurface Inflow and Outflow

Both subsurface groundwater inflow and outflow from the SMGB Model domain were simulated using constant or general head boundary conditions along the perimeter of the model domain. Constant head boundaries set a groundwater elevation or head at a specific model cell that allow sufficient inflow or outflow at that model cell to achieve the specified head. A general head boundary essentially defines a constant head at a distance. The interval between the specified head and model cell is defined by a conductance term that controls the amount of water than can flow into the model cell; therefore, the simulated groundwater elevation at the model cell can vary over time.

Constant and general head boundaries along the model layer peripheries were included to simulate the groundwater level in the areas bounding the model to allow groundwater to flow into and out of the model from areas outside the basin.

These areas were identified to represent areas of elevated local subsurface inflow were generally limited to the western and eastern margins of the basin in layers 3 and 4 (Lompico and Butano formations). These areas were simulated in the groundwater model using a head-dependent boundary condition. Specifically, these areas were simulated by:

- A constant-head boundary with an elevation of approximately 660 feet above mean sea level (amsl) along a small section of the southern edge of Model Layer 1 (Santa Margarita formation) to simulate groundwater inflow from precipitation falling on exposures of the Santa Margarita just south of the model boundary.
- A general-head boundary with elevations ranging from approximately 438 feet amsl along the eastern edge of Model Layer 7 (Lower Butano Aquifer) to simulate groundwater flow into the underlying bedrock towards a discharge along the Branciforte and Granite Creeks.

- A general-head boundary with elevations ranging from approximately 350 feet amsl along the southeastern edge of Model Layer 7 (Lower Butano Aquifer) to simulate groundwater flow through the Lower Butano towards a discharge along the West Branch of Soquel Creek.
- A general-head boundary with elevations ranging from approximately 350 feet amsl along the southwestern edge of Model Layer 7 (Lower Butano Aquifer) to simulate groundwater flow into the underlying bedrock.

The Model Layer 1 constant boundary and the West Soquel Creek boundary condition in Model Layer 7 were based on the conceptual model to account for groundwater flow into adjacent areas of the SMGB not specifically included in the Model. The southeastern and southwestern boundary conditions were added during the calibration process. To get the observed groundwater levels in the Butano prior to pumping required additional subsurface outflow from the Butano. Similarly, without a subsurface outflow in the southwest, groundwater elevations would be high enough to cause flowing artesian conditions in that area. Since this was not observed during the drilling of Mount Hermon Well #3, which is interpreted to have encountered the Butano, a boundary condition was added. It is reasonable to consider that there would be groundwater flow along the Ben Lomond fault or associated fractures to justify adding the boundary condition.

6.7 Distribution of Recharge and Runoff

Precipitation is the ultimate source of nearly all of the recharge in the SMGB through both direct percolation of precipitation through the soil and as the source of runoff for the local streams and rivers as infiltration through the streambed.

6.7.1 Conceptual Approach

The distribution of recharge and runoff was determined using a rule-based algorithm that portioned the total available rainfall for each quarter of the base period to groundwater recharge, stream runoff or consumptive use or other losses. The determination of this portioning was based on a series of rules based on local knowledge of conditions within the SMGB and contributing watershed, scientific understanding of the physical processes involved and review of relevant scientific literature. The following outlines the assumptions and methods used for calculating the total available precipitation for runoff and recharge. The overall to define the distribution of recharge and runoff included:

- Define the spatial distribution of the physical characteristics that influence the
- Define coefficients to
- Distribute the total rainfall for each 3-month stress period to runoff and recharge
- Partition rainfall to surface water runoff, groundwater recharge and consumptive use by vegetation or other losses

6.7.2 Physical Character Units

The partitioning of rainfall to runoff, groundwater recharge and consumptive losses is strongly controlled by the rainfall, geology and land use characteristics over the SMGB and contributing watershed. The partitioning of rainfall varies across this region due to variations in these key controlling factors. To incorporate this variability into the SMGB Model, physical character units (PCUs) are areas defined by their known physical characteristics.

A GIS layer was developed to define PCUs based on these local physical characteristics by grouping together the different combinations of isohytel, geology and land use zones. The eleven isohytel rainfall zones, eleven geology zones and eight land use zones make 968 possible combinations; however, only 125 of these combinations actually occur within the SMGB and contributing watershed.

The following describes the characteristics used in defining the isohytel, geology and land use zones used for developing the PCUs.

6.7.2.1 Isohytel Rainfall Zones

Rainfall, on average, varies across the SMGB primarily reflecting orographic effects of the surrounding mountains and other local microclimates. The isohytel map (Johnson, 2009) shows the distribution of average annual rainfall across the region (Figure 4-1). The typical pattern of the lowest rainfall occurring near Scotts Valley and the highest rainfall is associated with the orographic effects of Ben Lomond Mountain along the western portion of the SMGB. A GIS layer was developed that defines eleven isohytel zones based on the 2-inch isohytel contours that ranged from 35 to over 55 inches of average annual rainfall.

For the updated Model, the isohytel map used for the previous Model (ETIC, 2006) was replaced with one developed by Johnson (2009) based on detailed analysis of historical precipitation data from rain gauges in Santa Cruz County. This change helps to insure consistency in the analysis of work conducted by SVWD and SLVWD.

6.7.2.2 Geology Zones

Geology is another of the key controlling factor. In general, sandstone typically has higher groundwater recharge and lower runoff whereas shales, mudstones and siltstones typically have the reverse characteristics. The underlying geology for the SMGB is based on the USGS geologic map for the region shown on Figure 3-2. The zones are based on the geologic unit occurring at the surface. A brief summary of the geologic factors include the following:

- The Purisima is permeable sandstone that caps many of the hills near Scotts Valley, but it is underlain by the Santa Cruz Mudstone. Water that percolates into the Purisima in this area is considered to discharge to springs along the contact with the Santa Cruz Mudstone which significantly limit the recharge that can pass through it to the underlying aquifers. Therefore, the Purisima also has a very low recharge and a moderate runoff potential that is strongly influenced by the underlying Santa Cruz Mudstone.
- The Santa Cruz Mudstone is a thick, low-permeability formation that occurs near the surface in the vicinity of Scotts Valley. Where the Santa Cruz Mudstone overlies the Santa Margarita, it is considered to significantly limit the recharge that can pass through it to the underlying aquifers. Therefore, the Santa Cruz Mudstone has a very low recharge and a high runoff potential.
- The Santa Margarita is high-permeability sandstone that outcrops at the surface over a wide area of the SMGB. In general, the Santa Margarita has a high infiltration capacity that leads to high percolation and less runoff. Therefore, the Santa Margarita typically has the highest recharge potential and consequently produces relatively low runoff. The

upland Santa Margarita recharge rates are lower based on an assumption of steeper slopes in these areas limiting recharge.

- The Monterey is a thick, low-permeability predominantly shale formation that occurs near the surface over a large portion of the SMGB. However, it does contain sandstone interbeds, so it has a higher recharge coefficient than the Santa Cruz Mudstone, but a similar runoff coefficient.
- The Lompico is a high-permeability sandstone unit, but has limited outcrop areas with the majority of occurring in the Blackburn Gulch area. In other areas it occurs in steep topography that leads to higher runoff. The Lompico is considered to have moderate to high recharge and low to moderate runoff potential depending primarily on topography.
- The Zayante occurs in areas the SMGB, so it only affects the watershed calculations especially outside the SMGB. The Zayante lumps together multiple geologic units, and a moderate runoff potential.
- The Butano has limited outcrop in areas with the steep topography along the northern fringe of the SMGB. The Butano is geologically complex with interbedded high permeability sandstone layers and fine-grained siltstone layers. Recent data has helped in better understanding the recharge potential of the Butano (Kennedy/Jenks, 2013c). Therefore, the Butano is considered to range from low to moderate recharge and medium to high runoff potential.
- The Locatelli and granite occur in very limited areas and are generally low permeability units. Therefore, the Locatelli and granite have very low recharge and high runoff potential.

6.7.2.3 Land Use Zones

Land use is another important controlling factor that accounts for changes to the land surface from human activity. In general, more developed areas tend to have more impervious or modified land resulting in a higher runoff and lower recharge potential. The local land use is based on the County land use data shown in Figure 2-2. Some basic characteristics of the different land use categories used in determining the land use zones include:

- Developed areas, especially the commercial/industrial and suburban areas are considered to have large impermeable surface areas and storm drain systems that direct more of the total available precipitation to runoff.
- Irrigated lands in the SMGB are primarily large grass parklands or landscaping that is routinely watered. These areas have a higher recharge potential because the irrigation maintains the soil moisture due to the applied water. Return flows from applied water is also added to these zones separately further adding to their recharge potential.
- Less developed areas, such as the rural domestic and rural/native/undeveloped areas, have dominantly native vegetation helps reduce runoff and do not inhibit the recharge potential of the underlying geology.
- Modified areas such as quarries are assumed to have a more internal drainage system, so that the local runoff goes into the quarry where a portion is added to the recharge. Therefore, quarries have less runoff going to creeks and a higher recharge rate.

- Landfill is a special case for the Ben Lomond Landfill that is capped to nearly eliminate recharge and drainage management to limit runoff.

6.7.3 Rainfall Partitioning

The partitioning of rainfall was done by adapting a rational method approach. Although typically used for stormwater applications, this approach has also been applied for long-term regional analysis. The advantage of this approach is that is a relatively simple water balance approach that can be used in areas with limited spatial information, but incorporates an understanding of the physical processes that control the portioning of rainfall. The rational method provides a straightforward algebraic expression for estimating runoff based on the following formula (Chow *et al*, 1988):

$$Q = C * i * A$$

where:

Q = discharge is the volume of runoff or recharge per 3-month stress period

C = runoff coefficient is the percentage of the rainfall volume going to runoff or recharge

i = total available precipitation calculated for each 3-month stress period

A = area of the watershed or recharge area where contributing precipitation falls

Table 6-3 lists coefficients developed for the different PCUs for the development and calibration of the SMGB Model. The following summarizes the methods and information used to develop the coefficients for runoff, land use and consumptive use and other losses.

6.7.3.1 Runoff Coefficients

The runoff coefficient determines the percentage of the total available precipitation that is applied to runoff entering the surface streams. Development of runoff coefficients is based on empirical data that has been documented in the literature based on decades of practical experience. Some of the key references used for determining these coefficients i the SMGB include:

- *Runoff Coefficient (C) Fact Sheet,* by SWRCB (2011) – included in Appendix E
- *ODOT Hydraulics Manual* by ODOT (2014) – included in Appendix E
- *Highway Design Manual Chapter 810 Hydrology*, by CDOT (2014) – included in Appendix E
- *Runoff Coefficients for Use in Rational Method Calculations*, by Bengtson (2010) – included in Appendix E
- *Applied Hydrology* by Chow, Maidment and Mays (1988),
- *Estimation of Ground Water Recharge due to Rainfall by Modelling of Soil Moisture Movement* by Kumar (1993)
- *The landscape coefficient method*, by WUCOLS (2000)
- *Drainage Manual,* by Santa Clara County Dept. of Planning (2007)
- *California Impervious Surface Coefficients*, Cal EPA report by (Washburn *et al*, 2010)

- *Cumulative watershed effects*, US Forest Service Report (Elliot *et al*, eds., 2010)

Runoff coefficients are based on a conceptual understanding of the properties of the soils and geologic units in the SMGB and contributing watershed. Runoff coefficients for comparable geologic and land use conditions were researched based on the above listed references to develop a potential range for each PCU. Further assessment of the local conditions was used to develop an initial runoff coefficient for the SMGB Model that was further modified within the potential range for each PCU during calibration. Final quarterly runoff coefficients determined during model calibration are listed in Appendix E. Table 6-3 provides the average annual runoff coefficient as a general reference.

Runoff is subject to seasonal variations to account for consumptive use and other losses that would affect the volume of runoff reaching streams. In general, the runoff coefficients are higher in the winter and lower in the summer. Quarterly runoff coefficients were developed for each PCU, and these values are presented in Appendix E.

6.7.3.2 Recharge Coefficients

The recharge coefficient accounts for the portion of rainfall that percolates below the root zone so that it eventually recharges the groundwater and is not removed by consumptive use or other losses. Recharge accounts for water percolating through the soil column. Percolation to reach the groundwater may take considerable time, so the recharge rate to groundwater is assumed to be constant over the year. The volume of recharge will vary over time due to the changes in total available precipitation.

The recharge coefficients are strongly controlled by the underlying geology and the local land use. Highly permeable units such as the Santa Margarita and Lompico have higher infiltration rates, so have higher recharge coefficients, whereas the low permeability units such as the Santa Cruz Mudstone and Monterey have lower infiltration rates, so have low recharge coefficients.

Determination of the recharge coefficients are based on a conceptual understanding of the properties of the geologic units, soils and land use for the SMGB and contributing watershed. Some of the key references used for determining recharge coefficients are for the SMGB include (Johnson, 2001, 2002, 2003, 2009), (ETIC, 2005, 2006), Kennedy/Jenks (2013b, 2013c), Todd (1998, 2003) and USDA (1980).

Further assessment of the local conditions was used to develop an initial recharge coefficient for the SMGB Model that was further modified within the potential range for each PCU during calibration. Recharge coefficients were developed for each PCU, and these values are presented in Appendix E.

TABLE 6-3
RUNOFF AND RECHARGE COEFFICIENTS

Aquifer \ Land Use	Commercial/ Industrial	Suburban	Irrigated Area	Landfill	Quarry	Small Community	Rural Domestic	Rural/Native/Undeveloped
Runoff Coefficients - Average								
Purisima	82%	40%	26%	-	-	-	24%	21%
Santa Cruz Mudstone	85%	46%	32%	-	-	-	33%	27%
Santa Margarita - Quail Hollow	-	33%	-	26%	7%	30%	24%	12%
Santa Margarita - Scotts Valley	78%	33%	24%	-	7%	28%	22%	10%
Santa Margarita - Upland	-	-	-	-	-	-	29%	14%
Monterey	-	45%	-	26%	14%	40%	35%	22%
Lompico	-	-	-	-	-	-	32%	17%
Butano	-	-	-	-	-	35%	28%	14%
Locatelli	-	-	-	-	-	-	-	18%
Zayante	-	39%	-	-	-	32%	22%	10%
Granite	90%	-	-	-	-	-	-	-
Recharge Coefficients								
Purisima	1%	1%	1%	-	-	-	1%	1%
Santa Cruz Mudstone	1%	1%	1%	-	-	-	1%	1%
Santa Margarita - Quail Hollow	-	22%	-	1%	65%	48%	55%	65%
Santa Margarita - Scotts Valley	10%	22%	46%	-	55%	40%	45%	55%
Santa Margarita - Upland	-	-	-	-	-	-	14%	15%
Monterey	5%	5%	-	1%	5%	5%	5%	5%
Lompico	-	10%	-	-	35%	12%	14%	15%
Butano	-	-	-	-	-	25%	33%	35%
Locatelli	-	-	-	-	-	-	-	3%

Notes:

- Blank entries represent PCUs not present within the SMGB or contributing watershed
- Runoff coefficients represent annual average; however, quarterly coefficient applied are listed in Appendix E
- Coefficients for consumptive use and other losses are not directly input into the model so are not listed, but are listed in Appendix E.

6.7.3.3 Consumptive Use and Other Losses

Consumptive use or other losses accounts for water that either taken up by evapotranspiration processes in the unsaturated zone or otherwise not directed to either groundwater recharge or surface water runoff. This water is not directly accounted for in MODFLOW, but was used in determining the partitioning of rainfall to insure that consumptive use or other losses are being appropriately accounted for in the overall rainfall water balance.

Evapotranspiration is a primary consumptive use that varies based on the type of vegetation or ground cover a. Areas of more intensive vegetation such as the redwood forest can consume higher amounts of precipitation whereas more open areas will have a lower consumptive loss.

As for recharge and runoff, a coefficient was developed based on an understanding of the local conditions such as the large areas covered by redwood forest compared to more developed areas and a review of literature on the subject. The coefficient for consumptive use or other losses is varied quarterly to account for seasonal variation in vegetative update of water from the unsaturated zone. These were evaluated in context with the runoff coefficients to help get the initial seasonal variation in the runoff coefficient.

A significant portion of the rainfall falling on the Purisima and Santa Cruz Mudstone is considered to not reach the groundwater or surface water streams, but is lost to consumptive use or other outflows. Since this water does not reach the model domain, it is accounted for by applying a higher percentage coefficient for consumptive use and other loss percentage where these geologic units occur.

The coefficients for each PCU were tracked to insure that the total portioning between runoff, recharge and consumptive use and other losses always equal 100% to maintain the appropriate water balance over time. The consumptive use coefficients and the overall balance of coefficients are included in Appendix E.

6.7.3.4 Soil Moisture

Implied in the approach for portioning the rainfall is an assumption of the soil moisture budget. Soil moisture represents water in the unsaturated zone that is either held in place or is percolating downward by gravity. During the typical California climatic cycle of wet and dry seasons, the soil moisture can vary. During wet periods, as the soil moisture reaches capacity, the area may see an increase in the percentage of rainfall going towards runoff. During an extended drought, depletion of soil moisture may increase the recharge rate and consumptive use resulting in a decrease in runoff.

For the updated SMGB Model, the soil moisture budget is considered be relatively stable over time such that recharge from drought and wet cycles tends to average out over time. This is a simplifying assumption that is considered appropriate for the lack of soil moisture property data in the SMGB. The method does allow for the recharge coefficient to change over time and can even be allowed to change quarterly, so that more detailed scenarios could be developed.

6.8 Surface Recharge

The surface recharge includes the contributions from precipitation and return flows within the SMGB Model. The surface recharge is applied using zones that are defined by the geology and land use. The distribution of these zones is shown on Figure 6-10. Surface recharge is applied using the MODFLOW recharge package and using the methods outlined below. This summary discusses implementation of surface recharge into the SMGB model.

6.8.1 Precipitation Recharge

Precipitation is the primary source of groundwater recharge within the basin. Precipitation recharge applies the total available precipitation available for surface recharge per stress period. The MODFLOW Recharge package requires that recharge be defined as a rate that MODFLOW integrates over each recharge cell within the SMGB Model domain. The total available precipitation across the SMGB was calculated using the following assumptions and methods. A summary of precipitation recharge is presented in Appendix E.

- Quarterly precipitation totals for the period from 1984 through 2012 were tabulated for the SVWD and SLVWD rain gauges (Appendix C), which are continuously monitored.
- During periods of very high rainfall, saturated soils limit the amount of precipitation percolating into the soil and thus reduce the recharge potential. As a general rule, 50% of the total rainfall in excess of 20 inches is added to the total rainfall applied to surface recharge.
- A distribution function was used to account for delays in precipitation reaching the aquifer as surface recharge. Using this approach, all rainfall was accounted for but was distributed over multiple quarters. The distribution function was based on an initial assumption based on previous modeling and the conceptual understanding of the physical processes of infiltration and further modified during model calibration.
    - The final distribution function was 60% of the total rainfall during the current quarter, 30% from the previous quarter and 10% from the prior quarter.
- The quarterly rainfall was distributed proportionally to each isohytel zone consistent with the quarterly precipitation at the SLVWD and SVWD rain gauges. This approach captures seasonal variations in spatial distribution of precipitation across the SMGB. This allows that the actual rainfall distribution is honored. It incorporates the orographic effects when the difference between the SLVWD and SVWD gauges is high, but also distributes rainfall appropriately if the difference in minimal or in some cases reversed.
- The recharge rate is calculated separately for each quarter over the 1984 to 2012 base period. The recharge coefficient, as listed in Table 6-3, is applied to the area of each PCU based on the quarterly distributed rainfall per isohytel zone to determine the quarterly recharge rate from precipitation.

Because of the complex geology, a separate file was used to specify which model layer that the surface recharge would be applied. This is a change from the previous model where it was applied to the highest active layer. This change helped resolve issues where, for example, the high recharge rate from the Santa Margarita was applied to the much lower permeability Monterey, which led to unusually high groundwater levels at those locations. It is assumed that the precipitation falling on unsaturated areas of the Santa Margarita would not go the Monterey, and would most likely not reach the saturated groundwater areas.

6.8.2 Return Flows

Since the SMGB does not include large-scale irrigated agriculture, return flows are primarily include return flows from septic tanks, lawn irrigation, pipe leakage and quarry operations. Data for estimation of return flows in the SMGB is presented in Sections 2.6 and 2.7 and are summarized in Table 6-4.

Return flows are input into the SMGB Model using the MODFLOW Recharge package. The return flows are added to the appropriate land use categories as shown in Table 6-4. The total volume of return flows are divided by the land use category area to develop a rate that can be input using the MODFLOW Recharge package. Return flows are applied uniformly over time.

Septic system return flow accounts for the largest volume of return flow in the SMGB. There are an estimated 4,700 parcels with a septic system within the SMGB based on County permit records. The septic tank return flow was based on a uniform assumption of 40% of the estimated average daily use of 250 gallons of water per day per residence. Based on this, it is estimated that 658 AFY of septic tank return flow occurs in the SMGB.

Septic tank return flow was tabulated by counting the number of parcels within each land use zone containing septic tanks. Using the permit data provided by Santa Cruz County, a GIS analysis indicates that about 65% of those parcels are in the small community land use areas that are primarily located along the Highway 9 corridor. Most of the remainder, about 19%, is in the rural domestic land use area; and 12% in the rural/native/undeveloped land use areas.

The City of Scotts Valley provides wastewater collection, treatment and disposal within the city limits and some adjoining areas. However, a 1997 investigation of septic systems in the Scotts Valley area identified a large number of active septic systems within the City of Scotts Valley (Baseline, 1997, Todd, 2003). About 4%of the septic return flow is applied to the suburban areas of Scotts Valley.

Urban return flow accounts for return flows generated from lawn irrigation, pipe leakage and landscaping ponds. The Valley Gardens golf course and the Spring Lakes, Vista del Lago, and Montevalle mobile home parks maintain landscaping ponds. Todd (1998) estimated that about 14 AFY of return flow from the landscaping ponds. Pipe leakage is the amount of water that leaks from water and sewer pipes that percolates to groundwater. Studies of pipe leakage range from 5 to 30 percent of the total water use in an area (Lerner, 1986; Leauber, 1997; HydroFocus, 2007; CDWR, 2011). Recent water conservation efforts by the water districts have included accelerated repair and maintenance of water pipes to reduce pipe leakage. Lawn irrigation is generally assumed to apply near agronomic rates so return flows are considered minimal. Todd (1998) estimated over 200 AFY of return flows from lawn irrigation and pipe leakage.

Quarry operations return flows from water usage at the quarries. These were calculated as a percentage of the water usage at the quarry. The water usage was averaged over 5-year increments for estimating the return flow. The return flow was applied uniformly to the Hansen and Quail Hollow Quarries and adding the estimated return flow to the precipitation in that zone. This caused increased recharge at the quarries. Todd (1998) estimated over 200 AFY in quarry return flows. These are applied only for the years when the quarries were in operation.

Closures of the Hanson and Lonestar quarries in 2003 are reflected in the return flow input data. The Quail Hollow Quarry is still in operation or operational return flows are still applied.

The return flow volumes were tabulated and applied to the appropriate PCU to determine the quarterly recharge rate from return flows.

TABLE 6-4
SUMMARY OF RETURN FLOWS APPLIED IN SMGB MODEL

Land Use Type	Land Use Area	Septic	Urban	Quarry Operations
Units	acres	AFY	AFY	AFY
Commercial/Industrial	562	0	36	0
Rural Domestic	6,144	125	12	0
Rural/Native/Undeveloped	30,216	79	0	0
Small Community	2,158	428	45	0
Suburban	1,505	26	100	0
Irrigated Area	40	0	14	0
Landfill	84	0	0	0
Quarry	672	0	0	210
Total	41,381	658	207	210

6.8.3 Application of Surface Recharge to MODFLOW

In Groundwater Vistas 6, the data management is done by setting up database that specifies the recharge rate for each recharge zone for each stress period. The recharge zones are mapped into the SMGB Model using a GIS layer. The database is calculated in an EXCEL spreadsheet and output as a comma-delaminated file that is read directly into Groundwater Vistas 6. Use of the EXCEL spreadsheet allows for relatively easy data management of the recharge rates.

6.9 Streamflow

Streams are important hydrologic features within the SMGB. Locations of these features are shown on Figure 6-11. Groundwater-surface water interactions are dependent upon the relative gradient between the stream and the aquifer and the ability of the streambed to conduct water.

6.9.1 Stream Physical Characteristics

Groundwater-surface water interactions with the major tributary streams to the San Lorenzo River that flow across the SMGB are an important component of the water balance. Streams gather much of the precipitation that falls on the basin, and are a much faster route for water to move through the basin than is groundwater. These streams are simulated using the MODFLOW Streamflow Routing (SFR1) Package (Prudic *et al*, 2004). Figure 6-11 shows the locations of streams within the model domain.

In the previous SMGB Model, the streams were defined as boundary conditions using the Stream Package (STR; Prudic, 1989). The conversion to MODFLOW-NWT required that the simulation of groundwater–surface water interactions be converted to the Streamflow Routing

(SFR1) package. This package has several advanced features over the STR package. SFR1 provides a more realistic means to simulate surface runoff by adding runoff along the length of the stream rather than only at the head of the stream, and includes improved numerical methods of simulating groundwater-surface water interactions.

The SFR1 boundary conditions are applied to the model grid based on mapped locations of streams. Streams are divided into segments and reaches, with segments representing portions of streams between stream intersections (i.e. between locations where tributaries enter a stream, or where the stream enters another stream to which it is tributary) and reaches defined for each model cell within a stream segment (Prudic *et al*, 2004). Streambed elevations were estimated along the entire length for each stream using topographic maps and Santa Cruz County LiDAR data. Property data for the SFR1 stream segments is presented in Appendix E.

6.9.2 Runoff Volume Determination

The total available precipitation used for calculating both the recharge and runoff is derived from the measured precipitation in the SMGB. However, orographic effects make the distribution of rainfall variable across the SMGB. Therefore, rainfall distribution was based on an isohytel map that shows contours of average annual rainfall, including orographic effects, over the region (Figure 4-1). For the updated Model, the isohytel map used for the previous Model (ETIC, 2006) was replaced with one developed by Johnson (2009) based on detailed analysis of historical precipitation data from rain gauges in Santa Cruz County. This change helps to insure consistency in the analysis of work conducted by SVWD, SLVWD and others in the SMGB.

The total available precipitation across the SMGB was calculated using the following assumptions and methods:

- Quarterly precipitation totals were calculated for the SVWD and SLVWD rain gauges (Appendix C), which are the continuous monitored rain gauges in the SMGB. Data were tabulated for the period from 1984 through 2012.
- The quarterly rainfall was apportioned proportionally to each isohytel zone consistent with the quarterly precipitation total at the two rain gauges to capture variations in precipitation across the SMGB, primarily the orographic effects.
- It is assumed that during high rainfall periods, there is a higher percentage of runoff. For extremely wet quarters, only 50% of the total rainfall in excess of 20 inches is applied is applied to surface recharge, with the remainder added as excess runoff. This increases the contribution to runoff while maintaining the overall water balance.
- A distribution function was used to account for variability in runoff. Using this approach, all rainfall was accounted for but was distributed over multiple quarters. The distribution function was based on an initial assumption and modified during model calibration. For runoff, the distribution function was 80% of the total rainfall during the quarter and 20% from the previous quarter.
- Using these rules, the total available precipitation is calculated for each quarterly stress period for each of the eleven isohytel rainfall zones. The runoff coefficient is applied to each PCU within the contributing watershed to the SMGB

- The calculated runoff is included in the SFR1 Package. These watershed areas include some, but not all, areas within the SMGB, but also include upstream watershed areas outside of the SMGB for designated streams.

6.9.3 Application Runoff to MODFLOW

The distribution of runoff is calculated in an Excel spreadsheet that outputs the data as a MODFLOW SFR1 Package input file that can be read into the updated SMGB Model directly using the Groundwater Vistas 6 MODFLOW processor (ESI, 2011).

The SFR1 Package routes streamflow through network of channels or streams. The water balance tracks inflow and outflows at each stream reach including 1) specified inflows from the watershed outside the model domain; 2) the incoming upstream flow; 3) the specified inflow from surface runoff along the length of the stream; and 4) groundwater inflow or outflow that is calculated by the model. SFR1 applies streamflow generated outside of the SMGB at the first reach of each stream with headwaters outside the SMGB. Runoff from the areas within the SMGB is applied uniformly along the length of the stream segment.

MODFLOW then calculates the exchange of water between the stream and the aquifer based on the stream stage (which can be either specified or calculated based on the geometry of the streambed) and the conductance of the streambed. The inflow to the reach is modified by the calculated addition of or subtraction to groundwater and the total is routed to the next reach downstream. Where a tributary enters a stream, the flow downstream equals the total flow of the upstream reaches in both the main stream and the tributary, modified by exchange with groundwater. If the calculated leakage to groundwater exceeds the inflow to a stream reach, the reach goes dry, and no streamflow is passed to the next reach; there is then no flow in the stream unless at some downstream point there is a net input from the aquifer to the stream. A dry stream can be reactivated if the groundwater elevation in the underlying aquifer is greater than the streambed so that ground-water flow can enter the stream and it begins to flow again during the time step.

6.10 Rivers and Lakes

The San Lorenzo River and Loch Lomond Reservoir were defined separately from the smaller tributary streams in the SMGB. The following describes how these features were addressed in the SMGB Model.

6.10.1 San Lorenzo River

The San Lorenzo River is simulated using the MODFLOW River Package for the main river channel (Figure 6-11). The MODFLOW River Package allows either gaining or losing stretches along the river based on the relative difference between the stream stage and groundwater elevations to represent groundwater-surface water interactions.

Although the San Lorenzo River is the primary regional hydrologic feature, much of its course lies outside of the SMGB. The River is not simulated in the areas outside of the SMGB. Much of the course of the River within the SMGB is underlain by low permeability units such as the Monterey, which significantly reduces the groundwater-surface water interactions. Because of these characteristics, the river package is considered appropriate for simulating the River.

In addition, the short sections of Bear and Boulder Creeks in the far northwestern corner of the SMGB Model, near where they discharge into the San Lorenzo River, are also simulated using the MODFLOW River Package. These are streams with relatively large watersheds but only occur over a very small area of the SMGB Model near where they empty into the San Lorenzo River. Therefore, their interaction with the SMGB is limited, and use of the River Package was considered appropriate.

The river stage was estimated along the entire length based on the USGS topographic maps, Santa Cruz County LiDAR data, and available reports and data on the San Lorenzo River system. The riverbed conductance term includes the depth, width, and length of the stream segment in a model cell, and the transmissivity of the streambed materials based on an estimate of the streambed thickness and hydraulic conductivity. The riverbed hydraulic conductivity was determined during calibration and was comparable to the underlying aquifer material.

6.10.2 Loch Lomond

The Loch Lomond Reservoir was simulated using the MODFLOW River Package (Figure 6-11). An average lake stage was applied over the Base Period based on available reports and data on the Loch Lomond operations. Loch Lomond is considered a minor recharge source to the SMGB that primarily overlies the upper Butano and Monterey Aquifers. Only a small area of Loch Lomond overlies the Lompico. Also, there are no groundwater elevation data available in the Loch Lomond area to calibrate potential leakage rates. Because of this lack of data in this part of the SMGB, a simplified, regional approach for simulating Loch Lomond was applied. Average annual conditions were applied to simulate Loch Lomond, and these conditions remained constant throughout the simulation. An average lake stage of 575 feet and an average lakebed elevation of 530 feet were applied uniformly over the lake area. The lake bed conductance was applied over the entire cell. Loch Lomond overlies the upper Butano, Lompico and Monterey, so the hydraulic conductivity of the lake bed materials was set comparable to the underlying aquifer material.

6.11 Natural Discharge

Natural groundwater seepage represents outflows from springs and ephemeral streams, and is simulated using the MODFLOW drain package (Harbaugh *et al* 2000). The amount of groundwater flowing into or out of this boundary is influenced by the relative hydraulic gradient of the model at the location of the boundary condition.

6.11.1 Springs

The exposed sandstone along the margins of the outcrop area of Santa Margarita Sandstone is a potential area for springs to form (Figure 6-11). Therefore, the MODFLOW drain package was placed along much of the margin area of the Santa Margarita to allow groundwater to discharge from the Santa Margarita if hydraulic conditions are suitable. Discharge from the springs represents an outflow of groundwater from the SMGB. It is considered that most of these springs are small and that the water will be lost to evapotranspiration. Larger springs are incorporated into the SFR1 Package input so that they can connect with the streamflow.

Springs are represented as discharge points where groundwater is allowed to drain from the aquifer at a rate controlled by the hydraulic conductivity and the groundwater elevation. These seepages were set at elevations coincident with the lower extent of the Santa Margarita Sandstone to represent the hydraulic low point of the spring. The drain conductance was assigned a uniform 660 ft^2/d as representative of the overall average conditions for seepage based an average hydraulic conductivity of 3 ft/day occurring over a 220 square foot area representing the base of the Santa Margarita along the entire length of each model cell. The conductance worked satisfactorily, so was not updated during calibration.

6.11.2 Ephemeral Drainages

A few minor streams were simulated using the MODFLOW drain package rather than the SFR1 package shown on Figure 6-11. The drain package allows only for groundwater to discharge. This option was applied only to streams considered to only be gaining reaches where discharge may occur, but were not considered recharge locations.

This included five ephemeral streams flowing over low permeability units such as the Monterey and Locatelli. The potential runoff that may be handled by these ephemeral streams was included in the runoff calculations applied to the SFR1 Package so was accounted for and applied to the larger stream that the ephemeral stream emptied. The drain package was also applied to three streams with only short segments that flowed over the SMGB and drained directly to the San Lorenzo River or out of the SMGB. For both cases, the drain conductance term was set comparable to the underlying aquifer material. The elevation of the drain was estimated along the entire length of the ephemeral stream based on USGS topographic maps and Santa Cruz County LiDAR data.

6.11.3 Evapotranspiration

Evapotranspiration (ET) represents groundwater outflow from evaporation to the atmosphere and uptake by plants from the saturated zone. This is distinct from ET associated with soil moisture before it reaches the groundwater aquifer that is sustained by the total available precipitation not accounted for by runoff or recharge (see Section 6.6).

The MODFLOW ET package is used simulate ET directly from the groundwater aquifer. ET is defined over the entire model domain; however, ET only occurs in areas of shallow groundwater. In the SMGB, this is generally limited to riparian areas adjacent to streams. ET includes uptake from both phreatophytes (plants that require groundwater) and mesophytes (plants that can utilize groundwater) either directly from the saturated zone or from the overlying capillary fringe (Meinzer, 1927; Robinson, 1958; and Lewis and Burgy, 1964). ET from the capillary fringe is replenished with groundwater from the underlying aquifer, so it is also considered a loss of groundwater (Lubczynski, 2011).

The ET rate was developed using a method outlined in WUCOLS (2000) that multiples the ET_o rate by a vegetation or crop factor. The ET_o rate was based on data for Santa Cruz County by the University of California (Snyder *et al* 1992) and CIMIS (1998, 2005). The ET_o was calculated for each of the three-month stress periods (Table 6-5). The ET_o is the potential maximum ET rate; however, actual ET may be less depending upon the land use and vegetation. The landscape factor was derived from literature values from WUCOLS (2000) and Allen et al (1998). The landscape factor represents a percentage of the reference ET that is actually used by the vegetation. The landscape factors used are listed in Table 6-5.

The MODFLOW ET package is used simulate ET directly from the groundwater aquifer. Twelve ET zones were defined based on a combination of land use and vegetation type. Land use is based on County GIS data (Figure 2-2) and vegetation is based USDA soil survey data (Figure 3-6). ET is depth limited with an extinction depth ranging from of 1.0 feet to 12.0 feet, depending on the local land use and vegetation. MODFLOW decreases the ET linearly from the surface to an ET rate of zero at the extinction depth. Therefore, ET is highest when groundwater levels are near the surface and zero when groundwater levels are near the extinction depth. The ET zones applied are listed in Table 6-5 and shown on Figure 6-12.

ET is also a head-dependent boundary condition. The ground surface elevations were developed from the USGS topographic maps and Santa Cruz County LiDAR data. Because of the complex geology, a separate ET layer application file was used to specify the model layer to which the ET would be applied. This is a change from the previous model where it was applied to the highest active layer. ET is most prominent in the Santa Margarita Aquifer, but can occur in limited areas in other aquifers in locations where shallow groundwater occurs.

Another issue is that the NWT solver can experience convergence issues in areas where the ET extinction depth exceeds the model layer thickness (Niswonger *et al*, 2011). To eliminate this, an ET surface map was developed that adjusted the ET surface to keep the ET from exceeding the bottom of the model layer, or the cell was assigned the next lowest model layer in the ET layer application file.

TABLE 6-5
EVAPOTRANSPIRATION DATA APPLIED IN SMGB MODEL

Evapotranspiration Zone	Ref No.[1]	Extinction Depth	Factor[2]	Fall Oct-Dec	Winter Jan-Mar	Spring Apr-Jun	Summer Jul-Sep
Units		feet	%	in/quarter	in/quarter	in/quarter	in/quarter
Reference ETo				5.68	5.78	12.18	12.93
Commercial/Industrial	1	5.0	17%	0.99	1.01	2.13	2.26
Suburban	2	5.0	56%	3.20	3.25	6.85	7.27
Irrigated Area	3	5.0	80%	4.54	4.62	9.74	10.34
Open Space	4	7.0	40%	2.27	2.31	4.87	5.17
Open Grassland	5	5.0	60%	3.41	3.47	7.31	7.76
Redwood Forest	6	12.0	85%	4.83	4.91	10.35	10.99
Pine Forest	7	12.0	60%	3.41	3.47	7.31	7.76
Fir Forest	8	12.0	85%	4.83	4.91	10.35	10.99
Scrub Vegetation	9	7.0	50%	2.84	2.89	6.09	6.47
Landfill	10	1.0	1%	0.05	0.05	0.11	0.12
Quarry	11	1.0	23%	1.28	1.30	2.74	2.91
Other	12	7.0	40%	2.27	2.31	4.87	5.17

Note: [1]Reference number corresponds to ET zone number on Figure 6-12.
[2]Reference ET_o from Snyder *et al* (1992) and CIMIS (1999)
[3]Landscape Factor from Allen *et al* (1998) and WUCOLS (2000)

6.12 Initial Head Condition

As an initial step, a steady-state groundwater flow model was constructed for the SMGB. A steady-state simulation solves for groundwater elevations for a single stress period that is considered not to change over time. A steady-state calibration is typically evaluated using average conditions over a period of time. The primary purpose of the steady-state model was to serve as a time-effective process to develop the initial spatial distribution of groundwater levels and boundary conditions. With such a large and complex numerical model, the time required to run the model was significantly shorter than that for the transient model. This is especially important during the early stages of model development. The steady-state model is considered as only one step in the model development process. Therefore, the discussion of the steady-state calibration is limited, and the transient calibration is used for most interpretations.

The steady-state model was set up using a single stress period to simulate conditions prior to the transient model for the 28-year base period. The boundary conditions were based on an arithmetic average of the water balance components. The observed groundwater elevations used as calibration targets were also an arithmetic average for all water levels measured during the 28-year base period. This was not a true calibration process, but a model initialization step where getting the model to simulate the large-scale groundwater features prior to going to the more time-consuming transient model calibration.

The steady-state model was also used to develop the initial groundwater elevations that serve as the starting condition for the transient model. For this, groundwater pumping was applied to represent the long-term average pumping prior to 1985. The land use component used to estimate groundwater recharge was set to a predevelopment condition to reduce the effect of urbanization primarily in the Scotts Valley area. The results of the steady-state model were matched to available groundwater elevation data for the early 1980’s to obtain an appropriate starting condition. This was an iterative process and the steady-state model was updated during the transient model calibration to incorporate significant changes in the model setup.

The advantage of using steady-state model results for the starting condition is that the groundwater elevations are in a state of equilibrium with the model setup. This process helps to avoid water balance issues that can occur in the early time steps.

Section 7: Historical SMGB Model Calibration

Model calibration is the process reducing uncertainty in the simulation by matching simulated results to observed data. The more extensive the calibration process, the more constrained the model becomes, thereby reducing uncertainty in the results.

7.1 Calibration Approach

Model calibration is the process reducing uncertainty in the simulation by matching simulated results to observed data. The more extensive the calibration process, the more constrained the model becomes, thereby reducing uncertainty in the results. Calibrating to multiple data sets under differing stresses (i.e. recharge and discharge rates) reduces this “non-uniqueness”, thereby reducing the uncertainty. For the SMGB, model calibration was performed using the following data sets:

- Groundwater Elevations
- Streamflow
- Water Balance
- Convergence

During the calibration process, the aquifer properties and boundary conditions are varied within an acceptable range until the closest fit of the simulated versus measured data is achieved. There are multiple combinations of aquifer properties and boundary conditions that can be used to match a single set of groundwater elevation data. Calibrating over the 28-year base period from 1985 to 2012 included wet, dry, and normal years with varying degrees of pumping. This aspect of the calibration is important to demonstrate that the model has the capability to simulate historical changes in groundwater elevations and surface water flows, and is therefore capable of forecasting future conditions in the SMGB. This capability is necessary for the model to serve as a useful groundwater management tool.

7.2 Calibration to Groundwater Elevation Data

For the SMGB model, the primary calibration data are groundwater elevations that are evaluated by taking the difference, or residual, between simulated and measured groundwater elevations at the same time and location over the historical period from October 1984 to September 2012. Measured groundwater elevation data are collected from several different reporting agencies including SVWD and SLVWD as well as data from the environmental remediation sites in the SMGB. This comparison of observed versus simulated groundwater elevations is based 16,344 groundwater elevation measurements over the 28-year base period from 196 wells. The locations of these wells are shown on Figure 7-1. The groundwater elevation data was evaluated using several methods to assess the level of calibration. These criteria include:

- Statistical Analysis
- Hydrographs
- Groundwater Contour Maps and Flow Characteristics

Since the previous Model was updated by SVWD as part of the groundwater management program with data through 2012 (Kennedy/Jenks, 2013), improvement in the calibration can be measured by direct comparison of the performance of the two versions of the SMGB Model using the exact same data set.

It should be noted that some degree of difference or residual between the observed and simulated groundwater elevations is expected. Residuals may be due in part to localized effects or data quality issues. For example, residuals can result from using groundwater elevations from pumping wells as calibration targets. MODFLOW calculates the groundwater elevation for the center of a model cell rather than at the well location itself. MODFLOW also does not take into account the impact of well efficiency on groundwater elevations at pumping wells. In addition, the timing of the observed groundwater elevations does not exactly match the model stress periods.

7.2.1 Statistical Calibration

The calibration was evaluated using a statistical comparison of difference (or residual) between measured and simulated groundwater elevations. The primary performance measure is to improve upon the calibration from the previous Model. Table 7-1 provides a list of statistical measures to assess the calibration by comparing of the difference or residual between measured and simulated groundwater elevations.

A brief of the statistical measures used to evaluate the calibration results shown on Table 7-1 is summarized below:

- The residual mean is computed by dividing the sum of the residuals by the number of residual data values. The closer this value is to zero, the better the calibration especially as related to the water balance and estimating the change in aquifer storage. The residual mean of 0.7 feet is an improvement of 86% over the previous Model.
- The absolute residual mean is the arithmetic average for the absolute value of the residual so it provides a measure of the overall error in the model. The absolute residual mean of 13.3 feet is an improvement of 31% over the previous Model.
- The residual standard deviation evaluates the scatter of the data. A lower standard deviation indicates a closer fit between the simulated and observed data. The standard deviation for the calibrated model is 19.4 feet, which is an improvement of 32%.
- The Root Mean Square (RMS) Error is the square root of the arithmetic mean of the squares of the residuals is provides another measure of the overall error in the model. The RMS Error for the calibrated model is 19.4 feet, which is an improvement of 33%.

Figure 7-2 provides a scatter plot of measured versus simulated groundwater for both the updated and previous Models. The correlation coefficient ranges from 0.0 to 1.0 and is a measure of the closeness of fit of the data to a 1-to-1 correlation. A correlation of 1.0 is a perfect correlation. In general, the scatter along the correlation line is minor in comparison to the range of the data. Comparing the results between the two Model versions shows that the updated Model has a tighter fit with fewer outliers compared to the previous Model illustrating the general improvement in the model calibration. The correlation coefficient for the updated model is 0.96 as compared to 0.92 for the previous Model, which is an improvement of 5%. The correlation coefficient of 0.96 demonstrates a very strong correlation between simulated and observed groundwater elevations.

The scaled absolute residual the ratio of the absolute residual mean is divided by the range of observed groundwater elevations. This ratio helps to put the scatter of the residuals, as shown on Figure 7-2, into perspective with respect to the scale of the groundwater basin. This ratio for the SMGB Model is 0.019, which puts the statistical variability at less than 2% of the range. This is a 31% improvement over the previous Model. A ratio below 0.15 is generally considered a well calibrated (ESI 2011).

Overall, the results of the calibration showed a general improvement in the calibration of over 30% over the previous model. This indicates that the changes implemented for the updated Model were successful and resulted in improved model performance. Appendix F provides a summary statistics for each of the 196 wells used in the calibration process. On a well by well basis, the calibration improved for 64% of these wells. Of these, over 38% the absolute residual mean improved by greater than 5 feet, whereas only 17% decreased by 5 feet compared to the Previous Model. In some cases, both significant improvements and decreases occurred in closely spaced wells where the regional SMGB model was not able to resolve the local-scale groundwater gradients. Emphasis was on improving the calibration regionally and for wells with long-time histories.

TABLE 7-1
SUMMARY OF CALIBRATION FOR THE SMGB MODEL
RELATIVE DIFFERENCE TO PREVIOUS MODEL

Calibration Measure	Updated Model	Previous Model	Percent Change
Units	Feet	Feet	Percent
Residual Mean	0.7	-5.1	86%
Residual Standard Deviation	19.4	28.5	32%
Absolute Residual Mean	13.3	19.3	31%
Root Mean Square (RMS) Error	19.4	29,0	33%
Scaled Absolute Residual Mean	0.019	0.028	31%
Correlation Coefficient	96%	95%	5%
Number of Observations	16,344	16,344	same

Note: Previous Model is the ETIC (2006) version updated with data through 2012
Updated Model is the model version from this report with data through 2012.

The statistical analysis can also been performed per aquifer. Figure 7-2 shows the data grouped by aquifer, and Table 7-2 provides a summary for the statistical calibration analysis broken down by aquifer.

Although the data points used for both versions of the models are the same, the number of observations per aquifer did vary due to changes in the defining the hydrogeological conceptual model that resulted in changes to the configuration of the aquifers primarily in the Scotts Valley area. Most of the groundwater elevation data available in the SMGB is from wells completed in the Santa Margarita.

TABLE 7-2
SUMMARY OF MODEL STATISTICAL CALIBRATION VALUES BY AQUIFER

Calibration Measure	Updated Model[1]	Previous Model[2]	Percent Change
Units	Feet	Feet	Percent
Santa Margarita Aquifer			
Residual Mean	0.2	-5.0	95%
Absolute Residual Mean	9.5	14.5	35%
Residual Standard Deviation	13.7	20.7	34%
Root Mean Square Error	13.7	21.3	36%
Scaled Absolute Residual Mean	0.023	0.034	31%
Correlation Coefficient	98%	96%	2%
Number of Observations	11,173	12,413	-10%
Monterey Aquifer			
Residual Mean	6.3	-35.3	82%
Absolute Residual Mean	24.4	39.4	38%
Residual Standard Deviation	32.2	25.1	-28%
Root Mean Square Error	32.8	43.3	24%
Scaled Absolute Residual Mean	0.130	0.348	63%
Correlation Coefficient	61%	58%	6%
Number of Observations	744	288	158%
Lompico Aquifer			
Residual Mean	1.0	3.21	70%
Absolute Residual Mean	20.8	31.5	34%
Residual Standard Deviation	26.5	42.4	38%
Root Mean Square Error	26.5	42.5	38%
Scaled Absolute Residual Mean	0.055	0.084	34%
Correlation Coefficient	89%	73%	22%
Number of Observations	3,810	3,135	22%
Butano Aquifer			
Residual Mean	0.9	-49.6	98%
Absolute Residual Mean	29.9	56.7	47%
Residual Standard Deviation	36.5	48.2	24%
Root Mean Square Error	36.5	69.1	47%
Scaled Absolute Residual Mean	0.044	0.083	47%
Correlation Coefficient	93%	78%	19%
Number of Observations	202	172	17%
Locatelli Aquifer			
Residual Mean	1.4	-23.4	94%
Absolute Residual Mean	9.4	35.6	74%
Residual Standard Deviation	11.8	31.4	62%
Root Mean Square Error	11.9	39.1	70%
Scaled Absolute Residual Mean	0.077	0.188	59%
Correlation Coefficient	94%	63%	49%
Number of Observations	414	336	23%

Note: [1]Updated Model is the model version from this report with data through 2012.
[2]Previous Model is the ETIC (2006) version updated with data through 2012 (Kennedy/Jenks, 2013)

Because of the changes in the interpretation of the geology, the number of wells assigned to the Santa Margarita declined from 146 to 124. These were mostly wells associated with the environmental remediation along Mount Hermon Road in Scotts Valley that were moved to the Monterey and Lompico. Overall, there was significant improvement in each aquifer as shown on Table 7-2. The following provides a summary of the calibration per aquifer.

Overall, the calibration statistics for the Santa Margarita improved significantly. The residual mean for the Updated Model of 0.2 feet shows an improvement of 95% indicating an improved estimate of the water balance including groundwater-surface water interactions. Other statistical calibration measures improved from 31% to 36% demonstrating an overall improvement. The correlation coefficient for the Santa Margarita was already high, and increased by 2% from 96% to 98%.

Since the Santa Margarita Aquifer has a large number of wells spread over the SMGB, the statistical analysis can be regionalized.

- Bean Creek Subarea – for the 19 wells in this subarea, the absolute residual mean improved 16% to 6.0 feet.
- Quail Hollow/Olympia Subarea – for the 32 wells in this subarea, the absolute residual mean improved 21% to 11.2 feet.
- Scotts Valley Subarea – for the 59 wells in this subarea, the absolute residual mean improved 43% to 6.6 feet.
- Pasatiempo Subarea – for the 14 wells in this subarea, the absolute residual mean improved 5% to 12.9 feet.

Improvements in the statistical calibration in the Santa Margarita Aquifer are widespread, but are greatest in the Scotts Valley and Quail Hollow/Olympia subareas. The lower absolute residual mean in the Bean Creek and Scotts Valley Subareas is more a reflection of the lower range in groundwater level variation, whereas in the other subareas, active pumping either in or in units that influence the Santa Margarita leads to greater groundwater level variability with a higher absolute residual mean.

For the Monterey, the total number of wells in the Monterey increased from 7 to 10 wells including SVWD Well #9 and other nearby wells. SVWD Well #9 is pumping well, so the data are more highly variable, or noisy. The new data caused an increase in the standard deviation, which decreased by 28%, for the small data set in the Monterey. However, the residual mean, absolute residual mean and the scaled absolute residual mean improved by 82%, 38% and 63%, respectively, showing general improvement in the calibration for the Monterey wells. The geologic character of the Monterey is a primarily fine-grained unit that acts as a regional aquitard hydraulically separating the Santa Margarita and Lompico Aquifers. However, it does contain locally significant sand layers that have been used by water supply wells. The local nature of these sand layers presents a challenge for the regional scale of the SMGB Model.

The Lompico also had the greatest increase in data points due to an additional 16 wells shifted to the Lompico compared to the previous Model. Overall, the calibration statistics for the Lompico improved from 31% to 35% demonstrating a significant overall improvement in the calibration for the Lompico. The residual mean improved by 70% to 1.0 indicating an improved estimate of the water balance, and the correlation coefficient improved to 89% indicating a better fit to the data for the Lompico.

The Lompico Aquifer has a large number of wells mostly located along the eastern side of the SMGB and provides a major source of the water supply for SLVWD and SVWD. The two subareas were defined that allow for an assessment of the statistical analysis for these two subareas.

- Scotts Valley Subarea – for the 36 wells in this subarea, the absolute residual mean improved 30% to 20.5 feet.
- Pasatiempo Subarea – for the 15 wells in this subarea, the absolute residual mean improved 43% to 21.3 feet.

The statistical calibration for the two subareas is similar with the absolute residual mean ranging from 20.5 to 21.3 feet. Improvement was greater in the Pasatiempo Subarea. The Lompico is heavily pumped and much of the available data is from pumping wells which leads to greater groundwater level variability with a higher absolute residual mean.

The Butano is relatively data poor with only about 400 measurements from six wells; however, significant improvements to the calibration were achieved. A key part of this was due new data in the Butano and simulating the Butano with three model layers rather than one to better simulate vertical differences representing the geologic complexity of this very thick formation across the SMGB. Importantly, the residual mean decreased from -49.6 to 0.9 feet for an improvement of 98% indicating an improvement in the overall water balance. The absolute residual mean and residual standard deviation statistics improved from 24% to 47%. The variability is due to the primary source of groundwater level data is from the pumping wells, which are more highly variable, or noisy.

The Locatelli is a small aquifer limited to the southwestern part of the SMGB. However, several wells are located in the Locatelli. The calibration statistics for the Locatelli also improved significantly with parameters improved by 15% to 71%. Importantly, the residual mean decreased from -23 to 1.4 feet, and the absolute residual mean decreased from 35.6 to 9.4 feet. These changes resulted in the correlation coefficient to increase from 63% to 94%.

Based on the statistical evaluation, the model is considered to be reasonably well calibrated both on an overall level and with respect to each Aquifer. The Santa Margarita and Lompico are the important aquifer principally used for water supply, so the strong calibration in these units is important for use of the model for groundwater management. Most of the remaining statistical variability lays in the geologically complex and relatively data poor Monterey, Butano and Locatelli aquifers. These calibration data span a representative distribution of hydrologic conditions observed throughout the basin and over time.

7.2.2 Hydrograph Calibration

Hydrographs provide a detailed time history of groundwater elevations for specific wells. This time history data includes the impact of varying climatic and pumping stresses on the groundwater basin. Comparing hydrographs of model results versus observed data provides a measure of how well the model handles these changing conditions through time.

For calibration purposes, the hydrographs were inspected to evaluate how well the model results matched the overall magnitude and trend of the observed groundwater elevation data over time. For the transient model, it was considered more important to honor the overall trend of the data. A hydrograph was considered a good match if the model simulated the trend, but the groundwater elevations were offset.

Much of the available groundwater elevation data is from active production wells which show a wide range of groundwater levels for pumping and non-pumping conditions. Pumping levels include both instantaneous response to pumping and well efficiency effects, whereas, non-pumping conditions incorporate groundwater recovery without pumping. The model averages out operational conditions over a 3-month period, so the approach for calibration of pumping wells was to consider the simulated groundwater levels falling within the range of pumped and non-pumped conditions range as appropriately calibrated. This leads to a higher residual that affects the statistical analysis but is considered appropriate for the scale of the SMGB Model.

The flat-line portions on some hydrographs represent the model cell going dry at these locations in the previous Model. In the previous Model, if a model cell went dry, it remained inactive for the remainder of the simulation. By using the NWT solver, the model is able to "rewet" dry cells and keeps them active throughout the simulation.

Of the 196 wells with groundwater elevation data, 48 hydrographs from different parts of the basin are included on Figures 7-3 through 7-11 for the hydrograph evaluation. This representative sample includes about 25% of the total wells. The vertical scales for the set of six hydrographs shown on each figure are consistent to show the relative scale of variation in groundwater levels. The following provides a brief discussion of observations from each set of hydrographs.

In the vicinity of SLVWD's Quail Hollow and Olympia Subarea, six hydrographs are presented as representative of the 32 wells completed in the Santa Margarita Sandstone (Figure 7-3). Olympia #3 and Quail #5/#5A are pumping wells that illustrate the variability in measured data and the calibration approach of getting within the range. Olympia #3 shows a better match to the measured data whereas Quail Hollow #5/#5A show results similar to the previous Model. Quail Hollow Wells #8, MW-5 and MW-B illustrate the improvement for the calibration in the Quail Hollow area with a closer match to measured data. Ben Lomond Landfill MW-9 illustrates an area with low groundwater level variability with little change in calibration results.

In the Bean Creek Subarea, six hydrographs are presented as representative of the 19 wells completed in the Santa Margarita Sandstone (Figure 7-4). Results were mixed in this area. RMC #2 shows an example of significant calibration improvement by focusing some time to get a better match in this generally data poor area. Many wells are associated with the Watkins-Johnson Superfund Site. These include WJ-22 and Bowman Test Pit #1, which show minor improvement from the previous Model. Skypark M-1 is an example of improvement based on reclassification as this well was listed as Monterey in the previous Model, but review of data showed that it was completed in the Santa Margarita. Wells in the center of the SMGB showed little to no improvement. Mission Springs and TW-18 provide examples of the model calibration in this area. Attempts were made to improve the calibration, but this typically led to problems in other areas. This is a potential area for improvement in future model updates.

Figure 7-5 provides six hydrographs from western Scotts Valley near SVWD #9 and #10 comparing results from the Santa Margarita, Monterey and Lompico Aquifers. The results for SVWD #10 remained consistent, and removal of a data entry error in the pumping data for the previous Model fixed an issue of low groundwater levels in 2009. WJ-49 is completed in the upper Monterey (Model Layer 2) and shows improved calibration by splitting the Monterey. WJ-OB3 shows that the range in groundwater levels for the Santa Margarita is less than for the deeper horizons and that the model was able to simulate those vertical differences.

SVWD #9, #9 Monitor and Montevalle #3 represent three wells affected by the geologic reinterpretation. These wells originally put in a much thicker Santa Margarita Sandstone, but are now reclassified as being in the lower Monterey (Model Layer 3). The previous Model showed a better fit to the data, but this was controlled by adding an internal fault within the Santa Margarita. Removing the fault and reclassifying the wells represents a better conceptual understanding, but the degree of calibration declined. This may represent that the conditions in these wells represent more localized conditions, such as multiple water bearing zones in the Monterey, that are not captured in the regional SMGB Model. The difference is primarily in how quickly the groundwater levels drop in the early part of the model before 1990, but after 1990, the trend is much closer. Therefore, the model appears to overestimate the rate of decline in these wells during prior to 1990, but provides a reasonable simulation after 1990. The flat-line portions on #9 Monitor and Montevalle #3 represent the model cell going dry at these locations in the previous Model.

Figure 7-6 provides six hydrographs from the Camp Evers areas in western Scotts Valley near the intersection of Mount Hermon Road and Scotts Valley Drive that compares results from the Santa Margarita and Lompico Aquifers. Two pumping wells, Mañana Woods #2 and Spring Lakes #4 show minor improvements in the calibration. The environmental monitor wells MW-4 Chevron, MW-5 Shell, CEMW-12 and CEMW-22C show significant improvement in matching groundwater levels in this area. Much of this is due to the improved solved not letting downgradient areas in the Santa Margarita go dry and providing a more stable hydraulic communication between the Santa Margarita and Lompico in this area where the Monterey is absent.

Figure 7-7 provides six hydrographs from the Pasatiempo area west of the City of Scotts Valley for wells completed in the Santa Margarita Aquifer. In general, this was a problematic area in both versions of the Model that is not as well calibrated as other areas. However, some improvements were made in this area. Vista del Lago #1 to the south went dry in the previous Model, but now shows an improved calibration. SLVWD wells Pasatiempo MW-2, Champion and New Probation showed similar results compared to the previous Model with residuals ranging from 10 to 20 feet. Hidden Glen and Kaiser #3 did show improvement in calibration results. The flat-line portions on Vista del Lago #1 and Kaiser #3 represent the model cell going dry at these locations in the previous Model, indicating improvements mostly due to the NWT solver.

Figure 7-8 provides six hydrographs from the Pasatiempo area west of the City of Scotts Valley for wells completed in the Lompico Aquifer. Improvements in Lompico Aquifer in the Pasatiempo area were greater than in the Santa Margarita Aquifer. SLVWD wells Pasatiempo MW-1, Estrella, Pasatiempo #6 and Pasatiempo #7 showed improvement in matching measured data especially prior to 2004. After 2004, the simulation results indicate a recovery in groundwater levels that is not reflected by the measured data. This may reflect some additional unaccounted for pumping or a change in the recharge rate after 2004 that is not captured in the updated Model. Kaiser #4 and Mount Hermon #2 also show improvement in calibration compared to the previous Model.

Figure 7-9 provides six hydrographs from the El Pueblo area in central Scotts Valley for wells completed in the Lompico Aquifer. In general, calibration for this area improved slightly, but this was an area of better calibration in the previous Model so less effort was put into this area. The SVWD #6, #7, #11 Monitor, and #11B all show incremental improvement over the previous Model. TW-19 is located in northern Scotts Valley and shows a closer fit to observed data in this area. The Rockery Well, located south of the El Pueblo area, also shows a closer fit to measured data and shows that the model is able to represent the relatively low variation in groundwater levels in this area as compared to the El Pueblo wells.

Figure 7-10 provides six hydrographs from wells completed in the Butano and Locatelli Aquifers. SVWD Wells #3B, 7A and #15 Monitor show a better calibration with simulated results more within the range of the measured data. Oly #9 Well is from an environmental site in Boulder Creek that is completed either in the upper Butano (Model Layer 5) or the alluvium overlying the Butano. Elevation data from this well was surveyed to a local coordinate system and not to a regional system, so the measured groundwater elevations are estimated; however, the simulated results follow the general flat-lying trend indicating the groundwater-surface water interactions with the San Lorenzo River and its tributaries.

Data for the Locatelli shows that for these wells with long groundwater level histories, the model provides a reasonable estimate of the long-term trends. Since the Locatelli is a minor aquifer in the SMGB with no municipal pumping, no additional time to further refine the calibration for the Locatelli was undertaken.

In summary, the model results in Figure 7-3 to 7-10 show that the SMGB Model is able to match these appropriate responses in their respective areas. Overall, the results of the model calibration to the various criteria indicate that the model is reasonably well calibrated.

7.3 Calibration to Streamflow Data

An important function for the SMGB Model is to have the capability to assess groundwater-surface water interactions especially variation in baseflow due to changes in groundwater levels in the aquifers. The SMGB Model uses the MODFLOW-based SFR1 Package for simulating streamflow that uses a mass-balance or continuity approach for routing flow through a stream network. This approach is best suited for modeling long-term changes (months to years) in ground-water flow using averaged flows in streams. The SFR1 Package is not designed for the transient exchange of water between streams and aquifers to examine short-term (minutes to days) effects caused by rapidly changing streamflows.

7.3.1 USGS Stream Gauge Flows

The SFR1 Package through a stream network and calculates the water budget of each reach to determine the quantity of streamflow during each time step. The SFR1 Package routes streamflow through network of channels or streams. The water balance tracks inflow and outflows at each stream reach including 1) specified inflows from the watershed outside the model domain; 2) the incoming upstream flow; 3) the specified inflow from surface runoff along the length of the stream; and 4) groundwater inflow or outflow that is calculated by the model.

The approach to model calibration for streamflow is to verify that the SFR1 water balance is producing average flows over the 3-month time step that are comparable to those for the USGS stream gauge data in the SMGB. Since stream gauge data responds to short-term fluctuations in streamflow which the SFR1 Package does not; therefore, calibration is based on visual inspection. Figure 7-11 provides a comparison of streamflow in the SMGB Model at the Bean Creek, Carbonera Creek and Zayante Creek USGS streamflow gauges. The SMGB Model shows a good correspondence to the overall seasonal variation and magnitude when comparing the measured versus simulated streamflow. Some key observations from reviewing these figures include:

- The overall trend of the simulated streamflows reflects both the annual seasonal cycle in streamflows with peak flows in the winter and low flows in the summer.
- The long-term trend shows variability reflecting the appropriate streamflow variability during wet, normal and dry years. The lower wintertime peak flows during drought years are represented.
- The peak winter streamflows, although not as important for the Model since the streams will be flowing during these periods, are appropriate to allow the Model to simulate wintertime groundwater-surface water interactions.
- The shoulder periods for the spring and fall show appropriate magnitude so that the Model is providing representative seasonal variations in groundwater-surface water interactions.
- The summer streamflows are in the appropriate range of magnitude show that summer time baseflows are representative and that relative differences summertime streamflows should be reasonably accurate.

Appendix F provides a summary of the average, maximum and minimum streamflows for each stream segment simulated using the SFR1 Package. Based on the review of the streamflow data, the updated SMGB model is providing a representative simulation of surface water conditions appropriate for simulating groundwater-surface water interactions using MODFLOW.

One observation from these results is that a portion of Bean Creek in the central SMGB where it first flows onto the Santa Margarita has been noted to go dry during the summer months. Dry stretches of streams are allowed by the MODFLOW SFR1 Package resulting from surface water-groundwater interactions within the simulation that account for the volume of upstream flow and losses to the groundwater that include the underlying geology and streambed conditions. As shown by Segment 45, that portion of Bean Creek also goes dry during the model simulations. There is flow above this section supported by inflow from outside the SMGB and from the Butano. Within this dry section, Bean Creek flows onto an outcrop area of the Santa Margarita area where groundwater elevations are below the base of the streambed. Upstream flows during the summer are insufficient to sustain flow over this region leading to the observed dry stream conditions. Flow below this section is supported by inflow from the Santa Margarita Sandstone. The MODFLOW SFR1 Package provides a cell-by-cell water budget simulation results that can be used to evaluate the location of dry reaches of Bean Creek or other streams within the SMGB.

7.3.2 Bean Creek Baseflow

Baseflow is the portion of streamflow that originates from groundwater. Baseflow contributions vary with seasonal climatic cycles. Baseflow is highest in the wet season when groundwater levels are high due to increased recharge, but the overall contribution of baseflow to total streamflow is small because streamflow is dominated by runoff and upstream contributions to flow. In the dry season of late summer and early fall, baseflow contributions also decline as groundwater level declines; however, the overall percentage of baseflow to total streamflow can be relatively high due to diminished runoff and upstream contributions.

Determining the proportion of baseflow from total streamflow is difficult to evaluate. Baseflow is assumed to increase at a linear rate from the beginning of the wet season to until the extrapolated recession curve based on declining streamflow occurs in the spring. Johnson

(2001, 2009) performed stormflow-baseflow hydrograph separation analysis for the average mean-daily flows for Bean Creek. Johnson (2001, 2009) used hydrograph separation based on an exponential backward extension of the dry-season flow recession curve. The results of Johnson's (2001, 2009) analysis is summarized in Table 8-3.

The SFR1 Package in MODFLOW provides a water balance for each stream reach within the model that accounts for surface flow into and out of the reach, water exchange with the groundwater aquifer, losses to evapotranspiration and contributions from runoff and direct precipitation. To estimate baseflow contributions, the SFR1 reported groundwater flow from the aquifer to Bean Creek was calculated for all of the reaches representing the gaining portions of Bean Creek and its tributaries flowing over the Santa Margarita upstream of the USGS gauge location near Mount Hermon Road Bridge. The simulated baseflow contributions derived from the SFR1 water balance are also summarized on Table 8-3.

Table 8-3 provides a comparison of the Model based baseflow contributions to Bean Creek to those calculated by Johnson (2001, 2009) using the stormflow-baseflow hydrograph separation analysis. Two different comparisons are shown.

- The Annual Average Baseflow compares the recession curve for the entire hydrograph to the annual average baseflow determined from the SFR1 water balance.
- The Summertime Baseflow compares the recession curve that minimizes to the annual average baseflow determined from the SFR1 water balance

The results show that the SMGB model is about 10% to 15% higher than those estimated by Johnson (2001, 2009). Considering the inherent difficulties in determining the baseflow contribution to streamflow, this is considered a strong comparison showing that the SMGB Model determined baseflow contributions are in-line with previous work.

TABLE 7-3
COMPARISON OF SMGB MODEL RESULTS TO
BASEFLOW ANALYSIS (JOHNSON, 2001, 2009) FOR BEAN CREEK

	Annual Average Bean Creek Baseflow		Summertime Bean Creek Baseflow	
	Johnson (2001, 2009)	SMGB Model	Johnson (2001, 2009)	SMGB Model
Units	cfs	cfs	cfs	cfs
Average	2.7	3.1	3.3	3.4
Minimum	2.0	2.2	2.2	2.0
Maximum	3.8	4.0	5.2	5.5

7.4 Water Balance Calibrations

As another verification of the SMGB Model, it was run using the groundwater subareas described by Johnson (2009) to compare these local water balances. The SMGB Model calculates the water balance for 3-month intervals from October 1984 through September 2012. The results of the SMGB Model using the Johnson (2009) subareas are provided in Table 7-4.

Johnson (2009) developed local water balances using a combination of tabulated data for pumping and assumptions for developing estimates of recharge, baseflow contributions and other inflows and outflows. Groundwater pumping is based on data representative of pumping in 2001 to 2004. Johnson applied an average annual recharge rate uniformly over the entire subarea. Different recharge rates were applied based on geologic units. Return flows are also included in the recharge rate, as is the SMGB Model recharge total. Other groundwater inflows and outflows were based on an assumption of the overall change in aquifer storage based on an assessment of changes in groundwater levels and other previous studies. The subarea water balances from Johnson (2009) are also summarized in Table 7-4.

TABLE 7-4
COMPARISON OF SMGB MODEL TO
JOHNSON (2009) SUBAREA WATER BALANCES

	Recharge	Stream	GW Inflows	GW Pumping	Baseflow	Other Outflows	Aquifer Storage
Units	AF	AF	AF	AF	AF		
Quail Hollow Subarea (Johnson 2009)							
Johnson (2009)	3,900	0	0	500	1,900	1,500	0
SMGB Model	3,438	506	0	394	1,777	1,782	-9
Olympia Subarea (Johnson 2009)							
Johnson (2009)	2,000	0	0	570	1,250	200	0
SMGB Model	1,126	412	1,292	460	962	1,458	-50
Mission Springs Subarea (Johnson 2009)							
Johnson (2009)	900	300		150	750	300	0
SMGB Model	394	2,000	0	80	20	2,300	-6
Pasatiempo Subarea (Johnson 2009)							
Johnson (2009)	1,800	0	0	610	1,200		0
SMGB Model	1,739	1	140	670	33	1,384	-207
Camp Evers Subarea (Johnson 2009)							
Johnson (2009)	500	0	500	765	200		0
SMGB Model	432	96	1,234	977	754	122	-91
Scotts Valley Subarea (Johnson 2009)							
Johnson (2009)	3,000	0	0	1,500	0	0	-1,500
SMGB Model	1,160	1,980	0	801	1,631	1,130	-422
Total							
Johnson (2009)	12,100	300	500	4,095	5,300	2,000	-1,500
SMGB Model	8,289	4,995	2,666	3,382	5,177	8,176	-785

The comparison of the SMGB Model subarea water balances with those developed by Johnson (2009) in general show reasonable agreement considering the differences in methodology and time interval. The agreement is best in the Quail Hollow and Olympia subareas and least in the Mission Springs and Scotts Valley subarea. The development of the SMGB Model considered all of the same conceptual elements presented in the Johnson (2009) water balances, but the results indicate the variability expected when comparing conceptual analysis to a numerical model.

The total inflows for all six subareas were estimated as 12,900 AFY by Johnson (2009) compared to 15,950 AFY from the SMGB Model. The total outflows were estimated as 11,395 AFY by Johnson (2009) compared to 16,735 AFY from the SMGB Model. The Johnson (2009) estimate for the Scotts Valley subarea did not fully balance, so there is a discrepancy due to that. The estimated decline in aquifer storage was 1,500 AFY by Johnson (2009) compared to a decline of 785 AFY from the SMGB Model.

7.5 Convergence

A numerical model mathematically describes the conceptual model by solving the water balance and motion equations that govern groundwater flow and chemical transport (Bear and Verruijt 1987). To solve these equations, an iterative method is used to solve the matrix equations. For these iterative techniques, the procedure is repeated until the convergence criteria are met. The convergence criteria may be groundwater elevation change, water balance difference, or both. Convergence defines whether the model is mathematically stable and capable of producing reliable results.

For this model, the MODFLOW-NWT solver (Niswonger *et al*, 2011) was used was used. For the SMGB Model, the convergence parameter for groundwater elevation was set at 0.25 feet and 100 cubic feet per day of water balance differential. Convergence for groundwater elevation is evaluated at the grid cell level. If a single cell does not meet the requirement, then the solution procedure is repeated. The water balance convergence is evaluated for the entire model for each time step, so the solution procedure is repeated until the total water balance for each time step meets the convergence criteria. The model was able to successfully converge for all 112 stress periods using the set convergence parameters.

The primary method to check whether the model is numerically stable is to evaluate the differential in water balance. Iterative techniques provide an approximate solution for the model; therefore, there is always a water balance differential. This differential should be small, and typically a differential of less than 1% is considered as a good solution. The water balance differential for the SMGB Model is 0.00015%, indicating that the simulation water balance results are not affected by numerical instability at a meaningful scale.

The maximum water differential for a single stress period is 0.0045% during the Summer (July to September) of 2008. Instability in reaching convergence with the model is primarily associated with the stream package. During periods of very low surface water flow, instability can arise in areas where the groundwater surface is near the stage of the stream so that adjacent cells go from gaining to losing reaches. This causes a water flux instability that the NWT solver may have trouble resolving. These issues were reconciled in the calibrated model by minor changes in either stream properties or increasing the surface water flow by a minor amount. This issue may arise during use of the model for future case simulations especially when evaluating extended drought periods.

7.6 Utilization of Calibrated Model

Once calibration is achieved, the model is considered capable of forecasting future conditions with reasonable accuracy. The results of the Historical Model can be analyzed with respect of the hydrogeological conceptual model to document and expand upon our understanding of the SMGB. Input parameters can be set to simulate a wide range of potential future groundwater use, water quality, or hydrogeologic scenarios. The results can be evaluated for overall trends and more localized effects. The horizontal and vertical resolution used to construct the model dictate the range of scales that the model can evaluate. For example, a regional or basin-wide model will not likely contain the site-specific details of a more localized model, but a regional model will better evaluate a local area within the broader regional context. Based on the preceding discussion regarding the model calibration, the SMGB Model is consistent with the available data and conceptual model to produce reliable results for regional scale simulations.

Section 8: Historical SMGB Model Results

The groundwater model quantitatively combines data on basin geometry, aquifer properties, recharge, and discharge to further evaluate the hydrologic budget, groundwater flow and groundwater-surface water interactions of the SMGB. The following section summarizes the results of the calibrated Historical Model.

8.1 Model-Based Water Balance

A water balance provides a summary of how groundwater enters and exits the system, either for the entire basin or for a specifically defined subarea. Tabulating these results provides insights how the system responds to changing conditions.

8.1.1 Water Balance Components

A water balance is a quantitative statement of the balance of the total water gains and losses from the basin for a given time period. The major components of the water balance evaluated for the SMGB can be expressed by the following relationship:

$$\mathbf{P + R_i + Gb_i = Q + R_o + Gb_o + N_d \pm \Delta S}$$

where: P = Recharge from Precipitation and Return Flows

R_i = Groundwater recharge from Rivers and Streams

Gb_i = Groundwater Inflow

Q = Groundwater Pumpage

R_o = Groundwater Discharge to Rivers and Streams

N_d = Natural Discharge (Evapotranspiration, Springs)

Gb_o = Groundwater Outflow

ΔS = Change in Groundwater Storage

8.1.2 SMGB Water Balance Summary

Groundwater recharge or inflow to the SMGB is derived from percolation precipitation, streamflow, return flows, and subsurface inflow. Groundwater discharge or outflow from the SMGB is derived from well pumpage, subsurface outflow, stream discharge, and evapotranspiration. The difference between inflow and outflow is balanced by the change of groundwater in storage. The year-by-year water balance results from the calibrated model for recharge are presented in Table 8-1 and are graphically represented on Figure 8-1. A more detailed water balance is provided in Appendix G. In summary, the model results indicate the following:

- Precipitation and return flow recharge is approximately 244,000 acre-feet over the 28-year base period for an average annual recharge rate of 8,700 AFY. Precipitation is by far the largest component. The year-by-year results range from about 13,093 AFY in 1998 to 4,654 AFY in 1990 reflecting the influence of climatic variability.
- Throughout the basin there are gaining and losing stream reaches; however, basinwide, there is a net loss of groundwater to streams of approximately 48,000 acre-feet averaging about 1,700 AFY. Net groundwater discharge to streams varies from 145 acre-feet in the drought year of 1991 to 4,282 AFY in 1985 likely reflecting a period of higher groundwater levels.
- Well pumpage from municipal and private wells is a major outflow from the SMBG with approximately 103,500 acre-feet of groundwater pumped over the 28-year base period for an average annual pumping rate of 3,700 AFY. Pumping was highest in 1997 (4,409 AFY) and lowest in 2011 (2,694 AFY).
- Subsurface flows represent small areas of the SMGB that are represented in the model using boundary conditions. There is a small net recharge of about 10 AFY which is about 0.1% of the precipitation recharge. This indicates that the SMGB has little to no subsurface hydraulic communication with adjacent areas.
- The surface outflow shifts from a net outflow to a net inflow in 1997. This represents lowering groundwater levels decreasing outflows in the deeper aquifers whereas inflows into the Santa Margarita Aquifer along the southern margin remain more stable.
- Natural discharge primarily accounts for losses from springs along the Santa Margarita Sandstone – Monterey outcrop areas and evapotranspiration near streams from riparian vegetation of discharges. This is the largest groundwater loss, accounting for nearly half of the precipitation recharge.

Change in aquifer storage accounts for the inflows or outflows represented by changes in groundwater levels in the SMGB. Over the 28-year base period, groundwater storage decreased by about 27,000 acre-feet averaging a 970 AFY decline rate. However, annually, aquifer storage has both increased and decreased depending on the precipitation, pumping and groundwater-surface water interactions. These range from the greatest loss of 4,944 acre-feet during the period of rapid groundwater levels declines, to an increase of 3,084 acre-feet in 2011 representing a period of high precipitation and decrease groundwater pumping.

TABLE 8-1
YEAR-BY-YEAR HISTORICAL MODEL RESULTS
FROM 1985 TO 2012

Year	Precipitation Recharge	Rivers and Streams	Well Pumpage	Subsurface Flow	Natural Discharge	Change in Storage
Units	AF	AF	AF	AF	AF	AF
1985	7,582	-4,282	-2,901	-313	-5,030	-4,944
1986	9,901	-1,931	-3,123	-297	-4,792	-242
1987	4,802	-2,629	-3,835	-263	-3,922	-5,847
1988	5,245	-1,887	-3,718	-244	-3,548	-4,153
1989	6,102	-1,356	-3,438	-229	-3,450	-2,370
1990	4,654	-783	-3,267	-208	-3,118	-2,722
1991	6,195	-145	-3,550	-199	-3,192	-891
1992	7,887	-452	-3,602	-195	-3,534	104
1993	10,722	-507	-3,490	-198	-4,190	2,338
1994	6,599	-1,741	-4,079	-156	-3,802	-3,179
1995	12,169	-558	-3,639	-106	-4,574	3,292
1996	10,331	-1,688	-3,960	-23	-4,702	-40
1997	10,399	-2,777	-4,409	32	-4,871	-1,626
1998	13,093	-1,410	-3,901	76	-5,213	2,646
1999	8,822	-2,784	-3,957	114	-4,842	-2,647
2000	9,293	-1,571	-4,241	149	-4,624	-993
2001	7,694	-2,186	-4,455	176	-4,308	-3,078
2002	8,421	-2,408	-4,336	189	-4,293	-2,427
2003	8,754	-1,712	-4,393	189	-4,168	-1,330
2004	8,709	-1,972	-4,117	193	-4,171	-1,359
2005	11,651	-1,167	-3,431	196	-4,605	2,645
2006	12,921	-1,956	-3,736	188	-5,119	2,298
2007	5,980	-2,672	-4,025	219	-4,120	-4,617
2008	7,233	-1,246	-3,820	215	-3,835	-1,454
2009	8,068	-1,243	-3,430	220	-3,859	-245
2010	10,609	-1,082	-2,927	193	-4,310	2,483
2011	12,298	-1,708	-2,694	172	-4,984	3,084
2012	7,456	-2,099	-3,084	189	-4,338	-1,877
Total	**243,590**	**-47,953**	**-103,557**	**281**	**-119,513**	**-27,152**
Average	**8,700**	**-1,713**	**-3,698**	**10**	**-4,268**	**-970**

8.1.3 Model-Based Water Balance Summary by Aquifer

The Model-based water balance can also be evaluated for each aquifer as presented in Table 8-2. A more detailed water balance by aquifer and aquifer subareas is presented in Appendix G. A summary of the results presented in Table 8-2 include the following:

- About 75% of the precipitation recharge occurs in the Santa Margarita, with the remaining 25% occurring on the other aquifers. The Lompico receives less than 3% of the precipitation recharge owing to its limited outcrop area.
- For groundwater-surface water interactions, the Santa Margarita, Monterey and Butano all show a net discharge of groundwater to surface water whereas the Lompico shows a net recharge from streams.
- Well pumpage is greatest in the Lompico Aquifer with over 50% of the overall groundwater pumping, most of which is municipal. About 30% of the overall groundwater pumping is from the Santa Margarita, which includes most of the private pumping. The remainder of the pumping from the Monterey (primarily private) and Butano (primarily municipal).
- Subsurface flow for each aquifer primarily accounts for flow between the different aquifers. The Lompico and Monterey receive significant inflows primarily from the overlying Santa Margarita. The Butano also has a net subsurface flow to the Lompico. Subsurface inflow is the most significant source of recharge to the Lompico Aquifer.
- Natural discharge to springs and evapotranspiration is greatest in the Santa Margarita Aquifer accounting for about 86% of the total. This occurs in areas of shallow groundwater near streams and springs along the Santa Margarita-Monterey contact. The remaining 15% occurs primarily along streams in the other aquifers.
- About 50% of the change in aquifer storage has occurred in the Lompico Aquifer accounting for about 13,700 acre-feet of aquifer storage decline since 1985, and about 27%, 7,500 acre-feet has occurred in the Butano. About 20% of the aquifer storage decline has occurred in the Santa Margarita and Monterey.

The Model-based water balance for the Santa Margarita Aquifer has both the highest recharge and highest overall discharge of all of the other aquifers combined. Because of its stratigraphic position and high permeability, a high percentage of the precipitation that falls on the Santa Margarita goes to groundwater recharge where the majority is ultimately discharged to rivers, stream and natural discharge. However, a significant amount of leakage does occur that helps to sustain the deeper aquifers, especially the Lompico.

The Monterey has a wide area where it is exposed at the surface where it receives precipitation recharge and has groundwater-surface water interactions with numerous streams. However, owing to the fine-grained nature of the Monterey and its overall greater thickness, the water balance for the Monterey is significantly lower than that of the Santa Margarita.

The Lompico Aquifer has the highest pumping but also has the lowest precipitation recharge owing to its limited outcrop area, resulting in the relatively high declines in aquifer storage in the Lompico. Recharge to the Lompico is primarily derived from leakage from adjoining aquifers, primarily the Santa Margarita, but also from the Butano.

TABLE 8-2
SUMMARY OF HISTORICAL MODEL RESULTS
ANNUAL AVERAGE AND CUMULATIVE WATER BALANCE SUMMARY
BY AQUIFER FROM 1985 TO 2012

	Precipitation Recharge	Rivers and Streams	Well Pumpage	Subsurface Flow	Natural Discharge	Change in Storage
Units	**AF**	**AF**	**AF**	**AF**	**AF**	**AF**
SMGB Model						
Average	8,700	-1,713	-3,698	-15	-4,268	-994
Total	243,590	-47,953	-103,557	-413	-119,513	-27,845
Santa Margarita Aquifer						
Average	6,523	-841	-1,095	-1,011	-3,687	-111
Total	182,656	-23,551	-30,662	-28,315	-103,235	-3,106
Monterey Aquifer						
Average	854	-463	-281	132	-332	-89
Total	23,919	-12,956	-7,864	3,694	-9,284	-2,491
Lompico Aquifer						
Average	222	280	-1,995	1,117	-110	-486
Total	6,207	7,852	-55,871	31,289	-3,085	-13,609
Upper Butano Aquifer						
Average	512	-478	0	-25	-44	-35
Total	14,324	-13,389	0	-702	-1,227	-994
Lower Butano Aquifer						
Average	589	-211	-327	-227	-93	-270
Total	16,484	-5,908	-9,159	-6,349	-2,613	-7,546
Locatelli Aquifer						
Average	0	0	0	-1	-2	-4
Total	0	0	0	-31	-68	-99

The lower Butano is separated from the upper Butano by a thick siltstone; therefore, in this assessment, the Butano is shown as two separate aquifers. Both the upper and lower Butano and receives the majority of its recharge from precipitation. The lower Butano is a major water source for SVWD, so has significant pumping. The upper Butano is present within the SLVWD service area in the northwestern SMBG, and no wells were identified in the Upper Butano but unaccounted small domestic wells may be present. There is an overall net discharge of groundwater to the rivers and streams; however, the upper Butano does receive recharge from Loch Lomond. The model results show that the lower Butano has experienced significantly greater decline in aquifer storage than the upper Butano, which is likely attributable to higher groundwater pumping in the lower Butano.

The Locatelli is a minor aquifer located only the southwest corner of the SMGB, where a small outcrop area exists along Eagle Creek and the San Lorenzo River. This outcrop area is considered to be a discharge location and no precipitation recharge was assigned to this location. Recharge is primarily from subsurface flow from the Lompico. However, declining groundwater levels in the Lompico has diminished this recharge leading to declining water levels in the Locatelli.

8.1.4 Groundwater Pumping and Aquifer Storage Over Time

The Historical SMGB Model results changes in groundwater pumping and aquifer storage can also be evaluated by aquifer over time. Table 8-3 presents the change in aquifer storage by aquifer over four 7-year time intervals from 1985 to 2012, whereas Table 8-4 shows groundwater pumping for the same time intervals. Figure 8-2 shows the variation in aquifer storage over time. The Historical SMGB Model results are documented in the more detailed water balance by aquifer and aquifer subareas presented in Appendix G.

The time periods are based on dividing the 28-year base period into four equal time periods for a consistent water balance comparison; however, each time period has a distinctive climatic character as well. The climatic conditions are also a factor in assessing the changes in groundwater storage over time. In summary, the precipitation history is as follows:

- 1985 to 1991 is dominated by a period of prolonged drought with cumulative rainfall was 78 inches below average and 6 of the 7 years were below average precipitation.
- 1992 to 1998 is a wetter period when the cumulative rainfall was 33 inches above average and only 2 of the 7 years were below average precipitation. This includes two high rainfall years of 1995 and 1998.
- 1999 to 2005 is a variable period with generally near average precipitation where the cumulative rainfall was 6 inches above average, but 4 of the 7 years were below average precipitation. This period includes the high rainfall year of 2005.
- 2006 to 2012 is a period of highly variable precipitation resulting in a cumulative rainfall was 11 inches below average and 4 of the 7 years were below average precipitation. This period includes two very wet years (2006 and 2011) with an intervening 3-year drought period (2007 to 2009)

The Historical SMGB Model results, as shown on Tables 8-3 and 8-4, can be summarized for each aquifer with the following observations:

- In the Santa Margarita, the change in aquifer storage showed nearly full recovery in 1991-1998 followed by a period of minor change in aquifer storage. Groundwater pumping showed a general decline from 1985 to 2012 of about 35%. The dissimilar trends support the conceptual understanding of the Santa Margarita to be more responsive to variations in climate events. The aquifer storage decline from 1985 to 1991 and the subsequent recovery from 1992 to 1998 is more attributed to climatic variation of a drought followed by a recovery period than groundwater pumping.
- The Monterey has low levels of groundwater pumping and relatively minor changes in aquifer storage. The aquifer storage variations also attributed more to climatic variations than to groundwater pumping. However, pumping from SVWD #9 likely did contribute to the aquifer storage decline during the period from 1985 to 1991.
- The Lompico experienced the greatest decline in aquifer storage change of all of the aquifers. The relatively low recharge rates compared to the high degree of pumping is considered to be the primary cause of the historical declines in aquifer storage. The change in aquifer storage in the Lompico was highest from 1985 to 1991 but was still

significant from 1992 through 2005, but shows a slight recovery from 2006 to 2012. Change in aquifer storage as a percentage of total groundwater pumping declined from 55%, 25%, 23% and 2% over the four periods, respectively. This suggests that changes in the water balance, likely due to decreased outflows, are able to support the recent levels of pumping without much further decline in aquifer storage. However, calibration data indicated that the Model showed recovering groundwater levels in the Pasatiempo area that were not reflected in the measured data, which may be another explanation of the increase in aquifer storage in the Model results.

TABLE 8-3
SUMMARY OF HISTORICAL MODEL RESULTS
CHANGE IN AQUIFER STORAGE OVER TIME
BY AQUIFER FROM 1985 TO 2012

	1985-1991	1992-1998	1997 – 2005	2006 - 2012	Total
Units	AF	AF	AF	AF	AF
Entire SMGB					
Average	-3,024	505	-1,350	-109	-994
Total	-21,169	3,534	-9,449	-760	-27,845
Santa Margarita Aquifer					
Average	-1,091	1,091	-421	-22	-111
Total	-7,637	7,635	-2,948	-156	-3,106
Monterey Aquifer					
Average	-397	70	-31	2	-89
Total	-2,782	491	-217	17	-2,491
Lompico Aquifer					
Average	-880	-552	-551	38	-486
Total	-6,161	-3,861	-3,856	269	-13,609
Upper Butano Aquifer					
Average	-213	124	-45	-8	-35
Total	-1,489	871	-317	-59	-994
Lower Butano Aquifer					
Average	-441	-225	-297	-115	-270
Total	-3,086	-1,573	-2,081	-806	-7,546
Locatelli Aquifer					
Average	-2	-4	-4	-4	-4
Total	-14	-29	-29	-26	-99

- The Butano shows declines in aquifer storage that correspond to the increase in groundwater pumping starting in the mid-1990s. Change in aquifer storage as a percentage of total groundwater pumping declined from 64%, 53% to 30% over the latter three periods, which suggests that changes in the water balance in the Butano, likely due to decreased outflows, are able support the recent levels of pumping with smaller declines in aquifer storage than in the earlier time periods.

- The Locatelli also did not have groundwater pumping attributed to it. The decline in aquifer storage is related to groundwater level declines in the Lompico reducing recharge to the Locatelli.

TABLE 8-4
SUMMARY OF HISTORICAL MODEL RESULTS
GROUNDWATER PUMPING OVER TIME
BY AQUIFER FROM 1985 TO 2012

	1985-1991	1992-1998	1997 – 2005	2006 - 2012	Total
Units	AF	AF	AF	AF	AF
Entire SMGB					
Average	3,405	3,868	4,133	3,388	14,794
Total	23,833	27,079	28,930	23,716	103,557
Santa Margarita Aquifer					
Average	1,400	1,055	1,022	903	4,380
Total	9,801	7,384	7,154	6,323	30,662
Monterey Aquifer					
Average	423	311	223	167	1,123
Total	2,958	2,174	1,561	1,172	7,864
Lompico Aquifer					
Average	1,575	2,152	2,328	1,927	7,982
Total	11,027	15,061	16,297	13,487	55,871
Butano Aquifer					
Average	7	351	560	391	1,308
Total	47	2,460	3,918	2,734	9,159
Locatelli Aquifer					
Average	0	0	0	0	0
Total	0	0	0	0	0

8.2 Evaluation of Groundwater Flow

To evaluate the simulated groundwater flow, the groundwater elevation map are presented for each model layer for the final time step representing Summer (July to September, 2012) along with a drawdown map showing the total change in groundwater levels over the 28-year simulation. The groundwater contour maps show groundwater levels using a 25-foot contour interval to show regional trends. Groundwater flow is typically perpendicular to the contour lines. The drawdown maps also use a 25-foot contour interval. The drawdown maps show the long-term change in groundwater levels. The following summary discusses observations

Figure 8-3 presents the simulated groundwater elevation and drawdown maps for the Santa Margarita Aquifer (Model Layer 1). In the Santa Margarita Aquifer, the general trend is for groundwater to flow from upland areas and converge towards discharge areas primarily along the streams and springs. Some more specific observations include the following:

- The Santa Margarita Sandstone has extensive area where it is exposed at the surface. In these areas, the high permeability of the Santa Margarita leads to high recharge rates. Much of the central and eastern areas are overlain by the Santa Cruz Mudstone which limits the amount of recharge that reaches the Santa Margarita where it is present.
- In general there is little long-term drawdown in the Santa Margarita. Because of the high recharge rates, large areas of surface exposure and interactions with numerous streams, groundwater levels are primarily influenced by climatic variation.
- The Quail Hollow area is the nearly detached portion of the Santa Margarita west of Zayante Creek. Groundwater flows from the upland areas then curves towards either Zayante or Newell Creeks. Groundwater discharge also occurs at springs along the Santa Margarita margin.
- In the Bean Creek area in the central portion of the SMGB, groundwater flow is from the northern upland areas towards the south. In the upland areas, the Model results indicate that the streams tend to be losing reaches that recharge groundwater. The main discharge is along the lower Bean Creek in the south-central area, or towards springs along the western margin. Higher hydraulic conductivity and lower recharge lead to a flatter hydraulic gradient in this area.
- Carbonera Creek currently acts as a losing stream that recharges groundwater along its course on the eastern margin that is not underlain by the Santa Cruz Mudstone. Groundwater flow is generally southwestward towards discharge along Bean Creek.
- Urban development in the Scotts Valley has led to large areas being covered with impermeable surfaces and installation of storm drains that capture stormwater flow and direct it to Carbonera Creek. The SMGB Model includes this condition, which has led to a reduction in the groundwater recharge in these areas in the Model results.
- The purple areas on Figure 8-3 represent areas that are unsaturated. This area is underlain or adjacent to where the Santa Margarita and Lompico are indirect contact due to the pinchout of the Monterey. In these areas, the groundwater levels are supported by those in the underlying Lompico. Historically, this was an area of shallow groundwater; however, as groundwater levels dropped in the Lompico, levels in the Santa Margarita also dropped leading to the unsaturated conditions. Figure 8-3 shows drawdowns in this area greater than the thickness of the Santa Margarita. This represents the NWT solver tracking in the simulation to determine when a cell can be resaturated if conditions warrant.
- In the Pasatiempo area, high groundwater recharge rates occur on the surface exposures; however, this recharge has been reduced due to suburban residential development. Groundwater discharge is primarily occurs at springs along the Santa Margarita margin.
- Along the southern margin, the Santa Margarita is underlain by either crystalline bedrock or the siltstone of the Locatelli so that there is little leakage downward. Groundwater flow is towards the north where recharges the Lompico through the direct Santa Margarita-Lompico contact area.

- The southern boundary represents a groundwater divide that is primarily controlled by the surface topography. Groundwater in the Santa Margarita Sandstone south of the southern margin is considered to flow away from the SMGB.

Figures 8-4 and 8-5 present the groundwater elevation and drawdown maps for Model Layer 2 and 3 representing the upper and lower Monterey Aquifer, respectively. The thickness of the Monterey ranges from zero along the pinchout areas along the eastern SMGB margin to several hundred feet thick in the central basin in the center of the Scotts Valley Syncline. The Monterey is a generally fine-grained unit, but contains sand layers that are locally used for water supply. The simulation of the upper Monterey is focused on simulating the Monterey as a hydraulic barrier between the Santa Margarita and Lompico. Individual sand layers may respond to local hydraulic conditions. For this regional simulation, the upper Monterey is simulated as a single layer with generalized conditions that more focused on vertical groundwater flow rather than horizontal. Some more specific observations include the following:

- The general groundwater flow direction is towards the southwest toward the lower reaches of Bean, Zayante, Newell and Love Creeks as well as the San Lorenzo River. Groundwater flow is relatively slow in this low hydraulic conductivity unit.
- As discussed in the preceding section, groundwater exchange with streams is significantly lower than for the Santa Margarita due to the low permeability conditions in the Monterey.
- A portion of Model Layer 2 simulates the Lompico in the areas where the upper Monterey has been eroded by the overlying Santa Margarita Sandstone. MODFLOW requires this continuity to simulate groundwater flow from the Santa Margarita (Model Layer 2) to either the lower Monterey (Model Layer 3) or the Lompico (Model Layer 4). The drawdown in these areas is representative of groundwater conditions in the underlying unit. The unsaturated areas and areas of higher drawdown in the southeastern portion of Figure 8-4 and 8-5 represent conditions in the underlying unit.
- Groundwater levels in the lower Monterey are generally lower than the upper Monterey, but locally this does switch along the western parts of the Monterey.
- The upper Monterey is more representative of shallow surface conditions or is influenced by the Santa Margarita. The lower Monterey is more responsive to conditions in the Lompico. This is reflected in the drawdown maps where there is little long-term change in groundwater levels in the upper Monterey, whereas the lower Monterey shows more extensive drawdown over time.
- Splitting the Monterey into two layers allows the SMGB Model to better simulate the vertical differences in the Monterey.

Figure 8-6 presents the groundwater elevation and drawdown maps for the Lompico Aquifer (Model Layer 4). Some more specific observations include the following:

- In the Lompico Aquifer, the general trend is for groundwater to flow towards the primary pumping areas along the eastern margin.
- Groundwater recharge is restricted due limited areas where the Lompico occurs at the surface. The primary recharge areas are in Blackburn Gulch in the northeast and along the northern boundary including recharge from Loch Lomond.

- Recharge to the Lompico also comes through leakage from the Santa Margarita along the eastern margin where the Monterey is absent between the Santa Margarita and Lompico.
- Groundwater-surface water interactions are limited to Blackburn Gulch on the east, and the San Lorenzo in the northwest in the Boulder Creek – Ben Lomond area. The short stream reaches along the northern margin, such as Carbonera, Bean, Zayante and Lompico Creeks, also provide recharge to the Lompico Aquifer.
- Drawdown near the primary pumping centers is over 200 feet, but widespread areas of greater than 100 feet occur in the eastern SMGB and account for much of the decline in aquifer storage. The model results indicate declines of up to 25 feet over the 28-year base period occur along the western SMGB near Ben Lomond and Boulder Creek.

Figure 8-7 presents the groundwater elevation and drawdown maps for the upper Butano Aquifer (Model Layer 5). Model Layer 5 is complex due to unconformable stratigraphic relationship of the Butano with the overlying Lompico. The upper Butano is limited to the extreme northern SMGB. The extensive area in the central SMGB is an interlayer representing the lower Butano. The detached area to the south is the upper siltstone member of the Locatelli. Some more specific observations for the upper Butano Aquifer include the following:

- The upper Butano is recharged from precipitation falling on outcrop areas along the northern margin of the SMGB. Recharge also occurs from Loch Lomond Reservoir and Love Creek.
- Outflow from the upper Butano is primarily to nearby streams including the Zayante, Lompico, and Bear Creeks and the San Lorenzo River.
- There is no significant long-term drawdown since there is no significant pumping, so groundwater levels are primarily influenced by climatic variation.

Figures 8-8 and 8-9 present the groundwater elevation and drawdown maps for Model Layer 6 and 7 representing the lower Butano Aquifer. Due to its thickness, the lower Butano was simulated with two layers. Model Layer 6 is shown as the upper half on Figure 8-8, and the lower half is the interlayer for Model Layer 7.

- The recently installed Stonewood Well found high groundwater elevations that were above the level of Bean Creek suggesting groundwater discharge to Bean Creek. Model Layer 6 was able to show this relationship, but was not able to simulate the high groundwater level found in the Stonewood Well.
- Groundwater recharge occurs from precipitation and streams in the higher terrain in the far northeastern portion of the SMGB.
- Groundwater-surface water interactions are primarily gaining reaches where groundwater discharges to streams, especially along Bean Creek.
- The detached area to the south is the lower Locatelli. Groundwater recharge to the Locatelli is from the Lompico where the Locatelli basal sandstone is in contact with the Lompico. Groundwater flow is toward discharge areas along Eagle Creek and the San Lorenzo River in the far southwestern area.

Figure 8-9 presents the groundwater elevation and drawdown maps for the lower Butano Aquifer (Model Layer 7). Some more specific observations include the following:

- Model Layer 7 is completely in the subsurface, so recharge comes from leakage with overlying units of the Butano (Model Layer 6) and the Lompico (Model Layer 5).
- Groundwater pumping is the primary outflow from the lower Butano from SVWD Wells #3B and #7A in the eastern area.
- Drawdown is concentrated near the primary pumping centers with over 150 feet of drawdown over the 28-year base period, but widespread drawdown of greater than 50 feet has is simulated throughout the lower Butano.
- Limited amounts of subsurface outflow are simulated towards Soquel Creek along the far eastern margin, along Branciforte Creek in the southeast, and along Zayante Creek and the San Lorenzo River along the west.

From this description, groundwater flow through the SMGB is complex owing to the stratigraphic relationships present in the SMGB. Groundwater conditions in the Santa Margarita can be affected by pumping the Lompico where the Monterey is absent, but are generally unaffected elsewhere.

8.3 Groundwater-Surface Water Interactions

Groundwater-surface water interactions are a key part of the SMGB Model Update. Tables 8-5 and 8-6 provide average annual and summertime, respectively, groundwater contributions to baseflow by aquifer for the SMGB for seven year intervals. These data show the lowest baseflow contributions in the Santa Margarita occurred in 1985 to 1991, which is a period of extended drought. The highest occurred during 1997 to 2005, which is an extended wet period. Thus, indicating baseflows to the Santa Margarita are strongly influenced by climatic conditions. The baseflow contributions from the Monterey, Lompico and Butano are much lower. The Monterey and Butano show a similar climatic influence as seen in the Santa Margarita. The Lompico shows a long-term declining trend with the lowest baseflow contributions occurring in 2006 to 2012, which indicates the effects of groundwater level declines over time.

Since streamflow is strongly controlled by precipitation, comparing the trend of precipitation to streamflow can provide an indication how the contribution of groundwater to streamflow has changed over time. Figure 8-10 provides a summary graph showing the relationship of precipitation recharge versus groundwater discharge to streams both annually and for summertime (July through September) by aquifer over the 28-year base period. The long-term trend for precipitation is increasing representing the droughts in the earlier part of the base period compared to wetter conditions later in the base period. Summertime conditions are less dependent upon precipitation.

- For the Santa Margarita, the trend for annual discharge to streams in similar to precipitation including declines during the droughts and increases during wet years. The linear regression trend for annual groundwater discharge is slightly lower than for precipitation; however, with this level of analysis, it is unclear if there is any effect from groundwater pumping or if other limiting factors are the cause. The summer time discharge to streams for the Santa Margarita is relatively consistent over time, showing muted responses to drought and wet years.
- For the Monterey, the groundwater discharge to streams remains relatively constant over time. The fine-grained nature of the Monterey is likely the limiting factor such that

there is little variation in groundwater discharge to streams either on an annual basis or focused on summertime conditions.

- For the Lompico, the trends are more distinct. There is a clear downward trend in groundwater discharge to stream, both annually and during summertime. This is considered to reflect the effects of groundwater declines in the Lompico on groundwater discharge to streams. The annual decline is about 225 acre-feet (0.3 cfs) and 50 acre-feet in the summertime (0.1 cfs).
- For the Butano, there is a similar trend as observed for the Lompico, but the trend is less pronounced that is also considered an effect from groundwater level declines. The annual decline is about 180 acre-feet (0.2 cfs) and 50 acre-feet in the summertime (0.1 cfs).

Based on this analysis, changes in groundwater discharges to streams are primarily associated with changes in groundwater levels in the Lompico and Butano due to pumping. Overall changes in the Santa Margarita are less distinct, but the effects of groundwater pumping may be small compared to the overall variations in precipitation.

TABLE 8-5
SUMMARY OF HISTORICAL MODEL RESULTS
ANNUAL STREAM BASEFLOW BY AQUIFER FROM 1985 TO 2012

	1985-1991	1992-1998	1997 – 2005	2006 - 2012	Average
Entire SMGB					
Avg. cfs	6.7	8.2	9.1	8.6	8.2
Avg. AFY	4,870	5,970	6,590	6,220	5,910
Santa Margarita Aquifer					
Avg. cfs	4.3	5.6	6.5	6.1	5.6
Avg. AFY	3,100	4,060	4,690	4,410	4,070
Monterey Aquifer					
Avg. cfs	1.2	1.4	1.5	1.5	1.4
Avg. AFY	900	1,030	1,070	1,080	1,020
Lompico Aquifer					
Avg. cfs	0.3	0.2	0.1	0.1	0.2
Avg. AFY	220	170	100	60	140
Butano Aquifer					
Avg. cfs	0.9	1.0	1.0	0.9	0.9
Avg. AFY	650	700	730	660	690

TABLE 8-6
SUMMARY OF HISTORICAL MODEL RESULTS
SUMMERTIME STREAM BASEFLOW BY AQUIFER FROM 1985 TO 2012

	1985-1991	1992-1998	1997 – 2005	2006 - 2012	Average
Entire SMGB					
Avg. cfs	5.7	7.0	7.5	7.3	6.9
Avg. AFY	1,030	1,260	1,370	1,320	1,240
Santa Margarita Aquifer					
Avg. cfs	3.6	4.7	5.3	5.2	4.7
Avg. AFY	650	850	970	930	850
Monterey Aquifer					
Avg. cfs	1.1	1.3	1.3	1.4	1.3
Avg. AFY	210	240	240	250	230
Lompico Aquifer					
Avg. cfs	0.2	0.2	0.1	0.0	0.1
Avg. AFY	40	30	10	10	20
Butano Aquifer					
Avg. cfs	0.7	0.8	0.8	0.7	0.8
Avg. AFY	130	140	140	130	140

Section 9: Model Scenarios

After calibration the SMGB Model is considered capable of simulating future conditions with reasonable accuracy. By modifying the input data, the model provides the capability to simulate a wide range of potential future conditions. This section describes application of the updated SMGB Model for a variety of scenarios.

9.1 Model Scenario Development

This grant-funded project is focused on updating the SMGB model for future use by the local agencies. As such, there is not a specific project that is being evaluated. Therefore, the objective of these model scenarios is to "*take the Model through its paces*" by developing a set of scenarios of likely applications to demonstrate the capability of the Model. For this Study, the updated SMGB Model is applied as a quantitative tool for evaluating the potential future effects of groundwater management practices, enhanced recharge projects and climatic conditions on groundwater conditions and streamflow in the SMGB.

9.1.1 Approach

The overall approach is to adapt the updated SMGB model that has been calibrated to historical data (calibrated SMGB Model) for evaluation of potential future conditions. The physical characteristics of the SMGB Model including the geology, aquifer properties and physical hydrology that are not time dependent and do not change into the future. The primary changes are to the water balance components including the natural hydrology, represented by the precipitation and streamflow, and human interactions, which are primarily groundwater pumping, land use changes, and enhanced groundwater recharge projects.

Although comprehensive model scenarios can provide a more realistic simulation of future conditions, the model provides an opportunity to vary a minimal number of parameter while keeping others constant, which can often times contribute more to the overall understanding of the hydrogeology. The model scenarios also provide an opportunity to conduct a compare and contrast analysis. For example, a proposed groundwater management plan can be compared to a continuation of past practices. Also, different alternatives for future groundwater management can be compared to evaluate the advantages and limitations of the different alternatives.

In evaluating the model scenario results, it is recommended to emphasize changes to overall trends and the relative differences compared to a Base Case scenario. For this study, the Base Case represents a continuation of current pumping conditions to serve as a basis of comparison for the other model scenarios. By comparing the other scenarios to the Base Case, we can isolate key components so that its influence can be assessed without interference from other factors.

9.1.2 Scenario Setup

For this study, five case scenarios were defined to evaluate various groundwater-related issues and concerns in the basin. These scenarios include:

- **Base Case:** This scenario evaluates groundwater conditions assuming that recent pumping rates are held constant into the future and the natural hydrology repeats the 1985 to 2012 conditions. The purpose of this scenario is to serve as a basis of comparison for the other scenarios.
- **Planned Groundwater Management:** This scenario assesses groundwater conditions based on projected future water demand from SVWD and SLVWD planning documents (Kennedy/Jenks, 2011a; Johnson, 2009). Two variations are run to compare the proposed groundwater management to a continuation of past practices to provide insight into the sustainable pumping rates for the SMGB.
- **Enhanced Recharge Projects:** This scenario assesses groundwater conditions if groundwater recharge projects are used to increase groundwater in aquifer storage and improve stream baseflows. Two cases are presented based on the County's Conjunctive Use Study (Kennedy/Jenks, 2011b). The selected recharge projects include a 1,000 AFY injection well project into the Lompico at the Hanson Quarry site west of Scotts Valley and application of Low Impact Development (LID) recharge of stormwater in multiple locations in Scotts Valley.
- **Climatic Variability:** This scenario assesses the effects of climatic variations on groundwater conditions in the SMGB. Two cases are run. One applies average precipitation and the other applies more extreme weather conditions. These two cases provide insight on the effects of climatic variation on groundwater conditions in the SMGB and how the model can be used for a more comprehensive assessment of climate change.

These scenarios are designed to demonstrate the wide range of applications that can be evaluated using the updated SMGB Model. The following provides a more detailed discussion of the scenario setup and results.

9.2 Base Case

The purpose of Scenario 1 is to provide a Base Case to serve as a basis of comparison for the other scenarios. For the Base Case, the calibrated SMGB model is modified to reflect assumed future conditions. Specific to the model setup, the assumptions for the Base Case are defined as follows:

- The natural hydrology, represented by the precipitation and streamflow, is assumed to repeat the 28-year historical hydrology in the calibrated SMGB model as a reasonable approximation of future conditions that includes both periods of drought and high precipitation.
- Groundwater pumping is assumed as the average quarterly groundwater pumping for each well, based on the 3-year average pumping for the period from 2010 to 2012. This assumption allow for a straight-forward comparison of the effect of changing groundwater pumping or recharge operations relative to the effects if recent groundwater pumping and recharge were continued unchanged into the future.
- The initial groundwater elevations used for the model are based on the final stress period from the calibrated SMGB model representing Fall 2012 groundwater conditions.

- Aquifer properties such as hydraulic conductivity and storage coefficients are physical properties that do not change with time. Therefore, no changes to these properties were made in any of the scenarios.
- The properties and locations of physical features, such as streams, springs, subsurface boundaries, are not considered time dependent, so do not change with time. These characteristics remain the same as represented in the calibrated SMGB model.

For the Base Case, groundwater pumping is calculated by taking the average pumping on a well-by-well basis for each quarter to preserve the seasonal variation in pumping. Table 9-1 summarizes the water budget as both average annual volumes and relative to the Base Case. For the Base Case total groundwater pumping is about 2,800 AFY, which is 900 AFY less than the long-term average of 3,700 AFY in the historical Model (Table 9-1). More detailed water balance data for the Base Case is provided in Appendix H.

Figure 9-1 shows the groundwater pumping for the Base Case in context with the historical groundwater pumping. The total pumping for the Base Case is constant on an annual basis over the 28-year scenario. In the historical model, the period from 2009 to 2012 represents the lowest groundwater pumping over any three-year period during the 1985 to 2012 base period. This represents a combination of factors including significant reductions in industrial and environmental remediation pumping and water conservation efforts by the water districts.

The results on Figure 9-1 and Table 9-1 show that the groundwater in aquifer storage increases by an average of 100 AFY over the 28-year scenario compared to an average loss of 1,000 AFY over the 28-year historical Base Period. The order of magnitude difference is due to a combination of lower pumping and the effects of the lower initial groundwater elevations used for the Base Case.

The Base Case initial groundwater elevations are defined from the final stress period from the calibrated SMGB Model; therefore, the Base Case starts with groundwater elevations than does the calibrated SMGB Model. Figure 9-2 shows a comparison of the Base Case and historical SMGB Model for total groundwater discharge to streams and streamflow in Bean Creek. Both of these show graphs show that these flows at the end of the Base Case are slightly higher than at the end of the Historical Base Period.

Groundwater levels generally increase during the Base Case simulation period. Figure 9-3 provides maps comparing the difference in groundwater elevations in the Santa Margarita and Lompico Aquifers between the end of the Historical Model and the end of the Base Case Scenario. Some observations from Figure 9-3 include:

- Groundwater levels in the Santa Margarita show relatively minor changes over the Base Case Scenario. Some minor recovery in groundwater levels is shown in the vicinity of the SLVWD's Olympia and Quail Hollow wellfields.
- The area of greatest change is where the Santa Margarita overlies the Lompico; however, part of this change reflects changes in the Lompico and is an artifact related to how the MODFLOW NWT-solver tracks groundwater levels in areas where the Santa Margarita Aquifer is dry.
- In the Lompico, there is a broad area with an increase in groundwater levels over 20 feet in the Scotts Valley area reflecting lower groundwater pumping in the Base Case Scenario (Figure 9-3).

From this comparison, the Base Case reflects that the continuation of groundwater pumping at the 2009 to 2012 levels in context with a repeat of the 1985 to 2012 natural hydrology and having initial groundwater elevations at the simulated Fall 2012 levels produces a slight increase in groundwater levels and aquifer storage. The following model scenarios will be evaluated relative to this Base Case and in context with the historical model to provide a measure to evaluate the performance of the scenario.

TABLE 9-1
COMPARISON OF WATER BALANCE FOR BASE CASE, GW MGMT SCENARIOS AND HISTORICAL MODEL

Aquifer	Total Groundwater Inflows	Enhanced Recharge	Groundwater Pumping	Discharge to Rivers and Streams	Other Outflows	Change in Aquifer Storage
Units	**AFY**	**AFY**	**AFY**	**AFY**	**AFY**	**AFY**
Average Annual Water Budget						
Historical	13,800	0	3,700	6,700	4,400	-970
Base Case	13,900	0	2,800	6,600	4,300	140
GWMgmt #1	14,000	0	3,400	6,400	4,200	-50
GWMgmt #2	13,900	0	2,400	6,700	4,400	270
E-Rch #1	13,800	1,000	2,400	7,000	4,700	630
E-Rch #2	13,800	120	2,400	6,800	4,500	300
Water Budget Relative to Base Case						
Historical	-100	0	900	100	100	-1,110
Base Case	0	0	0	0	0	0
GWMgmt #1	100	0	600	-200	-100	-190
GWMgmt #2	0	0	-400	100	100	130
E-Rch #1	-100	1,000	-400	400	400	490
E-Rch #2	-100	120	-400	200	200	200

Note: Values in tables are rounded for convenience. More detailed data presented in Appendix H.

9.3 Planned Groundwater Management (GWMgmt) Scenarios

Simulating different groundwater management alternatives is a key model application. There are many potential groundwater management alternatives that can be formulated and run using the SMGB Model. For this Technical Study, the scenarios are based on planned pumping from published reports by SVWD and SLVWD as representative types of scenarios that the SMGB Model will be used to evaluate.

9.3.1 GWMgmt Scenario Setup

The Groundwater Management Scenario is setup as two cases to provide a compare and contrast assessment for different pumping strategies along with a comparison to the Base Case. These are based on the SVWD Urban Water Management Plan (UWMP) by Kennedy/Jenks (2011a) and the SLVWD Water Supply Master Plan (WSMP) by Johnson (2009). Total groundwater pumping for SVWD, SLVWD and the total SMGB is summarized in Table 9-2 for both cases. The approach for the two cases includes:

- GWMgmt #1 – assumes the proposed water demand in the WSMP and UWMP is met based on a higher reliance on groundwater pumping to represent past practices. Although this case is not planned for use, it provides a useful comparison.
- GWMgmt #2 – assumes that the groundwater pumping for meeting the water demand follows the strategy outlined in both the UWMP and WSMP including the various methods to reduce reliance on groundwater.
- All other conditions in the GWMgmt #1 and #2 are set the same as in the Base Case for provide for consistency in evaluating the scenario results.

SVWD is currently dependent upon local groundwater pumped from the SMGB for their potable water supply, so there is limited opportunity for significant changes over time. The SVWD UWMP (Kennedy/Jenks, 2011) assumes that increased use of recycled water and a minor amount of water obtained from outside sources. For SVWD, groundwater pumping is based on Table 3-1 in the UWMP (Kennedy/Jenks, 2011a) that assumes growth rates for the SVWD service area. In summary, the groundwater pumping assumptions for SVWD wells for GWMgmt #1 and #2 are as follows:

- For GWMgmt #1, recycled water is assumed to remain at 2012 levels and no future water exchanges are included. These values are added to the listed pumping to produce a higher annual pumping rate to represent past practices of reliance on groundwater supplies.
- For GWMgmt #2, SVWD groundwater pumping is set to the listed groundwater pumping in the UWMP. This accounts for the increased use of recycled water and future water exchanges.
- Since groundwater pumping in the UMWP is specified in 5-year increments, pumping is linearly interpolated for the intervening years. For consistency, the annual pumping was distributed to each well proportionally consistent with the 2009 to 2012 pumping distribution used in the Base Case.

For SLVWD, the water supply picture is more complex because of the use of surface water supplies in the Northern System where groundwater is used to supplement the water supply as surface water supplies diminishes over the year. However, the SLVWD availability of surface water sources vary from year-to-year based on climatic conditions. In summary, the groundwater pumping assumptions presented in the WSMP (Johnson, 2009) for SLVWD wells for GWMgmt #1 and #2 are as follows:

- For GWMgmt #1, SLVWD groundwater pumping is set at historical averages for the appropriate years based on data shown on Table 7-5a in the SLVWD WSMP (Johnson, 2009). For GWMgmt #1, no North-South intertie was assumed so that all groundwater demand in the Southern System was included to represent past practices of reliance on groundwater supplies.
- For GWMgmt #2, SLVWD groundwater pumping follows Table 7-6b in the WSMP (Johnson, 2009) that assumes a north-south intertie and utilization of the Loch Lomond water right allows for better use of surface water in the Southern District. This significantly reduces groundwater pumping for SLVWD as reflected on Table 9-2.

- Tables 7-5a and 7-6b from the SLVWD WSMP (Johnson, 2009) are tied to 1985 to 2008 climatic conditions, so this data were mapped directly into the GWMgmt #1 and #2 Scenarios to the appropriate natural hydrology periods in the updated SMGB Model, which runs from 1985 to 2012. The period from 2009 to 2012 was correlated to a similar rainfall year, and the pumping from that year was used as a realistic proxy.

Figure 9-1 shows the groundwater pumping for the GWMgmt #1 and #2 in context with the historical groundwater pumping. For GWMgmt #1, groundwater pumping is higher than the Base Case and generally ranges between 3,000 and 3,500 AFY. For GWMgmt #2, groundwater pumping is less than the Base Case and generally ranges between 2,300 and 3,200 AFY. The groundwater pumping for both cases shows variability reflecting climatic influences primarily on SLVWD groundwater usage. Most of the decrease in pumping is due to higher planned use of surface water supplies, including providing surface water to the Southern System that is currently reliant only on groundwater. More detailed water balance data for GWMgmt #1 and #2 are provided in Appendix H.

TABLE 9-2
GROUNDWATER PUMPING INPUT DATA FROM REPRESENTATIVE YEARS USED FOR BASE CASE, GWMgmt #1 AND #2 SCENARIOS

Scenario Year	1	6	11	16	21	26
Units	AFY	AFY	AFY	AFY	AFY	AFY
Base Case						
SVWD	1,335[1]					
SLVWD	755[1]					
Total SMGB	2,800[1]					
GWMgmt #1						
SVWD	1,358	1,484	1,505	1,526	1,565	1,602
SLVWD	1,202	1,457	958	1,100	1,058	965
Total SMGB	3,133	3,515	3,036	3,199	3,172	3,140
GWMgmt #2						
SVWD	1,358	1,484	1,345	1,316	1,315	1,352
SLVWD	375	501	193	242	272	255
Total SMGB	2,305	2,557	2,110	2,130	2,104	2,179

[1] Annual groundwater pumping for Base Case is constant over the simulation period

9.3.2 GWMgmt Scenario Results

The results of GWMgmt #1 and #2 are compared with the calibrated SMGB Model to provide the historical context of the results and relative to the Base Case to more clearly assess changes in groundwater conditions related to the parameter being evaluated. Comparing both approaches provides an assessment of how different groundwater management strategies affect long-term groundwater conditions.

The results for GWMgmt #1 and #2 shown on Figure 9-1 and Table 9-1 indicate that groundwater in aquifer storage differs between the two cases. As shown on Table 9-1 for GWMgmt #1, groundwater in aquifer storage decreases by about 190 AFY relative to the Base Case whereas GWMgmt #2 results show a 130 AFY increase in groundwater in aquifer storage over the 28-year scenario period. Figure 9-1 shows the change in groundwater in aquifer storage both in context with historical results and relative to the Base Case. In general, groundwater in aquifer storage for GWMgmt #1 and #2 show a similar trend as the Base Case. Relative to the Base Case, there is a gradual departure over time with GWMgmt #1 decreasing over time whereas GWMgmt #2 increases over time. The net result is that GWMgmt #1 has a cumulative 1,500 acre-foot decrease whereas a cumulative 7,500 acre-foot increase in groundwater in aquifer storage over the scenario period.

There is a significant decrease in aquifer storage during the early drought period, but less than the comparable period in the historical base period even though pumping for the early historical base period is about the same as GWMgmt #1. The key difference is the different starting groundwater levels that are higher in the historical base period (representing 1985) than for GWMgmt #1 and #2 (representing 2012). Groundwater pumping draws more from aquifer storage at higher groundwater levels, whereas at lower groundwater levels there is more capture of outflows in addition to aquifer storage.

Figure 9-2 shows GWMgmt #1 and #2 results of total groundwater discharge to streams for the entire SMGB and streamflow in Bean Creek both relative to the Base Case and in context with the historical SMGB Model. Since the natural hydrology input is the same for each model scenario, the variations are directly related to the effects of the different groundwater pumping and differences in water levels as they interact with constant head and general head boundary conditions. The graphs in Figure 9-2 show that stream flows at the end of the scenario period flows are slightly lower for GWMgmt #1 and are slightly higher for GWMgmt #2 relative to the Base Case. The changes for the entire SMGB are proportional to those for just Bean Creek. The difference relative to the Base Case is about 0.2 cfs for groundwater discharge to streams for the entire SMGB, and 0.1 cfs for streamflow in Bean Creek.

Figure 9-4 and 9-5 show maps comparing the cumulative change in groundwater elevations in the Santa Margarita and Lompico Aquifers over the 28-year scenario period relative to the Base Case. Some observations from Figures 9-3 and 9-4 include:

- Groundwater levels in the Santa Margarita show relatively minor changes relative to the Base Case. Some minor recovery in groundwater levels is shown in the vicinity of the SLVWD's Olympia and Quail Hollow wellfields.
- The area of greatest change is where the Santa Margarita overlies the Lompico; however, part of this change reflects changes in the Lompico. Groundwater levels in this area decrease in GWMgmt #1 and increase in GWMgmt #2.
- In the Lompico, the trends for GWMgmt #1 and #2 are opposite. In GWMgmt #1, there is a broad area with lower groundwater levels on the order of 10 to 20 feet in the Scotts Valley area whereas for GWMgmt #2 groundwater levels are generally 20 to 30 feet higher in the same area reflecting the differing groundwater pumping rates in the two scenarios.

9.3.3 Sustainable Yield

The sustainable yield is a concept that is applied to groundwater basins as a mechanism to define the natural limit of groundwater pumping. The sustainable yield represents the annual amount of water that can be taken from the existing wells in a basin over a period of years without "causing adverse impacts." Exceeding the sustainable yield for the basin may lead to perennial declines in groundwater levels which over time may result in widespread loss of well production. Any pumping will have an effect on the overall water balance so defining what an adverse impact is can be subjective and may differ among stakeholders.

Table 9-3 summarizes the groundwater pumping, change in aquifer storage over the 28-year scenario period. From the previous model study (ETIC, 2006), the sustainable yield has been to limit further depletion of aquifer storage beyond the ability of the basin to be replenished naturally. For this study, we can evaluate the results of the groundwater management scenario to determine the pumping rates where the aquifer storage change is zero over the scenario period. For this, a linear regression was calculated comparing average annual groundwater pumping rate vs change in aquifer storage for the Base Case, GWMgmt #1 and GWMgmt #2 for both the entire SMGB Model results and by evaluating each aquifer individually. The sustainable yield is defined by solving the linear regression equation for the groundwater pumping rate where the change in aquifer storage is zero. The sustainable yield based on this calculation is as follows:

- SMGB Model
    - 3,060 AFY
- SMGB by Aquifer
    - Santa Margarita Aquifer – 1,030 AFY
    - Monterey Aquifer – 170 AFY
    - Lompico Aquifer – 1,890 AFY
    - Butano Aquifer – 320 AFY
    - SMGB by summing aquifers – 3,410 AFY

The linear regression analysis for the SMGB for all aquifers is lower than the sum of the analysis performed for each individual aquifer. This is likely due to the composite effects being skewed towards the large pumping aquifer, principally the Lompico, and losing the effects of the variability seen between aquifers. Therefore, the aquifer analysis number is considered more appropriate, but the results of the two analyses give a sense of the variability in determining a sustainable yield for the SMGB.

For this study, the sustainable yield for groundwater pumping is in the range of 3,050 to 3,400 AFY. The higher estimate for the aquifer level analysis better identifies remaining yield potential remaining in specific aquifers whereas the entire SMGB Model analysis is more skewed by the effects in the larger aquifers. These values are consistent with the sustainable yield for the entire SMGB from the ETIC (2006) report of 3,320 AFY. An earlier estimate of 4,200 acre-feet was developed using a water balance approach without the use of a numerical model (Todd Engineers, 1998).

Looking at the results on an aquifer basis, the Santa Margarita may have additional pumping capacity, whereas the Lompico, Monterey and Butano are already near their pumping capacity.

The changes were almost entirely within the Santa Margarita Aquifer with little to no change in the Monterey, Lompico and Butano. These changes appear to be minor for the range of pumping evaluated, so that little variation in stream baseflows is indicated by these scenarios.

This estimate of sustainable yield is limited to an assessment of the existing well locations. An evaluation of new pumping sites located distant from existing locations to limit well interference has the potential to provide a higher sustainable yield estimate. The model provides a quantitative tool that could be used to further optimize groundwater pumping to maximize the sustainable yield while maintaining defined criteria for "adverse effects." In this manner, the SMGB Model could be used to locate additional pumping locations to supplement the water supply with little to no "adverse effects."

TABLE 9-3
SUSTAINABILITY OF GROUNDWATER PUMPING
RELATIVE TO AQUIFER STORAGE CHANGE AND STREAM DISCHARGE

Scenario	Groundwater Pumping	Change in Aquifer Storage	Discharge to Rivers and Streams	Bean Creek Summertime Baseflow
Units	AFY	AFY	AFY	cfs
Entire SMGB				
Base Case	2,840	105	6,110	1.79
GWMgmt #1	3,370	-130	5,970	1.74
GWMgmt #2	2,420	230	6,230	1.83
Santa Margarita Aquifer				
Base Case	630	35	4,380	1.28
GWMgmt #1	830	20	4,260	1.24
GWMgmt #2	400	65	4,480	1.31
Monterey Aquifer				
Base Case	170	15	1,040	0.33
GWMgmt #1	170	-5	1,040	0.33
GWMgmt #2	170	25	1,040	0.33
Lompico Aquifer				
Base Case	1,710	85	60	0.01
GWMgmt #1	1,990	-50	55	0.01
GWMgmt #2	1,520	65	165	0.01
Butano Aquifer				
Base Case	330	-25	635	0.17
GWMgmt #1	380	-95	625	0.17
GWMgmt #2	340	-25	640	0.18

Note: Values in tables are rounded for convenience. More detailed data presented in Appendix H.

Another potential adverse of the long-term groundwater pumping effect is changes in the streamflows. Table 9-3 summarizes the simulated discharge of groundwater to streams and the San Lorenzo River over the SMGB, and summertime streamflow in Bean Creek near the Mount

Hermon Road Bridge. The scenario results indicate changes to groundwater discharge to streamflow varies about 2% between the three scenarios. The scenario results indicate that the volume and location of the projected future pumping in these scenarios would have minor additional effect on streamflows. This suggests that the primary effects on streamflows likely have already been experienced as a result of historical groundwater level declines.

9.4 Enhanced Recharge (E-Rch) Project Scenarios

The evaluation of enhanced recharge projects to increase aquifer storage and improve stream baseflow is another key application for the updated SMGB Model. The enhanced recharge scenarios are adapted from the County's recent Conjunctive Use Study (Kennedy/Jenks, 2011b). The following describes the setup and results of two enhanced recharge scenarios that were selected as representative applications.

9.4.1 E-Rch #1 and #2 Approach

The Enhanced Recharge (E-Rch) Scenario is setup as two cases to provide a compare and contrast assessment for different types of recharge project and comparing those result to both the Base Case and the GWMgmt Scenarios. These include:

- E-Rch #1 applies a 1,000 AFY recharge project using injection wells into the Lompico at the Hanson Quarry site west of Scotts Valley
- E-Rch #2 applies Low Impact Development (LID) for stormwater recharge using near-surface recharge basins at multiple locations in Scotts Valley
- All other assumptions and input in the model are the same as GWMgmt #2 that includes the assumption that the groundwater management measures in the SVWD UWMP (Kennedy/Jenks, 2011a) and the SLVWD WSMP (Johnson, 2009) are enacted.

More detailed water balance data for E-Rch #1 and #2 is provided in Appendix H. The two enhanced recharge cases are adapted from the County's Conjunctive Use Study (Kennedy/Jenks, 2011b) to the updated SMGB Model.

9.4.2 E-Rch #1 Scenario Setup and Results

For E-Rch #1, twelve injection wells were simulated that were distributed over an area of approximately 80 acres within the former Hanson Quarry. Each well injected approximately 83 AFY of recharge water into the Lompico. The recharge was varied seasonally as follows:

- 25% of water recharged during the first quarter of the water year (October through December),
- 50% in the second quarter (January through March),
- 25% in the third quarter (April through June), and
- 0% in the fourth quarter (July through September).

This recharge bypasses the Santa Margarita and is injected directly into the Lompico. The County's Conjunctive Use Study (Kennedy/Jenks, 2011b) evaluated multiple potential recharge alternatives including injection wells and recharge basin for recharge into either the Santa Margarita or Lompico Aquifers. The Lompico has the highest available potential aquifer storage capacity; therefore, there is an operational advantage in recharging the Lompico directly with respect to increasing aquifer storage.

From Figure 9-1, it can be seen that aquifer storage increases at a relatively steady rate over first 15 years of the 28-year scenario and then levels off. Of the approximately 28,000 acre-feet of water added to the aquifer, it is estimated that nearly 10,000 acre-feet remain in storage. The increased groundwater levels result in increases in summertime stream baseflow in the area. Figure 9-2 shows that the overall groundwater discharge to streams increases by about 0.8 cfs, and the summertime streamflow in Bean Creek increases steadily over the 28-year scenario by about 0.48 cfs.

From the overall water budget, the SMGB model shows that approximately 36% of the enhanced recharge volume remains in aquifer storage after 28 years. About 30% discharges to the nearby streams and about 34% is discharged to the nearby springs or lost to ET (Table 9-1). However, the distribution is not constant over time. During the first half of the scenario period, the increase in aquifer storage is higher. During scenario years 1 through 14, about 69% of the recharge water goes into aquifer storage, whereas during scenario years 15 through 28, only about 5% goes into aquifer storage. Summertime streamflow in Bean Creek increases by 0.34 cfs over scenario years 1 to 14 then increases another 0.14 cfs during scenario years 15 through 28. This indicates that the efficiency of this project for both aquifer storage and summertime streamflow in Bean Creek is highest when groundwater levels are lower. The Model can be used to better optimize potential enhanced recharge options including simulation of additional groundwater pumping for managing groundwater levels.

Figure 9-6 shows the provide maps comparing the cumulative change in groundwater elevations for E-Rch #1 in the Santa Margarita and Lompico Aquifers over the 28-year scenario period relative to the Base Case Scenario. Some observations from Figures 9-6 include:

- Groundwater levels in the Santa Margarita Aquifer show significant increases where it directly overlies the Lompico to the point of resaturating much of the Santa Margarita. Increases on the order of 20 feet are relatively widespread in the southern SMGB.
- In the Lompico, groundwater levels recover over 100 feet in the southern SMGB and over 50 feet over the SMGB representing the increase volume of groundwater in aquifer storage.

The SMGB model could be run to optimize placement and operation of recharge systems. In addition, further site-specific investigations may find conditions that may affect the actual performance relative to the SMGB model, which is constructed on a regional scale.

9.4.3 E-Rch #2 Scenario Setup and Results

A second scenario was created to simulate surface recharge in a more dispersed system that was intended to mimic numerous small recharge basins. These scenarios evaluate the construction of low impact development (LID) style stormwater systems that would collect stormwater runoff into small percolation basins or other similar structures for groundwater recharge.

This scenario is derived from alternatives included in the County's Conjunctive Use Study (Kennedy/Jenks, 2011b) and adapted to the updated SMGB Model. LID recharge was assumed to occur from 21 locations along Mount Hermon Road and Scotts Valley Drive in Scotts Valley. The locations are based on a preliminary siting study conducted by SVWD that identified and evaluated potential sites in Scotts Valley (Kennedy/Jenks, 2012a). This scenario assumes large-scale retrofit of existing urbanized areas primarily commercial development with large shopping centers and extensive areas of large, paved parking lots. The model scenarios assume that a portion of the stormwater runoff from the roofs, parking areas and streets would be collected into small percolation basins or other similar structures for groundwater recharge. The recharge was applied to Model Layer 1 to represent the surface recharge from the LID locations.

The volume of stormwater recharge was developed by adapting a rainfall-recharge analysis performed for the Woodside Development along Scotts Valley Drive by Ruggeri-Jensen-Azar (2010a, 2010b) and Todd Engineers (2007) for the developer. Ruggeri-Jensen-Azar (2010b) analysis evaluated different rainfall amounts based on historical records from the SVWD rain gage located across the street from the site. Runoff was estimated using the Soil Conservation Service (SCS) unit hydrograph procedure. The results of the Continuous Simulation Model provided an estimate of the annual infiltration volume for the facility. The volume of stormwater recharge varied for each year based on the rainfall record. A linear regression analysis was applied to extend the 1990 to 2005 rainfall history used for the Continuous Simulation Model over the scenario period of 1985 to 2012.

The Woodside analysis was based on a drainage area of 12.3 acres contributing to the facility. The other 20 urban sites are considered to have smaller drainage areas, so the volume was made proportional to the estimated contributing drainage area (Kennedy/Jenks, 2012a). The total recharge from the LID facilities varied 15 to 210 AFY for an annual average of 188 AFY resulting in a cumulative recharge of about 3,300 acre-feet over the 28-year scenario period.

From Figure 9-1, it can be seen that aquifer storage increases at a slightly higher rate than for GWMgmt #2, which provides the underlying assumptions and conditions. Of the approximately 3,300 acre-feet of water added to the aquifer, it is estimated that about 970 acre-feet remain in storage representing about 30% of the total LID recharge The increased groundwater levels result in increases in summertime stream baseflow in the area. Groundwater discharge to streams increases about 1,500 acre-feet representing about 45% of the total recharge. Figure 9-2 shows the summertime streamflow in Bean Creek increases steadily over the 28-year scenario and in the final scenario year increases from 0.13 cfs in GWMgmt #4 to 0.24 cfs in E-Rch #2.

Figure 9-7 shows the provide maps comparing the cumulative change in groundwater elevations for E-Rch #1 in the Santa Margarita and Lompico Aquifers over the 28-year scenario period relative to the Base Case Scenario. Some observations from Figures 9-7 include:

- Groundwater levels in the Santa Margarita Aquifer show significant increases where it directly overlies the Lompico to the point of resaturating much of the Santa Margarita. Limited increases on the order of 5 feet are relatively widespread in the southern SMGB.
- In the Lompico, groundwater levels recover over 50 feet in the southern SMGB and over 20 feet over the SMGB representing the increase volume of groundwater in aquifer storage. Because much of the LID recharge is situated over the area where the Santa Margarita directly overlies the Lompico, a substantial amount of the recharge does reach and help sustain groundwater levels in the Lompico.

These model results indicate that the dispersed recharge from LID recharge facilities into the Santa Margarita has potential for increasing groundwater in storage and summertime baseflow. The volume of recharge is limited by the volume of stormwater that can be directed into a LID facility for groundwater recharge. The SMGB Model can be used as a quantitative tool to further evaluate and optimize the siting and design of the future LID projects.

9.5 Climatic Variability Scenario

The purpose of Climate Variability Scenario is to assess the influence of variations in climate, primarily precipitation, on groundwater conditions. In addition, the climate variation data was input into the calibrated historical model to evaluate the sensitivity of the SMGB Model to climate variations.

9.5.1 Climate Scenario Approach

The Climate Variability Scenario is setup as two cases to provide a compare and contrast assessment for different hydrologic conditions relative to the Base Case. Two cases for the Climate Variability Scenario were developed that modify the natural hydrology inputs to assess the effect on aquifer storage and stream baseflow. These include:

- Climate #1 assumes average precipitation conditions over the simulation period. This scenario helps to assess changes in baseflow and groundwater storage associated with an ongoing rainfall deficit..
- Climate Scenario #2 assumes that the difference from average precipitation is increased by 20% for each model stress period. Climate #2 evaluates one aspect of potential climate change characterized by more extreme precipitation conditions of having wetter “wet” years and drier “dry” years.
- All other conditions in the Climate #1 and #2 are set the same as in the Base Case for provide for consistency in evaluating the scenario results of simulated future conditions.

Table 9-4 provides a summary of the variation in total groundwater inflows applied for the Climate #1 and #2 scenarios compared to the Base Case. Data is presented for the Santa Margarita and Lompico Aquifers to provide a comparison of the differences in the effects of climatic variability. More detailed data on the distribution of recharge is provided in Appendix H.

The setup for Climate #1 and Climate #2 does not include modifications to assess the potential effects of soil moisture; however, these are potentially significant for a more rigorous climate analysis. The rational method approach developed for deriving the runoff and recharge calculations includes an accounting for evapotranspiration. For more comprehensive scenarios, these parameters can also be changed, either as a long-term average or varied over shorter time intervals, for assessing the effects of future climate change.

TABLE 9-4
BASE CASE AND CLIMATE VARIABILITY SCENARIO WATER BALANCE RELATIVE TO AQUIFER STORAGE CHANGE AND STREAM DISCHARGE

Scenario	Natural Recharge	Aquifer Groundwater Exchange	Change in Aquifer Storage	Discharge to Rivers and Streams	SMGB Summertime Baseflows
Units	AFY	AFY	AFY	AFY	cfs
Entire SMGB					
Base Case	13,900	0	140	6,650	1.79
Climate #1	14,800	0	210	7,150	1.90
Climate #2	13,700	0	110	6,540	1.76
Santa Margarita Aquifer					
Base Case	10,000	-1,190	30	4,380	1.28
Climate #1	10,660	-1,270	50	4,680	1.36
Climate #2	9,850	-1,170	30	4,320	1.26
Lompico Aquifer					
Base Case	750	1,220	80	90	0.01
Climate #1	760	1,270	110	110	0.01
Climate #2	750	1,200	70	90	0.01

Note: Values in tables are rounded for convenience. More detailed data presented in Appendix H.

9.5.2 Climate #1 Setup and Results

Climate #1 applies average precipitation over the entire scenario period. During the historical period of 1985 through 2012, there is a rainfall deficit of about 40 inches. Climate #1 provides a basis for understanding the contribution of this rainfall deficit to the cumulative change in aquifer storage during the base period.

The precipitation and hydrology input data for Climate #1 uses average quarterly precipitation based on long-term records at Scotts Valley and Boulder Creek. The pumping and initial groundwater elevations are the same as the Base Case. Climate #1 compares an assumption of a long-term average hydrology to a more naturally distributed hydrology.

The results of Climate #1 show that of the approximately 900 AFY of additional recharge compared to the Base Case, about 10% contributes to an increase in aquifer storage, 55% to increased stream baseflow and the remainder to other groundwater discharges (Table 9-4). The summertime contribution to stream baseflow was about 6% higher in Climate #1 compared to the Base Case.

Most of the approximately 660 AFY of additional recharge in the Santa Margarita Aquifer, only about 3% contributes to an increase in aquifer storage, whereas 45% goes to increased stream baseflow, about 10% flows to other aquifers, and the remainder to other groundwater discharges primarily springs (Table 9-4). In contrast, the Lompico Aquifer sees only about 10 AFY of increased recharge, but also receives about 50 AFY of increase inflow primarily from the Santa Margarita Aquifer. Of the total additional inflows to the Lompico, about 50% goes to aquifer storage, 30% to stream discharge, and 20% to other discharges.

As expected with uniformly applying average conditions, the change in basinwide aquifer storage and summertime streamflow in Bean Creek shows smoother year-to-year change than the more natural hydrology in the Base Case (Figure 9-8).

Figure 9-9 shows the provide maps comparing the cumulative change in groundwater elevations for Climate #1 in the Santa Margarita and Lompico Aquifers over the 28-year scenario period relative to the Base Case. Some observations from Figures 9-9 include:

- Groundwater levels in the Santa Margarita Aquifer show significant increases where it directly overlies the Lompico, to the point of resaturating much of the Santa Margarita. Increases on the order of 20 feet are relatively widespread in the entire Santa Margarita Aquifer.
- In the Lompico, groundwater levels recover over 20 feet in the southern SMGB over the SMGB representing the increase volume of groundwater in aquifer storage.

Most of the available aquifer storage is in the Lompico; however, the geology of the SMGB limits the recharge area for the Lompico, so it is less affected by variations in climate. Therefore, only about 10% of the decline in aquifer storage may be attributed to the rainfall deficit. This is consistent with groundwater elevation data that indicates that the SMGB aquifers are not subject to large seasonal variations due to climatic variations.

9.5.3 Climate #2 Scenario Setup and Results

Climate change is a growing concern for water managers in the SMGB. Although the understanding of what climate change will entail is evolving, especially for the California Coastal areas, a general consensus is that although average precipitation may remain similar, the year-to-year precipitation will become more extreme with wetter “wet” years and drier “dry” years. A state climate report issued in April 2009 (DWR, 2009) found that changing precipitation patterns will “result in longer and drier droughts and decreased groundwater levels, coupled with a higher frequency and severity of extreme flooding events.”

Climate change is a complex subject that may potentially have multiple impacts on the SMGB. For Climate #2, the focus is on assessing only the effects of more extreme variations in precipitation. To simulate this, the difference between the average and measured precipitation for each time period in the model was increased by 20%. This caused “wet” years to get wetter, “dry” years to get drier and “average” years to remain about the same. Since these changes roughly balance out, the total precipitation for Climate #2 is about 1% less than for the Base Case. Of the approximately 200 AFY of decreased recharge compared to the Base Case, about 10% is attributed to an increase in aquifer storage, 55% to a decrease in groundwater discharge to streams (Table 9-4). The summertime contribution to stream baseflow was about 2% lower in Climate #2 compared to the Base Case.

For the Santa Margarita Aquifer, of the approximately 150 AFY of decreased recharge in the Santa Margarita Aquifer, only about 10% is attributed to a decrease in aquifer storage, whereas 40% goes to increased stream baseflow, about 10% flows to other aquifers, and the remainder to other groundwater discharges primarily springs (Table 9-4). In the Lompico Aquifer, there is essentially no change in natural recharge, but a 20 AFY decrease in inflow primarily from the Santa Margarita Aquifer. This decreased inflow decreases aquifer storage about 10 AFY, where stream discharge is essentially unchanged. Because of the physical limitations for natural recharge reaching the Lompico, the climate variations have limited effect on changing the aquifer storage.

From Figure 9-8 shows that the aquifer storage and Bean Creek streamflow vary consistently with the Base Case, but reflect the input conditions of lower levels during the drought, but these levels recover during the subsequent wet periods to essentially balance out over the 28-year scenario period.

Figure 9-10 shows the provide maps comparing the cumulative change in groundwater elevations for Climate #1 in the Santa Margarita and Lompico Aquifers over the 28-year scenario period relative to the Base Case. The results on Figure 9-10 show little variation compared to the Base Case on Figure 9-3.

Climate #2 demonstrates the ability to the updated SMGB Model to be applied for climate analysis. The revised approach for estimating recharge and streamflow directly from precipitation data allows for development of a synthetic rainfall history that can be applied for evaluating groundwater conditions in the SGMB.

9.6 Additional Historical Aquifer Storage Assessment

Declining groundwater levels are a significant issue in the SMGB. The historical model indicates approximately 28,000 acre-feet of aquifer storage loss over the 1985 to 2012 Base Period. However, additional aquifer storage loss occurred as a result of groundwater pumping prior to 1985.

To develop the initial groundwater levels for the historical model, a steady-state model was used that provided a long-term estimate of groundwater pumping prior to 1985 that is representative of historical groundwater levels. Because groundwater levels were not stable prior to 1985, the steady-state model cannot be considered as calibrated, but it provides a reasonable approximation of groundwater levels in 1985. This steady-state version of the SMGB Model is used to provide an assessment of potential aquifer storage loss prior to 1985 and re-evaluates assessments of recharge loss due to urbanization.

Since a steady-state model does not consider aquifer storage properties, the analysis was done by comparing the difference in groundwater elevations between the predevelopment, non-pumping condition steady-state conditions compared to the long-term estimate of groundwater pumping prior to 1985 for the three major aquifers. The cell-by-cell groundwater elevations were exported and the analysis was performed using the Golden Graphics SURFER program. The groundwater elevation difference was then multiplied by the average storage coefficient for each respective aquifer to provide an estimate of the volume of groundwater in aquifer storage. Using the range in potential aquifer storage properties, the range in pre-1985 aquifer storage loss is estimated to have an error on the order of about 25%.

The results of the analysis are provided in Table 9-5. The pre-1985 aquifer storage loss is estimated about 3,800 acre-feet, with the majority derived from the Santa Margarita and Lompico Aquifers. This is consistent with observed pre-1985 groundwater levels declines which show that the largest decreases were observed after 1985. Therefore, pre-1985 storage losses are about 15% of the post-1985 storage losses.

The Santa Margarita Aquifer experienced the highest percentage losses. This is consistent with groundwater pumping in the Lompico in the Scotts Valley area affecting groundwater levels in the area where the Santa Margarita and Lompico are in direct contact. As these areas became unsaturated in the post-1985 period, a higher percentage of the aquifer storage loss shifted to the Lompico.

TABLE 9-5
COMPARISON OF ESTIMATED PRE-1985 TO SIMULATED 1985-2012 CHANGE IN AQUIFER STORAGE

Aquifer	Pre-1985 Estimate	1985 – 2012 Base Period	Change in Aquifer Storage
Units	acre-feet	acre-feet	acre-feet
SMGB	-3,830	-27,800	-31,630
Santa Margarita	-2,000	-3,100	-5,100
Lompico	-1,700	-13,600	-15,300
Butano	-130	-8,500	-8,630

Note: Values in tables are rounded for convenience. More detailed data presented in Appendix H.

9.7 Effects of Urbanization on Groundwater Recharge

The loss of groundwater recharge is integrally linked to the increased stormwater runoff from increased urbanization. The relatively high rainfall volumes in the Santa Cruz Mountains contribute to groundwater recharge, particularly in the areas where high permeability units are exposed at the ground surface. However, land use changes due to development in the SMGB have affected the recharge rates. This is especially the case for the increased impervious areas in the commercial/industrial and suburban land use primarily in the Scotts Valley area. Development along the Highway 9 corridor in Ben Lomond and Boulder Creek also has a similar effect; however, much of this development is outside the SMGB.

To evaluate the loss of groundwater recharge as a result of urbanization in the groundwater model, the land use factors used for the updated SMGB Model were changed back to those for undeveloped lands prior to development (Table 6-3). These results were applied over the area for each land use type. From this, the estimated change in groundwater recharge to the SMGB was estimated and the results are shown on Table 9-6.

The results shown on Table 9-6 are shown for the commercial/industrial and suburban land use primarily in the Scotts Valley area and other land use types over the remainder of the SMGB. These results indicate that the average decrease in groundwater recharge is about 1,900 AFY. Over the past 25 years, the volume of lost groundwater recharge is estimated to be approximately 53,000 acre-feet compared to nearly 400,000 to total recharge over the Base Period. Therefore, the results of urbanization have reduced total recharge in the SMGB by about 10% to 12%. This loss of groundwater recharge contributes to both the historic declines in groundwater levels observed in the SMGB and to reduced stream baseflows in the San Lorenzo River Watershed. From the scenario results, the amount of this recharge affecting groundwater storage would be in the range of 10% to 30%, and the change in stream baseflow would be in the range of 30% to 60%.

TABLE 9-6
CHANGE IN AQUIFER STORAGE OVER TIME
BY AQUIFER FROM 1985 TO 2012

Land Use	1985-1991	1992-1998	1997 – 2005	2006 - 2012	Total
Units	AF	AF	AF	AF	AF
Annual Average					
Suburban	-565	-850	-781	-769	-742
Comm/Ind	-345	-518	-477	-469	-452
Other Land Use	-515	-844	-742	-722	-706
Total	-1,425	-2,212	-2,000	-1,961	-1,899
Cumulative Total					
Suburban	-4,000	-5,900	-5,500	-5,400	-20,800
Comm/Ind	-2,400	-3,600	-3,300	-3,300	-12,700
Other Land Use	-3,600	-5,900	-5,200	-5,100	-19,800
Total	-10,000	-15,500	-14,000	-13,700	-53,200

Note: Values in tables are rounded for convenience.

Section 10: Summary and Conclusions

The objectives of the Santa Margarita Groundwater Modeling Project are to update, recalibrate, and improve the overall performance of the SMGB Model. This Technical Report provides documentation of the many updates and improvements to the SMGB Model. These include incorporation of new hydrogeological data and geologic interpretations into the SMGB Model setup and calibration. New modeling techniques were applied for better data management and to take advantage of new MODFLOW features. The updated model was used to evaluate potential future groundwater conditions using projected groundwater management approaches and the effects of climate variability.

10.1 Summary of SMGB Model Update

The conceptual model represents our understanding of the key hydrogeological characteristics and features that control how groundwater moves through the SMGB. The basic components of the hydrogeological conceptual model include the developing the geologic framework of the Basin aquifers, developing a water balance of recharge and outflows, and defining aquifer properties. The primary updates to the conceptual model involved the following:

- The SMGB Model incorporates an updated characterization of the Santa Margarita, Monterey, and Butano Aquifers based on new well data and geologic interpretations. This update in a redefines of the vertical thickness of the Santa Margarita and Monterey over a portion of the southern SMGB. The Butano was extended over more of the northern and central SMGB and updated to better represent its full stratigraphic thickness.
- The number of layers used to simulate the SMGB aquifers was increased from four to seven. The Monterey was subdivided into two model layers to account for the presence of more permeable sandstone layers in the lower Monterey. The Butano was subdivided into three model layers to simulate its substantial thickness and the thick shale unit that separates the upper and lower members of the Butano.
- All of the minor internal faults used to provide controls to groundwater flow and help with the calibration in some areas in the previous (ETIC, 2006) version were removed in the updated SMGB Model as recommended by the TAC.
- The model domain was extended to the northeast to include the Blackburn Gulch area that represents a key recharge area for the Lompico and Butano. This changed allowed for more direct simulation of groundwater-surface water interactions in this portion of the SMGB.
- The distribution of precipitation was partitioned among infiltration, runoff and consumptive loss using a rational method approach (Chow *et al*, 1988) using a spreadsheet based data management system. The process distributes groundwater recharge and runoff based on the geology, vegetation and land use factors across the SMGB using a simplified variation of more advanced distributed parameter models.
- The MODFLOW code was updated to MODFLOW NWT (Niswonger *et al*, 2011) to take advantage of new advanced features. For improved simulation of the groundwater–surface water interactions, the Streamflow Routing (SFR) package (Prudic *et al*, 2004)

was used to simulate streams including use of the GAGE package (Prudic *et al*, 2004) to monitor simulated flow in the streams.

- The overall distribution of aquifer properties and hydrogeologic features was updated based on recent data and hydrogeologic interpretations

Through these efforts, the calibration of the SMGB Model comparing simulated to measured groundwater levels from 1985 to 2012 was improved on the order of about 30% compared to the previous SMGB Model. Using the MODFLOW GAGE package, the model was also calibrated to streamflow by comparing simulated to measured streamflow at the USGS stream gage stations within the SMGB. These improvements make the SMGB a better quantitative tool for assessing groundwater conditions in the SMGB.

The updated Model was evaluated to determine that the cumulative change in aquifer storage in the SMGB since 1985 was approximately 28,000 acre-feet. Of that total, approximately 50% was experienced in the Lompico, 30% in the Butano, and 10% each in the Santa Margarita and Monterey. Pre-1985 aquifer storage declines were estimated using a steady-state version of the SMGB Model. Using this approach, an additional 4,000 acre-feet of aquifer storage decline was estimated for a total cumulative aquifer storage decline of 32,000 acre-feet. These results demonstrate that the Lompico is the most impacted aquifer with a cumulative decline of over 15,000 acre-feet. The overall change in net aquifer storage is consistent with previous estimates by Johnson (2009) and Kennedy/Jenks (2011b).

10.2 Summary of Scenario Results

Once calibrated, the SMGB Model is capable of serving as a quantitative tool to forecast future groundwater conditions. The primary applications for the SMGB Model are to assess options for managing future water supplies and the effects of climate variations. The selected future-case scenarios were grouped together to meet the following objectives:

- Base Case Scenario – represent a continuation of current pumping and repeats historical hydrological conditions to serve as a basis of comparison for the other model scenarios.
- Groundwater Management Scenario – assess the effects of implementation of groundwater management actions based on the SVWD UWMP (Kennedy/Jenks, 2011a) and the SLVWD WSMP (Johnson, 2009) to evaluate the effects of potential future groundwater pumping on aquifer storage and stream baseflow.
- Enhanced Recharge Scenario – assess the effects of implementation of potential future enhanced recharge projects based on the County's Conjunctive Use Project (Kennedy/Jenks, 2011b) on aquifer storage and stream baseflow.
- Climate Variation Scenario – provide an assessment of the effects of variations in the natural hydrology (precipitation and streamflow) on aquifer storage and stream baseflow.
- Sensitivity Analysis Scenario – evaluate the model calibration over the 1985 to 2012 base period by varying the natural hydrology using the same approach as for the Climate Variation Scenario.

Pumping in the Base Case is about 900 AFY less than in the calibrated SMGB Model. As a result, the aquifer storage increases 4,000 acre-feet during the Base Case whereas it decreased by about 28,000 acre-feet in the calibrated SMGB Model. This is due both to the difference in pumping, but also because the Base Case Scenario starts at a lower initial groundwater levels that account for the historical drawdown.

A key aspect of groundwater management is to better understand the sustainability of long-term groundwater pumping within the SMGB. The sustainable yield is intended to represent the rate of groundwater pumping that does not cause adverse conditions over time. Using an assumption that adverse conditions would be no further reduction in aquifer storage, analysis of the Groundwater Management Scenario indicates that the sustainable yield is on the order of 3,000 to 3,400 AFY using the current pumping locations. Potentially, the SMGB Model can be used to optimize the sustainable yield by distributing the pumping across the SMGB to increase pumping potential while maintaining aquifer storage and stream baseflows.

Another method to increase groundwater in aquifer storage is through enhanced recharge programs. Two cases were run for the Enhanced Recharge Scenario that evaluated options in the County's Conjunctive Use Project (Kennedy/Jenks, 2011b). Enhanced groundwater recharge using injection wells at the Hanson Quarry site was simulated. Of the 28,000 acre-feet of water injected, about 35% remains in aquifer storage, 30% discharges to nearby streams and the remainder discharges to springs or lost to ET. The second case evaluated LID recharge facilities in Scotts Valley. In this case, of the 3,300 acre-feet of stormwater recharge, about 30% remains in aquifer storage, 45% discharges to nearby streams and the remainder discharges to springs or lost to ET. These simulations show that enhanced recharge projects are beneficial for helping to increase the groundwater in aquifer storage and increasing stream baseflows.

The Climate Variability Scenario looked at two cases. The first case applied average annual precipitation. The results were that only about 10% of the aquifer storage loss is attributed to the 40-inch rainfall deficit over the 1985 to 2012 base period. The second case assessed one assumption of climate change that although average precipitation may remain similar, the year-to-year precipitation will become more extreme with wetter wet years and drier dry years. To simulate this, the difference between the average and measured precipitation for each time period in the model was increased by 20%. The results showed that this type of climate variability had a stronger effect on streamflows than on aquifer storage.

10.3 Applicability of Model Results

The SMGB Model is designed as a regional or basin-wide model to evaluate long-term, regional trends and the overall groundwater inflow and outflow to the basin. Within that scale, conditions are averaged. However, this model may not contain the site-specific details to evaluate some localized conditions that are due to geologic complexity or unique localized effects. For these areas, a more localized model may be required if such a detailed analysis is necessary. The regional model can provide a broader regional context for these localized models.

When evaluating model results, it is important to consider the strengths and limitations of the numerical model. The horizontal and vertical resolution used to construct the model dictates the range of scales that the model can evaluate. The results can be evaluated for overall trends and more localized effects. For example, a regional or basin-wide model will not likely contain the site-specific details of a more localized model, but a regional model will better evaluate a local area within the broader regional context.

With the improved calibration, the SMGB Model is considered capable of simulating future conditions with reasonable accuracy. Input parameters can be set to simulate a wide range of potential future groundwater uses or hydrogeologic scenarios. By modifying the input data, the model provides the capability to simulate a wide range of potential future conditions. The types of future conditions can include natural or climatic variations such as variation in rainfall over time in a drought scenario. Future groundwater practices can also be evaluated such as changes in the amount and distribution of groundwater pumpage, the addition of groundwater recharge programs, or evaluating the benefits of water projects on groundwater conditions. The impact of regional water quality issues, such as salts and nutrients, could also be addressed using the model. The updated SMGB Model provides another method to optimize the sustainable yield through balancing the amount of water entering and exiting the basin and the rate of groundwater flow through the basin.

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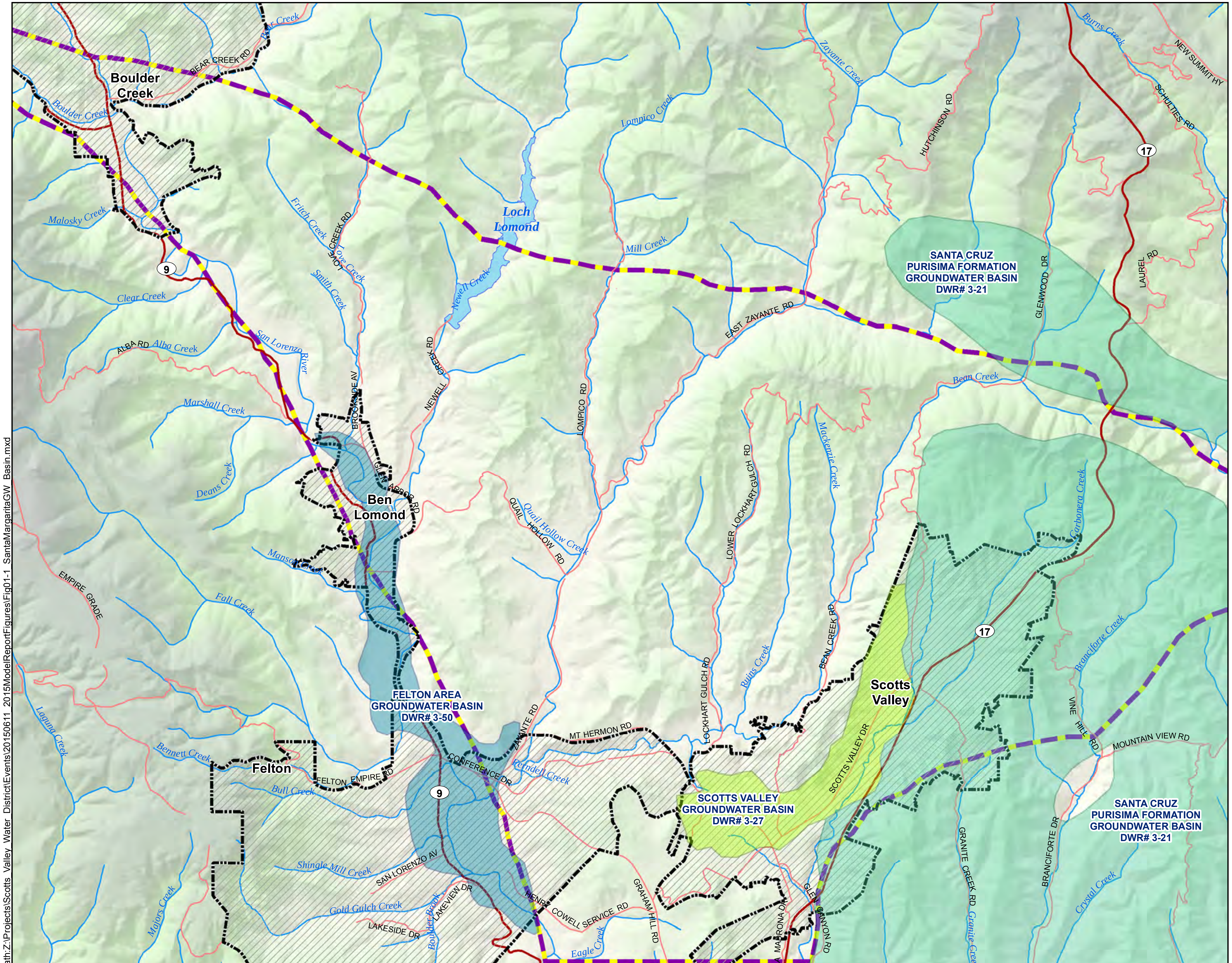
Figures



Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig01-1 SantaMargaritaGW Basin.mxd

LEGEND

- Santa Margarita Groundwater Basin Boundary
- Felton Area Groundwater Basin (DWR Basin 3-50)
- Santa Cruz Purisima Formation Groundwater Basin (DWR Basin 3-21)
- Scotts Valley Groundwater Basin (DWR Basin 3-27)
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

N

0 0.5 1

Scale: Miles

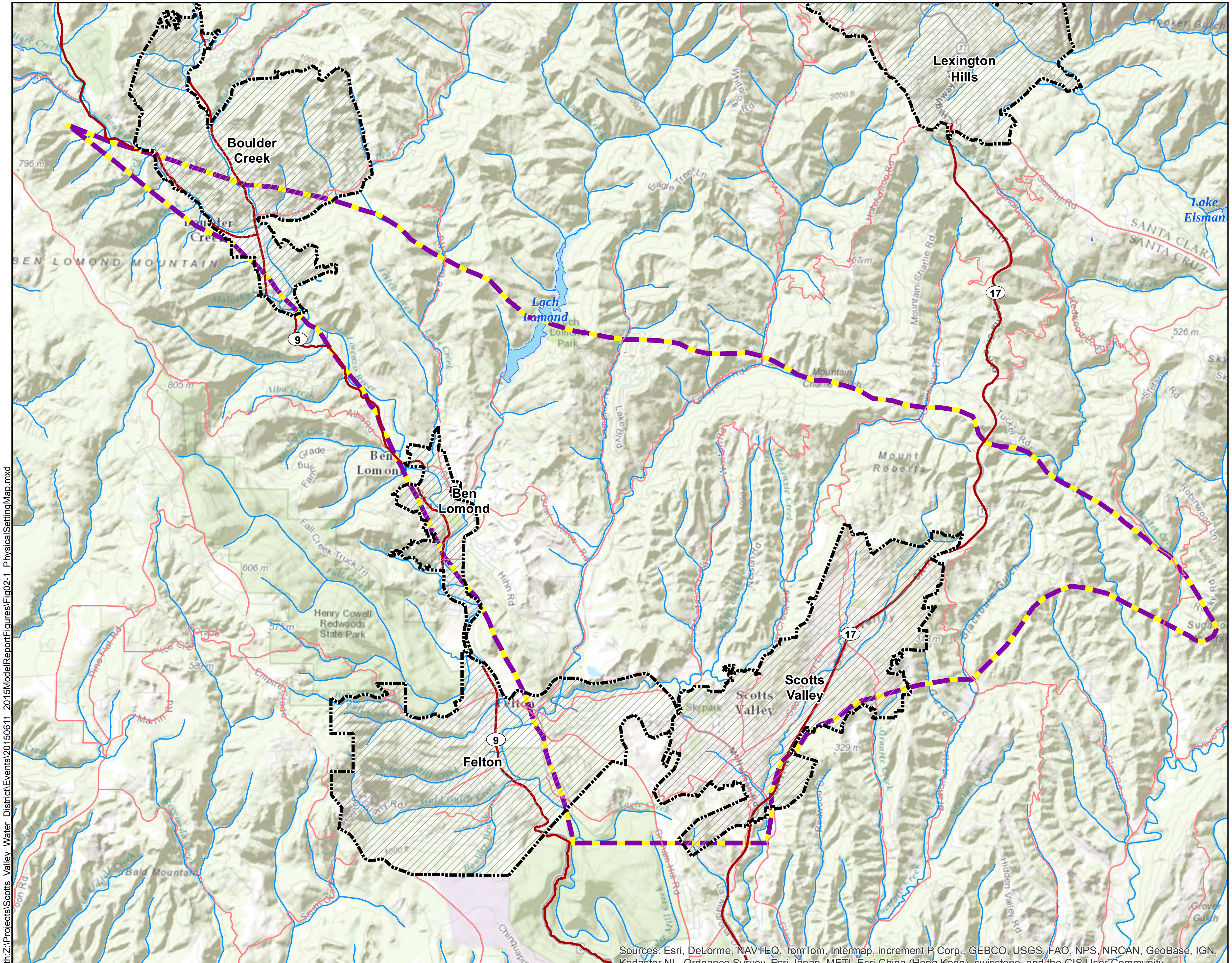
Kennedy/Jenks Consultants

Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Santa Margarita Groundwater Basin with DWR Groundwater Basins

K/J 1264001.00
June 2015

Figure 1-1



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LEGEND

- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

N

0 0.5 1

Scale: Miles

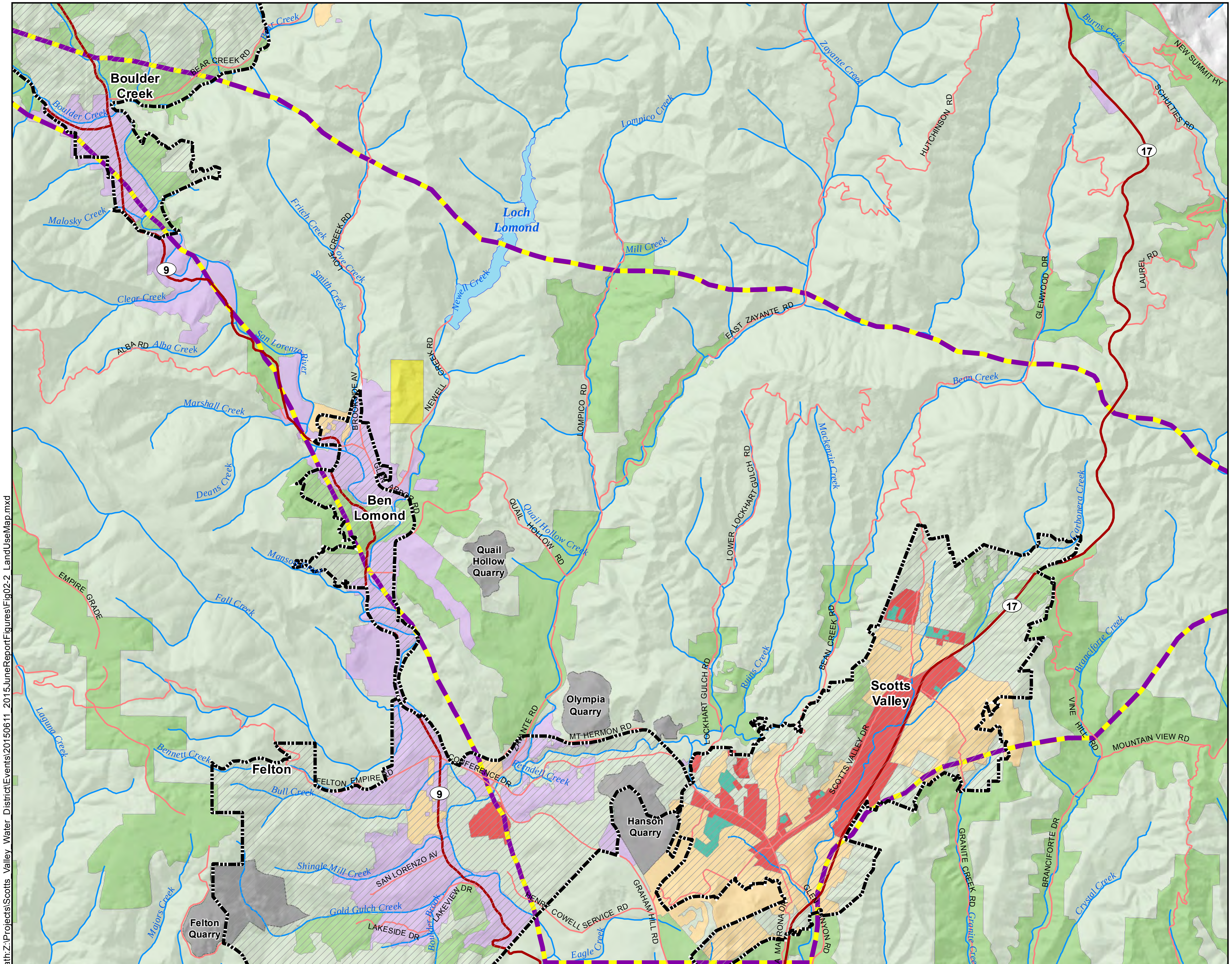
Kennedy/Jenks Consultants

Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Physical Setting of the Santa Margarita Groundwater Basin

K/J 1264001.00
June 2015

Figure 2-1



LEGEND

- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

Land Use

- Commercial/Industrial
- Suburban
- Small Community
- Rural Domestic
- Rural/Native/Undeveloped
- Irrigated Area
- Landfill
- Quarry

Data Source: Santa Cruz County Geographic Information System File Download Site, http://gis.co.santa-cruz.ca.us/file_download_site/

N

0 0.5 1

Scale: Miles

Kennedy/Jenks Consultants

Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Land Use Map

K/J 1264001.00
June 2015

Figure 2-2

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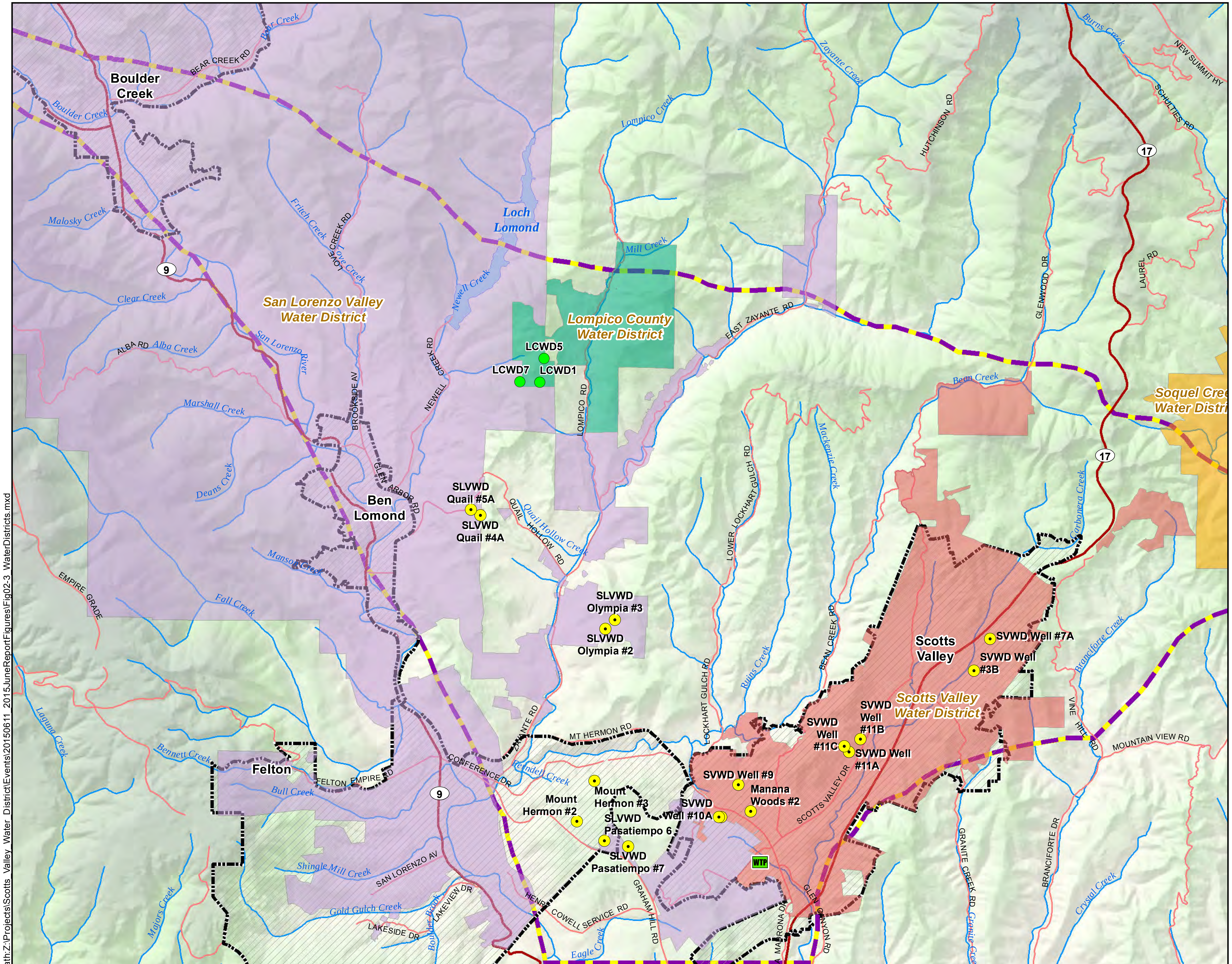

Kennedy/Jenks Consultants

Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Water Districts with Location of Pumping Wells

K/J 1264001.00
June 2015

Figure 2-3

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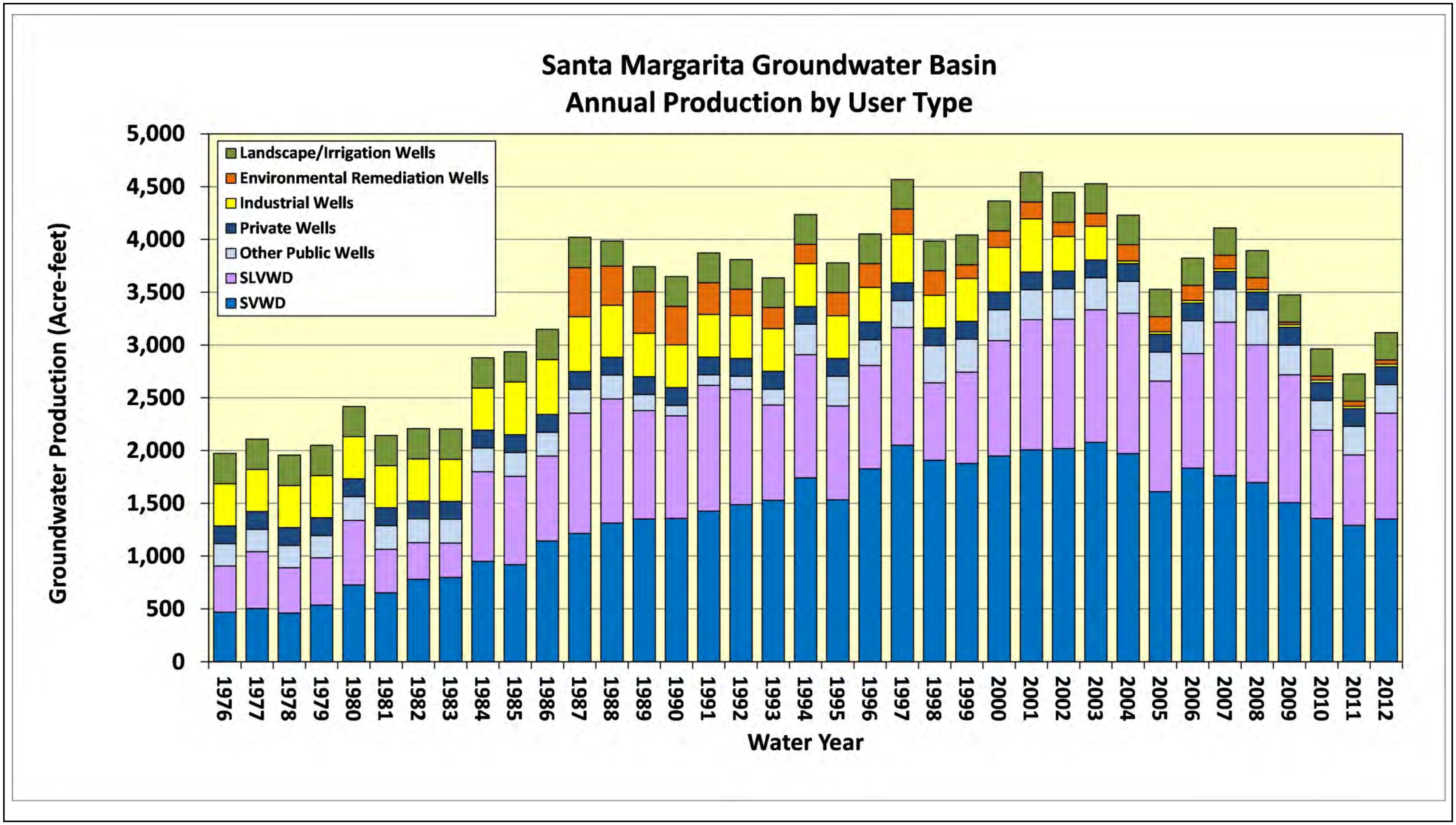

Kennedy/Jenks Consultants

Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Historical Groundwater Pumping by User Type from 1976 - 2012

K/J Project 1264001*00
June 2015

Figure 2-4

ERA	PERIOD	SERIES	FORMATION	LITHOLOGY	THICKNESS (feet)	DESCRIPTION
CENOZOIC	QUATERNARY	PLEISTOCENE-HOLOCENE	Terrace Alluvium		<50	Terrace deposits are weakly consolidated, poorly sorted sandy gravel to medium sands. Alluvium consists of unconsolidated, moderately sorted silt, sand and gravel along respective streams
			Unconformity			
CENOZOIC	QUATERNARY / TERTIARY	PLEISTOCENE-HOLOCENE / PLIOCENE	Purisma Formation		**0-500**	Very thick bedded yellowish-gray tuffaceous and diatomaceous siltstone with thick interbeds of bluish-gray semifriable andesitic sandstone
			Unconformity			
CENOZOIC	TERTIARY	MIOCENE	Santa Cruz Mudstone		0-200	Medium- to thick-bedded and faintly laminated pale yellowish-brown siliceous mudstone with scattered speroidal dolomite concretions; locally grades to sandy siltstone
CENOZOIC	TERTIARY	MIOCENE	Santa Margarita Sandstone		0-450	Very thick bedded and thickly crossbedded yellowish-gray to white friable arkosic sandstone
			Unconformity			
CENOZOIC	TERTIARY	MIOCENE	Monterey Formation		0-2,000	Medium- to thick-bedded and laminated olive-gray subsiliceous organic mudstone and sandy siltstone with few thick dolomite interbeds
CENOZOIC	TERTIARY	MIOCENE	Lompico Sandstone		200-300	Thick-bedded to massive yellowish-gray arkosic sandstone
			Unconformity			
CENOZOIC	TERTIARY	EOCENE	Butano Sandstone: Upper Sandstone Member		3,000	Thin- to very thick-bedded medium gray arkosic sandstone with thin interbeds of medium-gray siltstone
CENOZOIC	TERTIARY	EOCENE	Butano Sandstone: Middle Sandstone Mem.		250-750	Thin- to medium-bedded nodular olive-gray pyritic siltstone
CENOZOIC	TERTIARY	EOCENE	Butano Sandstone: Lower Sandstone Member		1,500	Very thick bedded to massive yellowish-gray arkosic sandstone with thick to very thick interbeds of sandy pebble conglomerate in lower part
			Unconformity			
			Not in contact within area			
CENOZOIC	TERTIARY	PALEOCENE	Locatelli Formation		800	Nodular olive-gray to pale-yellowish-brown micaceous siltstone; massive arkosic sandstone locally at base
			Non-conformable on crystalline complex of Ben Lomond Mountain			
MESOZOIC	CRETACEOUS		Crystalline Basement			Primary quartz diorite, light gray, medium gravel, plagioclase, and quartz with lesser amounts of feldspar, biotite, and hornblende

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Stratigraphic Column for the Santa Margarita Groundwater Basin

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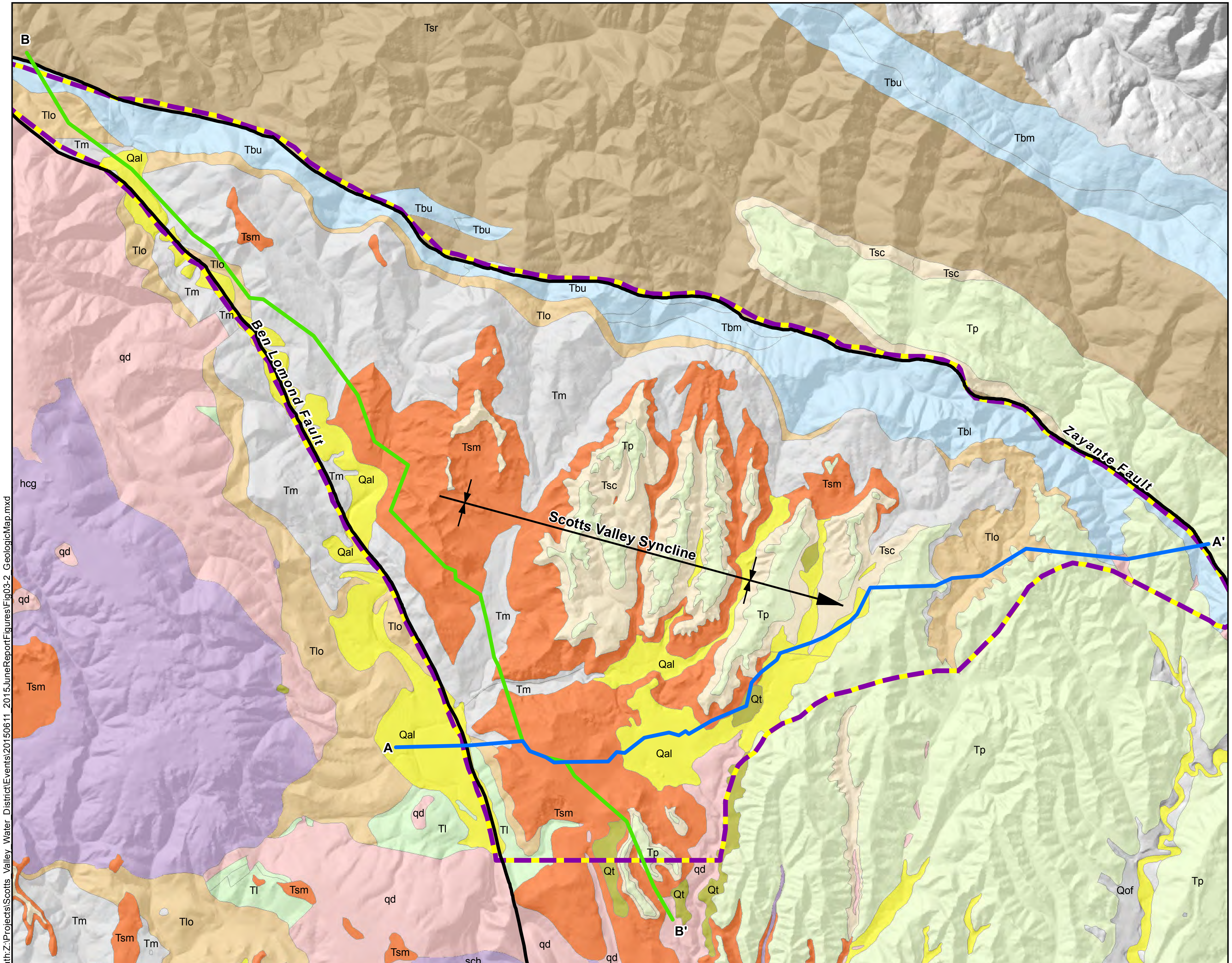
Figure 3-1



LEGEND

Syncline

Santa Margarita Groundwater Basin Boundary

Fault

Cross Section A-A'

Cross Section B-B'

Geologic Unit

Qal	Alluvium
Qt	Terrace Deposits
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tsr	Undifferentiated Lambert, Vaqueros, Zayante, and San Lorenzo Formation
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite
sch	Undifferentiated Plutonic and Metamorphic Rocks

Data Source: Brabb, E.E. (1997) Geologic map of Santa Cruz County, California: a digital database. U.S. Geological Survey, Open-File Report OF-97-489, scale 1:62,500.

N

0 0.5 1

Scale: Miles

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Map

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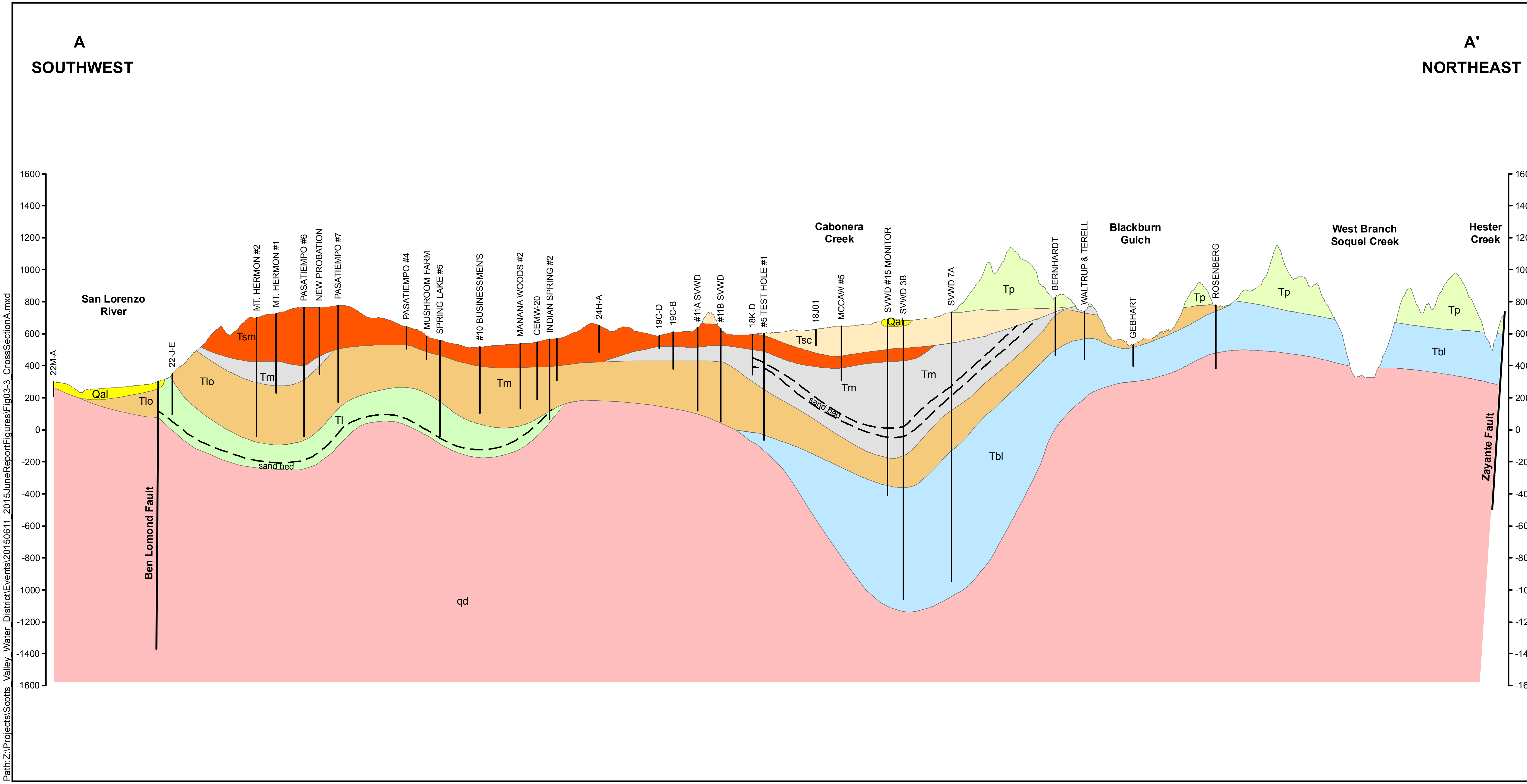
June 2015

Figure 3-2

Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\Fig03-2_GeologicMap.mxd



Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\Fig03-3_CrossSectionA.mxd

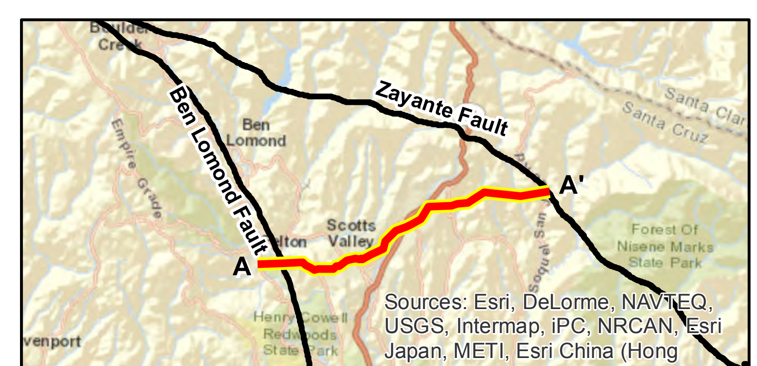
EXPLANATION

Geologic Unit

Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 — Well and Identifier

Feet
600'
300'
Vertical Scale
0 1500' 3000' Feet
Horizontal Scale
Exaggeration: 5x



Index Map

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section A-A'

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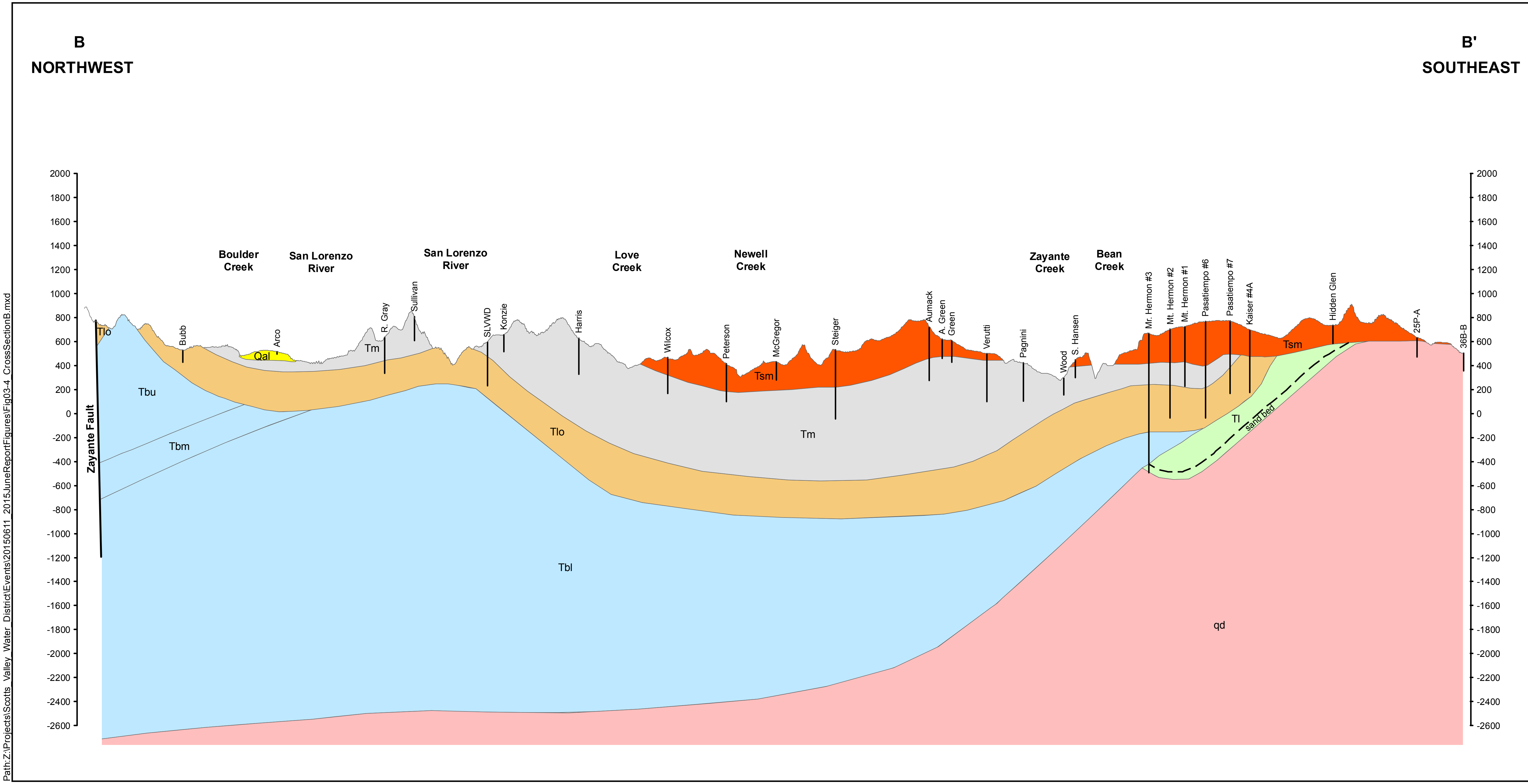
June 2015

Figure 3-3



Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\Fig03-4_CrossSectionB.mxd

Note:

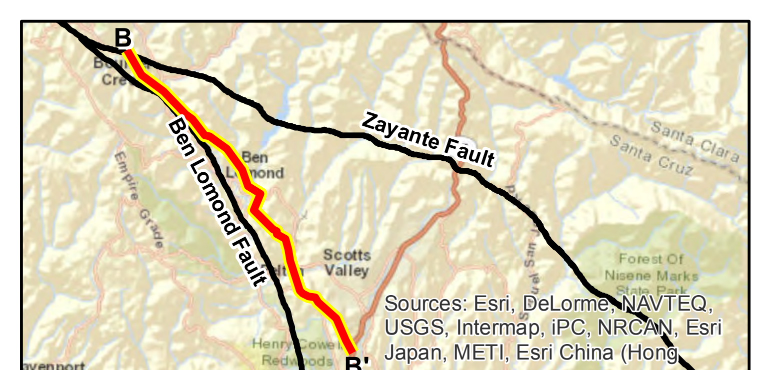
EXPLANATION

Geologic Unit

Symbol	Unit
Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 — Well and Identifier

Feet
800'
400'
Vertical Scale
0 2000' 4000' Feet
Horizontal Scale
Exaggeration: 5x



Index Map

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section B-B'

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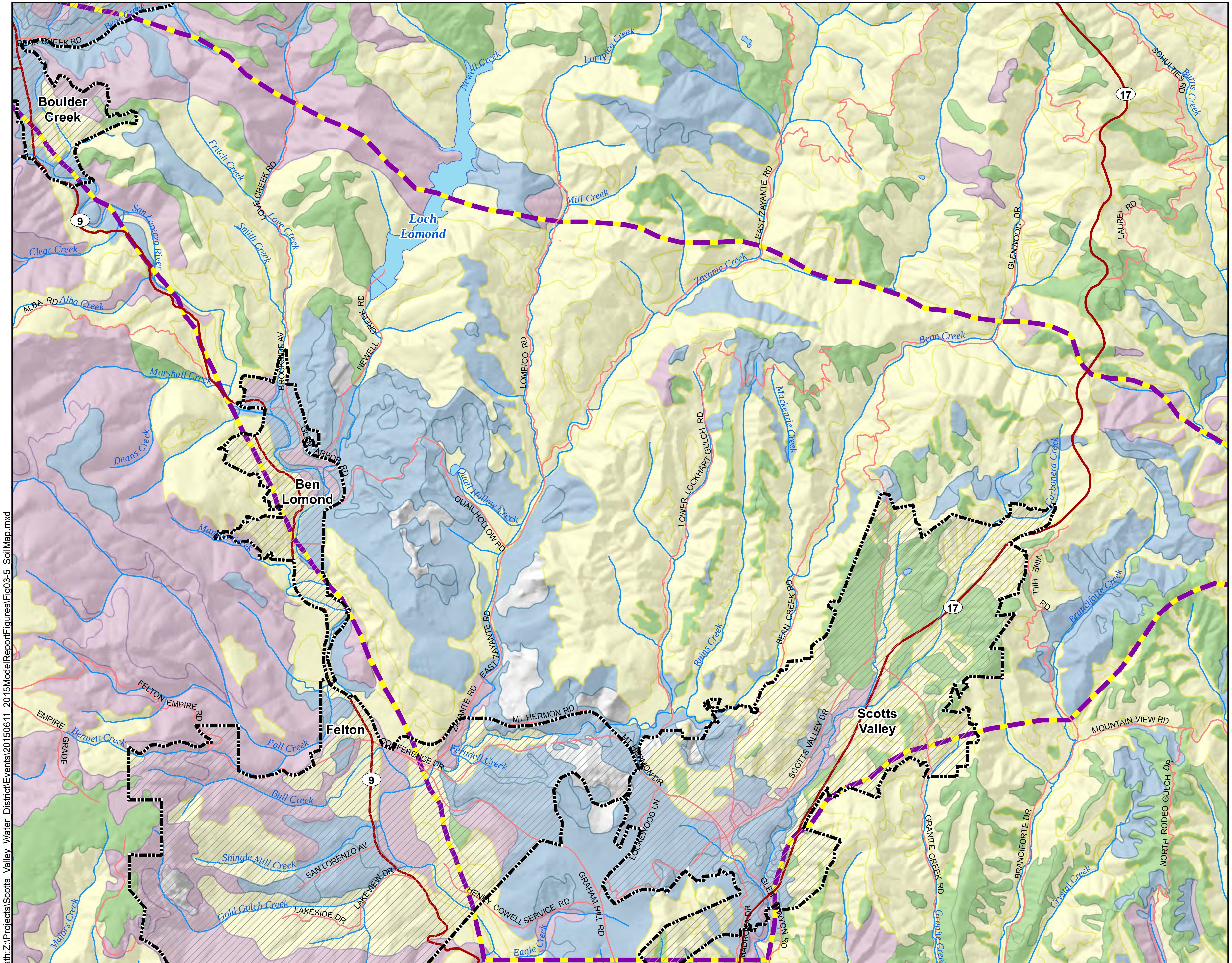
June 2015

Figure 3-4



LEGEND

- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

Hydrologic Soil Group

- A
- B
- C
- D

Data Source: U.S. Department of Agriculture, Natural Resources Conservation Service (2013) Soil Survey Geographic (SSURGO) database for Santa Cruz County, California, Scale: 1:24,000.

N

0 0.5 1

Scale: Miles

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Hydrologic Soil Group Map

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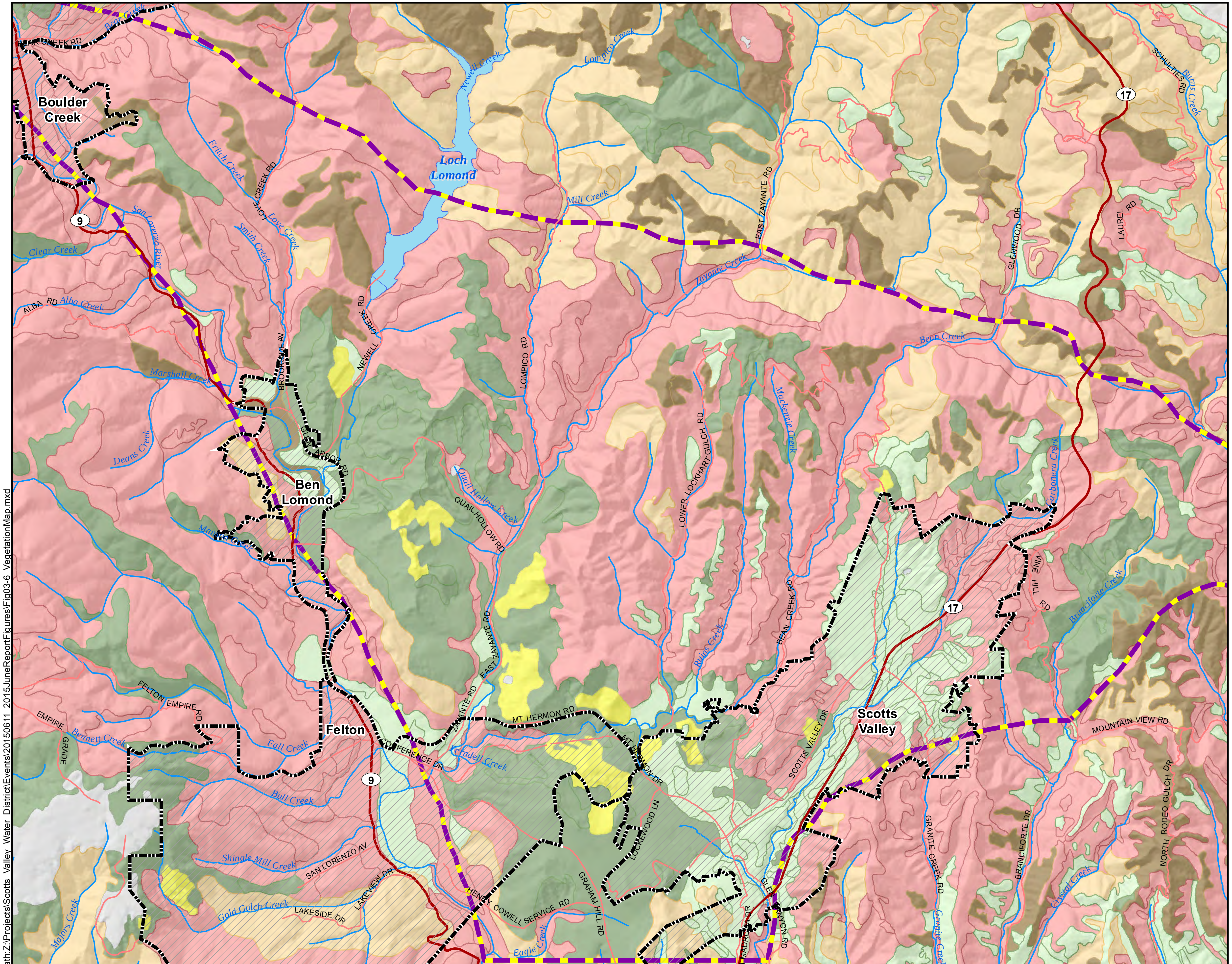
June 2015

Figure 3-5

Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig03-5_SoilMap.mxd



Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\Fig03-6_VegetationMap.mxd

LEGEND

Santa Margarita Groundwater Basin Boundary
City Limit
Lake
Stream
Major Highway
Major Road

Vegetation Type

Grass
Redwood
Pine
Fir
Scrub
Open Space
Not Available

Data Source: U.S. Department of Agriculture, Natural Resources Conservation Service (2013) Soil Survey Geographic (SSURGO) database for Santa Cruz County, California, Scale: 1:24,000.

N

0 0.5 1
Scale: Miles

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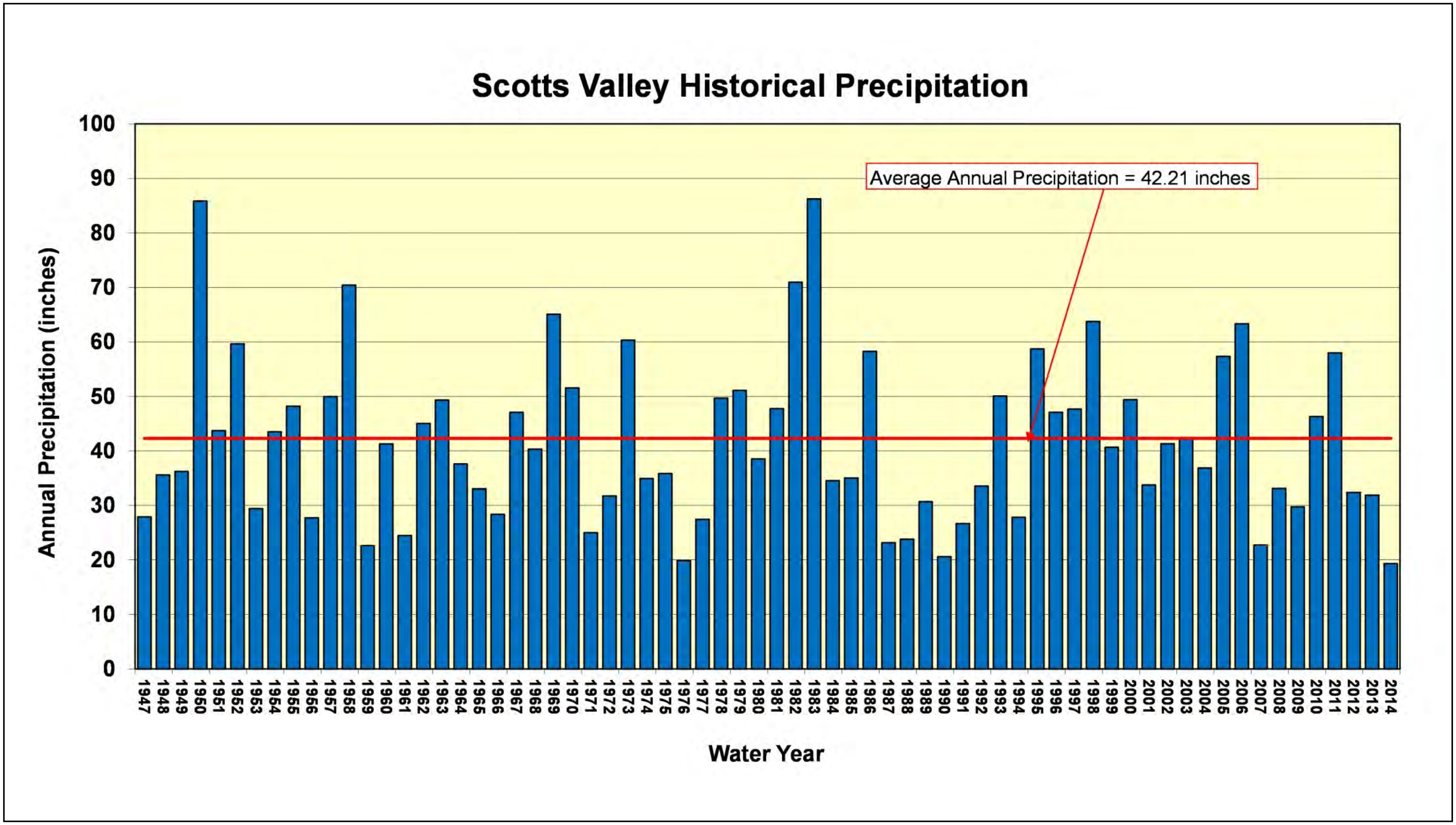
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Vegetation Map

K/J 1264001.00
June 2015

Figure 3-6



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Scotts Valley Water District

Historical Precipitation at Scotts Valley from 1947 - 2014

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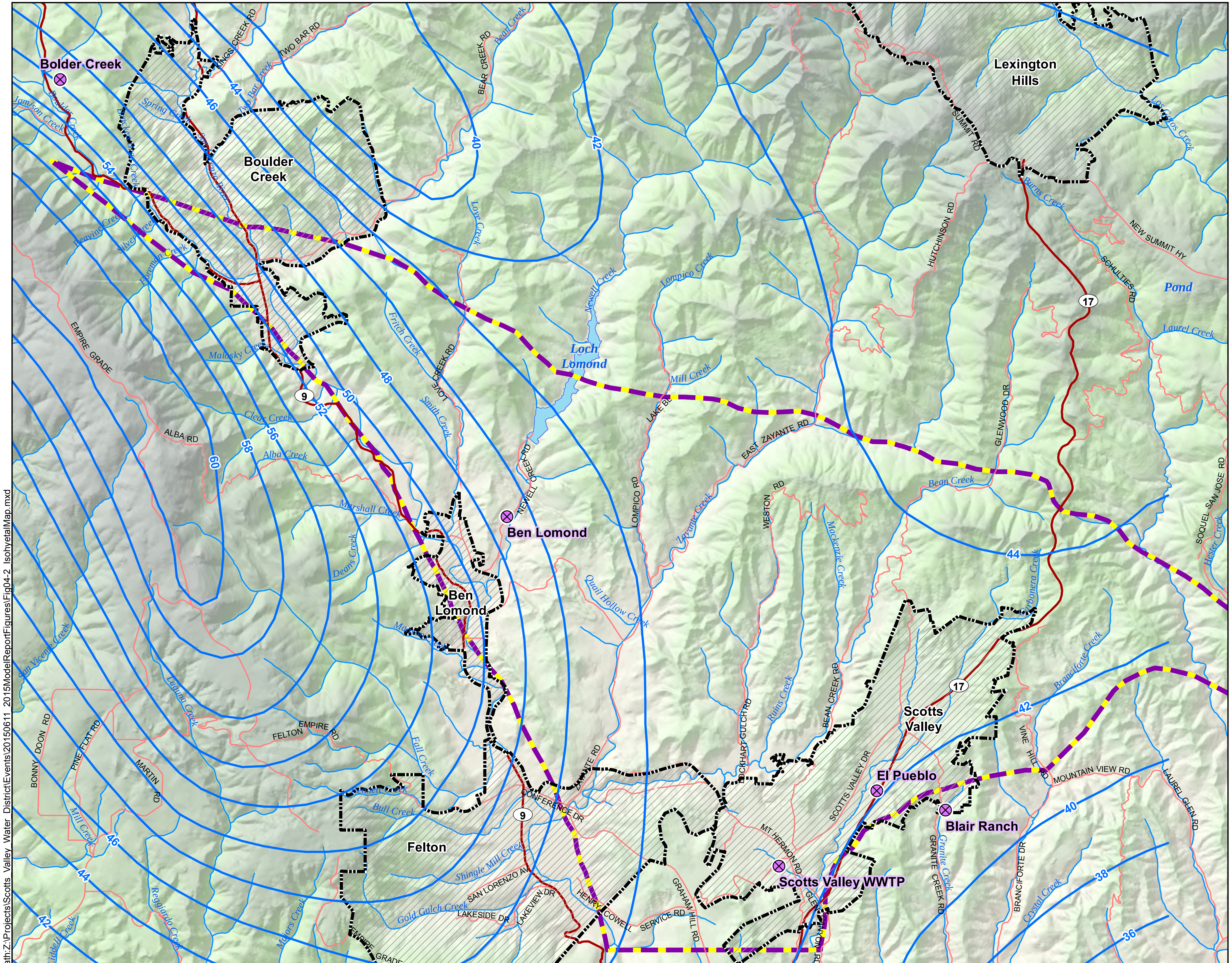
Figure 4-1



LEGEND

- Rain Gauge
- Precipitation Contour (inches per year)
- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

Data Source: San Lorenzo Valley Water District Water Supply Master Plan May 2009

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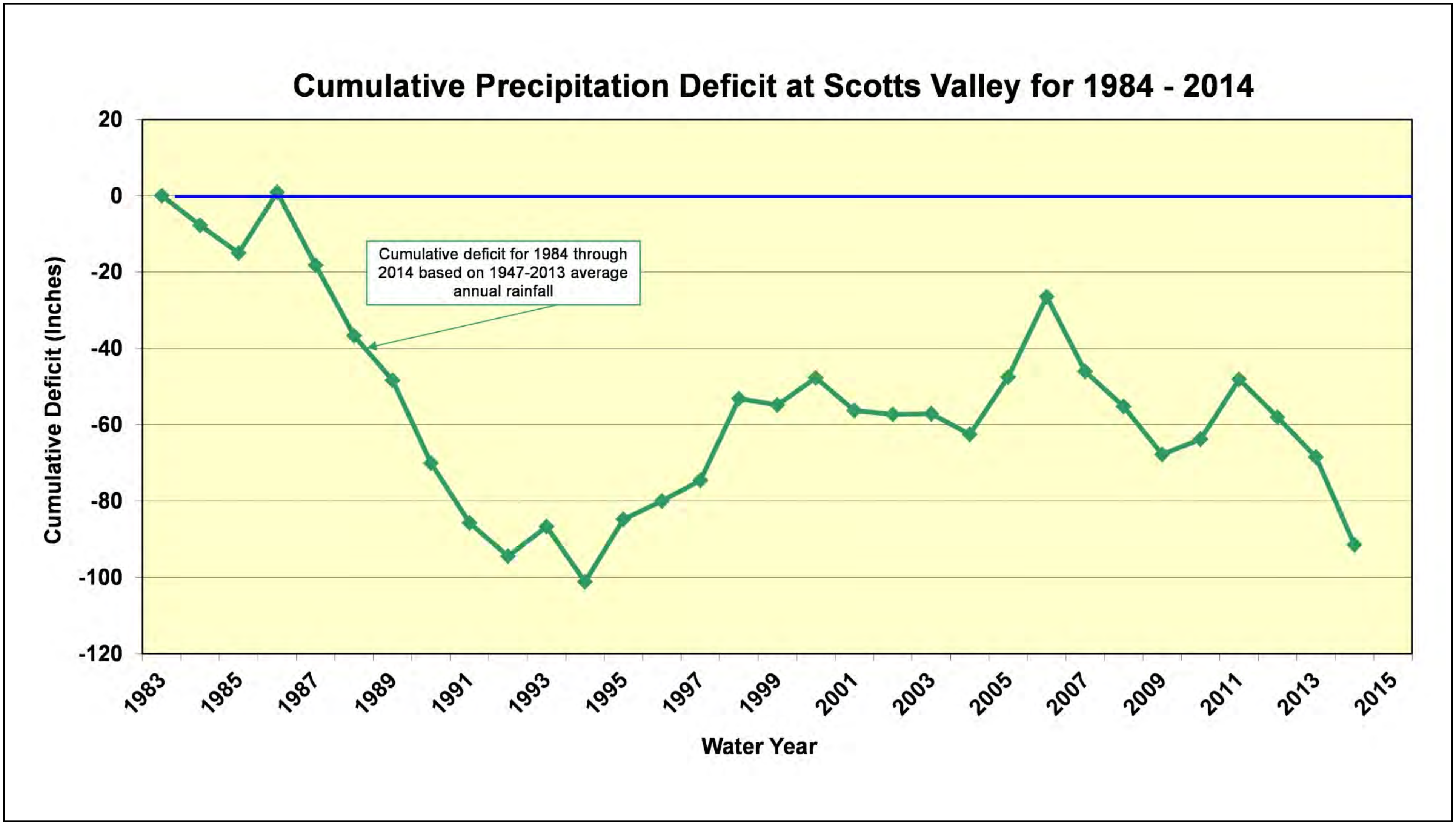
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Isohytel Map

K/J 1264001.00
June 2014

Figure 4-2

Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig04-2 IsohyetalMap.mxd



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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Cumulative Precipitation Deficit from 1984 - 2014

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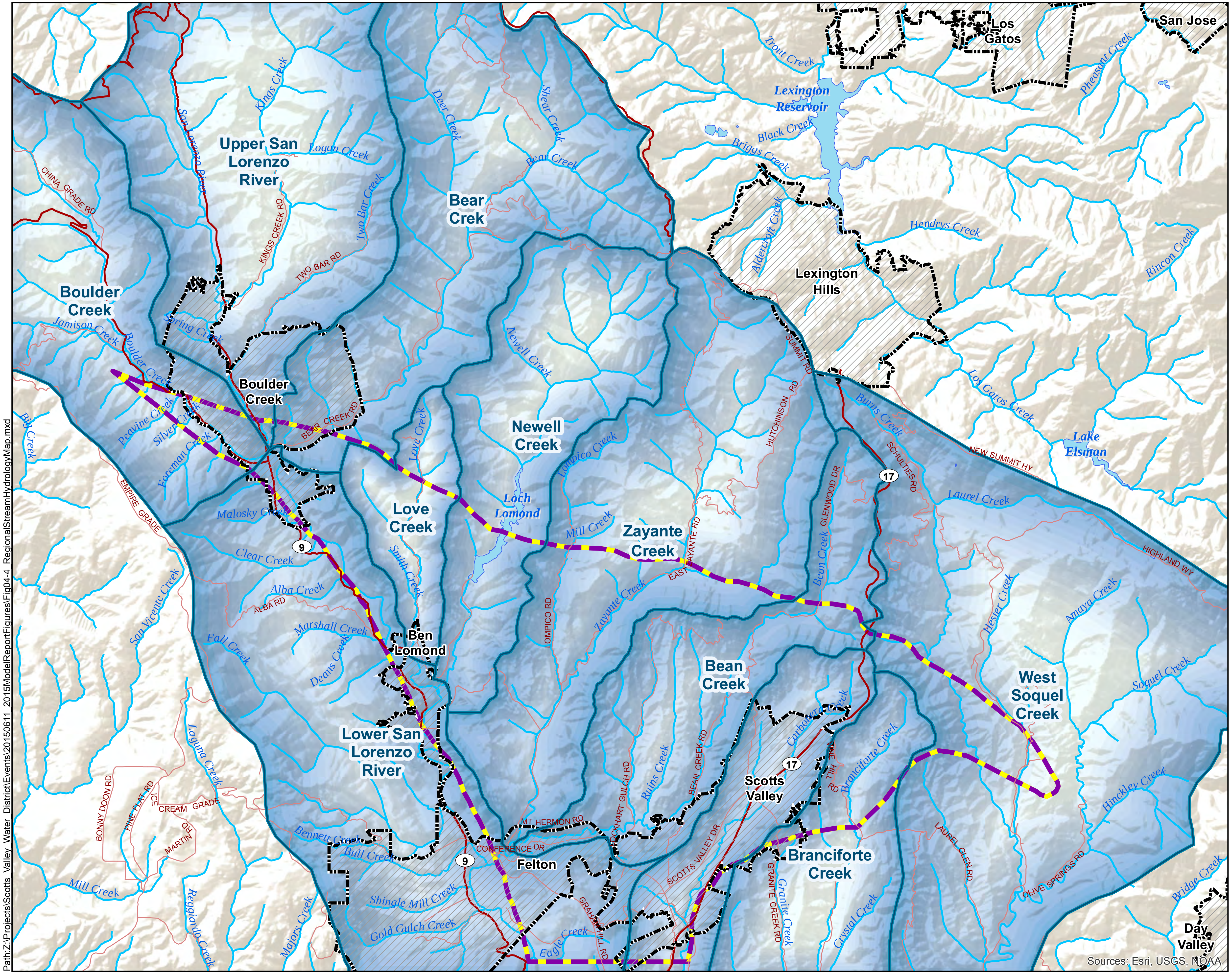
Figure 4-3



Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig04-4 RegionalStreamHydrologyMap.mxd

LEGEND

- Santa Margarita Groundwater Basin Boundary
- City Limit
- Watershed Boundary
- Lake
- Stream
- Major Highway
- Major Road

N

0 0.5 1

Scale: Miles

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

San Lorenzo River Watershed and Local Tributary Watersheds

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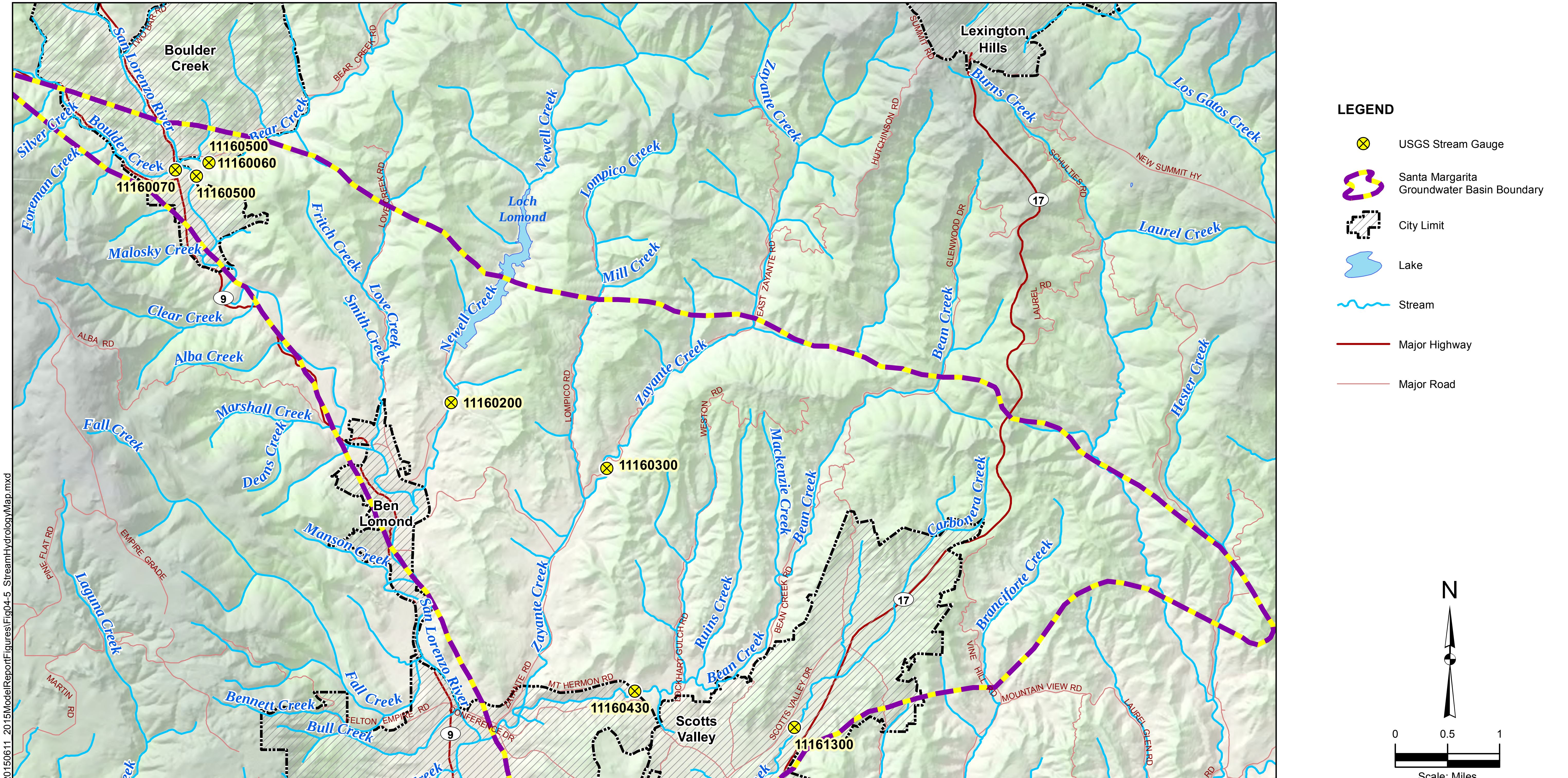
Figure 4-4



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Scotts Valley Water District

SMGB Stream Hydrology Map with USGS Stream Gauge Locations

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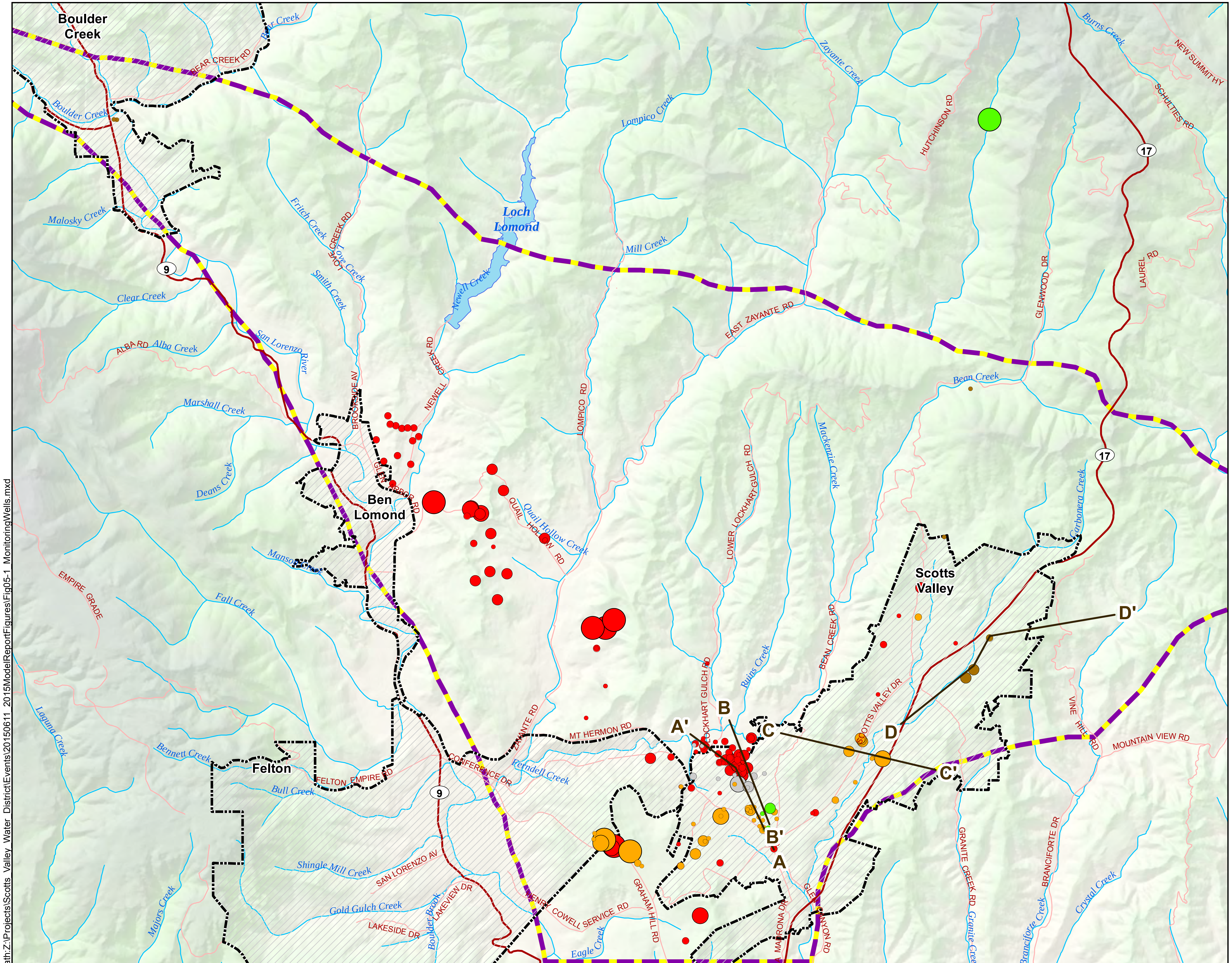
Figure 4-5

Path:Z:\Projects\Scotts Valley Water District\Events\20150611_2015ModelReportFigures\Fig04-5_StreamHydrologyMap.mxd



LEGEND

Monitoring Well Size by Number of Observations

- 1.0 - 50.00
- 50.01 - 100.00
- 100.01 - 200.00
- 200.01 - 300.00
- Greater Than 300

Monitoring Well Color By Aquifer

- Santa Margarita
- Monterey
- Lompico
- Butano
- Locatelli
- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road
- Cross Section Line

N

0 0.5 1

Scale: Miles

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Scotts Valley Water District

Location of Monitoring Wells

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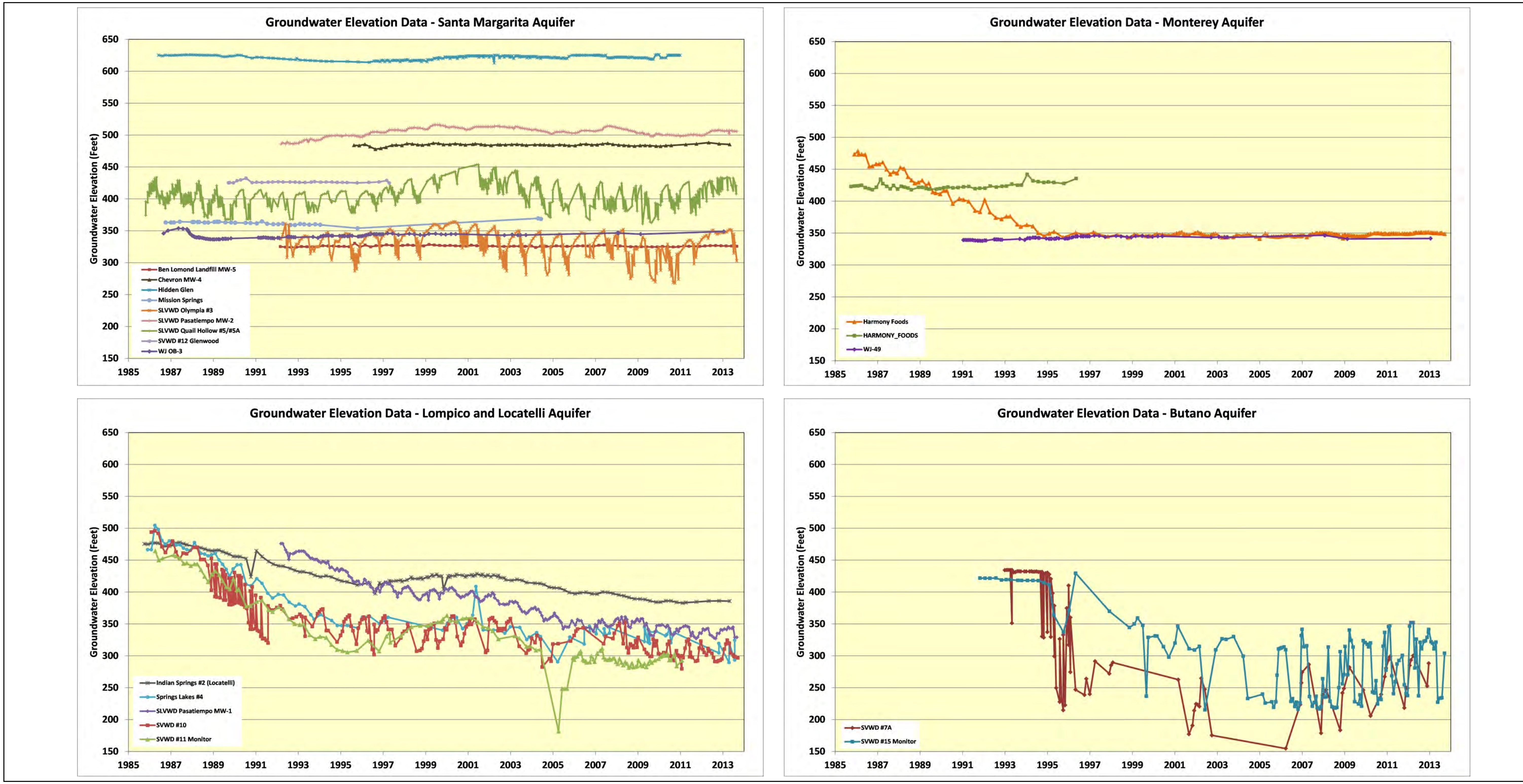
Figure 5-1

Path:Z:\Projects\Scotts Valley Water District\20150611 2015ModelReportFigures\Fig05-1 MonitoringWells.mxd



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Scotts Valley Water District

Representative Hydrographs from Measured Data Throughout the SMGB

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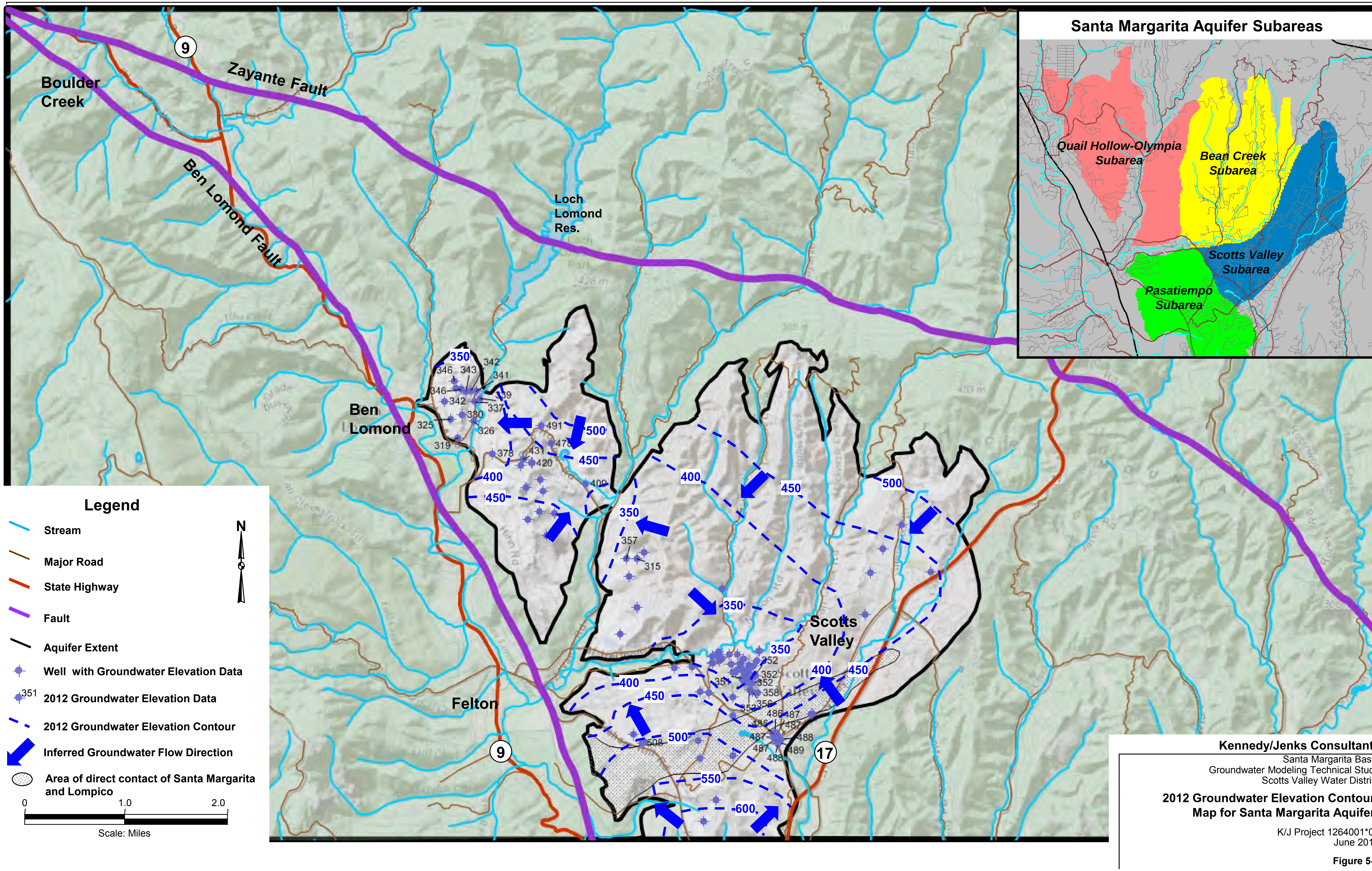
Figure 5-2


Santa Margarita Aquifer Subareas
Quail Hollow-Olympia Subarea
Bean Creek Subarea
Scotts Valley Subarea
Pasatiempo Subarea
Boulder Creek
Zayante Fault
Ben Lomond Fault
Loch Lomond Res.
Ben Lomond
Felton
Scotts Valley
Legend
Stream
Major Road
State Highway
Fault
Aquifer Extent
Well with Groundwater Elevation Data
351 2012 Groundwater Elevation Data
2012 Groundwater Elevation Contour
Inferred Groundwater Flow Direction
Area of direct contact of Santa Margarita and Lompico
0 1.0 2.0
Scale: Miles
N
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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District
2012 Groundwater Elevation Contour Map for Santa Margarita Aquifer
K/J Project 1264001*00
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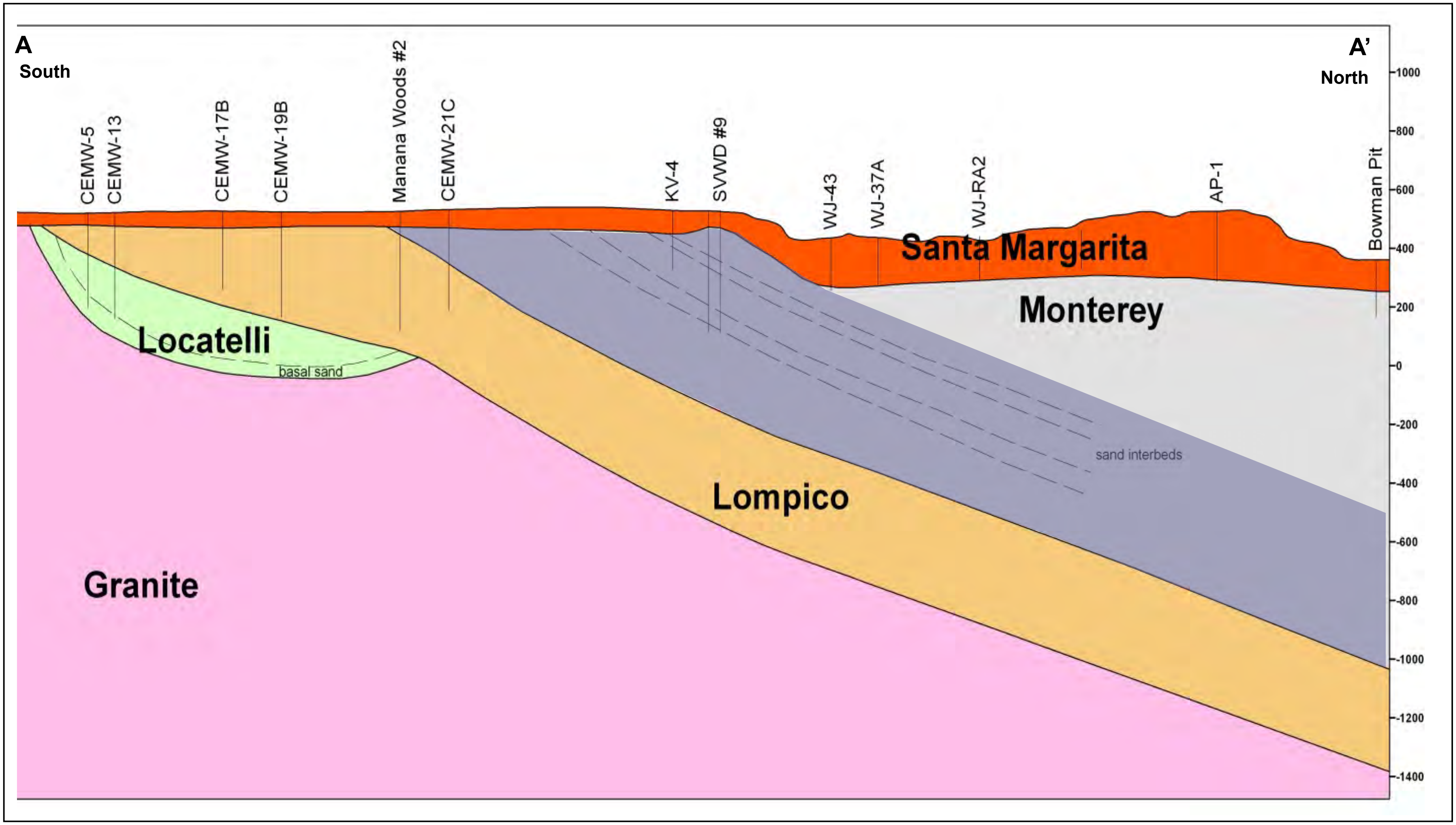
Figure 5-3



Note: Cross section line shown on Figure 5-1

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Groundwater Modeling Technical Study
Scotts Valley Water District

Cross Sections through Southern Scotts Valley

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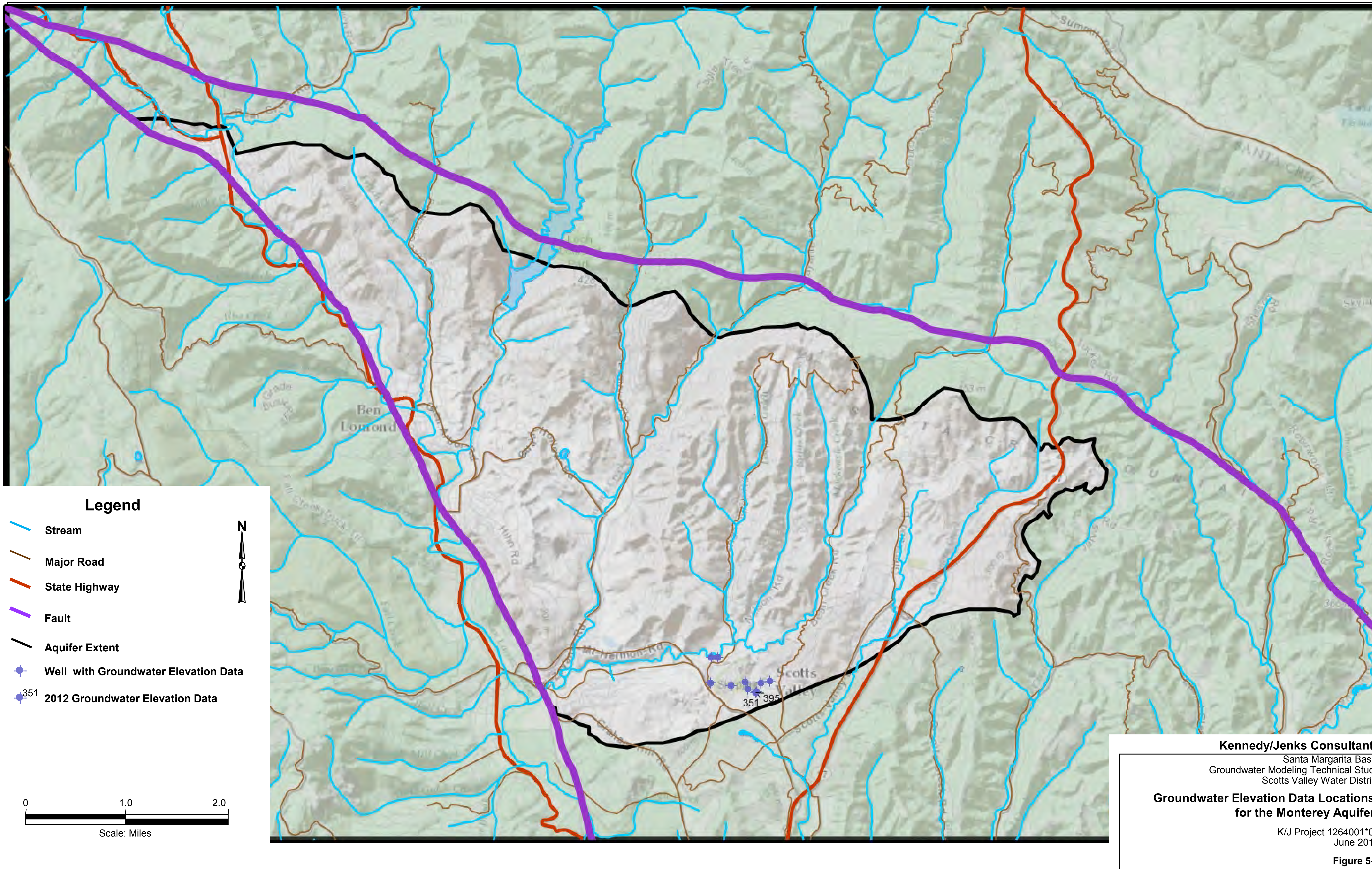
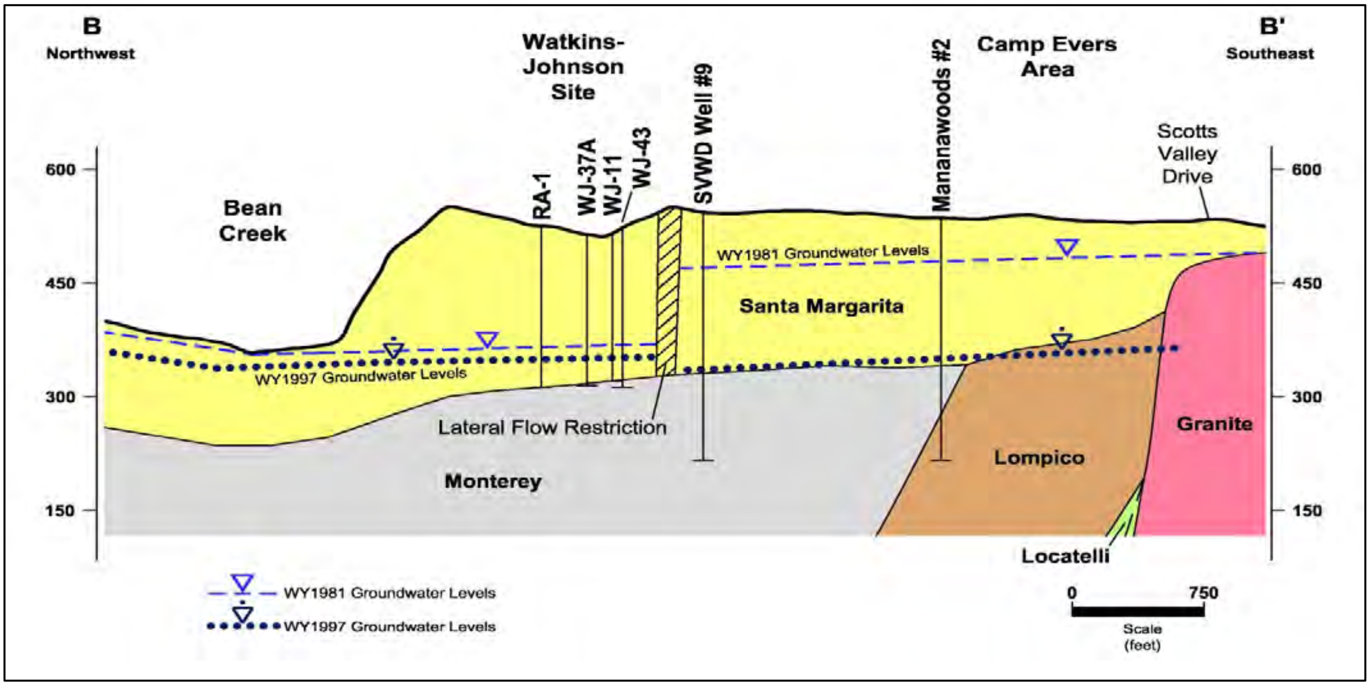
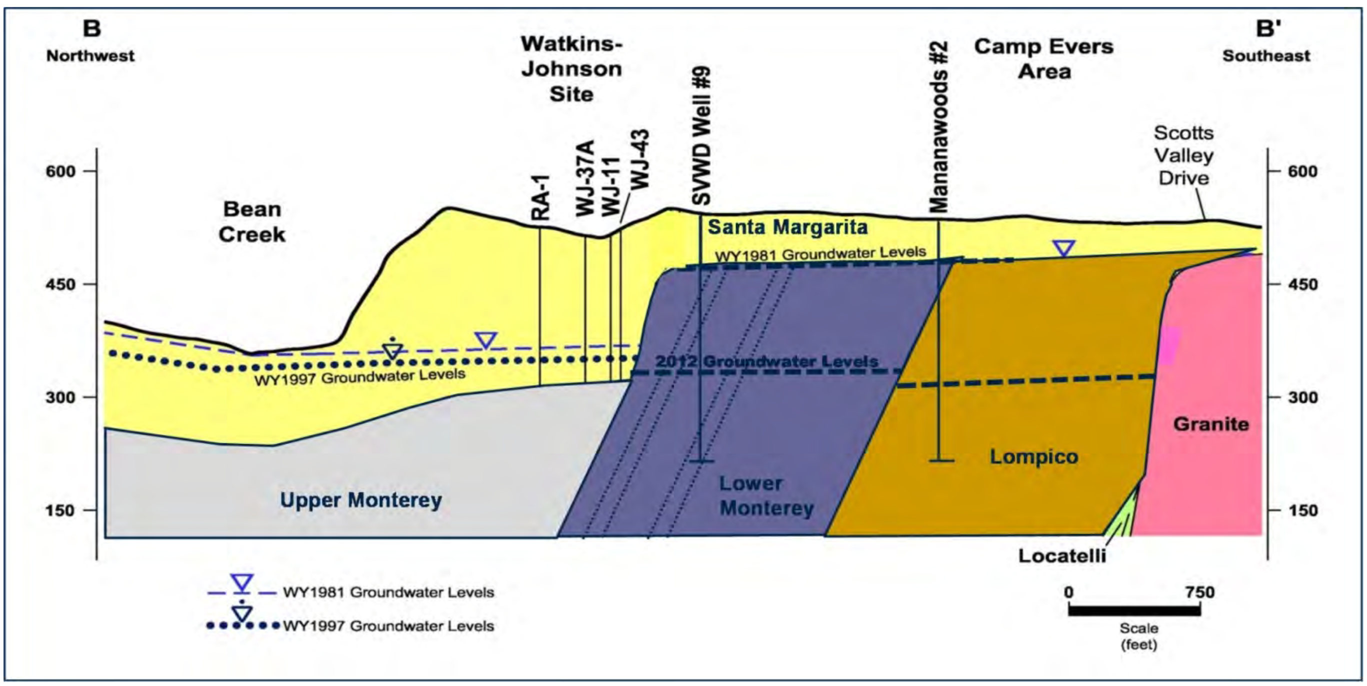
Figure 5-4


Legend
Stream
Major Road
State Highway
Fault
Aquifer Extent
Well with Groundwater Elevation Data
351 2012 Groundwater Elevation Data
N
0
1.0
2.0
Scale: Miles
Ben Lomond
Scotts Valley
351
395
Mt Hermon Rd
Kennedy/Jenks Consultants
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District
Groundwater Elevation Data Locations for the Monterey Aquifer
K/J Project 1264001*00
June 2015
Figure 5-5

PREVIOUS GEOLOGIC INTERPRETATION



REVISED GEOLOGIC INTERPRETATION



Note: Cross section line shown on Figure 5-1

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Groundwater Modeling Technical Study
Scotts Valley Water District

Comparative Cross Sections of Reinterpreted Geology near SVWD #9

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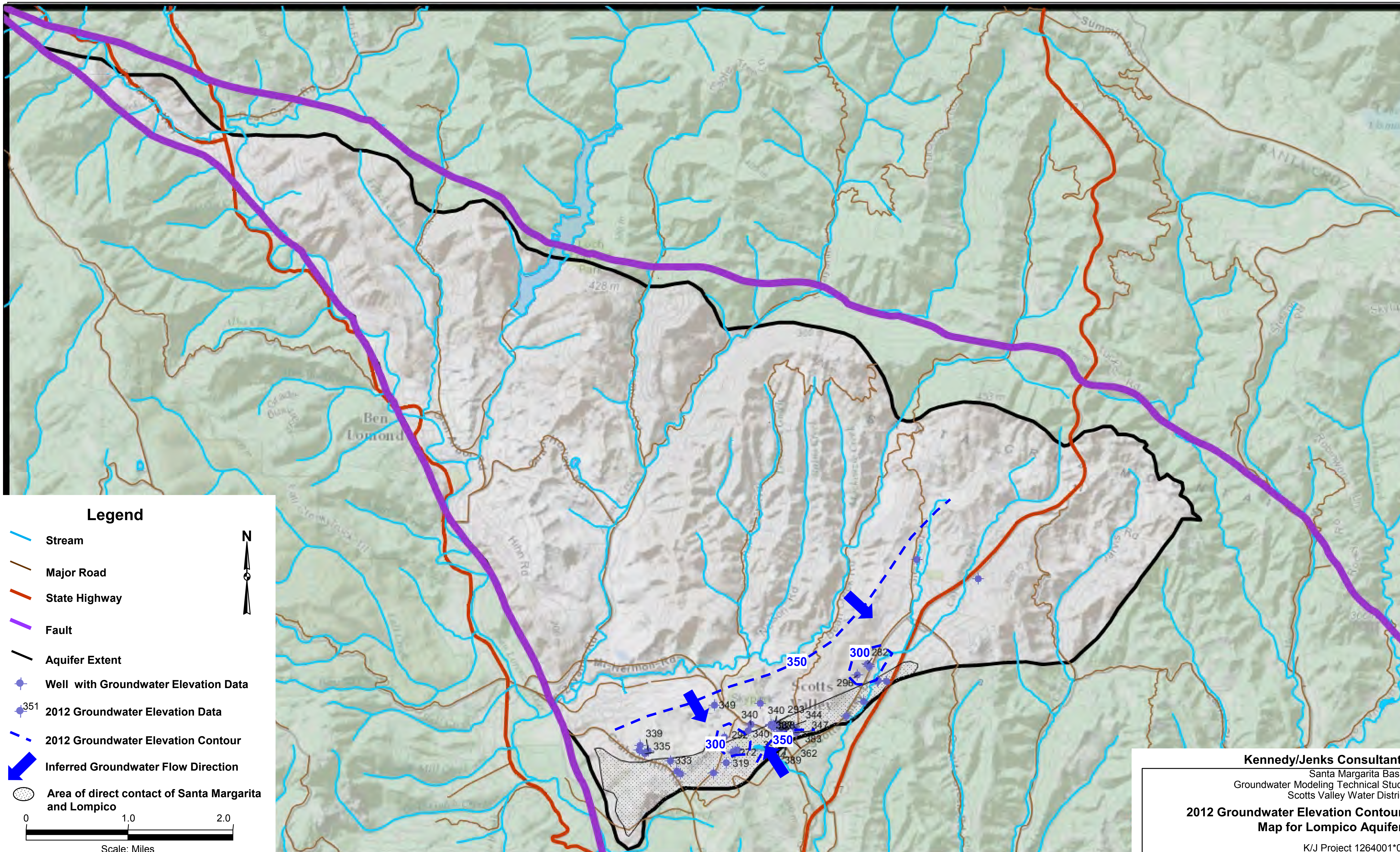
Figure 5-6



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Groundwater Modeling Technical Study
Scotts Valley Water District

2012 Groundwater Elevation Contour Map for Lompico Aquifer

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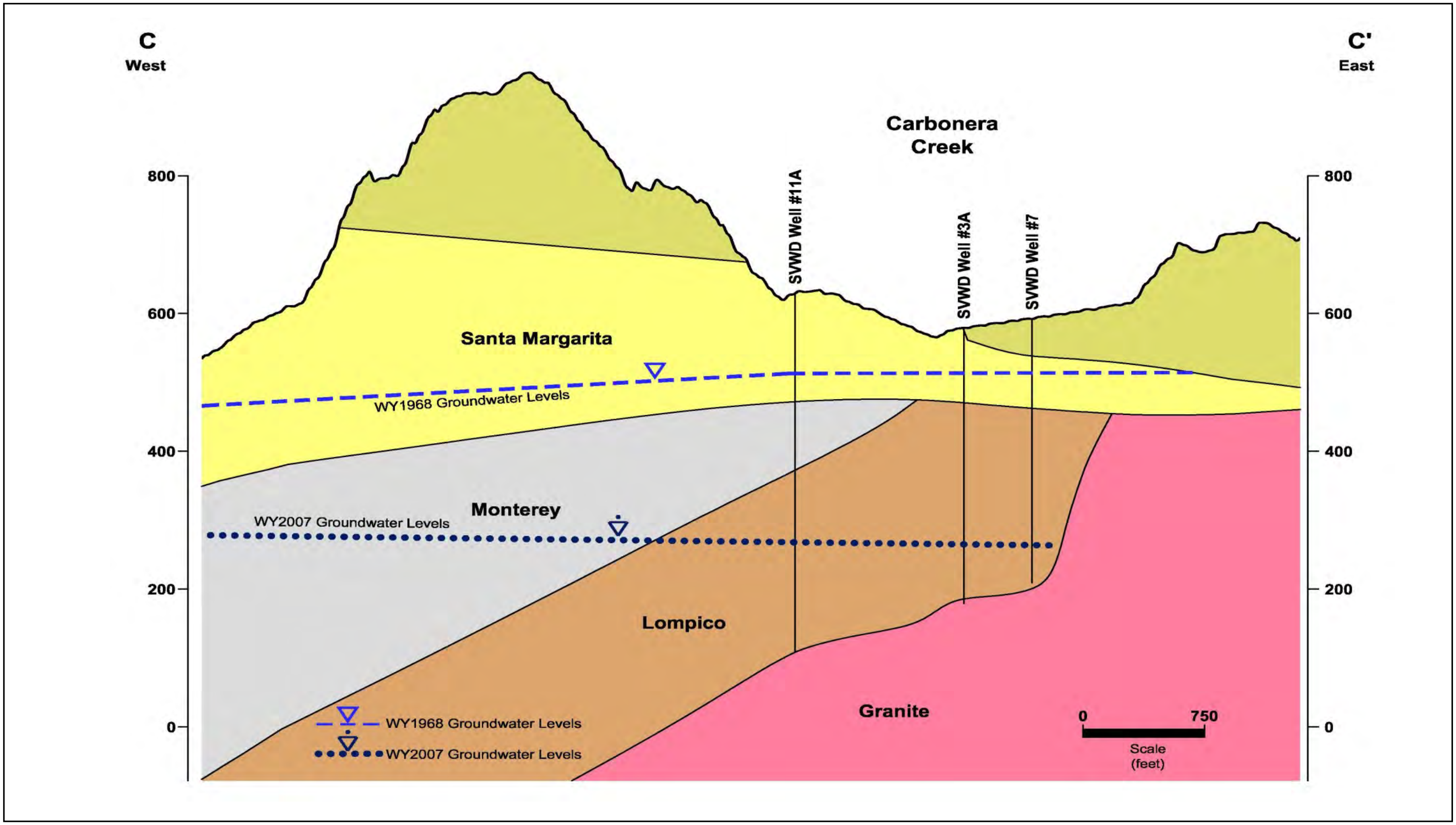
June 2015

Figure 5-7



Note: Cross section line shown on Figure 5-1

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Cross Section of Groundwater Levels in Lompico near Central Scotts Valley

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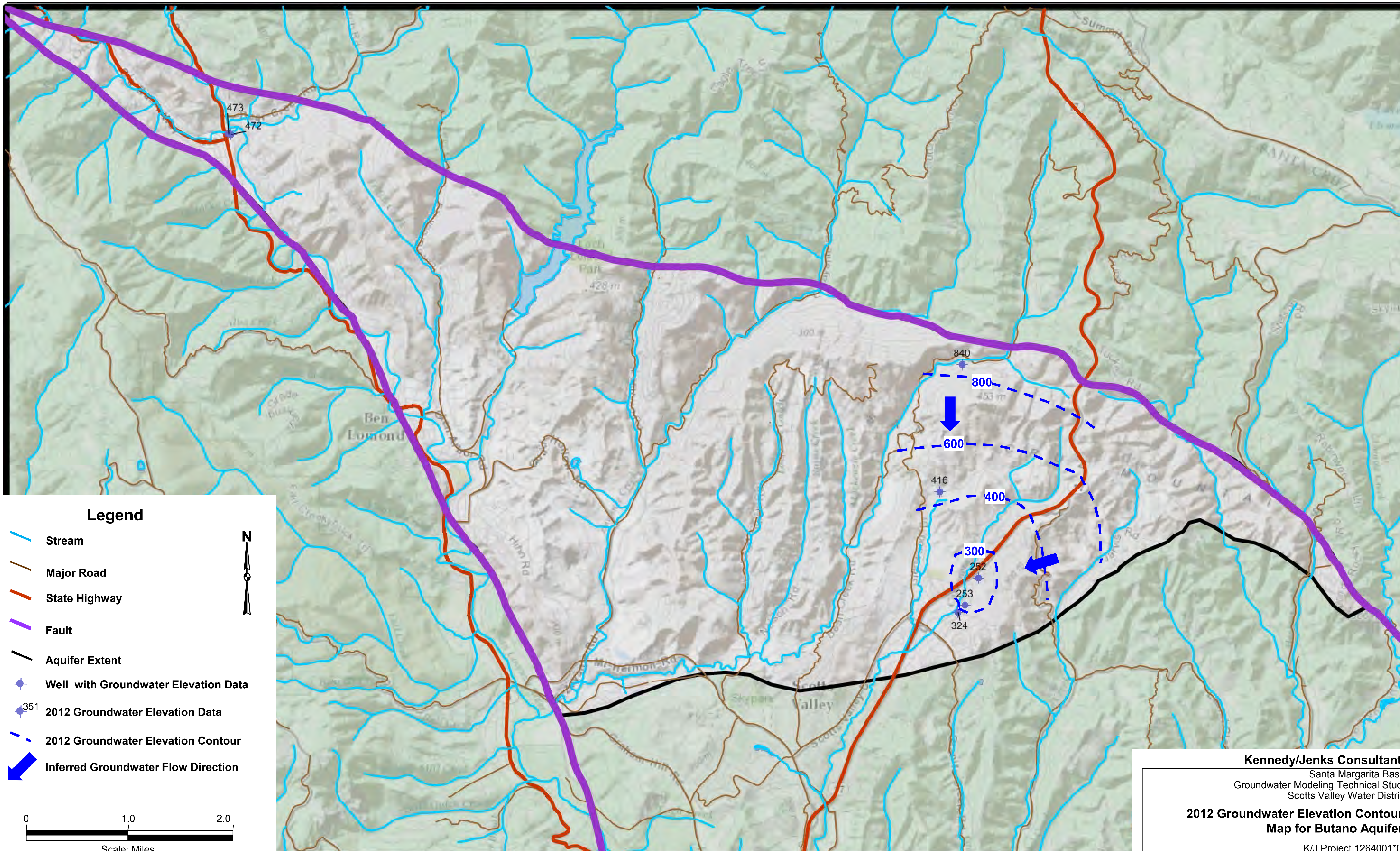
Figure 5-8



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Groundwater Modeling Technical Study
Scotts Valley Water District

2012 Groundwater Elevation Contour Map for Butano Aquifer

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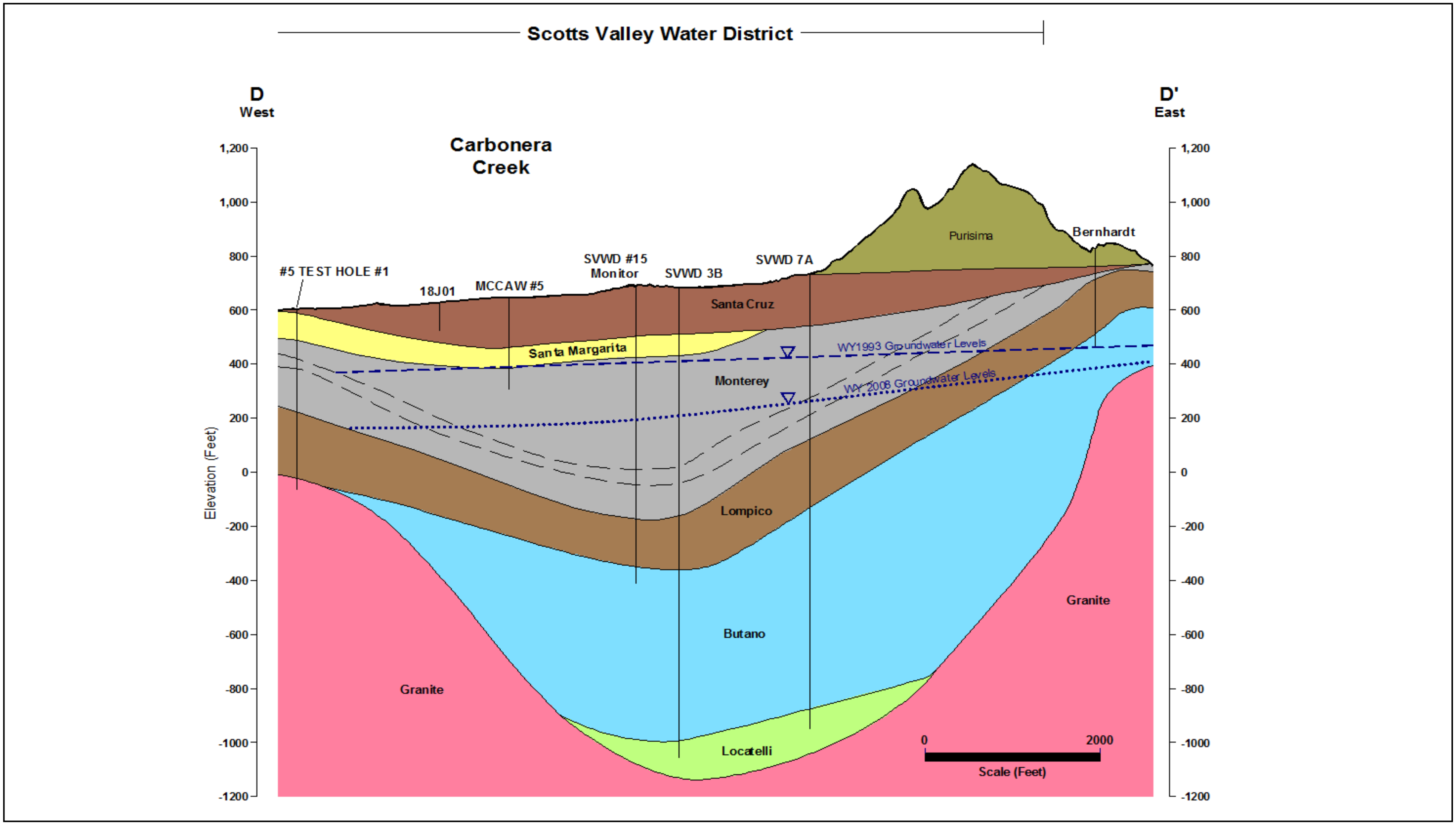
Figure 5-9



Note: Cross section line shown on Figure 5-1

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Cross Section of Groundwater Levels in Butano in North Scotts Valley

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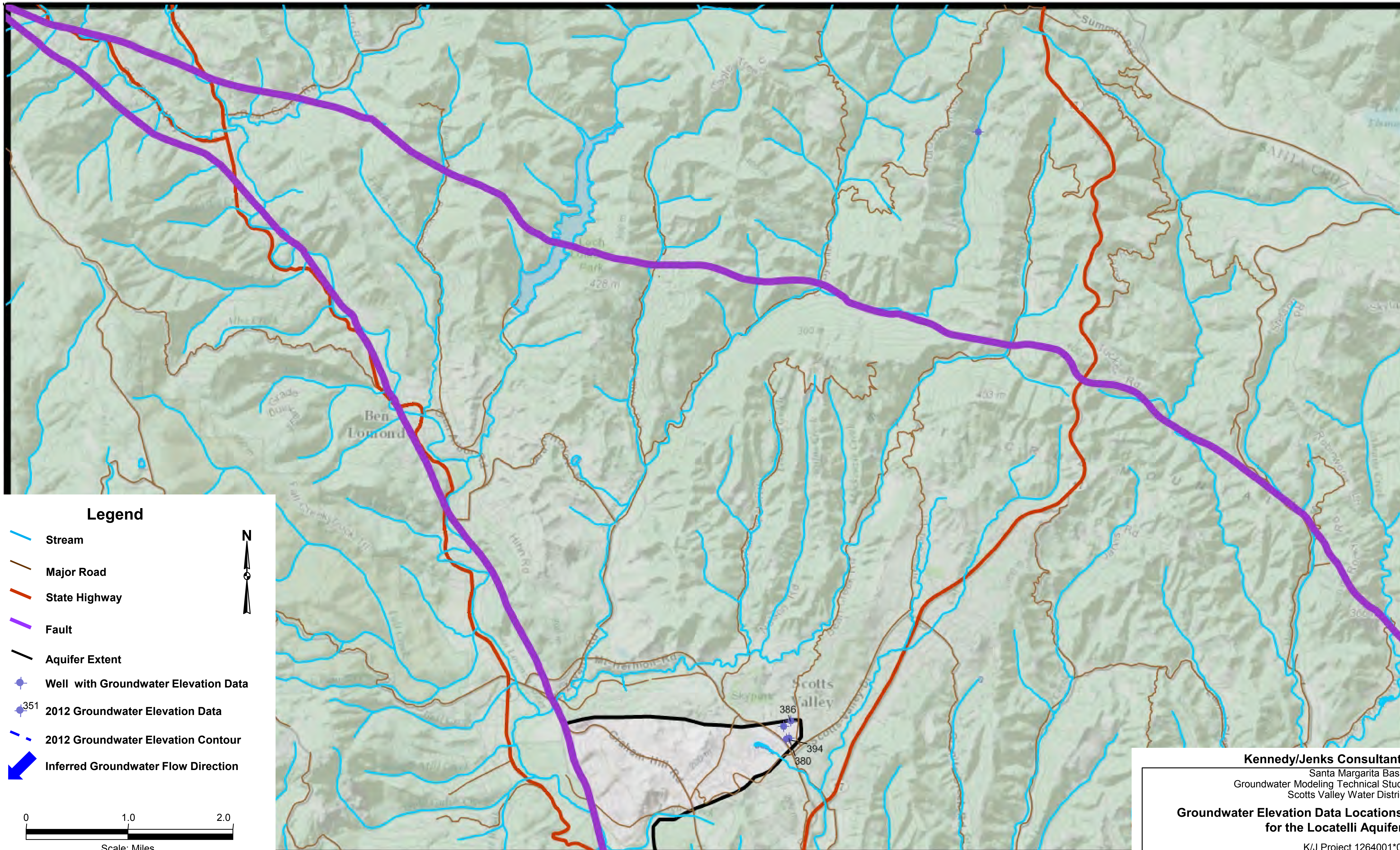
Figure 5-10



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Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Elevation Data Locations for the Locatelli Aquifer

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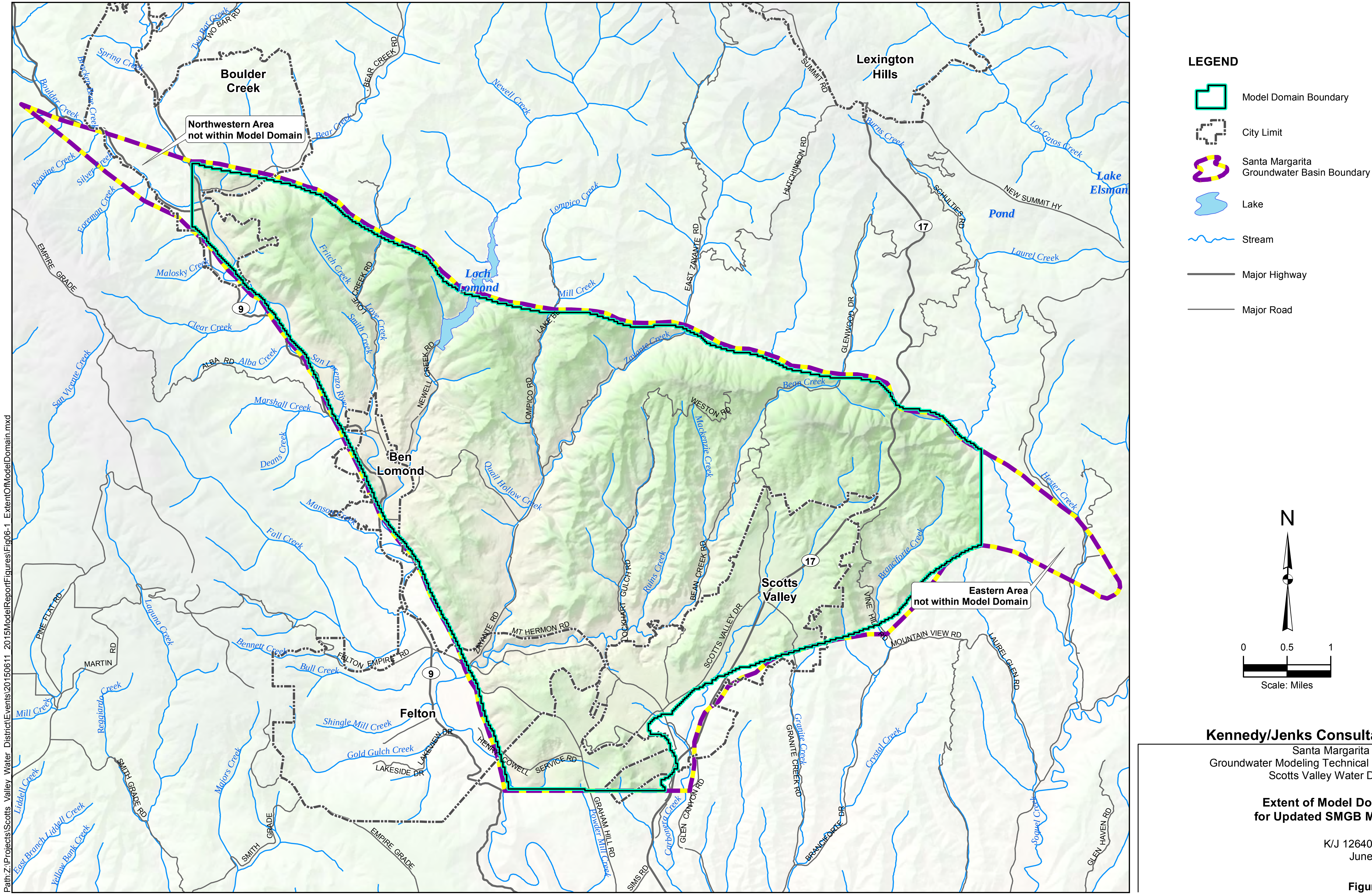
Figure 5-11



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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Extent of Model Domain for Updated SMGB Model

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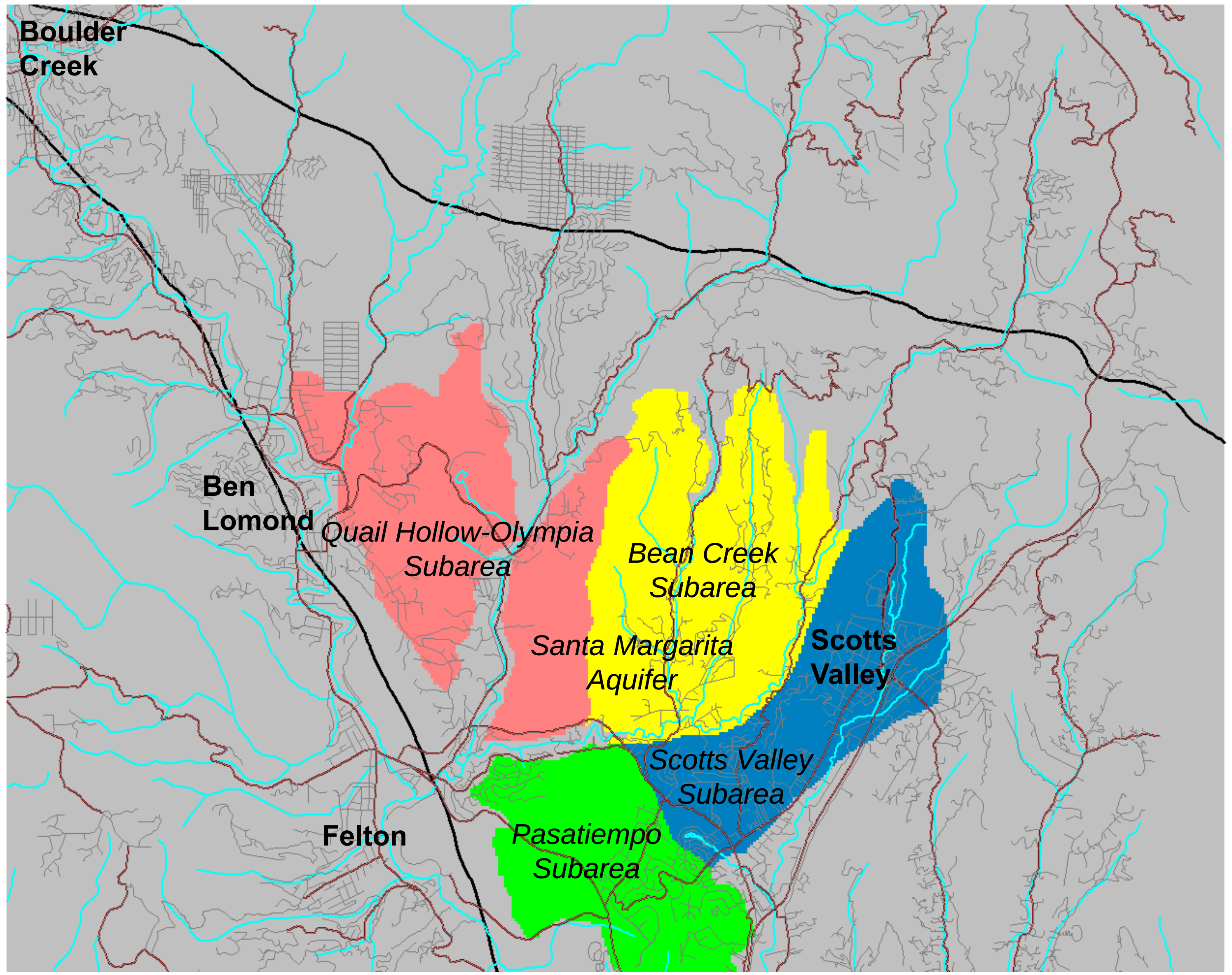
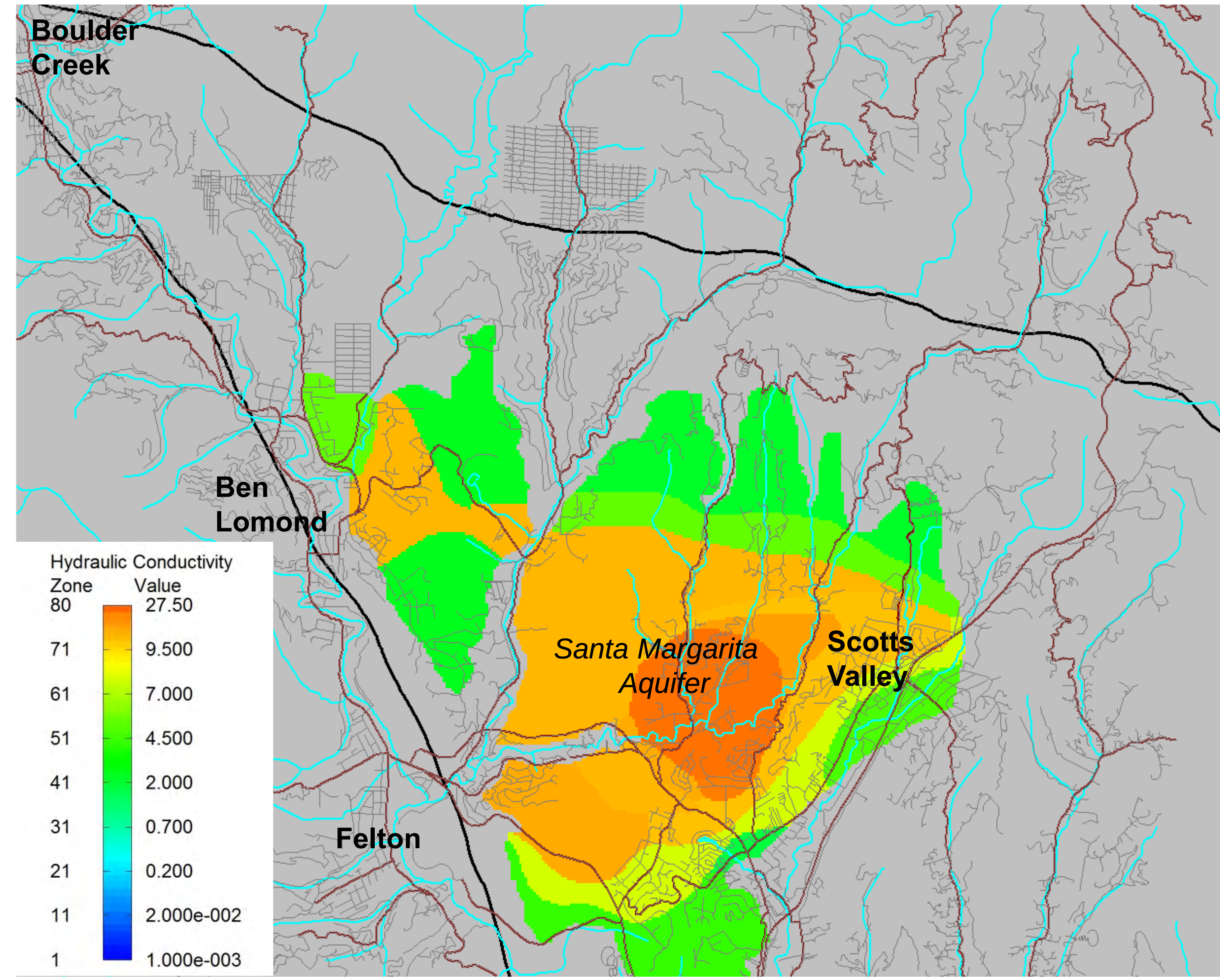
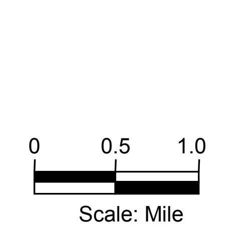
Figure 6-1

Santa Margarita Aquifer
Model Layer 1 Extent and HSU Subareas



Santa Margarita Aquifer
Hydraulic Conductivity Distribution





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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Extent, Subareas and Aquifer Properties
Model Layer 1
Santa Margarita Aquifer

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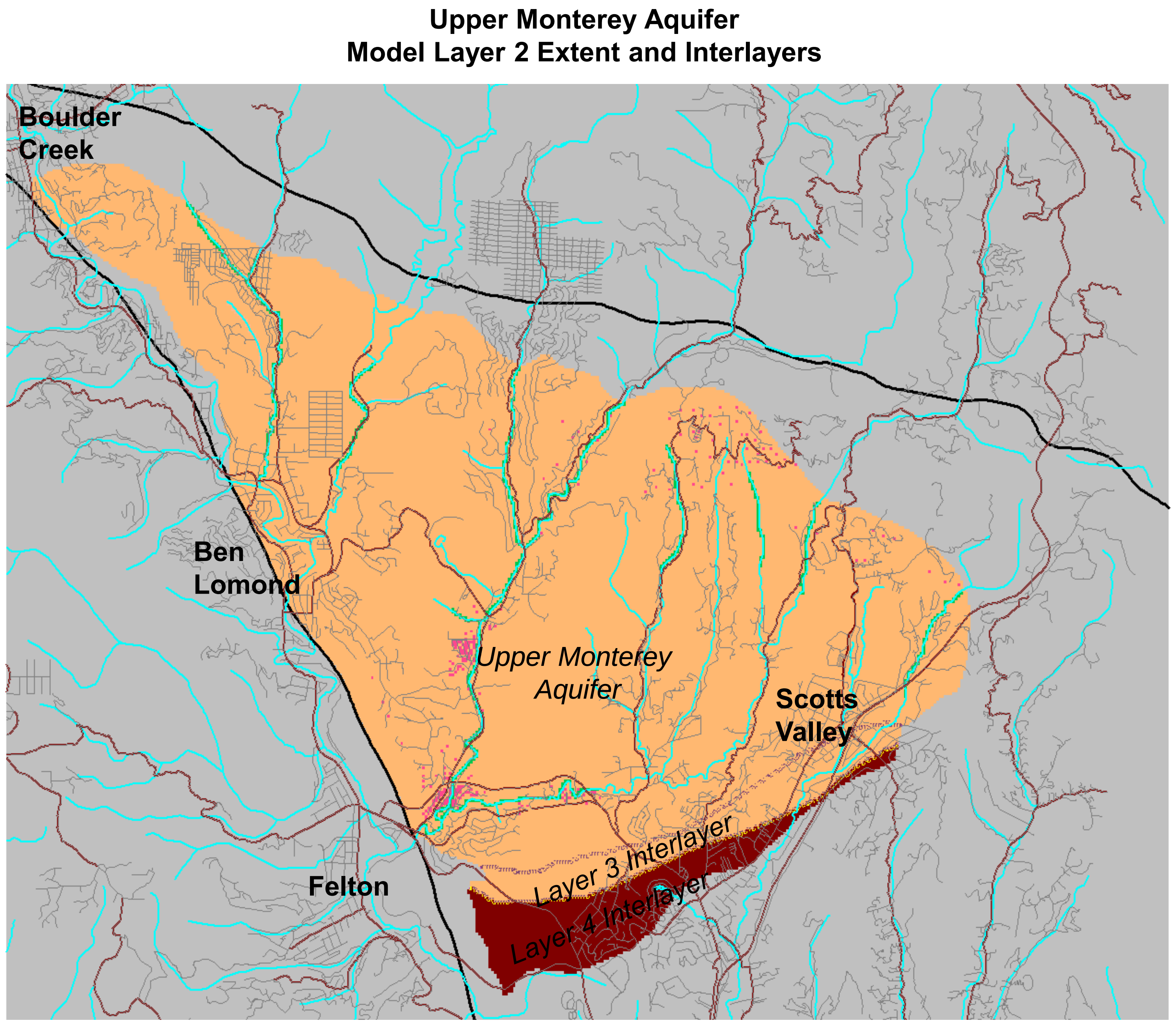
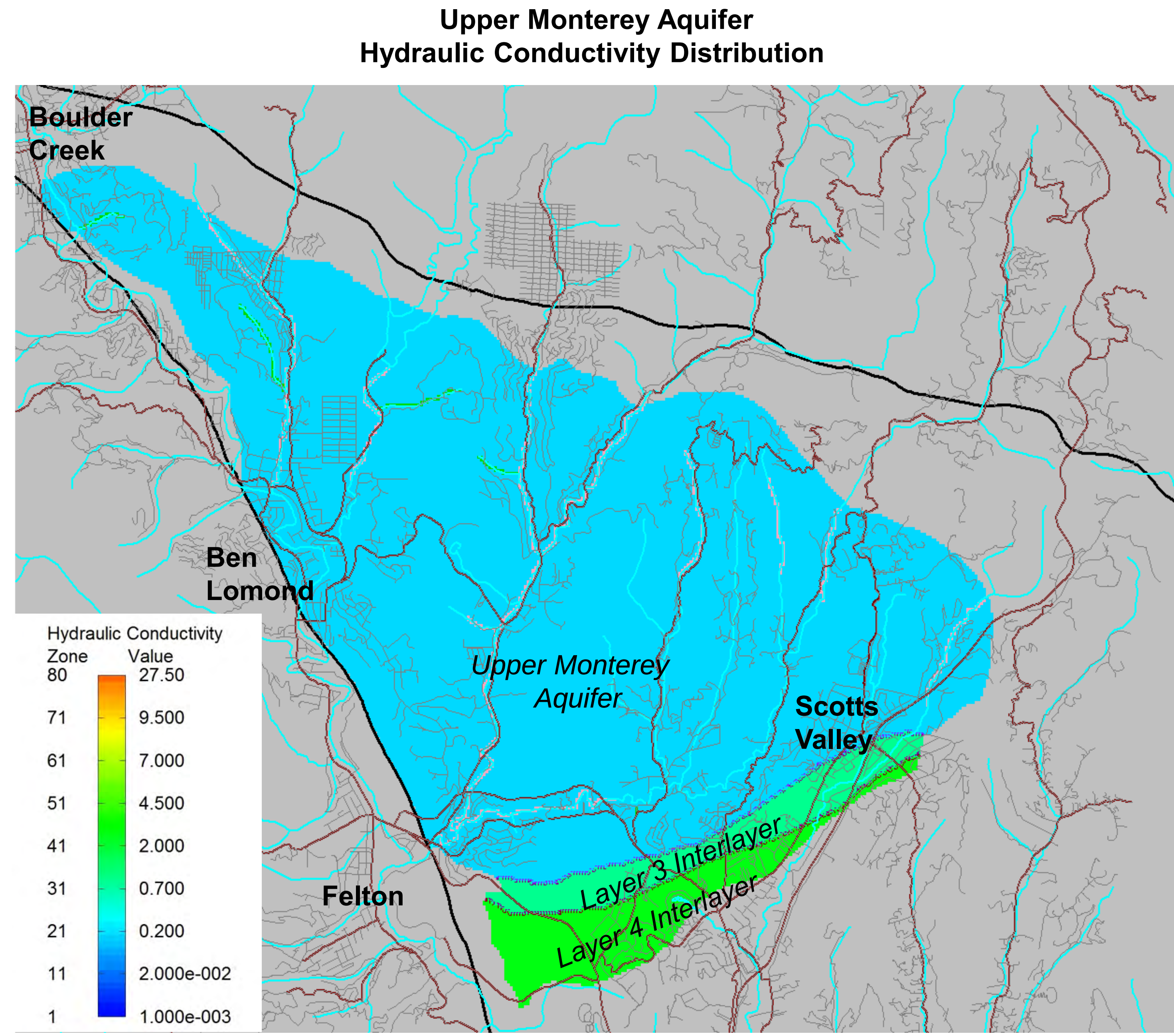
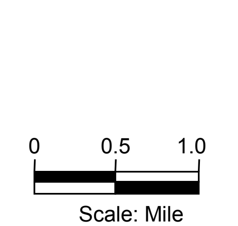
Figure 6-2







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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Extent, Subareas and Aquifer Properties Model Layer 2 – Upper Monterey Aquifer

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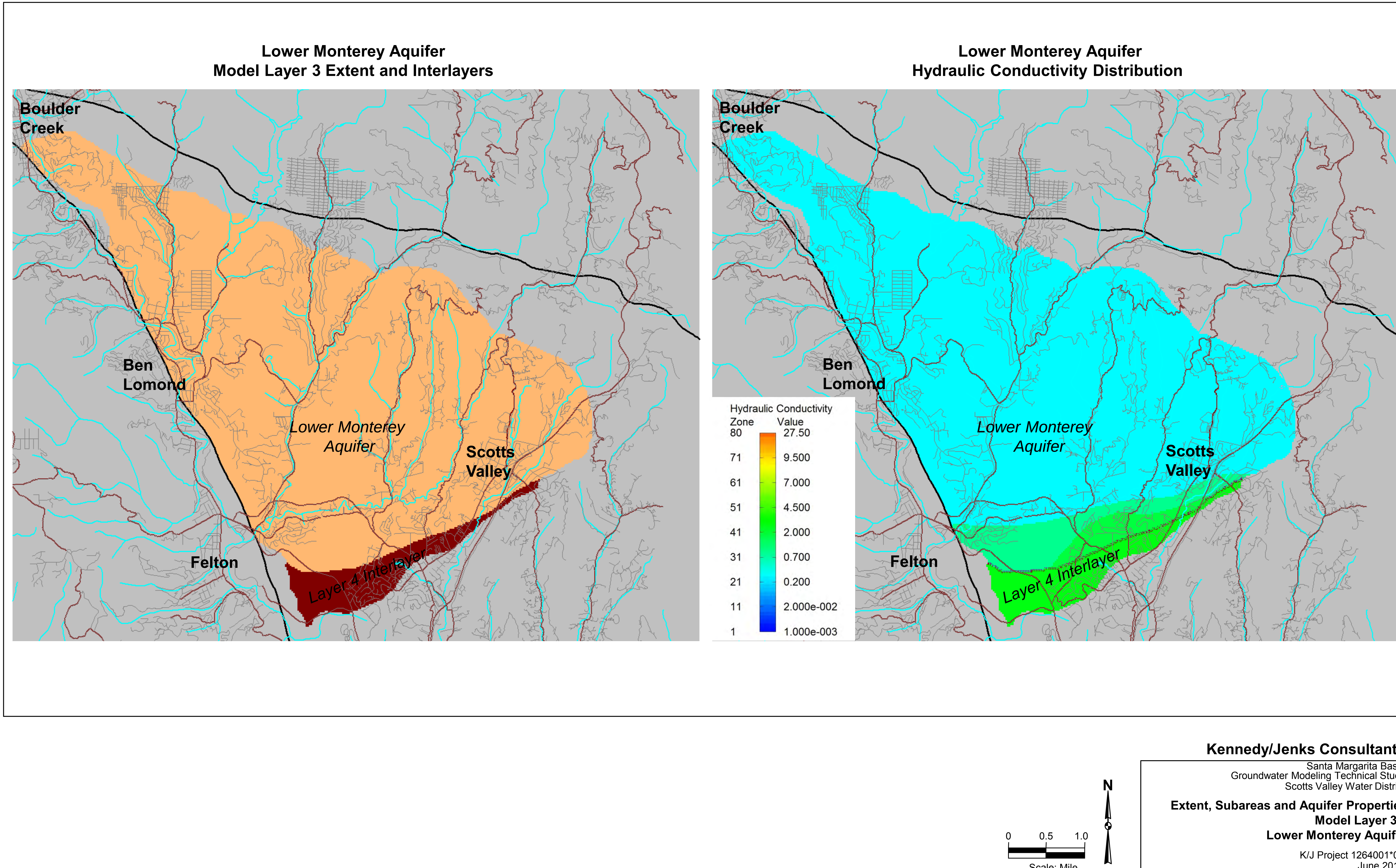
Figure 6-3



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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Extent, Subareas and Aquifer Properties
Model Layer 3 –
Lower Monterey Aquifer

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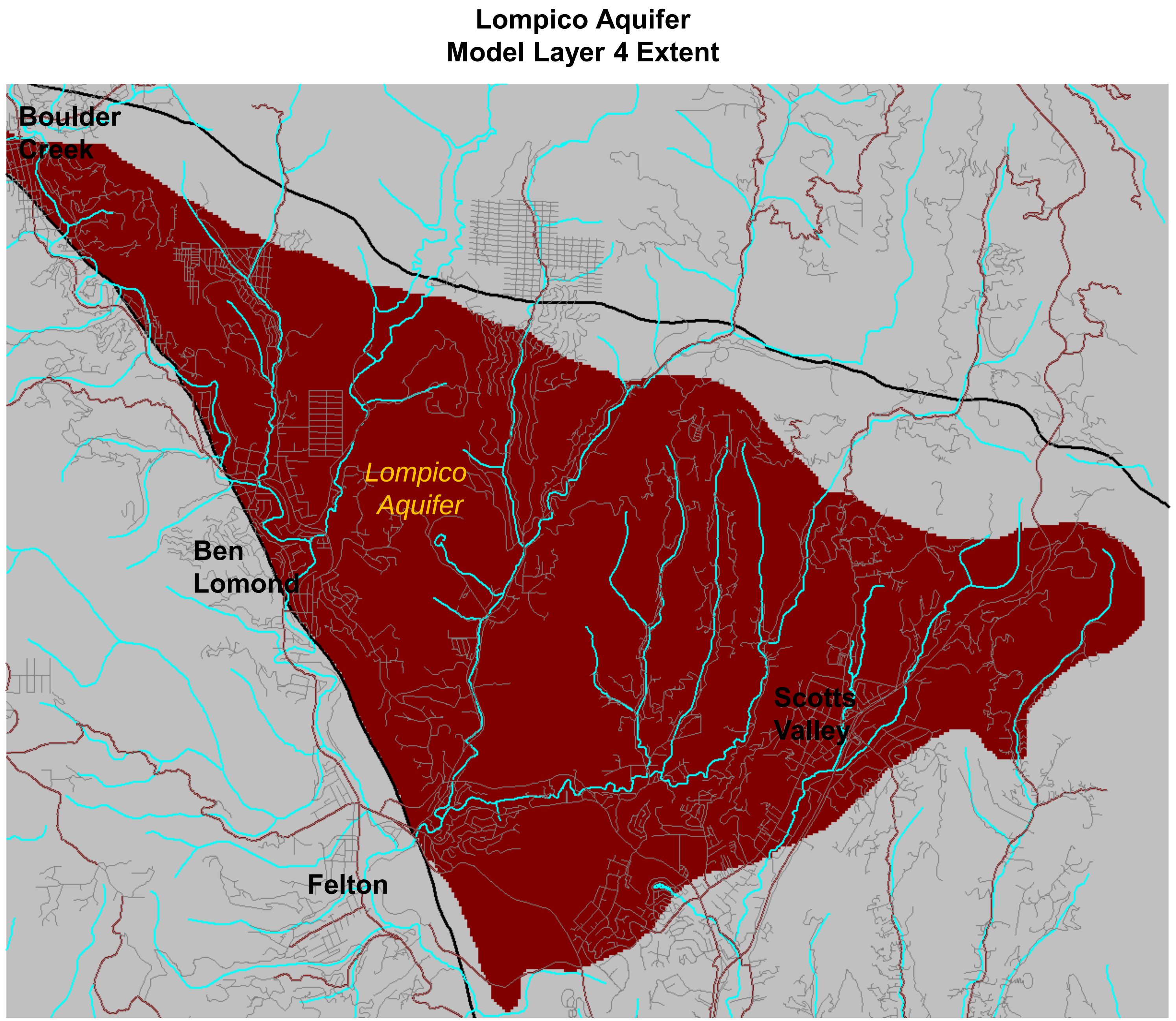
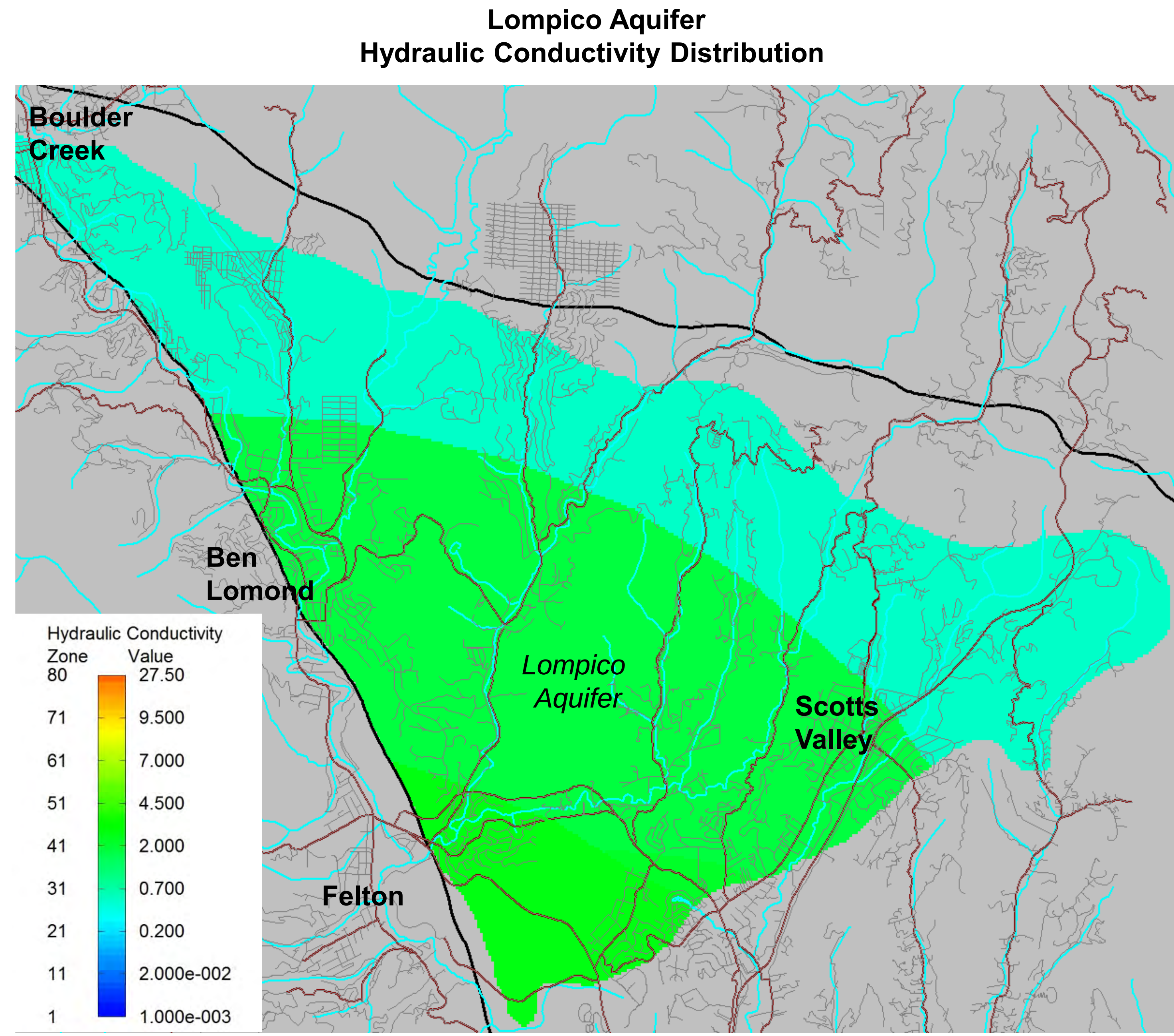
Figure 6-4





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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

**Extent, Subareas and Aquifer Properties
Model Layer 4 –
Lompico Aquifer**

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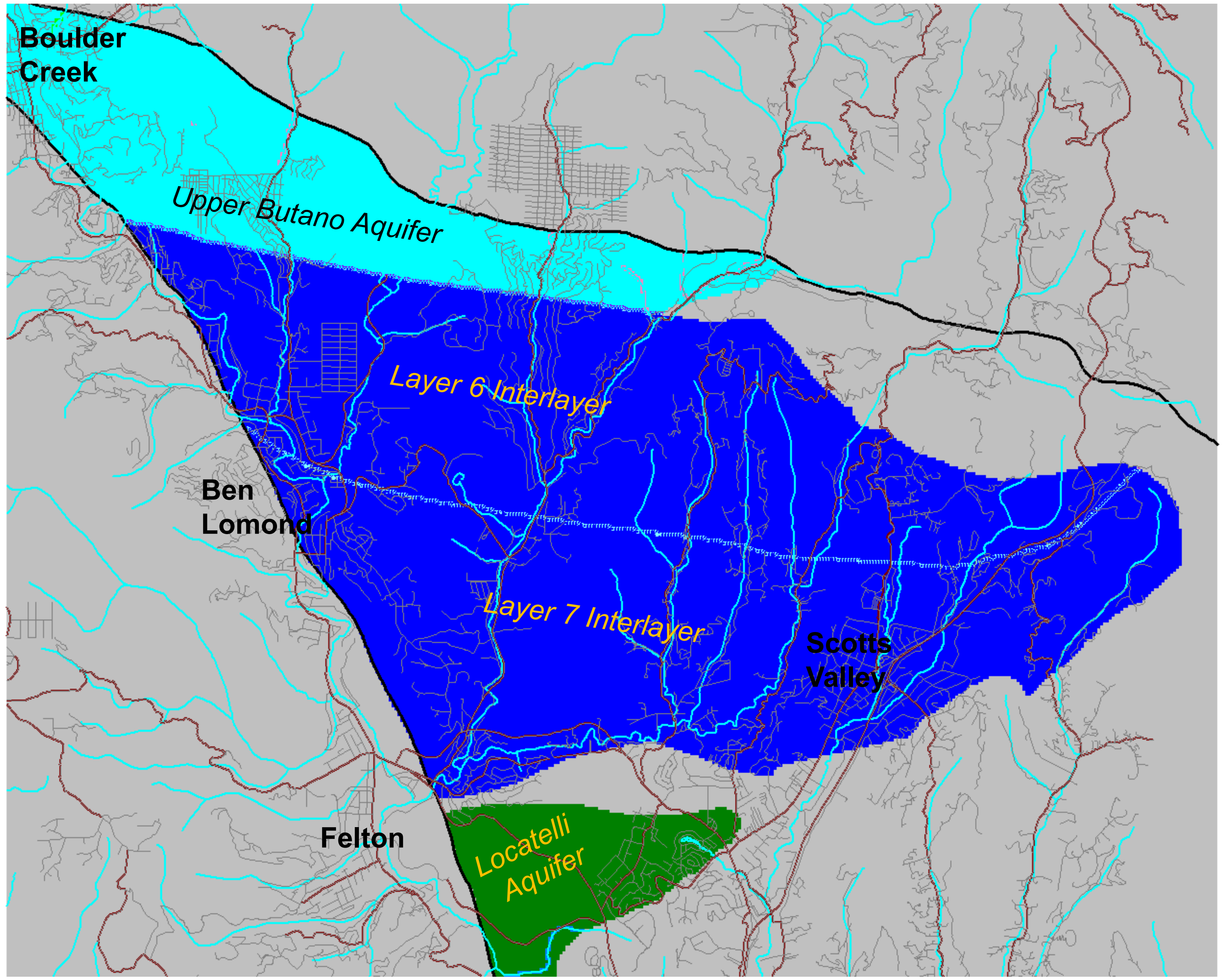
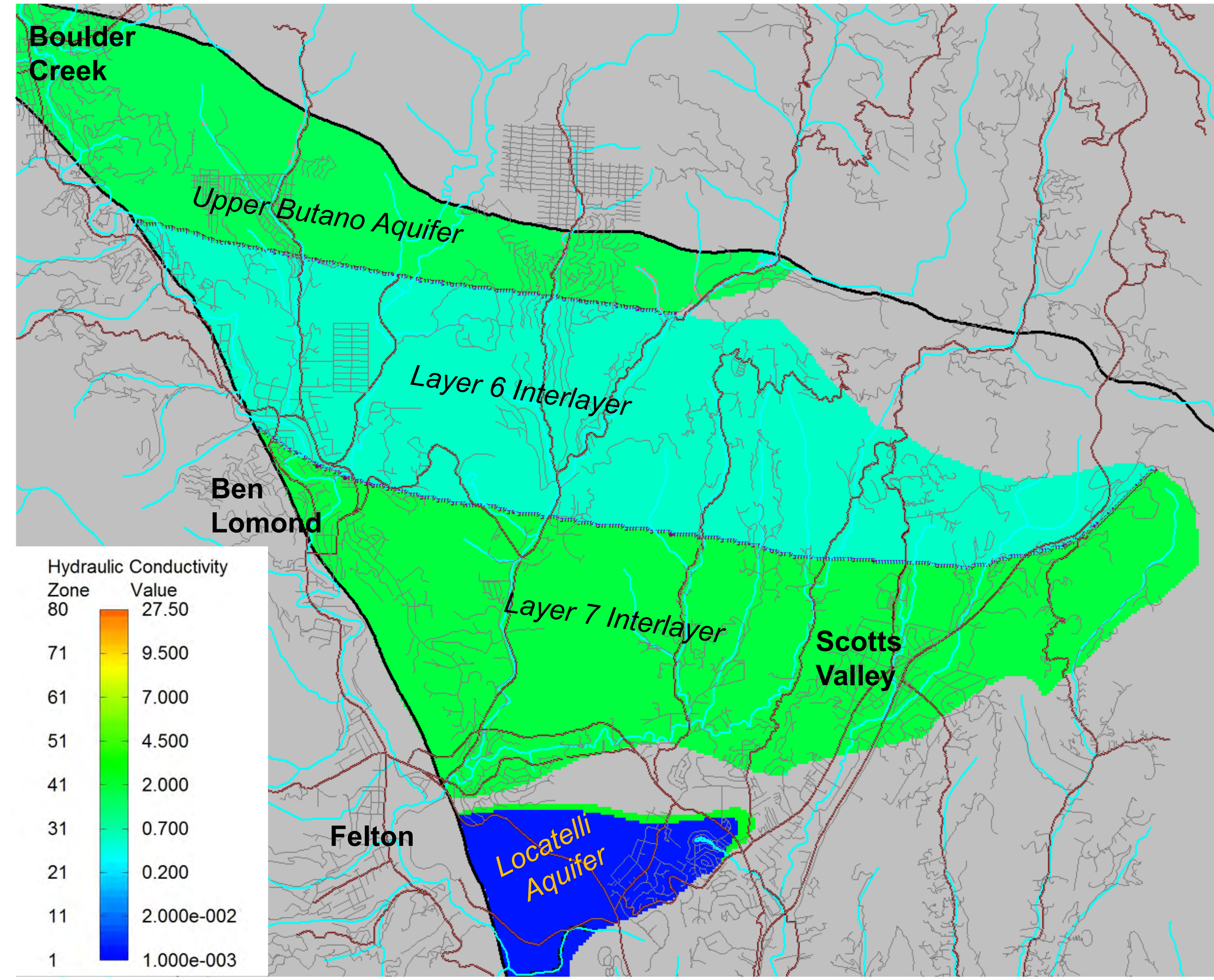
Figure 6-5





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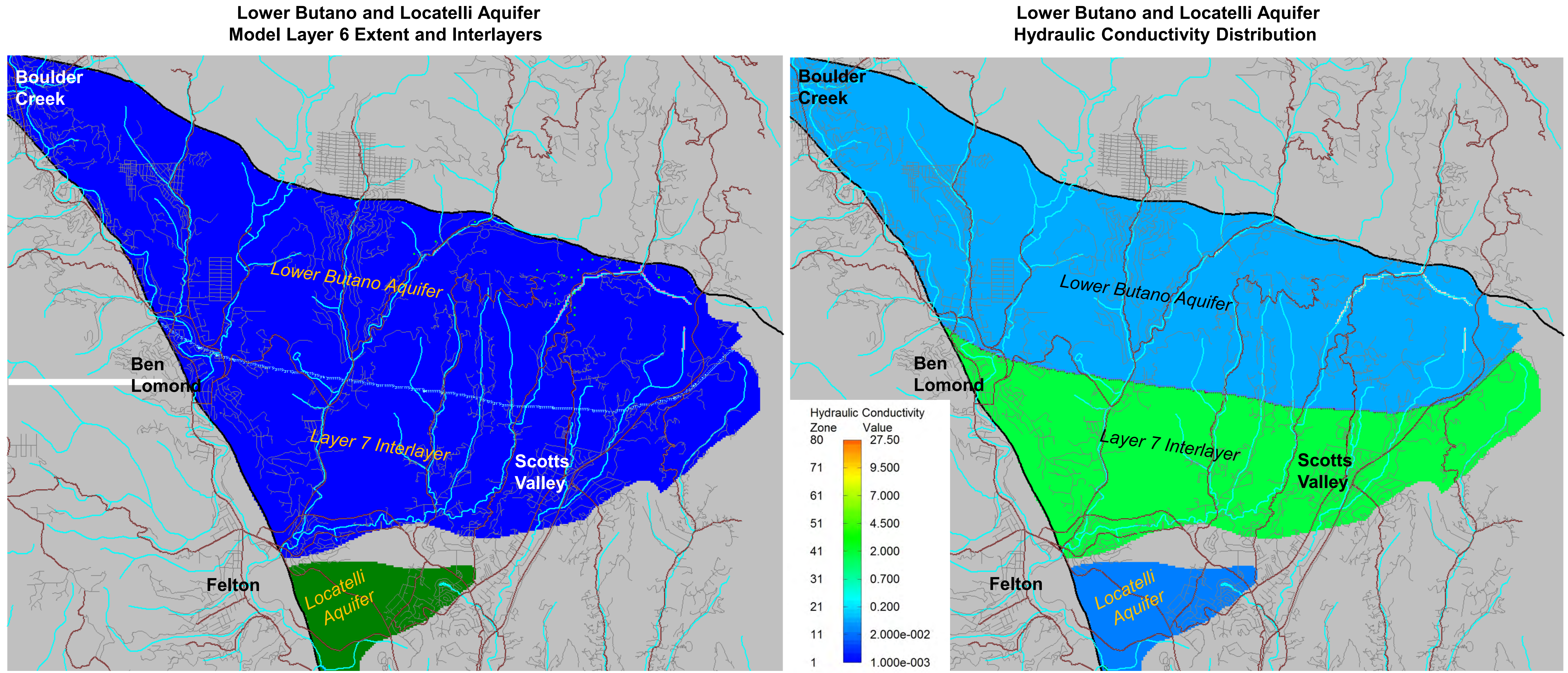
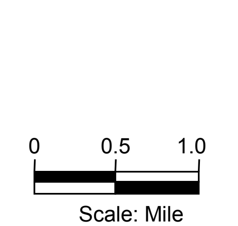
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

**Extent, Subareas and Aquifer Properties
Model Layer 5 –
Upper Butano Aquifer**

K/J Project 1264001*00
June 2015

Figure 6-6





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Scotts Valley Water District

Extent, Subareas and Aquifer Properties
Model Layer 6 –
Lower Butano Aquifer

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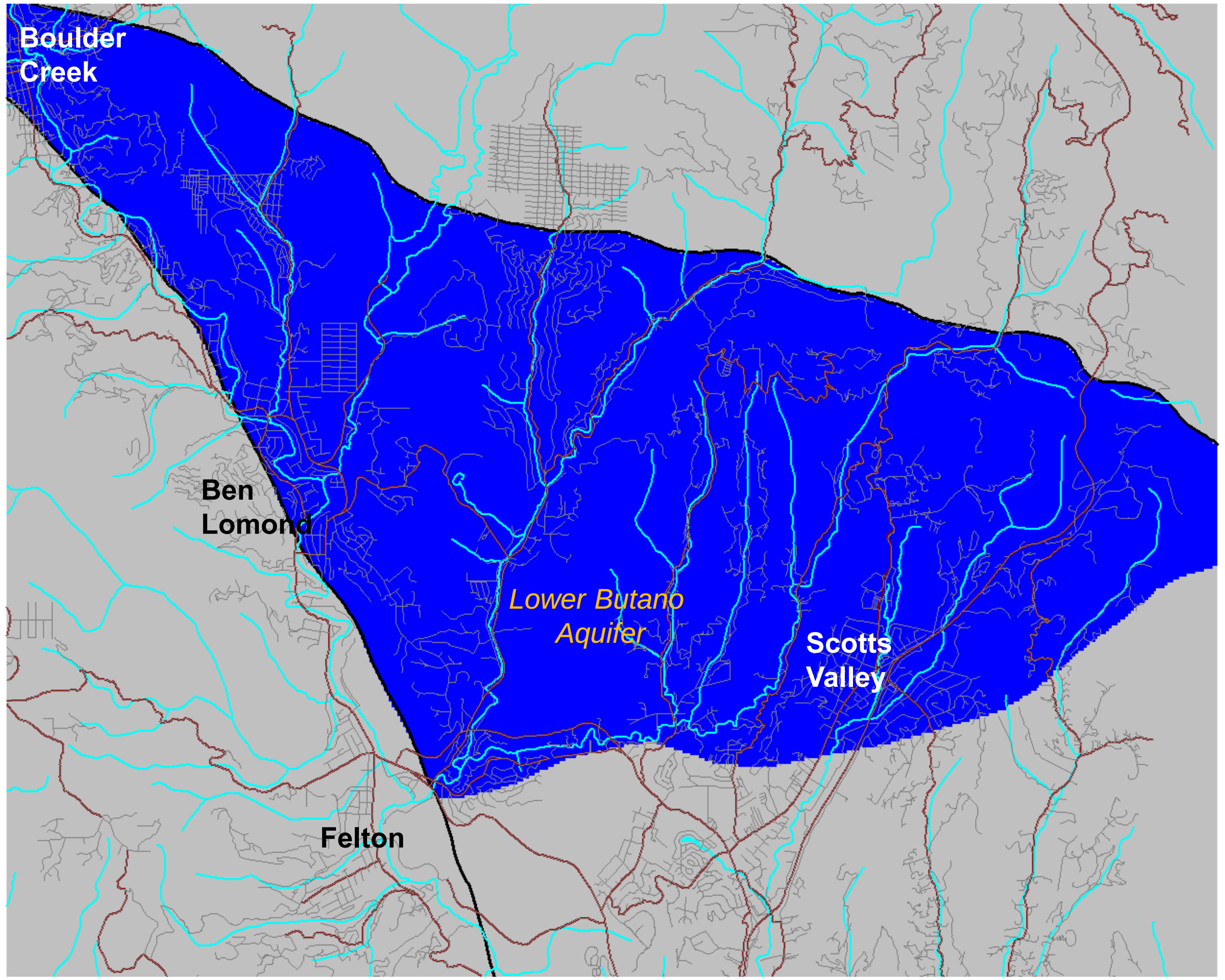
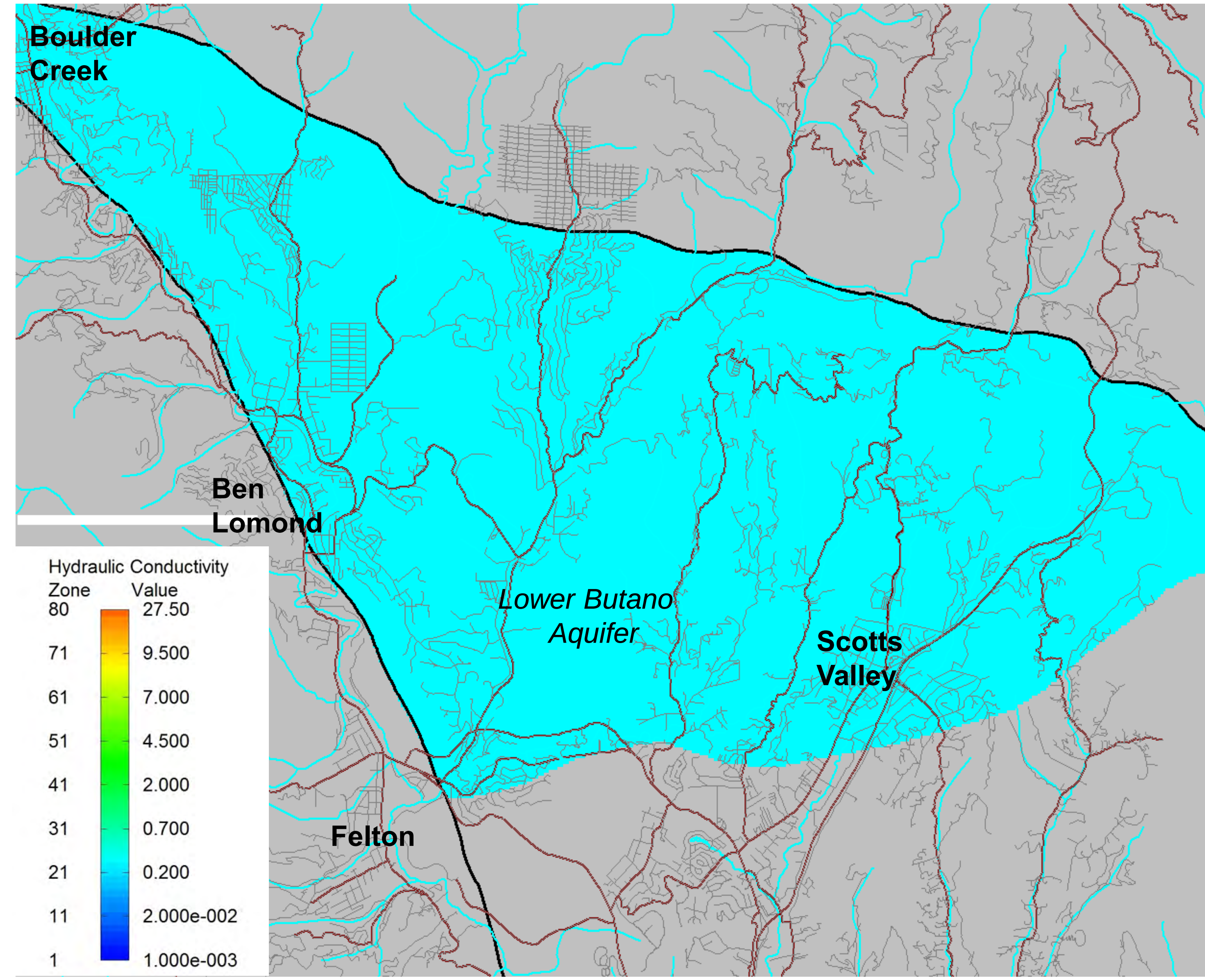
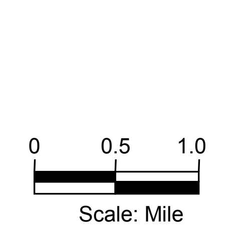
Figure 6-7

Lower Butano Aquifer
Model Layer 7 Extent



Lower Butano Aquifer
Hydraulic Conductivity Distribution





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Extent, Subareas and Aquifer Properties
Model Layer 7 –
Lower Butano Aquifer

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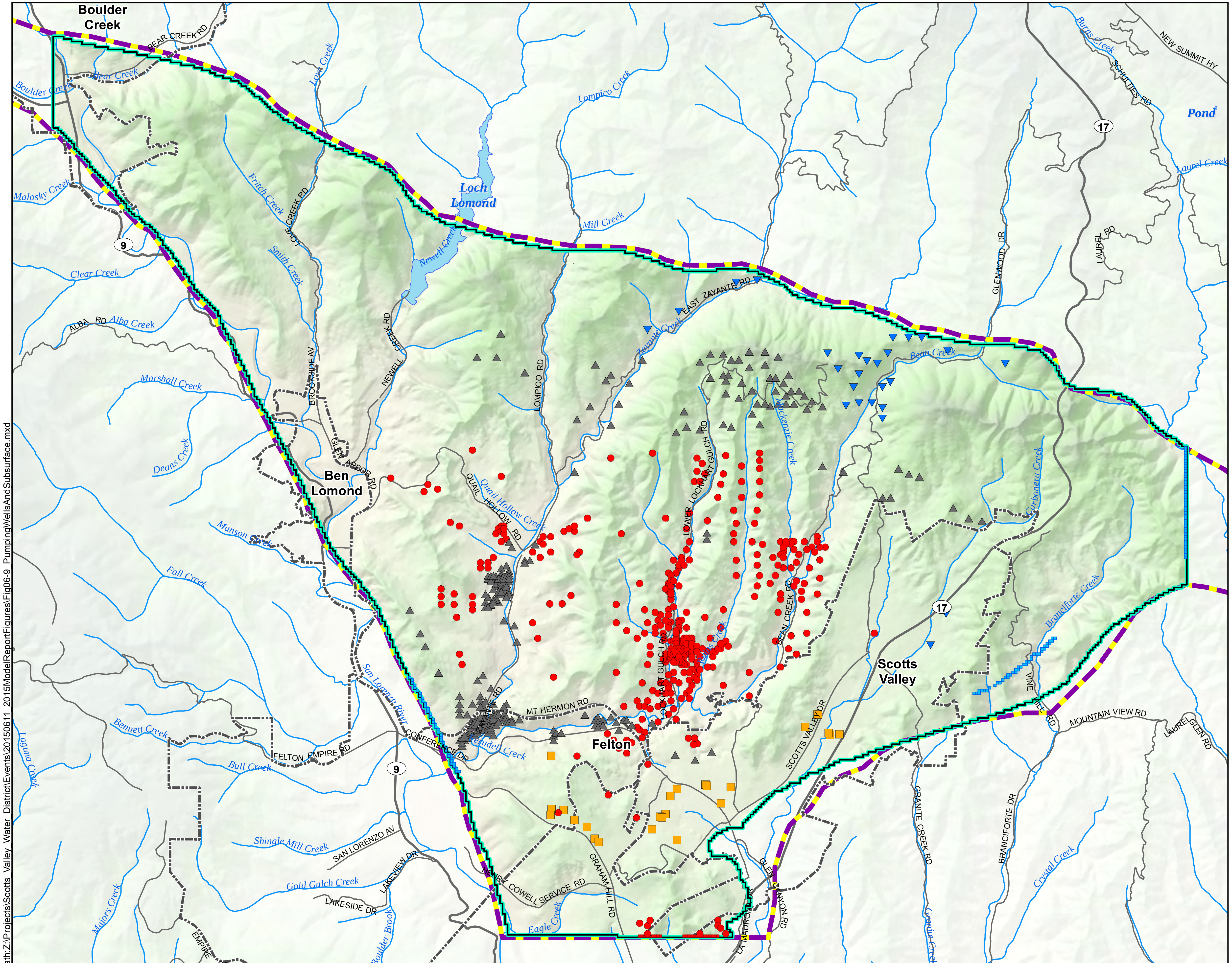
Figure 6-8



LEGEND

- Model Domain Boundary
- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Major Highway
- Major Road

Groundwater Pumping Wells By Aquifer Symbols Based on Bottom Layer

- Santa Margarita
- Monterrey
- Lompico
- Butano
- Groundwater Subsurface Boundary Conditions - Santa Margarita
- Goundwater Subsurface Boundary Conditions - Butano

N

0 0.5 1

Scale: Miles

Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig06-9_PumpingWellsAndSubsurface.mxd

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Pumping Wells and Subsurface Boundary Conditions Locations

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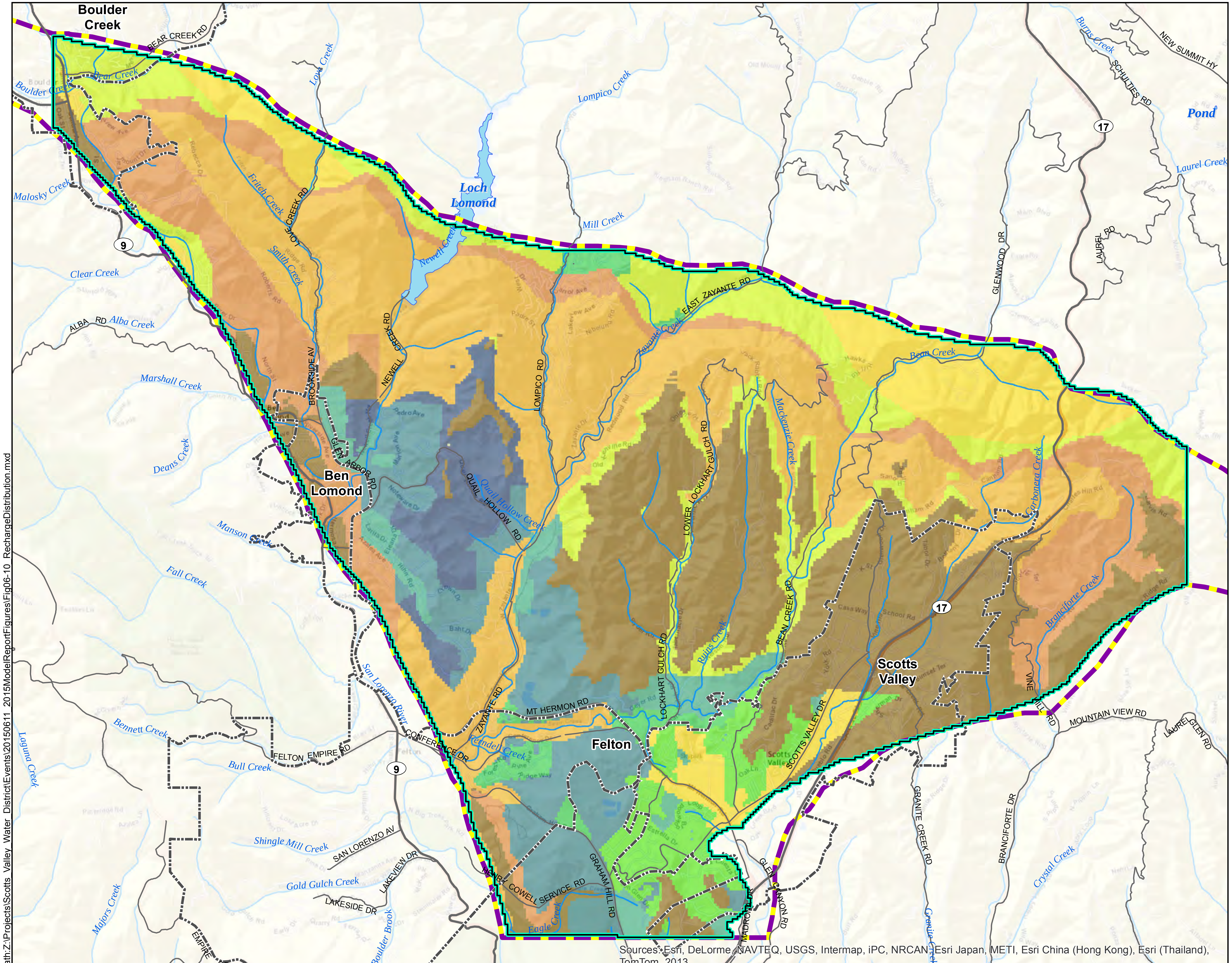
Figure 6-9



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LEGEND

- Model Domain Boundary
- City Limit
- Major Highway
- Major Road
- Santa Margarita Groundwater Basin Boundary
- Lake
- Stream

Average Annual Surface Recharge - inches per year (Includes Precipitation and Return Flow)

- 0.0 - 0.5
- 0.6 - 2.3
- 2.4
- 2.5 - 5.6
- 5.7 - 7.2
- 7.3 - 10.4
- 10.5 - 18.9
- 19.0 - 22.2
- 22.3 - 26.0
- 26.1 - 35.1

N

0 0.5 1

Scale: Miles

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Recharge Zones for the Updated SMGB Model

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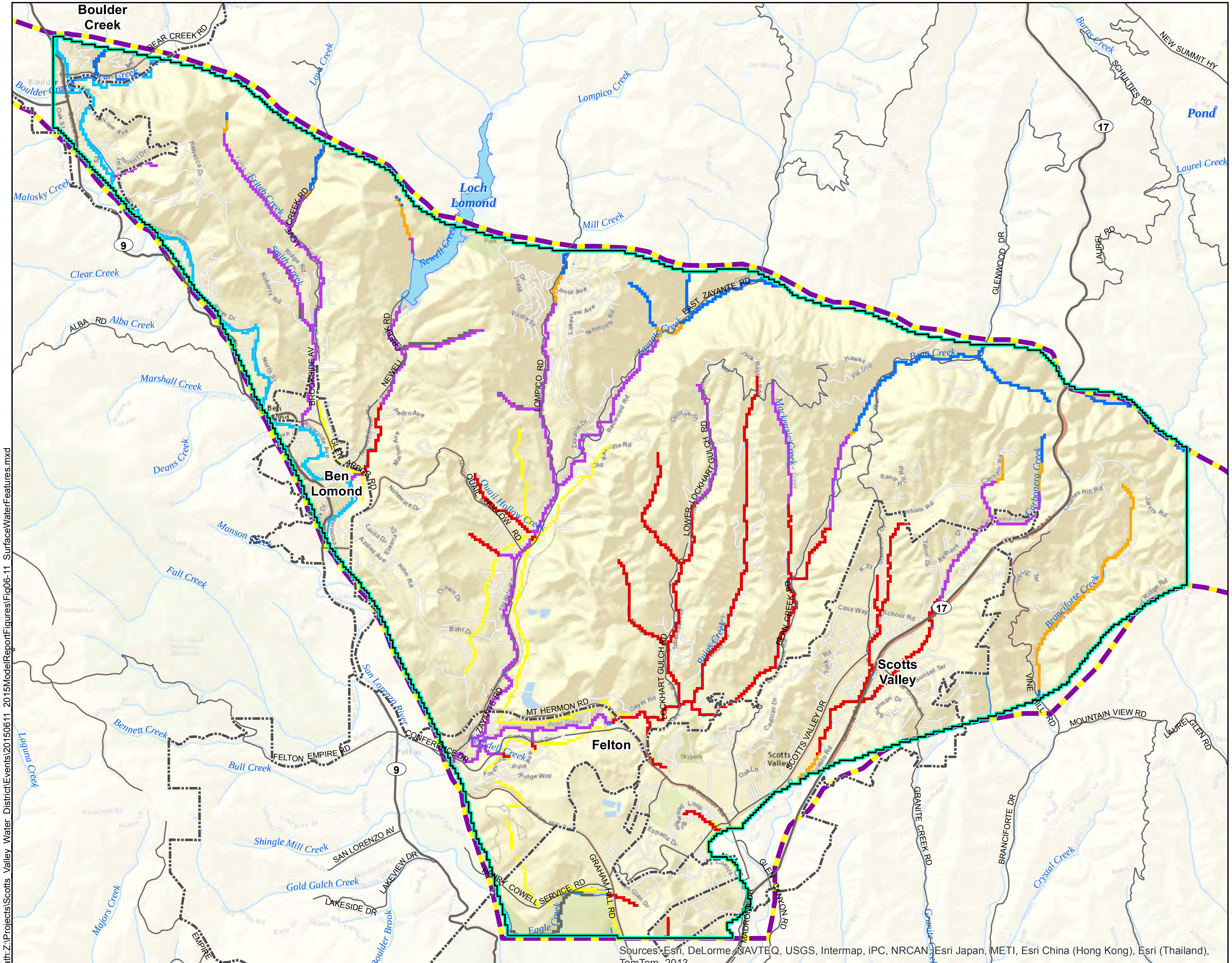
Figure 6-10



Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015ModelReportFigures\Fig06-11 SurfaceWaterFeatures.mxd

LEGEND

- Model Domain Boundary
- City Limit
- Major Highway
- Major Road
- Santa Margarita Groundwater Basin Boundary
- Lake
- Stream

Surface Water Features

- Santa Margarita
- Monterey
- Lompico
- Butano
- Springs
- Ephemeral Streams
- San Lorenzo River

N

0 0.5 1

Scale: Miles

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Surface Water Features in MODFLOW SFRI Package by Aquifer

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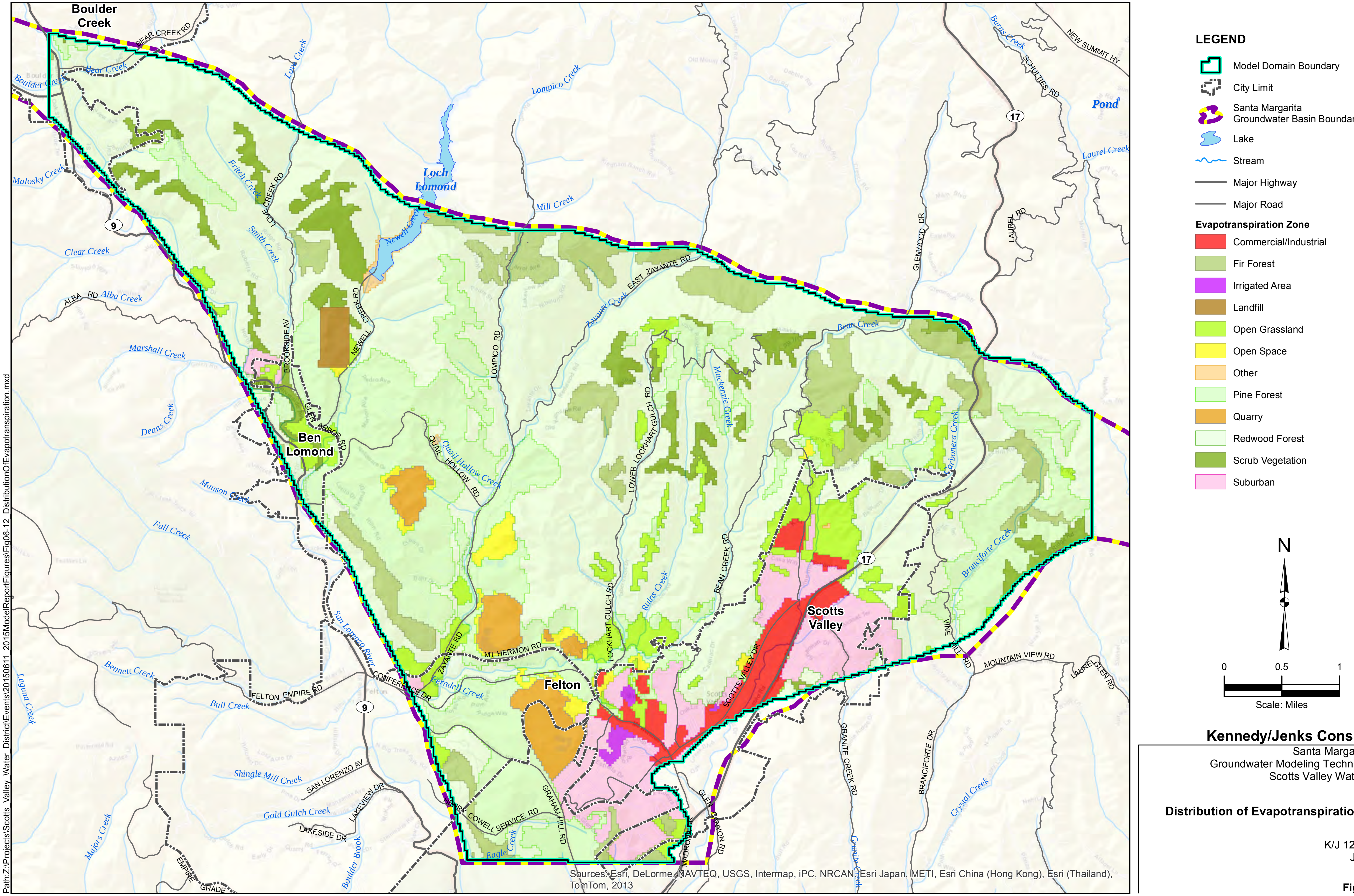
Figure 6-11



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Distribution of Evapotranspiration Zones

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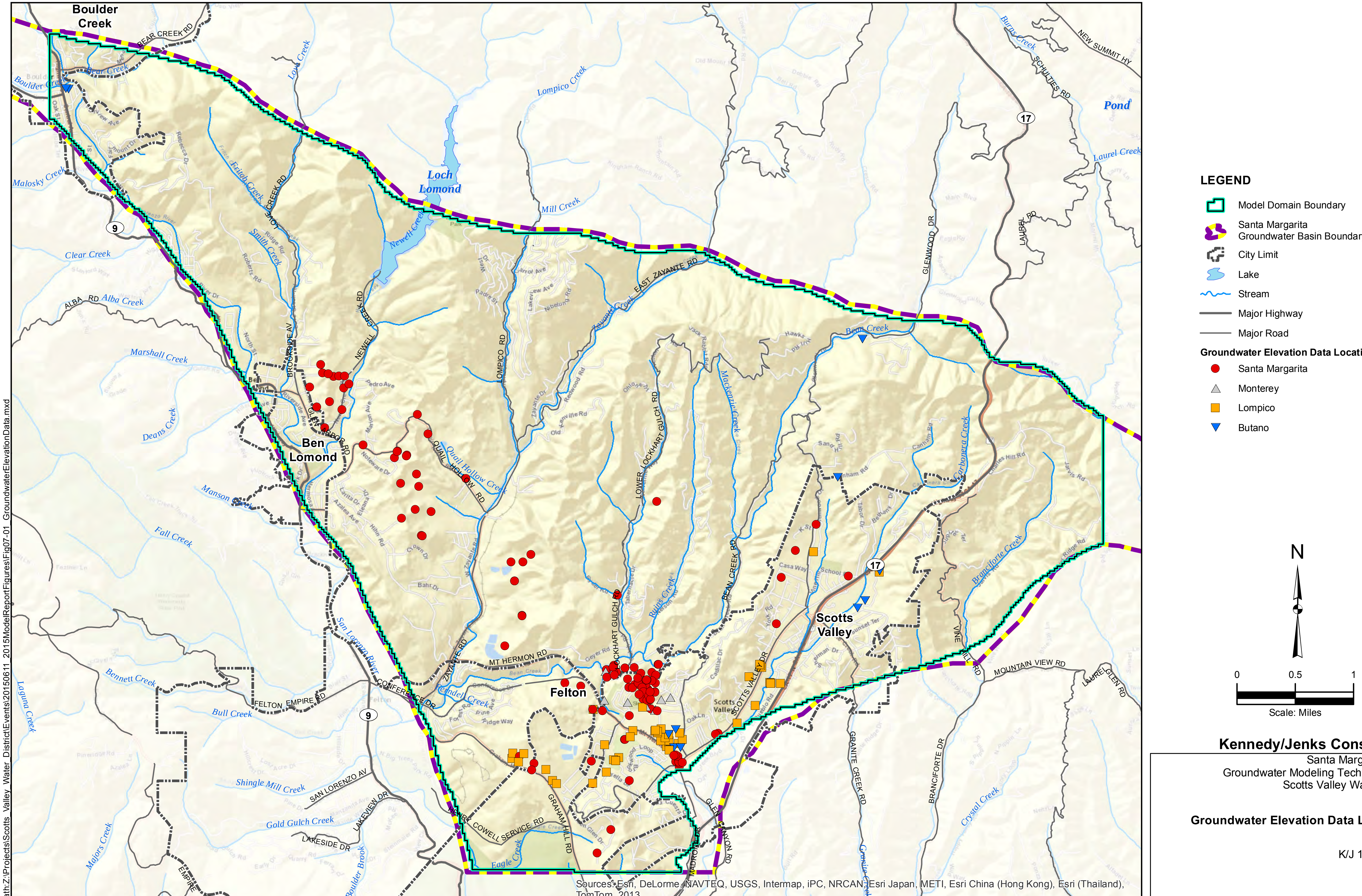
Figure 6-12



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

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Groundwater Elevation Data Locations

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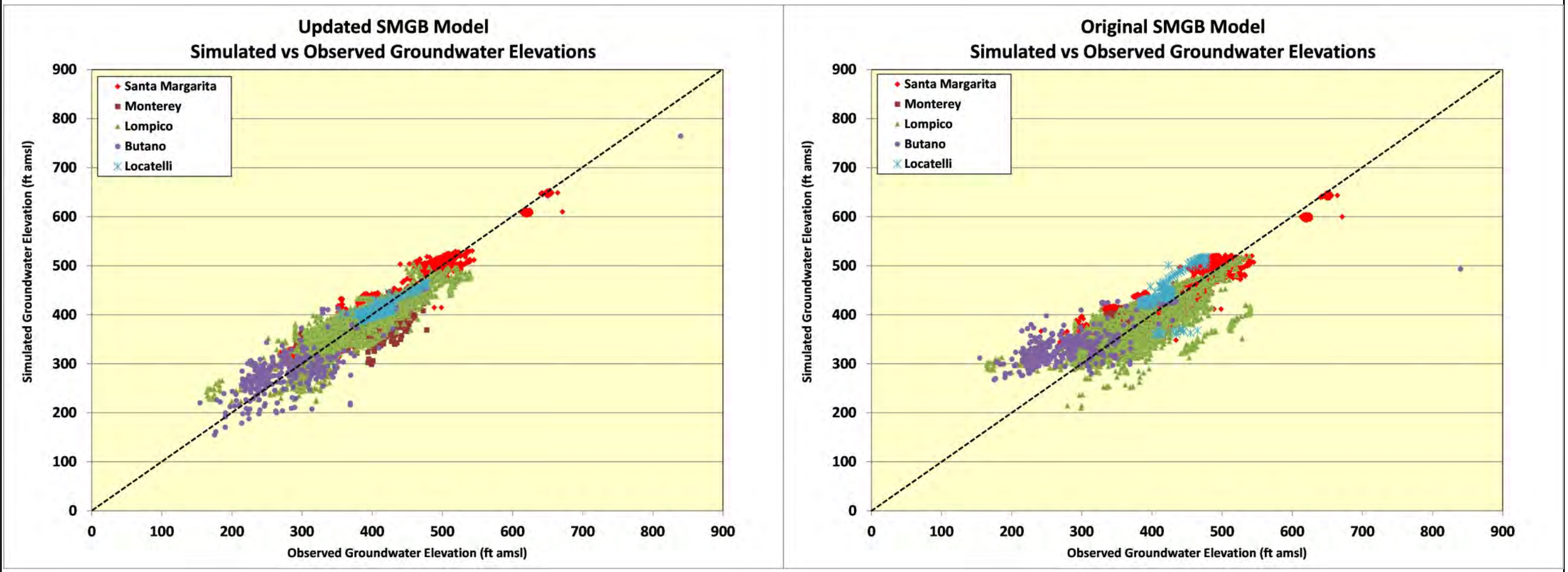
Figure 7-1



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Scatter Plots Comparing Original versus Updated SMGB Model Calibration Results

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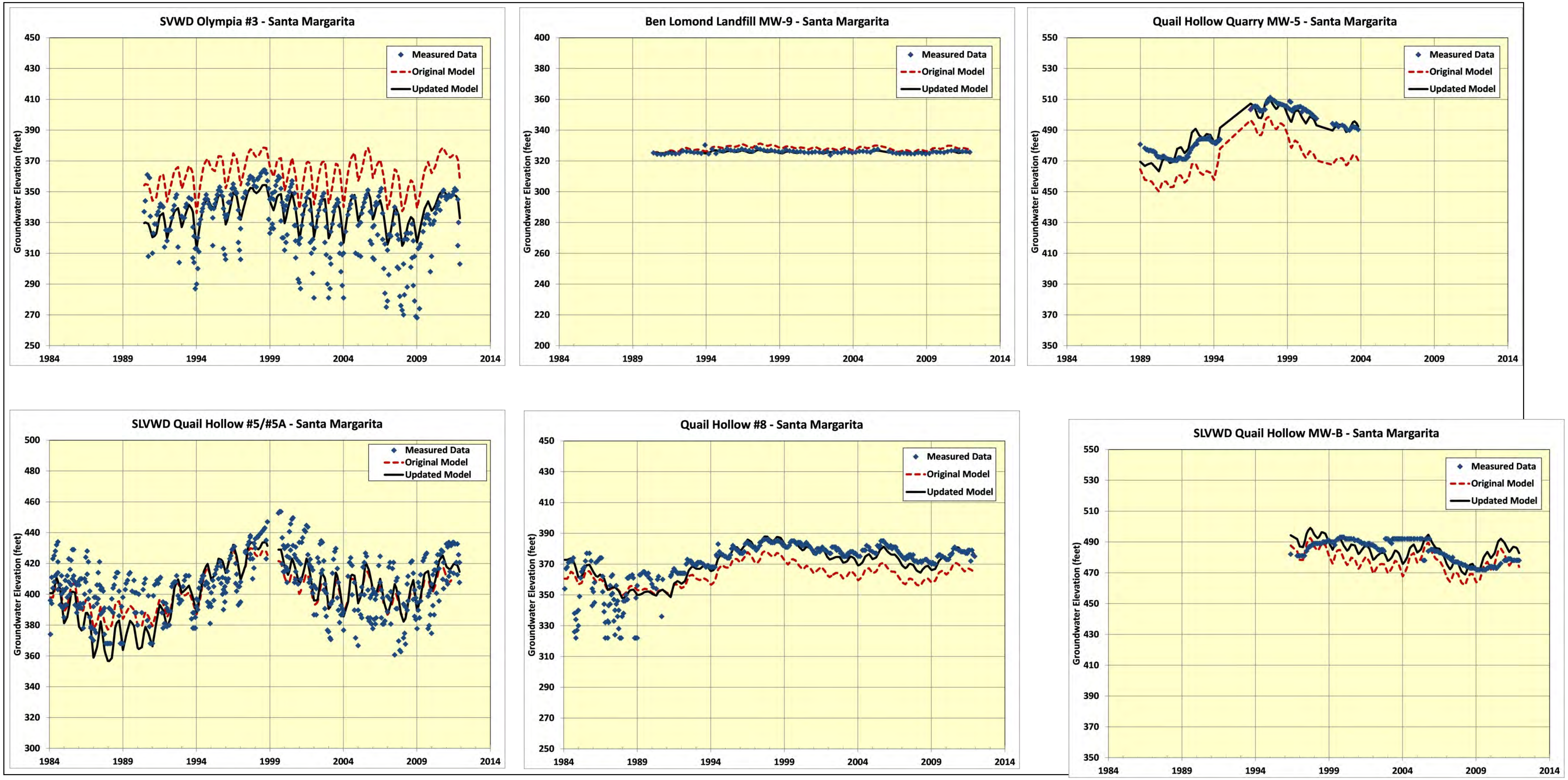
Figure 7-2



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Calibration Hydrographs from the Quail Hollow/Olympia Area

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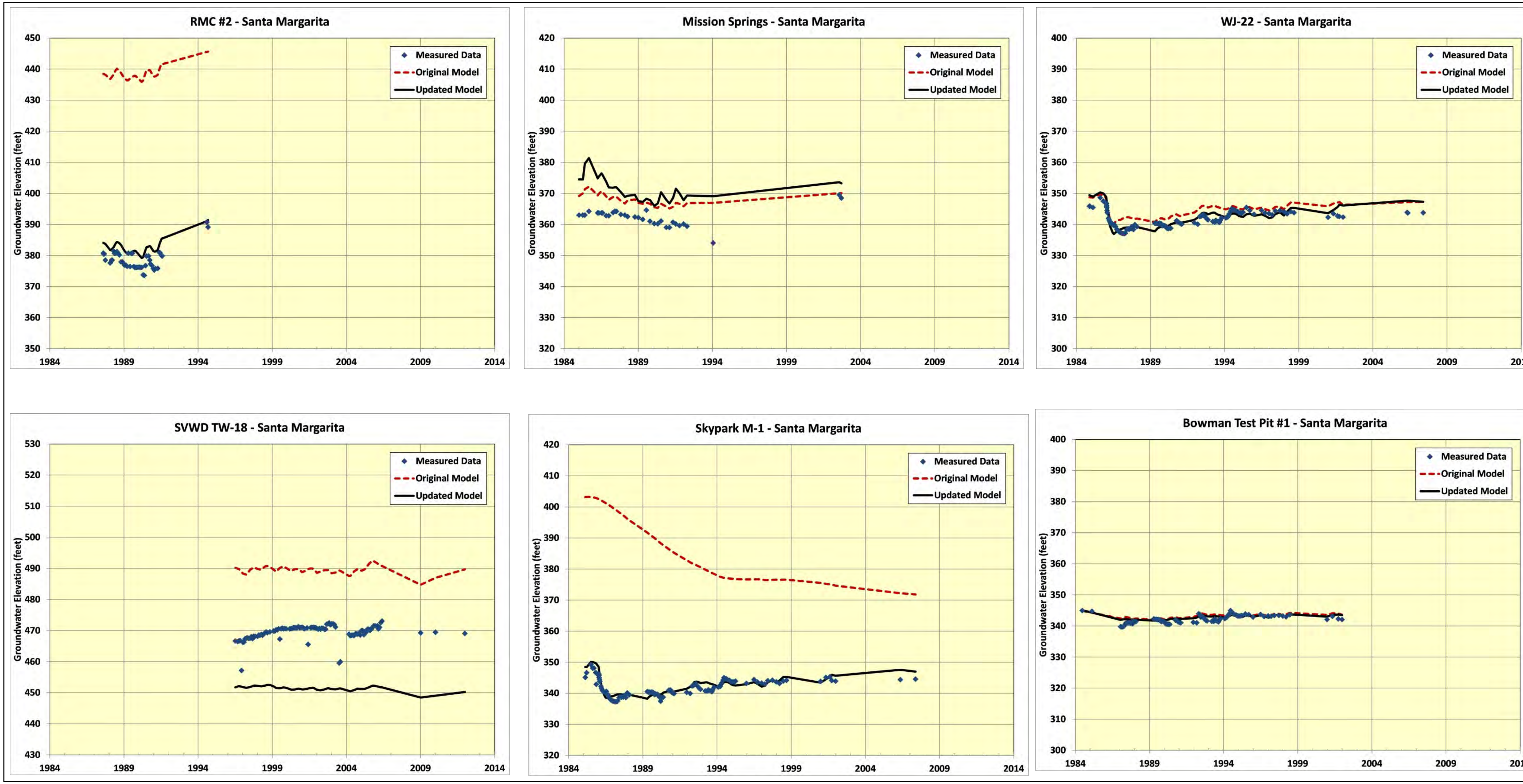
Figure 7-3



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Calibration Hydrographs from the Bean Creek – Watkins-Johnson Area

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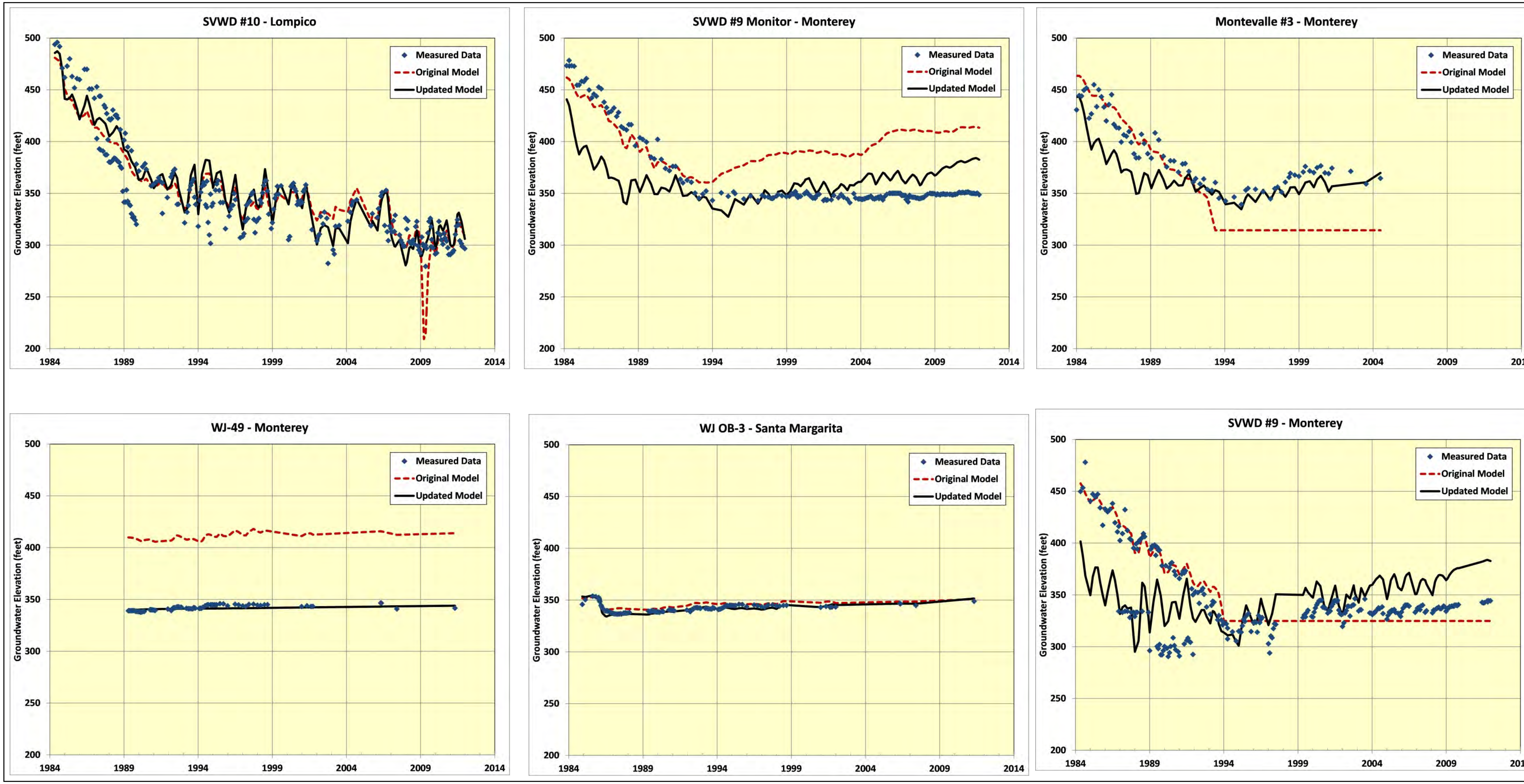
Figure 7-4



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Calibration Hydrographs from the SVWD #9 and #10-Scotts Valley Area

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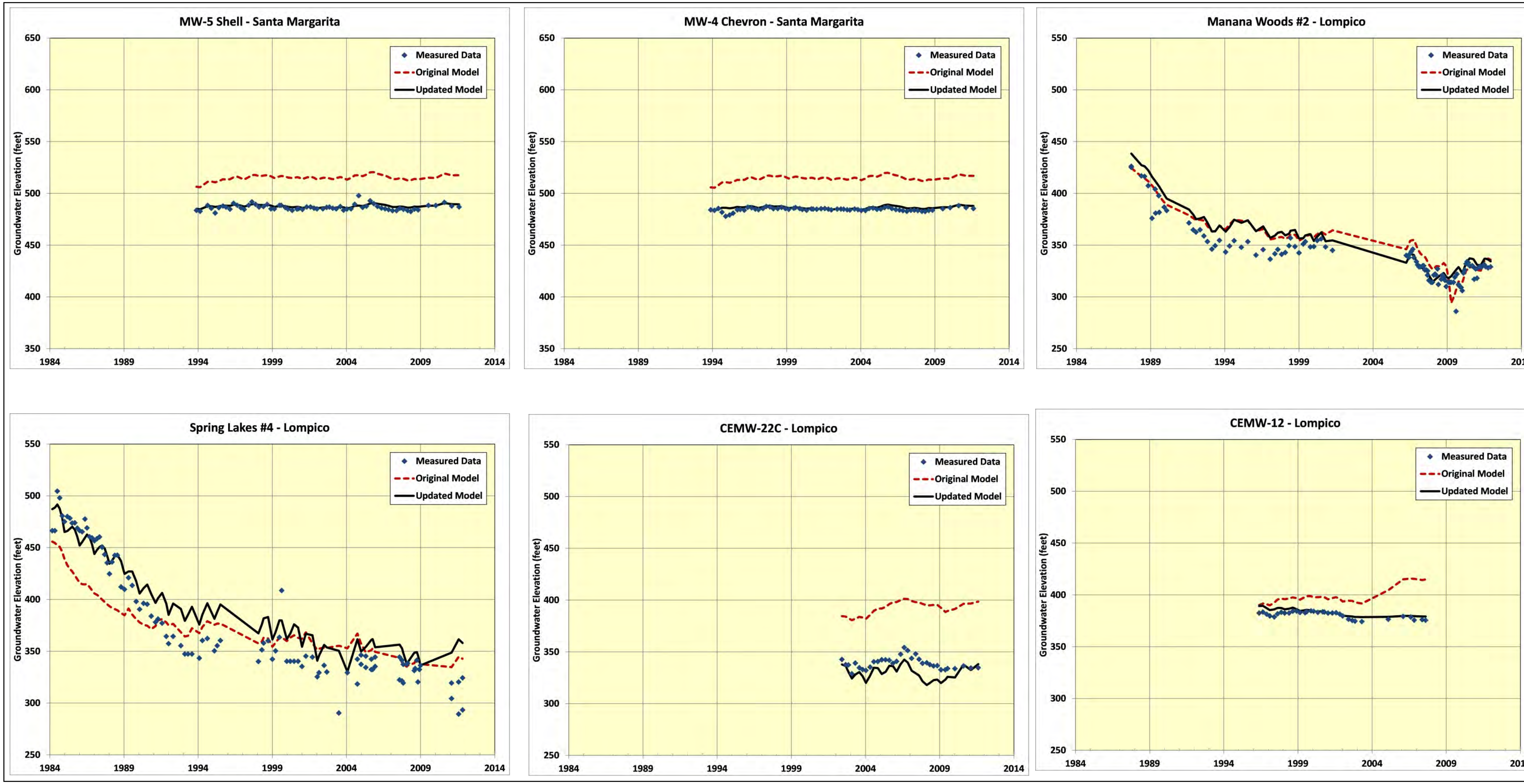
Figure 7-5



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Calibration Hydrographs from the Camp Evers-Scotts Valley Area

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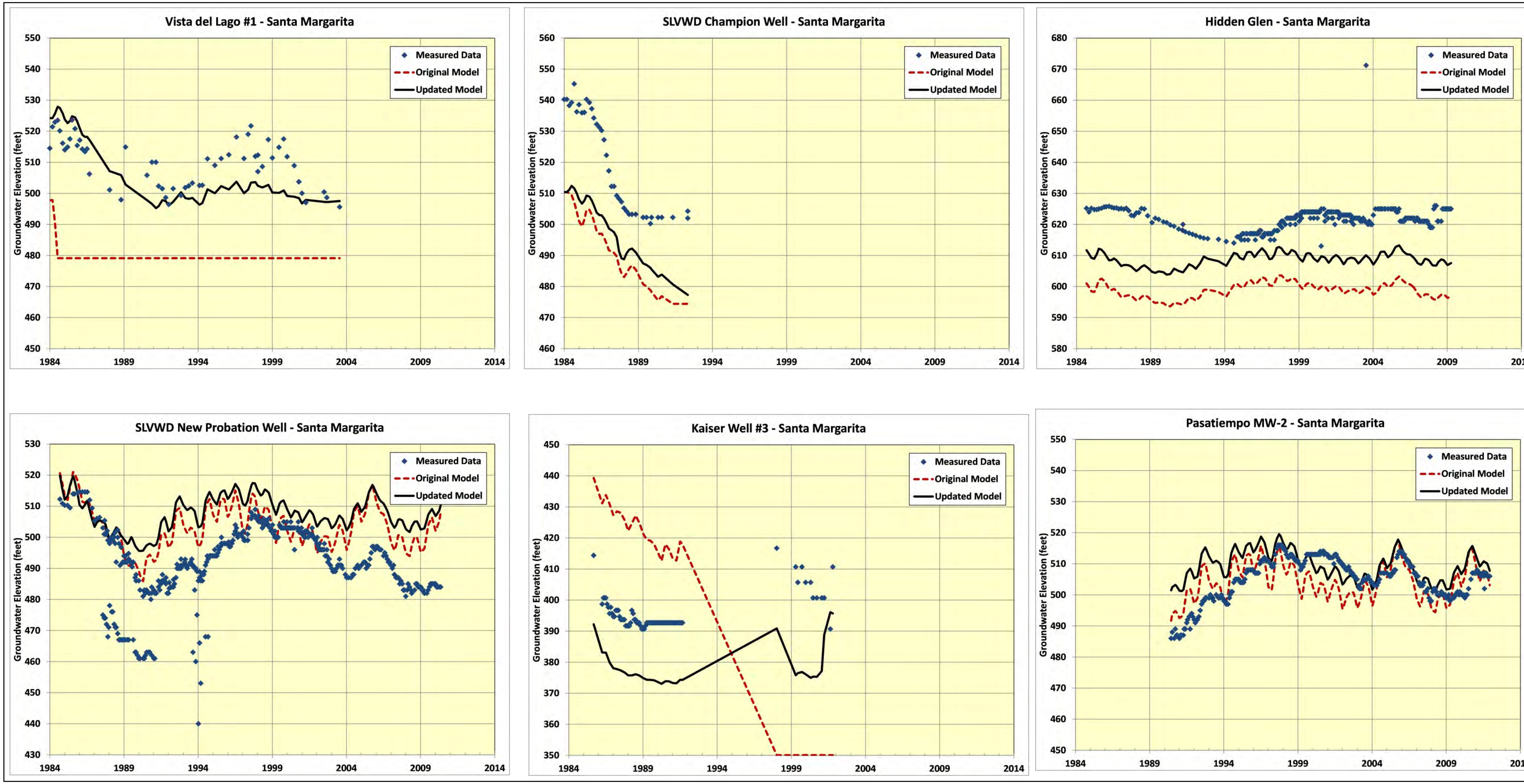
Figure 7-6



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Calibration Hydrographs from Santa Margarita in the SLVWD-Pasatiempo Area

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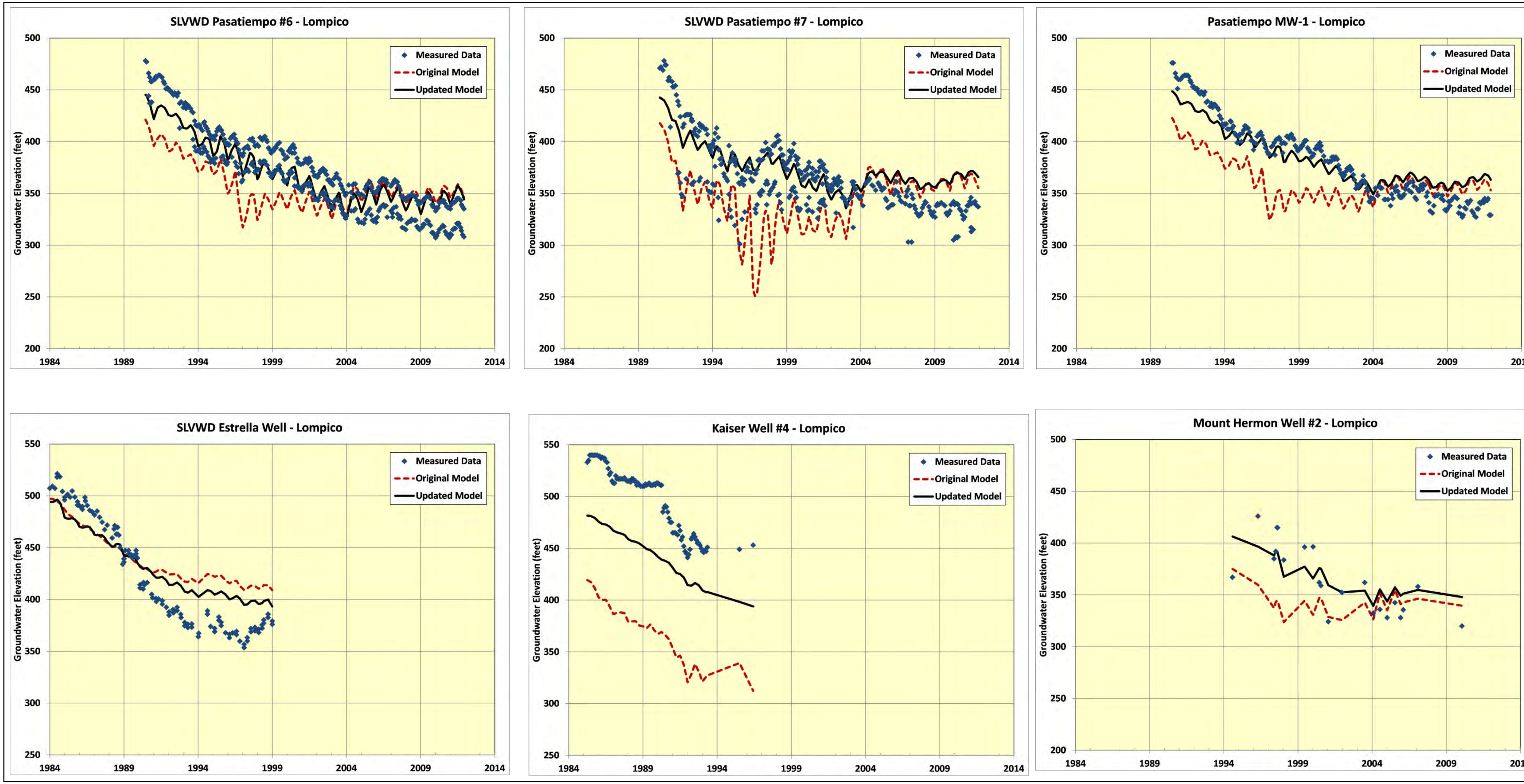
Figure 7-7



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Calibration Hydrographs from Lompico in the SLVWD-Pasatiempo Area

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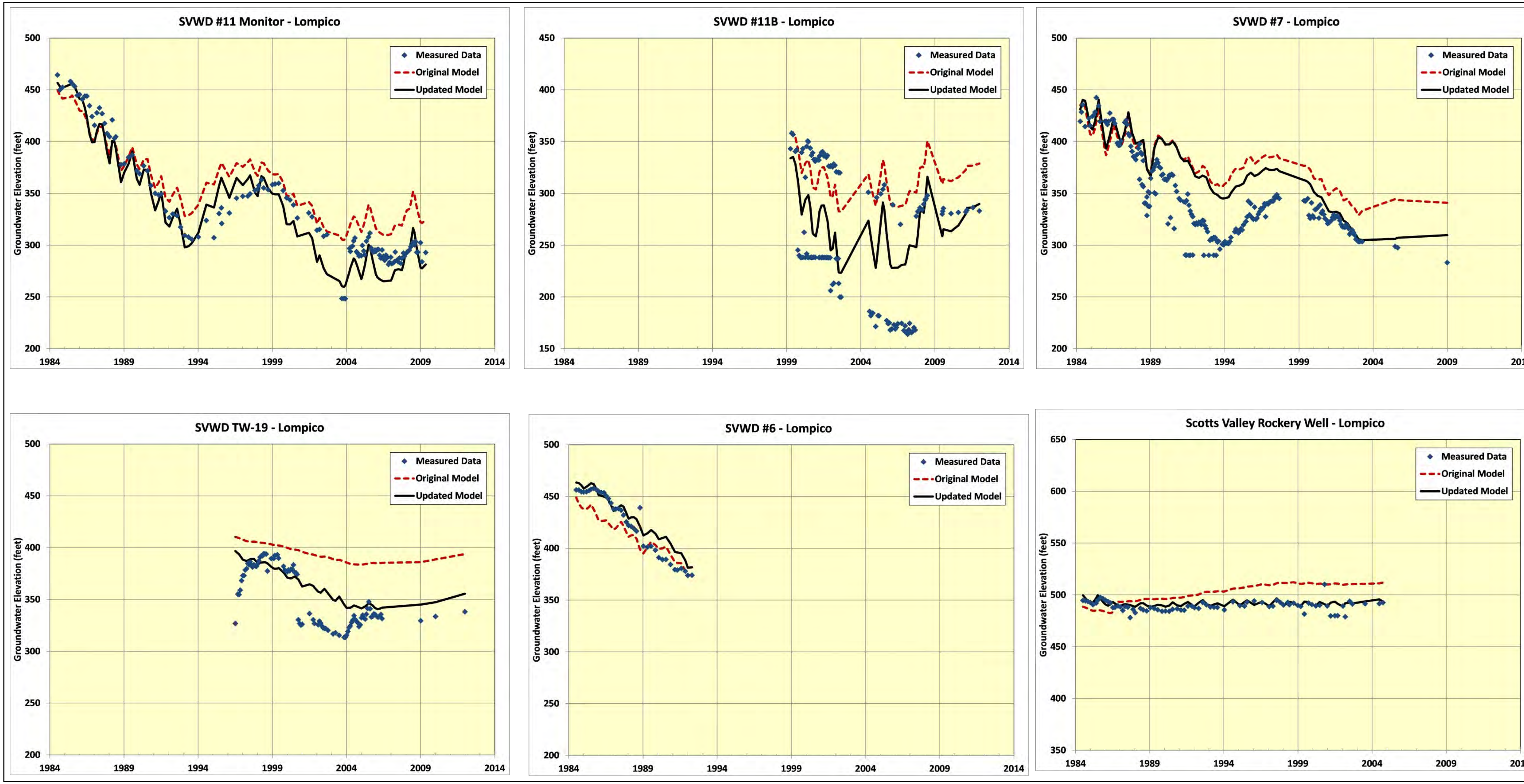
Figure 7-8



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Calibration Hydrographs from Lompico in the El Pueblo-Scotts Valley Area

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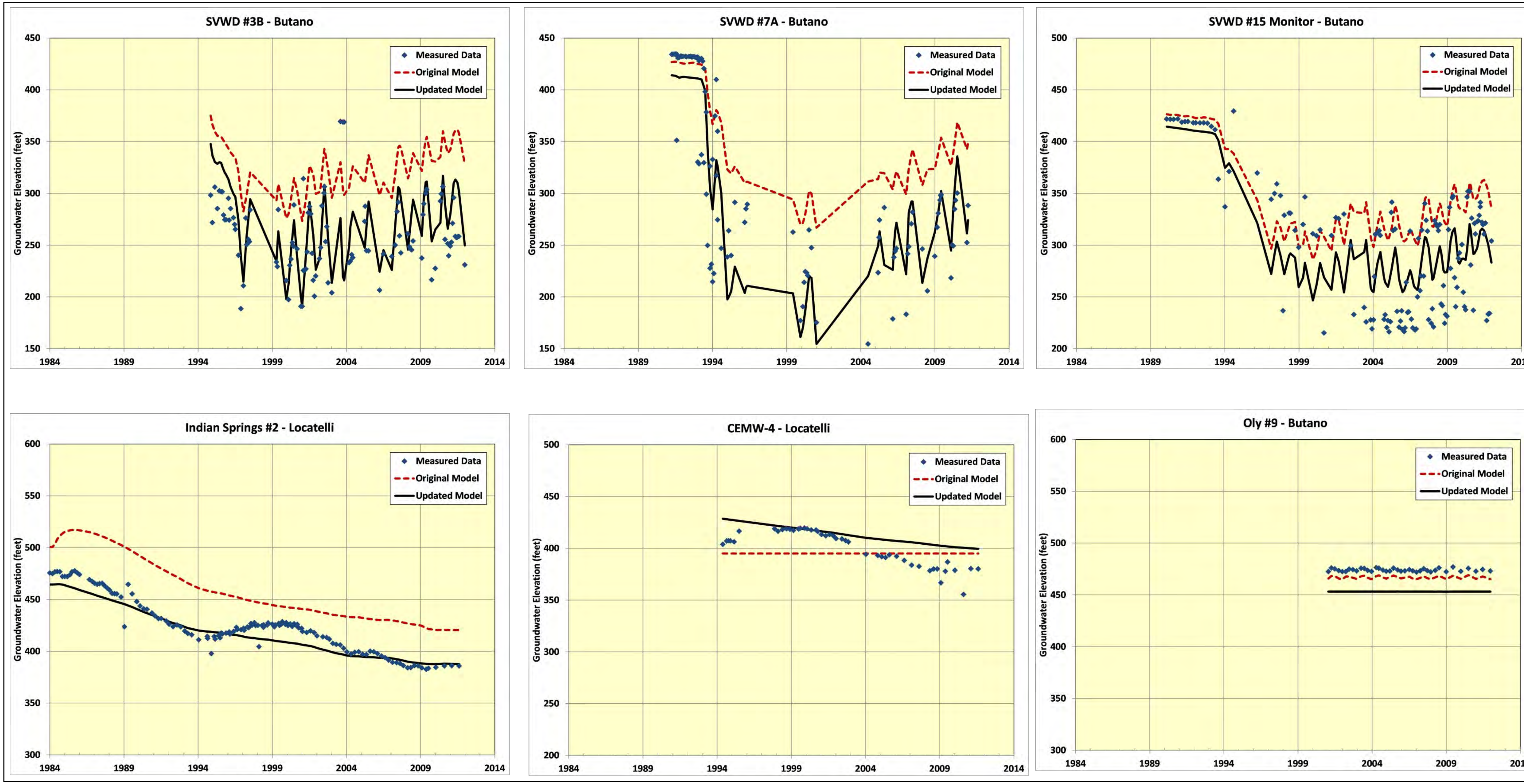
Figure 7-9



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Scotts Valley Water District

Calibration Hydrographs from the Butano and Locatelli in Scotts Valley

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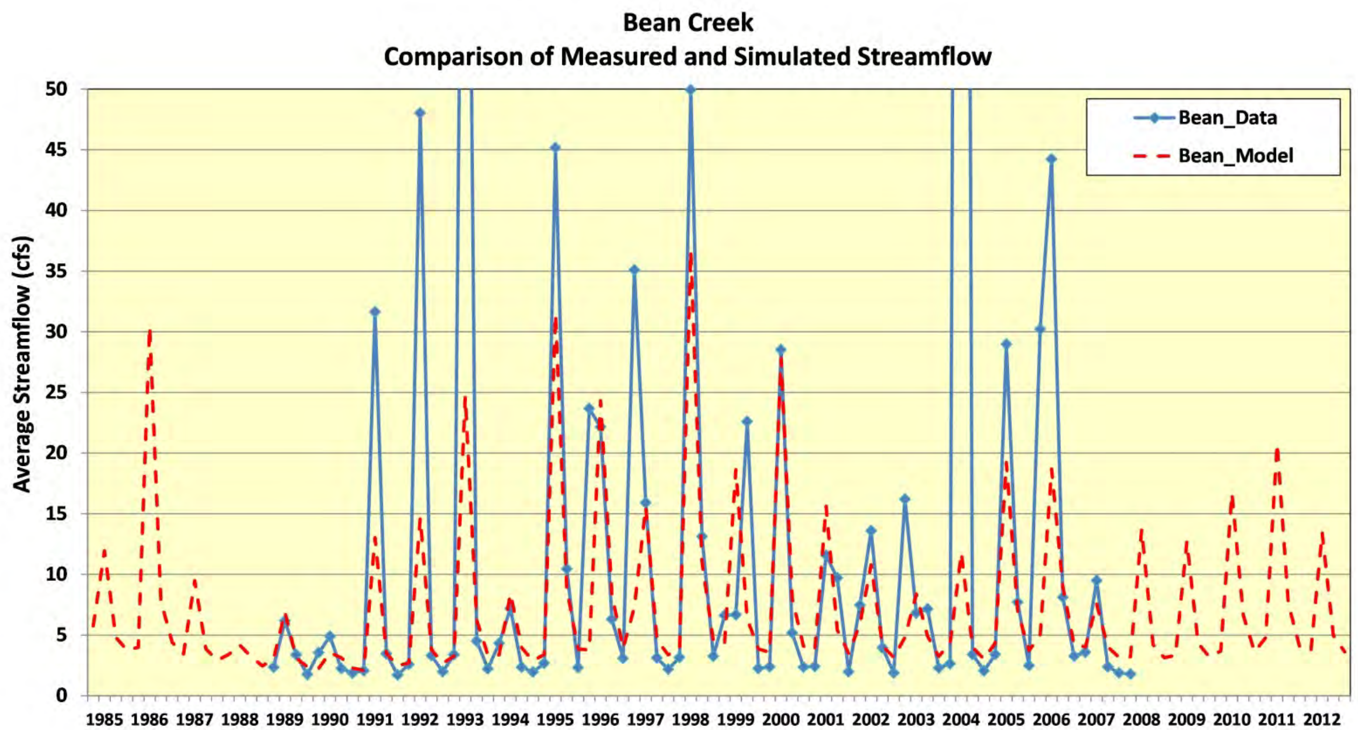
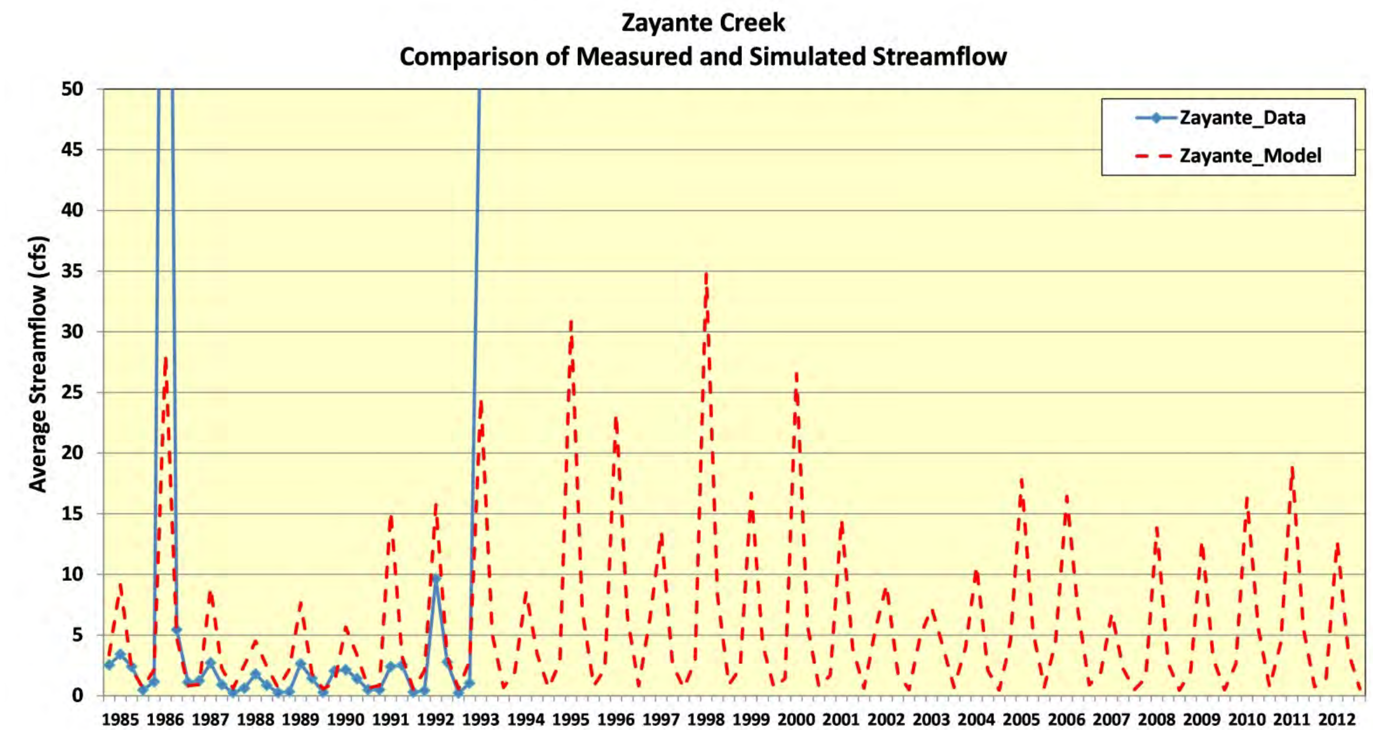
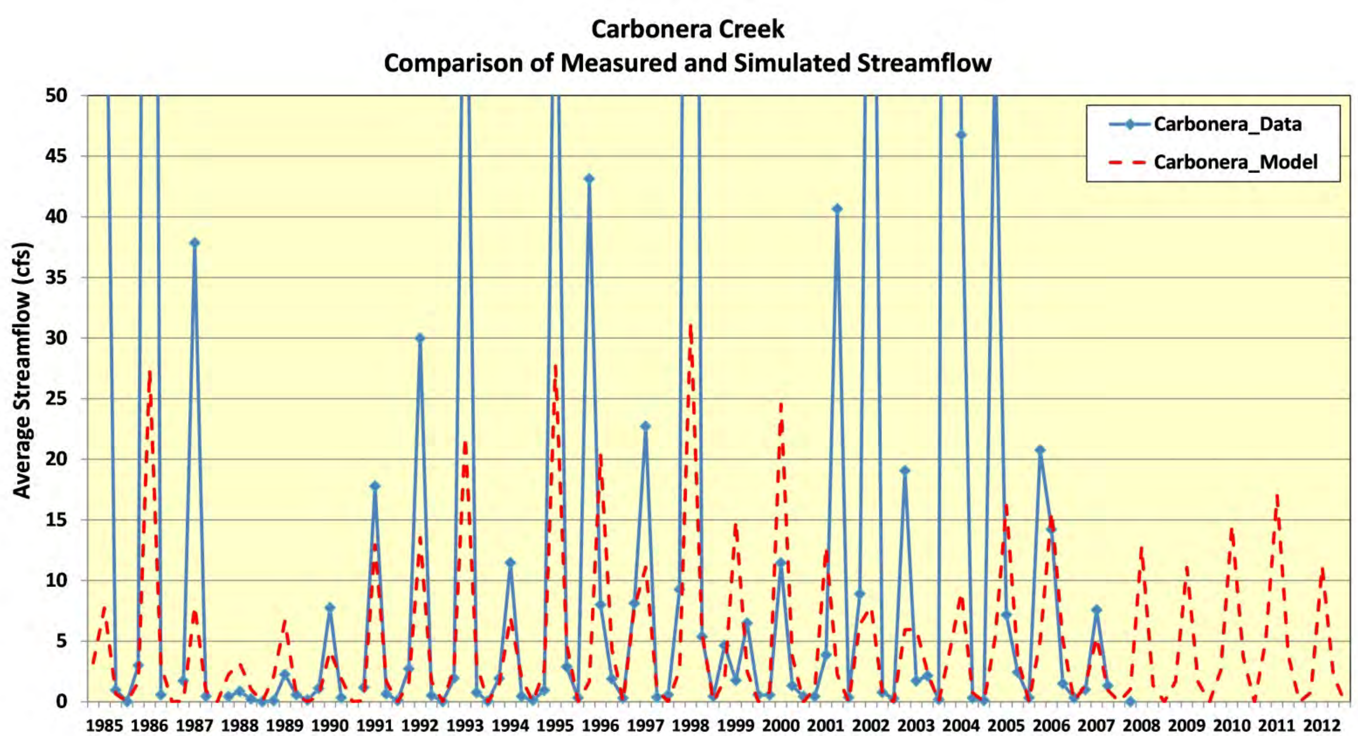
Figure 7-10







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Scotts Valley Water District

Comparison of Measured to Simulated Streamflow

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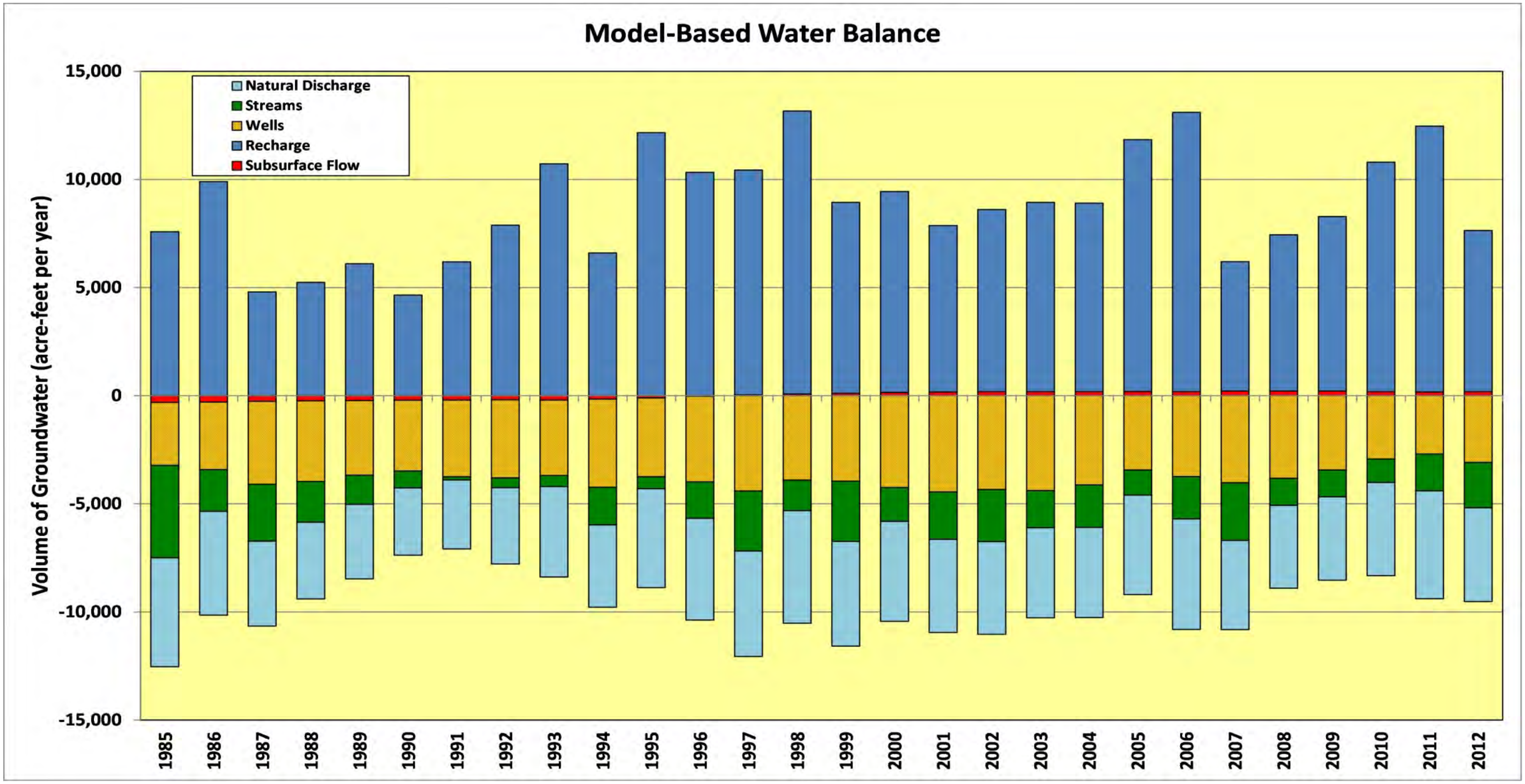
Figure 7-11



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Santa Margarita Basin
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Scotts Valley Water District

Updated SMGB Model Water Balance Summary Graph

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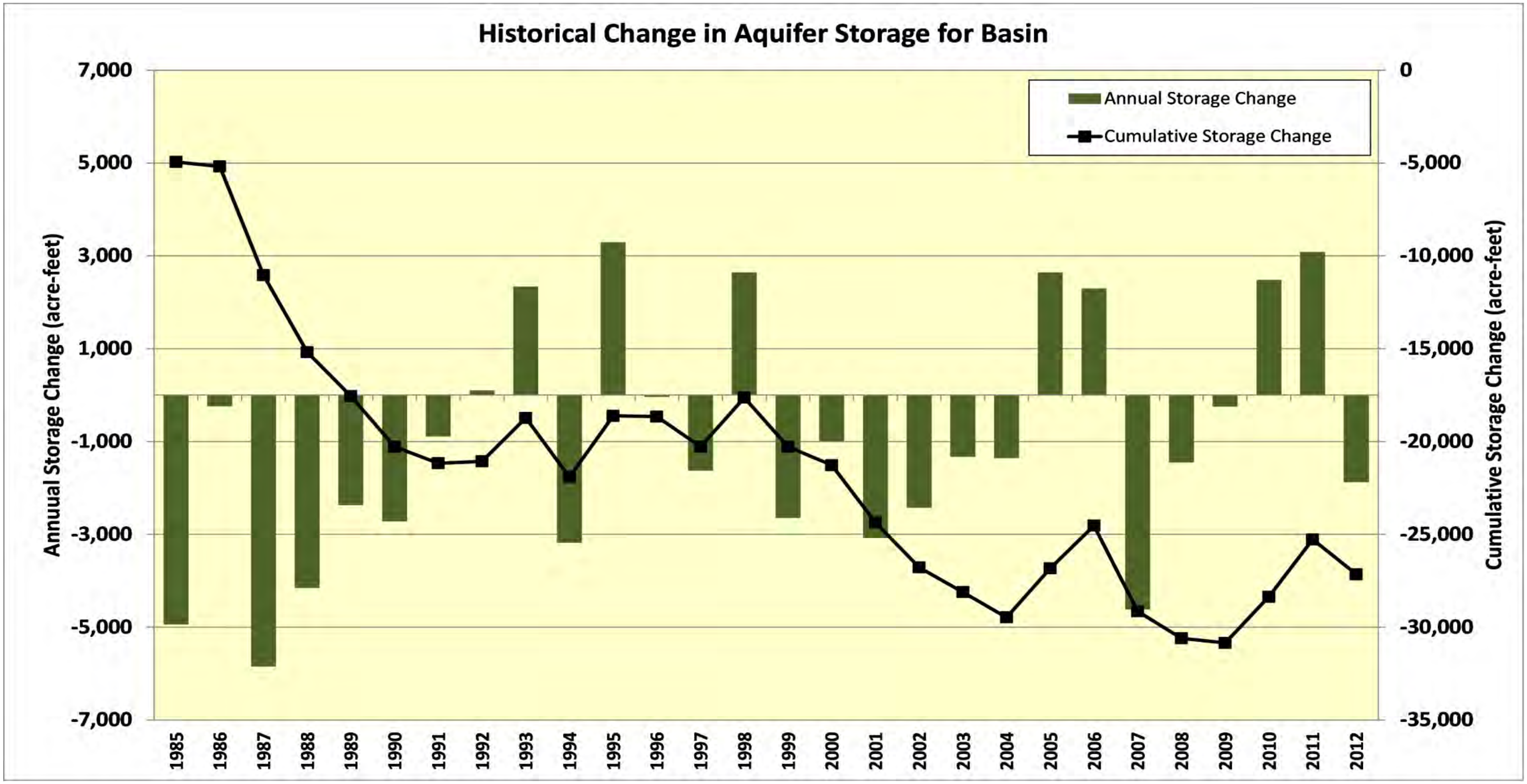
Figure 8-1



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Updated SMGB Model Change in Aquifer Storage Summary Graph

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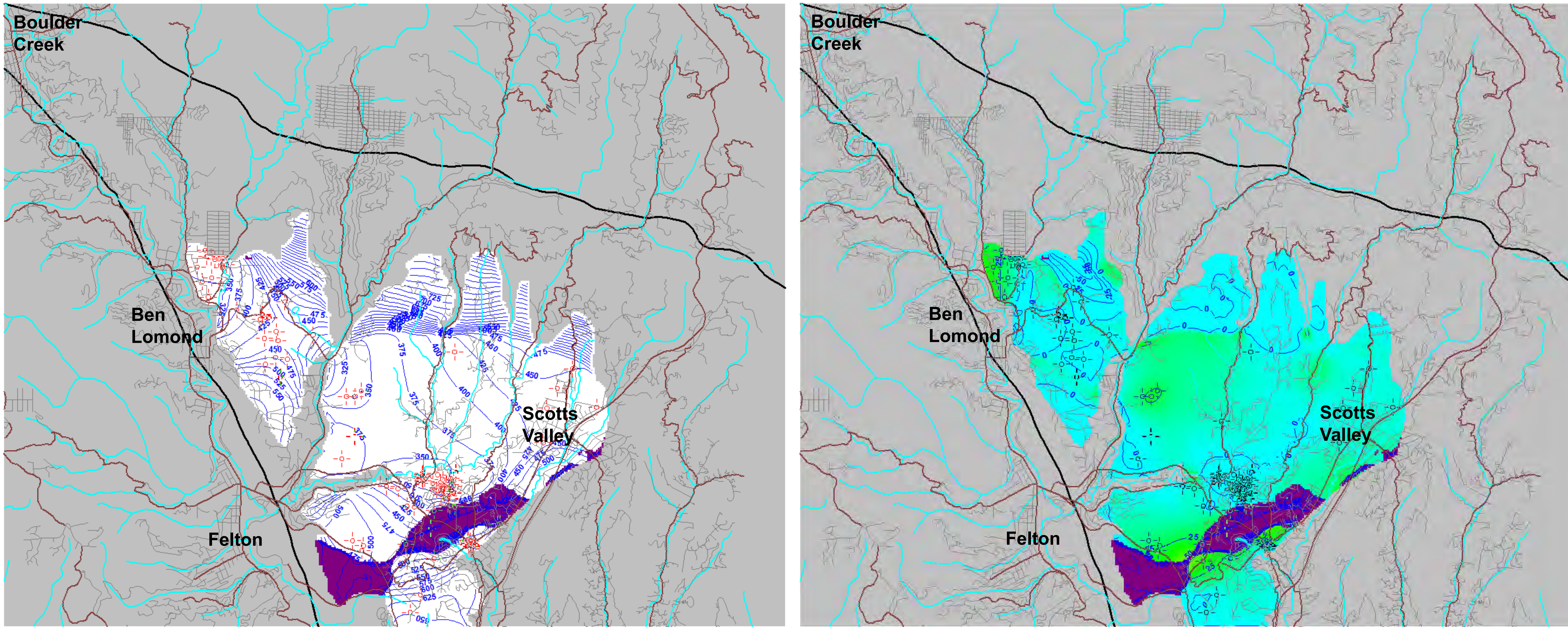
Figure 8-2



Legend

- Aquifer Unsaturated
- Groundwater Elevation Contour
- Groundwater Elevation Well

Drawdown 250.00 – 0.00

0 0.5 1.0 Scale: Mile

N

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Simulated Groundwater Elevations and Drawdown for Model Layer 1 – Santa Margarita Aquifer

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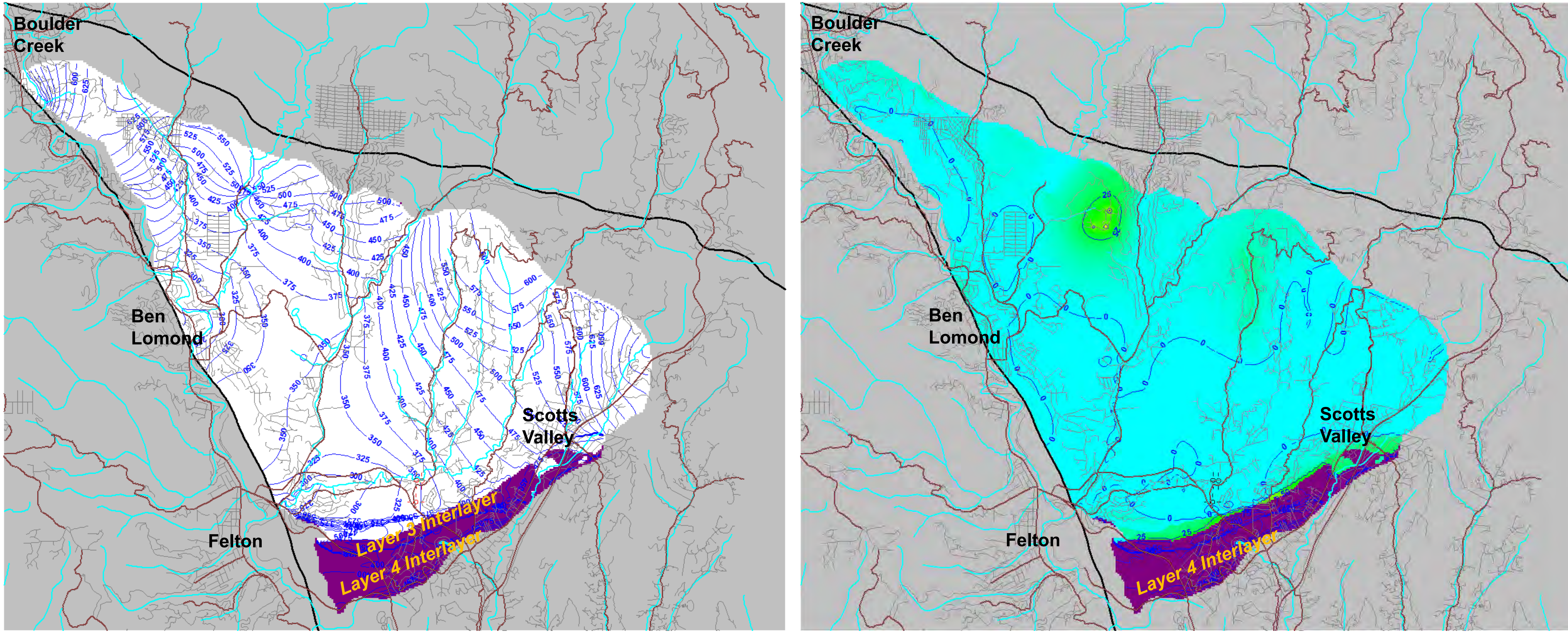
Figure 8-3



Legend

- Aquifer Unsaturated
- Groundwater Elevation Contour
- Groundwater Elevation Well

Drawdown
250.00
0.00

0 0.5 1.0
Scale: Mile

N

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Groundwater Modeling Technical Study
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Simulated Groundwater Elevations and Drawdown for Model Layer 2 – Upper Monterey Aquifer

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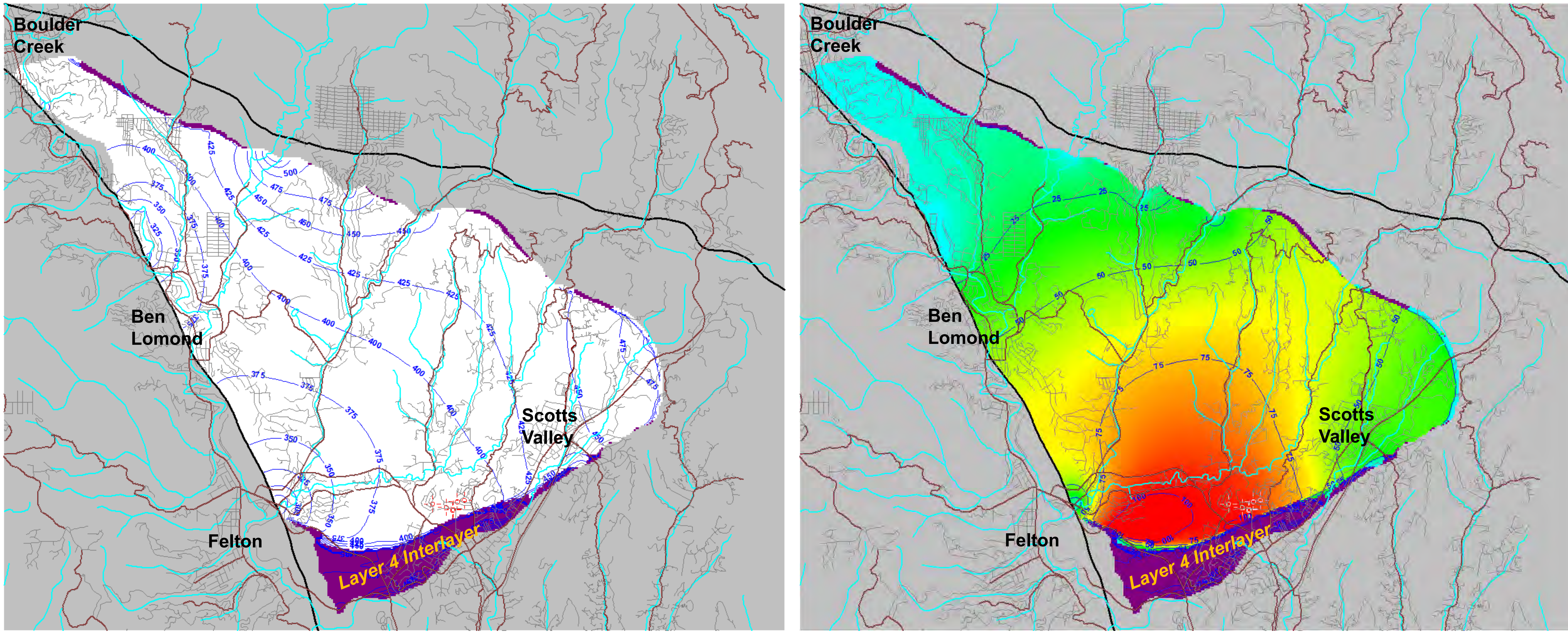
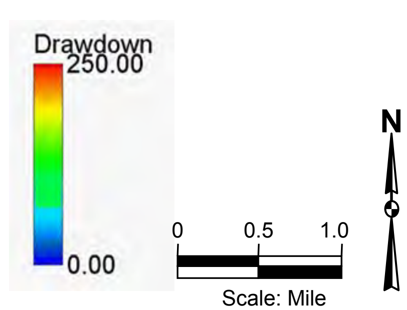
Figure 8-4



Legend

- Aquifer Unsaturated
- Groundwater Elevation Contour
- Groundwater Elevation Well



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Simulated Groundwater Elevations and Drawdown for Model Layer 2 – Lower Monterey Aquifer

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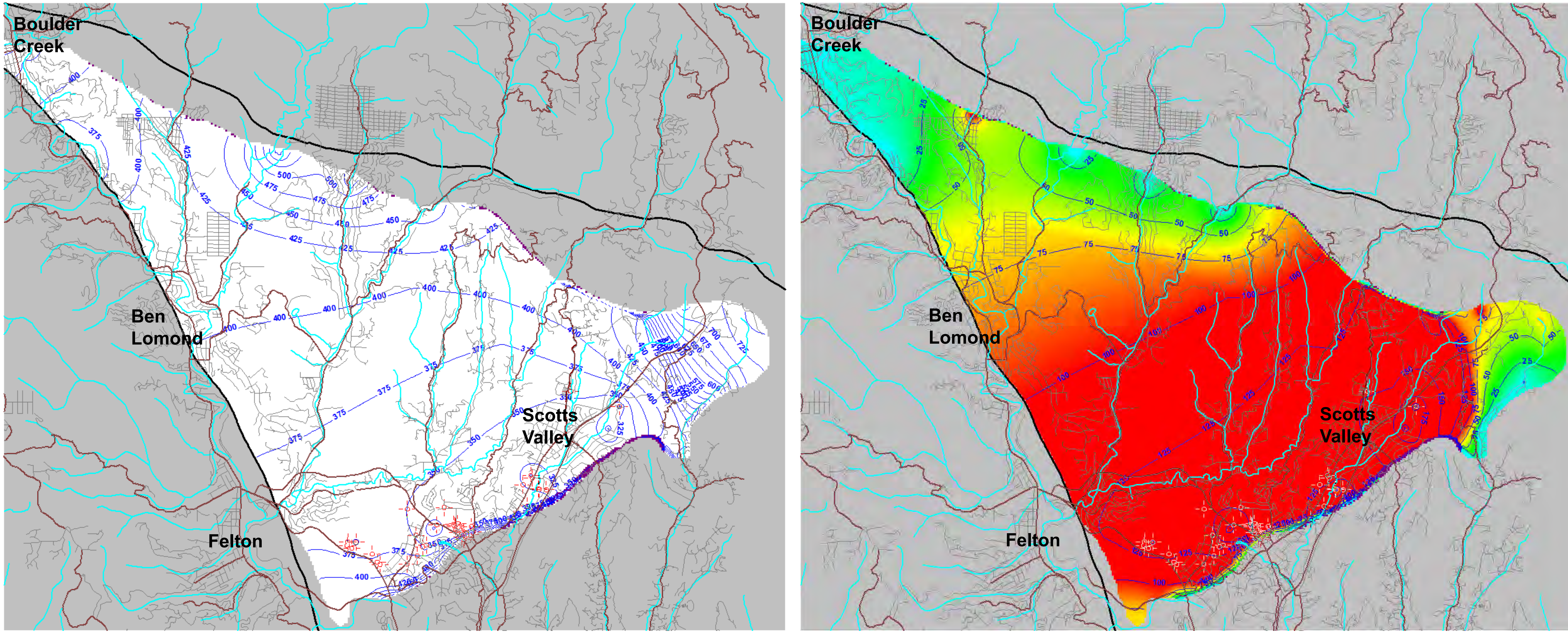
Figure 8-5



Legend

Aquifer Unsaturated

Groundwater Elevation Contour

Groundwater Elevation Well

Drawdown
250.00
0.00

0 0.5 1.0
Scale: Mile

N

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Groundwater Modeling Technical Study
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Simulated Groundwater Elevations and Drawdown for Model Layer 4 – Lompico Aquifer

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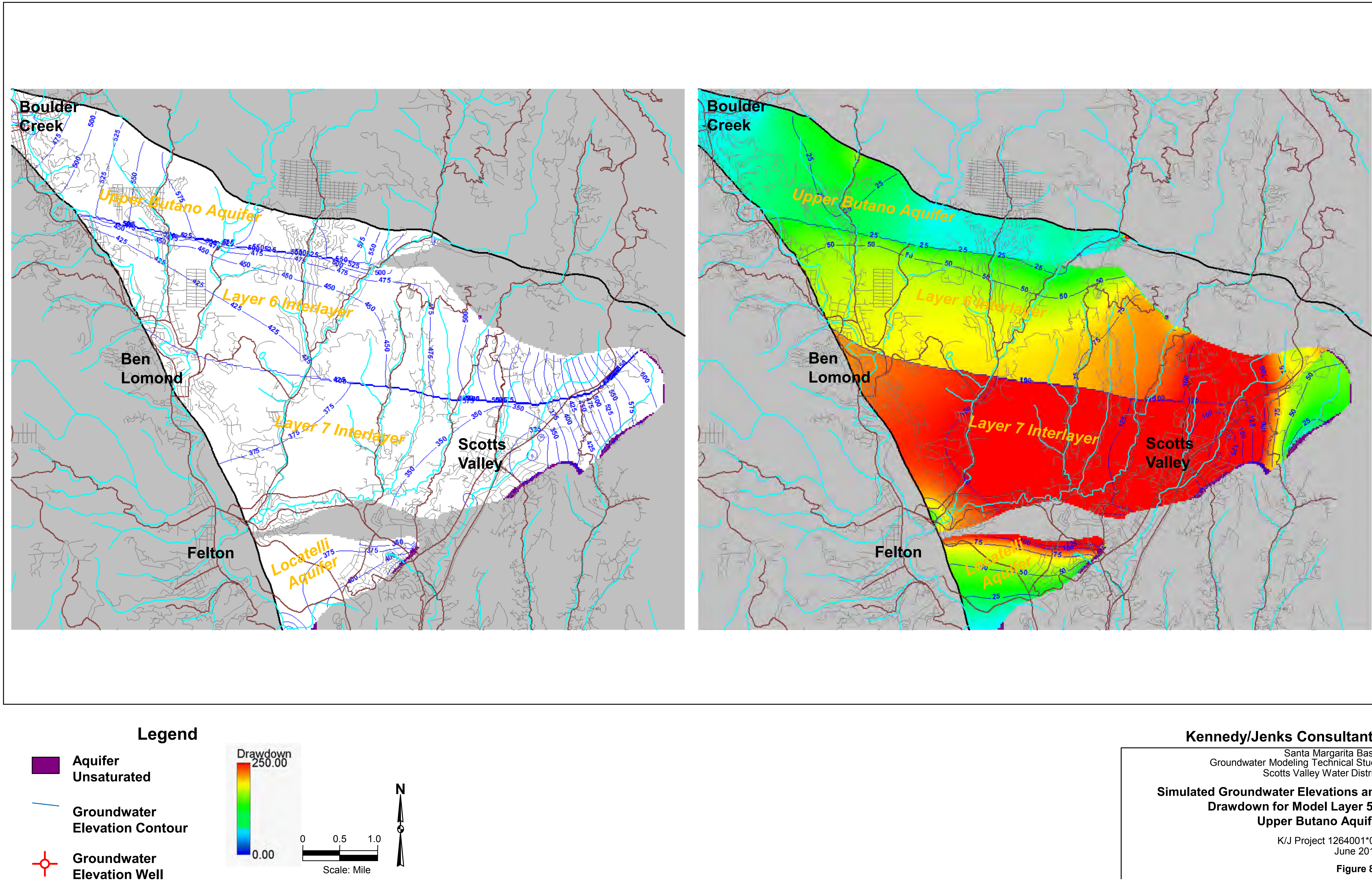
Figure 8-6



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Simulated Groundwater Elevations and Drawdown for Model Layer 5 – Upper Butano Aquifer

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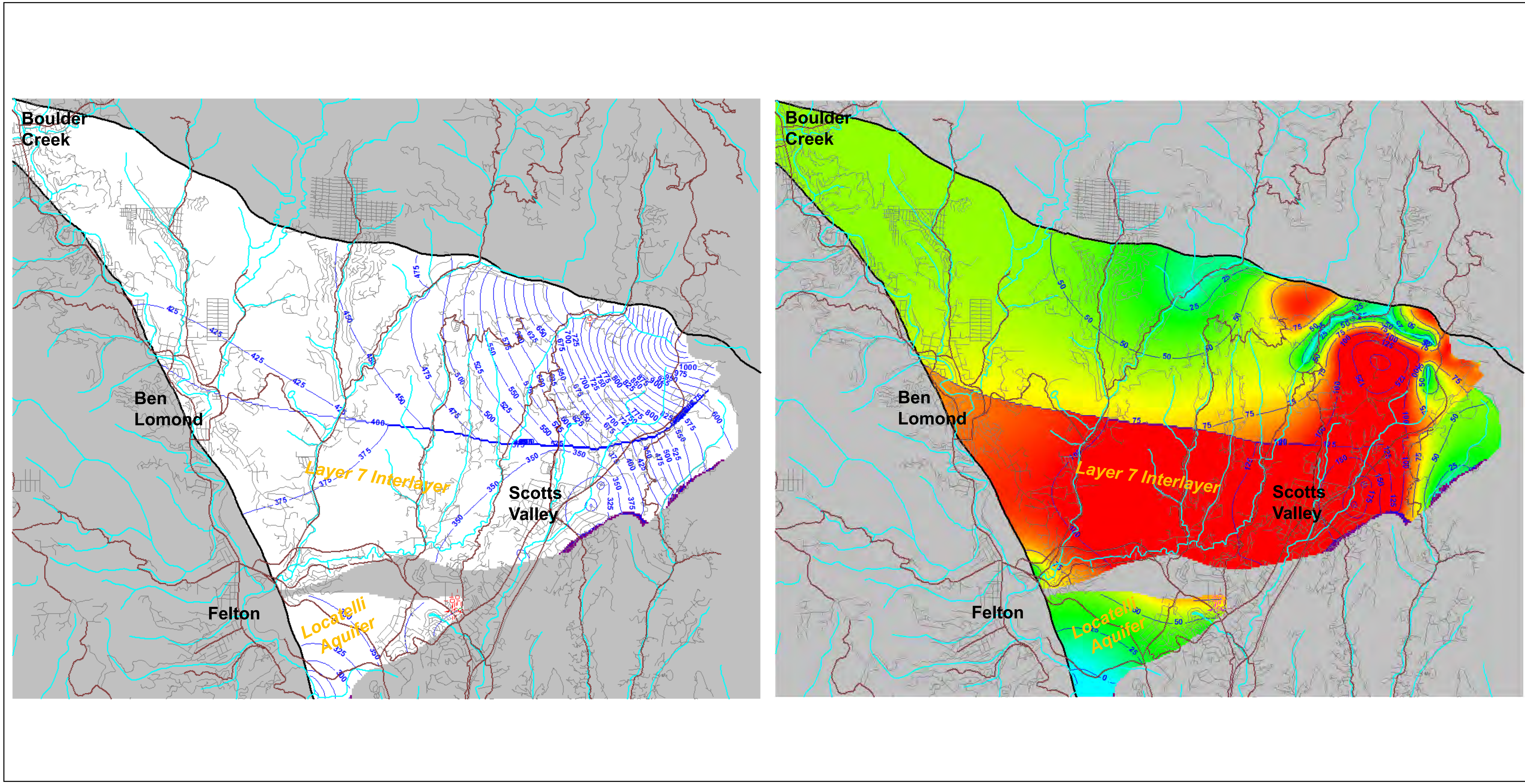
Figure 8-7



Legend

Aquifer Unsaturated

Groundwater Elevation Contour

Groundwater Elevation Well

Drawdown
250.00
0.00

0 0.5 1.0
Scale: Mile

N

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Simulated Groundwater Elevations and Drawdown for Model Layer 6 – Middle Butano Aquifer

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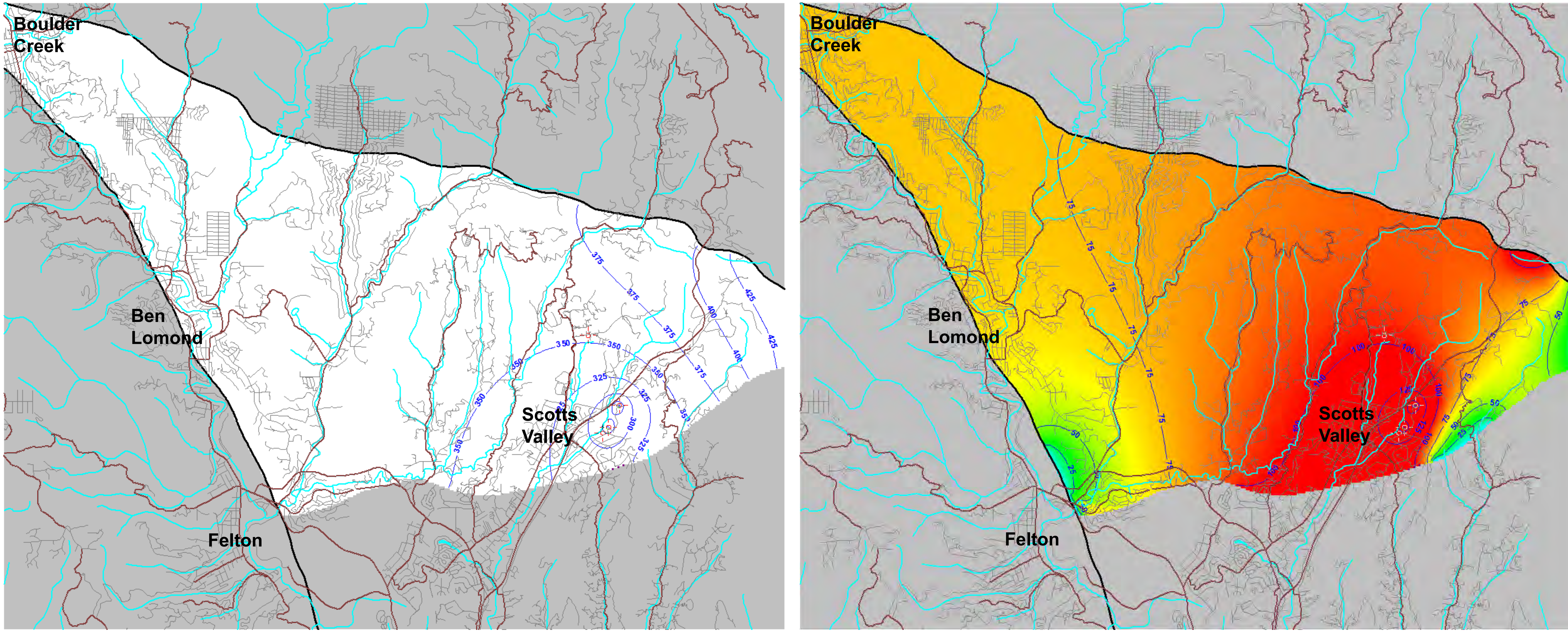
Figure 8-8



Legend

- Aquifer Unsaturated
- Groundwater Elevation Contour
- Groundwater Elevation Well

Drawdown 250.00 – 0.00

Scale: Mile (0, 0.5, 1.0)

N

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Groundwater Modeling Technical Study
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Simulated Groundwater Elevations and Drawdown for Model Layer 7 – Lower Butano Aquifer

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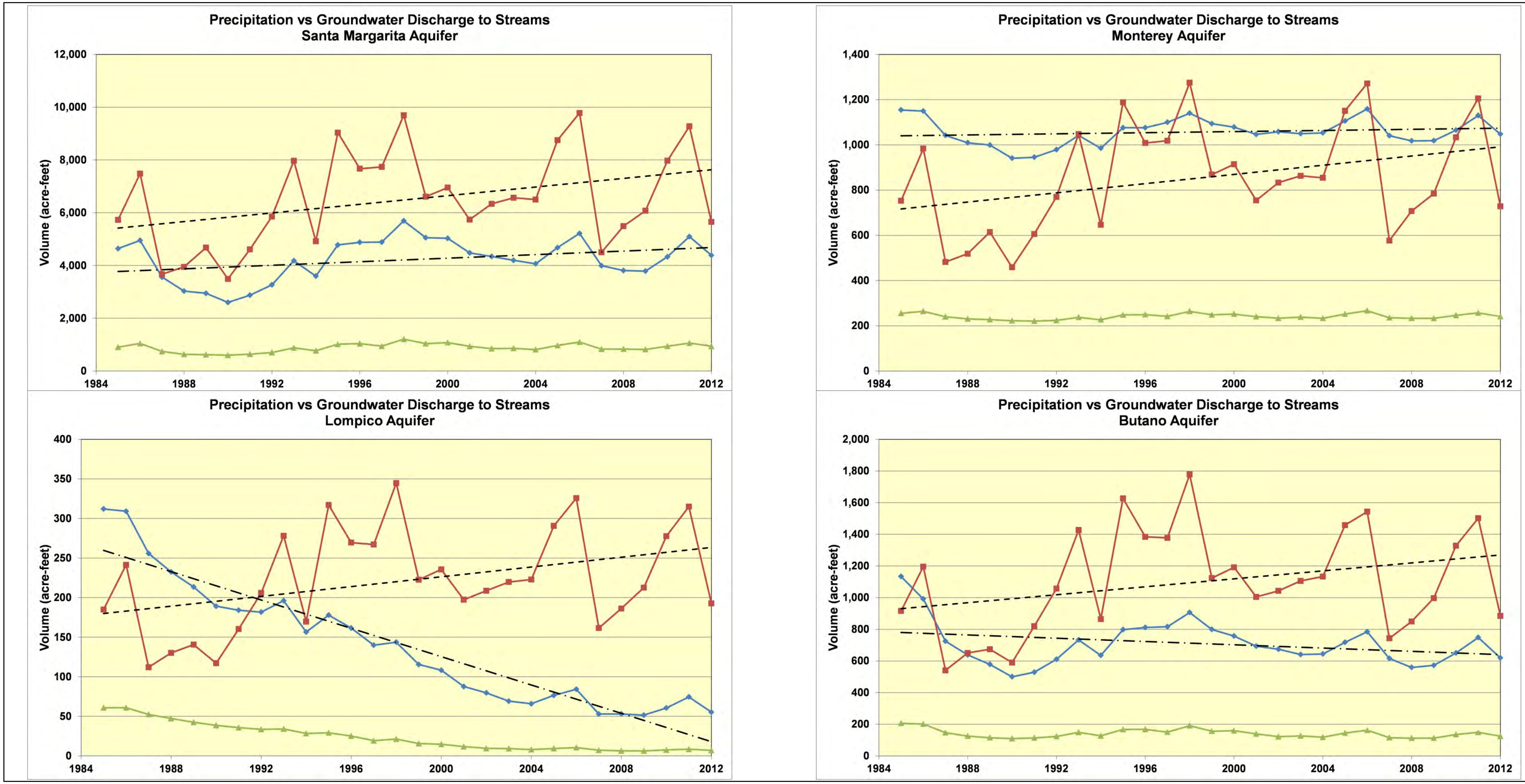
Figure 8-9



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Scotts Valley Water District

Model Results - Annual and Summertime Groundwater Discharge to Streams by Aquifer

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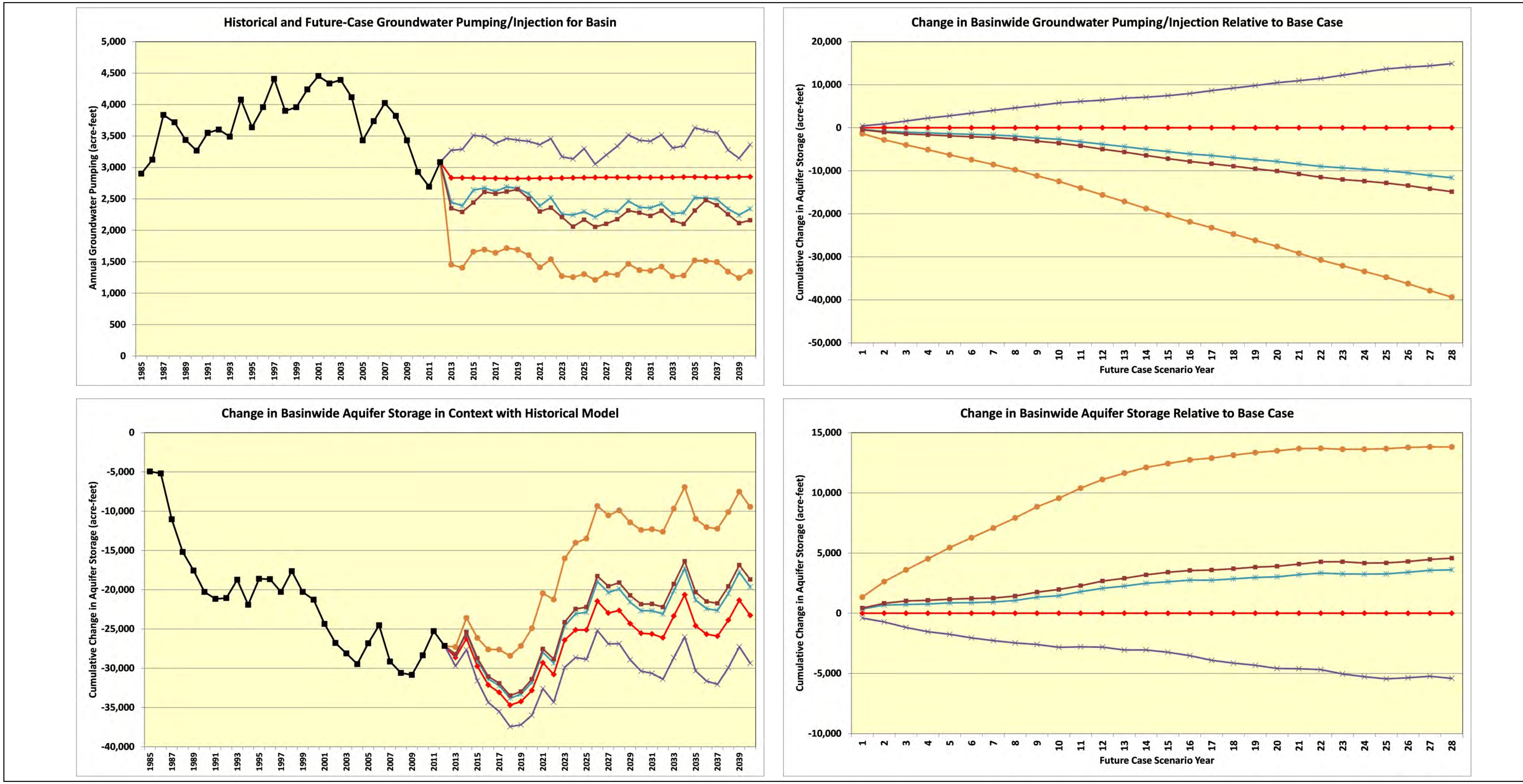
Figure 8-10



Legend

- Base Case
- GW Management #1
- GW Management #2
- Enhanced Recharge #1
- Enhanced Recharge #2
- Calibrated SMGB Model

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Management Scenario Pumping and Aquifer Storage

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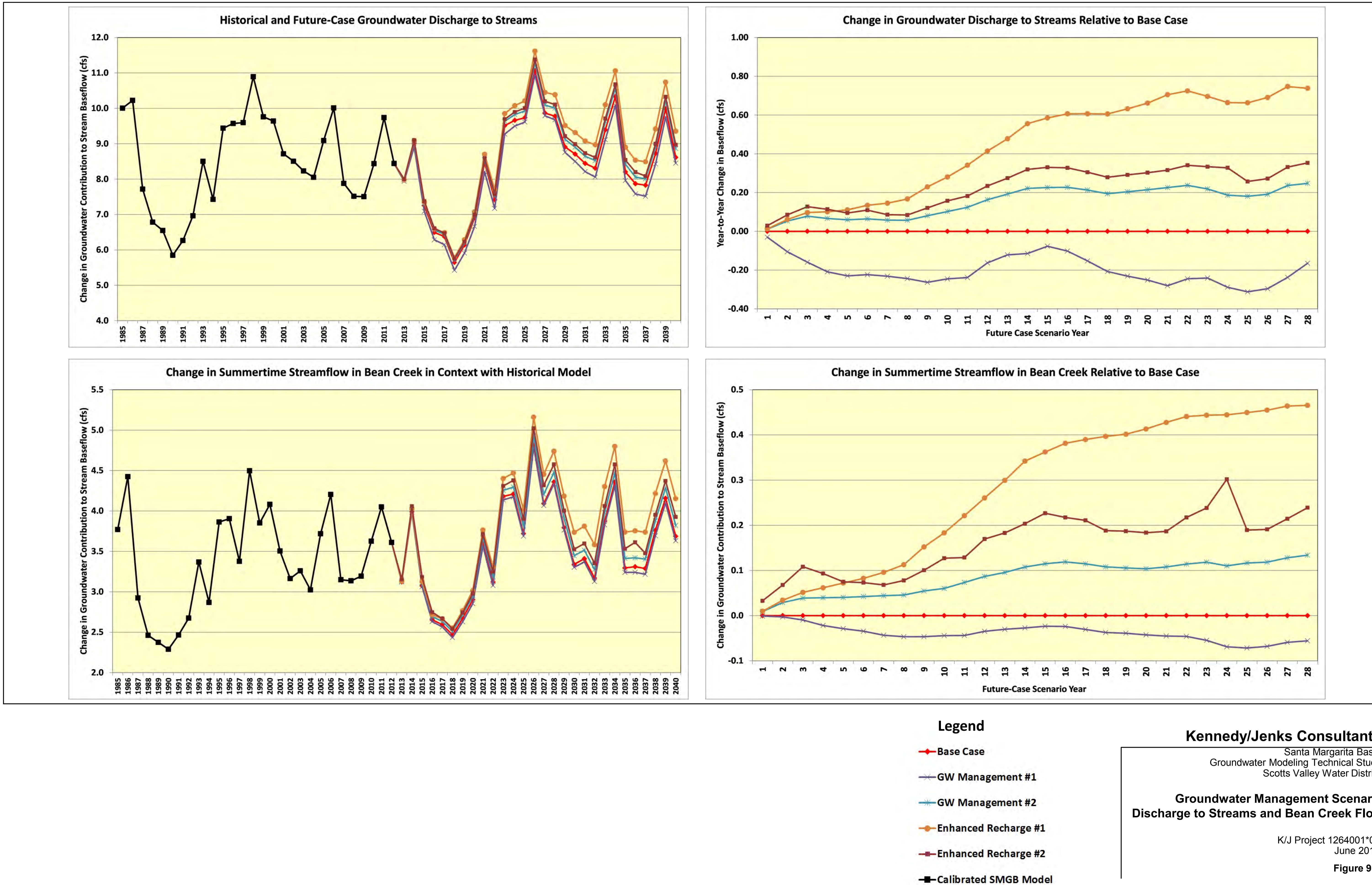
Figure 9-1



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Groundwater Management Scenario Discharge to Streams and Bean Creek Flow

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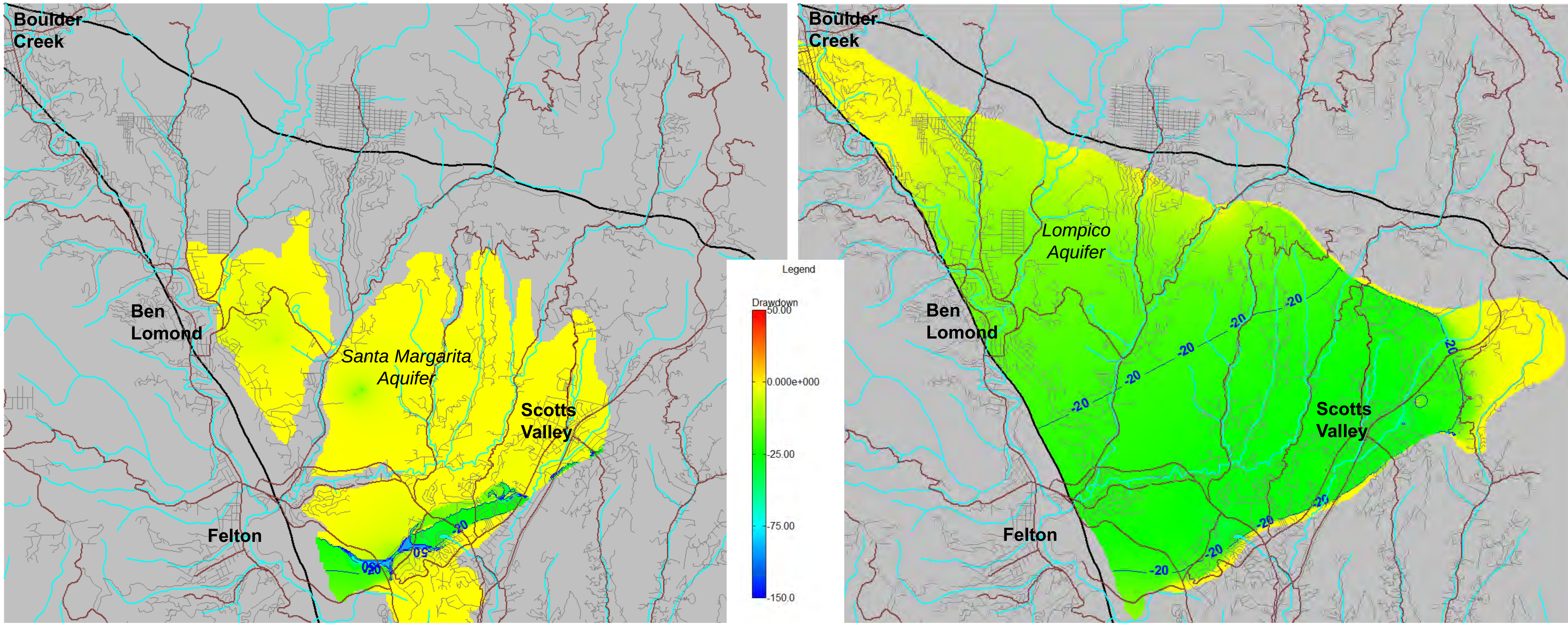
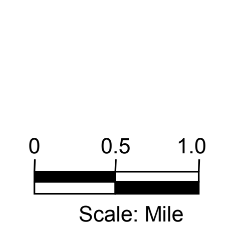
Figure 9-2

Base Case Scenario
Santa Margarita Aquifer
Change in Groundwater Levels Relative to End of Historical Model

Base Case Scenario
Lompico Aquifer
Change in Groundwater Levels Relative to End of Historical Model



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.



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Santa Margarita Basin
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Scotts Valley Water District

Base Case Scenario
Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

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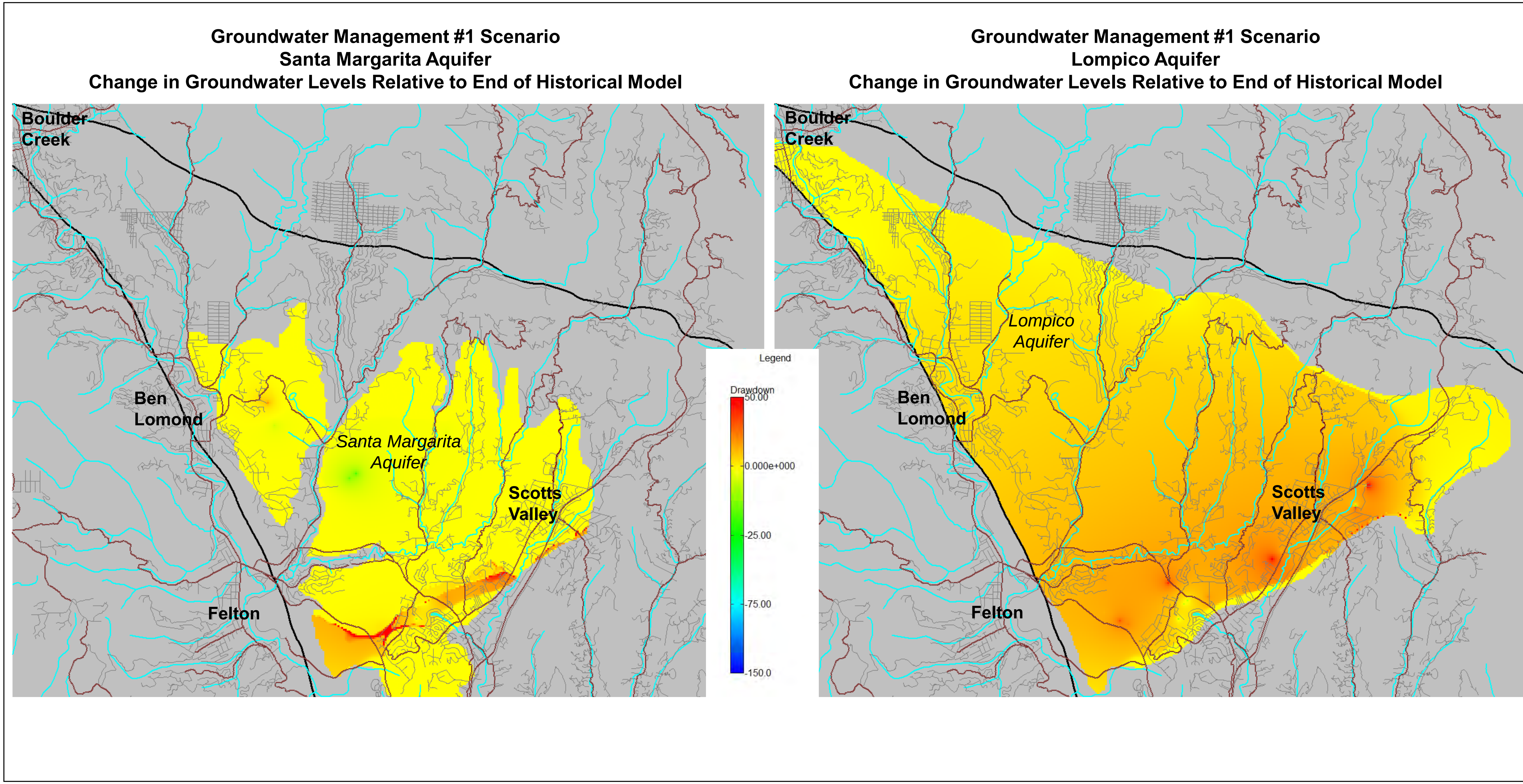
Figure 9-3



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

0 0.5 1.0
Scale: Mile
N

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Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Management #1
Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

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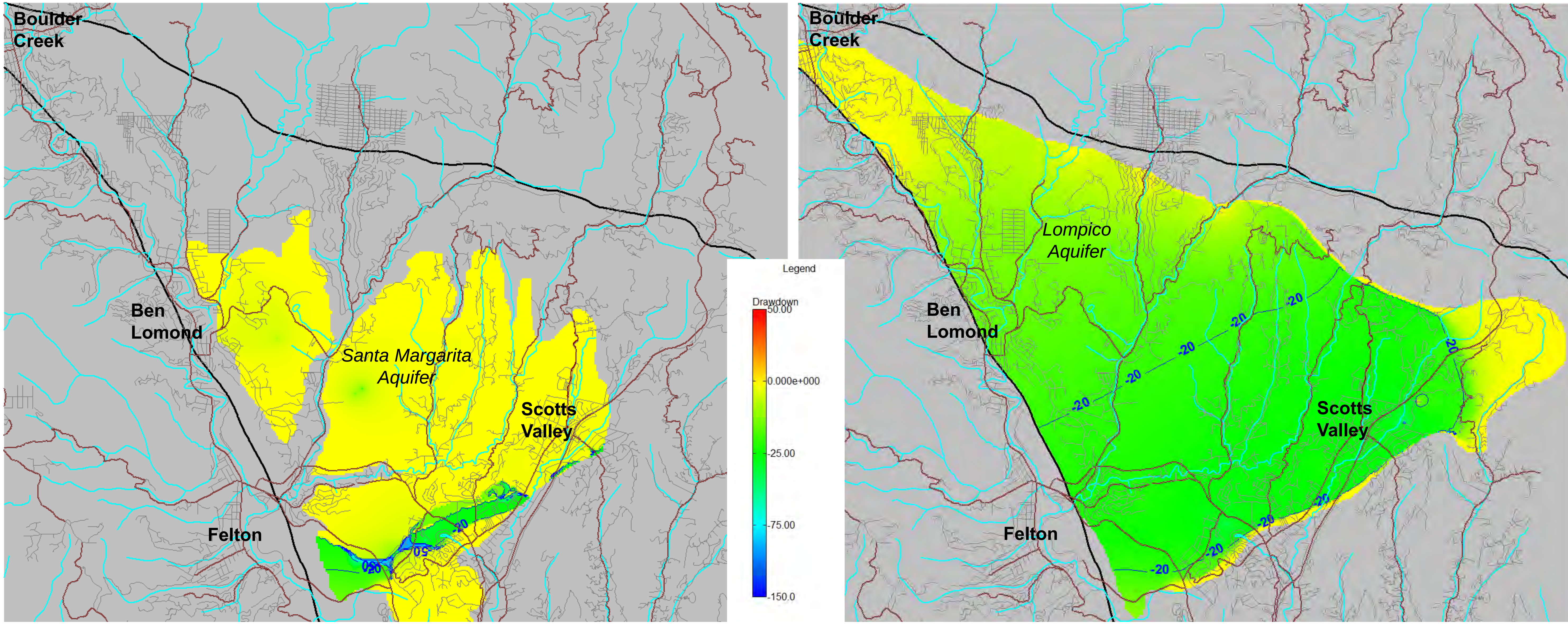
Figure 9-4

Groundwater Management #2 Scenario
Santa Margarita Aquifer
Change in Groundwater Levels Relative to End of Historical Model

Groundwater Management #2 Scenario
Lompico Aquifer
Change in Groundwater Levels Relative to End of Historical Model



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

N

0 0.5 1.0
Scale: Mile

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Groundwater Modeling Technical Study
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Groundwater Management #2 Scenario Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

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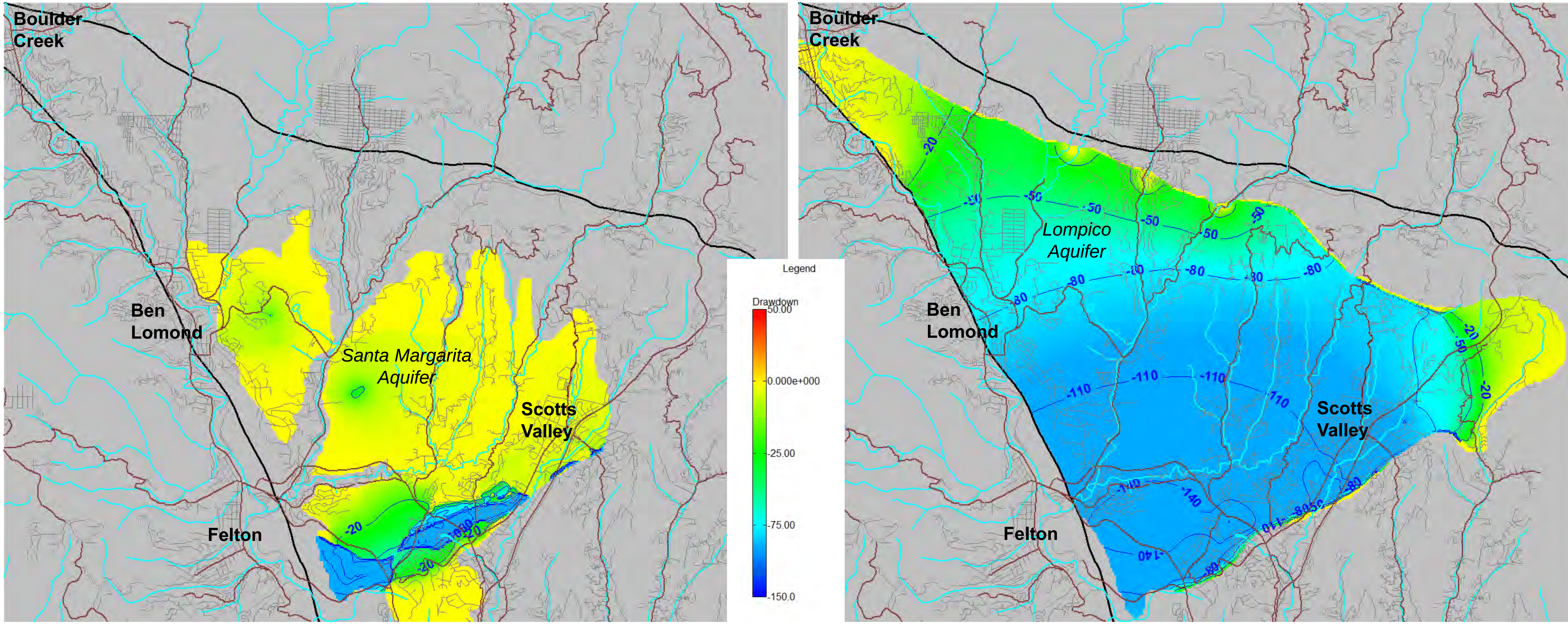
Figure 9-5

Artificial Recharge #1 Scenario
Santa Margarita Aquifer
Change in Groundwater Levels Relative to End of Historical Model

Artificial Recharge #1 Scenario
Lompico Aquifer
Change in Groundwater Levels Relative to End of Historical Model



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

N
0 0.5 1.0
Scale: Mile

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Groundwater Modeling Technical Study
Scotts Valley Water District

Enhanced Recharge #1 Scenario
Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

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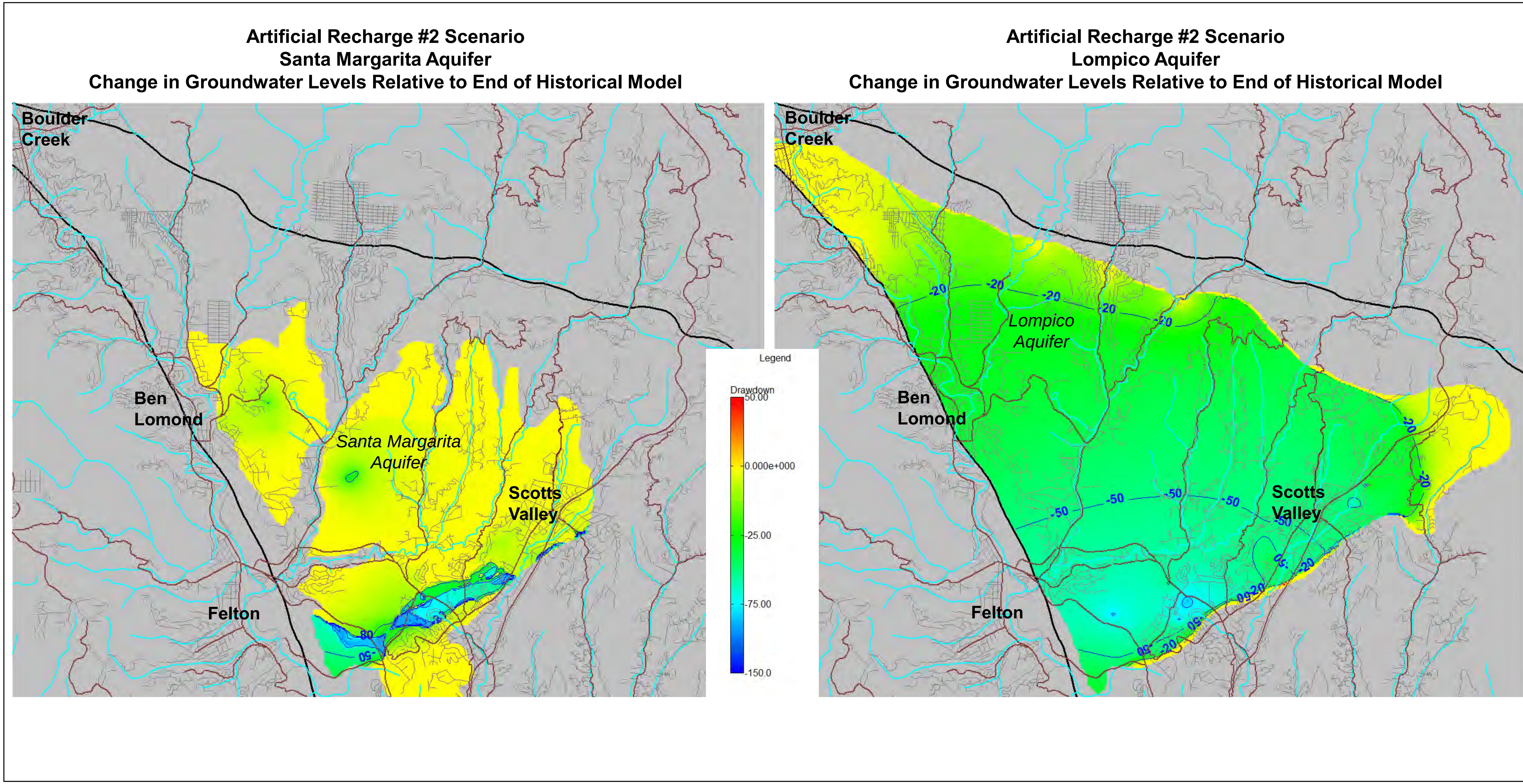
Figure 9-6



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

0 0.5 1.0
Scale: Mile

N

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Enhanced Recharge #2 Scenario Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

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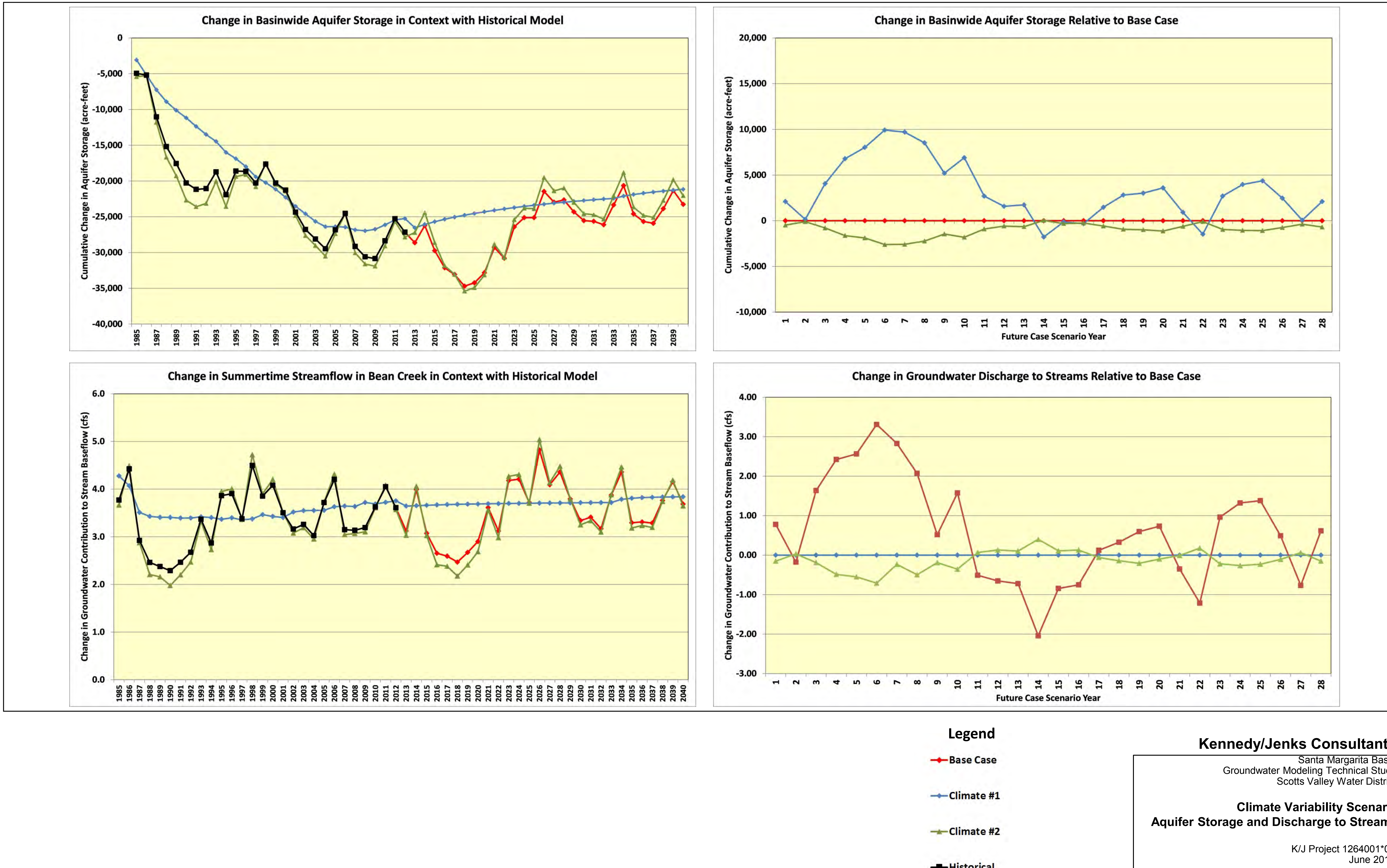
June 2015

Figure 9-7



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Groundwater Modeling Technical Study
Scotts Valley Water District

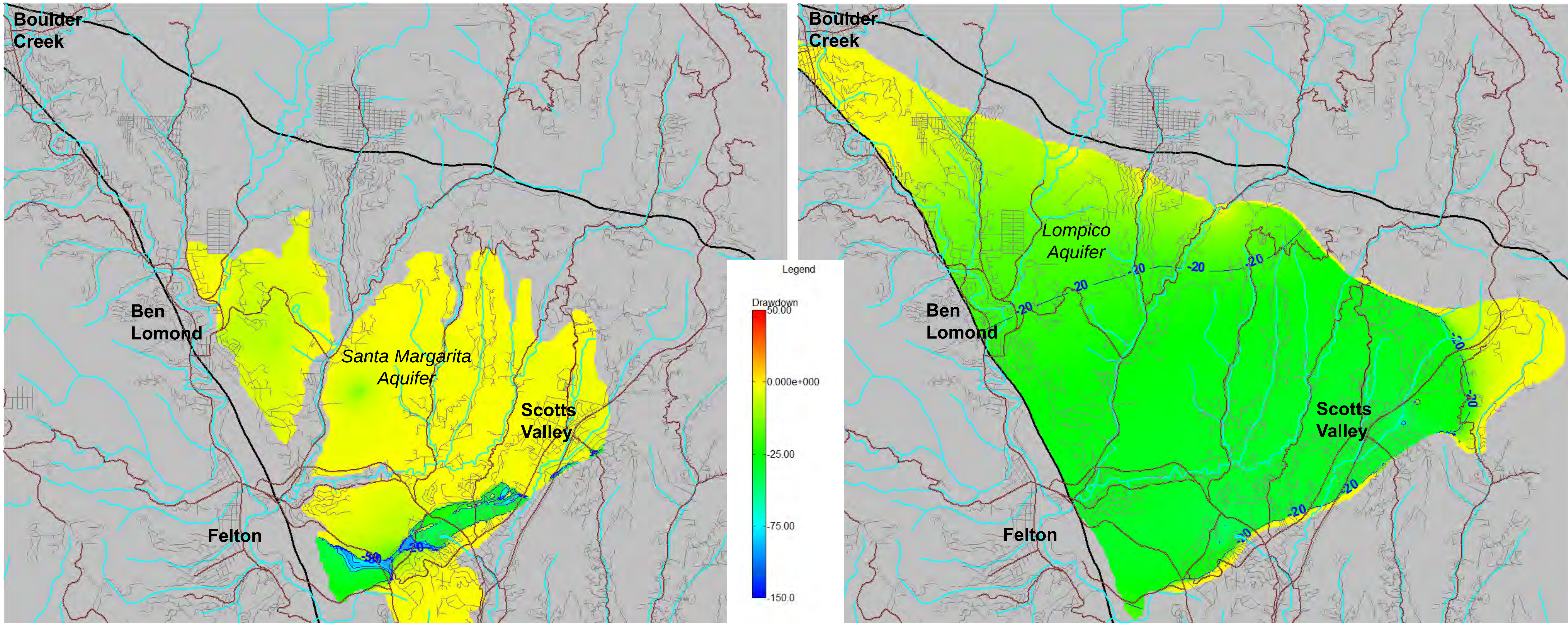
Climate Variability Scenario
Aquifer Storage and Discharge to Streams

K/J Project 1264001*00
June 2015

Figure 9-8

Climate Variability #1 Scenario
Santa Margarita Aquifer
Change in Groundwater Levels Relative to End of Historical Model

Climate Variability #1 Scenario
Lompico Aquifer
Change in Groundwater Levels Relative to End of Historical Model



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

N

0 0.5 1.0

Scale: Mile

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Groundwater Modeling Technical Study
Scotts Valley Water District

Climate Variability #1 Scenario Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

K/J Project 1264001*00
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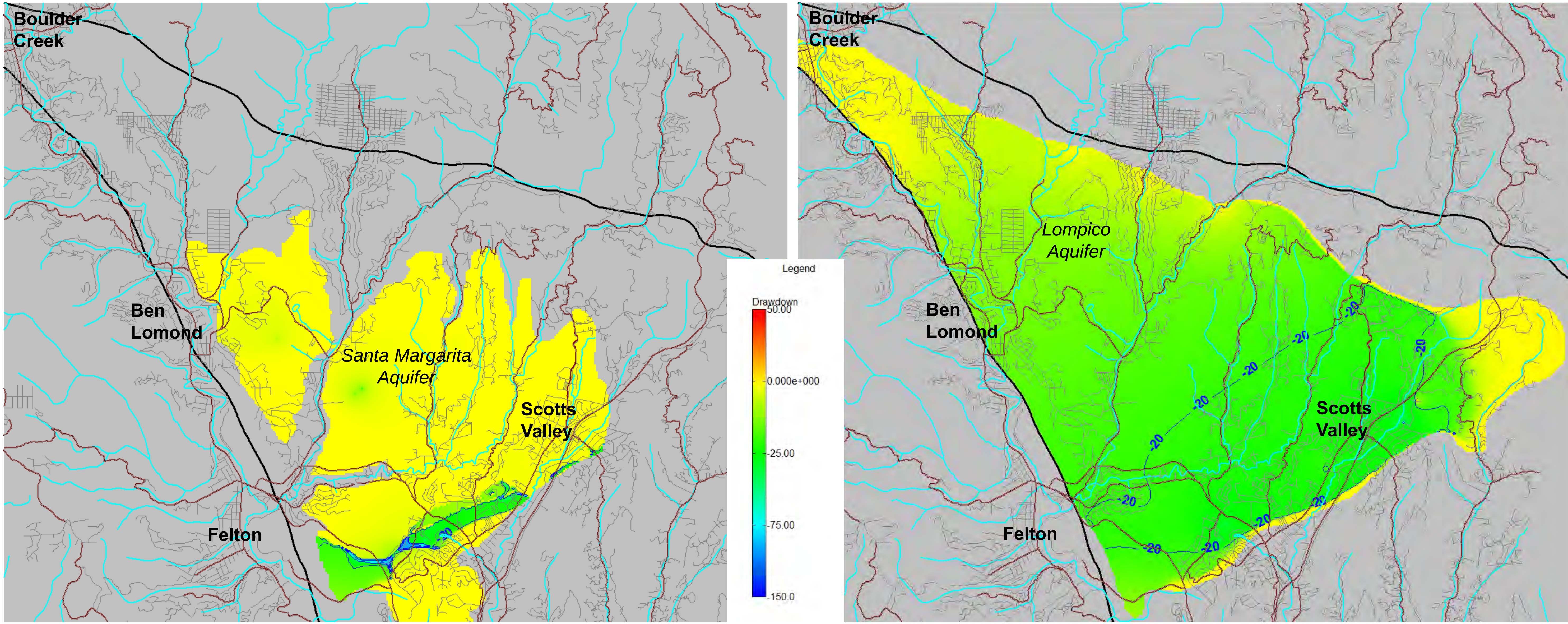
Figure 9-9

Climate Variability #2 Scenario
Santa Margarita Aquifer
Change in Groundwater Levels Relative to End of Historical Model

Climate Variability #2 Scenario
Lompico Aquifer
Change in Groundwater Levels Relative to End of Historical Model



NOTE: Maps show Drawdown; therefore, a positive number is a decrease in groundwater elevation Whereas a negative number is an increase in groundwater elevation.

N

0 0.5 1.0
Scale: Mile

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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Climate Variability #2 Scenario
Change in Groundwater Levels for Santa Margarita and Lompico Aquifers

K/J Project 1264001*00
June 2015

Figure 9-10

Appendix A: Summary of Annual Groundwater Pumping in the SMGB from 1976 to 2012

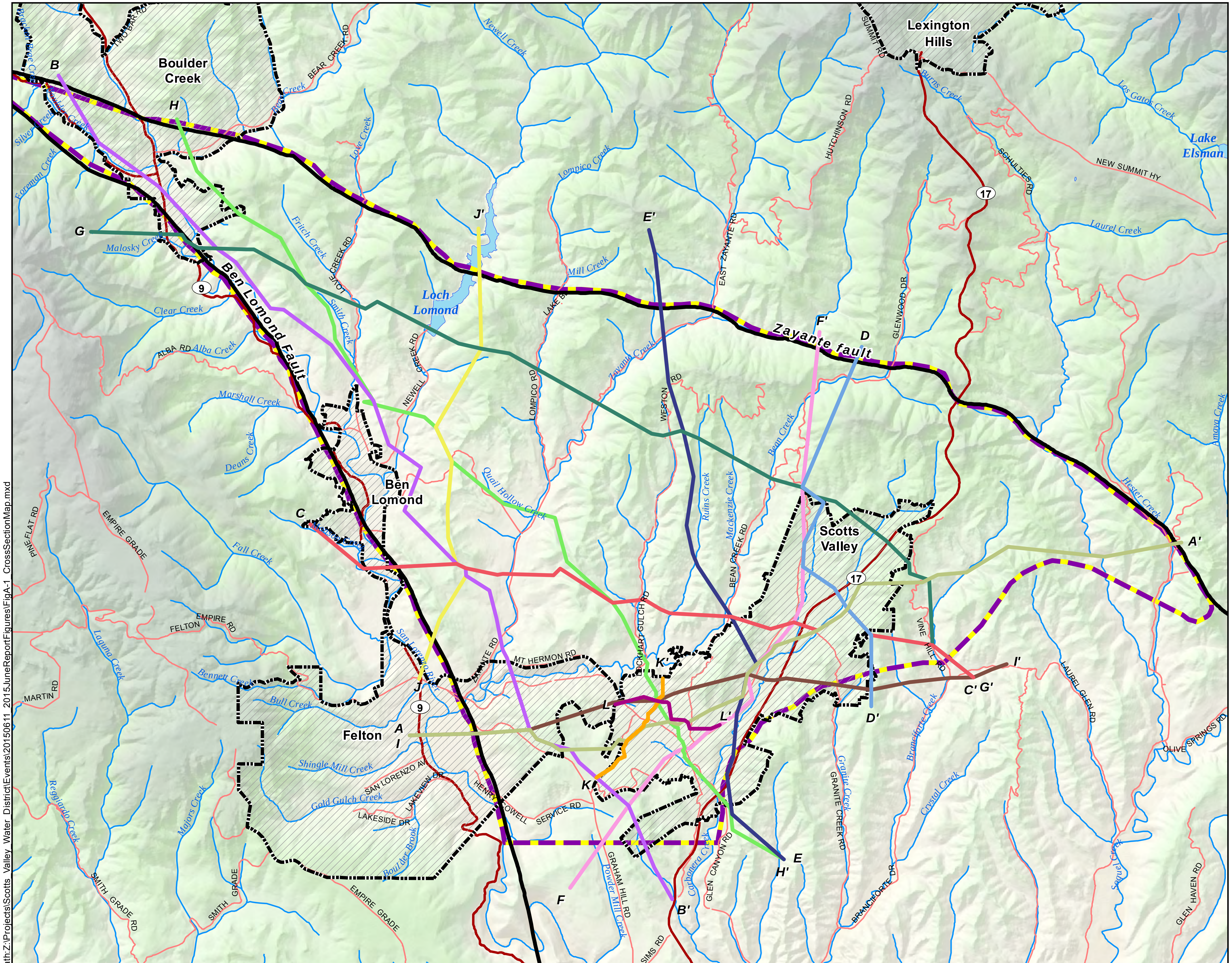
APPENDIX A: Summary of Annual Groundwater Pumping in the SMGB from 1976 to 2012

Name	SUBAREA	AQUIFER	Type	WY1976	WY1977	WY1978	WY1979	WY1980	WY1981	WY1982	WY1983	WY1984	WY1985	WY1986	WY1987	WY1988	WY1989	WY1990	WY1991	WY1992	WY1993	WY1994	WY1995	WY1996	WY1997	WY1998	WY1999	WY2000	WY2001	WY2002	WY2003	WY2004
#10BUSINESSMENS	SV	Lompico	SVWD	0	0	0	0	0	0	140	28	0	107	425	349	397	398	586	545	477	489	364	140	387	448	365	343	263	221	374	405	331
#11A	SV	Lompico	SVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	152	46	68	53	54	102
#11B	SV	Lompico	SVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	241	535	498	684	606
#11LOMPICO	SV	Lompico	SVWD	0	0	0	0	0	0	0	0	0	0	0	327	444	534	558	660	810	788	844	468	320	230	228	134	132	0	0	0	0
#3AELPUEBLO	SV	Lompico	SVWD	0	0	86	0	0	0	0	0	94	190	140	150	15	15	2	3	9	4	0	0	0	0	0	0	0	0	0	0	0
#3BSVWD	SV	Butano	SVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	239	223	213	341	315	203	218	285
#3ELPUEBLO	SV	Lompico	SVWD	470	503	112	72	261	267	188	87	106	60	74	15	33	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#6SVWD	SV	Lompico	SVWD	0	0	172	160	157	10	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
#7ASVWD	SV	Butano	SVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	326	673	989	986	875	916	848	757	770	630	603
#7ELPUEBLO	SV	Lompico	SVWD	0	0	90	304	309	249	231	274	325	138	211	128	84	154	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0
#9CITYHALL	SV	Monterey	SVWD	0	0	0	0	0	125	219	407	426	424	293	246	341	225	183	206	162	214	207	252	129	148	129	118	77	111	122	85	44
HIDDENOAKS	SV	Lompico	SVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	10	28	32	2	0	0	0	0	0	0	0	0	0	0
ChampionP#4	PT	Santa Margarita	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EstrellaP#3	PT	Lompico	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	15	26	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Manana#2	SV	Lompico	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	70	70	70	70	70	70	70	70	70	70	70	73	65	68	66	59
NewProbationP#5	PT	Santa Margarita	SLVWD	100	110	120	130	160	160	160	160	169	192	179	224	179	171	140	116	36	10	16	9	0	0	0	1	0	0	0	0	0
OldProbationP#1	PT	Santa Margarita	SLVWD	10	10	10	10	10	10	10	10	1	13	35	0	20	66	118	67	0	0	0	0	0	0	0	0	0	0	0	0	0
OlympiaNo.1	BL	Santa Margarita	SLVWD	0	0	0	0	0	0	0	0	23	47	56	60	69	41	21	31	3	1	2	1	0	0	0	0	0	0	0	0	0
OlympiaNo.2	BL	Santa Margarita	SLVWD	0	0	0	0	0	0	0	0	219	165	115	361	334	304	348	363	356	202	347	267	199	304	179	245	226	274	263	266	273
OlympiaNo.3	BL	Santa Margarita	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	106	105	133	149	15	145	125	14	22	215	233	178	157	203
Pasatiempo6	PT	Lompico	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	4	31	40	95	111	167	183	204	224	183	230	229	289
Pasatiempo7	PT	Lompico	SLVWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	259	268	252	271	274	263	152	201	209	264	203	207	138
QuailHollow3	BL	Santa Margarita	SLVWD	83	88	61	61	68	54	62	24	86	88	64	70	90	65	50	32	16	26	53	13	0	0	0	0	0	0	0	0	0
QuailHollow4	BL	Santa Margarita	SLVWD	132	183	133	152	205	113	55	64	188	183	239	239	280	175	150	223	169	123	151	107	125	110	105	122	109	57	159	176	210
QuailHollow5/QuailHollow	BL	Santa Margarita	SLVWD	99	120	93	87	103	47	59	47	140	120	105	155	130	91	64	89	57	39	87	41	55	76	31	1	37	157	123	154	158
QuailHollow7/QuailHollow	BL	Santa Margarita	SLVWD	13	28	14	8	66	28	1	21	22	28	11	31	45	17	2	3	18	0	0	0	0	0	0	0	0	0	0	0	0
CEEW-1	SV	Lompico	Remediation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	17
WatkinsJohnsonRA-1	SV	Santa Margarita	Remediation	0	0	0	0	0	0	0	0	0	0	0	96	90	95	87	72	60	48	44	53	54	57	56	31	38	38	18	0	0
WatkinsJohnsonRA-2	SV	Santa Margarita	Remediation	0	0	0	0	0	0	0	0	0	0	0	133	120	126	122	102	85	68	59	70	76	77	74	45	53	54	86	100	137
WatkinsJohnsonRA-3	SV	Santa Margarita	Remediation	0	0	0	0	0	0	0	0	0	0	0	177	156	173	155	126	105	84	80	97	96	104	102	55	66	67	31	0	0
WatkinsJohnsonRA-4	SV	Santa Margarita	Remediation	0	0	0	0	0	0	0	0	0	0	0	59	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MHA#1	SV	Lompico	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	51	63	60	72	77	126	0	0	0	0	0	0
MHA#2	PT	Lompico	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	121	72	77	126	215	193	184	189	206	202
MHA#3	PT	Lompico	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FernGroveClub	BL	Santa Margarita	Other	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
FernGroveClub2	BL	Santa Margarita	Other	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
HiddenMeadows	BL	Santa Margarita	Other	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
LCWD1	BL	Monterey	Other	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
LCWD5	BL	Monterey	Other	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
LCWD7	BL	Monterey	Other	0	0	0	0	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Manana#1	SV	Lompico	Other	60	60	60	60	60	60	60	60	60	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MissionSprings	BL	Santa Margarita	Other	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
MountainBrookTrailerPark	SV	Santa Margarita	Other	19	19	19	19	19	19	19	19	19	19	19	19	19	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SpringLakes3	PT	Lompico	Other	48	48	48	48	48	48	48	48	48	48	48	48	48	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montevalle#3	SV	Monterey	Landscape	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
SpringLakes2	PT	Santa Margarita	Landscape	48	48	48	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SpringLakes4	PT	Lompico	Landscape	0	0	0	0	48	48	48	48	48	48	48	48	48	48	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SpringLakes5	PT	Lompico	Landscape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
SpringLakes6	SV	Lompico	Landscape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ValleyGardensGolfCourse	SV	Lompico	Landscape	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
VistadelLago	PT	Lompico	Landscape	87	87	87	87	87	87	87	87	87	87	87	87	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
HarmonyFoods	SV	Monterey	Industrial	34	34	34	34	34	34	34	34	34	34	34	34	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kaiser#2	PT	Santa Margarita	Industrial	50	50	50	50	50	50	50	50	50	50	30	30	30	30	30	30	30	30	30	30	12	36	43	30	30	21	21	21	0
Kaiser#3	PT	Santa Margarita	Industrial	200	200	200	200	200	200	200	200	200	200	140	140	140	140	140	140	140	140	140	140	79	181	72	140	140	166	21	21	0
Kaiser#4	PT	Lompico	Industrial	0	0	0	0	0	0	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	105	80	100	109	141	109	109	0
Kaiser#4A	PT	Lompico	Industrial	0	0	0	0	0	0	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	105	80	100	109	141	141	141	0
Lonestar	BL	Santa Margarita	Industrial	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	3	0
QHQ_Active	BL	Santa Margarita	Industrial	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Silverking	SV	Monterey	Industrial	81	81	81	81	81	81	81	81	81	81	81	81	81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic		Santa Margarita	Private	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Domestic		Monterey	Private	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Domestic		Butano	Private	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Total				**1,972**	**2,108**	**1,956**	**2,050**	**2,418**	**2,143**	**2,207**	**2,203**	**2,879**	**2,937**	**3,147**	**4,020**	**3,984**	**3,743**	**3,647**	**3,872**	**3,809**	**3,636**	**4,235**	**3,778**	**4,051**	**4,568**	**3,984**	**4,042**	**4,364**	**4,636**	**4,444**	**4,528**	**4,231**
WELL TYPE SUBTOTALS																																
SVWD				470	503	460	537	726	651	780	798	951	919	1,143	1,215	1,314	1,351	1,359	1,425	1,488	1,529	1,742	1,533	1,826	2,051	1,908	1,877	1,948	2,007	2,021	2,077	1,971
SLVWD				437	540	431	448	612	412	347	326	848	837	804	1,140	1,177	1,027	970	1,193	1,093	903	1,167	890	981	1,115	734	866	1,094	1,233	1,224	1,256	1,330
Other				211	211	211	211	226	226	226	226	226	226	226	226	226	154	99	99	125	150	288	280	244	254	351	314	292	283	288	305	301
Industrial				400	400	400	400	400	400	400	400	400	500	520	520	493	412	405	405	405	405	405	405	326	461	310	405	424	504	327	320	25
Remediation				0	0	0	0	0	0	0	0	0	0	0	465	369	394	364	300	250	200	184	220	226	238	232	131	157	160	135	121	154
Landscape				286	286	286	286	286	286	286	286	286	286	286	286	237	237	281	281	281	281	281	281	281	281	281	281	281	281	281	281	281
Private				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AQUIFER SUBTOTALS																																
Santa Margarita				940	1,043	934	951	1,067	867	802	781	1,303	1,292	1,179	1,980	1,906	1,688	1,615	1,687	1,365	1,090	1,345	1,030	1,028	1,257	862	878	1,101	1,255	1,087	1,075	1,158
Monterey				247	247	247	247	262	387	481	669	688	686	555	508	576	379	330	353	309	361	354	399	276	295	276	265	225	258	269	232	191
Lompico				778	811	768	845	1,082	882	918	746	881	951	1,407	1,525	1,495	1,669	1,696	1,826	2,127	2,179	2,203	1,669	1,750	1,785	1,742	1,763	1,842	2,046	2,109	2,366	1,986
Butano				7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	9	7	332	680	997	1,232	1,105	1,136	1,196	1,079	980	855	895

APPENDIX A: Summary

Name	WY2005	WY2006	WY2007	WY2008	WY2009	WY2010	WY2011	WY2012
#10BUSINESSMENS	152	435	151	543	398	358	360	375
#11A	117	75	133	84	36	20	1	13
#11B	410	395	550	364	318	400	394	321
#11LOMPICO	0	0	0	0	0	0	0	0
#3AELPUEBLO	0	0	0	0	0	0	0	0
#3BSVWD	233	279	409	185	234	150	224	141
#3ELPUEBLO	0	0	0	0	0	0	0	0
#6SVWD	0	0	0	0	0	0	0	0
#7ASVWD	644	595	456	452	505	427	310	497
#7ELPUEBLO	0	0	0	0	0	0	0	0
#9CITYHALL	54	54	65	68	16	3	3	4
HIDDENOAKS	0	0	0	0	0	0	0	0
ChampionP#4	0	0	0	0	0	0	0	0
EstrellaP#3	0	0	0	0	0	0	0	0
Manana#2	59	32	51	51	43	39	24	37
NewProbationP#5	0	0	0	0	0	0	0	0
OldProbationP#1	0	0	0	0	0	0	0	0
OlympiaNo.1	0	0	0	0	0	0	0	0
OlympiaNo.2	204	245	320	306	314	265	122	266
OlympiaNo.3	88	110	232	213	225	31	6	128
Pasatiempo6	292	261	247	263	258	245	284	256
Pasatiempo7	49	111	141	126	109	86	75	90
QuailHollow3	0	0	0	0	0	0	0	0
QuailHollow4	204	170	269	218	151	77	95	190
QuailHollow5/QuailHollow	152	157	191	129	110	93	60	36
QuailHollow7/QuailHollow	0	0	0	0	0	0	0	0
CEEW-1	14	12	9	1	1	0	0	0
WatkinsJohnsonRA-1	0	0	0	0	0	0	0	0
WatkinsJohnsonRA-2	129	131	119	110	23	36	46	39
WatkinsJohnsonRA-3	0	0	0	0	0	0	0	0
WatkinsJohnsonRA-4	0	0	0	0	0	0	0	0
MHA#1	0	0	0	0	0	0	0	0
MHA#2	176	211	108	92	136	145	124	136
MHA#3	0	0	107	139	48	38	46	37
FernGroveClub	10	10	10	10	10	10	10	10
FernGroveClub2	11	11	11	11	11	11	11	11
HiddenMeadows	3	3	3	3	3	3	3	3
LCWD1	15	15	15	15	15	15	15	15
LCWD5	15	15	15	15	15	15	15	15
LCWD7	15	15	15	15	15	15	15	15
Manana#1	0	0	0	0	0	0	0	0
MissionSprings	30	30	30	30	30	30	30	30
MountainBrookTrailerPark	0	0	0	0	0	0	0	0
SpringLakes3	0	0	0	0	0	0	0	0
Montevalle#3	38	38	38	38	38	38	38	38
SpringLakes2	0	0	0	0	0	0	0	0
SpringLakes4	0	0	0	0	0	0	0	0
SpringLakes5	23	23	23	23	23	23	23	23
SpringLakes6	46	46	46	46	46	46	46	46
ValleyGardensGolfCourse	113	113	113	113	113	113	113	113
VistadelLago	38	38	38	38	38	38	38	38
HarmonyFoods	0	0	0	0	0	0	0	0
Kaiser#2	0	0	0	0	0	0	0	0
Kaiser#3	0	0	0	0	0	0	0	0
Kaiser#4	0	0	0	0	0	0	0	0
Kaiser#4A	0	0	0	0	0	0	0	0
Lonestar	0	0	0	0	0	0	0	0
QHQ_Active	25	25	25	25	25	25	25	25
Silverking	0	0	0	0	0	0	0	0
Domestic	97	97	97	97	97	97	97	97
Domestic	64	64	64	64	64	64	64	64
Domestic	7	7	7	7	7	7	7	7
Total	**3,527**	**3,823**	**4,108**	**3,894**	**3,474**	**2,963**	**2,725**	**3,116**
WELL TYPE SUBTOTALS								
SVWD	1,612	1,833	1,764	1,696	1,507	1,357	1,292	1,351
SLVWD	1,047	1,086	1,452	1,306	1,210	836	667	1,004
Other	275	310	314	330	283	282	270	271
Industrial	25	25	25	25	25	25	25	25
Remediation	143	143	127	112	23	36	46	39
Landscape	258	258	258	258	258	258	258	258
Private	0	0	0	0	0	0	0	0
AQUIFER SUBTOTALS								
Santa Margarita	953	989	1,307	1,153	999	678	505	836
Monterey	202	201	212	215	163	150	150	151
Lompico	1,489	1,752	1,717	1,884	1,566	1,552	1,530	1,484
Butano	884	881	871	643	746	583	541	645

Appendix B: Additional Geologic Cross Sections and Geologic Structure Maps



LEGEND

- Santa Margarita Groundwater Basin Boundary
- City Limit
- Lake
- Stream
- Fault
- Major Highway
- Major Road

Cross Section

- A-A'
- B-B'
- C-C'
- D-D'
- E-E'
- F-F'
- G-G'
- H-H'
- I-I'
- J-J'
- K-K'
- L-L'

Note:
Cross-Section A-A' and B-B" are report Figures 3-3 and 3-4 respectively, so are not included in Appendix A.

N

0 0.5 1

Scale: Miles

Kennedy/Jenks Consultants

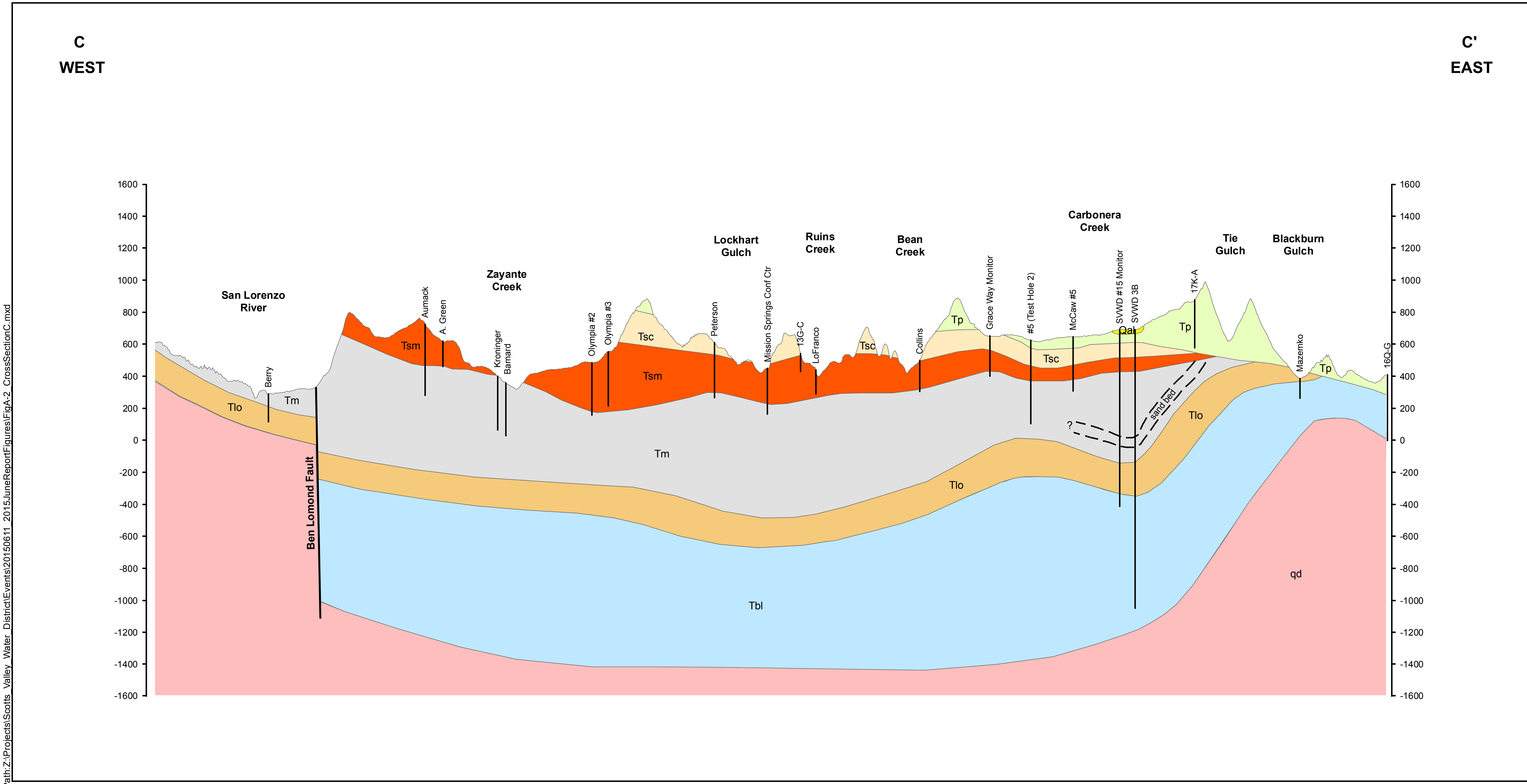
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section Map

K/J 1264001.00
Jaune 2015

Figure A-1

Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015JuneReportFigures\FigA-1 CrossSectionMap.mxd



Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015JuneReportFigures\FigA-2 CrossSectionC.mxd

EXPLANATION

Geologic Unit

Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

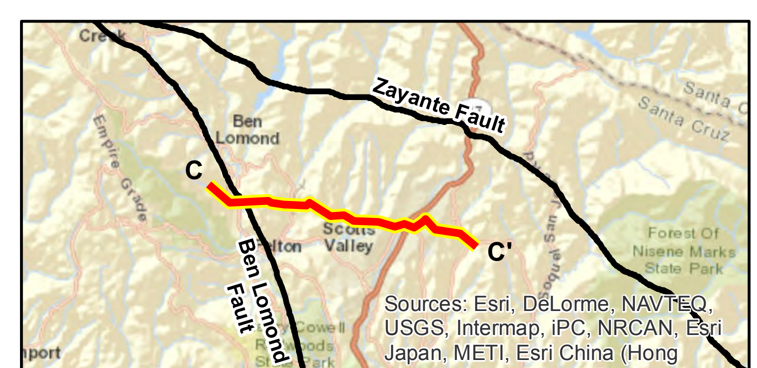
SVWD-1 — Well and Identifier

Feet 600' 300' Vertical Scale

0 1500' 3000' Feet

Horizontal Scale

Exaggeration: 5x



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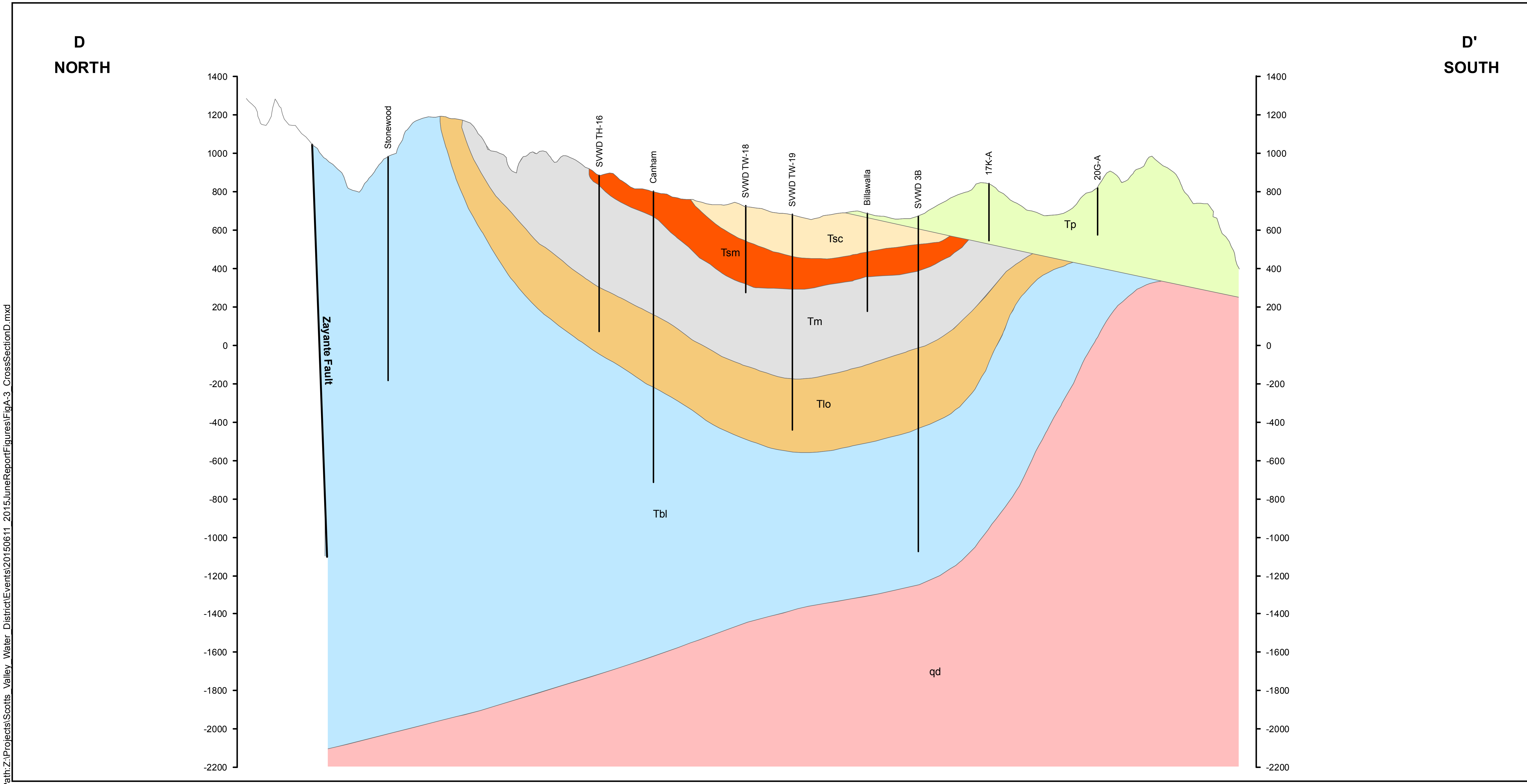
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section C-C'

K/J 1264001.00
June 2015

Figure A-2



Path:Z:\Projects\Scotts Valley Water District\Events\20150611 2015JuneReportFigures\FigA-3 CrossSectionD.mxd

Note:

EXPLANATION

Geologic Unit

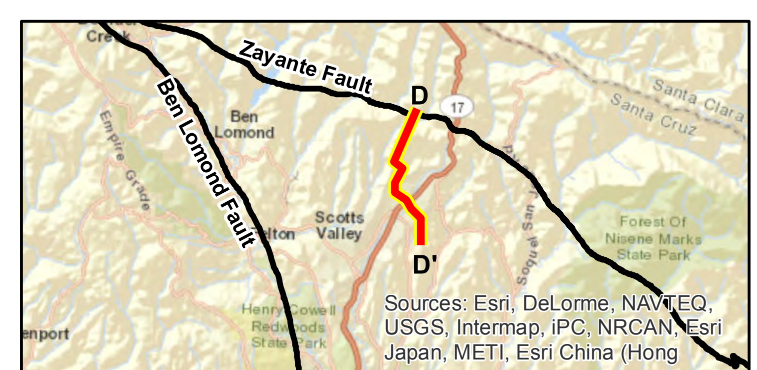
Symbol	Unit	Symbol	Unit
Qal	Alluvium	Tbu	Butano Formation - Upper Member
Tp	Purisima Formation	Tbm	Butano Formation - Middle Member
Tsc	Santa Cruz Mudstone	Tbl	Butano Formation - Lower Member
Tsm	Santa Margarita	Tl	Locatelli Formation
Tm	Monterey Formation	qd	Crystalline Bedrock-Granite
Tlo	Lompico Sandstone		

SVWD-1 — Well and Identifier

Vertical Scale: 0, 250', 500' Feet

Horizontal Scale: 0, 1250', 2500' Feet

Exaggeration: 5x



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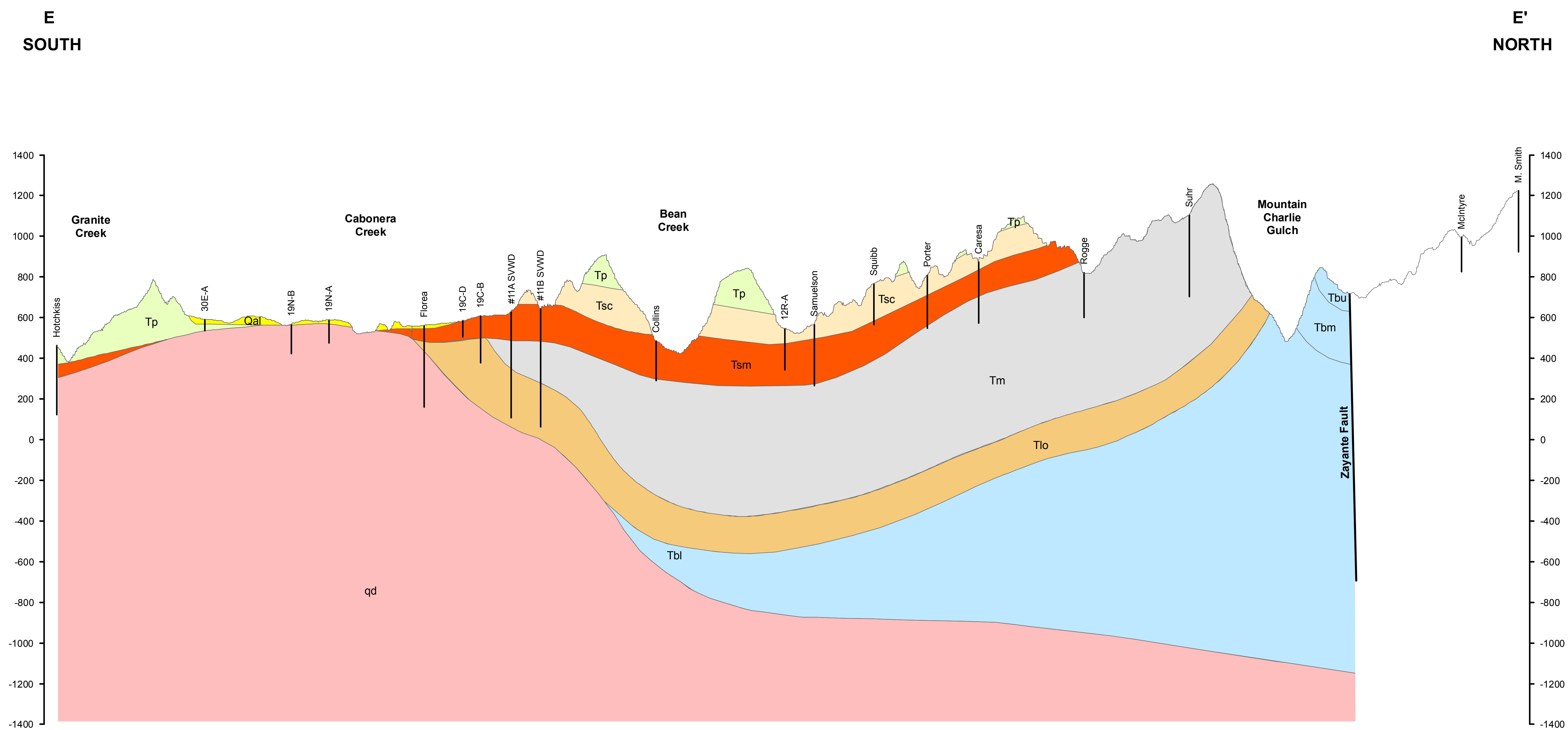
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section D-D'

K/J 1264001.00
June 2015

Figure A-3

Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\FigA-4_CrossSectionE.mxd



Note:

EXPLANATION

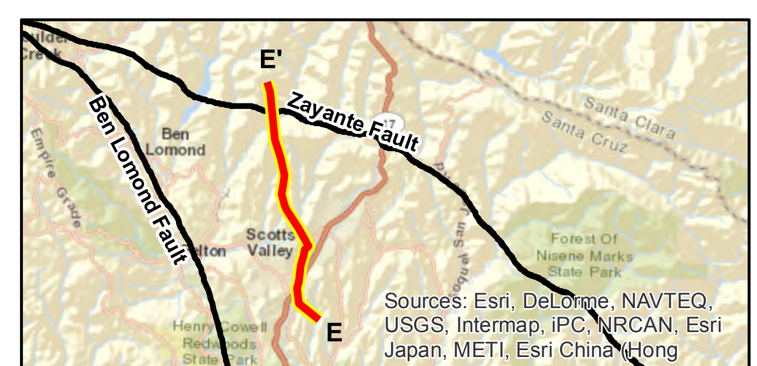
Geologic Unit

Symbol	Unit
Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 Well and Identifier

Feet 500' 250' Vertical Scale

0 1250' 2500' Feet
Horizontal Scale
Exaggeration: 5x



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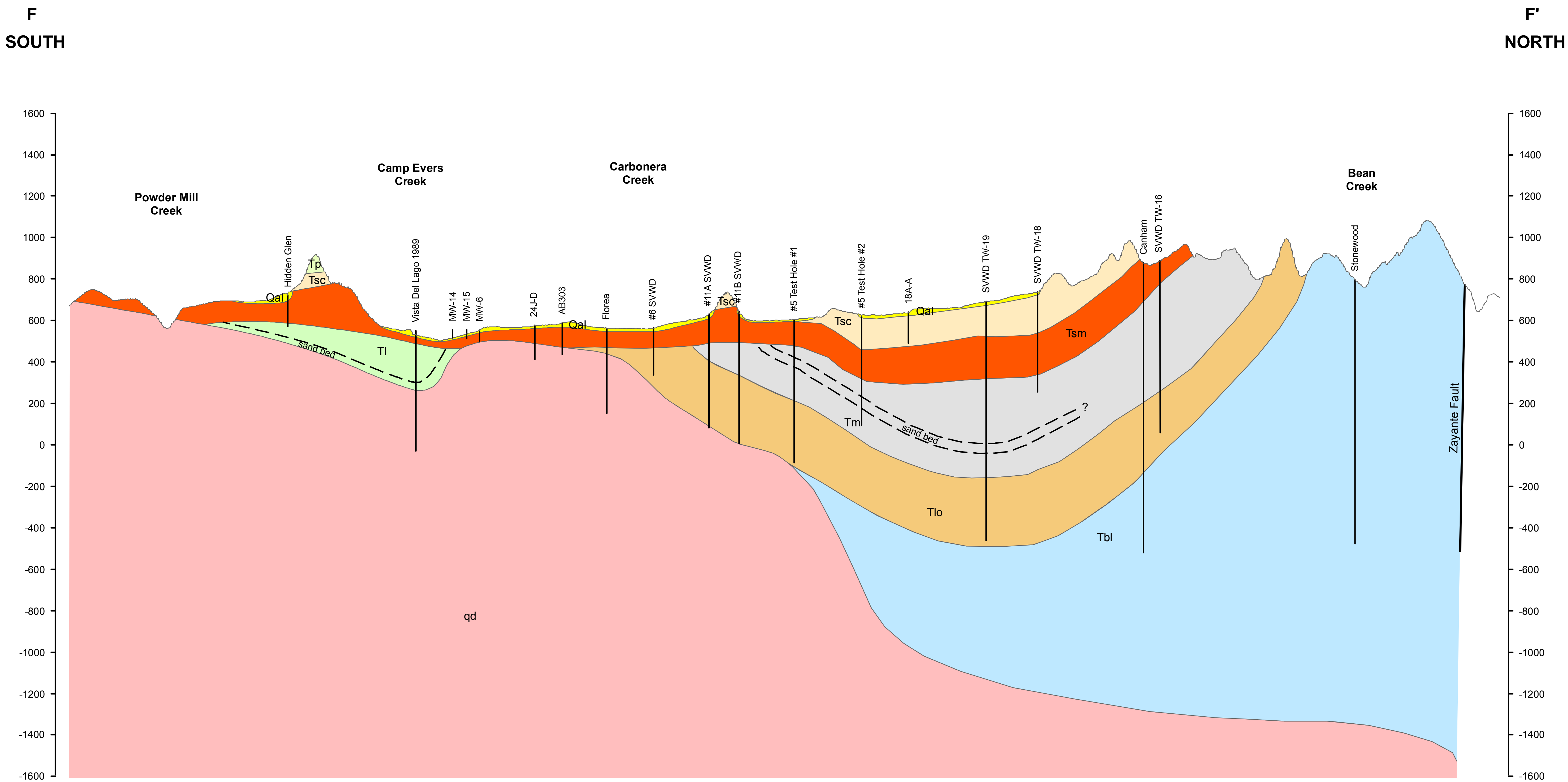
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section E-E'

K/J 1264001.00
June 2015

Figure A-4



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Note:

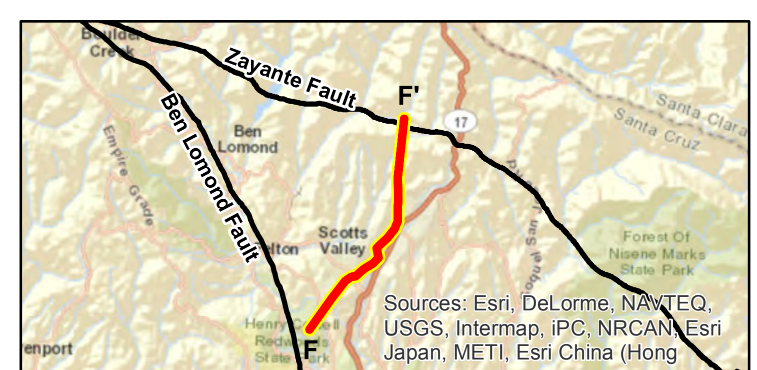
EXPLANATION

Geologic Unit

Symbol	Geologic Unit	Symbol	Geologic Unit
Qal	Alluvium	Tbu	Butano Formation - Upper Member
Tp	Purisima Formation	Tbm	Butano Formation - Middle Member
Tsc	Santa Cruz Mudstone	Tbl	Butano Formation - Lower Member
Tsm	Santa Margarita Sandstone	Tl	Locatelli Formation
Tm	Monterey Formation	qd	Crystalline Bedrock-Granite
Tlo	Lompico Sandstone		

SVWD-1 — Well and Identifier

Feet
500'
250'
Vertical Scale
0 1250' 2500' Feet
Horizontal Scale
Exaggeration: 5x



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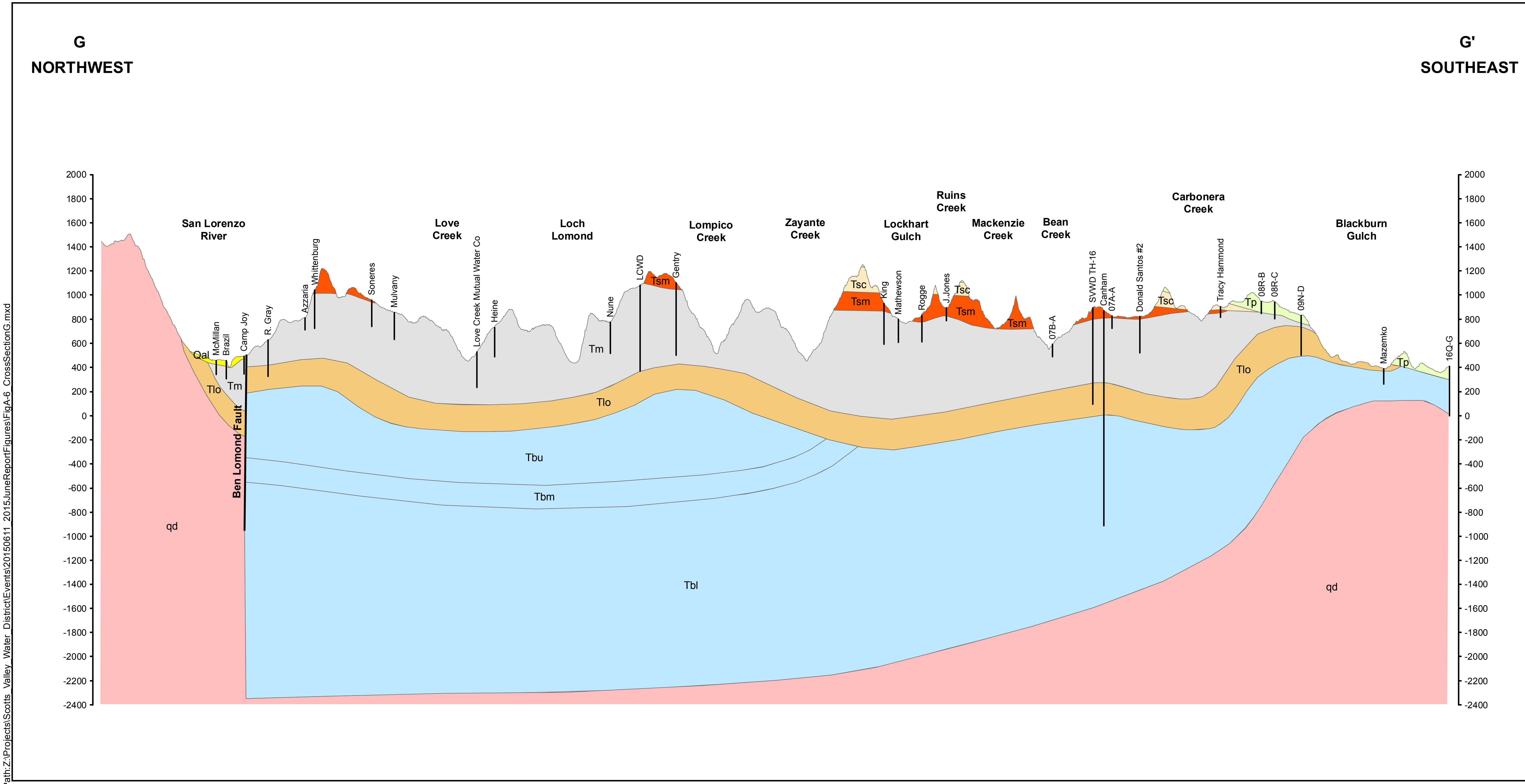
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section F-F'

K/J 1264001.00
June 2015

Figure A-5



Path:Z:\Projects\Scotts_Valley_Water_District\Events\20150611_2015JuneReportFigures\FigA-6_CrossSectionG.mxd

Note:

EXPLANATION

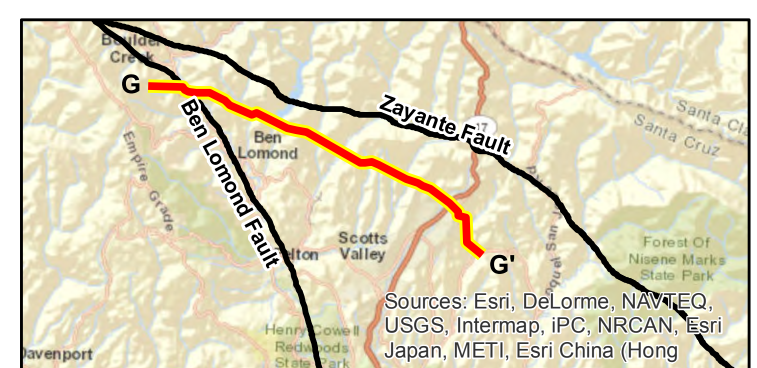
Geologic Unit

Symbol	Geologic Unit
Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1

Well and Identifier

Feet
800'
400'
Vertical Scale
0
2000'
4000'
Feet
Horizontal Scale
Exaggeration: 5x



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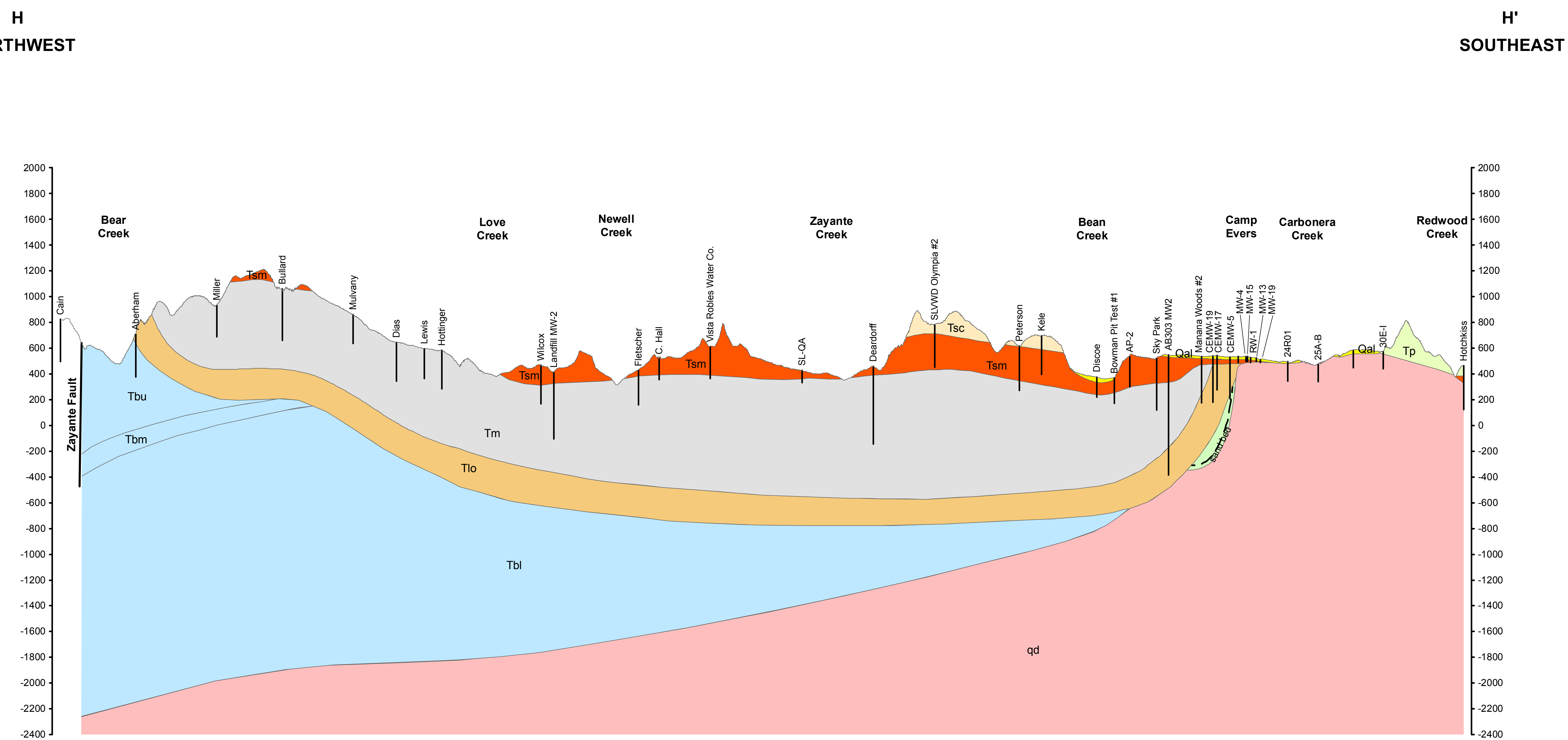
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section G-G'

K/J 1264001.00
June 2015

Figure A-6



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Note:

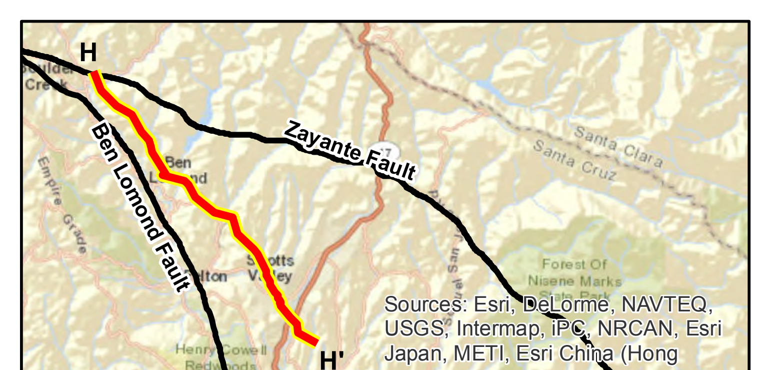
EXPLANATION

Geologic Unit

Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 — Well and Identifier

Vertical Scale: Feet 0, 400', 800'
Horizontal Scale: 0, 2000', 4000' Feet
Exaggeration: 5x



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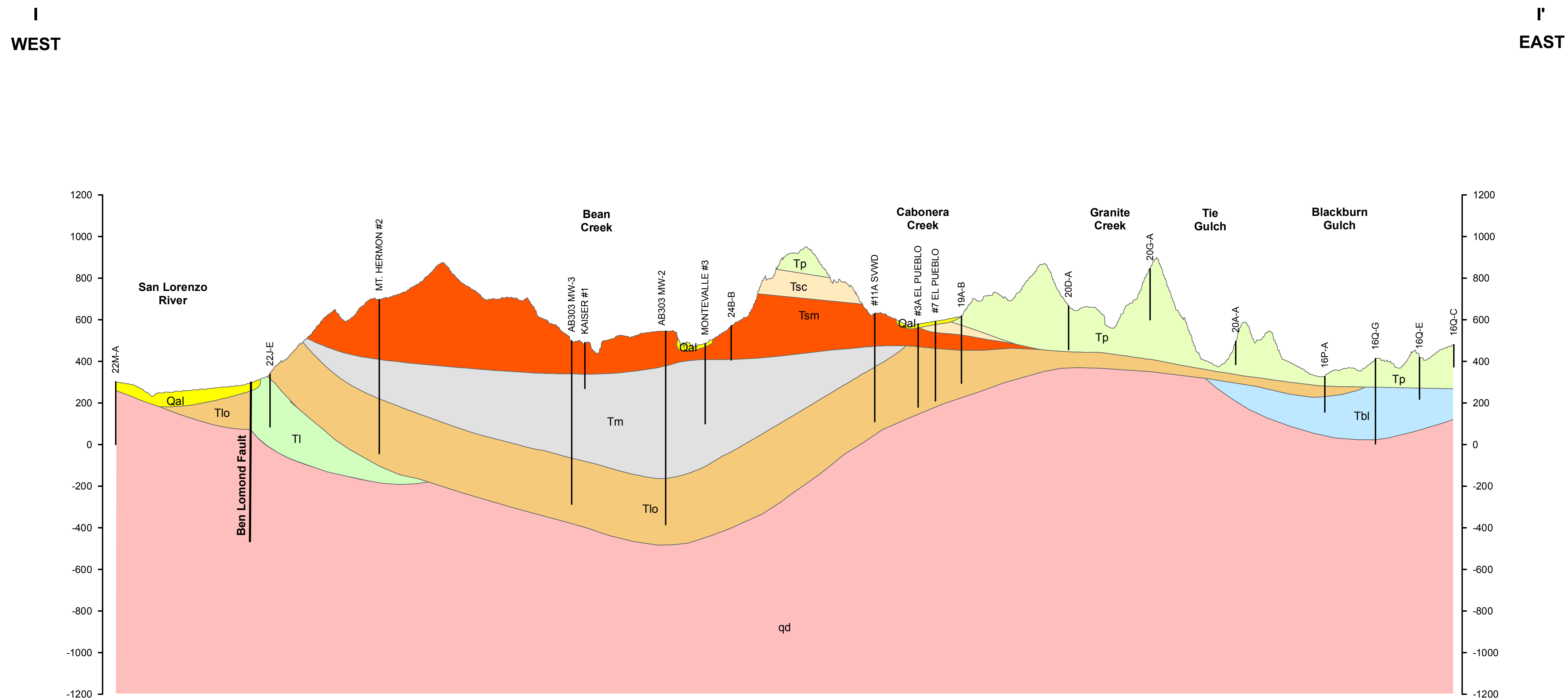
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section H-H'

K/J 1264001.00
June 2015

Figure A-7



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Note:

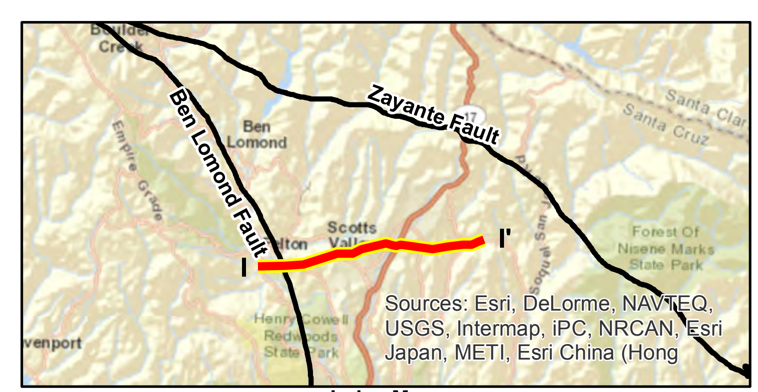
EXPLANATION

Geologic Unit

Symbol	Unit	Symbol	Unit
Qal	Alluvium	Tbu	Butano Formation - Upper Member
Tp	Purisima Formation	Tbm	Butano Formation - Middle Member
Tsc	Santa Cruz Mudstone	Tbl	Butano Formation - Lower Member
Tsm	Santa Margarita Sandstone	Tl	Locatelli Formation
Tm	Monterey Formation	qd	Crystalline Bedrock-Granite
Tlo	Lompico Sandstone		

SVWD-1 — Well and Identifier

Feet
500'
250'
Vertical Scale
0 1250' 2500' Feet
Horizontal Scale
Exaggeration: 5x



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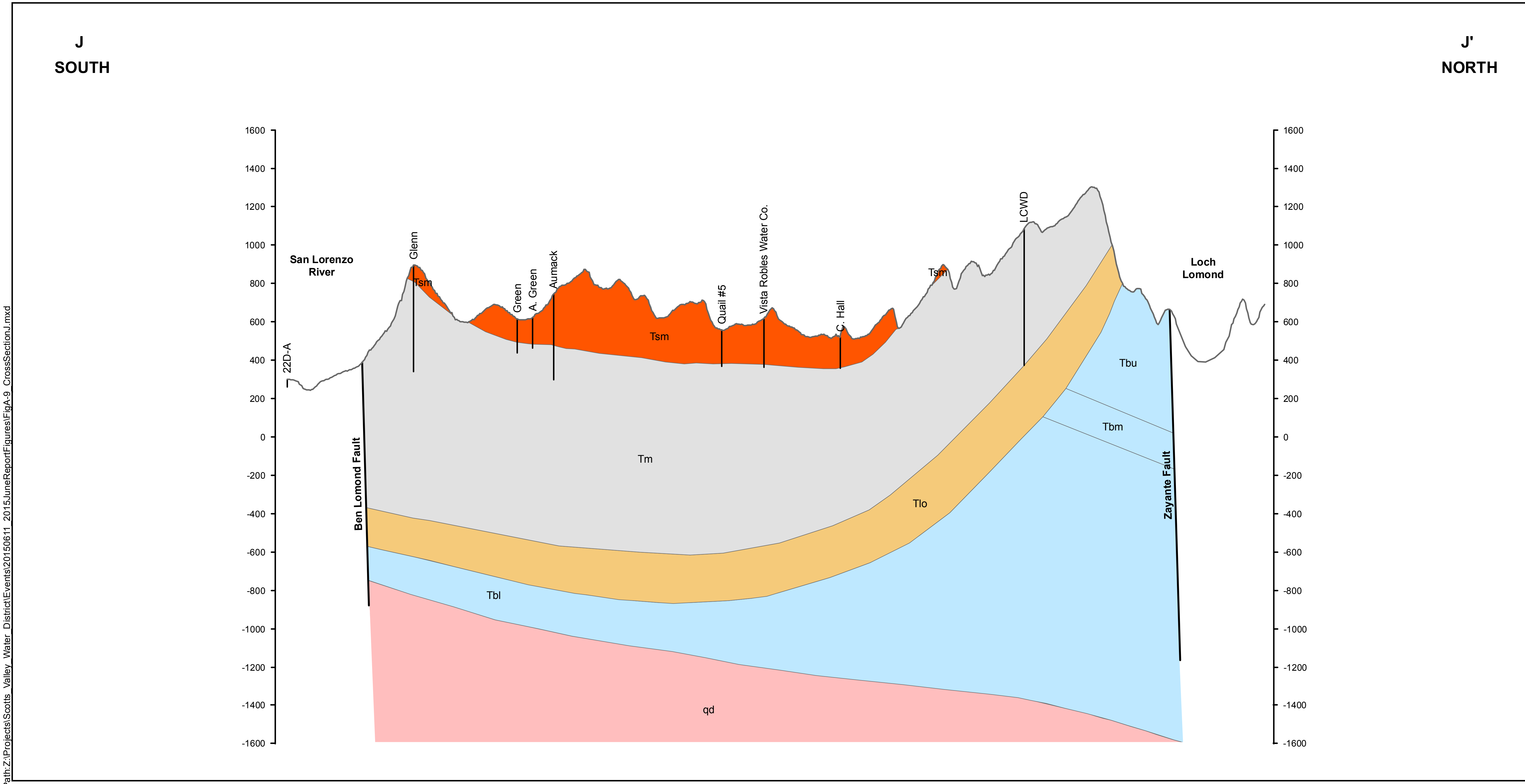
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section I-I'

K/J 1264001.00
June 2015

Figure A-8



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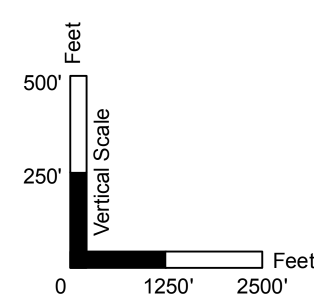
Note:

EXPLANATION

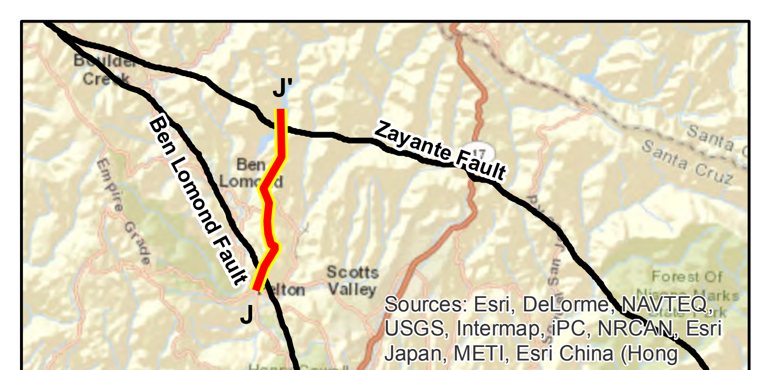
Geologic Unit

Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 — Well and Identifier



Horizontal Scale
Exaggeration: 5x



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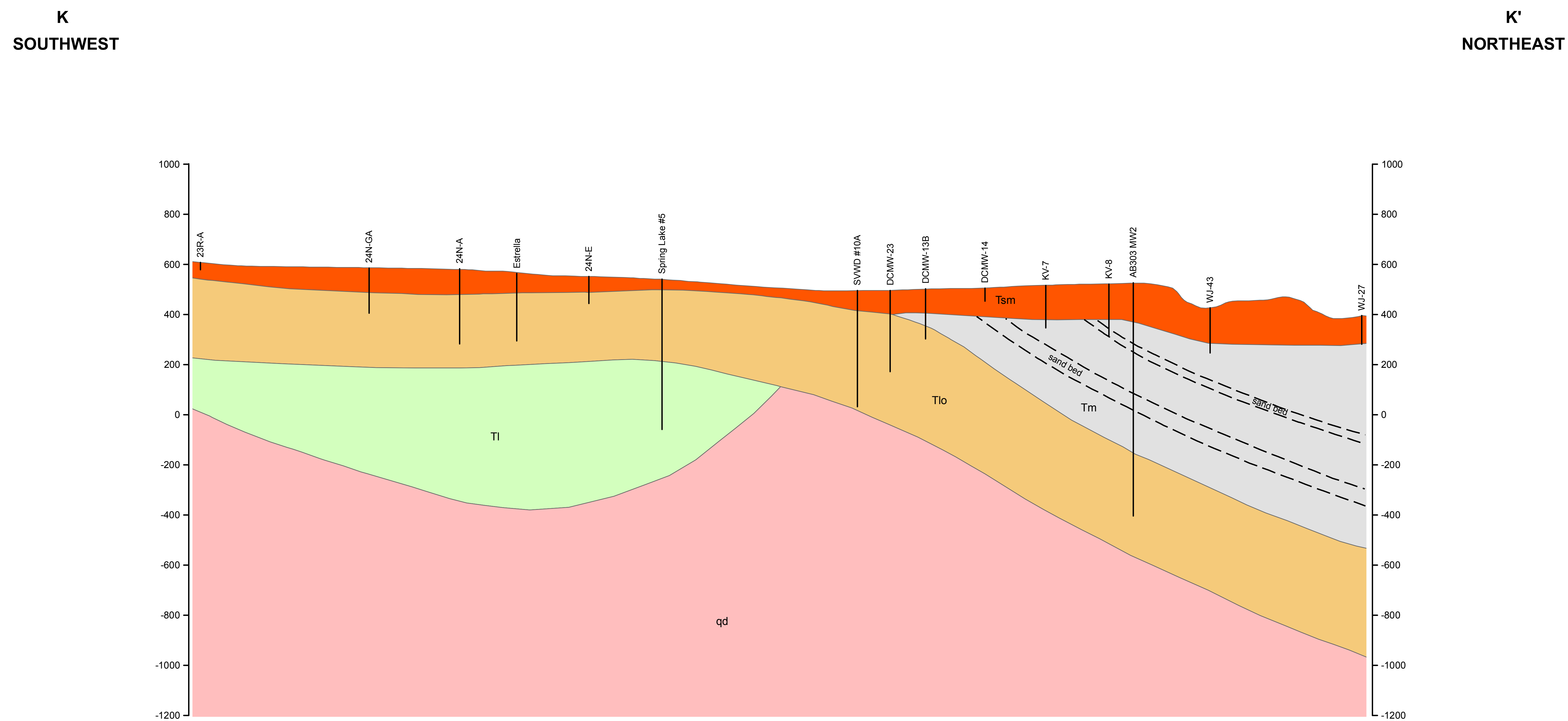
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section J-J'

K/J 1264001.00
June 2015

Figure A-9



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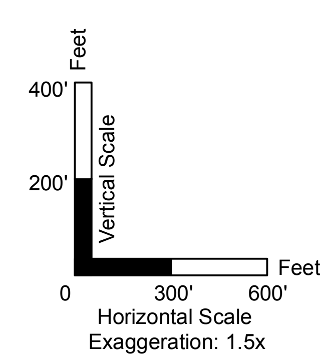
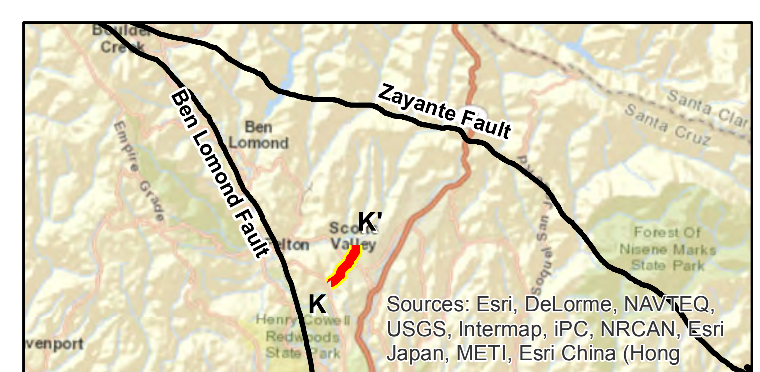
EXPLANATION

Geologic Unit

Symbol	Unit
Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SVWD-1 — Well and Identifier





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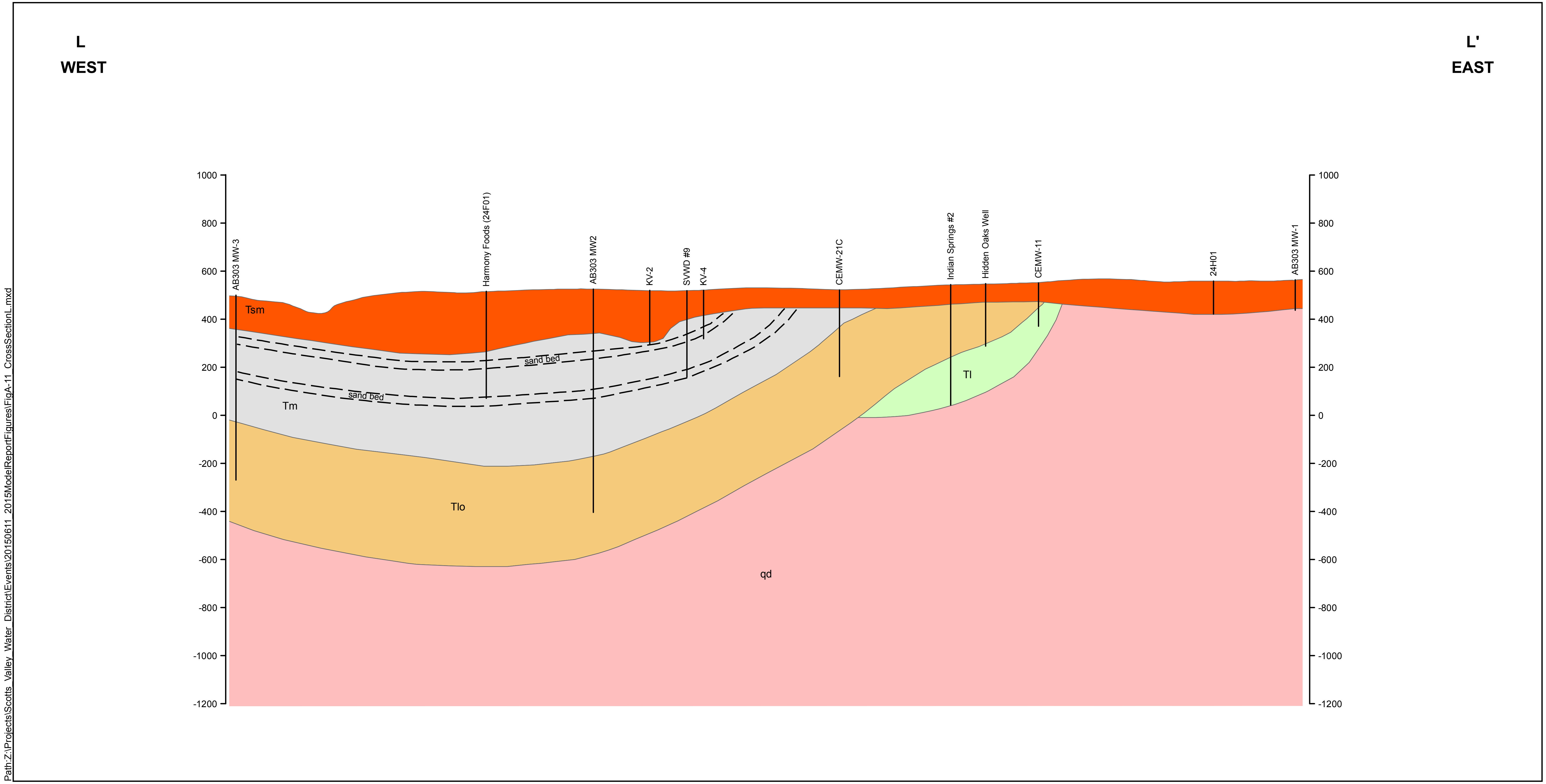
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section K-K'

K/J 1264001.00
June 2014

Figure A-10

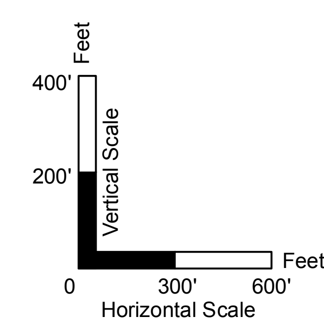


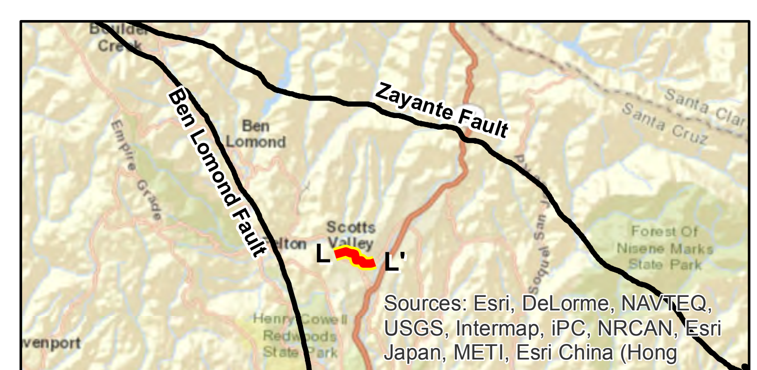
EXPLANATION

Geologic Unit

Unit	Description
Qal	Alluvium
Tp	Purisima Formation
Tsc	Santa Cruz Mudstone
Tsm	Santa Margarita Sandstone
Tm	Monterey Formation
Tlo	Lompico Sandstone
Tbu	Butano Formation - Upper Member
Tbm	Butano Formation - Middle Member
Tbl	Butano Formation - Lower Member
Tl	Locatelli Formation
qd	Crystalline Bedrock-Granite

SWWD-1 — Well and Identifier





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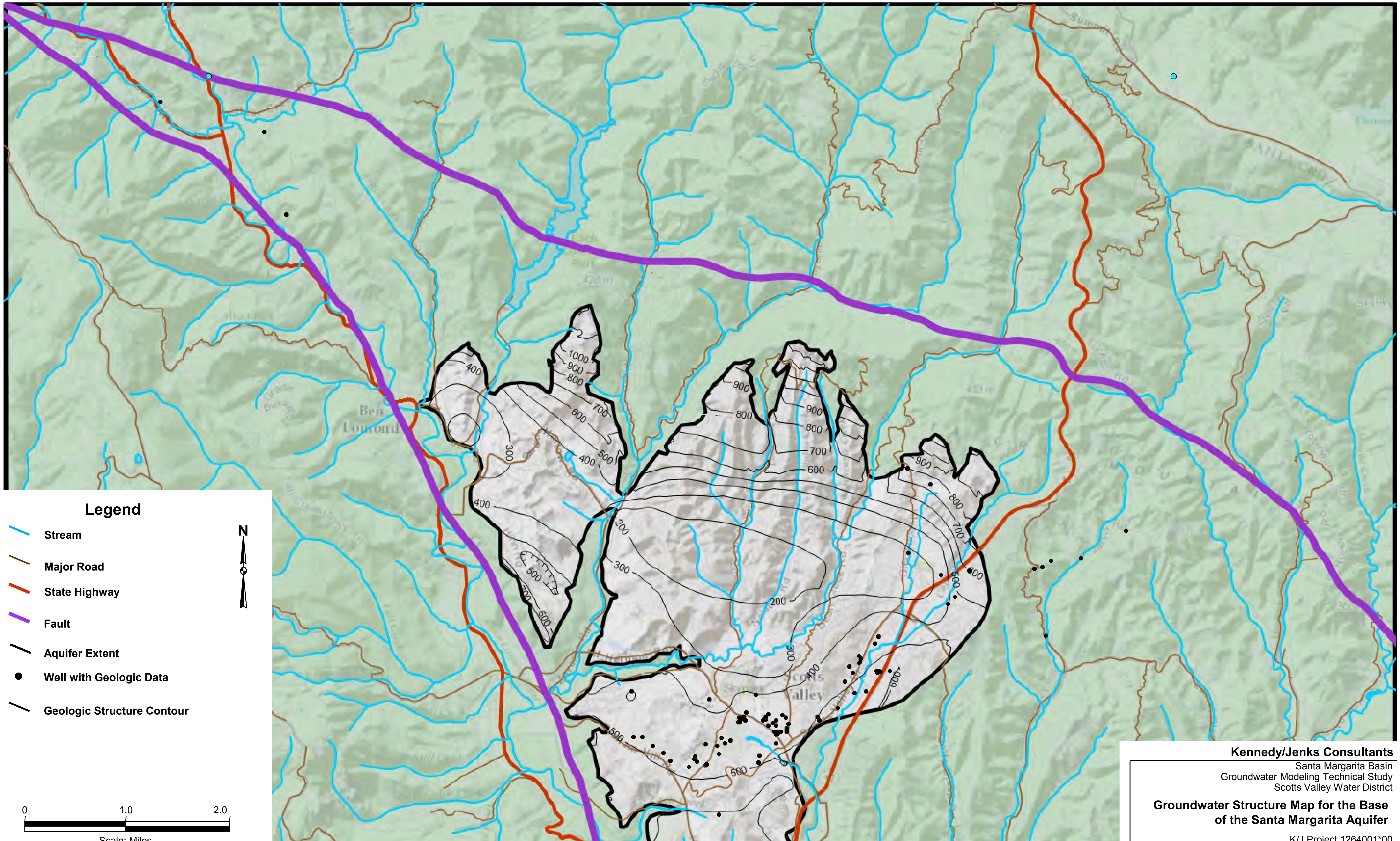
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Geologic Cross Section L-L'

K/J 1264001.00
June 2014

Figure A-11



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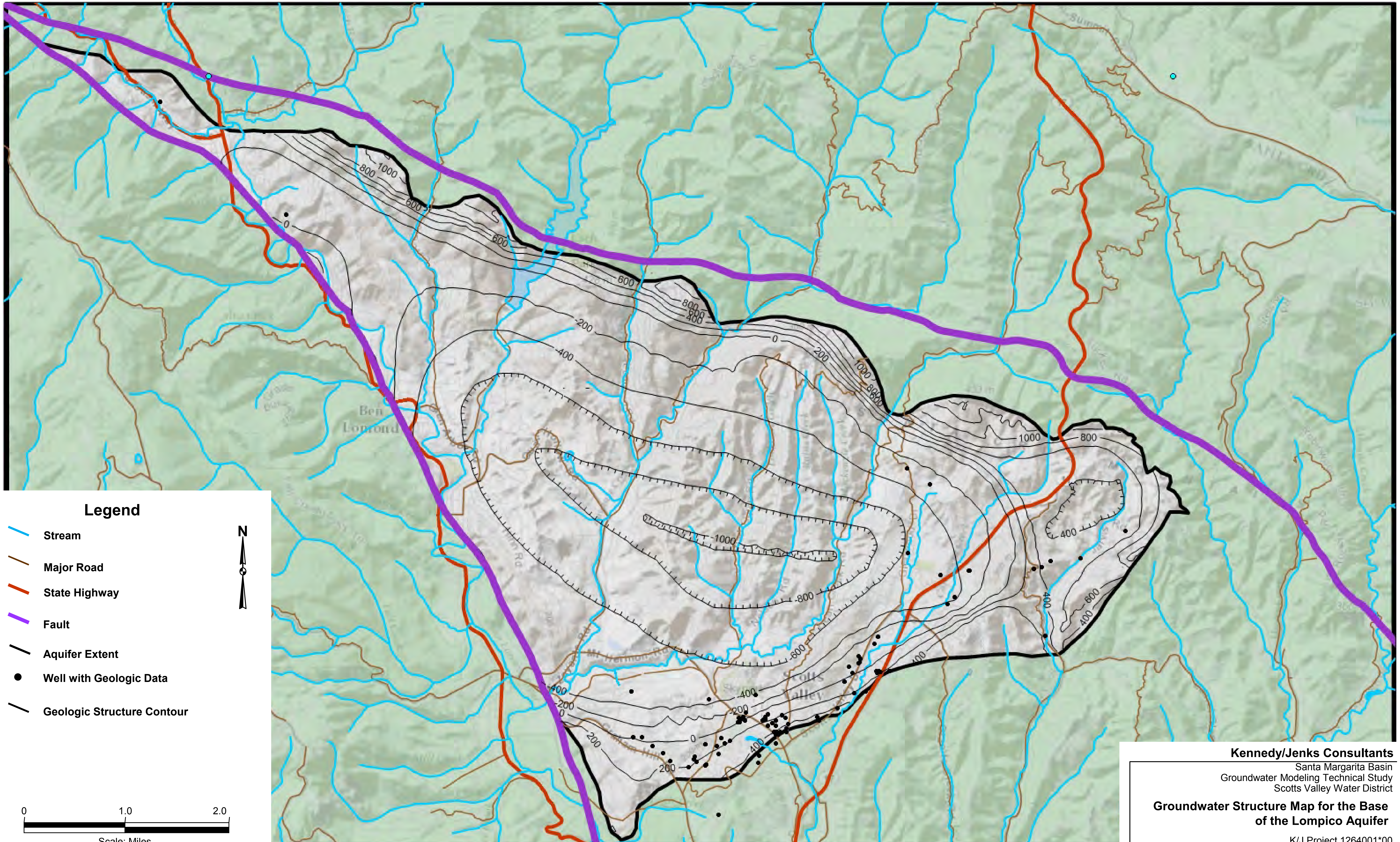
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Structure Map for the Base of the Santa Margarita Aquifer

K/J Project 1264001*00
June 2015

Figure A-12



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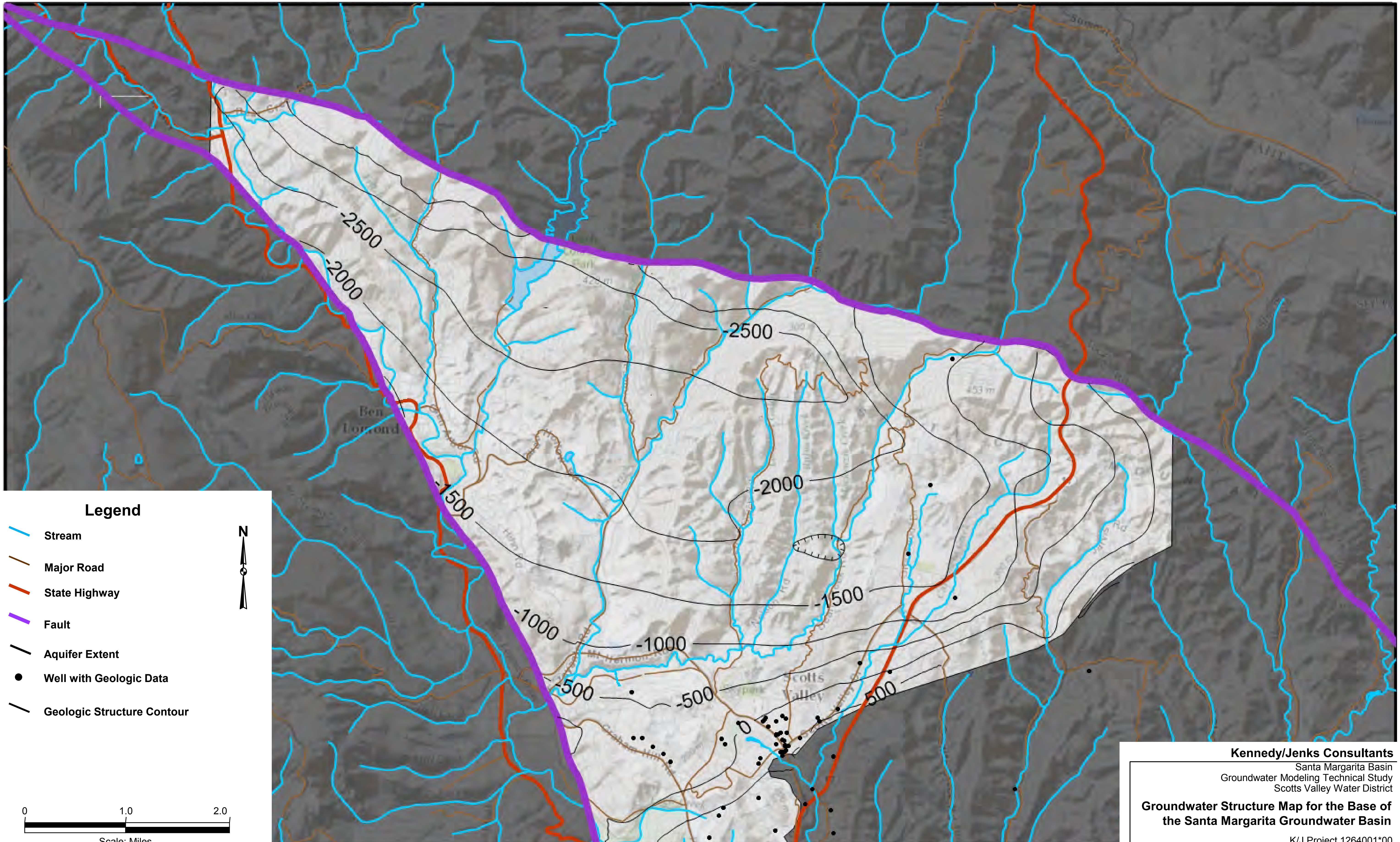
Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Structure Map for the Base of the Lompico Aquifer

K/J Project 1264001*00
June 2015

Figure A-13



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Santa Margarita Basin
Groundwater Modeling Technical Study
Scotts Valley Water District

Groundwater Structure Map for the Base of the Santa Margarita Groundwater Basin

K/J Project 1264001*00
June 2015

Figure A-14

Appendix C: Hydrologic data for precipitation, USGS Stream gauges and measured spring flows

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

Blair/Granite Creek Road

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1975				0.86	10.26	9.72	4.11	0.00	0.07	0.12	0.57	0.08	---
1976	5.72	0.55	0.98	0.37	1.74	5.00	3.24	0.00	0.30	0.02	1.89	1.68	21.49
1977	0.61	2.90	3.06	2.66	1.84	2.99	0.48	1.25	0.09	0.00	0.00	2.67	18.55
1978	0.53	3.62	8.08	18.16	8.66	9.26	6.56	0.00	0.16	0.00	0.00	1.50	56.53
1979	0.00	5.44	1.27	11.98	10.71	5.42	2.05	1.03	0.00	0.00	0.00	0.00	37.9
1980	5.70	2.99	10.28	13.45	13.12	2.64	3.19	0.91	0.40	0.84	0.00	0.00	53.52
1981	0.03	0.18	4.59										---
Average	2.10	2.61	4.71	7.91	7.72	5.84	3.27	0.53	0.17	0.16	0.41	0.99	

El Pueblo Yard

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1946										0.00	0.00	0.05	---
1947	9.33	1.00	4.35	1.12	4.80	5.34	0.35	0.91	0.68	0.00	0.00	0.00	27.88
1948	0.80	1.10	11.20	2.50	2.59	6.01	8.62	2.12	0.55	0.00	0.00	0.10	35.59
1949	0.10	4.00	5.51	4.47	7.57	12.71	0.00	0.60	0.00	0.00	0.00	1.25	36.21
1950	6.58	23.68	12.87	17.52	15.83	5.53	2.72	1.12	0.00	0.00	0.00	0.00	85.85
1951	2.35	4.10	20.56	6.63	2.95	3.66	1.89	1.44	0.00	0.00	0.00	0.15	43.73
1952	0.00	4.83	14.38	19.74	4.78	11.35	1.98	0.56	2.02	0.00	0.00	0.00	59.64
1953	0.80	4.82	0.51	9.61	0.00	5.75	5.95	1.54	0.00	0.00	0.42	0.00	29.4
1954	0.00	7.80	9.98	7.27	5.75	8.66	3.30	0.75	0.00	0.00	0.00	0.00	43.51
1955	0.10	3.42	25.46	8.19	3.14	1.00	5.63	0.80	0.00	0.00	0.00	0.45	48.19
1956	3.18	0.00	1.19	13.61	3.85	0.15	3.25	1.83	0.00	0.00	0.00	0.65	27.71
1957	6.85	1.10	7.15	8.29	11.35	3.68	3.05	7.66	0.15	0.00	0.20	0.50	49.98
1958	0.00	0.25	2.50	10.18	22.17	14.42	9.80	0.70	0.63	0.00	0.25	9.50	70.4
1959	0.00	0.00	0.75	8.05	12.22	0.50	1.10	0.00	0.00	0.00	0.00	0.00	22.62
1960	0.18	7.80	2.91	12.35	11.72	3.33	2.42	0.40	0.00	0.00	0.00	0.15	41.26
1961	0.10	5.93	4.27	5.01	1.95	4.92	1.30	0.75	0.00	0.00	0.23	0.00	24.46
1962	6.99	0.81	5.00	4.60	20.33	6.77	0.35	0.00	0.00	0.00	0.00	0.18	45.03
1963	3.34	9.84	0.34	9.15	8.75	6.88	9.24	1.60	0.00	0.00	0.00	0.18	49.32
1964	2.79	5.66	17.51	5.99	0.15	3.43	0.81	0.46	0.82	0.00	0.00	0.00	37.62
1965	0.08	9.05	7.00	6.15	2.00	3.29	4.83	0.00	0.00	0.32	0.05	0.27	33.04
1966	0.00	9.14	9.03	3.39	4.83	0.40	1.25	0.16	0.15	0.00	0.00	0.00	28.35
1967	0.47	2.22	4.51	17.33	0.70	9.84	9.52	0.24	1.80	0.00	0.40	0.05	47.08
1968	2.27	4.55	12.89	7.10	5.63	6.15	1.05	0.57	0.00	0.00	0.00	0.10	40.31
1969	3.92	2.16	12.89	22.93	16.57	2.36	4.22	0.03	0.02	0.00	0.00	0.00	65.1
1970	1.05	12.69	10.74	17.58	3.48	3.99	1.11	0.02	0.42	0.00	0.11	0.37	51.56

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

El Pueblo Yard

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1971	0.02	3.54	9.47	2.85	0.65	4.19	2.25	0.38	0.00	0.25	0.00	1.41	25.01
1972	4.52	13.15	3.75	3.36	2.79	0.42	3.08	0.08	0.29	0.00	0.00	0.29	31.73
1973	3.67	13.18	7.47	12.22	15.21	5.28	0.23	0.04	0.00	3.00	0.00	0.00	60.3
1974	2.36	1.93	5.66	7.63	1.82	10.18	4.16	0.02	0.38	0.12	0.57	0.08	34.91
1975	5.72	0.55	0.98	0.86	10.26	9.72	4.11	0.00	0.07	0.00	1.89	1.68	35.84
1976	0.61	2.90	3.06	0.37	1.74	5.00	3.24	0.00	0.30	0.00	0.00	2.67	19.89
1977	0.53	3.62	8.08	2.66	1.84	2.99	4.88	1.25	0.09	0.00	0.00	1.50	27.44
1978	0.00	5.44	1.27	18.16	8.66	9.26	6.56	0.00	0.00	0.34	0.00	0.00	49.69
1979	5.70	2.99	10.28	11.98	10.71	5.42	2.15	1.03	0.00	0.84	0.00	0.00	51.1
1980	0.03	0.18	4.59	13.45	13.12	2.74	3.19	0.91	0.04	0.00	0.00	0.28	38.53
1981	2.47	12.29	7.88	11.21	3.06	9.72	0.47	0.64	0.00	0.00	0.00	0.00	47.74
1982	0.14	11.20	5.90	28.80	6.88	8.26	8.40	0.03	0.00	0.00	0.04	1.28	70.93
1983	5.35	10.50	7.74	13.90	18.00	19.90	7.80	0.98	0.00	0.00	0.17	1.91	86.25
1984	1.70	12.70	12.90	0.54	2.49	2.62	1.13	0.02	0.18	0.01	0.00	0.25	34.54
1985	2.80	13.80	2.95	1.72	4.20	7.92	0.73	0.11	0.15	0.09	0.02	0.54	35.03
1986	1.12	7.14	2.62	7.38	22.40	15.00	0.48	0.83	0.00	0.00	0.00	1.30	58.27
1987	0.03	0.05	2.47	4.51	9.06	6.31	0.70	0.00	0.02	0.00	0.00	0.00	23.15
1988	1.19	2.30	10.70	4.58	0.68	0.00	3.13	1.07	0.16	0.00	0.00	0.00	23.81
1989	0.19	5.90	8.89	2.06	1.39	10.60	0.67	0.08	0.03	0.00	0.03	0.83	30.67
1990	3.53	1.58	0.01	3.42	3.69	2.13	0.16	5.79	0.00	0.00	0.12	0.15	20.58
1991	0.50	0.24	1.65	0.61	5.39	17.19	0.51	0.06	0.40	0.00	0.02	0.07	26.64
1992	2.37	1.46	5.42	3.03	15.30	4.65	0.45	0.00	0.82	0.00	0.05	0.00	33.55
1993	3.41	0.20	11.54	18.51	10.22	3.17	1.37	0.96	0.68	0.00	0.00	0.00	50.06
1994	0.73	2.74	5.52	3.51	9.72	0.68	2.75	2.10	0.01	0.00	0.00	0.05	27.81
1995	1.79	8.29	4.78	23.88	0.65	13.62	3.79	0.89	1.04	0.01	0.00	0.00	58.74
1996	0.00	0.32	10.03	13.52	11.35	5.14	2.38	4.31	0.03	0.00	0.00	0.00	47.08
1997	2.89	6.95	22.43	12.33	0.17	1.50	0.58	0.16	0.12	0.00	0.54	0.00	47.67
1998	0.68	10.12	4.06	14.21	21.81	6.17	2.85	3.65	0.01	0.00	0.01	0.17	63.74
1999	1.02	9.11	1.85	9.25	11.08	5.22	2.58	0.03	0.36	0.00	0.02	0.14	40.66
2000	0.35	5.69	0.53	18.02	17.57	2.77	2.69	1.01	0.18	0.00	0.20	0.40	49.41
2001	5.14	1.38	0.94	8.68	10.65	4.05	2.67	0.00	0.07	0.00	0.00	0.16	33.74
2002	1.13	9.93	16.45	4.97	2.69	4.66	0.52	0.90	0.00	0.00	0.05	0.00	41.3
2003	0.00	5.80	21.40	2.77	2.95	2.54	5.75	1.09	0.16	0.00	0.00	0.00	42.46
2004	0.19	3.93	17.55	4.44	9.69	0.35	0.65	0.07	0.00	0.00	0.00	0.00	36.87
2005	7.24	3.25	14.39	8.30	7.20	10.01	3.79	2.13	0.94	0.02	0.00	0.08	57.35
2006	0.19	2.84	21.73	6.55	5.26	15.29	10.44	1.01	0.01	0.00	0.01	0.00	63.33

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

El Pueblo Yard

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
2007	0.25	3.30	5.67	0.89	9.24	0.30	2.17	0.46	0.00	0.10	0.01	0.33	22.72
2008	1.93	0.52	5.50	17.59	6.96	0.36	0.35	0.00	0.00	0.01	0.00	0.04	33.26
2009	1.59	4.80	4.38	1.80	15.28	3.47	0.52	1.42	0.01	0.00	0.00	0.26	33.53
2010	9.70	0.33	5.21	11.37	8.66	4.35	5.41	1.17	0.00	0.01	0.07	0.00	46.28
2011	3.92	5.13	15.36	1.97	10.59	13.40	0.75	3.42	3.40	0.00	0.04	0.02	58
2012	2.93	3.41	0.15	6.80	2.84	12.33	3.64	0.02	0.20	0.02	0.00	0.02	32.36
2013	1.61	11.32	13.25	1.31	0.47								---
Average	2.13	5.25	7.91	8.58	7.57	6.05	3.00	0.95	0.26	0.08	0.08	0.45	

Hacienda Drive

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1974										3.00	0.00	0.00	---
1975	3.00	2.90	9.00	0.75	14.15	16.80	4.35	0.00	0.00	0.00	0.70	4.60	56.25
1976	0.00	3.00	1.60	0.00	5.10	1.30	3.15	0.00	0.45	0.00	2.10	4.50	21.2
1977	0.00	3.35	4.20	1.50	2.45	5.15	0.50	0.00	0.20	0.00	0.00	3.00	20.35
1978	0.00	6.50	10.85	27.25	11.55	12.60	8.55	0.00	0.20	0.00	0.00	1.55	79.05
1979	0.00	6.45	1.90	16.55	15.65	7.85							---
Average	0.60	4.44	5.51	9.21	9.78	8.74	4.14	0.00	0.21	0.60	0.56	2.73	

San Lorenzo River, Santa Cruz

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1948											0.04	0.00	---
1949	0.74	0.70	10.49	4.23	3.83	8.19	0.02	0.36	0.00	0.03	0.07	0.08	28.74
1950	0.05	2.11	4.91	11.72	7.11	2.48	1.87	0.76	0.03	0.01	0.00	0.35	31.4
1951	1.97	11.39	9.35	5.31	4.20	3.60	1.46	1.00	0.03	0.00	0.04	0.00	38.35
1952	1.49	2.11	15.79	13.60	3.24	5.87	1.38	0.33	0.77	0.00	0.00	0.00	44.58
1953	0.00	2.86	7.82	3.53	0.00	4.10	4.97	0.69	0.22	0.00	0.22	0.00	24.41
1954	0.33	3.73	0.73	4.60	3.79	6.65	2.56	0.64	0.47	0.00	0.34	0.00	23.84
1955	0.10	5.61	4.82	6.58	1.88	0.48	3.58	0.83	0.00	0.00	0.00	0.00	23.88
1956	0.05	3.74	21.07	9.34	1.46	0.26	1.89	1.49	0.00	0.07	0.02	0.28	39.67
1957	1.83	0.02	0.96	5.90	4.90	2.03	1.96	4.03	0.16	0.06	0.05	0.29	22.19
1958	5.34	0.97	5.48	7.70	13.86	7.51	4.47	0.43	0.18	0.00	0.00	0.32	46.26
1959	0.06	0.37	0.75	10.40	7.13	1.01	0.56	0.00	0.00	0.00	0.09	2.71	23.08
1960	0.00	0.00	0.78	8.98	7.03	2.44	1.67	0.39	0.02	0.02	0.02	0.08	21.43
1961	0.31	4.35	1.76	3.92	1.27	3.97	0.04	0.70	0.15	0.00	0.11	0.16	16.74
1962	0.05	3.66	2.08	3.68	11.96	4.70	0.80	0.02	0.04	0.00	0.05	0.31	27.35
1963	2.95	0.99	3.70	7.15	4.91	5.81	7.41	0.55	0.03	0.02	0.06	0.16	33.74

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

San Lorenzo River, Santa Cruz

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1964	1.85	6.72	0.33	5.33	0.20	3.26	0.16	0.44	0.37	0.00	0.17	0.20	19.03
1965	1.67	3.81	13.06	3.78	1.71	2.98	3.43	0.02	0.07	0.00	0.11	0.00	30.64
1966	0.12	6.93	4.54	2.17	4.72	0.39	0.79	0.10	0.15	0.32	0.10	0.15	20.48
1967	0.05	6.17	6.87	8.74	0.74	7.26	8.26	0.40	1.51	0.00	0.00	0.00	40
1968	0.13	2.14	3.10	3.82	4.93	5.64	0.97	0.18	0.00	0.00	0.55	0.00	21.46
1969	1.50	4.31	7.27	14.80	12.01	1.99	2.87	0.08	0.04	0.00	0.00	0.07	44.94
1970	1.77	1.34	6.75	13.03	3.11	3.39	0.23	0.03	0.53	0.00	0.00	0.00	30.18
1971	1.24	9.55	8.18	2.44	1.02	2.45	1.74	0.24	0.00	0.00	0.06	0.32	27.24
1972	0.48	3.74	7.48	1.79	1.81	0.32	1.92	0.03	0.14	0.04	0.00	1.33	19.08
1973	3.41	10.54	3.38	7.84	12.99	5.01	0.05	0.04	0.00	0.00	0.00	0.41	43.67
1974	2.71	9.56	6.27	5.99	2.00	7.35	4.86	0.02	0.31	2.89	0.00	0.00	41.96
1975	1.94	1.07	3.91	1.28	5.72	6.65	2.63	0.00	0.10	0.14	0.85	0.00	24.29
1976	3.65	0.49	0.30	0.32	3.89	1.93	2.11	0.00	0.20	0.01	1.25	1.22	15.37
1977	0.46	3.80	2.63	1.75	1.55	2.24	0.21	0.74	0.07	0.01	0.00	1.35	14.81
1978	0.26	1.72	6.09	11.40	6.13	5.98	5.30	0.01	0.08	0.00	0.00	0.62	37.59
1979	0.00	4.48	1.08	10.06	7.55	3.83	1.29	0.66	0.00	0.20	0.00	0.00	29.15
1980	3.45	2.52	6.79	9.97	8.69	2.02	2.21	0.61	0.17	0.71	0.00	0.00	37.14
1981	0.04	0.17	2.57	7.05	2.62	8.51	0.26	0.35	0.00	0.00	0.00	0.17	21.74
1982	1.26	7.05	4.36	13.38	6.63	7.84	6.05	0.05	0.27	0.00	0.06	1.19	48.14
1983	2.50	6.47	2.99	9.16	9.74	15.16	5.08	0.60	0.00	0.00	0.23	2.00	53.93
1984	1.07	8.58	8.14	0.33	2.40	1.94	1.18	0.11	0.15	0.00	0.00	0.11	24.01
1985	3.59	11.06	2.39	1.71	3.28	6.60	0.42	0.20	0.14	0.13	0.02	0.14	29.68
1986	0.92	5.68	3.91	6.93	12.20	8.24	0.77	0.60	0.00	0.00	0.00	1.74	40.99
1987	0.05	0.05	1.68	3.47	5.28	4.48	0.84	0.00	0.00	0.00	0.00	0.00	15.85
1988	0.94	3.05	7.16	4.44	0.74	0.05	1.74	0.59	0.02	0.00	0.00	0.00	18.73
1989	0.30	4.46	7.78	1.36	1.52	7.00	0.72	0.10	0.02	0.00	0.07	0.87	24.2
1990	2.19	1.12	0.05	2.64	3.33	2.65	0.43	4.11	0.03	0.00	0.00	0.21	16.76
1991	0.67	0.47	1.65	0.81	4.92	10.60	0.80	0.06	0.26	0.02	0.04	0.06	20.36
1992	2.26	1.51	4.25	3.19	11.10	4.35	0.28	0.00	0.55	0.00	0.02	0.00	27.51
1993	1.18	0.23	7.10	13.85	8.02	3.44	1.37	0.94	0.56	0.00	0.00	0.00	36.69
1994	0.61	2.73	4.00	2.59	8.18	0.74	1.82	1.98	0.00	0.00	0.00	0.06	22.71
1995	0.36	4.88	3.24	17.56	0.47	8.49	5.13	1.34	1.54	0.00	0.00	0.00	43.01
1996	0.00	0.19	6.64	8.40	9.20	3.15	1.58	2.43	0.00	0.00	0.00	0.00	31.59
1997	2.44	7.33	13.74	10.12	0.29	1.26	0.70	0.07	0.19	0.00	0.45	0.01	36.6
1998	0.47	9.59	3.67	15.58	18.63	4.68	3.11	3.87	0.14	0.00	0.00	0.08	59.82
1999	0.88	5.30	1.74	7.44	10.66	4.08	2.97	0.04	0.34	0.00	0.02	0.18	33.65

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

San Lorenzo River, Santa Cruz

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
2000	0.29	3.41	0.77	11.84	14.06	2.41	1.50	1.27	0.19	0.00	0.22	0.31	36.27
2001	4.74	1.26	1.03	5.92	7.00	3.29	1.76	0.00	0.10	0.00	0.02	0.20	25.32
2002	0.70	6.28	11.07	3.73	2.28	3.52	0.35	0.81	0.00	0.00	0.04	0.04	28.82
2003	0.04	4.27	15.21	2.77	2.94	2.54	5.75	1.09	0.16	0.00	0.00	0.00	34.77
2004	0.19	3.93	17.55	4.44	9.69	0.35	0.43	0.09	0.00	0.06	0.00	0.02	36.75
2005	5.80	1.23	10.28	5.98	6.26	7.65	3.03	1.34	1.01	0.01	0.02	0.01	42.62
2006	0.12	1.82	12.62	6.37	2.76	10.99	7.20	0.78	0.00	0.00	0.00	0.00	42.66
2007	0.14	3.26	4.73	0.80	5.86	0.33	1.53	0.55	0.00	0.00	0.00	0.38	17.58
2008	1.40	0.54	3.83	12.16	6.10	0.51	0.48	0.00	0.00	0.00	0.00	0.01	25.03
2009	0.80	1.94	3.00	1.84	10.30	2.07	0.42	1.67	0.00	0.00	0.02	0.36	22.42
2010	4.08	0.19	4.06	8.19	5.78	3.17	4.49	0.74	0.00	0.02	0.03	0.01	30.76
2011	3.16	4.05	9.40	2.17	5.75	10.87	0.66	1.53	2.35	0.01	0.06	0.05	40.06
2012	2.63	2.54	0.13	3.68	0.94	7.38	3.10	0.06	0.19	0.03	0.00	0.02	20.7
2013	0.53	3.34	5.82	0.30	0.32	1.37							---
Average	1.33	3.68	5.62	6.33	5.46	4.33	2.18	0.67	0.22	0.08	0.08	0.29	

Wastewater Treatment Plant

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
1986										0.00	0.00	1.78	---
1987	0.00	0.03	2.61	4.69	8.56	6.29	0.79	0.00	0.08	0.00	0.00	1.24	24.29
1988	4.45	10.21	5.31	0.96	0.01	3.23	1.48	0.07	0.00	0.00	0.00	0.00	25.72
1989	0.00	7.76	10.42	2.18	1.98	11.70	0.99	0.15	0.11	0.00	0.01	1.02	36.32
1990	3.56	1.75	0.07	4.06	3.79	2.79	0.29	6.10	0.03	0.00	0.11	0.29	22.84
1991	0.39	0.37	2.81	0.47	6.19	18.79	0.65	0.17	0.36	0.02	0.02	0.04	30.28
1992	3.38	1.75	6.50	3.47	16.74	5.83	0.53	0.00	1.15	0.00	0.05	0.00	39.4
1993	3.73	0.26	13.55	23.94	11.96	3.84	1.46	1.09	0.93	0.01	0.01	0.85	61.63
1994	2.96	6.40	4.42	11.14	0.85	3.83	3.36	0.02	0.00	0.00	0.00	0.05	33.03
1995	2.18	8.96	5.63	27.38	0.71	16.02	6.24	1.37	1.29	0.01	0.00	0.00	69.79
1996	0.34	0.00	11.60	17.62	13.45	6.40	2.94	5.00	0.03	0.00	0.00	0.01	57.39
1997	3.42	6.03	26.10	16.06	0.27	1.90	0.89	0.14	0.19	0.02	0.59	0.00	55.61
1998	0.88	12.34	4.98	18.35	27.16	7.56	4.09	5.44	0.03	0.00	0.01	0.22	81.06
1999	1.17	10.22	2.13	11.29	12.28	6.07	3.84	0.05	0.52	0.00	0.00	0.18	47.75
2000	0.46	5.43	0.64	17.45	20.47	2.89	3.15	0.96	0.16	0.00	0.19	0.45	52.25
2001	5.91	1.66	1.19	9.08	11.04	4.05	3.16	0.00	0.07	0.00	0.01	0.22	36.39
2002	1.31	9.49	18.30	5.44	3.41	5.02	0.39	1.00	0.00	0.00	0.03	0.00	44.39
2003	0.00	6.25	23.70	3.04	3.11	2.57	6.16	1.30	0.13	0.00	0.01	0.00	46.27

Data Table B-1

Scotts Valley Area Historic WY Precipitation

(inches)

Wastewater Treatment Plant

WY	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	WY Total
2004	0.25	4.16	17.20	4.64	11.28	1.40	0.93	0.07	0.00	0.06	0.00	0.16	40.15
2005	7.82	3.65	15.03	8.90	7.53	10.64	4.39	2.68	1.06	0.00	0.00	0.11	61.81
2006	0.11	2.31	21.95	7.34	5.35	15.54	11.59	0.91	0.00	0.00	0.00	0.00	65.1
2007	0.41	2.70	6.79	0.78	10.10	0.38	2.54	0.49	0.00	0.00	0.00	0.34	24.53
2008	2.24	0.58	6.43	19.82	7.53	0.34	0.40	0.00	0.00	0.00	0.00	0.00	37.34
2009	1.73	5.31	4.64	2.13	17.42	2.94	0.50	1.41	0.01	0.00	0.00	0.27	36.36
2010	8.45	0.37	4.92	11.47	8.33	4.56	5.23	1.25	0.00	0.03	0.04	0.00	44.65
2011	4.62	5.09	15.17	2.05	10.65	13.79	0.74	3.41	3.15	0.00	0.04	0.02	58.73
2012	3.26	3.67	0.18	7.57	2.37	12.87	3.58	0.03	0.17	0.02	0.00	0.00	33.72
2013	1.59	10.80	13.67										---
Average	2.39	4.72	9.11	9.28	8.56	6.59	2.70	1.27	0.36	0.01	0.04	0.27	

Data Table C-2

Spring Discharges - Scotts Valley, CA

Eagle Creek

DATE	Discharge (cfs)	Discharge (gpm)
3/28/2001	1.81	812.38
10/16/2001	0.33	148.11
3/21/2002	0.84	377.02
9/25/2002	0.33	148.11
4/7/2003	0.66	296.23
10/16/2003	0.33	148.11
3/24/2004	0.66	296.23
11/15/2004	0.42	188.51
4/20/2005	0.66	296.23
10/25/2005	0.35	157.99

Ferndell Spring

DATE	Discharge (cfs)	Discharge (gpm)
4/6/2000	0.27	119.57
3/7/2001	0.33	149.46
3/1/2002	0.27	119.57
4/1/2003	0.27	119.57
4/22/2004	0.27	119.57
1/5/2005	0.33	149.46
1/12/2005	0.33	149.46
10/5/2005	0.24	109.60
11/14/2006	0.27	120.02
10/23/2008	0.19	85.01
4/13/2009	0.18	80.00
10/7/2009	0.09	40.00
1/17/2011	0.18	80.00
1/15/2012	0.22	99.99

Redwood Spring

DATE	Discharge (cfs)	Discharge (gpm)
4/6/2000	0.16	69.75
3/7/2001	0.17	74.73
3/1/2002	0.17	74.73
4/1/2003	0.16	69.75
4/22/2004	0.17	74.73
1/5/2005	0.17	74.73
1/12/2005	0.17	74.73
10/1/2005	0.13	59.78

11/14/2006	0.13	60.01
10/23/2008	0.10	45.00
4/13/2009	0.17	75.00
10/7/2009	0.08	37.00
1/17/2011	0.09	40.00
1/15/2012	0.11	50.00

Data Table C-3

Bean Creek Average Monthly Stream Flow

(cfs)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1989					3.15	17.00	4.22	2.33	2.20	1.88	1.84	1.98
1990	2.98	4.10	3.01	4.03	4.65	3.92	2.62	3.01	2.14	2.00	1.90	1.76
1991	1.96	2.00	2.16	2.11	2.42	32.00	4.57	2.33	1.96	1.71	1.87	1.83
1992	2.47	2.23	4.20	2.89	52.00	13.20	3.77	2.45	2.53	2.27	1.99	2.02
1993	2.13	1.96	12.10	80.10	52.10	22.60	7.91	3.88	3.01	2.33	2.28	2.26
1994	2.15	2.41	4.44	3.79	21.20	3.81	3.18	2.85	1.79	2.04	2.03	1.87
1995	3.14	5.02	4.87	99.70	13.10	71.80	11.20	11.90	4.34	2.86	2.18	2.10
1996	1.96	2.06	7.07	32.40	63.70	37.10	11.40	10.50	4.57	2.96	2.55	2.22
1997	2.31	5.21	72.50	96.20	15.70	6.40	4.78	3.55	2.78	2.02	2.02	2.16
1998	2.26	5.89	7.47	52.90	167.00	34.10	21.70	12.20	9.41	4.89	3.31	2.63
1999	2.92	5.01	4.80	23.30	47.20	18.20	17.10	4.16	3.10	2.39	2.17	2.08
2000	1.95	3.68	2.74	37.50	95.60	26.30	8.64	5.35	3.78	2.90	2.39	2.50
2001	3.79	2.73	2.70	11.00	31.10	23.20	4.63	2.79	2.17	2.02	1.85	1.73
2002	2.06	4.29	29.40	25.10	9.24	10.40	5.23	3.42	2.52	2.18	1.95	1.83
2003	2.04	3.71	47.30	18.80	6.26	7.39	10.80	7.33	3.56	2.45	2.00	1.94
2004	1.83	2.73	24.73	33.23	33.74	13.55	4.81	3.27	2.75	2.40	2.08	2.10
2005	5.90	4.10	27.14	41.35	37.70	38.52	14.51	5.86	4.25	3.19	2.58	2.35
2006	2.04	2.43	39.05	29.97	11.95	44.06	50.93	9.47	5.32	4.14	3.54	2.80
2007	2.66	3.36	4.55	3.25	9.96	4.73	3.24	2.35	2.16	1.94	1.77	1.71
Month Average	**2.59**	**3.50**	**16.68**	**33.20**	**35.67**	**22.54**	**10.28**	**5.21**	**3.39**	**2.56**	**2.23**	**2.10**

Data Table C-4

Carbonera Creek Average Monthly Stream Flow

(cfs)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1985						7.96	1.33	0.50	0.21	0.01	0.00	0.14
1986	0.45	4.01	7.27	15.40	63.90	32.00	1.89	0.39	0.07	0.04	0.00	0.23
1987	0.04	0.00	0.51	1.26	11.40	5.14	0.41	0.10	0.00	0.01	0.02	0.03
1988	0.25	1.06	7.98	6.57	0.95	0.25	1.85	0.51	0.00	0.03	0.05	0.04
1989	0.29	4.86	10.90	3.10	1.42	20.60	0.91	0.34	0.25	0.21	0.91	0.68
1990	3.01	1.64	0.61	2.12	3.11	1.48	0.45	3.22	0.35	0.01	0.04	0.05
1991	0.20	0.18	0.63	0.35	2.24	25.10	1.16	0.25	0.12	0.02	0.09	0.37
1992	0.86	0.55	2.92	2.50	29.40	3.52	0.62	0.23	0.21	0.04	0.02	0.00
1993	0.48	0.12	6.83	40.30	19.30	4.44	1.63	0.83	0.37	0.09	0.05	0.05
1994	0.27	1.20	3.13	2.57	11.60	0.91	1.22	0.94	0.15	0.04	0.01	0.03
1995	0.73	3.99	3.63	41.00	4.79	28.50	3.70	3.94	0.93	0.39	0.37	0.25
1996	0.22	0.30	5.97	15.80	22.50	10.70	3.60	4.72	0.53	0.26	0.18	0.24
1997	1.34	6.24	38.30	33.90	3.09	1.89	0.96	0.36	0.47	0.49	0.61	0.39
1998	0.73	6.02	5.02	23.50	68.10	11.00	7.42	5.63	1.95	0.59	0.37	0.41
1999	0.58	5.60	1.96	15.00	23.60	8.56	6.26	0.65	0.46	0.51	0.38	0.36
2000	0.38	2.99	0.73	31.10	55.40	14.30	4.73	1.21	0.57	0.37	0.43	0.38
2001	2.36	0.96	0.84	9.07	19.70	8.68	2.29	0.59	0.37	0.31	0.21	0.21
2002	0.50	5.59	24.10	11.00	3.22	3.82	1.21	0.84	0.30	0.26	0.28	0.15
2003	0.07	2.52	30.40	5.89	2.33	3.03	4.84	2.42	0.68	0.18	0.11	0.10
2004	0.02	1.34	19.33	12.48	14.82	3.44	0.53	0.31	0.15	0.10	0.03	0.04
2005	3.84	2.15	27.74	20.17	14.35	18.89	4.44	2.40	1.11	0.32	0.33	0.18
2006	0.12	0.96	30.92	14.81	7.16	23.59	30.17	1.95	0.56	0.19	0.30	0.25
2007	0.22	1.21	3.64	0.78	10.60	1.30	1.26	0.24	0.04	0.03	0.01	0.06
Month Average	**0.77**	**2.43**	**10.61**	**14.03**	**17.86**	**10.40**	**3.60**	**1.42**	**0.43**	**0.19**	**0.21**	**0.20**

Appendix D: Groundwater elevation and aquifer test data summary

APPENDIX D - Groundwater Elevation Data Summary for 1985 to 2013

Well	Aquifer	Number of Data Points	Minimum Groundwater Elevation	Maximum Groundwater Elevation	Range of Groundwater Elevations	Earliest Data	Most Recent Data
Unit		#	feet	feet	feet	year	year
#12 GLENWOOD MONITOR	Santa Margarita	30	424.7	432.2	7.5	1989	1997
AP-1	Santa Margarita	98	333.7	347.6	13.9	1988	2009
AP-2	Santa Margarita	86	337.3	345.0	7.7	1988	2003
AP-3	Santa Margarita	59	336.8	347.6	10.8	1988	1996
AP-3N	Santa Margarita	12	345.5	349.0	3.5	2002	2010
BCW-2	Santa Margarita	54	346.3	358.0	11.7	1987	1994
BCW-3	Santa Margarita	103	346.3	353.3	7.1	1987	2003
BCW-6	Santa Margarita	53	331.9	340.3	8.5	1988	2003
BCW-7	Santa Margarita	71	334.7	337.2	2.5	1988	2003
BCW-8	Santa Margarita	26	334.7	335.5	0.8	1988	2003
BILLAWALLA	Santa Margarita	28	433.4	440.3	6.9	1986	1990
BL Ashram	Santa Margarita	90	325.2	334.3	9.2	1991	2013
BL Machlis	Santa Margarita	78	316.0	361.6	45.6	1991	2013
BL MW-01	Santa Margarita	86	344.6	375.2	30.6	1988	2013
BL MW-02	Santa Margarita	98	330.6	358.4	27.8	1988	2013
BL MW-03	Santa Margarita	98	329.5	347.0	17.6	1988	2013
BL MW-04	Santa Margarita	99	334.4	351.5	17.1	1988	2013
BL MW-05	Santa Margarita	88	332.2	355.8	23.6	1991	2013
BL MW-06	Santa Margarita	90	328.9	356.1	27.1	1991	2013
BL MW-07	Santa Margarita	82	320.9	331.3	10.4	1992	2013
BL MW-08	Santa Margarita	84	306.6	323.3	16.7	1992	2013
BL MW-09	Santa Margarita	85	323.7	330.3	6.6	1992	2013
BL MW-10	Santa Margarita	76	333.8	350.6	16.8	1994	2013
BL MW-11	Santa Margarita	74	336.1	356.6	20.6	1994	2013
BOWMAN PIT TEST #1	Santa Margarita	84	339.7	345.0	5.3	1986	2003
CASA WAY	Santa Margarita	66	399.6	410.9	11.3	1986	2002
CHAMPION	Santa Margarita	38	500.3	545.3	45.0	1985	1994
DH-9	Santa Margarita	74	367.2	383.3	16.1	1986	2003
GRACE WAY MONITOR	Santa Margarita	16	448.5	457.1	8.6	1988	1991
HIDDEN GLEN	Santa Margarita	231	613.0	671.2	58.2	1986	2010
KAISER #2	Santa Margarita	186	377.3	414.0	36.7	1985	2006
KAISER #3	Santa Margarita	79	390.7	416.7	26.0	1987	2003
KV-1	Santa Margarita	9	351.0	353.4	2.4	2012	2013
KV-2	Santa Margarita	9	350.9	356.1	5.2	2012	2013
KV-4	Santa Margarita	9	353.4	357.8	4.4	2012	2013
Lonestar #1	Santa Margarita	45	391.3	404.0	12.7	1989	1994
Lonestar #2	Santa Margarita	45	354.5	363.5	9.0	1989	1994
MISSION SPRINGS	Santa Margarita	35	354.0	369.5	15.5	1986	2004
MW-1 Chevron	Santa Margarita	64	472.2	491.2	19.0	1996	2013
MW-2 Chevron	Santa Margarita	62	474.5	492.5	18.0	1996	2013
MW-2 Shell	Santa Margarita	47	486.9	495.4	8.5	1995	2013
MW-3 Chevron	Santa Margarita	62	482.0	492.3	10.3	1996	2013
MW-3 Shell	Santa Margarita	66	483.0	491.6	8.6	1995	2013
MW-4 Chevron	Santa Margarita	66	477.8	488.1	10.3	1995	2013
MW-4 Shell	Santa Margarita	34	483.0	492.8	9.8	1995	2005
MW-5 Chevron	Santa Margarita	66	481.8	492.2	10.4	1995	2013
MW-5 Shell	Santa Margarita	65	481.0	497.8	16.8	1995	2013

APPENDIX D - Groundwater Elevation Data Summary for 1985 to 2013

Well	Aquifer	Number of Data Points	Minimum Groundwater Elevation	Maximum Groundwater Elevation	Range of Groundwater Elevations	Earliest Data	Most Recent Data
Unit		#	feet	feet	feet	year	year
MW-6 Chevron	Santa Margarita	38	486.5	494.0	7.5	1995	2004
MW-6 Shell	Santa Margarita	12	504.6	515.7	11.1	1996	2009
MW-7 Chevron	Santa Margarita	38	484.7	496.0	11.3	1995	2004
MW-8 Chevron	Santa Margarita	63	470.7	487.9	17.2	1995	2013
NEW PROBATION	Santa Margarita	377	440.0	514.7	74.7	1986	2012
OB-1	Santa Margarita	113	334.9	353.4	18.5	1986	2013
OB-2	Santa Margarita	114	335.6	353.5	17.9	1986	2013
OB-3	Santa Margarita	111	336.4	353.8	17.3	1986	2013
OLD PROBATION	Santa Margarita	145	460.0	519.0	59.0	1990	2003
Olympia 1	Santa Margarita	353	301.0	369.0	68.0	1986	2013
Olympia 2	Santa Margarita	443	271.0	370.0	99.0	1986	2013
Olympia 3	Santa Margarita	308	268.0	364.0	96.0	1992	2013
Pasatiempo MW-2	Santa Margarita	247	486.0	516.0	30.0	1992	2013
QHQ Active Well	Santa Margarita	2	464.1	464.6	0.5	1990	1991
QHQ Inactive Well	Santa Margarita	141	439.7	477.1	37.4	1990	2005
QHQ MW-2	Santa Margarita	122	473.8	508.2	34.4	1990	2005
QHQ MW-4	Santa Margarita	136	443.0	487.1	44.1	1990	2007
QHQ MW-5	Santa Margarita	139	470.3	511.2	40.9	1990	2005
QHQ MW-6B	Santa Margarita	151	466.0	532.9	66.9	1990	2007
QHQ MW-7	Santa Margarita	87	380.7	480.4	99.8	1998	2007
Quail #3	Santa Margarita	68	391.0	444.0	53.0	1987	1998
Quail #4	Santa Margarita	295	376.0	458.0	82.0	1985	2002
Quail #4A	Santa Margarita	186	362.5	498.5	136.0	2002	2013
Quail #5	Santa Margarita	247	368.0	447.0	79.0	1985	2000
Quail #5A	Santa Margarita	221	360.7	453.7	93.0	2001	2013
Quail #8	Santa Margarita	329	322.0	386.0	64.0	1985	2013
Quail MW-A	Santa Margarita	171	408.0	413.0	5.0	1998	2013
Quail MW-B	Santa Margarita	170	472.0	493.0	21.0	1998	2013
Quail MW-C	Santa Margarita	161	475.0	526.0	51.0	1998	2013
RA-1	Santa Margarita	121	332.0	353.4	21.5	1986	2013
RA-2	Santa Margarita	105	328.8	352.2	23.4	1987	2010
RA-3	Santa Margarita	110	332.4	346.7	14.3	1987	2013
RA-4	Santa Margarita	91	331.3	372.3	41.0	1987	2013
RMC-2	Santa Margarita	49	373.6	390.7	17.1	1989	1996
RMC-5	Santa Margarita	2	371.4	371.7	0.4	1996	1996
RMC-6	Santa Margarita	61	354.8	371.7	16.9	1989	2001
SK-1	Santa Margarita	67	324.1	340.8	16.7	1988	2003
SK-2	Santa Margarita	53	319.4	340.1	20.8	1988	1997
SKYPARK	Santa Margarita	3	336.7	351.7	15.0	1985	1986
SKYPARK M-1	Santa Margarita	113	337.2	349.2	11.9	1986	2009
SKYPARK M-2	Santa Margarita	13	345.0	348.8	3.8	1986	1987
SUPPLY WELL	Santa Margarita	79	338.0	349.4	11.4	1986	2013
SV ROCKERY	Santa Margarita	78	478.0	510.1	32.1	1986	2006
SV1-MW	Santa Margarita	57	640.3	664.3	24.0	1986	2004
SV3-MW B	Santa Margarita	73	465.3	542.7	77.4	1986	2010
SV4-MW	Santa Margarita	80	369.0	417.1	48.1	1986	2013
SV5-MW A	Santa Margarita	6	436.4	470.1	33.7	1986	1988

APPENDIX D - Groundwater Elevation Data Summary for 1985 to 2013

Well	Aquifer	Number of Data Points	Minimum Groundwater Elevation	Maximum Groundwater Elevation	Range of Groundwater Elevations	Earliest Data	Most Recent Data
Unit		#	feet	feet	feet	year	year
SV5-MW B	Santa Margarita	87	428.7	471.4	42.7	1986	2007
SVWD AB303 MW-1	Santa Margarita	3	477.8	487.1	9.3	2004	2011
SVWD MW-3B (SHALLOW)	Santa Margarita	4	404.9	452.7	47.8	2004	2013
TW-18	Santa Margarita	105	457.1	473.0	15.9	1998	2013
VISTA DEL LAGO #1	Santa Margarita	58	495.6	523.6	28.0	1985	2005
WATKINS JOHNSON	Santa Margarita	13	345.3	353.3	8.0	1985	1987
Wescosa Well	Santa Margarita	6	430.8	433.4	2.6	1999	2001
WJ-11	Santa Margarita	127	337.9	354.1	16.3	1986	2013
WJ-21	Santa Margarita	59	337.0	349.0	12.0	1986	2013
WJ-22	Santa Margarita	114	337.0	348.6	11.6	1986	2009
WJ-23	Santa Margarita	50	344.7	356.3	11.6	1986	1994
WJ-25A	Santa Margarita	117	327.2	350.5	23.3	1986	2013
WJ-26	Santa Margarita	111	311.7	353.9	42.2	1986	2013
WJ-27A	Santa Margarita	102	338.5	353.0	14.5	1986	2002
WJ-28	Santa Margarita	56	329.3	353.0	23.7	1986	1994
WJ-29A	Santa Margarita	110	338.8	378.6	39.8	1986	2010
WJ-29B	Santa Margarita	15	342.6	356.8	14.2	1986	1994
WJ-29C	Santa Margarita	2	351.3	352.3	1.0	1986	1987
WJ-30	Santa Margarita	32	337.9	342.2	4.3	1988	1994
WJ-30A	Santa Margarita	37	338.3	342.0	3.7	1988	1994
WJ-32	Santa Margarita	8	356.0	357.8	1.9	1988	1992
WJ-32A	Santa Margarita	25	348.2	349.4	1.2	1988	1992
WJ-37A	Santa Margarita	110	336.3	352.3	16.0	1988	2013
WJ-40	Santa Margarita	73	338.9	344.9	6.0	1989	2003
WJ-41	Santa Margarita	122	337.0	351.0	14.1	1989	2013
WJ-43	Santa Margarita	116	337.9	434.3	96.5	1989	2013
WJ-44	Santa Margarita	13	336.5	337.5	1.0	1989	1992
WJ-45	Santa Margarita	14	336.0	336.7	0.8	1989	1992
WJ-46	Santa Margarita	58	329.2	342.4	13.2	1989	2003
WJ-48	Santa Margarita	72	297.4	347.9	50.5	1991	2011
#9 MONITOR WELL	Monterey	200	341.0	478.3	137.3	1985	2013
HARMONY FOODS	Monterey	48	417.8	442.0	24.2	1985	1996
KV-3	Monterey	9	391.0	398.0	7.0	2011	2013
MONTEVALLE #2	Monterey	33	442.0	460.1	18.1	1985	1991
MONTEVALLE #3	Monterey	76	339.3	454.9	115.6	1985	2006
SK-3	Monterey	21	337.6	344.9	7.3	1988	1992
SK-4	Monterey	5	343.0	343.0	0.0	1989	1989
SKYPRK SUPLY	Monterey	33	343.4	369.0	25.5	1988	1994
SVWD #9	Monterey	245	290.4	477.9	187.5	1986	2013
WJ-49	Monterey	74	337.7	346.6	8.9	1991	2013
#11 MONITOR	Lompico	136	181.6	464.3	282.7	1986	2011
#13 MONITOR	Lompico	14	449.0	481.0	32.0	1990	1993
#3 EL PUEBLO	Lompico	3	398.4	403.0	4.6	1988	1988
#3A EL PUEBLO	Lompico	22	353.4	438.1	84.7	1986	1991
#6 SVWD	Lompico	40	373.8	457.9	84.1	1986	1994
CEEW-1	Lompico	33	354.7	415.8	61.2	2003	2013
CEMW-11	Lompico	9	400.7	422.8	22.1	1996	2000

APPENDIX D - Groundwater Elevation Data Summary for 1985 to 2013

Well	Aquifer	Number of Data Points	Minimum Groundwater Elevation	Maximum Groundwater Elevation	Range of Groundwater Elevations	Earliest Data	Most Recent Data
Unit		#	feet	feet	feet	year	year
CEMW-12	Lompico	34	374.2	384.5	10.3	1998	2009
CEMW-15	Lompico	45	378.2	426.6	48.4	2001	2013
CEMW-17B	Lompico	37	359.5	388.7	29.2	2003	2013
CEMW-18C	Lompico	36	345.5	362.3	16.8	2003	2013
CEMW-19B	Lompico	33	343.5	360.4	16.9	2003	2013
CEMW-20A	Lompico	29	346.9	359.5	12.7	2003	2013
CEMW-20B	Lompico	36	342.1	359.5	17.4	2003	2013
CEMW-21C	Lompico	36	287.6	341.7	54.1	2003	2013
CEMW-22A	Lompico	33	337.2	351.8	14.6	2004	2013
CEMW-22B	Lompico	34	337.2	352.4	15.2	2004	2013
CEMW-22C	Lompico	34	328.8	354.2	25.4	2004	2013
CEMW-23B	Lompico	34	332.8	374.5	41.8	2004	2013
CEMW-23C	Lompico	34	330.3	353.8	23.5	2004	2013
CEMW-9	Lompico	59	380.0	429.7	49.7	1996	2013
DC MW-13B	Lompico	48	327.2	345.6	18.4	2004	2013
EL PUEBLO WELL FIELD	Lompico	2	416.0	423.0	7.0	1985	1985
ESTRELLA	Lompico	117	353.4	521.4	168.0	1985	2000
FLOREA	Lompico	77	452.5	494.0	41.5	1986	2006
HIDDEN OAKS	Lompico	84	378.7	485.6	106.9	1987	2013
KAISER #4	Lompico	100	441.0	540.0	99.0	1986	1998
KAISER #4A	Lompico	17	405.0	465.0	60.0	1998	2004
Lompico Test	Lompico	84	288.3	367.3	79.0	2000	2011
MANANA WOODS #2	Lompico	105	286.0	426.1	140.1	1989	2013
MT. HERMON #1	Lompico	17	338.0	408.4	70.4	1998	2009
MT. HERMON #2	Lompico	22	319.9	425.9	106.0	1996	2011
MUSHROOM FARM	Lompico	42	382.2	520.3	138.1	1986	2002
OLD MANANA WOODS	Lompico	55	345.3	472.6	127.3	1985	2002
Pasatiempo #6	Lompico	467	307.0	478.0	171.0	1992	2013
Pasatiempo #7	Lompico	349	301.0	478.0	177.0	1992	2013
Pasatiempo MW-1	Lompico	249	327.0	476.0	149.0	1992	2013
SPRING LAKES #3	Lompico	28	428.2	510.4	82.2	1985	1990
SPRING LAKES #4	Lompico	104	289.3	504.5	215.2	1985	2013
SPRING LAKES #5	Lompico	48	309.2	412.0	102.8	1991	2004
SPRING LAKES #6	Lompico	10	252.0	292.0	40.0	2005	2013
SV3-MW C	Lompico	74	414.7	538.8	124.2	1986	2010
SVWD #10	Lompico	255	279.5	495.9	216.4	1986	2013
SVWD #10A	Lompico	21	293.4	328.0	34.6	2009	2013
SVWD #11	Lompico	125	254.6	440.6	186.1	1987	2008
SVWD #11A	Lompico	109	253.4	363.9	110.5	1998	2013
SVWD #11B	Lompico	119	164.0	358.2	194.2	2000	2013
SVWD #7	Lompico	210	283.1	442.5	159.5	1985	2010
SVWD AB303 MW-2	Lompico	2	378.0	382.2	4.2	2004	2010
SVWD MW-3A (DEEP)	Lompico	4	342.0	382.7	40.7	2004	2012
TW-19	Lompico	95	313.4	394.1	80.7	1998	2013
#15 MONITOR	Butano	138	215.2	429.4	214.2	1991	2013
Canham Well	Butano	1	416.3	416.3	0.0	2013	2013
Oly-10	Butano	38	471.5	475.4	3.9	2002	2013

APPENDIX D - Groundwater Elevation Data Summary for 1985 to 2013

Well	Aquifer	Number of Data Points	Minimum Groundwater Elevation	Maximum Groundwater Elevation	Range of Groundwater Elevations	Earliest Data	Most Recent Data
Unit		#	feet	feet	feet	year	year
Oly-9	Butano	38	472.0	477.0	5.0	2002	2013
Stonewood	Butano	1	840.0	840.0	0.0	2013	2013
SVWD #3B	Butano	105	188.6	369.5	180.9	1996	2013
SVWD #7A	Butano	93	154.6	434.5	279.9	1992	2012
CEMW-13	Locatelli	21	390.6	430.3	39.7	2001	2012
CEMW-20C	Locatelli	1	390.9	390.9	0.0	2008	2008
CEMW-4	Locatelli	47	355.4	419.5	64.1	1996	2013
INDIAN SPRING #2	Locatelli	133	382.6	477.5		1985	2013

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Ben Lomond Landfill	Oct-89	SM	K_h	1.6	ft/d	Slug test analysis	EMCON, Oct 1989, cited in Johnson, Sep 2001a	MW-1 and MW-4; Likely representative of local fine-grained sandstones (Johnson, September 2001a)
Ben Lomond Landfill	Jul-90	SM	K_h	50	ft/d	Unknown	EMCON, Jul 1990, cited in Johnson, Sep 2001a	P-1; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Dec-94	SM	T	1,470	ft^2/d	Neuman	CH2MHILL, Dec 1994, cited in Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Dec-94	SM	K_h	42	ft/d		CH2MHILL, Dec 1994, cited in Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Dec-94	SM	K_v/K_h	0.2	--	Neuman	CH2MHILL, Dec 1994, cited in Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Dec-94	SM	S	0.006	--	Neuman	CH2MHILL, Dec 1994, cited in Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Dec-94	SM	S_y	0.2	--	Neuman	CH2MHILL, Dec 1994, cited in Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Sep-01	SM	T	1,500	ft^2/d	Neuman	Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Sep-01	SM	K_h	43	ft/d		Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Sep-01	SM	K_v/K_h	0.1	--	Neuman	Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Sep-01	SM	S	0.008	--	Neuman	Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Ben Lomond Landfill	Sep-01	SM	S_y	0.12	--	Neuman	Johnson, Sep 2001a	MW-5; Likely representative of basal gravel (Johnson, September 2001a)
Entire Area	Jun-97	SM	K_h	5.3	ft/d		Todd, Jun 1997	Average value based on existing information
Entire Area	Apr-81	SM	SC	10	gpm/ft		Muir, Apr 1981	Average
Entire Area	Apr-81	SM	SC	2 to 40	gpm/ft		Muir, Apr 1981	Range
Entire Area	Aug-81	SM	K_h	6 to 50	ft/d		Ellis, Aug 1981, cited in Johnson, Sep 2001a	
Kaiser #4	Sep-01	SM	K_h	7 to 20	ft/d		Johnson, Sep 2001b	Assumes the aquifers are continuous together
Kaiser #4	Sep-01	SM	K_v	1	ft/d		Johnson, Sep 2001b	Assumes the aquifers are continuous together
Olympia #2	May-80	SM	SC	10	gpm/ft		Geoconsultants, May 1980, cited in Johnson, Dec 1989	
Olympia #2	May-80	SM	T	1,600	ft^2/d	Grain size analysis	Geoconsultants, May 1980, cited in Johnson, Dec 1989	
Olympia #2	May-80	SM	K_h	40	ft/d		Geoconsultants, May 1980, cited in Johnson, Dec 1989	
Olympia #2	May-80	SM	b	40	ft		Geoconsultants, May 1980, cited in Johnson, Dec 1989	Length of screened interval
Olympia #2	Aug-81	SM	T	1,600	ft^2/d	Unknown	Ellis, Aug 1981, cited in Johnson, Sep 2001a	Pumping well
Olympia #2	Aug-81	SM	K_h	9 to 10	ft/d		Ellis, Aug 1981, cited in Johnson, Sep 2001a	
Olympia #2	Aug-81	SM	S_y	0.2	--	Unknown	Ellis, Aug 1981, cited in Johnson, Sep 2001a	
Olympia #2	Jun-87	SM	K_h	9.4	ft/d		Jacobvitz, Jun 1987, cited in WJE, Feb 1993	Note that Johnson (Dec 1989) states that this is a bad estimate
Olympia #2	Dec-89	SM	T	2,400	ft^2/d	Neuman	Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Dec-89	SM	K_h	18	ft/d		Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Dec-89	SM	K_v/K_h	0.5	ft/d	Neuman	Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Dec-89	SM	b	130	ft		Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Dec-89	SM	S	0.0026	--	Neuman	Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Dec-89	SM	S_y	0.19	--	Neuman	Johnson, Dec 1989	Pumping well and 5 observation wells
Olympia #2	Sep-01	SM	SC	13.2	gpm/ft		Johnson, Sep 2001a	From driller's log
Olympia #2	Sep-01	SM	T	2,640	ft^2/d	Based on SC	Johnson, Sep 2001a	

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Olympia #2	Sep-01	SM	K_h	20	ft/d		Johnson, Sep 2001a	
Olympia #2	Sep-01	SM	T	3,400 to 4,200	ft^2/d	Neuman	Johnson, Sep 2001a	Pumping well and 5 observation wells
Olympia #2	Sep-01	SM	K_h	26 to 34	ft/d		Johnson, Sep 2001a	Pumping well and 5 observation wells
Olympia #2	Sep-01	SM	K_v/K_h	0.3 to 0.8	--	Neuman	Johnson, Sep 2001a	Pumping well and 5 observation wells
Olympia #2	Sep-01	SM	S	0.018 to 0.02	--	Neuman	Johnson, Sep 2001a	Pumping well and 5 observation wells
Olympia #2	Sep-01	SM	S_y	0.17 to 0.25	--	Neuman	Johnson, Sep 2001a	Pumping well and 5 observation wells
Olympia #2T	May-80	SM	SC	10	gpm/ft		Geoconsultants, May 1980, cited in Johnson, September 2001a	
Olympia #2T	May-80	SM	T	6,200	ft^2/d	Grain size analysis	Geoconsultants, May 1980, cited in Johnson, September 2001a	
Olympia #2T	May-80	SM	K_h	40	ft/d		Geoconsultants, May 1980, cited in Johnson, September 2001a	
Olympia #2T	Sep-01	SM	T	2,000	ft^2/d	Based on SC	Johnson, September 2001a	
Olympia #2T	Sep-01	SM	K_h	13	ft/d		Johnson, September 2001a	
Olympia #3	Sep-01	SM	SC	13.9	gpm/ft		Johnson, Sep 2001a	
Olympia #3	Sep-01	SM	T	1,975	ft^2/d	Theis	Johnson, Sep 2001a	Pumping well
Olympia #3	Sep-01	SM	K_h	16 to 21	ft/d		Johnson, Sep 2001a	
Plum Valley	Apr-81	SM	SC	6.7	gpm/ft		Geoconsultants, Apr 1981	Test Well #1
Plum Valley	Apr-81	SM	T	2,120	ft^2/d	Cooper-Jacob	Geoconsultants, Apr 1981	Test Well #1
Plum Valley	Nov-81	SM	SC	8.7	gpm/ft		Geoconsultants, Nov 1981	Pumping well (Test Well #1); measured at start of 30-day test
Plum Valley	Nov-81	SM	SC	5.6	gpm/ft		Geoconsultants, Nov 1981	Pumping well (Test Well #1); measured at end of 30-day test
Plum Valley	Nov-81	SM	T	2,700	ft^2/d	Cooper-Jacob	Geoconsultants, Nov 1981	Pumping well (Test Well #1)
Plum Valley	Apr-81	SM	SC	3.2	gpm/ft		Geoconsultants, Apr 1981	Test Well #2
Plum Valley	Apr-81	SM	T	294	ft^2/d	Cooper-Jacob	Geoconsultants, Apr 1981	Test Well #2
Plum Valley	Nov-81	SM	T	6,700	ft^2/d	Cooper-Jacob	Geoconsultants, Nov 1981	Observation well (Test Well #2); likely not representative
Plum Valley	Nov-81	SM	T	6,000	ft^2/d	Cooper-Jacob	Geoconsultants, Nov 1981	Observation well (Santa Cruz Aggregates Well); likely not representative
Plum Valley	Jan-84	SM	T	3,070	ft^2/d	Cooper-Jacob?	Todd, Jan 1984	Measurements from Observation Well #2
Plum Valley	Jan-84	SM	S	0.14	--	Cooper-Jacob?	Todd, Jan 1984	Measurements from Observation Well #2
Plum Valley	Jun-87	SM	K_h	71.5	ft/d		Jacobvitz, Jun 1987, cited in WJE, Feb 1993	
Plum Valley	Jun-87	SM	S	0.13	--	Unknown	Jacobvitz, Jun 1987, cited in WJE, Feb 1993	
QH-3	Jul-88	SM	SC	3.2	gpm/ft		Johnson, Jul 1988, cited in Johnson, Sep 2001a	
QH-3	Jul-88	SM	T	480 to 820	ft^2/d	Cooper-Jacob	Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8); superceded by Johnson, Sep 2001a
QH-3	Jul-88	SM	K_h	10 to 16	ft/d		Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8); superceded by Johnson, Sep 2001a
QH-3	Jul-88	SM	T	450 to 720	ft^2/d	Cooper-Jacob	Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8); superceded by Johnson, Sep 2001a
QH-3	Jul-88	SM	K_h	9 to 14	ft/d		Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8); superceded by Johnson, Sep 2001a
QH-3	Sep-01	SM	T	430	ft^2/d	Neuman	Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8)
QH-3	Sep-01	SM	K_h	6 to 8	ft/d		Johnson, Sep 2001a	Pumping well and observation wells (QH-4, QH-5, and QH-8)
QH-3	Sep-01	SM	SC	2.5	gpm/ft		Johnson, Sep 2001a	
QH-3	Sep-01	SM	T	500	ft^2/d	Based on SC	Johnson, Sep 2001a	
QH-3	Sep-01	SM	K_h	5.5	ft/d	Based on SC	Johnson, Sep 2001a	
QH-4	Jun-00	SM	SC	5.5	gpm/ft		Johnson, Jun 2000, cited in Johnson, Sep 2001a	
QH-4	Jun-00	SM	T	750	ft^2/d	Neuman	Johnson, Jun 2000, cited in Johnson, Sep 2001a	Pumping well
QH-4	Jun-00	SM	K_h	6.6 to 7.9	ft/d		Johnson, Jun 2000, cited in Johnson, Sep 2001a	Pumping well

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
QH-4	Jun-00	SM	T	650	ft^2/d	Neuman	Johnson, Jun 2000, cited in Johnson, Sep 2001a	Observation well (QH-2)
QH-4	Jun-00	SM	K_h	5.8 to 6.4	ft/d		Johnson, Jun 2000, cited in Johnson, Sep 2001a	Observation well (QH-2)
QH-4	Jun-00	SM	K_v/K_h	1	--		Johnson, Jun 2000, cited in Johnson, Sep 2001a	Observation well (QH-2)
QH-4	Jun-00	SM	S	0.019	--		Johnson, Jun 2000, cited in Johnson, Sep 2001a	Observation well (QH-2)
QH-4	Jun-00	SM	S_y	0.18	--		Johnson, Jun 2000, cited in Johnson, Sep 2001a	Observation well (QH-2)
QH-4	Sep-01	SM	SC	3.5	gpm/ft		Johnson, Sep 2001a	
QH-4	Sep-01	SM	T	680	ft^2/d	Based on SC	Johnson, Sep 2001a	
QH-4	Sep-01	SM	K_h	7.7	ft/d	Based on SC	Johnson, Sep 2001a	
QH-5	Jul-88	SM	SC	6.9	gpm/ft		Johnson, Jul 1988, cited in Johnson, Sep 2001a	
QH-5	Jul-88	SM	T	415 to 440	ft^2/d	Cooper-Jacob	Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8); superceded by Johnson, Sep 2001a
QH-5	Jul-88	SM	K_h	7.5 to 8	ft/d		Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8); superceded by Johnson, Sep 2001a
QH-5	Jul-88	SM	T	360	ft^2/d	Boulton	Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8); superceded by Johnson, Sep 2001a
QH-5	Jul-88	SM	K_h	6.5	ft/d		Johnson, Jul 1988, cited in Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8); superceded by Johnson, Sep 2001a
QH-5	Sep-01	SM	T	600	ft^2/d	Neuman	Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8)
QH-5	Sep-01	SM	K_h	9 to 11	ft/d		Johnson, Sep 2001a	Pumping well and observation wells (QH-3, QH-4, and QH-8)
QH-5	Sep-01	SM	SC	2.8	gpm/ft		Johnson, Sep 2001a	
QH-5	Sep-01	SM	T	550	ft^2/d	Based on SC	Johnson, Sep 2001a	
QH-5	Sep-01	SM	K_h	6.8	ft/d	Based on SC	Johnson, Sep 2001a	
QH-5A	Sep-01	SM	SC	6.3	gpm/ft		Johnson, Sep 2001a	
QH-5A	Sep-01	SM	T	950	ft^2/d	Neuman	Johnson, Sep 2001a	Pumping well
QH-5A	Sep-01	SM	K_h	10 to 13	ft/d		Johnson, Sep 2001a	Pumping well
QH-8	Sep-01	SM	SC	1	gpm/ft		Johnson, Sep 2001a	
QH-8	Sep-01	SM	T	200	ft^2/d	Based on SC	Johnson, Sep 2001a	
QH-8	Sep-01	SM	K_h	3	ft/d	Based on SC	Johnson, Sep 2001a	
Quail Hollow Area	Sep-01	SM	K_h	6 to 7	ft/d		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Quail Hollow Area	Sep-01	SM	K_v/K_h	0.3 to 0.8	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Quail Hollow Area	Sep-01	SM	S_y	0.18	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Quail Hollow Area	Sep-01	SM	S	0.02	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Quail Hollow Area	Sep-01	SM	K_h	2 to 40	ft/d		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Quail Hollow Area	Sep-01	SM	K_v/K_h	0.1 to 1	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Quail Hollow Area	Sep-01	SM	S_y	0.12 to 0.25	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Quail Hollow Area	Sep-01	SM	S	0.008 to 0.02	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Quail Hollow Basin	Aug-81	SM	K_h	6.7	ft/d		Ellis, Aug 1981, cited in Johnson, Sep 2001a	Average
Quail Hollow Basin	Jul-88	SM	K_h	6.7	ft/d		Johnson, Jul 1988, cited in WJE, Aug 1992	

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Quail Hollow Basin	Jul-88	SM	K_h	0.2	ft/d		Johnson, Jul 1988, cited in WJE, Aug 1992	
Quail Hollow Ranch	Sep-01	SM	SC	6.1	gpm/ft		Johnson, Sep 2001a	
Quail Hollow Ranch	Sep-01	SM	T	760	ft^2/d	Neuman	Johnson, Sep 2001a	Pumping well
Quail Hollow Ranch	Sep-01	SM	K_h	6.4	ft/d		Johnson, Sep 2001a	Pumping well
SVWD #10	Jul-80	SM	T	1,200	ft^2/d		Geoconsultants, Jul 1980	
SVWD MW-3	May-03	SM	T	1,764	ft^2/d	Cooper-Jacob	Todd, May 2003	Pumping well
SVWD MW-3	May-03	SM	K_h	12.6 to 35.3	ft/d		Todd, May 2003	Range depending on estimate of b
SVWD MW-3	May-03	SM	SC	4.1	gpm/ft		Todd, May 2003	30-minute specific capacity
Watkins-Johnson	Sep-85	SM	T	4,630 to 6,000	ft^2/d	See notes	RLSA, Sep 1985	Pumping well (RA-1) with observation wells OB-1 to OB-3; Cooper-Jacob, Boulton, and Theis methods used
Watkins-Johnson	Sep-85	SM	K_h	106 to 136	ft/d		RLSA, Sep 1985	
Watkins-Johnson	Sep-85	SM	S_y	0.18	--	See notes	RLSA, Sep 1985	Pumping well (RA-1) with observation wells OB-1 to OB-3; Cooper-Jacob, Boulton, and Theis methods used
Watkins-Johnson	Sep-85	SM	K_h	106	ft/d		RLSA, Sep 1985	Average
Watkins-Johnson	Sep-85	SM	b	44	ft		RLSA, Sep 1985	Average
Watkins-Johnson	Sep-85	SM	T	4,226	ft^2/d	Boulton and Theis	RLSA, Sep 1985	Average
Watkins-Johnson	Sep-86	SM	K_h	128	ft/d		RLSA, Sep 1986	Pumping wells RA-1 to RA-4 and observation wells including OB-1
Watkins-Johnson	Sep-86	SM	b	60	ft		RLSA, Sep 1986	Pumping wells RA-1 to RA-4 and observation wells including OB-1
Watkins-Johnson	Sep-86	SM	T	7,750	ft^2/d	Butt & McElwee (decon	RLSA, Sep 1986	Pumping wells RA-1 to RA-4 and observation wells including OB-1
Watkins-Johnson	Sep-86	SM	S	0.06	--	Butt & McElwee (decon	RLSA, Sep 1986	Pumping wells RA-1 to RA-4 and observation wells including OB-1
Watkins-Johnson	Sep-88	SM	T	5,100	ft^2/d	Boulton	RLSA, Sep 1988	Pumping well SK-1 and observation wells including OB-1
Watkins-Johnson	Sep-88	SM	b	40	ft		RLSA, Sep 1988	Pumping well SK-1 and observation wells including OB-1
Watkins-Johnson	Sep-88	SM	K_h	128	ft/d		RLSA, Sep 1988	Pumping well SK-1 and observation wells including OB-1
Watkins-Johnson	Sep-88	SM	S_y	0.02	--	Boulton	RLSA, Sep 1988	Pumping well SK-1 and observation wells including OB-1
Westside Santa Cruz	Jan-88	SM	SC	5.6	gpm/ft		Johnson, Jan 1988	
Westside Santa Cruz	Jan-88	SM	T	950 to 1,070	ft^2/d	Cooper-Jacob and Theis	Johnson, Jan 1988	Pumping well (Wolfsen)
Westside Santa Cruz	Jan-88	SM	K_h	6 to 14	ft/d		Johnson, Jan 1988	Pumping well (Wolfsen)
Westside Santa Cruz	Jan-88	SM	T	1,240 to 2,000	ft^2/d	Cooper-Jacob and Theis	Johnson, Jan 1988	Observation well (11S/2W-22L)
Westside Santa Cruz	Jan-88	SM	K_h	8 to 27	ft/d		Johnson, Jan 1988	Observation well (11S/2W-22L)
Westside Santa Cruz	Jan-88	SM	S	0.000032 to 0.00014	--	Cooper-Jacob and Theis	Johnson, Jan 1988	Observation well (11S/2W-22L)
Westside Santa Cruz	Jan-88	SM	T	900 to 1,500	ft^2/d	Cooper-Jacob and Theis	Johnson, Jan 1988	Observation well (City MW)
Westside Santa Cruz	Jan-88	SM	K_h	6 to 20	ft/d		Johnson, Jan 1988	Observation well (City MW)
Westside Santa Cruz	Jan-88	SM	S	0.0018 to 0.0026	--	Cooper-Jacob and Theis	Johnson, Jan 1988	Observation well (City MW)
Westside Santa Cruz	Sep-01	SM	T	630	ft^2/d	Hantush-Jacob	Johnson, Sep 2001a	Pumping well (Wolfsen)
Westside Santa Cruz	Sep-01	SM	K_h	4 to 8	ft/d		Johnson, Sep 2001a	Pumping well (Wolfsen)
Westside Santa Cruz	Sep-01	SM	T	950	ft^2/d	Hantush-Jacob	Johnson, Sep 2001a	Observation well (11S/2W-22L)
Westside Santa Cruz	Sep-01	SM	K_h	6 to 12	ft/d		Johnson, Sep 2001a	Observation well (11S/2W-22L)
Westside Santa Cruz	Sep-01	SM	S	0.00012	--	Hantush-Jacob	Johnson, Sep 2001a	Observation well (11S/2W-22L)
Westside Santa Cruz	Sep-01	SM	T	550	ft^2/d	Hantush-Jacob	Johnson, Sep 2001a	Observation well (City MW)
Westside Santa Cruz	Sep-01	SM	K_h	3.5 to 7	ft/d		Johnson, Sep 2001a	Observation well (City MW)
Westside Santa Cruz	Sep-01	SM	S	0.003	--	Hantush-Jacob	Johnson, Sep 2001a	Observation well (City MW)
Wilder Ranch Area	1979	SM	SC	2.7 to 27	gpm/ft		ESA, 1979	
Wilder Ranch Area	1979	SM	T	1,000 to 8,000	ft^2/d	Based on SC	ESA, 1979	
Wilder Ranch Area	May-84	SM	K_h	13 to 100	ft/d		HEA, May 1984	
Entire Area	Jun-97	M	K_h	0.067	ft/d		Todd, Jun 1997	Average value based on previously-existing model and calibration process
Entire Area	Sep-01	M	K_h	0.1 to 0.2	ft/d		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Entire Area	Sep-01	M	K_v/K_h	0.01	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	M	S_y	0.02	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	M	S	0.001 to 0.002	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	M	K_h	0.05 to 1	ft/d		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Entire Area	Sep-01	M	K_v/K_h	0.001 to 0.1	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Entire Area	Sep-01	M	S_y	0.01 to 0.03	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Entire Area	Sep-01	M	S	0.00001 to 0.005	--		Johnson, Sep 2001a, cited in Johnson, Jun 2002	Range
Plum Valley	Oct-82	M	T	500	ft^2/d	Unknown	Geoconsultants, Oct 1982, cited in Johnson, Sep 2001a	Possibly connected to Santa Margarita via fractures or gravel pack (Butler, 1983)
Plum Valley	Oct-82	M	K_h	3	ft/d		Geoconsultants, Oct 1982, cited in Johnson, Sep 2001a	Possibly connected to Santa Margarita via fractures or gravel pack (Butler, 1983)
Plum Valley	Jan-84	M	T	174	ft^2/d	Unknown	Todd, Jan 1984	Confined interbeds within the Monterey; Measurements from Observation Well #1
Plum Valley	Jan-84	M	b	270	ft		Todd, Jan 1984, Cited in Johnson, Sep 2001a	Confined interbeds within the Monterey
Plum Valley	Jan-84	M	K_h	0.65	ft/d		Todd, Jan 1984, Cited in Johnson, Sep 2001a	Confined interbeds within the Monterey
Plum Valley	Jan-84	M	S	0.0024	--	Unknown	Todd, Jan 1984	Confined interbeds within the Monterey; Measurements from Observation Well #1
SVWD #9	Oct-80	M	T	990	ft^2/d	Cooper-Jacob?	Geoconsultants, Oct 1980, cited in Johnson, Sep 2001b	Pumping well and several observation wells
SVWD #9	Oct-80	M	SC	3.4	gpm/ft		Geoconsultants, Oct 1980, cited in Johnson, Sep 2001b	
SVWD #9	Dec-98	M	SC	3.1	gpm/ft		Todd, Dec 1998	Measured in September 1988 to April 1989 or September 1987 to April 1988
SVWD #9	Dec-98	M	SC	4.3	gpm/ft		Todd, Dec 1998	Measured in June 1988 to April 1989
SVWD #9	Dec-98	M	SC	2.7	gpm/ft		Todd, Dec 1998	Measured in June 1991 to February 1992
SVWD #9	Dec-98	M	SC	2.1	gpm/ft		Todd, Dec 1998	Measured in May 1996 to July 1997
SVWD #9	Dec-98	M	SC	2	gpm/ft		Todd, Dec 1998	Measured in September 1997 to June 1998
SVWD #9	Sep-01	M	K'	0.21	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #9	Sep-01	M	K'	0.06	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #9 observation well)
SVWD #9	Sep-01	M	K'	0.08	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Manana Woods #2)
SVWD #9	Sep-01	M	K'	0.03	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #10)
SVWD #9	Sep-01	M	T	1,165	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #9	Sep-01	M	S	0.1	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #9	Sep-01	M	K_h	2.9	ft/d		Johnson, Sep 2001b	Pumping well
SVWD #9	Sep-01	M	T	2,080	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #9 observation well)
SVWD #9	Sep-01	M	S	0.0118	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #9 observation well)
SVWD #9	Sep-01	M	K_h	5.2	ft/d		Johnson, Sep 2001b	Observation well (SVWD #9 observation well)
SVWD #9	Sep-01	M	T	2,300	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Manana Woods #2)
SVWD #9	Sep-01	M	S	0.0017	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Manana Woods #2)
SVWD #9	Sep-01	M	K_h	5.8	ft/d		Johnson, Sep 2001b	Observation well (Manana Woods #2)
SVWD #9	Sep-01	M	T	2,000	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #10)
SVWD #9	Sep-01	M	S	0.001	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #10)
SVWD #9	Sep-01	M	K_h	5	ft/d		Johnson, Sep 2001b	Observation well (SVWD #10)
Entire Area	Jun-97	L	K_h	0.94	ft/d		Todd, Jun 1997	Average value based on existing information
Entire Area	Sep-01	L	K_h	5 to 6	ft/d		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Average

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Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Entire Area	Sep-01	L	b	400	ft		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	L	T	2,000 to 2,400	ft^2/d		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	L	K_v	0.5 to 1	ft/d		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	L	S_y	0.04 to 0.07	--		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Average
Entire Area	Sep-01	L	K_h	3 to 7	ft/d		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Range
Entire Area	Sep-01	L	K_v	0.1 or more	ft/d		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Range
Entire Area	Sep-01	L	S	0.0005	--		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Where confined
Entire Area	Sep-01	L	S	0.001 to 0.01	--		Johnson, Sep 2001b, cited in Johnson, Jun 2002	Range; Where semi-confined
Estrella	Aug-92	L	T	2,270	ft^2/d	Unknown	WJE, Aug 1992	
Hidden Oaks	Feb-85	L	SC	3.3	gpm/ft		Geoconsultants, Feb 1985	
Hidden Oaks	Feb-85	L	T	483	ft^2/d	Cooper-Jacob	Geoconsultants, Feb 1985	Pumping well, recovery data; questionable results, test not constant-rate
Hidden Oaks	Feb-85	L	T	1,412	ft^2/d	Cooper-Jacob	Geoconsultants, Feb 1985	Observation well, drawdown data; questionable results, test not constant-rate
Hidden Oaks	Feb-85	L	T	706	ft^2/d	Cooper-Jacob	Geoconsultants, Feb 1985	Observation well, recovery data; questionable results, test not constant-rate
Hidden Oaks	Dec-98	L	SC	5.6	gpm/ft		Todd, Dec 1998	Measured in July to September 1989
Kaiser #4	Jul-86	L	T	13,300	ft^2/d		Ellis, Jul 1986, cited in Johnson, Sep 2001b	Pumping well and 5 observation wells
Kaiser #4	Jul-86	L	SC	17.6	gpm/ft		Ellis, Jul 1986, cited in Johnson, Sep 2001b	Pumping well and 5 observation wells
Kaiser #4	Sep-01	L	T	2,130	ft^2/d	Neuman	Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	S	0.02	--	Neuman	Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	S_y	0.044	--	Neuman	Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	K_h	12	ft/d		Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	K_v/K_h	0.1	--	Neuman	Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	b	180	ft		Johnson, Sep 2001b	Observation well (Pennington)
Kaiser #4	Sep-01	L	T	4,500	ft^2/d	Neuman	Johnson, Sep 2001b	Pumping well, results questionable
Kaiser #4	Sep-01	L	S	0	--	Neuman	Johnson, Sep 2001b	Pumping well, results questionable
Kaiser #4	Sep-01	L	S_y	0	--	Neuman	Johnson, Sep 2001b	Pumping well, results questionable
Kaiser #4	Sep-01	L	b	180	ft		Johnson, Sep 2001b	Pumping well, results questionable
Kaiser #4	Sep-01	L	K_h	25	ft/d		Johnson, Sep 2001b	Pumping well, results questionable
Kaiser #4	Sep-01	L	K_v/K_h	2	--	Neuman	Johnson, Sep 2001b	Pumping well, results questionable
Mt. Hermon #1	Sep-01	L	K'	0.0001	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #1	Sep-01	L	K'	0.01	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6), recovery only
Mt. Hermon #1	Dec-90	L	T	1,165	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1990, cited in Johnson, Sep 2001b	Pumping well
Mt. Hermon #1	Dec-90	L	T	1,750 to 2,000	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1990, cited in Johnson, Sep 2001b	Observation well (Pasatiempo #6 MW-1)
Mt. Hermon #1	Dec-90	L	S	0.000008	--	Cooper-Jacob	Geoconsultants, Dec 1990, cited in Johnson, Sep 2001b	Observation well (Pasatiempo #6 MW-1)
Mt. Hermon #1	Dec-90	L	T	1,520 to 2,300	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1990, cited in Johnson, Sep 2001b	Observation well (Pasatiempo #6)
Mt. Hermon #1	Sep-01	L	T	1,250	ft^2/d	Theis	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #1	Sep-01	L	S	0.00001	--	Theis	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #1	Sep-01	L	K_h	3	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #1	Sep-01	L	T	1,440	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #1	Sep-01	L	S	< 0.000001	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only

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Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Mt. Hermon #1	Sep-01	L	K_h	3.6	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #1	Sep-01	L	T	1,250	ft^2/d	Theis	Johnson, Sep 2001b	Observation well (SLVWD #6)
Mt. Hermon #1	Sep-01	L	S	0.00062	--	Theis	Johnson, Sep 2001b	Observation well (SLVWD #6)
Mt. Hermon #1	Sep-01	L	K_h	3.1	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6)
Mt. Hermon #1	Sep-01	L	T	1,380	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6), recovery only
Mt. Hermon #1	Sep-01	L	S	0.0000015	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6), recovery only
Mt. Hermon #1	Sep-01	L	K_h	3.5	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6), recovery only
Mt. Hermon #2	Sep-01	L	K'	0.03	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Sep-01	L	K'	0.01	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Sep-01	L	K'	0.0084	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1), recovery only
Mt. Hermon #2	Sep-01	L	K'	0.01	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #2	Sep-01	L	K'	0.014	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #2	Jan-94	L	T	1,770 to 1,990	ft^2/d	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Jan-94	L	SC	5.4	gpm/ft	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Jan-94	L	T	1,600 to 1,630	ft^2/d	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Jan-94	L	S	0.00022	--	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Jan-94	L	T	2,120 to 2,150	ft^2/d	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Observation well (Pasatiempo #6 MW-1)
Mt. Hermon #2	Jan-94	L	S	0.00018	--	Cooper-Jacob	Geoconsultants, Jan 1994, cited in Johnson, Sep 2001b	Observation well (Pasatiempo #6 MW-1)
Mt. Hermon #2	Sep-01	L	T	1,920	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Sep-01	L	S	0.0008	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Sep-01	L	K_h	4.8	ft/d		Johnson, Sep 2001b	Pumping well
Mt. Hermon #2	Sep-01	L	T	1,615	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Sep-01	L	S	0.00033	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Sep-01	L	K_h	4	ft/d		Johnson, Sep 2001b	Observation well (Mt. Hermon #1)
Mt. Hermon #2	Sep-01	L	T	1,660	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1), recovery only
Mt. Hermon #2	Sep-01	L	S	0.00014	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Mt. Hermon #1), recovery only
Mt. Hermon #2	Sep-01	L	K_h	4.2	ft/d		Johnson, Sep 2001b	Observation well (Mt. Hermon #1), recovery only
Mt. Hermon #2	Sep-01	L	T	2,000	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #2	Sep-01	L	S	0.00026	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #2	Sep-01	L	K_h	5	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Mt. Hermon #2	Sep-01	L	T	1,890	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #2	Sep-01	L	S	0.000046	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Mt. Hermon #2	Sep-01	L	K_h	4.7	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1), recovery only
Old Probation	Aug-92	L	T	2,000 to 2,670	ft^2/d	Unknown	WJE, Aug 1992	
Pasatiempo #6	Sep-01	L	K'	0.22	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Pasatiempo #6	Sep-01	L	K'	1.6	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Pasatiempo #6	Sep-01	L	K'	0.048	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-01	L	K'	0.033	ft/d	Hantush	Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-90	L	T	2,000 to 2,670	ft^2/d	Unknown	Ellis, Sep 1990, cited in Johnson, Sep 2001b	Pumping well and 3 observation wells
Pasatiempo #6	Sep-90	L	SC	10.4	gpm/ft		Ellis, Sep 1990, cited in Johnson, Sep 2001b	Pumping well and 3 observation wells
Pasatiempo #6	Sep-01	L	T	2,000	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Pasatiempo #6	Sep-01	L	S	0.03	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
Pasatiempo #6	Sep-01	L	K_h	5	ft/d		Johnson, Sep 2001b	Pumping well
Pasatiempo #6	Sep-01	L	T	2,400	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Pasatiempo #6	Sep-01	L	S	0.06	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Pasatiempo #6	Sep-01	L	K_h	6	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6 MW-1)
Pasatiempo #6	Sep-01	L	T	2,100	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #7)

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Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
Pasatiempo #6	Sep-01	L	S	0.0015	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-01	L	K_h	5.3	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-01	L	T	2,300	ft^2/d	Hantush	Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-01	L	S	0.0012	--	Hantush	Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #6	Sep-01	L	K_h	5.8	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #7)
Pasatiempo #7	Sep-01	L	K'	10	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well; results suspect
Pasatiempo #7	Sep-01	L	K'	0.11	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Kaiser #4)
Pasatiempo #7	Sep-01	L	K'	0.2	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6)
Pasatiempo #7	Sep-90	L	T	2,270	ft^2/d	Unknown	Ellis, Sep 1990, cited in Johnson, Sep 2001b	Pumping well and 3 observation wells
Pasatiempo #7	Sep-90	L	SC	3.6	gpm/ft		Ellis, Sep 1990, cited in Johnson, Sep 2001b	Pumping well and 3 observation wells
Pasatiempo #7	Sep-01	L	T	1,000	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well; results suspect
Pasatiempo #7	Sep-01	L	S	0.07	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well; results suspect
Pasatiempo #7	Sep-01	L	K_h	3.1	ft/d		Johnson, Sep 2001b	Pumping well; results suspect
Pasatiempo #7	Sep-01	L	T	2,400	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Kaiser #4)
Pasatiempo #7	Sep-01	L	S	0.00112	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (Kaiser #4)
Pasatiempo #7	Sep-01	L	K_h	7.5	ft/d		Johnson, Sep 2001b	Observation well (Kaiser #4)
Pasatiempo #7	Sep-01	L	T	2,150	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6)
Pasatiempo #7	Sep-01	L	S	0.0011	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SLVWD #6)
Pasatiempo #7	Sep-01	L	K_h	5.2	ft/d		Johnson, Sep 2001b	Observation well (SLVWD #6)
Pasatiempo #7	Sep-01	L	b	320	ft		Johnson, Sep 2001b	
SVWD #10	Aug-80	L	T	1,200	ft^2/d	Cooper-Jacob	Geoconsultants, Aug 1980	Pumping well, recovery data
SVWD #10	Oct-80	L	T	1,280	ft^2/d	Cooper-Jacob	Geoconsultants, Oct 1982, cited in Johnson, Sep 2001b	Pumping well
SVWD #10	Oct-80	L	SC	10.3	gpm/ft		Geoconsultants, Oct 1982, cited in Johnson, Sep 2001b	
SVWD #10	Dec-98	L	SC	5.9	gpm/ft		Todd, Dec 1998	Measured in June 1980
SVWD #10	Dec-98	L	SC	6.2	gpm/ft		Todd, Dec 1998	Measured in December 1987 to January 1990
SVWD #10	Dec-98	L	SC	6.5	gpm/ft		Todd, Dec 1998	Measured in January to February 1992
SVWD #10	Dec-98	L	SC	6.3	gpm/ft		Todd, Dec 1998	Measured in May 1996 to July 1997
SVWD #10	Dec-98	L	SC	6.4	gpm/ft		Todd, Dec 1998	Measured in October 1997 to June 1998
SVWD #10	Sep-01	L	K'	0.22	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #10	Sep-01	L	T	2,300	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #10	Sep-01	L	S	0.034	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #10	Sep-01	L	K_h	5.8	ft/d		Johnson, Sep 2001b	Pumping well
SVWD #10A	Jul-07	L	SC	5.3	gpm/ft		Feeney, Jul 2007	Approximate 24-hour SC
SVWD #10A	Jul-12	L	T	2,018	ft^2/d	Cooper-Jacob	Feeney, Jul 2007	Pumping well
SVWD #11	Sep-01	L	K'	0.07	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11	Sep-01	L	K'	0.08	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11), recovery data
SVWD #11	Dec-86	L	SC	8.2	gpm/ft		Geoconsultants, Dec 1986	
SVWD #11	Dec-86	L	T	3,183	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1986	Pumping well, recovery data
SVWD #11	Dec-86	L	T	2,951	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1986	Observation well, recovery data
SVWD #11	Dec-86	L	S	0.0002	--	Cooper-Jacob	Geoconsultants, Dec 1986	
SVWD #11	Jun-87	L	T	2,600	ft^2/d	Unknown	Geoconsultants, Jun 1987, cited in Todd, Aug 1987	Pumping well
SVWD #11	Jun-87	L	SC	8.3	gpm/ft		Geoconsultants, Jun 1987, cited in Todd, Aug 1987	
SVWD #11	Jun-87	L	T	2,280 to 2,430	ft^2/d	Unknown	Geoconsultants, Jun 1987, cited in Todd, Aug 1987	Observation well (SVWD MW-11)
SVWD #11	Aug-92	L	T	2,433	ft^2/d	Unknown	WJE, Aug 1992	
SVWD #11	Dec-98	L	SC	7.8	gpm/ft		Todd, Dec 1998	Measured in July 1986
SVWD #11	Dec-98	L	SC	10.2	gpm/ft		Todd, Dec 1998	Measured in August 1987 to February 1990
SVWD #11	Dec-98	L	SC	10.4	gpm/ft		Todd, Dec 1998	Measured in July 1991 to February 1992
SVWD #11	Dec-98	L	SC	8.5	gpm/ft		Todd, Dec 1998	Measured in February to July 1997
SVWD #11	Dec-98	L	SC	8.3	gpm/ft		Todd, Dec 1998	Measured in December 1997 to April 1998

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
SVWD #11	Sep-01	L	T	2,340	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11	Sep-01	L	S	0.0002	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11	Sep-01	L	K_h	5.9	ft/d		Johnson, Sep 2001b	Pumping well
SVWD #11	Sep-01	L	T	2,050	ft^2/d	Neuman	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11	Sep-01	L	S	0.00015	--	Neuman	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11	Sep-01	L	S_y	0.009	--	Neuman	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11	Sep-01	L	K_h	5.1	ft/d		Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11	Sep-01	L	K_v/K_h	0.02	--	Neuman	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11	Sep-01	L	T	2,323	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11), recovery data
SVWD #11	Sep-01	L	S	0.00073	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11), recovery data
SVWD #11	Sep-01	L	K_h	5.8	ft/d		Johnson, Sep 2001b	Observation well (SVWD Test well #11), recovery data
SVWD #11A	Sep-97	L	SC	2	gpm/ft		Todd, Sep 1997	Projected 24-hour SC
SVWD #11A	Sep-97	L	T	600	ft^2/d	Cooper-Jacob	Todd, Sep 1997	
SVWD #11A	Sep-97	L	K_h	5.2	ft/d		Todd, Sep 1997	
SVWD #11A	Sep-97	L	SC	2.1	gpm/ft		Todd, Sep 1997	
SVWD #11A	Sep-97	L	T	641	ft^2/d	Cooper-Jacob	Todd, Sep 1997	Pumping well, recovery data
SVWD #11A	Sep-97	L	b	115	ft		Todd, Sep 1997	
SVWD #11A	Sep-97	L	K_h	5.23	ft/d		Todd, Sep 1997	
SVWD #11A	Sep-97	L	T	588	ft^2/d	Cooper-Jacob	Todd, Sep 1997	Pumping well, drawdown data
SVWD #11A	Dec-98	L	SC	2	gpm/ft		Todd, Dec 1998	Measured in July 1997
SVWD #11A	Dec-98	L	SC	1.8	gpm/ft		Todd, Dec 1998	Measured in February 1998
SVWD #11B	Sep-01	L	K'	1.3	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11B	Sep-01	L	K'	0.67	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #11)
SVWD #11B	Sep-01	L	K'	0.082	ft/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11B	Sep-99	L	SC	5.2 to 5.5	gpm/ft		Todd, Sep 1999	Step test
SVWD #11B	Sep-99	L	SC	5.5	gpm/ft		Todd, Sep 1999	Constant-rate test; projected 24-hour SC = 5.1 gpm/ft
SVWD #11B	Sep-99	L	T	2,294	ft^2/d	Cooper-Jacob	Todd, Sep 1999	Pumping well, drawdown data
SVWD #11B	Sep-99	L	T	2,294	ft^2/d	Cooper-Jacob	Todd, Sep 1999	Observation well (SVWD #11), drawdown data
SVWD #11B	Sep-99	L	T	3,441	ft^2/d	Cooper-Jacob	Todd, Sep 1999	Observation well (SVWD Test Well #11), drawdown data
SVWD #11B	Sep-01	L	T	2,135	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11B	Sep-01	L	S	0.0019	--	Hantush-Jacob	Johnson, Sep 2001b	Pumping well
SVWD #11B	Sep-01	L	K_h	5.3	ft/d		Johnson, Sep 2001b	Pumping well
SVWD #11B	Sep-01	L	T	2,525	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #11)
SVWD #11B	Sep-01	L	S	0.0028	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD #11)
SVWD #11B	Sep-01	L	K_h	6.3	ft/d		Johnson, Sep 2001b	Observation well (SVWD #11)
SVWD #11B	Sep-01	L	T	2,710	ft^2/d	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11B	Sep-01	L	S	0.0012	--	Hantush-Jacob	Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #11B	Sep-01	L	K_h	6.8	ft/d		Johnson, Sep 2001b	Observation well (SVWD Test well #11)
SVWD #3A	May-84	L	SC	3.5	gpm/ft		Geoconsultants, May 1984	
SVWD #3A	May-84	L	T	1,800	ft^2/d	Theis	Geoconsultants, May 1984	
SVWD #3A	Dec-98	L	SC	3.2	gpm/ft		Todd, Dec 1998	Measured in April 1984
SVWD #3A	Dec-98	L	SC	2.6	gpm/ft		Todd, Dec 1998	Measured in February to June 1992
SVWD #7	Dec-98	L	SC	7.9	gpm/ft		Todd, Dec 1998	Measured in April 1988 to February 1990
SVWD MW-2	May-03	L	T	110	ft^2/d	Cooper-Jacob	Todd, May 2003	Pumping well
SVWD MW-2	May-03	L	K_h	0.65 to 2.2	ft/d		Todd, May 2003	Range depending on estimate of b
SVWD MW-2	May-03	L	SC	1.12	gpm/ft		Todd, May 2003	30-minute specific capacity
SVWD TW-11	May-85	L	SC	1.5	gpm/ft		Geoconsultants, May 1985	Note that SC is lower than later test, indicating incomplete development
SVWD TW-11	May-85	L	T	1,294	ft^2/d	Cooper-Jacob	Geoconsultants, May 1985	Pumping well, recovery data
SVWD TW-11	Dec-85	L	SC	2.2	gpm/ft		Geoconsultants, Dec 1985	
SVWD TW-11	Dec-85	L	T	1,453	ft^2/d	Cooper-Jacob	Geoconsultants, Dec 1985	Pumping well, recovery data
SVWD TW-11 and #11A	Sep-01	L	T	600 to 1,400	ft^2/d	Various	Johnson, Sep 2001b	Considered too low; wells may be inefficient
SVWD TW-13	Jun-89	L	SC	1	gpm/ft		Geoconsultants, Jun 1989	

APPENDIX D: Aquifer Test Data Summary

Site	Date	Aquifer	Parameter	Value	Units	Method	Source	Notes
SVWD TW-13	Jun-89	L	T	1,390	ft^2/d	Cooper-Jacob	Geoconsultants, Jun 1989	Pumping well, recovery data
SVWD TW-19	May-97	L	SC	0.6	gpm/ft		Todd, May 1997	
SVWD TW-19	May-97	L	T	74	ft^2/d	Cooper-Jacob	Todd, May 1997	May be affected by pumping at SVWD #7A
SVWD TW-19	May-97	L	K_h	0.74	ft/d		Todd, May 1997	
SVWD TW-19	Sep-01	L	T	200 to 300	ft^2/d	Various	Johnson, Sep 2001b	Lower than other values possibly because of thicker aquitard and thinner aquifer at this location
SVWD TW-19	Mar-13	L	T	6,940	ft^2/d	Cooper-Jacob	Kennedy/Jenks, Dec 2013	Slope 1
SVWD TW-19	Mar-13	L	T	1,630	ft^2/d	Cooper-Jacob	Kennedy/Jenks, Dec 2013	Slope 2
SVWD TW-19	Mar-13	L	S	0.00068	--	Cooper-Jacob	Kennedy/Jenks, Dec 2013	Slope 1
SVWD TW-19	Mar-13	L	S	0.0017	--	Cooper-Jacob	Kennedy/Jenks, Dec 2013	Slope 2
Stonewood Well	Nov-12	B	SC	0.175	gpm/ft		Kennedy/Jenks, Dec 2013	
Stonewood Well	Nov-12	B	T	355	ft^2/d	Razack & Huntley	Kennedy/Jenks, Dec 2013	Based on specific capacity
SVWD #15	Jan-13	B	T	856	ft^2/d	Theis Recovery	Kennedy/Jenks, Dec 2013	
SVWD #15	Oct-90	B	T	1,637	ft^2/d	Sieve analysis results	Geoconsultants, Oct 1990	Based on estimated saturated thickness and sieve analysis
SVWD #15	Oct-90	B	SC	0.78	gpm/ft		Geoconsultants, Oct 1990	
SVWD #15	Oct-90	B	T	177	ft^2/d	Cooper-Jacob	Geoconsultants, Oct 1990	Pumping well, recovery data; report poses possible reasons for low T
SVWD #3B	May-95	B	SC	1.6	gpm/ft		Geoconsultants, May 1995	
SVWD #3B	May-95	B	T	255	ft^2/d	Cooper-Jacob	Geoconsultants, May 1995	Pumping well, drawdown data
SVWD #3B	May-95	B	T	271	ft^2/d	Cooper-Jacob	Geoconsultants, May 1995	Pumping well, recovery data
SVWD #3B	May-95	B	T	391	ft^2/d	Cooper-Jacob	Geoconsultants, May 1995	Observation well, drawdown data
SVWD #3B	May-95	B	T	444	ft^2/d	Cooper-Jacob	Geoconsultants, May 1995	Observation well, recovery data
SVWD #3B	May-95	B	S	0.012	--	Cooper-Jacob	Geoconsultants, May 1995	
SVWD #3B	Dec-98	B	SC	1.8	gpm/ft		Todd, Dec 1998	Measured in March 1995
SVWD #3B	Dec-98	B	SC	2	gpm/ft		Todd, Dec 1998	Measured in October 1997 to April 1998
SVWD #7A	Nov-91	B	SC	4.6	gpm/ft		Geoconsultants, Nov 1991	
SVWD #7A	Nov-91	B	T	588	ft^2/d	Cooper-Jacob	Geoconsultants, Nov 1991	Pumping well, drawdown data
SVWD #7A	Nov-91	B	T	1,070	ft^2/d	Cooper-Jacob	Geoconsultants, Nov 1991	Pumping well, recovery data
SVWD #7A	Dec-98	B	SC	4.1	gpm/ft		Todd, Dec 1998	Measured in July 1991
SVWD #7A	Dec-98	B	SC	4	gpm/ft		Todd, Dec 1998	Measured in January 1997
SVWD #7A	Dec-98	B	SC	4	gpm/ft		Todd, Dec 1998	Measured in March to June 1998
SVWD #7A	Mar-13	B	T	240	ft^2/d	Distance-drawdown	Kennedy/Jenks, Dec 2013	
SVWD #7A	Mar-13	B	S	0.00074	--	Distance-drawdown	Kennedy/Jenks, Dec 2013	
Entire Area	Sep-01	A	K_h	10 to 20	ft/d		Johnson, Sep 2001a	Average
Entire Area	Sep-01	A	K_v/K_h	0.1	--		Johnson, Sep 2001a	Average
Entire Area	Sep-01	A	S_y	0.3	--		Johnson, Sep 2001a	Average
Entire Area	Sep-01	A	K_h	5 to 100	ft/d		Johnson, Sep 2001a	Range
Entire Area	Sep-01	A	K_v/K_h	0.01 to 0.5	--		Johnson, Sep 2001a	Range
Entire Area	Sep-01	A	S_y	0.2 to 0.4	--		Johnson, Sep 2001a	Range
Aquifers:				Parameters:			Units:	
A = Alluvium				b = Aquifer thickness			-- = Unitless	
B = Butano				K_h = Horizontal hydraulic conductivity			ft = Feet	
L = Lompico				K_v = Vertical hydraulic conductivity			ft/d = Feet per day	
M = Monterey				K_v/K_h = Aquifer anisotropy			ft^2/d = Square feet per day	
S = Santa Margarita				K' = Confining unit hydraulic conductivity			gpm/ft = Gallons per minute per foot	
				S = Storativity				
				SC = Specific Capacity				
				S_y = Specific Yield				
				T = Transmissivity				

Appendix E: Data for estimating recharge and runoff for SMGB Model

Appendix E - Quarterly Runoff Coefficients

Q1 - Fall	Commercial/Industrial	Suburban	Irrigated Area	Landfill	Quarry	Small Community	Rural Domestic	Rural/Native/Undeveloped
Purisima	83%	29%	16%	15%	5%	20%	12%	8%
Santa Cruz Mudstone	88%	32%	25%	15%	5%	35%	25%	15%
Santa Margarita - Quail Hollow	80%	28%	20%	15%	1%	26%	20%	5%
Santa Margarita - Scotts Valley	80%	28%	20%	15%	1%	22%	16%	2%
Santa Margarita - Upland	80%	33%	20%	15%	1%	29%	23%	8%
Monterey	85%	38%	25%	15%	5%	33%	27%	12%
Lompico	80%	37%	20%	15%	1%	30%	25%	9%
Lompico-SLR	80%	28%	20%	15%	1%	24%	18%	4%
Butano	80%	32%	20%	15%	1%	29%	22%	8%
Locatelli	85%	32%	25%	15%	5%	27%	21%	3%
Zayante	80%	32%	10%	15%	1%	29%	15%	5%
Granite	90%	32%	25%	15%	5%	27%	21%	17%

Q2 - Winter	Commercial/Industrial	Suburban	Irrigated Area	Landfill	Quarry	Small Community	Rural Domestic	Rural/Native/Undeveloped
Purisima	90%	65%	50%	60%	24%	55%	50%	50%
Santa Cruz Mudstone	95%	80%	50%	60%	28%	65%	60%	60%
Santa Margarita - Quail Hollow	86%	44%	35%	60%	11%	38%	32%	21%
Santa Margarita - Scotts Valley	85%	44%	35%	60%	11%	38%	32%	18%
Santa Margarita - Upland	87%	51%	35%	60%	11%	45%	39%	24%
Monterey	91%	56%	50%	60%	26%	53%	49%	36%
Lompico	89%	55%	40%	60%	11%	49%	44%	28%
Lompico-SLR	88%	46%	40%	60%	11%	40%	34%	20%
Butano	88%	50%	45%	60%	11%	45%	38%	24%
Locatelli	91%	55%	50%	60%	28%	52%	48%	36%
Zayante	85%	50%	25%	60%	11%	40%	30%	15%
Granite	95%	75%	60%	60%	28%	52%	48%	45%

Q3 - Spring	Commercial/Industrial	Suburban	Irrigated Area	Landfill	Quarry	Small Community	Rural Domestic	Rural/Native/Undeveloped
Purisima	85%	45%	30%	25%	14%	35%	28%	20%
Santa Cruz Mudstone	87%	48%	36%	25%	19%	40%	35%	30%
Santa Margarita - Quail Hollow	85%	40%	30%	25%	9%	34%	28%	17%
Santa Margarita - Scotts Valley	84%	40%	30%	25%	9%	34%	28%	14%
Santa Margarita - Upland	86%	47%	30%	25%	9%	41%	35%	20%
Monterey	90%	52%	36%	25%	18%	43%	39%	30%
Lompico	85%	51%	21%	25%	9%	40%	37%	24%
Lompico-SLR	85%	42%	21%	25%	9%	36%	30%	16%
Butano	85%	46%	25%	25%	9%	41%	34%	20%
Locatelli	90%	50%	35%	25%	19%	45%	41%	27%
Zayante	75%	46%	20%	25%	9%	35%	24%	14%
Granite	90%	50%	35%	25%	19%	45%	41%	38%

Q4 - Summer	Commercial/Industrial	Suburban	Irrigated Area	Landfill	Quarry	Small Community	Rural Domestic	Rural/Native/Undeveloped
Purisima	70%	20%	9%	5%	5%	18%	5%	4%
Santa Cruz Mudstone	70%	25%	15%	5%	5%	20%	12%	4%
Santa Margarita - Quail Hollow	65%	20%	12%	5%	5%	22%	16%	5%
Santa Margarita - Scotts Valley	65%	20%	12%	5%	5%	18%	12%	5%
Santa Margarita - Upland	65%	25%	12%	5%	5%	25%	19%	5%
Monterey	78%	34%	25%	5%	5%	30%	24%	8%
Lompico	70%	33%	20%	5%	5%	25%	20%	7%
Lompico-SLR	70%	24%	20%	5%	5%	20%	14%	5%
Butano	73%	28%	20%	5%	5%	25%	18%	5%
Locatelli	75%	27%	25%	5%	5%	25%	19%	8%
Zayante	65%	28%	12%	5%	5%	25%	18%	4%
Granite	85%	37%	20%	5%	5%	30%	25%	10%

AppendIx E - Balance of Average Annual Coefficients

AVERAGE RECHARGE

Q1 - Fall	Commercial/Ind	Suburban	Irrigated Area	Landfill	Quarry	Small Communit	Rural Domestic	Rural/Native/Undeveloped
Purisima	1%	1%	1%	1%	1%	1%	1%	1%
Santa Cruz Mudstone	1%	1%	1%	1%	1%	1%	1%	1%
Santa Margarita - Quail Hollow	10%	22%	46%	1%	65%	48%	55%	65%
Santa Margarita - Scotts Valley	10%	22%	46%	1%	55%	40%	45%	55%
Santa Margarita - Upland	7%	9%	14%	1%	45%	13%	14%	15%
Monterey	5%	5%	5%	1%	5%	5%	5%	5%
Lompico	6%	10%	15%	1%	35%	12%	14%	15%
Lompico-SLR	6%	10%	15%	1%	35%	12%	14%	15%
Butano	7%	26%	33%	1%	40%	25%	33%	35%
Locatelli	1%	2%	3%	1%	3%	2%	2%	3%
Zayante	5%	10%	26%	1%	10%	10%	10%	15%
Granite	1%	2%	3%	1%	3%	2%	2%	3%

AVERAGE RUNOFF COEFFICIENT

Q1 - Fall	Commercial/Ind	Suburban	Irrigated Area	Landfill	Quarry	Small Communit	Rural Domestic	Rural/Native/Undeveloped
Purisima	82%	40%	26%	26%	12%	32%	24%	21%
Santa Cruz Mudstone	85%	46%	32%	26%	14%	40%	33%	27%
Santa Margarita - Quail Hollow	79%	33%	24%	26%	7%	30%	24%	12%
Santa Margarita - Scotts Valley	78%	33%	24%	26%	7%	28%	22%	10%
Santa Margarita - Upland	79%	39%	24%	26%	7%	35%	29%	14%
Monterey	86%	45%	34%	26%	14%	40%	35%	22%
Lompico	81%	44%	25%	26%	7%	36%	32%	17%
Lompico-SLR	81%	35%	25%	26%	7%	30%	24%	11%
Butano	81%	39%	28%	26%	7%	35%	28%	14%
Locatelli	85%	41%	34%	26%	14%	37%	32%	18%
Zayante	76%	39%	17%	26%	7%	32%	22%	10%
Granite	90%	49%	35%	26%	14%	38%	34%	27%

AVERAGE LOSSES

Q1 - Fall	Commercial/Ind	Suburban	Irrigated Area	Landfill	Quarry	Small Communit	Rural Domestic	Rural/Native/Undeveloped
Purisima	17%	59%	73%	73%	87%	67%	75%	79%
Santa Cruz Mudstone	14%	53%	68%	73%	85%	59%	66%	72%
Santa Margarita - Quail Hollow	11%	45%	30%	73%	28%	22%	21%	23%
Santa Margarita - Scotts Valley	12%	45%	30%	73%	38%	32%	33%	35%
Santa Margarita - Upland	14%	52%	62%	73%	48%	52%	57%	71%
Monterey	9%	50%	61%	73%	82%	56%	60%	74%
Lompico	13%	46%	60%	73%	58%	52%	55%	68%
Lompico-SLR	13%	55%	60%	73%	58%	58%	62%	74%
Butano	12%	35%	40%	73%	53%	40%	39%	51%
Locatelli	14%	57%	63%	73%	83%	61%	66%	79%
Zayante	19%	51%	57%	73%	83%	58%	68%	76%
Granite	9%	50%	62%	73%	83%	60%	64%	70%

TOTAL

Q1 - Fall	Commercial/Ind	Suburban	Irrigated Area	Landfill	Quarry	Small Communit	Rural Domestic	Rural/Native/Undeveloped
Purisima	100%	100%	100%	100%	100%	100%	100%	100%
Santa Cruz Mudstone	100%	100%	100%	100%	100%	100%	100%	100%
Santa Margarita - Quail Hollow	100%	100%	100%	100%	100%	100%	100%	100%
Santa Margarita - Scotts Valley	100%	100%	100%	100%	100%	100%	100%	100%
Santa Margarita - Upland	100%	100%	100%	100%	100%	100%	100%	100%
Monterey	100%	100%	100%	100%	100%	100%	100%	100%
Lompico	100%	100%	100%	100%	100%	100%	100%	100%
Lompico-SLR	100%	100%	100%	100%	100%	100%	100%	100%
Butano	100%	100%	100%	100%	100%	100%	100%	100%
Locatelli	100%	100%	100%	100%	100%	100%	100%	100%
Zayante	100%	100%	100%	100%	100%	100%	100%	100%
Granite	100%	100%	100%	100%	100%	100%	100%	100%

APPENDIX E - Rainfall Distribution over Time

		1984_Q1	1984_Q2	1984_Q3	1984_Q4	1985_Q1	1985_Q2	1985_Q3	1985_Q4	1986_Q1	1986_Q2	1986_Q3	1986_Q4	1987_Q1	1987_Q2	1987_Q3	1987_Q4	1988_Q1	1988_Q2	1988_Q3
Rain	Scotts Valley	27.3	5.65	1.33	0.26	19.55	13.84	0.99	0.65	10.88	44.78	1.31	1.30	2.55	19.88	0.72	0	14.19	5.26	4.36
	Boulder Creek	43.16	8.5	1.7	0.00	18.60	14.20	0.80	0.40	12.00	41.30	0.80	1.14	1.80	16.5	0.5	0	14.8	5.7	4.3
		15.86	2.85	0.37	-0.26	-0.95	0.36	-0.19	-0.25	1.12	-3.48	-0.51	-0.16	-0.75	-3.38	-0.22	0	0.61	0.44	-0.06
		3.17	0.57	0.07	-0.05	-0.19	0.07	-0.04	-0.05	0.22	-0.70	-0.10	-0.03	-0.15	-0.68	-0.04	0.00	0.12	0.09	-0.01
Quarterly rain (ft/d)																				
	35					0.0112	0.0130	0.0062	0.0020	0.0059	0.0212	0.0110	0.0043	0.0022	0.0124	0.0065	0.0021	0.0076	0.0065	0.0050
	37					0.0111	0.0130	0.0062	0.0020	0.0060	0.0210	0.0108	0.0042	0.0021	0.0122	0.0063	0.0021	0.0077	0.0066	0.0051
	39					0.0110	0.0130	0.0061	0.0019	0.0061	0.0209	0.0107	0.0041	0.0020	0.0120	0.0062	0.0021	0.0078	0.0067	0.0051
	41					0.0109	0.0130	0.0061	0.0019	0.0062	0.0208	0.0106	0.0040	0.0019	0.0117	0.0061	0.0020	0.0078	0.0068	0.0051
	43					0.0108	0.0129	0.0061	0.0019	0.0063	0.0206	0.0104	0.0039	0.0018	0.0113	0.0058	0.0019	0.0079	0.0068	0.0052
	45					0.0107	0.0129	0.0061	0.0018	0.0064	0.0205	0.0103	0.0039	0.0017	0.0109	0.0056	0.0019	0.0080	0.0069	0.0052
	47					0.0106	0.0129	0.0061	0.0018	0.0065	0.0204	0.0102	0.0038	0.0016	0.0105	0.0054	0.0018	0.0080	0.0070	0.0052
	49					0.0105	0.0129	0.0060	0.0018	0.0066	0.0202	0.0101	0.0037	0.0015	0.0100	0.0052	0.0017	0.0081	0.0071	0.0052
	51					0.0103	0.0129	0.0060	0.0017	0.0068	0.0201	0.0099	0.0036	0.0014	0.0096	0.0050	0.0016	0.0081	0.0072	0.0053
	53					0.0102	0.0128	0.0060	0.0017	0.0069	0.0200	0.0098	0.0036	0.0013	0.0092	0.0047	0.0016	0.0082	0.0073	0.0053
	55					0.0101	0.0128	0.0060	0.0017	0.0070	0.0198	0.0097	0.0035	0.0012	0.0088	0.0045	0.0015	0.0083	0.0073	0.0053
Quarterly rain (inches/qtr)																				
	35	17.78	3.94	1.11	0.42	20.12	13.62	1.10	0.80	10.21	46.87	1.62	1.40	3.00	21.91	0.85	0.00	13.82	5.00	4.40
	37	20.96	4.51	1.18	0.36	19.93	13.70	1.07	0.75	10.43	46.17	1.51	1.36	2.85	21.23	0.81	0.00	13.95	5.08	4.38
	39	24.13	5.08	1.26	0.31	19.74	13.77	1.03	0.70	10.66	45.48	1.41	1.33	2.70	20.56	0.76	0.00	14.07	5.17	4.37
	41	27.3	5.65	1.33	0.26	19.55	13.84	0.99	0.65	10.88	44.78	1.31	1.30	2.55	19.88	0.72	0	14.19	5.26	4.36
	43	30.47	6.22	1.40	0.21	19.36	13.91	0.95	0.60	11.10	44.08	1.21	1.27	2.40	19.20	0.68	0.00	14.31	5.35	4.35
	45	33.64	6.79	1.48	0.16	19.17	13.98	0.91	0.55	11.33	43.39	1.11	1.24	2.25	18.53	0.63	0.00	14.43	5.44	4.34
	47	36.82	7.36	1.55	0.10	18.98	14.06	0.88	0.50	11.55	42.69	1.00	1.20	2.10	17.85	0.59	0.00	14.56	5.52	4.32
	49	39.99	7.93	1.63	0.05	18.79	14.13	0.84	0.45	11.78	42.00	0.90	1.17	1.95	17.18	0.54	0.00	14.68	5.61	4.31
	51	43.16	8.50	1.70	0.00	18.60	14.20	0.80	0.40	12.00	41.30	0.80	1.14	1.80	16.50	0.50	0.00	14.80	5.70	4.30
	53	46.33	9.07	1.77	-0.05	18.41	14.27	0.76	0.35	12.22	40.60	0.70	1.11	1.65	15.82	0.46	0.00	14.92	5.79	4.29
	55	49.50	9.64	1.85	-0.10	18.22	14.34	0.72	0.30	12.45	39.91	0.60	1.08	1.50	15.15	0.41	0.00	15.04	5.88	4.28
Maximum Precipitation Filter																				
	35	17.78	3.94	1.11	0.42	20.06	13.62	1.10	0.80	10.21	33.43	1.62	1.40	3.00	20.95	0.85	0.00	13.82	5.00	4.40
	37	20.48	4.51	1.18	0.36	19.93	13.70	1.07	0.75	10.43	33.09	1.51	1.36	2.85	20.62	0.81	0.00	13.95	5.08	4.38
	39	22.06	5.08	1.26	0.31	19.74	13.77	1.03	0.70	10.66	32.74	1.41	1.33	2.70	20.28	0.76	0.00	14.07	5.17	4.37
	41	23.65	5.65	1.33	0.26	19.55	13.84	0.99	0.65	10.88	32.39	1.31	1.30	2.55	19.88	0.72	0.00	14.19	5.26	4.36
	43	25.24	6.22	1.40	0.21	19.36	13.91	0.95	0.60	11.10	32.04	1.21	1.27	2.40	19.20	0.68	0.00	14.31	5.35	4.35
	45	26.82	6.79	1.48	0.16	19.17	13.98	0.91	0.55	11.33	31.69	1.11	1.24	2.25	18.53	0.63	0.00	14.43	5.44	4.34
	47	28.41	7.36	1.55	0.10	18.98	14.06	0.88	0.50	11.55	31.35	1.00	1.20	2.10	17.85	0.59	0.00	14.56	5.52	4.32
	49	29.99	7.93	1.63	0.05	18.79	14.13	0.84	0.45	11.78	31.00	0.90	1.17	1.95	17.18	0.54	0.00	14.68	5.61	4.31
	51	31.58	8.50	1.70	0.00	18.60	14.20	0.80	0.40	12.00	30.65	0.80	1.14	1.80	16.50	0.50	0.00	14.80	5.70	4.30
	53	33.17	9.07	1.77	-0.05	18.41	14.27	0.76	0.35	12.22	30.30	0.70	1.11	1.65	15.82	0.46	0.00	14.92	5.79	4.29
	55	34.75	9.64	1.85	-0.10	18.22	14.34	0.72	0.30	12.45	29.95	0.60	1.08	1.50	15.15	0.41	0.00	15.04	5.88	4.28
Distribution of infiltration over time																				
	35					12.27	14.23	6.76	2.17	6.48	23.20	12.02	4.67	2.38	13.61	7.10	2.35	8.38	7.14	5.52
	37					12.19	14.23	6.74	2.14	6.59	23.06	11.88	4.58	2.27	13.36	6.95	2.30	8.45	7.23	5.55
	39					12.06	14.21	6.72	2.11	6.71	22.91	11.73	4.50	2.16	13.11	6.81	2.26	8.52	7.32	5.58
	41					11.94	14.20	6.70	2.07	6.82	22.76	11.59	4.41	2.05	12.82	6.65	2.20	8.59	7.41	5.61
	43					11.82	14.18	6.68	2.04	6.94	22.62	11.45	4.33	1.94	12.37	6.41	2.12	8.65	7.50	5.64
	45					11.70	14.16	6.66	2.00	7.05	22.47	11.30	4.24	1.83	11.92	6.16	2.04	8.72	7.59	5.68
	47					11.57	14.14	6.64	1.97	7.17	22.32	11.16	4.16	1.72	11.46	5.92	1.96	8.79	7.68	5.71
	49					11.45	14.12	6.62	1.93	7.28	22.18	11.02	4.07	1.61	11.01	5.67	1.88	8.86	7.77	5.74
	51					11.33	14.10	6.60	1.90	7.40	22.03	10.88	3.99	1.50	10.55	5.43	1.80	8.93	7.86	5.77
	53					11.21	14.08	6.58	1.87	7.52	21.88	10.73	3.90	1.39	10.10	5.19	1.72	9.00	7.95	5.80
	55					11.09	14.06	6.56	1.83	7.63	21.74	10.59	3.82	1.28	9.65	4.94	1.64	9.07	8.04	5.83
									35.30				46.11				24.89			

APPENDIX E - Rainfall Distribution over Time

1988_Q4	1989_Q1	1989_Q2	1989_Q3	1989_Q4	1990_Q1	1990_Q2	1990_Q3	1990_Q4	1991_Q1	1991_Q2	1991_Q3	1991_Q4	1992_Q1	1992_Q2	1992_Q3	1992_Q4	1993_Q1	1993_Q2	1993_Q3	1993_Q4	1994_Q1
0	14.98	14.05	0.78	0.86	5.12	9.24	5.95	0.27	2.39	23.19	0.97	0.09	9.25	22.98	1.27	0.05	15.15	31.9	3.01	0	8.99
0	10.1	12	1	0.6	4.3	12.05	6.08	0.33	3.9	31.07	1.56	0.14	14.47	29.97	1.57	0	20.27	42.54	4.04	0	12.04
0	-4.88	-2.05	0.22	-0.26	-0.82	2.81	0.13	0.06	1.51	7.88	0.59	0.05	5.22	6.99	0.3	-0.05	5.12	10.64	1.03	0	3.05
0.00	-0.98	-0.41	0.04	-0.05	-0.16	0.56	0.03	0.01	0.30	1.58	0.12	0.01	1.04	1.40	0.06	-0.01	1.02	2.13	0.21	0.00	0.61
0.0017	0.0102	0.0133	0.0062	0.0021	0.0034	0.0058	0.0058	0.0024	0.0014	0.0105	0.0055	0.0019	0.0034	0.0120	0.0063	0.0021	0.0067	0.0158	0.0086	0.0027	0.0041
0.0017	0.0097	0.0128	0.0060	0.0021	0.0033	0.0060	0.0059	0.0025	0.0016	0.0115	0.0060	0.0021	0.0040	0.0130	0.0068	0.0022	0.0073	0.0166	0.0091	0.0029	0.0045
0.0017	0.0091	0.0123	0.0058	0.0020	0.0032	0.0063	0.0061	0.0026	0.0018	0.0120	0.0064	0.0022	0.0046	0.0136	0.0071	0.0023	0.0079	0.0175	0.0096	0.0030	0.0048
0.0017	0.0086	0.0118	0.0056	0.0020	0.0031	0.0065	0.0063	0.0026	0.0019	0.0125	0.0067	0.0023	0.0052	0.0143	0.0074	0.0023	0.0084	0.0184	0.0101	0.0032	0.0052
0.0017	0.0081	0.0113	0.0055	0.0019	0.0030	0.0068	0.0064	0.0027	0.0021	0.0130	0.0070	0.0024	0.0058	0.0150	0.0077	0.0024	0.0090	0.0192	0.0106	0.0033	0.0055
0.0017	0.0075	0.0108	0.0053	0.0019	0.0029	0.0071	0.0066	0.0027	0.0023	0.0135	0.0073	0.0025	0.0063	0.0156	0.0081	0.0025	0.0096	0.0201	0.0111	0.0035	0.0059
0.0017	0.0070	0.0103	0.0051	0.0018	0.0028	0.0073	0.0067	0.0028	0.0024	0.0140	0.0076	0.0026	0.0069	0.0163	0.0084	0.0026	0.0101	0.0209	0.0116	0.0037	0.0063
0.0017	0.0065	0.0098	0.0049	0.0018	0.0027	0.0076	0.0069	0.0029	0.0026	0.0146	0.0079	0.0027	0.0075	0.0170	0.0087	0.0026	0.0107	0.0218	0.0121	0.0038	0.0066
0.0017	0.0059	0.0093	0.0048	0.0017	0.0026	0.0078	0.0070	0.0029	0.0028	0.0151	0.0082	0.0028	0.0081	0.0177	0.0090	0.0027	0.0112	0.0226	0.0126	0.0040	0.0070
0.0017	0.0054	0.0088	0.0046	0.0016	0.0025	0.0081	0.0072	0.0030	0.0030	0.0156	0.0085	0.0029	0.0087	0.0183	0.0093	0.0028	0.0115	0.0234	0.0131	0.0041	0.0073
0.0017	0.0049	0.0084	0.0044	0.0016	0.0024	0.0083	0.0073	0.0031	0.0031	0.0161	0.0088	0.0031	0.0093	0.0190	0.0097	0.0029	0.0117	0.0241	0.0135	0.0043	0.0077
0.00	17.91	15.28	0.65	1.02	5.61	7.55	5.87	0.23	1.48	18.46	0.62	0.06	6.12	18.79	1.09	0.08	12.08	25.52	2.39	0.00	7.16
0.00	16.93	14.87	0.69	0.96	5.45	8.12	5.90	0.25	1.79	20.04	0.73	0.07	7.16	20.18	1.15	0.07	13.10	27.64	2.60	0.00	7.77
0.00	15.96	14.46	0.74	0.91	5.28	8.68	5.92	0.26	2.09	21.61	0.85	0.08	8.21	21.58	1.21	0.06	14.13	29.77	2.80	0.00	8.38
0	14.98	14.05	0.78	0.86	5.12	9.24	5.95	0.27	2.39	23.19	0.97	0.09	9.25	22.98	1.27	0.05	15.15	31.9	3.01	0	8.99
0.00	14.00	13.64	0.82	0.81	4.96	9.80	5.98	0.28	2.69	24.77	1.09	0.10	10.29	24.38	1.33	0.04	16.17	34.03	3.22	0.00	9.60
0.00	13.03	13.23	0.87	0.76	4.79	10.36	6.00	0.29	2.99	26.34	1.21	0.11	11.34	25.78	1.39	0.03	17.20	36.16	3.42	0.00	10.21
0.00	12.05	12.82	0.91	0.70	4.63	10.93	6.03	0.31	3.30	27.92	1.32	0.12	12.38	27.17	1.45	0.02	18.22	38.28	3.63	0.00	10.82
0.00	11.08	12.41	0.96	0.65	4.46	11.49	6.05	0.32	3.60	29.49	1.44	0.13	13.43	28.57	1.51	0.01	19.25	40.41	3.83	0.00	11.43
0.00	10.10	12.00	1.00	0.60	4.30	12.05	6.08	0.33	3.90	31.07	1.56	0.14	14.47	29.97	1.57	0.00	20.27	42.54	4.04	0.00	12.04
0.00	9.12	11.59	1.04	0.55	4.14	12.61	6.11	0.34	4.20	32.65	1.68	0.15	15.51	31.37	1.63	-0.01	21.29	44.67	4.25	0.00	12.65
0.00	8.15	11.18	1.09	0.50	3.97	13.17	6.13	0.35	4.50	34.22	1.80	0.16	16.56	32.77	1.69	-0.02	22.32	46.80	4.45	0.00	13.26
0.00	17.91	15.28	0.65	1.02	5.61	7.55	5.87	0.23	1.48	18.46	0.62	0.06	6.12	18.79	1.09	0.08	12.08	22.76	2.39	0.00	7.16
0.00	16.93	14.87	0.69	0.96	5.45	8.12	5.90	0.25	1.79	20.02	0.73	0.07	7.16	20.09	1.15	0.07	13.10	23.82	2.60	0.00	7.77
0.00	15.96	14.46	0.74	0.91	5.28	8.68	5.92	0.26	2.09	20.81	0.85	0.08	8.21	20.79	1.21	0.06	14.13	24.89	2.80	0.00	8.38
0.00	14.98	14.05	0.78	0.86	5.12	9.24	5.95	0.27	2.39	21.60	0.97	0.09	9.25	21.49	1.27	0.05	15.15	25.95	3.01	0.00	8.99
0.00	14.00	13.64	0.82	0.81	4.96	9.80	5.98	0.28	2.69	22.38	1.09	0.10	10.29	22.19	1.33	0.04	16.17	27.01	3.22	0.00	9.60
0.00	13.03	13.23	0.87	0.76	4.79	10.36	6.00	0.29	2.99	23.17	1.21	0.11	11.34	22.89	1.39	0.03	17.20	28.08	3.42	0.00	10.21
0.00	12.05	12.82	0.91	0.70	4.63	10.93	6.03	0.31	3.30	23.96	1.32	0.12	12.38	23.59	1.45	0.02	18.22	29.14	3.63	0.00	10.82
0.00	11.08	12.41	0.96	0.65	4.46	11.49	6.05	0.32	3.60	24.75	1.44	0.13	13.43	24.29	1.51	0.01	19.25	30.21	3.83	0.00	11.43
0.00	10.10	12.00	1.00	0.60	4.30	12.05	6.08	0.33	3.90	25.54	1.56	0.14	14.47	24.99	1.57	0.00	20.14	31.27	4.04	0.00	12.04
0.00	9.12	11.59	1.04	0.55	4.14	12.61	6.11	0.34	4.20	26.32	1.68	0.15	15.51	25.68	1.63	-0.01	20.65	32.33	4.25	0.00	12.65
0.00	8.15	11.18	1.09	0.50	3.97	13.17	6.13	0.35	4.50	27.11	1.80	0.16	16.56	26.38	1.69	-0.02	21.16	33.40	4.45	0.00	13.26
1.82	11.18	14.54	6.76	2.33	3.74	6.32	6.35	2.66	1.55	11.55	6.06	2.07	3.75	13.11	6.90	2.25	7.38	17.29	9.47	2.99	4.54
1.82	10.60	14.00	6.57	2.27	3.63	6.60	6.52	2.73	1.74	12.57	6.62	2.26	4.39	14.21	7.43	2.40	8.00	18.23	10.02	3.16	4.92
1.83	10.01	13.46	6.38	2.21	3.52	6.88	6.69	2.80	1.92	13.14	6.96	2.38	5.03	14.94	7.78	2.48	8.61	19.18	10.56	3.33	5.31
1.83	9.42	12.92	6.18	2.16	3.41	7.17	6.85	2.87	2.11	13.70	7.30	2.50	5.67	15.68	8.13	2.56	9.23	20.12	11.11	3.50	5.70
1.84	8.84	12.39	5.99	2.10	3.30	7.45	7.02	2.94	2.30	14.27	7.64	2.62	6.32	16.41	8.48	2.64	9.85	21.06	11.65	3.67	6.08
1.84	8.25	11.85	5.79	2.04	3.19	7.73	7.19	3.01	2.48	14.83	7.97	2.74	6.96	17.15	8.83	2.72	10.47	22.01	12.20	3.83	6.47
1.85	7.66	11.31	5.60	1.98	3.08	8.01	7.36	3.08	2.67	15.39	8.31	2.87	7.60	17.88	9.18	2.81	11.08	22.95	12.74	4.00	6.85
1.85	7.08	10.77	5.40	1.92	2.97	8.30	7.53	3.16	2.86	15.96	8.65	2.99	8.24	18.61	9.53	2.89	11.70	23.90	13.29	4.17	7.24
1.86	6.49	10.23	5.21	1.86	2.86	8.58	7.69	3.23	3.05	16.52	8.99	3.11	8.88	19.35	9.88	2.97	12.24	24.80	13.82	4.34	7.63
1.87	5.90	9.69	5.02	1.80	2.75	8.86	7.86	3.30	3.23	17.09	9.32	3.23	9.52	20.08	10.23	3.05	12.55	25.59	14.31	4.51	8.01
1.87	5.32	9.15	4.82	1.74	2.64	9.15	8.03	3.37	3.42	17.65	9.66	3.35	10.16	20.81	10.58	3.13	12.86	26.38	14.81	4.68	8.40
23.06				33.44				19.47				23.20				28.43				39.41	

APPENDIX E - Rainfall Distribution over Time

1994_Q2	1994_Q3	1994_Q4	1995_Q1	1995_Q2	1995_Q3	1995_Q4	1996_Q1	1996_Q2	1996_Q3	1996_Q4	1997_Q1	1997_Q2	1997_Q3	1997_Q4	1998_Q1	1998_Q2	1998_Q3	1998_Q4	1999_Q1	1999_Q2	1999_Q3
13.91	4.86	0.05	14.86	38.15	5.72	0.01	10.35	30.01	6.72	0	32.27	14	0.86	0.54	14.86	42.19	6.51	0.18	11.98	25.55	2.97
16.71	4.6	0	19.02	53.09	7.95	0	13.87	42.49	8.78	0	35.2	25.26	1.35	0.83	19.18	59.24	11.4	0	12.5	29.69	4.49
2.8	-0.26	-0.05	4.16	14.94	2.23	-0.01	3.52	12.48	2.06	0	2.93	11.26	0.49	0.29	4.32	17.05	4.89	-0.18	0.52	4.14	1.52
0.56	-0.05	-0.01	0.83	2.99	0.45	0.00	0.70	2.50	0.41	0.00	0.59	2.25	0.10	0.06	0.86	3.41	0.98	-0.04	0.10	0.83	0.30
0.0087	0.0067	0.0025	0.0072	0.0169	0.0103	0.0035	0.0049	0.0139	0.0096	0.0034	0.0143	0.0109	0.0046	0.0010	0.0069	0.0176	0.0102	0.0035	0.0068	0.0150	0.0081
0.0091	0.0069	0.0026	0.0077	0.0179	0.0110	0.0037	0.0053	0.0148	0.0102	0.0037	0.0145	0.0122	0.0053	0.0013	0.0074	0.0188	0.0113	0.0039	0.0069	0.0153	0.0084
0.0096	0.0071	0.0026	0.0081	0.0189	0.0117	0.0040	0.0058	0.0156	0.0108	0.0039	0.0147	0.0135	0.0060	0.0015	0.0079	0.0200	0.0124	0.0043	0.0071	0.0155	0.0087
0.0101	0.0073	0.0026	0.0086	0.0200	0.0124	0.0042	0.0062	0.0165	0.0115	0.0041	0.0149	0.0148	0.0067	0.0018	0.0084	0.0211	0.0134	0.0047	0.0072	0.0158	0.0090
0.0106	0.0075	0.0027	0.0090	0.0210	0.0132	0.0045	0.0066	0.0174	0.0121	0.0043	0.0151	0.0161	0.0074	0.0021	0.0089	0.0223	0.0145	0.0051	0.0073	0.0160	0.0092
0.0110	0.0077	0.0027	0.0095	0.0221	0.0139	0.0047	0.0070	0.0183	0.0127	0.0046	0.0153	0.0174	0.0081	0.0023	0.0094	0.0235	0.0156	0.0055	0.0075	0.0163	0.0095
0.0115	0.0078	0.0027	0.0099	0.0231	0.0146	0.0050	0.0075	0.0192	0.0134	0.0048	0.0155	0.0186	0.0087	0.0026	0.0099	0.0247	0.0167	0.0059	0.0076	0.0165	0.0098
0.0120	0.0080	0.0028	0.0104	0.0242	0.0154	0.0053	0.0079	0.0200	0.0140	0.0050	0.0157	0.0193	0.0091	0.0027	0.0104	0.0258	0.0178	0.0063	0.0077	0.0168	0.0101
0.0124	0.0082	0.0028	0.0108	0.0252	0.0161	0.0055	0.0083	0.0209	0.0146	0.0053	0.0159	0.0199	0.0095	0.0029	0.0109	0.0270	0.0188	0.0067	0.0079	0.0170	0.0104
0.0129	0.0084	0.0028	0.0113	0.0263	0.0168	0.0058	0.0087	0.0218	0.0153	0.0055	0.0161	0.0206	0.0098	0.0031	0.0113	0.0282	0.0199	0.0071	0.0080	0.0173	0.0107
0.0134	0.0086	0.0028	0.0115	0.0272	0.0175	0.0060	0.0092	0.0227	0.0159	0.0057	0.0163	0.0213	0.0102	0.0032	0.0116	0.0292	0.0210	0.0075	0.0082	0.0175	0.0110
12.23	5.02	0.08	12.36	29.19	4.38	0.02	8.24	22.52	5.48	0.00	30.51	7.24	0.57	0.37	12.27	31.96	3.58	0.29	11.67	23.07	2.06
12.79	4.96	0.07	13.20	32.17	4.83	0.01	8.94	25.02	5.90	0.00	31.10	9.50	0.66	0.42	13.13	35.37	4.55	0.25	11.77	23.89	2.36
13.35	4.91	0.06	14.03	35.16	5.27	0.01	9.65	27.51	6.31	0.00	31.68	11.75	0.76	0.48	14.00	38.78	5.53	0.22	11.88	24.72	2.67
13.91	4.86	0.05	14.86	38.15	5.72	0.01	10.35	30.01	6.72	0	32.27	14	0.86	0.54	14.86	42.19	6.51	0.18	11.98	25.55	2.97
14.47	4.81	0.04	15.69	41.14	6.17	0.01	11.05	32.51	7.13	0.00	32.86	16.25	0.96	0.60	15.72	45.60	7.49	0.14	12.08	26.38	3.27
15.03	4.76	0.03	16.52	44.13	6.61	0.01	11.76	35.00	7.54	0.00	33.44	18.50	1.06	0.66	16.59	49.01	8.47	0.11	12.19	27.21	3.58
15.59	4.70	0.02	17.36	47.11	7.06	0.00	12.46	37.50	7.96	0.00	34.03	20.76	1.15	0.71	17.45	52.42	9.44	0.07	12.29	28.03	3.88
16.15	4.65	0.01	18.19	50.10	7.50	0.00	13.17	39.99	8.37	0.00	34.61	23.01	1.25	0.77	18.32	55.83	10.42	0.04	12.40	28.86	4.19
16.71	4.60	0.00	19.02	53.09	7.95	0.00	13.87	42.49	8.78	0.00	35.20	25.26	1.35	0.83	19.18	59.24	11.40	0.00	12.50	29.69	4.49
17.27	4.55	-0.01	19.85	56.08	8.40	0.00	14.57	44.99	9.19	0.00	35.79	27.51	1.45	0.89	20.04	62.65	12.38	-0.04	12.60	30.52	4.79
17.83	4.50	-0.02	20.68	59.07	8.84	0.00	15.28	47.48	9.60	0.00	36.37	29.76	1.55	0.95	20.91	66.06	13.36	-0.07	12.71	31.35	5.10
12.23	5.02	0.08	12.36	24.59	4.38	0.02	8.24	21.26	5.48	0.00	25.26	7.24	0.57	0.37	12.27	25.98	3.58	0.29	11.67	21.53	2.06
12.79	4.96	0.07	13.20	26.09	4.83	0.01	8.94	22.51	5.90	0.00	25.55	9.50	0.66	0.42	13.13	27.69	4.55	0.25	11.77	21.95	2.36
13.35	4.91	0.06	14.03	27.58	5.27	0.01	9.65	23.76	6.31	0.00	25.84	11.75	0.76	0.48	14.00	29.39	5.53	0.22	11.88	22.36	2.67
13.91	4.86	0.05	14.86	29.08	5.72	0.01	10.35	25.01	6.72	0.00	26.14	14.00	0.86	0.54	14.86	31.10	6.51	0.18	11.98	22.78	2.97
14.47	4.81	0.04	15.69	30.57	6.17	0.01	11.05	26.25	7.13	0.00	26.43	16.25	0.96	0.60	15.72	32.80	7.49	0.14	12.08	23.19	3.27
15.03	4.76	0.03	16.52	32.06	6.61	0.01	11.76	27.50	7.54	0.00	26.72	18.50	1.06	0.66	16.59	34.51	8.47	0.11	12.19	23.60	3.58
15.59	4.70	0.02	17.36	33.56	7.06	0.00	12.46	28.75	7.96	0.00	27.01	20.38	1.15	0.71	17.45	36.21	9.44	0.07	12.29	24.02	3.88
16.15	4.65	0.01	18.19	35.05	7.50	0.00	13.17	30.00	8.37	0.00	27.31	21.50	1.25	0.77	18.32	37.92	10.42	0.04	12.40	24.43	4.19
16.71	4.60	0.00	19.02	36.55	7.95	0.00	13.87	31.25	8.78	0.00	27.60	22.63	1.35	0.83	19.18	39.62	11.40	0.00	12.50	24.85	4.49
17.27	4.55	-0.01	19.85	38.04	8.40	0.00	14.57	32.49	9.19	0.00	27.89	23.76	1.45	0.89	20.02	41.33	12.38	-0.04	12.60	25.26	4.79
17.83	4.50	-0.02	20.34	39.53	8.84	0.00	15.28	33.74	9.60	0.00	28.19	24.88	1.55	0.95	20.45	43.03	13.36	-0.07	12.71	25.67	5.10
9.49	7.39	2.78	7.94	18.47	11.24	3.78	5.39	15.23	10.49	3.77	15.70	11.92	5.04	1.11	7.53	19.31	11.17	3.84	7.44	16.45	8.86
10.01	7.59	2.81	8.44	19.62	12.04	4.07	5.85	16.19	11.18	4.02	15.92	13.36	5.80	1.40	8.07	20.59	12.35	4.29	7.59	16.73	9.18
10.52	7.79	2.84	8.93	20.76	12.84	4.35	6.32	17.15	11.88	4.27	16.14	14.80	6.57	1.69	8.62	21.88	13.54	4.73	7.74	17.00	9.50
11.04	7.99	2.88	9.42	21.91	13.64	4.63	6.79	18.11	12.57	4.52	16.35	16.24	7.33	1.98	9.16	23.17	14.72	5.17	7.89	17.28	9.81
11.56	8.19	2.91	9.91	23.05	14.44	4.91	7.25	19.07	13.26	4.76	16.57	17.68	8.09	2.27	9.71	24.46	15.91	5.61	8.04	17.55	10.13
12.08	8.38	2.95	10.40	24.20	15.24	5.19	7.72	20.03	13.95	5.01	16.79	19.12	8.86	2.56	10.26	25.75	17.09	6.06	8.19	17.83	10.45
12.60	8.58	2.98	10.89	25.34	16.04	5.48	8.18	20.99	14.64	5.26	17.00	20.33	9.51	2.81	10.80	27.03	18.27	6.50	8.34	18.11	10.76
13.12	8.78	3.02	11.38	26.49	16.84	5.76	8.65	21.95	15.34	5.51	17.22	21.09	9.93	2.99	11.35	28.32	19.46	6.94	8.49	18.38	11.08
13.64	8.98	3.05	11.87	27.63	17.64	6.04	9.12	22.91	16.03	5.76	17.44	21.86	10.36	3.17	11.89	29.61	20.64	7.38	8.64	18.66	11.40
14.16	9.17	3.09	12.36	28.78	18.43	6.32	9.58	23.87	16.72	6.01	17.66	22.62	10.78	3.34	12.42	30.89	21.83	7.82	8.79	18.93	11.71
14.68	9.37	3.12	12.65	29.82	19.20	6.60	10.05	24.83	17.41	6.26	17.87	23.39	11.21	3.52	12.71	32.05	22.97	8.27	8.94	19.21	12.03
		25.33				44.16				37.25				36.49				45.30			

APPENDIX E - Rainfall Distribution over Time

1999_Q4	2000_Q1	2000_Q2	2000_Q3	2000_Q4	2001_Q1	2001_Q2	2001_Q3	2001_Q4	2002_Q1	2002_Q2	2002_Q3	2002_Q4	2003_Q1	2003_Q2	2003_Q3	2003_Q4	2004_Q1	2004_Q2	2004_Q3	2004_Q4	2005_Q1
0.16	6.57	38.36	3.88	0.6	7.46	23.38	2.74	0.16	27.51	12.32	1.42	0.05	27.2	8.26	7	0	21.67	14.48	0.72	0.17	24.88
0.28	7.39	44.88	4.92	1	9.96	27.47	4.42	0.08	32.27	11.28	1.35	0	28.7	8.27	10.1	0.03	25.21	19.12	0.69	0.2	27.51
0.12	0.82	6.52	1.04	0.4	2.5	4.09	1.68	-0.08	4.76	-1.04	-0.07	-0.05	1.5	0.01	3.1	0.03	3.54	4.64	-0.03	0.03	2.63
0.02	0.16	1.30	0.21	0.08	0.50	0.82	0.34	-0.02	0.95	-0.21	-0.01	-0.01	0.30	0.00	0.62	0.01	0.71	0.93	-0.01	0.01	0.53
0.0026	0.0035	0.0166	0.0098	0.0036	0.0037	0.0129	0.0071	0.0025	0.0124	0.0132	0.0064	0.0016	0.0128	0.0109	0.0072	0.0022	0.0112	0.0118	0.0054	0.0014	0.0120
0.0027	0.0037	0.0170	0.0101	0.0037	0.0040	0.0132	0.0074	0.0026	0.0127	0.0132	0.0064	0.0016	0.0129	0.0109	0.0075	0.0023	0.0115	0.0124	0.0057	0.0014	0.0121
0.0028	0.0038	0.0174	0.0104	0.0039	0.0043	0.0136	0.0078	0.0027	0.0130	0.0132	0.0063	0.0016	0.0130	0.0109	0.0079	0.0025	0.0118	0.0130	0.0060	0.0015	0.0123
0.0030	0.0039	0.0178	0.0107	0.0041	0.0046	0.0140	0.0081	0.0028	0.0133	0.0133	0.0063	0.0015	0.0131	0.0110	0.0082	0.0027	0.0120	0.0136	0.0063	0.0016	0.0124
0.0031	0.0040	0.0182	0.0110	0.0042	0.0049	0.0143	0.0085	0.0029	0.0136	0.0133	0.0063	0.0015	0.0131	0.0110	0.0086	0.0028	0.0123	0.0142	0.0065	0.0017	0.0125
0.0032	0.0042	0.0186	0.0113	0.0044	0.0052	0.0147	0.0088	0.0031	0.0139	0.0133	0.0063	0.0015	0.0132	0.0111	0.0090	0.0030	0.0126	0.0148	0.0068	0.0018	0.0127
0.0034	0.0043	0.0190	0.0116	0.0045	0.0055	0.0151	0.0091	0.0032	0.0142	0.0133	0.0063	0.0015	0.0133	0.0111	0.0093	0.0032	0.0128	0.0154	0.0071	0.0019	0.0128
0.0035	0.0044	0.0194	0.0119	0.0047	0.0059	0.0154	0.0095	0.0033	0.0144	0.0133	0.0062	0.0014	0.0134	0.0112	0.0097	0.0034	0.0131	0.0161	0.0074	0.0020	0.0130
0.0036	0.0045	0.0198	0.0122	0.0049	0.0062	0.0158	0.0098	0.0034	0.0147	0.0133	0.0062	0.0014	0.0135	0.0112	0.0100	0.0035	0.0133	0.0167	0.0077	0.0020	0.0131
0.0038	0.0047	0.0202	0.0126	0.0050	0.0065	0.0162	0.0102	0.0035	0.0150	0.0134	0.0062	0.0014	0.0135	0.0112	0.0104	0.0037	0.0136	0.0173	0.0080	0.0021	0.0133
0.0039	0.0048	0.0206	0.0129	0.0052	0.0068	0.0166	0.0105	0.0037	0.0153	0.0134	0.0062	0.0013	0.0136	0.0113	0.0107	0.0039	0.0138	0.0176	0.0081	0.0022	0.0134
0.09	6.08	34.45	3.26	0.36	5.96	20.93	1.73	0.21	24.65	12.94	1.46	0.08	26.30	8.25	5.14	-0.02	19.55	11.70	0.74	0.15	23.30
0.11	6.24	35.75	3.46	0.44	6.46	21.74	2.07	0.19	25.61	12.74	1.45	0.07	26.60	8.26	5.76	-0.01	20.25	12.62	0.73	0.16	23.83
0.14	6.41	37.06	3.67	0.52	6.96	22.56	2.40	0.18	26.56	12.53	1.43	0.06	26.90	8.26	6.38	-0.01	20.96	13.55	0.73	0.16	24.35
0.16	6.57	38.36	3.88	0.6	7.46	23.38	2.74	0.16	27.51	12.32	1.42	0.05	27.2	8.26	7	0	21.67	14.48	0.72	0.17	24.88
0.18	6.73	39.66	4.09	0.68	7.96	24.20	3.08	0.14	28.46	12.11	1.41	0.04	27.50	8.26	7.62	0.01	22.38	15.41	0.71	0.18	25.41
0.21	6.90	40.97	4.30	0.76	8.46	25.02	3.41	0.13	29.41	11.90	1.39	0.03	27.80	8.26	8.24	0.01	23.09	16.34	0.71	0.18	25.93
0.23	7.06	42.27	4.50	0.84	8.96	25.83	3.75	0.11	30.37	11.70	1.38	0.02	28.10	8.27	8.86	0.02	23.79	17.26	0.70	0.19	26.46
0.26	7.23	43.58	4.71	0.92	9.46	26.65	4.08	0.10	31.32	11.49	1.36	0.01	28.40	8.27	9.48	0.02	24.50	18.19	0.70	0.19	26.98
0.28	7.39	44.88	4.92	1.00	9.96	27.47	4.42	0.08	32.27	11.28	1.35	0.00	28.70	8.27	10.10	0.03	25.21	19.12	0.69	0.20	27.51
0.30	7.55	46.18	5.13	1.08	10.46	28.29	4.76	0.06	33.22	11.07	1.34	-0.01	29.00	8.27	10.72	0.04	25.92	20.05	0.68	0.21	28.04
0.33	7.72	47.49	5.34	1.16	10.96	29.11	5.09	0.05	34.17	10.86	1.32	-0.02	29.30	8.27	11.34	0.04	26.63	20.98	0.68	0.21	28.56
0.09	6.08	27.22	3.26	0.36	5.96	20.46	1.73	0.21	22.33	12.94	1.46	0.08	23.15	8.25	5.14	-0.02	19.55	11.70	0.74	0.15	21.65
0.11	6.24	27.88	3.46	0.44	6.46	20.87	2.07	0.19	22.80	12.74	1.45	0.07	23.30	8.26	5.76	-0.01	20.13	12.62	0.73	0.16	21.91
0.14	6.41	28.53	3.67	0.52	6.96	21.28	2.40	0.18	23.28	12.53	1.43	0.06	23.45	8.26	6.38	-0.01	20.48	13.55	0.73	0.16	22.18
0.16	6.57	29.18	3.88	0.60	7.46	21.69	2.74	0.16	23.76	12.32	1.42	0.05	23.60	8.26	7.00	0.00	20.84	14.48	0.72	0.17	22.44
0.18	6.73	29.83	4.09	0.68	7.96	22.10	3.08	0.14	24.23	12.11	1.41	0.04	23.75	8.26	7.62	0.01	21.19	15.41	0.71	0.18	22.70
0.21	6.90	30.48	4.30	0.76	8.46	22.51	3.41	0.13	24.71	11.90	1.39	0.03	23.90	8.26	8.24	0.01	21.54	16.34	0.71	0.18	22.97
0.23	7.06	31.14	4.50	0.84	8.96	22.92	3.75	0.11	25.18	11.70	1.38	0.02	24.05	8.27	8.86	0.02	21.90	17.26	0.70	0.19	23.23
0.26	7.23	31.79	4.71	0.92	9.46	23.33	4.08	0.10	25.66	11.49	1.36	0.01	24.20	8.27	9.48	0.02	22.25	18.19	0.70	0.19	23.49
0.28	7.39	32.44	4.92	1.00	9.96	23.74	4.42	0.08	26.14	11.28	1.35	0.00	24.35	8.27	10.10	0.03	22.61	19.12	0.69	0.20	23.76
0.30	7.55	33.09	5.13	1.08	10.46	24.14	4.76	0.06	26.61	11.07	1.34	-0.01	24.50	8.27	10.72	0.04	22.96	20.02	0.68	0.21	24.02
0.33	7.72	33.74	5.34	1.16	10.96	24.55	5.09	0.05	27.09	10.86	1.32	-0.02	24.65	8.27	11.34	0.04	23.31	20.49	0.68	0.21	24.28
2.82	3.88	18.17	10.73	3.92	4.01	14.10	7.77	2.69	13.63	14.49	6.99	1.78	14.06	11.91	7.88	2.36	12.24	12.88	5.91	1.48	13.11
2.97	4.02	18.61	11.07	4.09	4.35	14.51	8.15	2.82	13.95	14.50	6.97	1.75	14.15	11.95	8.26	2.55	12.65	13.61	6.24	1.58	13.27
3.12	4.15	19.05	11.40	4.27	4.70	14.91	8.52	2.95	14.26	14.52	6.95	1.72	14.23	12.00	8.65	2.74	12.92	14.27	6.55	1.67	13.43
3.26	4.29	19.50	11.74	4.44	5.04	15.31	8.90	3.09	14.58	14.53	6.92	1.69	14.32	12.04	9.04	2.93	13.20	14.94	6.86	1.77	13.59
3.41	4.42	19.94	12.08	4.62	5.39	15.72	9.27	3.22	14.89	14.55	6.90	1.66	14.40	12.09	9.43	3.12	13.48	15.60	7.17	1.86	13.75
3.56	4.56	20.38	12.41	4.79	5.73	16.12	9.65	3.35	15.20	14.57	6.88	1.63	14.49	12.13	9.81	3.31	13.75	16.27	7.48	1.96	13.91
3.71	4.70	20.82	12.75	4.97	6.08	16.52	10.02	3.48	15.52	14.58	6.85	1.60	14.57	12.18	10.20	3.50	14.03	16.93	7.79	2.05	14.06
3.85	4.83	21.27	13.09	5.14	6.42	16.93	10.39	3.62	15.83	14.60	6.83	1.56	14.66	12.22	10.59	3.69	14.31	17.59	8.10	2.14	14.22
4.00	4.97	21.71	13.42	5.32	6.77	17.33	10.77	3.75	16.15	14.62	6.81	1.53	14.75	12.27	10.98	3.88	14.58	18.26	8.41	2.24	14.38
4.15	5.10	22.15	13.76	5.50	7.11	17.73	11.14	3.88	16.46	14.63	6.78	1.50	14.83	12.31	11.36	4.06	14.86	18.91	8.71	2.33	14.54
4.29	5.24	22.59	14.10	5.67	7.46	18.14	11.52	4.01	16.78	14.65	6.76	1.47	14.92	12.36	11.75	4.25	15.13	19.29	8.88	2.38	14.70
36.47				37.78				29.83				37.17				36.91				34.08	

APPENDIX E - Rainfall Distribution over Time

2005_Q2	2005_Q3	2005_Q4	2006_Q1	2006_Q2	2006_Q3	2006_Q4	2007_Q1	2007_Q2	2007_Q3	2007_Q4	2008_Q1	2008_Q2	2008_Q3	2008_Q4	2009_Q1	2009_Q2	2009_Q3	2009_Q4	2010_Q1	2010_Q2	2010_Q3
25.51	6.86	0.1	24.76	27.1	11.46	0.01	9.22	10.43	2.63	0.44	7.95	24.91	0.22	0.05	10.77	20.55	1.95	0.26	15.24	24.38	6.58
28.69	7.34	0.15	25.73	23.86	12.78	0.03	11.35	13.02	2.55	0.43	8.21	24.7	0.32	0	13.09	24.93	2.26	0	17.35	28.94	9.18
3.18	0.48	0.05	0.97	-3.24	1.32	0.02	2.13	2.59	-0.08	-0.01	0.26	-0.21	0.1	-0.05	2.32	4.38	0.31	-0.26	2.11	4.56	2.6
0.64	0.10	0.01	0.19	-0.65	0.26	0.00	0.43	0.52	-0.02	0.00	0.05	-0.04	0.02	-0.01	0.46	0.88	0.06	-0.05	0.42	0.91	0.52
0.0179	0.0115	0.0038	0.0127	0.0195	0.0146	0.0052	0.0053	0.0070	0.0046	0.0018	0.0046	0.0145	0.0070	0.0021	0.0052	0.0124	0.0067	0.0023	0.0079	0.0153	0.0097
0.0181	0.0117	0.0039	0.0128	0.0193	0.0146	0.0052	0.0056	0.0074	0.0048	0.0018	0.0047	0.0145	0.0070	0.0021	0.0054	0.0130	0.0070	0.0024	0.0081	0.0156	0.0102
0.0184	0.0119	0.0039	0.0128	0.0192	0.0147	0.0052	0.0058	0.0078	0.0050	0.0019	0.0047	0.0145	0.0070	0.0021	0.0057	0.0136	0.0074	0.0025	0.0084	0.0160	0.0106
0.0186	0.0120	0.0040	0.0129	0.0190	0.0148	0.0053	0.0061	0.0082	0.0051	0.0019	0.0047	0.0145	0.0070	0.0021	0.0059	0.0141	0.0076	0.0025	0.0086	0.0163	0.0111
0.0189	0.0122	0.0041	0.0130	0.0189	0.0148	0.0053	0.0064	0.0086	0.0053	0.0020	0.0047	0.0145	0.0070	0.0021	0.0062	0.0144	0.0078	0.0026	0.0088	0.0167	0.0115
0.0191	0.0124	0.0041	0.0130	0.0187	0.0149	0.0054	0.0066	0.0090	0.0055	0.0020	0.0048	0.0145	0.0070	0.0021	0.0064	0.0148	0.0080	0.0026	0.0090	0.0171	0.0120
0.0194	0.0125	0.0042	0.0131	0.0186	0.0150	0.0054	0.0069	0.0094	0.0057	0.0020	0.0048	0.0145	0.0070	0.0021	0.0067	0.0152	0.0082	0.0026	0.0093	0.0174	0.0124
0.0196	0.0127	0.0043	0.0132	0.0184	0.0150	0.0055	0.0071	0.0098	0.0058	0.0021	0.0048	0.0145	0.0070	0.0021	0.0069	0.0155	0.0084	0.0026	0.0095	0.0178	0.0129
0.0199	0.0129	0.0043	0.0132	0.0183	0.0151	0.0055	0.0074	0.0102	0.0060	0.0021	0.0048	0.0145	0.0070	0.0021	0.0072	0.0159	0.0086	0.0027	0.0097	0.0181	0.0133
0.0201	0.0130	0.0044	0.0133	0.0181	0.0152	0.0056	0.0076	0.0106	0.0062	0.0022	0.0049	0.0145	0.0071	0.0021	0.0074	0.0163	0.0088	0.0027	0.0099	0.0185	0.0138
0.0203	0.0132	0.0044	0.0134	0.0180	0.0152	0.0056	0.0079	0.0110	0.0063	0.0022	0.0049	0.0145	0.0071	0.0021	0.0077	0.0166	0.0090	0.0027	0.0102	0.0189	0.0142
23.60	6.57	0.07	24.18	29.04	10.67	0.00	7.94	8.88	2.68	0.45	7.79	25.04	0.16	0.08	9.38	17.92	1.76	0.42	13.97	21.64	5.02
24.24	6.67	0.08	24.37	28.40	10.93	0.00	8.37	9.39	2.66	0.44	7.85	24.99	0.18	0.07	9.84	18.80	1.83	0.36	14.40	22.56	5.54
24.87	6.76	0.09	24.57	27.75	11.20	0.01	8.79	9.91	2.65	0.44	7.90	24.95	0.20	0.06	10.31	19.67	1.89	0.31	14.82	23.47	6.06
25.51	6.86	0.1	24.76	27.1	11.46	0.01	9.22	10.43	2.63	0.44	7.95	24.91	0.22	0.05	10.77	20.55	1.95	0.26	15.24	24.38	6.58
26.15	6.96	0.11	24.95	26.45	11.72	0.01	9.65	10.95	2.61	0.44	8.00	24.87	0.24	0.04	11.23	21.43	2.01	0.21	15.66	25.29	7.10
26.78	7.05	0.12	25.15	25.80	11.99	0.02	10.07	11.47	2.60	0.44	8.05	24.83	0.26	0.03	11.70	22.30	2.07	0.16	16.08	26.20	7.62
27.42	7.15	0.13	25.34	25.16	12.25	0.02	10.50	11.98	2.58	0.43	8.11	24.78	0.28	0.02	12.16	23.18	2.14	0.10	16.51	27.12	8.14
28.05	7.24	0.14	25.54	24.51	12.52	0.03	10.92	12.50	2.57	0.43	8.16	24.74	0.30	0.01	12.63	24.05	2.20	0.05	16.93	28.03	8.66
28.69	7.34	0.15	25.73	23.86	12.78	0.03	11.35	13.02	2.55	0.43	8.21	24.70	0.32	0.00	13.09	24.93	2.26	0.00	17.35	28.94	9.18
29.33	7.44	0.16	25.92	23.21	13.04	0.03	11.78	13.54	2.53	0.43	8.26	24.66	0.34	-0.01	13.55	25.81	2.32	-0.05	17.77	29.85	9.70
29.96	7.53	0.17	26.12	22.56	13.31	0.04	12.20	14.06	2.52	0.43	8.31	24.62	0.36	-0.02	14.02	26.68	2.38	-0.10	18.19	30.76	10.22
21.80	6.57	0.07	22.09	24.52	10.67	0.00	7.94	8.88	2.68	0.45	7.79	22.52	0.16	0.08	9.38	17.92	1.76	0.42	13.97	20.82	5.02
22.12	6.67	0.08	22.19	24.20	10.93	0.00	8.37	9.39	2.66	0.44	7.85	22.50	0.18	0.07	9.84	18.80	1.83	0.36	14.40	21.28	5.54
22.44	6.76	0.09	22.28	23.87	11.20	0.01	8.79	9.91	2.65	0.44	7.90	22.48	0.20	0.06	10.31	19.67	1.89	0.31	14.82	21.73	6.06
22.76	6.86	0.10	22.38	23.55	11.46	0.01	9.22	10.43	2.63	0.44	7.95	22.46	0.22	0.05	10.77	20.28	1.95	0.26	15.24	22.19	6.58
23.07	6.96	0.11	22.48	23.23	11.72	0.01	9.65	10.95	2.61	0.44	8.00	22.43	0.24	0.04	11.23	20.71	2.01	0.21	15.66	22.65	7.10
23.39	7.05	0.12	22.57	22.90	11.99	0.02	10.07	11.47	2.60	0.44	8.05	22.41	0.26	0.03	11.70	21.15	2.07	0.16	16.08	23.10	7.62
23.71	7.15	0.13	22.67	22.58	12.25	0.02	10.50	11.98	2.58	0.43	8.11	22.39	0.28	0.02	12.16	21.59	2.14	0.10	16.51	23.56	8.14
24.03	7.24	0.14	22.77	22.25	12.52	0.03	10.92	12.50	2.57	0.43	8.16	22.37	0.30	0.01	12.63	22.03	2.20	0.05	16.93	24.01	8.66
24.35	7.34	0.15	22.87	21.93	12.78	0.03	11.35	13.02	2.55	0.43	8.21	22.35	0.32	0.00	13.09	22.47	2.26	0.00	17.35	24.47	9.18
24.66	7.44	0.16	22.96	21.61	13.04	0.03	11.78	13.54	2.53	0.43	8.26	22.33	0.34	-0.01	13.55	22.90	2.32	-0.05	17.77	24.93	9.70
24.98	7.53	0.17	23.06	21.28	13.31	0.04	12.20	14.06	2.52	0.43	8.31	22.31	0.36	-0.02	14.02	23.34	2.38	-0.10	18.19	25.38	10.22
19.59	12.65	4.19	13.93	21.35	15.97	5.65	5.83	7.71	5.06	1.96	5.08	15.89	7.63	2.35	5.67	13.57	7.37	2.57	8.69	16.73	10.66
19.86	12.83	4.26	14.00	21.18	16.04	5.70	6.11	8.15	5.25	2.00	5.11	15.90	7.64	2.35	5.94	14.24	7.72	2.65	8.93	17.12	11.15
20.13	13.01	4.33	14.07	21.02	16.11	5.75	6.40	8.59	5.44	2.05	5.14	15.90	7.65	2.34	6.22	14.90	8.07	2.72	9.17	17.52	11.64
20.40	13.19	4.39	14.14	20.85	16.18	5.80	6.68	9.03	5.63	2.10	5.17	15.90	7.66	2.34	6.50	15.40	8.33	2.77	9.42	17.91	12.13
20.67	13.37	4.46	14.21	20.69	16.25	5.85	6.96	9.46	5.82	2.14	5.19	15.90	7.67	2.34	6.78	15.80	8.54	2.80	9.66	18.31	12.62
20.94	13.55	4.53	14.29	20.53	16.32	5.90	7.25	9.90	6.01	2.19	5.22	15.91	7.69	2.34	7.05	16.20	8.76	2.83	9.90	18.70	13.11
21.21	13.72	4.59	14.36	20.36	16.39	5.95	7.53	10.34	6.19	2.23	5.25	15.91	7.70	2.34	7.33	16.60	8.97	2.86	10.15	19.10	13.60
21.48	13.90	4.66	14.43	20.20	16.46	6.00	7.81	10.78	6.38	2.28	5.28	15.91	7.71	2.33	7.61	17.01	9.19	2.89	10.39	19.49	14.09
21.75	14.08	4.73	14.50	20.03	16.53	6.05	8.10	11.22	6.57	2.33	5.31	15.92	7.72	2.33	7.89	17.41	9.40	2.92	10.64	19.89	14.58
22.02	14.26	4.79	14.57	19.87	16.60	6.09	8.38	11.66	6.76	2.37	5.34	15.92	7.73	2.33	8.16	17.81	9.62	2.96	10.88	20.28	15.08
22.29	14.44	4.86	14.64	19.70	16.68	6.14	8.66	12.10	6.95	2.42	5.37	15.92	7.74	2.33	8.44	18.21	9.83	2.99	11.12	20.68	15.57
		50.22				56.92				21.52				30.99				30.55			

APPENDIX E - Rainfall Distribution over Time

2010_Q4	2011_Q1	2011_Q2	2011_Q3	2011_Q4	2012_Q1	2012_Q2	2012_Q3	2012_Q4
0.08	24.41	25.96	7.57	0.06	6.49	21.97	3.86	0.04
0.05	26.45	31.22	7.14	0.01	6.93	24.88	2.95	0
-0.03	2.04	5.26	-0.43	-0.05	0.44	2.91	-0.91	-0.04
-0.01	0.41	1.05	-0.09	-0.01	0.09	0.58	-0.18	-0.01
0.0033	0.0123	0.0176	0.0121	0.0041	0.0041	0.0127	0.0085	0.0031
0.0035	0.0125	0.0180	0.0122	0.0042	0.0042	0.0129	0.0085	0.0030
0.0037	0.0126	0.0183	0.0123	0.0042	0.0042	0.0131	0.0085	0.0030
0.0039	0.0128	0.0187	0.0125	0.0042	0.0043	0.0133	0.0085	0.0030
0.0041	0.0129	0.0190	0.0126	0.0042	0.0043	0.0135	0.0084	0.0030
0.0042	0.0131	0.0194	0.0127	0.0042	0.0043	0.0136	0.0084	0.0029
0.0044	0.0133	0.0197	0.0128	0.0043	0.0044	0.0138	0.0084	0.0029
0.0046	0.0134	0.0200	0.0129	0.0043	0.0044	0.0140	0.0084	0.0029
0.0048	0.0136	0.0204	0.0130	0.0043	0.0044	0.0142	0.0084	0.0029
0.0050	0.0137	0.0207	0.0132	0.0043	0.0045	0.0144	0.0084	0.0028
0.0051	0.0139	0.0211	0.0133	0.0043	0.0045	0.0146	0.0084	0.0028
0.10	23.19	22.80	7.83	0.09	6.23	20.22	4.41	0.06
0.09	23.59	23.86	7.74	0.08	6.31	20.81	4.22	0.06
0.09	24.00	24.91	7.66	0.07	6.40	21.39	4.04	0.05
0.08	24.41	25.96	7.57	0.06	6.49	21.97	3.86	0.04
0.07	24.82	27.01	7.48	0.05	6.58	22.55	3.68	0.03
0.07	25.23	28.06	7.40	0.04	6.67	23.13	3.50	0.02
0.06	25.63	29.12	7.31	0.03	6.75	23.72	3.31	0.02
0.06	26.04	30.17	7.23	0.02	6.84	24.30	3.13	0.01
0.05	26.45	31.22	7.14	0.01	6.93	24.88	2.95	0.00
0.04	26.86	32.27	7.05	0.00	7.02	25.46	2.77	-0.01
0.04	27.27	33.32	6.97	-0.01	7.11	26.04	2.59	-0.02
0.10	21.59	21.40	7.83	0.09	6.23	20.11	4.41	0.06
0.09	21.80	21.93	7.74	0.08	6.31	20.40	4.22	0.06
0.09	22.00	22.45	7.66	0.07	6.40	20.69	4.04	0.05
0.08	22.21	22.98	7.57	0.06	6.49	20.99	3.86	0.04
0.07	22.41	23.51	7.48	0.05	6.58	21.28	3.68	0.03
0.07	22.61	24.03	7.40	0.04	6.67	21.57	3.50	0.02
0.06	22.82	24.56	7.31	0.03	6.75	21.86	3.31	0.02
0.06	23.02	25.08	7.23	0.02	6.84	22.15	3.13	0.01
0.05	23.23	25.61	7.14	0.01	6.93	22.44	2.95	0.00
0.04	23.43	26.14	7.05	0.00	7.02	22.73	2.77	-0.01
0.04	23.63	26.66	6.97	-0.01	7.11	23.02	2.59	-0.02
3.65	13.49	19.33	13.28	4.54	4.55	13.94	9.30	3.37
3.85	13.66	19.71	13.40	4.56	4.59	14.14	9.29	3.34
4.04	13.83	20.08	13.53	4.58	4.63	14.34	9.27	3.31
4.24	14.01	20.46	13.66	4.61	4.67	14.54	9.26	3.28
4.44	14.18	20.83	13.78	4.63	4.71	14.74	9.25	3.25
4.64	14.35	21.21	13.91	4.65	4.75	14.94	9.23	3.22
4.84	14.52	21.59	14.04	4.67	4.79	15.14	9.22	3.19
5.03	14.70	21.96	14.16	4.69	4.83	15.34	9.21	3.16
5.23	14.87	22.34	14.29	4.71	4.88	15.54	9.20	3.13
5.43	15.04	22.71	14.42	4.73	4.92	15.74	9.18	3.10
5.63	15.21	23.09	14.54	4.75	4.96	15.94	9.17	3.07
41.04				51.33				31.36

APPENDIX E - SFR1 Stream Segment Data

STREAM INFLOW

					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Seg #	Stream	Bed K	Elev Up	Elev Down	1985_Q1	1985_Q2	1985_Q3	1985_Q4	1986_Q1	1986_Q2	1986_Q3	1986_Q4	1987_Q1	1987_Q2	1987_Q3	1987_Q4	1988_Q1	1988_Q2	1988_Q3	1988_Q4
10	Upper Love Creek - Butano	1	642	589	1.29E+04	3.74E+04	7.27E+03	1.07E+02	7.36E+03	1.26E+05	2.21E+04	5.05E+02	1.41E+03	3.92E+04	9.18E+03	2.23E+01	9.53E+03	1.72E+04	9.69E+03	5.22E+02
15	Lower Newell - Monterey	0.1	405	343	1.16E+05	3.39E+05	6.47E+04	7.97E+02	6.71E+04	1.13E+06	1.95E+05	4.30E+03	1.23E+04	3.48E+05	8.01E+04	1.69E+02	8.65E+04	1.57E+05	8.66E+04	4.58E+03
17	Lompico Creek - Butano	1	598	520	2.62E+04	7.24E+04	1.39E+04	1.98E+02	1.51E+04	2.41E+05	4.18E+04	1.07E+03	2.75E+03	7.42E+04	1.72E+04	4.21E+01	1.95E+04	3.35E+04	1.86E+04	1.15E+03
24	Zayante - Mountain House Gulch	0.5	495	475	1.49E+05	5.20E+05	8.22E+04	5.62E+02	8.91E+04	1.69E+06	2.42E+05	4.72E+03	1.45E+04	5.10E+05	9.70E+04	1.30E+02	1.13E+05	2.44E+05	1.11E+05	5.40E+03
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	5	600	465	1.94E+04	9.18E+04	1.03E+04	8.73E+01	1.12E+04	3.06E+05	3.09E+04	4.74E+02	2.04E+03	9.41E+04	1.27E+04	1.86E+01	1.44E+04	4.24E+04	1.38E+04	5.06E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	5	520	425	1.94E+04	9.18E+04	1.03E+04	8.73E+01	1.12E+04	3.06E+05	3.09E+04	4.74E+02	2.04E+03	9.41E+04	1.27E+04	1.86E+01	1.44E+04	4.24E+04	1.38E+04	5.06E+02
42	Bean Creek Inflow - Butano	0.1	818	808	6.35E+04	2.46E+05	3.03E+04	1.87E+02	3.82E+04	7.96E+05	8.87E+04	1.66E+03	6.01E+03	2.38E+05	3.54E+04	4.03E+01	4.85E+04	1.16E+05	4.10E+04	1.94E+03

STREAM RUNOFF

					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Seg #	Stream	Bed K	Elev Up	Elev Down	1985_Q1	1985_Q2	1985_Q3	1985_Q4	1986_Q1	1986_Q2	1986_Q3	1986_Q4	1987_Q1	1987_Q2	1987_Q3	1987_Q4	1988_Q1	1988_Q2	1988_Q3	1988_Q4
1	Upper Blackburn Gulch	5	900	490	1.91E+04	7.39E+04	1.04E+04	1.23E+02	1.10E+04	2.46E+05	3.12E+04	6.55E+02	2.01E+03	7.60E+04	1.28E+04	2.62E+01	1.41E+04	3.41E+04	1.38E+04	6.96E+02
2	Lower Blackburn Gulch	5	488	378	5.72E+04	1.61E+05	2.29E+04	4.38E+02	3.25E+04	5.43E+05	6.96E+04	2.04E+03	6.26E+03	1.69E+05	2.90E+04	9.11E+01	4.21E+04	7.40E+04	3.05E+04	2.10E+03
3	Carbonera Creek - Butano	1	998	910	9.17E+03	2.97E+04	4.79E+03	5.41E+01	5.33E+03	9.84E+04	1.43E+04	3.14E+02	9.49E+02	3.02E+04	5.87E+03	1.16E+01	6.85E+03	1.38E+04	6.42E+03	3.40E+02
4	Carbonera Creek - Monterey	0.1	905	787	1.83E+04	5.94E+04	9.58E+03	1.08E+02	1.07E+04	1.97E+05	2.87E+04	6.29E+02	1.90E+03	6.03E+04	1.17E+04	2.33E+01	1.37E+04	2.75E+04	1.28E+04	6.80E+02
5	Carbonera Creek - Monterey	0.1	785	724	1.83E+04	5.94E+04	9.58E+03	1.08E+02	1.07E+04	1.97E+05	2.87E+04	6.29E+02	1.90E+03	6.03E+04	1.17E+04	2.33E+01	1.37E+04	2.75E+04	1.28E+04	6.80E+02
6	Carbonera Creek - Santa Cruz Mudstone	0.005	723	588	7.63E+04	1.72E+05	2.36E+04	4.95E+02	4.39E+04	5.75E+05	7.11E+04	2.61E+03	8.07E+03	1.78E+05	2.93E+04	1.05E+02	5.66E+04	7.97E+04	3.15E+04	2.77E+03
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	0.005	715	590	1.14E+05	2.59E+05	3.54E+04	7.42E+02	6.58E+04	8.63E+05	1.07E+05	3.91E+03	1.21E+04	2.66E+05	4.39E+04	1.57E+02	8.49E+04	1.20E+05	4.73E+04	4.15E+03
8	Carbonera Creek - Santa Margarita	0.1	586	551	9.14E+04	1.33E+05	2.27E+04	7.00E+02	5.22E+04	4.47E+05	6.88E+04	3.47E+03	9.83E+03	1.39E+05	2.85E+04	1.47E+02	6.76E+04	6.14E+04	3.04E+04	3.63E+03
9	Carbonera Creek - Lompico	0.1	550	528	1.02E+04	1.48E+04	2.53E+03	7.78E+01	5.81E+03	4.97E+04	7.64E+03	3.85E+02	1.09E+03	1.54E+04	3.16E+03	1.63E+01	7.51E+03	6.83E+03	3.37E+03	4.03E+02
10	Upper Love Creek - Butano	1	642	589	8.64E+03	2.75E+04	4.72E+03	3.08E+01	5.17E+03	8.93E+04	1.39E+04	2.72E+02	8.31E+02	2.68E+04	5.55E+03	7.22E+00	6.57E+03	1.29E+04	6.37E+03	3.13E+02
11	Upper Love Creek - Monterey	0.1	587	515	4.65E+03	1.48E+04	2.54E+03	1.66E+01	2.78E+03	4.81E+04	7.47E+03	1.47E+02	4.47E+02	1.44E+04	2.99E+03	3.89E+00	3.54E+03	6.94E+03	3.43E+03	1.69E+02
12	Fitch Creek	0.1	755	515	2.42E+04	8.27E+04	1.41E+04	8.49E+01	1.49E+04	2.64E+05	4.05E+04	7.76E+02	2.14E+03	7.74E+04	1.58E+04	1.11E+01	1.88E+04	3.93E+04	1.91E+04	9.56E+02
13	Middle Love Creek	0.1	513	435	3.81E+04	1.12E+05	1.85E+04	1.30E+02	2.40E+04	3.53E+05	5.25E+04	1.23E+03	3.14E+03	1.02E+05	2.01E+04	4.38E+00	3.00E+04	5.40E+04	2.54E+04	1.60E+03
14	Lower Love Creek	0.1	433	285	1.63E+04	4.82E+04	7.95E+03	5.59E+01	1.03E+04	1.51E+05	2.25E+04	5.27E+02	1.35E+03	4.36E+04	8.63E+03	1.88E+00	1.28E+04	2.31E+04	1.09E+04	6.88E+02
15	Lower Newell - Monterey	0.1	405	343	2.87E+04	1.03E+05	1.61E+04	1.03E+02	1.73E+04	3.34E+05	4.72E+04	9.16E+02	2.72E+03	9.98E+04	1.88E+04	2.25E+01	2.19E+04	4.84E+04	2.18E+04	1.07E+03
16	Lower Newell - Santa Margarita	10	341	305	4.81E+04	1.03E+05	1.69E+04	1.70E+02	2.99E+04	3.26E+05	4.84E+04	1.58E+03	4.13E+03	9.49E+04	1.88E+04	1.55E+01	3.75E+04	4.91E+04	2.31E+04	1.99E+03
17	Lompico Creek - Butano	1	598	520	2.71E+04	5.03E+04	8.90E+03	1.94E+02	1.56E+04	1.68E+05	2.67E+04	1.05E+03	2.84E+03	5.16E+04	1.10E+04	4.12E+01	2.01E+04	2.33E+04	1.19E+04	1.12E+03
18	Lompico Creek - Monterey	0.1	520	405	2.49E+04	5.90E+04	9.95E+03	1.75E+02	1.45E+04	1.96E+05	2.98E+04	1.01E+03	2.59E+03	6.01E+04	1.22E+04	3.77E+01	1.86E+04	2.74E+04	1.33E+04	1.09E+03
19	Lower Lompico - Monterey	0.1	403	352	2.49E+04	5.90E+04	9.95E+03	1.75E+02	1.45E+04	1.96E+05	2.98E+04	1.01E+03	2.59E+03	6.01E+04	1.22E+04	3.77E+01	1.86E+04	2.74E+04	1.33E+04	1.09E+03
20	Unnamed Creek #2 off Zayante Creek - Butano	1	618	477	3.87E+03	1.13E+04	1.97E+03	2.39E+01	2.24E+03	3.77E+04	5.93E+03	1.30E+02	4.07E+02	1.16E+04	2.44E+03	5.08E+00	2.88E+03	5.23E+03	2.64E+03	1.38E+02
21	Unnamed Creek #3 off Zayante Creek - Butano	1	978	462	9.04E+03	2.64E+04	4.61E+03	5.57E+01	5.22E+03	8.79E+04	1.38E+04	3.02E+02	9.50E+02	2.71E+04	5.69E+03	1.19E+01	6.72E+03	1.22E+04	6.16E+03	3.23E+02
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	5	488	353	3.03E+04	7.40E+04	1.17E+04	1.32E+02	1.83E+04	2.40E+05	3.42E+04	1.17E+03	2.86E+03	7.16E+04	1.36E+04	2.79E+01	2.32E+04	3.49E+04	1.58E+04	1.37E+03
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	5	458	323	3.03E+04	7.40E+04	1.17E+04	1.32E+02	1.83E+04	2.40E+05	3.42E+04	1.17E+03	2.86E+03	7.16E+04	1.36E+04	2.79E+01	2.32E+04	3.49E+04	1.58E+04	1.37E+03
24	Zayante - Mountain House Gulch	0.5	495	475	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	0.5	475	460	1.29E+04	3.77E+04	6.58E+03	7.96E+01	7.45E+03	1.26E+05	1.98E+04	4.32E+02	1.36E+03	3.87E+04	8.13E+03	1.69E+01	9.60E+03	1.74E+04	8.80E+03	4.61E+02
26	Upper Zayante - Monterey	0.1	468	353	4.92E+04	1.47E+05	2.30E+04	3.44E+02	2.84E+04	4.89E+05	6.92E+04	1.87E+03	5.17E+03	1.50E+05	2.85E+04	7.31E+01	3.66E+04	6.79E+04	3.08E+04	1.99E+03
27	Middle Zayante - Monterey	0.1	352.4	338	2.28E+04	5.55E+04	8.79E+03	9.89E+01	1.37E+04	1.80E+05	2.57E+04	8.80E+02	2.15E+03	5.37E+04	1.02E+04	2.10E+01	1.74E+04	2.61E+04	1.19E+04	1.03E+03
28	Middle Zayante - Monterey	0.1	338	323	1.52E+04	3.70E+04	5.86E+03	6.59E+01	9.14E+03	1.20E+05	1.71E+04	5.87E+02	1.43E+03	3.58E+04	6.82E+03	1.40E+01	1.16E+04	1.74E+04	7.92E+03	6.86E+02
29	Lower Zayante - Monterey	0.1	338	323	5.31E+04	1.29E+05	2.05E+04	2.31E+02	3.20E+04	4.19E+05	5.99E+04	2.05E+03	5.01E+03	1.25E+05	2.39E+04	4.89E+01	4.06E+04	6.10E+04	2.77E+04	2.40E+03
30	Upper Lockhart Gulch - Monterey	0.1	845	540	7.76E+03	3.67E+04	4.12E+03	3.49E+01	4.48E+03	1.22E+05	1.24E+04	1.90E+02	8.16E+02	3.76E+04	5.09E+03	7.43E+00	5.77E+03	1.70E+04	5.50E+03	2.02E+02
31	Upper Lockhart Gulch - Santa Margarita	5	538	465	1.16E+04	5.51E+04	6.17E+03	5.24E+01	6.72E+03	1.83E+05	1.85E+04	2.84E+02	1.22E+03	5.65E+04	7.63E+03	1.11E+01	8.66E+03	2.55E+04	8.26E+03	3.03E+02
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	5	600	465	7.76E+02	3.67E+03	4.12E+02	3.49E+00	4.48E+02	1.22E+04	1.24E+03	1.90E+01	8.16E+01	3.76E+03	5.09E+02	7.43E-01	5.77E+02	1.70E+03	5.50E+02	2.02E+01
33	Middle Lockhart Gulch - Santa Margarita	10	465	400	7.76E+03	3.67E+04	4.12E+03	3.49E+01	4.48E+03	1.22E+05	1.24E+04	1.90E+02	8.16E+02	3.76E+04	5.09E+03	7.43E+00	5.77E+03	1.70E+04	5.50E+03	2.02E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	5	520	425	7.76E+02	3.67E+03	4.12E+02	3.49E+00	4.48E+02	1.22E+04	1.24E+03	1.90E+01	8.16E+01	3.76E+03	5.09E+02	7.43E-01	5.77E+02	1.70E+03	5.50E+02	2.02E+01
35	Lower Lockhart Gulch - Santa Margarita	12	425	345	1.01E+04	4.77E+04	5.35E+03	4.54E+01	5.83E+03	1.59E+05	1.61E+04	2.46E+02	1.06E+03	4.89E+04	6.61E+03	9.66E+00	7.50E+03	2.21E+04	7.16E+03	2.63E+02
36	Upper Ruins Creek - Santa Margarita	2	1000	700	6.15E+03	2.92E+04	3.18E+03	2.89E+01	3.55E+03	9.72E+04	9.56E+03	1.57E+02	6.47E+02	2.99E+04	3.93E+03	6.14E+00	4.57E+03	1.35E+04	4.26E+03	1.67E+02
37	Middle Ruins Creek - Santa Cruz Mudstone	0.005	700	475	2.15E+04	1.02E+05	1.11E+04	1.01E+02	1.24E+04	3.40E+05	3.35E+04	5.48E+02	2.26E+03	1.05E+05	1.38E+04	2.15E+01	1.60E+04	4.73E+04	1.49E+04	5.85E+02
38	Lower Ruins Creek - Santa Margarita	12	475	342	3.08E+03	1.46E+04	1.59E+03	1.44E+01	1.78E+03	4.86E+04	4.78E+03	7.84E+01	3.23E+02	1.50E+04	1.97E+03	3.07E+00	2.29E+03	6.75E+03	2.13E+03	8.36E+01
39	Mackenzie Creek - Monterey	0.1	900	600	1.07E+04	3.95E+04	5.49E+03	5.97E+01	6.20E+03	1.32E+05	1.65E+04	3.24E+02	1.13E+03	4.05E+04	6.78E+03	1.27E+01	7.98E+03	1.83E+04	7.34E+03	3.46E+02
40	Mackenzie Creek - Santa Margarita	10	595	460	1.07E+04	3.95E+04	5.49E+03	5.97E+01	6.20E+03	1.32E+05	1.65E+04	3.24E+02	1.13E+03	4.05E+04	6.78E+03	1.27E+01	7.98E+03	1.83E+04	7.34E+03	3.46E+02
41	Unnamed Creek #8 off Bean Creek - Butano	0.1	1098	810	1.55E+04	4.62E+04	7.95E+03	4.97E+01	9.27E+03	1.50E+05	2.33E+04	4.39E+02	1.49E+03	4.51E+04	9.35E+03	1.16E+01	1.18E+04	2.17E+04	1.07E+04	5.06E+02
42	Bean Creek Inflow - Butano	0.1	818	808	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	0.1	807	579	1.55E+04	4.62E+04	7.95E+03	4.97E+01	9.27E+03	1.50E+05	2.33E+04	4.39E+02	1.49E+03	4.51E+04	9.35E+03	1.16E+01	1.18E+04	2.17E+04	1.07E+04	5.06E+02
44	Upper Bean Creek - Monterey	0.1	576	501	2.80E+04	9.67E+04	1.48E+04	1.75E+02	1.62E+04	3.22E+05	4.44E+04	9.53E+02	2.94E+03	9.91E+04	1.83E+04	3.72E+01	2.08E+04	4.47E+04	1.98E+04	1.02E+03
45	Upper Bean Creek - Santa Margarita	2	500	458	1.20E+04	4.14E+04	6.34E+03	7.49E+01	6.93E+03	1.38E+05	1.90E+04	4.08E+02	1.26E+03	4.25E+04	7.83E+03	1.60E+01	8.93E+03	1.92E+04	8.48E+03	4.36E+02
46	Middle Bean Creek - Santa Margarita	10	457	391	1.64E+04	7.01E+04	8.58E+03	1.01E+02	9.45E+03	2.33E+05	2.58E+04	5.48E+02	1.72E+03	7.19E+04	1.06E+04	2.15E+01	1.22E+04	3.24E+04	1.15E+04	5.85E+02
47	Middle Bean Creek - Santa Margarita	15	390	342	7.02E+03	3.00E+04	3.68E+03	4.33E+01	4.05E+03	1.00E+05	1.10E+04	2.35E+02	7.38E+02	3.08E+04	4.54E+03	9.21E+00	5.22E+03	1.39E+04	4.92E+03	2.51E+02
48	Lower Bean Creek - Santa Margarita	15	341	325	2.55E+04	6.18E+04	1.02E+04	1.78E+02	1.48E+04	2.05E+05	3.05E+04	1.04E+03	2.63E+03	6.28E+04	1.25E+04	3.84E+01	1.90E+04	2.87E+04	1.37E+04	1.13E+03
49	Lower Bean Creek - Monterey	0.1	320	240	2.55E+04	6.18E+04	1.02E+04	1.78E+02	1.48E+04	2.05E+05	3.05E+04	1.04E+03	2.63E+03	6.28E+04	1.25E+04	3.84E+01	1.90E+04	2.87E+04	1.37E+04	1.13E+03

APPENDIX E - SFR1 Stream Segment Data

STREAM INFLOW

		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Seg #	Stream	1989_Q1	1989_Q2	1989_Q3	1989_Q4	1990_Q1	1990_Q2	1990_Q3	1990_Q4	1991_Q1	1991_Q2	1991_Q3	1991_Q4	1992_Q1	1992_Q2	1992_Q3	1992_Q4	1993_Q1	1993_Q2	1993_Q3	1993_Q4
10	Upper Love Creek - Butano	9.12E+03	3.37E+04	6.88E+03	2.05E+02	3.09E+03	2.18E+04	1.50E+04	7.44E+02	1.56E+03	5.89E+04	1.30E+04	8.41E+01	6.93E+03	6.14E+04	1.32E+04	1.15E+02	1.10E+04	9.75E+04	2.16E+04	3.76E+02
15	Lower Newell - Monterey	7.93E+04	2.99E+05	6.09E+04	1.71E+03	2.73E+04	2.02E+05	1.35E+05	6.56E+03	1.51E+04	5.57E+05	1.20E+05	8.11E+02	6.60E+04	5.80E+05	1.22E+05	1.05E+03	1.02E+05	9.17E+05	1.99E+05	3.43E+03
17	Lompico Creek - Butano	1.78E+04	6.38E+04	1.31E+04	4.26E+02	6.15E+03	4.32E+04	2.91E+04	1.64E+03	3.41E+03	1.19E+05	2.59E+04	2.04E+02	1.49E+04	1.24E+05	2.61E+04	2.62E+02	2.31E+04	1.96E+05	4.29E+04	8.60E+02
24	Zayante - Mountain House Gulch	9.41E+04	4.37E+05	7.63E+04	1.76E+03	3.39E+04	3.26E+05	1.77E+05	7.80E+03	2.24E+04	9.39E+05	1.67E+05	1.15E+03	9.52E+04	9.69E+05	1.65E+05	1.33E+03	1.42E+05	1.52E+06	2.73E+05	4.39E+03
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	1.32E+04	8.09E+04	9.67E+03	1.88E+02	4.56E+03	5.48E+04	2.15E+04	7.24E+02	2.52E+03	1.51E+05	1.92E+04	8.98E+01	1.10E+04	1.57E+05	1.93E+04	1.16E+02	1.71E+04	2.49E+05	3.17E+04	3.79E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	1.32E+04	8.09E+04	9.67E+03	1.88E+02	4.56E+03	5.48E+04	2.15E+04	7.24E+02	2.52E+03	1.51E+05	1.92E+04	8.98E+01	1.10E+04	1.57E+05	1.93E+04	1.16E+02	1.71E+04	2.49E+05	3.17E+04	3.79E+02
42	Bean Creek Inflow - Butano	3.91E+04	2.04E+05	2.81E+04	6.08E+02	1.43E+04	1.56E+05	6.59E+04	2.81E+03	9.83E+03	4.54E+05	6.28E+04	4.31E+02	4.16E+04	4.68E+05	6.21E+04	4.89E+02	6.17E+04	7.35E+05	1.03E+05	1.61E+03

STREAM RUNOFF

		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Seg #	Stream	1989_Q1	1989_Q2	1989_Q3	1989_Q4	1990_Q1	1990_Q2	1990_Q3	1990_Q4	1991_Q1	1991_Q2	1991_Q3	1991_Q4	1992_Q1	1992_Q2	1992_Q3	1992_Q4	1993_Q1	1993_Q2	1993_Q3	1993_Q4
1	Upper Blackburn Gulch	1.30E+04	6.53E+04	9.75E+03	2.61E+02	4.48E+03	4.39E+04	2.16E+04	9.96E+02	2.45E+03	1.21E+05	1.92E+04	1.22E+02	1.07E+04	1.26E+05	1.94E+04	1.58E+02	1.67E+04	1.99E+05	3.18E+04	5.19E+02
2	Lower Blackburn Gulch	4.05E+04	1.46E+05	2.17E+04	8.30E+02	1.37E+04	9.35E+04	4.72E+04	2.99E+03	6.85E+03	2.52E+05	4.07E+04	3.34E+02	3.04E+04	2.63E+05	4.15E+04	4.59E+02	4.83E+04	4.17E+05	6.78E+04	1.50E+03
3	Carbonera Creek - Butano	6.15E+03	2.59E+04	4.49E+03	1.23E+02	2.14E+03	1.79E+04	1.01E+04	4.88E+02	1.23E+03	4.98E+04	9.08E+03	6.28E+01	5.33E+03	5.17E+04	9.13E+03	7.90E+01	8.21E+03	8.17E+04	1.50E+04	2.59E+02
4	Carbonera Creek - Monterey	1.23E+04	5.18E+04	8.98E+03	2.46E+02	4.28E+03	3.58E+04	2.02E+04	9.76E+02	2.46E+03	9.96E+04	1.82E+04	1.26E+02	1.07E+04	1.03E+05	1.83E+04	1.58E+02	1.64E+04	1.63E+05	3.00E+04	5.19E+02
5	Carbonera Creek - Monterey	1.23E+04	5.18E+04	8.98E+03	2.46E+02	4.28E+03	3.58E+04	2.02E+04	9.76E+02	2.46E+03	9.96E+04	1.82E+04	1.26E+02	1.07E+04	1.03E+05	1.83E+04	1.58E+02	1.64E+04	1.63E+05	3.00E+04	5.19E+02
6	Carbonera Creek - Santa Cruz Mudstone	5.22E+04	1.53E+05	2.22E+04	1.04E+03	1.80E+04	1.02E+05	4.93E+04	3.96E+03	9.79E+03	2.82E+05	4.37E+04	4.83E+02	4.29E+04	2.93E+05	4.41E+04	6.28E+02	6.68E+04	4.64E+05	7.23E+04	2.06E+03
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	7.84E+04	2.29E+05	3.33E+04	1.56E+03	2.69E+04	1.54E+05	7.39E+04	5.94E+03	1.47E+04	4.22E+05	6.55E+04	7.24E+02	6.43E+04	4.40E+05	6.62E+04	9.42E+02	1.00E+05	6.96E+05	1.08E+05	3.09E+03
8	Carbonera Creek - Santa Margarita	6.36E+04	1.19E+05	2.15E+04	1.40E+03	2.17E+04	7.84E+04	4.72E+04	5.18E+03	1.14E+04	2.13E+05	4.13E+04	6.07E+02	5.01E+04	2.22E+05	4.19E+04	8.10E+02	7.87E+04	3.52E+05	6.86E+04	2.66E+03
9	Carbonera Creek - Lompico	7.06E+03	1.32E+04	2.39E+03	1.55E+02	2.41E+03	8.71E+03	5.25E+03	5.76E+02	1.26E+03	2.37E+04	4.59E+03	6.75E+01	5.56E+03	2.47E+04	4.65E+03	9.00E+01	8.74E+03	3.92E+04	7.62E+03	2.95E+02
10	Upper Love Creek - Butano	5.40E+03	2.30E+04	4.38E+03	1.01E+02	1.95E+03	1.73E+04	1.02E+04	4.53E+02	1.31E+03	4.99E+04	9.64E+03	6.75E+01	5.56E+03	5.16E+04	9.56E+03	7.79E+01	8.29E+03	8.10E+04	1.58E+04	2.56E+02
11	Upper Love Creek - Monterey	2.91E+03	1.24E+04	2.36E+03	5.42E+01	1.05E+03	9.32E+03	5.50E+03	2.44E+02	7.04E+02	2.69E+04	5.19E+03	3.64E+01	2.99E+03	2.78E+04	5.15E+03	4.19E+01	4.46E+03	4.36E+04	8.50E+03	1.38E+02
12	Fitch Creek	1.40E+04	6.61E+04	1.29E+04	2.67E+02	5.30E+03	5.44E+04	3.12E+04	1.39E+03	4.10E+03	1.62E+05	3.07E+04	2.36E+02	1.71E+04	1.66E+05	3.01E+04	2.53E+02	2.48E+04	2.60E+05	5.00E+04	8.36E+02
13	Middle Love Creek	2.06E+04	8.68E+04	1.69E+04	3.96E+02	8.12E+03	7.64E+04	4.19E+04	2.35E+03	6.99E+03	2.33E+05	4.27E+04	4.35E+02	2.88E+04	2.38E+05	4.15E+04	4.45E+02	4.10E+04	3.72E+05	6.90E+04	1.47E+03
14	Lower Love Creek	8.84E+03	3.72E+04	7.22E+03	1.70E+02	3.48E+03	3.28E+04	1.80E+04	1.01E+03	2.99E+03	9.98E+04	1.83E+04	1.87E+02	1.23E+04	1.02E+05	1.78E+04	1.91E+02	1.76E+04	1.59E+05	2.96E+04	6.31E+02
15	Lower Newell - Monterey	1.77E+04	8.55E+04	1.49E+04	3.35E+02	6.46E+03	6.54E+04	3.50E+04	1.55E+03	4.44E+03	1.90E+05	3.33E+04	2.36E+02	1.88E+04	1.96E+05	3.30E+04	2.68E+02	2.79E+04	3.07E+05	5.45E+04	8.84E+02
16	Lower Newell - Santa Margarita	2.71E+04	8.10E+04	1.55E+04	5.29E+02	1.04E+04	6.86E+04	3.79E+04	2.91E+03	8.43E+03	2.06E+05	3.79E+04	5.13E+02	3.50E+04	2.12E+05	3.70E+04	5.38E+02	5.03E+04	3.31E+05	6.14E+04	1.78E+03
17	Lompico Creek - Butano	1.84E+04	4.44E+04	8.37E+03	4.17E+02	6.35E+03	3.00E+04	1.86E+04	1.61E+03	3.52E+03	8.29E+04	1.66E+04	1.99E+02	1.54E+04	8.62E+04	1.67E+04	2.57E+02	2.39E+04	1.36E+05	2.75E+04	8.42E+02
18	Lompico Creek - Monterey	1.67E+04	5.16E+04	9.34E+03	3.95E+02	5.82E+03	3.55E+04	2.09E+04	1.56E+03	3.32E+03	9.87E+04	1.88E+04	1.99E+02	1.44E+04	1.02E+05	1.89E+04	2.51E+02	2.22E+04	1.62E+05	3.11E+04	8.25E+02
19	Lower Lompico - Monterey	1.67E+04	5.16E+04	9.34E+03	3.95E+02	5.82E+03	3.55E+04	2.09E+04	1.56E+03	3.32E+03	9.87E+04	1.88E+04	1.99E+02	1.44E+04	1.02E+05	1.89E+04	2.51E+02	2.22E+04	1.62E+05	3.11E+04	8.25E+02
20	Unnamed Creek #2 off Zayante Creek - Butano	2.64E+03	9.97E+03	1.86E+03	5.14E+01	9.10E+02	6.75E+03	4.13E+03	1.98E+02	5.04E+02	1.86E+04	3.68E+03	2.46E+01	2.20E+03	1.94E+04	3.71E+03	3.16E+01	3.41E+03	3.07E+04	6.09E+03	1.04E+02
21	Unnamed Creek #3 off Zayante Creek - Butano	6.15E+03	2.33E+04	4.33E+03	1.20E+02	2.12E+03	1.58E+04	9.65E+03	4.62E+02	1.18E+03	4.35E+04	8.59E+03	5.73E+01	5.13E+03	4.52E+04	8.66E+03	7.38E+01	7.97E+03	7.15E+04	1.42E+04	2.42E+02
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	1.86E+04	6.13E+04	1.08E+04	4.27E+02	6.81E+03	4.71E+04	2.55E+04	1.99E+03	4.72E+03	1.37E+05	2.43E+04	3.06E+02	2.00E+04	1.41E+05	2.40E+04	3.46E+02	2.96E+04	2.22E+05	3.97E+04	1.14E+03
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	1.86E+04	6.13E+04	1.08E+04	4.27E+02	6.81E+03	4.71E+04	2.55E+04	1.99E+03	4.72E+03	1.37E+05	2.43E+04	3.06E+02	2.00E+04	1.41E+05	2.40E+04	3.46E+02	2.96E+04	2.22E+05	3.97E+04	1.14E+03
24	Zayante - Mountain House Gulch	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	8.79E+03	3.32E+04	6.19E+03	1.71E+02	3.03E+03	2.25E+04	1.38E+04	6.60E+02	1.68E+03	6.21E+04	1.23E+04	8.19E+01	7.33E+03	6.46E+04	1.24E+04	1.05E+02	1.14E+04	1.02E+05	2.03E+04	3.46E+02
26	Upper Zayante - Monterey	3.35E+04	1.29E+05	2.17E+04	7.39E+02	1.16E+04	8.76E+04	4.83E+04	2.85E+03	6.40E+03	2.42E+05	4.30E+04	3.54E+02	2.80E+04	2.51E+05	4.33E+04	4.55E+02	4.34E+04	3.98E+05	7.11E+04	1.49E+03
27	Middle Zayante - Monterey	1.40E+04	4.59E+04	8.13E+03	3.21E+02	5.11E+03	3.53E+04	1.91E+04	1.49E+03	3.54E+03	1.03E+05	1.82E+04	2.29E+02	1.50E+04	1.06E+05	1.80E+04	2.60E+02	2.22E+04	1.66E+05	2.98E+04	8.56E+02
28	Middle Zayante - Monterey	9.32E+03	3.06E+04	5.42E+03	2.14E+02	3.41E+03	2.36E+04	1.27E+04	9.94E+02	2.36E+03	6.85E+04	1.21E+04	1.53E+02	9.98E+03	7.06E+04	1.20E+04	1.73E+02	1.48E+04	1.11E+05	1.99E+04	5.70E+02
29	Lower Zayante - Monterey	3.26E+04	1.07E+05	1.90E+04	7.48E+02	1.19E+04	8.24E+04	4.46E+04	3.48E+03	8.26E+03	2.40E+05	4.25E+04	5.35E+02	3.49E+04	2.47E+05	4.20E+04	6.06E+02	5.17E+04	3.88E+05	6.95E+04	2.00E+03
30	Upper Lockhart Gulch - Monterey	5.28E+03	3.24E+04	3.87E+03	7.51E+01	1.82E+03	2.19E+04	8.62E+03	2.90E+02	1.01E+03	6.05E+04	7.67E+03	3.59E+01	4.41E+03	6.29E+04	7.74E+03	4.63E+01	6.84E+03	9.94E+04	1.27E+04	1.52E+02
31	Upper Lockhart Gulch - Santa Margarita	7.92E+03	4.85E+04	5.80E+03	1.13E+02	2.73E+03	3.29E+04	1.29E+04	4.35E+02	1.51E+03	9.07E+04	1.15E+04	5.39E+01	6.61E+03	9.43E+04	1.16E+04	6.94E+01	1.03E+04	1.49E+05	1.90E+04	2.28E+02
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	5.28E+02	3.24E+03	3.87E+02	7.51E+00	1.82E+02	2.19E+03	8.62E+02	2.90E+01	1.01E+02	6.05E+03	7.67E+02	3.59E+00	4.41E+02	6.29E+03	7.74E+02	4.63E+00	6.84E+02	9.94E+03	1.27E+03	1.52E+01
33	Middle Lockhart Gulch - Santa Margarita	5.28E+03	3.24E+04	3.87E+03	7.51E+01	1.82E+03	2.19E+04	8.62E+03	2.90E+02	1.01E+03	6.05E+04	7.67E+03	3.59E+01	4.41E+03	6.29E+04	7.74E+03	4.63E+01	6.84E+03	9.94E+04	1.27E+04	1.52E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	5.28E+02	3.24E+03	3.87E+02	7.51E+00	1.82E+02	2.19E+03	8.62E+02	2.90E+01	1.01E+02	6.05E+03	7.67E+02	3.59E+00	4.41E+02	6.29E+03	7.74E+02	4.63E+00	6.84E+02	9.94E+03	1.27E+03	1.52E+01
35	Lower Lockhart Gulch - Santa Margarita	6.87E+03	4.21E+04	5.03E+03	9.77E+01	2.37E+03	2.85E+04	1.12E+04	3.77E+02	1.31E+03	7.86E+04	9.97E+03	4.67E+01	5.73E+03	8.17E+04	1.01E+04	6.01E+01	8.90E+03	1.29E+05	1.65E+04	1.97E+02
36	Upper Ruins Creek - Santa Margarita	4.19E+03	2.57E+04	2.99E+03	6.21E+01	1.44E+03	1.74E+04	6.66E+03	2.39E+02	8.00E+02	4.81E+04	5.93E+03	2.97E+01	3.49E+03	5.00E+04	5.98E+03	3.82E+01	5.42E+03	7.91E+04	9.81E+03	1.25E+02
37	Middle Ruins Creek - Santa Cruz Mudstone	1.47E+04	9.00E+04	1.05E+04	2.17E+02	5.06E+03	6.10E+04	2.33E+04	8.38E+02	2.80E+03	1.68E+05	2.08E+04	1.04E+02	1.22E+04	1.75E+05	2.09E+04	1.34E+02	1.90E+04	2.77E+05	3.43E+04	4.39E+02
38	Lower Ruins Creek - Santa Margarita	2.09E+03	1.29E+04	1.50E+03	3.11E+01	7.22E+02	8.71E+03	3.33E+03	1.20E+02	4.00E+02	2.40E+04	2.96E+03	1.49E+01	1.75E+03	2.50E+04	2.99E+03	1.91E+01	2.71E+03	3.95E+04	4.91E+03	6.27E+01
39	Mackenzie Creek - Monterey	7.31E+03	3.48E+04	5.16E+03	1.28E+02	2.52E+03	2.36E+04	1.15E+04	4.95E+02	1.40E+03	6.51E+04	1.02E+04	6.15E+01	6.10E+03	6.77E+04	1.03E+04	7.91E+01	9.47E+03	1.07E+05	1.69E+04	2.60E+02
40	Mackenzie Creek - Santa Margarita	7.31E+03	3.48E+04	5.16E+03	1.28E+02	2.52E+03	2.36E+04	1.15E+04	4.95E+02	1.40E+03	6.51E+04	1.02E+04	6.15E+01	6.10E+03	6.77E+04	1.03E+04	7.91E+01	9.47E+03	1.07E+05	1.69E+04	2.60E+02
41	Unnamed Creek #8 off Bean Creek - Butano	9.69E+03	3.87E+04	7.37E+03	1.62E+02	3.51E+03	2.91E+04	1.72E+04	7.31E+02	2.35E+03	8.41E+04	1.62E+04	1.09E+02	9.97E+03	8.68E+04	1.61E+04	1.26E+02	1.49E+04	1.36E+05	2.66E+04	4.14E+02
42	Bean Creek Inflow - Butano	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	9.69E+03	3.87E+04	7.37E+03	1.62E+02	3.51E+03	2.91E+04	1.72E+04	7.31E+02	2.35E+03	8.41E+04	1.62E+04	1.09E+02	9.97E+03	8.68E+04	1.61E+04	1.26E+02	1.49E+04	1.36E+05	2.66E+04	4.14E+02
44	Upper Bean Creek - Monterey	1.90E+04	8.51E+04	1.39E+04	3.77E+02	6.58E+03	5.77E+04	3.10E+04	1.46E+03	3.65E+03	1.59E+05	2.76E+04	1.81E+02	1.59E+04	1.66E+05	2.78E+04	2.33E+02	2.47E+04	2.62E+05	4.57E+04	7.64E+02
45	Upper Bean Creek - Santa Margarita	8.16E+03	3.65E+04	5.96E+03	1.62E+02	2.82E+03	2.47E+04	1.33E+04	6.25E+02	1.56E+03	6.83E+04	1.18E+04	7.77E+01	6.83E+03	7.10E+04	1.19E+04	9.98E+01	1.06E+04	1.12E+05	1.96E+04	3.28E+02
46	Middle Bean Creek - Santa Margarita	1.11E+04	6.18E+04	8.06E+03	2.17E+02	3.84E+03	4.18E+04	1.80E+04	8.38E+02	2.13E+03	1.15E+05	1.60E+04	1.04E+02	9.30E+03	1.20E+05	1.61E+04	1.34E+02	1.44E+04	1.90E+05	2.64E+04	4.39E+02
47	Middle Bean Creek - Santa Margarita	4.77E+03	2.65E+04	3.46E+03	9.31E+01	1.65E+03	1.79E+04	7.70E+03	3.59E+02	9.12E+02	4.95E+04	6.85E+03	4.45E+01	3.99E+03	5.14E+04	6.91E+03	5.73E+01	6.18E+03	8.14E+04	1.13E+04	1.88E+02
48	Lower Bean Creek - Santa Margarita	1.70E+04	5.39E+04	9.56E+03	4.09E+02	5.94E+03	3.73E+04	2.15E+04	1.62E+03	3.42E+03	1.04E+05	1.94E+04	2.10E+02	1.49E+04	1.08E+05	1.95E+04	2.63E+02	2.28E+04	1.71E+05	3.20E+04	8.64E+02
49	Lower Bean Creek - Monterey	1.70E+04	5.39E+04	9.56E+03	4.09E+02	5.94E+03	3.73E+04	2.15E+04	1.62E+03	3.42E+03	1.04E+05	1.94E+04	2.10E+02	1.49E+04	1.08E+05	1.95E+04	2.63E+02	2.28E+04	1.71E+05	3.20E+04	8.64E+02

STREAM INFLOW

Seg #	Stream	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
		1994_Q1	1994_Q2	1994_Q3	1994_Q4	1995_Q1	1995_Q2	1995_Q3	1995_Q4	1996_Q1	1996_Q2	1996_Q3	1996_Q4	1997_Q1	1997_Q2	1997_Q3	1997_Q4	1998_Q1	1998_Q2	1998_Q3	1998_Q4	1999_Q1
10	Upper Love Creek - Butano	6.38E+03	3.39E+04	1.50E+04	5.83E+02	1.06E+04	1.22E+05	3.09E+04	7.85E+02	7.40E+03	9.00E+04	2.85E+04	9.15E+02	2.80E+04	5.06E+04	8.75E+03	1.27E+02	1.07E+04	1.37E+05	3.59E+04	9.84E+02	7.99E+03
15	Lower Newell - Monterey	5.95E+04	3.14E+05	1.34E+05	5.10E+03	9.85E+04	1.15E+06	2.86E+05	7.18E+03	6.90E+04	8.55E+05	2.64E+05	8.30E+03	2.56E+05	4.80E+05	8.38E+04	1.32E+03	9.91E+04	1.30E+06	3.36E+05	9.25E+03	7.26E+04
17	Lompico Creek - Butano	1.34E+04	6.70E+04	2.89E+04	1.27E+03	2.22E+04	2.46E+05	6.15E+04	1.80E+03	1.56E+04	1.83E+05	5.67E+04	2.08E+03	5.76E+04	1.03E+05	1.81E+04	3.32E+02	2.23E+04	2.77E+05	7.24E+04	2.32E+03	1.63E+04
24	Zayante - Mountain House Gulch	8.29E+04	5.04E+05	1.74E+05	5.94E+03	1.36E+05	1.92E+06	3.95E+05	9.20E+03	9.61E+04	1.45E+06	3.62E+05	1.05E+04	3.41E+05	8.22E+05	1.23E+05	2.09E+03	1.37E+05	2.17E+06	4.75E+05	1.25E+04	9.52E+04
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	9.95E+03	8.50E+04	2.14E+04	5.62E+02	1.64E+04	3.12E+05	4.55E+04	7.93E+02	1.15E+04	2.32E+05	4.20E+04	9.17E+02	4.27E+04	1.30E+05	1.34E+04	1.47E+02	1.65E+04	3.51E+05	5.35E+04	1.02E+03	1.21E+04
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	9.95E+03	8.50E+04	2.14E+04	5.62E+02	1.64E+04	3.12E+05	4.55E+04	7.93E+02	1.15E+04	2.32E+05	4.20E+04	9.17E+02	4.27E+04	1.30E+05	1.34E+04	1.47E+02	1.65E+04	3.51E+05	5.35E+04	1.02E+03	1.21E+04
42	Bean Creek Inflow - Butano	3.59E+04	2.41E+05	6.45E+04	2.13E+03	5.86E+04	9.29E+05	1.49E+05	3.38E+03	4.17E+04	7.00E+05	1.36E+05	3.83E+03	1.46E+05	4.04E+05	4.72E+04	8.01E+02	5.92E+04	1.05E+06	1.80E+05	4.64E+03	4.07E+04

STREAM RUNOFF

Seg #	Stream	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
		1994_Q1	1994_Q2	1994_Q3	1994_Q4	1995_Q1	1995_Q2	1995_Q3	1995_Q4	1996_Q1	1996_Q2	1996_Q3	1996_Q4	1997_Q1	1997_Q2	1997_Q3	1997_Q4	1998_Q1	1998_Q2	1998_Q3	1998_Q4	1999_Q1
1	Upper Blackburn Gulch	9.71E+03	6.82E+04	2.15E+04	7.74E+02	1.61E+04	2.50E+05	4.56E+04	1.09E+03	1.13E+04	1.85E+05	4.20E+04	1.26E+03	4.18E+04	1.04E+05	1.33E+04	1.97E+02	1.62E+04	2.81E+05	5.35E+04	1.39E+03	1.19E+04
2	Lower Blackburn Gulch	2.80E+04	1.46E+05	4.71E+04	2.34E+03	4.67E+04	5.21E+05	9.69E+04	3.14E+03	3.25E+04	3.85E+05	8.95E+04	3.66E+03	1.23E+05	2.16E+05	2.73E+04	5.00E+02	4.69E+04	5.87E+05	1.12E+05	3.92E+03	3.53E+04
3	Carbonera Creek - Butano	4.78E+03	2.77E+04	9.99E+03	3.77E+02	7.88E+03	1.03E+05	2.16E+04	5.43E+02	5.54E+03	7.65E+04	1.99E+04	6.25E+02	2.03E+04	4.30E+04	6.41E+03	1.05E+02	7.93E+03	1.16E+05	2.55E+04	7.08E+02	5.74E+03
4	Carbonera Creek - Monterey	9.55E+03	5.55E+04	2.00E+04	7.55E+02	1.58E+04	2.05E+05	4.31E+04	1.09E+03	1.11E+04	1.53E+05	3.97E+04	1.25E+03	4.06E+04	8.59E+04	1.28E+04	2.10E+02	1.59E+04	2.31E+05	5.09E+04	1.42E+03	1.15E+04
5	Carbonera Creek - Monterey	9.55E+03	5.55E+04	2.00E+04	7.55E+02	1.58E+04	2.05E+05	4.31E+04	1.09E+03	1.11E+04	1.53E+05	3.97E+04	1.25E+03	4.06E+04	8.59E+04	1.28E+04	2.10E+02	1.59E+04	2.31E+05	5.09E+04	1.42E+03	1.15E+04
6	Carbonera Creek - Santa Cruz Mudstone	3.88E+04	1.59E+05	4.90E+04	3.08E+03	6.42E+04	5.81E+05	1.04E+05	4.31E+03	4.50E+04	4.32E+05	9.56E+04	4.99E+03	1.67E+05	2.43E+05	3.02E+04	7.78E+02	6.46E+04	6.55E+05	1.22E+05	5.53E+03	4.75E+04
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	5.82E+04	2.39E+05	7.34E+04	4.62E+03	9.64E+04	8.72E+05	1.56E+05	6.46E+03	6.75E+04	6.47E+05	1.43E+05	7.48E+03	2.51E+05	3.64E+05	4.54E+04	1.17E+03	9.69E+04	9.83E+05	1.82E+05	8.29E+03	7.12E+04
8	Carbonera Creek - Santa Margarita	4.57E+04	1.22E+05	4.70E+04	4.05E+03	7.59E+04	4.41E+05	9.82E+04	5.55E+03	5.30E+04	3.27E+05	9.06E+04	6.44E+03	1.99E+05	1.83E+05	2.82E+04	9.48E+02	7.63E+04	4.97E+05	1.15E+05	7.03E+03	5.67E+04
9	Carbonera Creek - Lompico	5.08E+03	1.35E+04	5.22E+03	4.49E+02	8.43E+03	4.90E+04	1.09E+04	6.16E+02	5.89E+03	3.63E+04	1.01E+04	7.16E+02	2.21E+04	2.04E+04	3.13E+03	1.05E+02	8.47E+03	5.52E+04	1.27E+04	7.81E+02	6.30E+03
10	Upper Love Creek - Butano	4.83E+03	2.67E+04	1.00E+04	3.45E+02	7.88E+03	1.02E+05	2.29E+04	5.38E+02	5.59E+03	7.69E+04	2.10E+04	6.11E+02	1.98E+04	4.40E+04	7.17E+03	1.24E+02	7.95E+03	1.15E+05	2.75E+04	7.33E+02	5.52E+03
11	Upper Love Creek - Monterey	2.60E+03	1.44E+04	5.39E+03	1.86E+02	4.25E+03	5.51E+04	1.23E+04	2.89E+02	3.01E+03	4.14E+04	1.13E+04	3.29E+02	1.07E+04	2.37E+04	3.86E+03	6.66E+01	4.28E+03	6.22E+04	1.48E+04	3.95E+02	2.97E+03
12	Fitch Creek	1.45E+04	8.35E+04	3.03E+04	1.04E+03	2.34E+04	3.31E+05	7.28E+04	1.76E+03	1.68E+04	2.50E+05	6.66E+04	1.97E+03	5.73E+04	1.49E+05	2.39E+04	4.61E+02	2.37E+04	3.73E+05	8.92E+04	2.49E+03	1.58E+04
13	Middle Love Creek	2.39E+04	1.17E+05	4.04E+04	1.73E+03	3.85E+04	4.74E+05	1.01E+05	3.10E+03	2.77E+04	3.61E+05	9.22E+04	3.45E+03	9.23E+04	2.21E+05	3.42E+04	8.83E+02	3.89E+04	5.35E+05	1.25E+05	4.50E+03	2.51E+04
14	Lower Love Creek	1.03E+04	5.01E+04	1.73E+04	7.44E+02	1.65E+04	2.03E+05	4.33E+04	1.33E+03	1.19E+04	1.55E+05	3.95E+04	1.48E+03	3.96E+04	9.48E+04	1.47E+04	3.78E+02	1.67E+04	2.29E+05	5.36E+04	1.93E+03	1.08E+04
15	Lower Newell - Monterey	1.62E+04	1.01E+05	3.43E+04	1.17E+03	2.65E+04	3.89E+05	7.90E+04	1.85E+03	1.88E+04	2.92E+05	7.24E+04	2.10E+03	6.62E+04	1.68E+05	2.50E+04	4.38E+02	2.67E+04	4.38E+05	9.54E+04	2.55E+03	1.84E+04
16	Lower Newell - Santa Margarita	2.94E+04	1.05E+05	3.67E+04	2.16E+03	4.74E+04	4.20E+05	8.97E+04	3.74E+03	3.40E+04	3.19E+05	8.19E+04	4.18E+03	1.15E+05	1.93E+05	2.99E+04	1.02E+03	4.79E+04	4.74E+05	1.10E+05	5.35E+03	3.15E+04
17	Lompico Creek - Butano	1.39E+04	4.66E+04	1.85E+04	1.25E+03	2.29E+04	1.71E+05	3.94E+04	1.76E+03	1.61E+04	1.27E+05	3.63E+04	2.03E+03	5.95E+04	7.14E+04	1.16E+04	3.25E+02	2.31E+04	1.93E+05	4.63E+04	2.27E+03	1.69E+04
18	Lompico Creek - Monterey	1.29E+04	5.50E+04	2.07E+04	1.20E+03	2.13E+04	2.03E+05	4.46E+04	1.73E+03	1.50E+04	1.51E+05	4.11E+04	1.99E+03	5.51E+04	8.51E+04	1.32E+04	3.31E+02	2.15E+04	2.29E+05	5.27E+04	2.25E+03	1.56E+04
19	Lower Lompico - Monterey	1.29E+04	5.50E+04	2.07E+04	1.20E+03	2.13E+04	2.03E+05	4.46E+04	1.73E+03	1.50E+04	1.51E+05	4.11E+04	1.99E+03	5.51E+04	8.51E+04	1.32E+04	3.31E+02	2.15E+04	2.29E+05	5.27E+04	2.25E+03	1.56E+04
20	Unnamed Creek #2 off Zayante Creek - Butano	1.99E+03	1.05E+04	4.10E+03	1.54E+02	3.28E+03	3.85E+04	8.74E+03	2.17E+02	2.30E+03	2.86E+04	8.06E+03	2.51E+02	8.52E+03	1.61E+04	2.56E+03	4.01E+01	3.30E+03	4.33E+04	1.03E+04	2.80E+02	2.42E+03
21	Unnamed Creek #3 off Zayante Creek - Butano	4.63E+03	2.45E+04	9.57E+03	3.59E+02	7.66E+03	8.97E+04	2.04E+04	5.06E+02	5.37E+03	6.67E+04	1.88E+04	5.85E+02	1.99E+04	3.75E+04	5.98E+03	9.35E+01	7.71E+03	1.01E+05	2.40E+04	6.53E+02	5.64E+03
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	1.72E+04	7.26E+04	2.49E+04	1.51E+03	2.81E+04	2.81E+05	5.76E+04	2.39E+03	2.00E+04	2.11E+05	5.28E+04	2.71E+03	7.00E+04	1.22E+05	1.83E+04	5.70E+02	2.83E+04	3.16E+05	6.96E+04	3.29E+03	1.94E+04
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	1.72E+04	7.26E+04	2.49E+04	1.51E+03	2.81E+04	2.81E+05	5.76E+04	2.39E+03	2.00E+04	2.11E+05	5.28E+04	2.71E+03	7.00E+04	1.22E+05	1.83E+04	5.70E+02	2.83E+04	3.16E+05	6.96E+04	3.29E+03	1.94E+04
24	Zayante - Mountain House Gulch	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	6.62E+03	3.49E+04	1.37E+04	5.12E+02	1.09E+04	1.28E+05	2.91E+04	7.23E+02	7.67E+03	9.52E+04	2.69E+04	8.36E+02	2.84E+04	5.35E+04	8.55E+03	1.34E+02	1.10E+04	1.44E+05	3.43E+04	9.33E+02	8.05E+03
26	Upper Zayante - Monterey	2.52E+04	1.36E+05	4.79E+04	2.21E+03	4.17E+04	4.99E+05	1.02E+05	3.12E+03	2.92E+04	3.71E+05	9.40E+04	3.61E+03	1.08E+05	2.08E+05	2.99E+04	5.77E+02	4.20E+04	5.62E+05	1.20E+05	4.03E+03	3.07E+04
27	Middle Zayante - Monterey	1.29E+04	5.44E+04	1.87E+04	1.13E+03	2.10E+04	2.10E+05	4.32E+04	1.79E+03	1.50E+04	1.58E+05	3.96E+04	2.03E+03	5.25E+04	9.15E+04	1.37E+04	4.27E+02	2.12E+04	2.37E+05	5.22E+04	2.47E+03	1.46E+04
28	Middle Zayante - Monterey	8.61E+03	3.63E+04	1.25E+04	7.53E+02	1.40E+04	1.40E+05	2.88E+04	1.20E+03	9.98E+03	1.06E+05	2.64E+04	1.36E+03	3.50E+04	6.10E+04	9.14E+03	2.85E+02	1.42E+04	1.58E+05	3.48E+04	1.65E+03	9.72E+03
29	Lower Zayante - Monterey	3.01E+04	1.27E+05	4.36E+04	2.63E+03	4.91E+04	4.91E+05	1.01E+05	4.19E+03	3.49E+04	3.70E+05	9.24E+04	4.75E+03	1.22E+05	2.14E+05	3.20E+04	9.97E+02	4.96E+04	5.54E+05	1.22E+05	5.76E+03	3.40E+04
30	Upper Lockhart Gulch - Monterey	3.98E+03	3.40E+04	8.55E+03	2.25E+02	6.58E+03	1.25E+05	1.82E+04	3.17E+02	4.61E+03	9.27E+04	1.68E+04	3.67E+02	1.71E+04	5.21E+04	5.35E+03	5.86E+01	6.62E+03	1.41E+05	2.14E+04	4.09E+02	4.84E+03
31	Upper Lockhart Gulch - Santa Margarita	5.97E+03	5.10E+04	1.28E+04	3.37E+02	9.87E+03	1.87E+05	2.73E+04	4.76E+02	6.92E+03	1.39E+05	2.52E+04	5.50E+02	2.56E+04	7.81E+04	8.02E+03	8.79E+01	9.93E+03	2.11E+05	3.21E+04	6.14E+02	7.26E+03
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	3.98E+02	3.40E+03	8.55E+02	2.25E+01	6.58E+02	1.25E+04	1.82E+03	3.17E+01	4.61E+02	9.27E+03	1.68E+03	3.67E+01	1.71E+03	5.21E+03	5.35E+02	5.86E+00	6.62E+02	1.41E+04	2.14E+03	4.09E+01	4.84E+02
33	Middle Lockhart Gulch - Santa Margarita	3.98E+03	3.40E+04	8.55E+03	2.25E+02	6.58E+03	1.25E+05	1.82E+04	3.17E+02	4.61E+03	9.27E+04	1.68E+04	3.67E+02	1.71E+04	5.21E+04	5.35E+03	5.86E+01	6.62E+03	1.41E+05	2.14E+04	4.09E+02	4.84E+03
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	3.98E+02	3.40E+03	8.55E+02	2.25E+01	6.58E+02	1.25E+04	1.82E+03	3.17E+01	4.61E+02	9.27E+03	1.68E+03	3.67E+01	1.71E+03	5.21E+03	5.35E+02	5.86E+00	6.62E+02	1.41E+04	2.14E+03	4.09E+01	4.84E+02
35	Lower Lockhart Gulch - Santa Margarita	5.17E+03	4.42E+04	1.11E+04	2.92E+02	8.55E+03	1.62E+05	2.37E+04	4.13E+02	6.00E+03	1.20E+05	2.18E+04	4.77E+02	2.22E+04	6.77E+04	6.95E+03	7.62E+01	8.60E+03	1.83E+05	2.78E+04	5.32E+02	6.29E+03
36	Upper Ruins Creek - Santa Margarita	3.15E+03	2.70E+04	6.61E+03	1.86E+02	5.21E+03	9.92E+04	1.41E+04	2.62E+02	3.66E+03	7.37E+04	1.30E+04	3.03E+02	1.35E+04	4.14E+04	4.13E+03	4.85E+01	5.24E+03	1.12E+05	1.66E+04	3.38E+02	3.84E+03
37	Middle Ruins Creek - Santa Cruz Mudstone	1.10E+04	9.46E+04	2.31E+04	6.51E+02	1.82E+04	3.47E+05	4.93E+04	9.18E+02	1.28E+04	2.58E+05	4.54E+04	1.06E+03	4.74E+04	1.45E+05	1.45E+04	1.70E+02	1.84E+04	3.91E+05	5.79E+04	1.18E+03	1.34E+04
38	Lower Ruins Creek - Santa Margarita	1.58E+03	1.35E+04	3.30E+03	9.29E+01	2.61E+03	4.96E+04	7.04E+03	1.31E+02	1.83E+03	3.68E+04	6.49E+03	1.52E+02	6.77E+03	2.07E+04	2.07E+03	2.42E+01	2.62E+03	5.59E+04	8.28E+03	1.69E+02	1.92E+03
39	Mackenzie Creek - Monterey	5.50E+03	3.66E+04	1.14E+04	3.85E+02	9.10E+03	1.34E+05	2.43E+04	5.43E+02	6.38E+03	9.98E+04	2.24E+04	6.27E+02	2.36E+04	5.61E+04	7.13E+03	1.00E+02	9.15E+03	1.51E+05	2.85E+04	7.00E+02	6.70E+03
40	Mackenzie Creek - Santa Margarita	5.50E+03	3.66E+04	1.14E+04	3.85E+02	9.10E+03	1.34E+05	2.43E+04	5.43E+02	6.38E+03	9.98E+04	2.24E+04	6.27E+02	2.36E+04	5.61E+04	7.13E+03	1.00E+02	9.15E+03	1.51E+05	2.85E+04	7.00E+02	6.70E+03
41	Unnamed Creek #8 off Bean Creek - Butano	8.66E+03	4.49E+04	1.68E+04	5.56E+02	1.41E+04	1.72E+05	3.85E+04	8.67E+02	1.00E+04	1.30E+05	3.53E+04	9.86E+02	3.55E+04	7.41E+04	1.21E+04	2.00E+02	1.43E+04	1.94E+05	4.63E+04	1.18E+03	9.89E+03
42	Bean Creek Inflow - Butano	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	8.66E+03	4.49E+04	1.68E+04	5.56E+02	1.41E+04	1.72E+05	3.85E+04	8.67E+02	1.00E+04	1.30E+05	3.53E+04	9.86E+02	3.55E+04	7.41E+04	1.21E+04	2.00E+02	1.43E+04	1.94E+05	4.63E+04	1.18E+03	9.89E+03
44	Upper Bean Creek - Monterey	1.44E+04	8.96E+04	3.07E+04	1.13E+03	2.38E+04	3.29E+05	6.56E+04	1.60E+03	1.67E+04	2.44E+05	6.04E+04	1.85E+03	6.17E+04	1.37E+05	1.93E+04	2.96E+02	2.39E+04	3.70E+05	7.71E+04	2.06E+03	1.75E+04
45	Upper Bean Creek - Santa Margarita	6.16E+03	3.84E+04	1.32E+04	4.85E+02	1.02E+04	1.41E+05	2.81E+04	6.85E+02	7.14E+03	1.05E+05	2.59E+04	7.91E+02	2.64E+04	5.88E+04	8.25E+03	1.27E+02	1.02E+04	1.59E+05	3.30E+04	8.84E+02	7.49E+03
46	Middle Bean Creek - Santa Margarita	8.39E+03	6.49E+04	1.78E+04	6.50E+02	1.39E+04	2.38E+05	3.80E+04	9.17E+02	9.73E+03	1.77E+05	3.50E+04	1.06E+03	3.60E+04	9.94E+04	1.11E+04	1.69E+02	1.40E+04	2.68E+05	4.46E+04	1.18E+03	1.02E+04
47	Middle Bean Creek - Santa Margarita	3.60E+03	2.78E+04	7.63E+03	2.79E+02	5.95E+03	1.02E+05	1.63E+04	3.93E+02	4.17E+03	7.58E+04	1.50E+04	4.54E+02	1.54E+04	4.26E+04	4.77E+03	7.26E+01	5.98E+03	1.15E+05	1.91E+04	5.07E+02	4.38E+03
48	Lower Bean Creek - Santa Margarita	1.33E+04	5.78E+04	2.13E+04	1.25E+03	2.19E+04	2.14E+05	4.60E+04	1.81E+03	1.54E+04	1.60E+05	4.23E+04	2.08E+03	5.65E+04	8.97E+04	1.37E+04	3.52E+02	2.21E+04	2.41E+05	5.43E+04	2.36E+03	1.60E+04
49	Lower Bean Creek - Monterey	1.33E+04	5.78E+04	2.13E+04	1.25E+03	2.19E+04	2.14E+05	4.60E+04	1.81E+03	1.54E+04	1.60E+05	4.23E+04	2.08E+03	5.65E+04	8.97E+04	1.37E+04	3.52E+02	2.21E+04	2.41E+05	5.43E+04	2.36E+03	1.60E+04

STREAM INFLOW

		58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Seg #	Stream	1999_Q2	1999_Q3	1999_Q4	2000_Q1	2000_Q2	2000_Q3	2000_Q4	2001_Q1	2001_Q2	2001_Q3	2001_Q4	2002_Q1	2002_Q2	2002_Q3	2002_Q4	2003_Q1	2003_Q2	2003_Q3	2003_Q4	2004_Q1	2004_Q2
10	Upper Love Creek - Butano	6.84E+04	1.80E+04	3.87E+02	4.32E+03	1.11E+05	2.59E+04	6.04E+02	5.26E+03	5.90E+04	1.65E+04	3.62E+02	2.32E+04	3.84E+04	7.26E+03	1.22E+02	2.19E+04	3.00E+04	1.77E+04	9.89E+02	1.63E+04	4.27E+04
15	Lower Newell - Monterey	6.32E+05	1.65E+05	3.59E+03	3.96E+04	1.02E+06	2.36E+05	5.63E+03	4.92E+04	5.48E+05	1.52E+05	3.39E+03	2.14E+05	3.48E+05	6.42E+04	1.07E+03	1.99E+05	2.72E+05	1.63E+05	9.07E+03	1.51E+05	3.97E+05
17	Lompico Creek - Butano	1.35E+05	3.54E+04	9.01E+02	8.92E+03	2.18E+05	5.06E+04	1.41E+03	1.11E+04	1.17E+05	3.28E+04	8.50E+02	4.83E+04	7.43E+04	1.38E+04	2.67E+02	4.49E+04	5.81E+04	3.51E+04	2.27E+03	3.40E+04	8.48E+04
24	Zayante - Mountain House Gulch	1.01E+06	2.23E+05	4.73E+03	5.29E+04	1.63E+06	3.14E+05	7.50E+03	6.86E+04	8.86E+05	2.08E+05	4.54E+03	2.92E+05	5.34E+05	8.04E+04	1.24E+03	2.63E+05	4.19E+05	2.24E+05	1.17E+04	2.06E+05	6.43E+05
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	1.71E+05	2.62E+04	3.97E+02	6.60E+03	2.77E+05	3.75E+04	6.23E+02	8.22E+03	1.48E+05	2.42E+04	3.75E+02	3.58E+04	9.42E+04	1.02E+04	1.18E+02	3.33E+04	7.37E+04	2.59E+04	1.00E+03	2.52E+04	1.07E+05
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	1.71E+05	2.62E+04	3.97E+02	6.60E+03	2.77E+05	3.75E+04	6.23E+02	8.22E+03	1.48E+05	2.42E+04	3.75E+02	3.58E+04	9.42E+04	1.02E+04	1.18E+02	3.33E+04	7.37E+04	2.59E+04	1.00E+03	2.52E+04	1.07E+05
42	Bean Creek Inflow - Butano	4.83E+05	8.36E+04	1.75E+03	2.27E+04	7.81E+05	1.17E+05	2.78E+03	2.98E+04	4.24E+05	7.82E+04	1.68E+03	1.26E+05	2.52E+05	2.96E+04	4.45E+02	1.13E+05	1.98E+05	8.41E+04	4.31E+03	8.92E+04	3.08E+05

STREAM RUNOFF

		58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Seg #	Stream	1999_Q2	1999_Q3	1999_Q4	2000_Q1	2000_Q2	2000_Q3	2000_Q4	2001_Q1	2001_Q2	2001_Q3	2001_Q4	2002_Q1	2002_Q2	2002_Q3	2002_Q4	2003_Q1	2003_Q2	2003_Q3	2003_Q4	2004_Q1	2004_Q2
1	Upper Blackburn Gulch	1.37E+05	2.63E+04	5.43E+02	6.47E+03	2.22E+05	3.76E+04	8.50E+02	8.02E+03	1.19E+05	2.43E+04	5.11E+02	3.50E+04	7.58E+04	1.03E+04	1.62E+02	3.26E+04	5.93E+04	2.60E+04	1.37E+03	2.46E+04	8.62E+04
2	Lower Blackburn Gulch	2.94E+05	5.64E+04	1.55E+03	1.91E+04	4.75E+05	8.13E+04	2.41E+03	2.31E+04	2.53E+05	5.19E+04	1.44E+03	1.02E+05	1.65E+05	2.29E+04	4.92E+02	9.67E+04	1.29E+05	5.54E+04	3.95E+03	7.18E+04	1.83E+05
3	Carbonera Creek - Butano	5.58E+04	1.24E+04	2.73E+02	3.14E+03	9.03E+04	1.76E+04	4.30E+02	3.95E+03	4.85E+04	1.15E+04	2.59E+02	1.71E+04	3.05E+04	4.74E+03	7.91E+01	1.58E+04	2.39E+04	1.23E+04	6.87E+02	1.21E+04	3.52E+04
4	Carbonera Creek - Monterey	1.12E+05	2.47E+04	5.47E+02	6.29E+03	1.81E+05	3.52E+04	8.59E+02	7.89E+03	9.70E+04	2.29E+04	5.17E+02	3.42E+04	6.09E+04	9.47E+03	1.58E+02	3.16E+04	4.77E+04	2.45E+04	1.37E+03	2.41E+04	7.03E+04
5	Carbonera Creek - Monterey	1.12E+05	2.47E+04	5.47E+02	6.29E+03	1.81E+05	3.52E+04	8.59E+02	7.89E+03	9.70E+04	2.29E+04	5.17E+02	3.42E+04	6.09E+04	9.47E+03	1.58E+02	3.16E+04	4.77E+04	2.45E+04	1.37E+03	2.41E+04	7.03E+04
6	Carbonera Creek - Santa Cruz Mudstone	3.20E+05	5.98E+04	2.15E+03	2.59E+04	5.18E+05	8.56E+04	3.37E+03	3.20E+04	2.78E+05	5.53E+04	2.03E+03	1.40E+05	1.77E+05	2.34E+04	6.46E+02	1.30E+05	1.38E+05	5.91E+04	5.44E+03	9.84E+04	2.01E+05
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	4.81E+05	8.97E+04	3.23E+03	3.88E+04	7.77E+05	1.28E+05	5.05E+03	4.81E+04	4.16E+05	8.29E+04	3.04E+03	2.10E+05	2.66E+05	3.51E+04	9.69E+02	1.96E+05	2.08E+05	8.87E+04	8.16E+03	1.48E+05	3.02E+05
8	Carbonera Creek - Santa Margarita	2.46E+05	5.68E+04	2.75E+03	3.07E+04	3.97E+05	8.17E+04	4.30E+03	3.77E+04	2.12E+05	5.25E+04	2.58E+03	1.65E+05	1.37E+05	2.26E+04	8.49E+02	1.55E+05	1.07E+05	5.60E+04	7.00E+03	1.16E+05	1.54E+05
9	Carbonera Creek - Lompico	2.73E+04	6.31E+03	3.06E+02	3.42E+03	4.41E+04	9.07E+03	4.78E+02	4.19E+03	2.36E+04	5.83E+03	2.87E+02	1.84E+04	1.52E+04	2.52E+03	9.44E+01	1.73E+04	1.19E+04	6.23E+03	7.77E+02	1.29E+04	1.71E+04
10	Upper Love Creek - Butano	5.36E+04	1.29E+04	2.77E+02	3.07E+03	8.66E+04	1.81E+04	4.40E+02	4.00E+03	4.70E+04	1.20E+04	2.66E+02	1.70E+04	2.82E+04	4.61E+03	7.20E+01	1.53E+04	2.22E+04	1.29E+04	6.85E+02	1.20E+04	3.41E+04
11	Upper Love Creek - Monterey	2.89E+04	6.94E+03	1.49E+02	1.65E+03	4.66E+04	9.76E+03	2.37E+02	2.15E+03	2.53E+04	6.47E+03	1.43E+02	9.15E+03	1.52E+04	2.48E+03	3.88E+01	8.23E+03	1.19E+04	6.96E+03	3.69E+02	6.46E+03	1.84E+04
12	Fitch Creek	1.67E+05	4.05E+04	9.24E+02	8.91E+03	2.70E+05	5.62E+04	1.48E+03	1.20E+04	1.48E+05	3.80E+04	8.99E+02	5.02E+04	8.49E+04	1.36E+04	2.17E+02	4.39E+04	6.70E+04	4.10E+04	2.25E+03	3.55E+04	1.08E+05
13	Middle Love Creek	2.34E+05	5.55E+04	1.65E+03	1.44E+04	3.78E+05	7.65E+04	2.66E+03	1.99E+04	2.08E+05	5.24E+04	1.62E+03	8.20E+04	1.16E+05	1.77E+04	3.60E+02	7.04E+04	9.14E+04	5.67E+04	3.99E+03	5.81E+04	1.51E+05
14	Lower Love Creek	1.00E+05	2.38E+04	7.08E+02	6.16E+03	1.62E+05	3.28E+04	1.14E+03	8.51E+03	8.91E+04	2.25E+04	6.94E+02	3.52E+04	4.95E+04	7.59E+03	1.54E+02	3.02E+04	3.92E+04	2.43E+04	1.71E+03	2.49E+04	6.49E+04
15	Lower Newell - Monterey	2.02E+05	4.44E+04	9.59E+02	1.03E+04	3.27E+05	6.23E+04	1.52E+03	1.35E+04	1.77E+05	4.15E+04	9.23E+02	5.70E+04	1.06E+05	1.57E+04	2.45E+02	5.10E+04	8.31E+04	4.46E+04	2.37E+03	4.03E+04	1.29E+05
16	Lower Newell - Santa Margarita	2.11E+05	4.96E+04	1.98E+03	1.79E+04	3.40E+05	6.87E+04	3.17E+03	2.44E+04	1.86E+05	4.67E+04	1.93E+03	1.01E+05	1.06E+05	1.63E+04	4.49E+02	8.79E+04	8.34E+04	5.04E+04	4.80E+03	7.17E+04	1.36E+05
17	Lompico Creek - Butano	9.39E+04	2.27E+04	8.81E+02	9.21E+03	1.52E+05	3.24E+04	1.38E+03	1.15E+04	8.14E+04	2.10E+04	8.31E+02	4.99E+04	5.17E+04	8.83E+03	2.62E+02	4.64E+04	4.04E+04	2.24E+04	2.23E+03	3.51E+04	5.89E+04
18	Lompico Creek - Monterey	1.11E+05	2.56E+04	8.68E+02	8.53E+03	1.79E+05	3.65E+04	1.36E+03	1.07E+04	9.62E+04	2.37E+04	8.21E+02	4.64E+04	6.05E+04	9.84E+03	2.52E+02	4.29E+04	4.74E+04	2.54E+04	2.18E+03	3.27E+04	6.97E+04
19	Lower Lompico - Monterey	1.11E+05	2.56E+04	8.68E+02	8.53E+03	1.79E+05	3.65E+04	1.36E+03	1.07E+04	9.62E+04	2.37E+04	8.21E+02	4.64E+04	6.05E+04	9.84E+03	2.52E+02	4.29E+04	4.74E+04	2.54E+04	2.18E+03	3.27E+04	6.97E+04
20	Unnamed Creek #2 off Zayante Creek - Butano	2.11E+04	5.03E+03	1.09E+02	1.32E+03	3.41E+04	7.19E+03	1.70E+02	1.64E+03	1.83E+04	4.65E+03	1.02E+02	7.14E+03	1.16E+04	1.96E+03	3.22E+01	6.64E+03	9.09E+03	4.98E+03	2.74E+02	5.03E+03	1.33E+04
21	Unnamed Creek #3 off Zayante Creek - Butano	4.92E+04	1.17E+04	2.54E+02	3.08E+03	7.96E+04	1.68E+04	3.98E+02	3.83E+03	4.27E+04	1.09E+04	2.39E+02	1.67E+04	2.71E+04	4.57E+03	7.52E+01	1.55E+04	2.12E+04	1.16E+04	6.40E+02	1.17E+04	3.09E+04
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	1.46E+05	3.23E+04	1.24E+03	1.09E+04	2.35E+05	4.54E+04	1.97E+03	1.43E+04	1.28E+05	3.02E+04	1.19E+03	6.04E+04	7.60E+04	1.14E+04	3.14E+02	5.39E+04	5.97E+04	3.25E+04	3.05E+03	4.27E+04	9.29E+04
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	1.46E+05	3.23E+04	1.24E+03	1.09E+04	2.35E+05	4.54E+04	1.97E+03	1.43E+04	1.28E+05	3.02E+04	1.19E+03	6.04E+04	7.60E+04	1.14E+04	3.14E+02	5.39E+04	5.97E+04	3.25E+04	3.05E+03	4.27E+04	9.29E+04
24	Zayante - Mountain House Gulch	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	7.03E+04	1.68E+04	3.62E+02	4.39E+03	1.14E+05	2.40E+04	5.68E+02	5.47E+03	6.10E+04	1.55E+04	3.42E+02	2.38E+04	3.87E+04	6.53E+03	1.07E+02	2.21E+04	3.03E+04	1.66E+04	9.14E+02	1.68E+04	4.42E+04
26	Upper Zayante - Monterey	2.74E+05	5.87E+04	1.56E+03	1.67E+04	4.43E+05	8.40E+04	2.45E+03	2.08E+04	2.37E+05	5.43E+04	1.47E+03	9.07E+04	1.51E+05	2.28E+04	4.64E+02	8.44E+04	1.18E+05	5.81E+04	3.95E+03	6.39E+04	1.72E+05
27	Middle Zayante - Monterey	1.09E+05	2.43E+04	9.30E+02	8.15E+03	1.76E+05	3.40E+04	1.48E+03	1.07E+04	9.59E+04	2.27E+04	8.96E+02	4.53E+04	5.70E+04	8.55E+03	2.36E+02	4.05E+04	4.48E+04	2.44E+04	2.29E+03	3.20E+04	6.97E+04
28	Middle Zayante - Monterey	7.29E+04	1.62E+04	6.20E+02	5.43E+03	1.18E+05	2.27E+04	9.85E+02	7.13E+03	6.39E+04	1.51E+04	5.97E+02	3.02E+04	3.80E+04	5.70E+03	1.57E+02	2.70E+04	2.99E+04	1.63E+04	1.53E+03	2.13E+04	4.65E+04
29	Lower Zayante - Monterey	2.55E+05	5.66E+04	2.17E+03	1.90E+04	4.12E+05	7.94E+04	3.45E+03	2.50E+04	2.24E+05	5.29E+04	2.09E+03	1.06E+05	1.33E+05	2.00E+04	5.50E+02	9.44E+04	1.05E+05	5.69E+04	5.35E+03	7.47E+04	1.63E+05
30	Upper Lockhart Gulch - Monterey	6.85E+04	1.05E+04	1.59E+02	2.64E+03	1.11E+05	1.50E+04	2.49E+02	3.29E+03	5.93E+04	9.70E+03	1.50E+02	1.43E+04	3.77E+04	4.08E+03	4.72E+01	1.33E+04	2.95E+04	1.04E+04	4.01E+02	1.01E+04	4.30E+04
31	Upper Lockhart Gulch - Santa Margarita	1.03E+05	1.57E+04	2.38E+02	3.96E+03	1.66E+05	2.25E+04	3.74E+02	4.93E+03	8.90E+04	1.45E+04	2.25E+02	2.15E+04	5.65E+04	6.12E+03	7.07E+01	2.00E+04	4.42E+04	1.56E+04	6.02E+02	1.51E+04	6.45E+04
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	6.85E+03	1.05E+03	1.59E+01	2.64E+02	1.11E+04	1.50E+03	2.49E+01	3.29E+02	5.93E+03	9.70E+02	1.50E+01	1.43E+03	3.77E+03	4.08E+02	4.72E+00	1.33E+03	2.95E+03	1.04E+03	4.01E+01	1.01E+03	4.30E+03
33	Middle Lockhart Gulch - Santa Margarita	6.85E+04	1.05E+04	1.59E+02	2.64E+03	1.11E+05	1.50E+04	2.49E+02	3.29E+03	5.93E+04	9.70E+03	1.50E+02	1.43E+04	3.77E+04	4.08E+03	4.72E+01	1.33E+04	2.95E+04	1.04E+04	4.01E+02	1.01E+04	4.30E+04
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	6.85E+03	1.05E+03	1.59E+01	2.64E+02	1.11E+04	1.50E+03	2.49E+01	3.29E+02	5.93E+03	9.70E+02	1.50E+01	1.43E+03	3.77E+03	4.08E+02	4.72E+00	1.33E+03	2.95E+03	1.04E+03	4.01E+01	1.01E+03	4.30E+03
35	Lower Lockhart Gulch - Santa Margarita	8.90E+04	1.36E+04	2.07E+02	3.43E+03	1.44E+05	1.95E+04	3.24E+02	4.27E+03	7.71E+04	1.26E+04	1.95E+02	1.86E+04	4.90E+04	5.30E+03	6.13E+01	1.73E+04	3.83E+04	1.35E+04	5.22E+02	1.31E+04	5.59E+04
36	Upper Ruins Creek - Santa Margarita	5.44E+04	8.10E+03	1.31E+02	2.09E+03	8.80E+04	1.16E+04	2.06E+02	2.60E+03	4.72E+04	7.50E+03	1.24E+02	1.13E+04	3.00E+04	3.15E+03	3.90E+01	1.05E+04	2.34E+04	8.02E+03	3.32E+02	7.99E+03	3.42E+04
37	Middle Ruins Creek - Santa Cruz Mudstone	1.91E+05	2.84E+04	4.60E+02	7.33E+03	3.08E+05	4.06E+04	7.21E+02	9.12E+03	1.65E+05	2.62E+04	4.34E+02	3.97E+04	1.05E+05	1.10E+04	1.36E+02	3.69E+04	8.20E+04	2.81E+04	1.16E+03	2.79E+04	1.20E+05
38	Lower Ruins Creek - Santa Margarita	2.72E+04	4.05E+03	6.57E+01	1.05E+03	4.40E+04	5.80E+03	1.03E+02	1.30E+03	2.36E+04	3.75E+03	6.19E+01	5.67E+03	1.50E+04	1.58E+03	1.95E+01	5.27E+03	1.17E+04	4.01E+03	1.66E+02	3.99E+03	1.71E+04
39	Mackenzie Creek - Monterey	7.37E+04	1.40E+04	2.72E+02	3.65E+03	1.19E+05	2.00E+04	4.26E+02	4.55E+03	6.39E+04	1.29E+04	2.56E+02	1.98E+04	4.05E+04	5.44E+03	8.07E+01	1.84E+04	3.17E+04	1.38E+04	6.86E+02	1.39E+04	4.63E+04
40	Mackenzie Creek - Santa Margarita	7.37E+04	1.40E+04	2.72E+02	3.65E+03	1.19E+05	2.00E+04	4.26E+02	4.55E+03	6.39E+04	1.29E+04	2.56E+02	1.98E+04	4.05E+04	5.44E+03	8.07E+01	1.84E+04	3.17E+04	1.38E+04	6.86E+02	1.39E+04	4.63E+04
41	Unnamed Creek #8 off Bean Creek - Butano	9.03E+04	2.17E+04	4.47E+02	5.51E+03	1.46E+05	3.05E+04	7.10E+02	7.17E+03	7.91E+04	2.02E+04	4.30E+02	3.05E+04	4.75E+04	7.77E+03	1.16E+02	2.74E+04	3.73E+04	2.18E+04	1.11E+03	2.15E+04	5.74E+04
42	Bean Creek Inflow - Butano	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	9.03E+04	2.17E+04	4.47E+02	5.51E+03	1.46E+05	3.05E+04	7.10E+02	7.17E+03	7.91E+04	2.02E+04	4.30E+02	3.05E+04	4.75E+04	7.77E+03	1.16E+02	2.74E+04	3.73E+04	2.18E+04	1.11E+03	2.15E+04	5.74E+04
44	Upper Bean Creek - Monterey	1.80E+05	3.77E+04	8.01E+02	9.54E+03	2.92E+05	5.39E+04	1.26E+03	1.19E+04	1.56E+05	3.49E+04	7.55E+02	5.17E+04	9.92E+04	1.47E+04	2.37E+02	4.81E+04	7.76E+04	3.73E+04	2.02E+03	3.64E+04	1.13E+05
45	Upper Bean Creek - Santa Margarita	7.73E+04	1.62E+04	3.43E+02	4.09E+03	1.25E+05	2.31E+04	5.38E+02	5.09E+03	6.70E+04	1.50E+04	3.24E+02	2.22E+04	4.25E+04	6.28E+03	1.02E+02	2.06E+04	3.33E+04	1.60E+04	8.66E+02	1.56E+04	4.86E+04
46	Middle Bean Creek - Santa Margarita	1.31E+05	2.18E+04	4.60E+02	5.57E+03	2.11E+05	3.12E+04	7.20E+02	6.93E+03	1.13E+05	2.02E+04	4.33E+02	3.02E+04	7.19E+04	8.50E+03	1.36E+02	2.81E+04	5.63E+04	2.16E+04	1.16E+03	2.13E+04	8.21E+04
47	Middle Bean Creek - Santa Margarita	5.60E+04	9.36E+03	1.97E+02	2.39E+03	9.06E+04	1.34E+04	3.09E+02	2.97E+03	4.86E+04	8.66E+03	1.86E+02	1.29E+04	3.08E+04	3.64E+03	5.84E+01	1.20E+04	2.41E+04	9.27E+03	4.97E+02	9.11E+03	3.52E+04
48	Lower Bean Creek - Santa Margarita	1.16E+05	2.63E+04	9.11E+02	8.74E+03	1.88E+05	3.75E+04	1.43E+03	1.10E+04	1.01E+05	2.44E+04	8.63E+02	4.76E+04	6.35E+04	1.01E+04	2.63E+02	4.39E+04	4.97E+04	2.61E+04	2.29E+03	3.35E+04	7.33E+04
49	Lower Bean Creek - Monterey	1.16E+05	2.63E+04	9.11E+02	8.74E+03	1.88E+05	3.75E+04	1.43E+03	1.10E+04	1.01E+05	2.44E+04	8.63E+02	4.76E+04	6.35E+04	1.01E+04	2.63E+02	4.39E+04	4.97E+04	2.61E+04	2.29E+03	3.35E+04	7.33E+04

APPENDIX E - SFR1 Stream Segment Data

STREAM INFLOW

Seg #	Stream	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
		2004_Q3	2004_Q4	2005_Q1	2005_Q2	2005_Q3	2005_Q4	2006_Q1	2006_Q2	2006_Q3	2006_Q4	2007_Q1	2007_Q2	2007_Q3	2007_Q4	2008_Q1	2008_Q2	2008_Q3	2008_Q4	2009_Q1	2009_Q2	2009_Q3
10	Upper Love Creek - Butano	7.66E+03	2.88E+01	1.96E+04	7.44E+04	2.48E+04	8.80E+02	1.90E+04	7.40E+04	3.40E+04	1.53E+03	6.37E+03	2.66E+04	9.10E+03	2.86E+02	5.17E+03	6.05E+04	1.17E+04	0.00E+00	7.47E+03	5.15E+04	1.31E+04
15	Lower Newell - Monterey	7.03E+04	2.50E+02	1.80E+05	6.84E+05	2.23E+05	7.80E+03	1.73E+05	6.60E+05	3.04E+05	1.36E+04	5.89E+04	2.47E+05	8.22E+04	2.51E+03	4.69E+04	5.46E+05	1.04E+05	0.00E+00	6.90E+04	4.80E+05	1.19E+05
17	Lompico Creek - Butano	1.51E+04	6.25E+01	4.06E+04	1.46E+05	4.80E+04	1.95E+03	3.89E+04	1.41E+05	6.53E+04	3.42E+03	1.33E+04	5.28E+04	1.77E+04	6.28E+02	1.06E+04	1.17E+05	2.23E+04	0.00E+00	1.56E+04	1.03E+05	2.56E+04
24	Zayante - Mountain House Gulch	9.54E+04	2.86E+02	2.42E+05	1.09E+06	2.91E+05	9.37E+03	2.27E+05	9.78E+05	3.91E+05	1.66E+04	8.04E+04	3.98E+05	1.08E+05	2.94E+03	6.14E+04	8.35E+05	1.33E+05	0.00E+00	9.38E+04	7.85E+05	1.59E+05
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	1.12E+04	2.76E+01	3.01E+04	1.85E+05	3.55E+04	8.61E+02	2.88E+04	1.78E+05	4.83E+04	1.51E+03	9.84E+03	6.69E+04	1.31E+04	2.77E+02	7.83E+03	1.48E+05	1.65E+04	0.00E+00	1.15E+04	1.30E+05	1.89E+04
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	1.12E+04	2.76E+01	3.01E+04	1.85E+05	3.55E+04	8.61E+02	2.88E+04	1.78E+05	4.83E+04	1.51E+03	9.84E+03	6.69E+04	1.31E+04	2.77E+02	7.83E+03	1.48E+05	1.65E+04	0.00E+00	1.15E+04	1.30E+05	1.89E+04
42	Bean Creek Inflow - Butano	3.58E+04	1.02E+02	1.04E+05	5.17E+05	1.08E+05	3.39E+03	9.72E+04	4.58E+05	1.45E+05	6.00E+03	3.47E+04	1.91E+05	4.01E+04	1.06E+03	2.62E+04	3.94E+05	4.90E+04	0.00E+00	4.05E+04	3.77E+05	5.94E+04

STREAM RUNOFF

Seg #	Stream	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
		2004_Q3	2004_Q4	2005_Q1	2005_Q2	2005_Q3	2005_Q4	2006_Q1	2006_Q2	2006_Q3	2006_Q4	2007_Q1	2007_Q2	2007_Q3	2007_Q4	2008_Q1	2008_Q2	2008_Q3	2008_Q4	2009_Q1	2009_Q2	2009_Q3
1	Upper Blackburn Gulch	1.12E+04	3.80E+01	2.94E+04	1.49E+05	3.57E+04	1.18E+03	2.83E+04	1.44E+05	4.86E+04	2.07E+03	9.62E+03	5.37E+04	1.31E+04	3.81E+02	7.67E+03	1.19E+05	1.66E+04	6.62E+01	1.13E+04	1.04E+05	1.90E+04
2	Lower Blackburn Gulch	2.40E+04	1.16E+02	8.65E+04	3.19E+05	7.79E+04	3.53E+03	8.40E+04	3.19E+05	1.07E+05	6.15E+03	2.81E+04	1.14E+05	2.86E+04	1.15E+03	2.28E+04	2.60E+05	3.67E+04	1.99E+02	3.29E+04	2.20E+05	4.10E+04
3	Carbonera Creek - Butano	5.28E+03	1.84E+01	1.43E+04	6.03E+04	1.66E+04	5.81E+02	1.37E+04	5.73E+04	2.25E+04	1.02E+03	4.71E+03	2.19E+04	6.13E+03	1.86E+02	3.71E+03	4.78E+04	7.70E+03	0.00E+00	5.51E+03	4.26E+04	8.90E+03
4	Carbonera Creek - Monterey	1.06E+04	3.69E+01	2.86E+04	1.21E+05	3.32E+04	1.16E+03	2.74E+04	1.15E+05	4.51E+04	2.04E+03	9.41E+03	4.37E+04	1.23E+04	3.72E+02	7.42E+03	9.56E+04	1.54E+04	0.00E+00	1.10E+04	8.52E+04	1.78E+04
5	Carbonera Creek - Monterey	1.06E+04	3.69E+01	2.86E+04	1.21E+05	3.32E+04	1.16E+03	2.74E+04	1.15E+05	4.51E+04	2.04E+03	9.41E+03	4.37E+04	1.23E+04	3.72E+02	7.42E+03	9.56E+04	1.54E+04	0.00E+00	1.10E+04	8.52E+04	1.78E+04
6	Carbonera Creek - Santa Cruz Mudstone	2.55E+04	1.51E+02	1.18E+05	3.47E+05	8.12E+04	4.70E+03	1.13E+05	3.36E+05	1.11E+05	8.22E+03	3.85E+04	1.25E+05	2.99E+04	1.52E+03	3.07E+04	2.78E+05	3.79E+04	0.00E+00	4.50E+04	2.43E+05	4.32E+04
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	3.83E+04	2.27E+02	1.76E+05	5.21E+05	1.22E+05	7.05E+03	1.70E+05	5.05E+05	1.66E+05	1.23E+04	5.77E+04	1.88E+05	4.49E+04	2.27E+03	4.61E+04	4.17E+05	5.68E+04	0.00E+00	6.76E+04	3.65E+05	6.48E+04
8	Carbonera Creek - Santa Margarita	2.42E+04	1.99E+02	1.40E+05	2.67E+05	7.78E+04	6.14E+03	1.35E+05	2.62E+05	1.06E+05	1.07E+04	4.55E+04	9.58E+04	2.86E+04	1.99E+03	3.67E+04	2.15E+05	3.65E+04	0.00E+00	5.33E+04	1.85E+05	4.12E+04
9	Carbonera Creek - Lompico	2.69E+03	2.22E+01	1.55E+04	2.96E+04	8.65E+03	6.82E+02	1.50E+04	2.91E+04	1.18E+04	1.19E+03	5.06E+03	1.06E+04	3.18E+03	2.21E+02	4.07E+03	2.39E+04	4.05E+03	0.00E+00	5.93E+03	2.06E+04	4.58E+03
10	Upper Love Creek - Butano	5.51E+03	1.66E+01	1.40E+04	5.75E+04	1.68E+04	5.45E+02	1.32E+04	5.15E+04	2.25E+04	9.63E+02	4.68E+03	2.11E+04	6.22E+03	1.71E+02	3.56E+03	4.41E+04	7.62E+03	0.00E+00	5.45E+03	4.17E+04	9.17E+03
11	Upper Love Creek - Monterey	2.97E+03	8.92E+00	7.55E+03	3.09E+04	9.04E+03	2.93E+02	7.10E+03	2.77E+04	1.21E+04	5.19E+02	2.52E+03	1.14E+04	3.35E+03	9.19E+01	1.92E+03	2.37E+04	4.10E+03	0.00E+00	2.94E+03	2.24E+04	4.94E+03
12	Fitch Creek	1.73E+04	4.92E+01	4.09E+04	1.78E+05	5.12E+04	1.69E+03	3.77E+04	1.50E+05	6.77E+04	3.01E+03	1.38E+04	6.63E+04	1.90E+04	5.18E+02	1.01E+04	1.32E+05	2.28E+04	0.00E+00	1.61E+04	1.32E+05	2.85E+04
13	Middle Love Creek	2.38E+04	8.08E+01	6.61E+04	2.48E+05	6.88E+04	2.88E+03	6.03E+04	2.00E+05	9.00E+04	5.15E+03	2.26E+04	9.31E+04	2.56E+04	8.66E+02	1.62E+04	1.80E+05	3.01E+04	0.00E+00	2.62E+04	1.87E+05	3.88E+04
14	Lower Love Creek	1.02E+04	3.46E+01	2.83E+04	1.06E+05	2.95E+04	1.23E+03	2.59E+04	8.55E+04	3.86E+04	2.21E+03	9.67E+03	3.99E+04	1.10E+04	3.71E+02	6.92E+03	7.69E+04	1.29E+04	0.00E+00	1.12E+04	8.02E+04	1.66E+04
15	Lower Newell - Monterey	1.90E+04	5.61E+01	4.70E+04	2.16E+05	5.75E+04	1.86E+03	4.40E+04	1.92E+05	7.69E+04	3.30E+03	1.57E+04	7.98E+04	2.13E+04	5.81E+02	1.19E+04	1.65E+05	2.60E+04	0.00E+00	1.83E+04	1.58E+05	3.15E+04
16	Lower Newell - Santa Margarita	2.13E+04	1.01E+02	8.21E+04	2.23E+05	6.22E+04	3.54E+03	7.54E+04	1.85E+05	8.18E+04	6.33E+03	2.79E+04	8.36E+04	2.31E+04	1.08E+03	2.02E+04	1.64E+05	2.75E+04	0.00E+00	3.24E+04	1.67E+05	3.48E+04
17	Lompico Creek - Butano	9.68E+03	6.11E+01	4.19E+04	1.02E+05	3.07E+04	1.91E+03	4.02E+04	9.79E+04	4.18E+04	3.34E+03	1.37E+04	3.67E+04	1.13E+04	6.14E+02	1.09E+04	8.11E+04	1.43E+04	0.00E+00	1.61E+04	7.13E+04	1.64E+04
18	Lompico Creek - Monterey	1.09E+04	5.89E+01	3.88E+04	1.20E+05	3.45E+04	1.85E+03	3.72E+04	1.14E+05	4.68E+04	3.25E+03	1.28E+04	4.34E+04	1.27E+04	5.94E+02	1.01E+04	9.50E+04	1.60E+04	0.00E+00	1.49E+04	8.45E+04	1.84E+04
19	Lower Lompico - Monterey	1.09E+04	5.89E+01	3.88E+04	1.20E+05	3.45E+04	1.85E+03	3.72E+04	1.14E+05	4.68E+04	3.25E+03	1.28E+04	4.34E+04	1.27E+04	5.94E+02	1.01E+04	9.50E+04	1.60E+04	0.00E+00	1.49E+04	8.45E+04	1.84E+04
20	Unnamed Creek #2 off Zayante Creek - Butano	2.15E+03	7.54E+00	6.00E+03	2.28E+04	6.81E+03	2.35E+02	5.76E+03	2.20E+04	9.27E+03	4.12E+02	1.96E+03	8.25E+03	2.51E+03	7.57E+01	1.56E+03	1.82E+04	3.17E+03	0.00E+00	2.30E+03	1.60E+04	3.63E+03
21	Unnamed Creek #3 off Zayante Creek - Butano	5.01E+03	1.76E+01	1.40E+04	5.33E+04	1.59E+04	5.49E+02	1.34E+04	5.14E+04	2.16E+04	9.61E+02	4.58E+03	1.92E+04	5.86E+03	1.77E+02	3.65E+03	4.25E+04	7.40E+03	0.00E+00	5.37E+03	3.74E+04	8.47E+03
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	1.38E+04	7.21E+01	4.97E+04	1.56E+05	4.19E+04	2.40E+03	4.65E+04	1.38E+05	5.59E+04	4.24E+03	1.66E+04	5.75E+04	1.55E+04	7.46E+02	1.25E+04	1.19E+05	1.89E+04	0.00E+00	1.94E+04	1.14E+05	2.30E+04
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	1.38E+04	7.21E+01	4.97E+04	1.56E+05	4.19E+04	2.40E+03	4.65E+04	1.38E+05	5.59E+04	4.24E+03	1.66E+04	5.75E+04	1.55E+04	7.46E+02	1.25E+04	1.19E+05	1.89E+04	0.00E+00	1.94E+04	1.14E+05	2.30E+04
24	Zayante - Mountain House Gulch	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	7.16E+03	2.51E+01	2.00E+04	7.61E+04	2.27E+04	7.85E+02	1.92E+04	7.34E+04	3.09E+04	1.37E+03	6.55E+03	2.75E+04	8.37E+03	2.52E+02	5.21E+03	6.08E+04	1.06E+04	0.00E+00	7.67E+03	5.35E+04	1.21E+04
26	Upper Zayante - Monterey	2.51E+04	1.09E+02	7.62E+04	2.96E+05	7.95E+04	3.39E+03	7.32E+04	2.85E+05	1.08E+05	5.93E+03	2.50E+04	1.07E+05	2.93E+04	1.09E+03	1.99E+04	2.36E+05	3.70E+04	0.00E+00	2.92E+04	2.08E+05	4.24E+04
27	Middle Zayante - Monterey	1.04E+04	5.40E+01	3.73E+04	1.17E+05	3.14E+04	1.80E+03	3.49E+04	1.03E+05	4.19E+04	3.18E+03	1.25E+04	4.31E+04	1.16E+04	5.60E+02	9.40E+03	8.90E+04	1.42E+04	0.00E+00	1.45E+04	8.53E+04	1.72E+04
28	Middle Zayante - Monterey	6.92E+03	3.60E+01	2.48E+04	7.79E+04	2.09E+04	1.20E+03	2.33E+04	6.89E+04	2.79E+04	2.12E+03	8.31E+03	2.87E+04	7.76E+03	3.73E+02	6.27E+03	5.93E+04	9.45E+03	0.00E+00	9.69E+03	5.68E+04	1.15E+04
29	Lower Zayante - Monterey	2.42E+04	1.26E+02	8.70E+04	2.73E+05	7.32E+04	4.19E+03	8.14E+04	2.41E+05	9.78E+04	7.43E+03	2.91E+04	1.01E+05	2.71E+04	1.31E+03	2.19E+04	2.08E+05	3.31E+04	0.00E+00	3.39E+04	1.99E+05	4.02E+04
30	Upper Lockhart Gulch - Monterey	4.48E+03	1.10E+01	1.20E+04	7.41E+04	1.42E+04	3.44E+02	1.15E+04	7.14E+04	1.93E+04	6.03E+02	3.94E+03	2.68E+04	5.23E+03	1.11E+02	3.13E+03	5.91E+04	6.61E+03	0.00E+00	4.61E+03	5.20E+04	7.57E+03
31	Upper Lockhart Gulch - Santa Margarita	6.71E+03	1.65E+01	1.80E+04	1.11E+05	2.13E+04	5.16E+02	1.73E+04	1.07E+05	2.90E+04	9.04E+02	5.90E+03	4.01E+04	7.85E+03	1.66E+02	4.70E+03	8.87E+04	9.91E+03	0.00E+00	6.91E+03	7.80E+04	1.13E+04
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	4.48E+02	1.10E+00	1.20E+03	7.41E+03	1.42E+03	3.44E+01	1.15E+03	7.14E+03	1.93E+03	6.03E+01	3.94E+02	2.68E+03	5.23E+02	1.11E+01	3.13E+02	5.91E+03	6.61E+02	0.00E+00	4.61E+02	5.20E+03	7.57E+02
33	Middle Lockhart Gulch - Santa Margarita	4.48E+03	1.10E+01	1.20E+04	7.41E+04	1.42E+04	3.44E+02	1.15E+04	7.14E+04	1.93E+04	6.03E+02	3.94E+03	2.68E+04	5.23E+03	1.11E+02	3.13E+03	5.91E+04	6.61E+03	0.00E+00	4.61E+03	5.20E+04	7.57E+03
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	4.48E+02	1.10E+00	1.20E+03	7.41E+03	1.42E+03	3.44E+01	1.15E+03	7.14E+03	1.93E+03	6.03E+01	3.94E+02	2.68E+03	5.23E+02	1.11E+01	3.13E+02	5.91E+03	6.61E+02	0.00E+00	4.61E+02	5.20E+03	7.57E+02
35	Lower Lockhart Gulch - Santa Margarita	5.82E+03	1.43E+01	1.56E+04	9.63E+04	1.85E+04	4.48E+02	1.50E+04	9.28E+04	2.51E+04	7.83E+02	5.12E+03	3.48E+04	6.80E+03	1.44E+02	4.07E+03	7.69E+04	8.59E+03	0.00E+00	5.99E+03	6.76E+04	9.84E+03
36	Upper Ruins Creek - Santa Margarita	3.46E+03	9.11E+00	9.53E+03	5.89E+04	1.10E+04	2.85E+02	9.14E+03	5.68E+04	1.49E+04	4.98E+02	3.12E+03	2.13E+04	4.04E+03	9.15E+01	2.48E+03	4.70E+04	5.11E+03	0.00E+00	3.65E+03	4.14E+04	5.85E+03
37	Middle Ruins Creek - Santa Cruz Mudstone	1.21E+04	3.19E+01	3.33E+04	2.06E+05	3.84E+04	9.96E+02	3.20E+04	1.99E+05	5.23E+04	1.74E+03	1.09E+04	7.45E+04	1.42E+04	3.20E+02	8.68E+03	1.65E+05	1.79E+04	0.00E+00	1.28E+04	1.45E+05	2.05E+04
38	Lower Ruins Creek - Santa Margarita	1.73E+03	4.56E+00	4.76E+03	2.95E+04	5.49E+03	1.42E+02	4.57E+03	2.84E+04	7.47E+03	2.49E+02	1.56E+03	1.06E+04	2.02E+03	4.58E+01	1.24E+03	2.35E+04	2.55E+03	0.00E+00	1.83E+03	2.07E+04	2.92E+03
39	Mackenzie Creek - Monterey	5.97E+03	1.89E+01	1.66E+04	7.98E+04	1.89E+04	5.89E+02	1.60E+04	7.68E+04	2.58E+04	1.03E+03	5.44E+03	2.88E+04	6.97E+03	1.89E+02	4.33E+03	6.37E+04	8.81E+03	0.00E+00	6.37E+03	5.60E+04	1.01E+04
40	Mackenzie Creek - Santa Margarita	5.97E+03	1.89E+01	1.66E+04	7.98E+04	1.89E+04	5.89E+02	1.60E+04	7.68E+04	2.58E+04	1.03E+03	5.44E+03	2.88E+04	6.97E+03	1.89E+02	4.33E+03	6.37E+04	8.81E+03	0.00E+00	6.37E+03	5.60E+04	1.01E+04
41	Unnamed Creek #8 off Bean Creek - Butano	9.28E+03	2.67E+01	2.52E+04	9.68E+04	2.83E+04	8.79E+02	2.36E+04	8.67E+04	3.78E+04	1.55E+03	8.39E+03	3.56E+04	1.05E+04	2.75E+02	6.38E+03	7.42E+04	1.28E+04	0.00E+00	9.79E+03	7.01E+04	1.54E+04
42	Bean Creek Inflow - Butano	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	9.28E+03	2.67E+01	2.52E+04	9.68E+04	2.83E+04	8.79E+02	2.36E+04	8.67E+04	3.78E+04	1.55E+03	8.39E+03	3.56E+04	1.05E+04	2.75E+02	6.38E+03	7.42E+04	1.28E+04	0.00E+00	9.79E+03	7.01E+04	1.54E+04
44	Upper Bean Creek - Monterey	1.61E+04	5.54E+01	4.34E+04	1.95E+05	5.10E+04	1.73E+03	4.17E+04	1.88E+05	6.95E+04	3.03E+03	1.42E+04	7.05E+04	1.88E+04	5.57E+02	1.13E+04	1.56E+05	2.38E+04	0.00E+00	1.66E+04	1.37E+05	2.72E+04
45	Upper Bean Creek - Santa Margarita	6.90E+03	2.38E+01	1.86E+04	8.37E+04	2.19E+04	7.42E+02	1.79E+04	8.05E+04	2.98E+04	1.30E+03	6.09E+03	3.02E+04	8.06E+03	2.39E+02	4.84E+03	6.67E+04	1.02E+04	0.00E+00	7.13E+03	5.88E+04	1.17E+04
46	Middle Bean Creek - Santa Margarita	9.33E+03	3.19E+01	2.54E+04	1.42E+05	2.96E+04	9.95E+02	2.43E+04	1.36E+05	4.03E+04	1.74E+03	8.30E+03	5.11E+04	1.09E+04	3.20E+02	6.60E+03	1.13E+05	1.38E+04	0.00E+00	9.72E+03	9.93E+04	1.58E+04
47	Middle Bean Creek - Santa Margarita	4.00E+03	1.37E+01	1.09E+04	6.06E+04	1.27E+04	4.27E+02	1.04E+04	5.84E+04	1.73E+04	7.47E+02	3.56E+03	2.19E+04	4.67E+03	1.37E+02	2.83E+03	4.84E+04	5.90E+03	0.00E+00	4.16E+03	4.26E+04	6.76E+03
48	Lower Bean Creek - Santa Margarita	1.12E+04	6.13E+01	3.98E+04	1.26E+05	3.54E+04	1.93E+03	3.81E+04	1.19E+05	4.80E+04	3.39E+03	1.31E+04	4.56E+04	1.30E+04	6.19E+02	1.03E+04	9.95E+04	1.64E+04	0.00E+00	1.53E+04	8.89E+04	1.89E+04
49	Lower Bean Creek - Monterey	1.12E+04	6.13E+01	3.98E+04	1.26E+05	3.54E+04	1.93E+03	3.81E+04	1.19E+05	4.80E+04	3.39E+03	1.31E+04	4.56E+04	1.30E+04	6.19E+02	1.03E+04	9.95E+04	1.64E+04	0.00E+00	1.53E+04	8.89E+04	1.89E+04

STREAM INFLOW

		100	101	102	103	104	105	106	107	108	109	110	111	112
Seg #	Stream	2009_Q4	2010_Q1	2010_Q2	2010_Q3	2010_Q4	2011_Q1	2011_Q2	2011_Q3	2011_Q4	2012_Q1	2012_Q2	2012_Q3	2012_Q4
10	Upper Love Creek - Butano	2.07E+02	1.05E+04	6.67E+04	2.49E+04	9.14E+02	1.89E+04	7.74E+04	2.61E+04	9.45E+02	4.20E+03	5.25E+04	1.66E+04	4.25E+02
15	Lower Newell - Monterey	1.86E+03	9.63E+04	6.19E+05	2.28E+05	8.36E+03	1.73E+05	7.17E+05	2.35E+05	8.26E+03	3.82E+04	4.84E+05	1.48E+05	3.63E+03
17	Lompico Creek - Butano	4.66E+02	2.17E+04	1.32E+05	4.91E+04	2.10E+03	3.90E+04	1.53E+05	5.05E+04	2.07E+03	8.61E+03	1.03E+05	3.18E+04	9.06E+02
24	Zayante - Mountain House Gulch	2.30E+03	1.29E+05	9.99E+05	3.10E+05	1.07E+04	2.31E+05	1.16E+06	3.04E+05	9.63E+03	5.04E+04	7.73E+05	1.88E+05	4.00E+03
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	2.06E+02	1.61E+04	1.68E+05	3.64E+04	9.24E+02	2.89E+04	1.94E+05	3.73E+04	9.11E+02	6.38E+03	1.31E+05	2.35E+04	4.00E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	2.06E+02	1.61E+04	1.68E+05	3.64E+04	9.24E+02	2.89E+04	1.94E+05	3.73E+04	9.11E+02	6.38E+03	1.31E+05	2.35E+04	4.00E+02
42	Bean Creek Inflow - Butano	8.38E+02	5.54E+04	4.78E+05	1.17E+05	3.94E+03	9.91E+04	5.53E+05	1.13E+05	3.45E+03	2.16E+04	3.69E+05	6.95E+04	1.41E+03

STREAM RUNOFF

		100	101	102	103	104	105	106	107	108	109	110	111	112
Seg #	Stream	2009_Q4	2010_Q1	2010_Q2	2010_Q3	2010_Q4	2011_Q1	2011_Q2	2011_Q3	2011_Q4	2012_Q1	2012_Q2	2012_Q3	2012_Q4
1	Upper Blackburn Gulch	2.82E+02	1.57E+04	1.34E+05	3.64E+04	1.26E+03	2.83E+04	1.56E+05	3.75E+04	1.25E+03	6.25E+03	1.05E+05	2.37E+04	5.52E+02
2	Lower Blackburn Gulch	8.31E+02	4.64E+04	2.86E+05	7.81E+04	3.66E+03	8.35E+04	3.32E+05	8.23E+04	3.80E+03	1.85E+04	2.25E+05	5.24E+04	1.71E+03
3	Carbonera Creek - Butano	1.40E+02	7.66E+03	5.48E+04	1.72E+04	6.32E+02	1.38E+04	6.35E+04	1.75E+04	6.11E+02	3.03E+03	4.28E+04	1.10E+04	2.65E+02
4	Carbonera Creek - Monterey	2.79E+02	1.53E+04	1.10E+05	3.43E+04	1.26E+03	2.75E+04	1.27E+05	3.49E+04	1.22E+03	6.06E+03	8.55E+04	2.19E+04	5.31E+02
5	Carbonera Creek - Monterey	2.79E+02	1.53E+04	1.10E+05	3.43E+04	1.26E+03	2.75E+04	1.27E+05	3.49E+04	1.22E+03	6.06E+03	8.55E+04	2.19E+04	5.31E+02
6	Carbonera Creek - Santa Cruz Mudstone	1.12E+03	6.30E+04	3.14E+05	8.29E+04	5.02E+03	1.13E+05	3.63E+05	8.55E+04	4.99E+03	2.50E+04	2.46E+05	5.40E+04	2.20E+03
7	Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	1.68E+03	9.44E+04	4.70E+05	1.24E+05	7.53E+03	1.70E+05	5.45E+05	1.28E+05	7.49E+03	3.75E+04	3.68E+05	8.09E+04	3.30E+03
8	Carbonera Creek - Santa Margarita	1.46E+03	7.48E+04	2.40E+05	7.88E+04	6.46E+03	1.35E+05	2.78E+05	8.21E+04	6.56E+03	2.98E+04	1.88E+05	5.20E+04	2.92E+03
9	Carbonera Creek - Lompico	1.62E+02	8.31E+03	2.67E+04	8.75E+03	7.18E+02	1.50E+04	3.09E+04	9.12E+03	7.29E+02	3.31E+03	2.09E+04	5.78E+03	3.25E+02
10	Upper Love Creek - Butano	1.34E+02	7.49E+03	5.30E+04	1.79E+04	6.26E+02	1.34E+04	6.13E+04	1.75E+04	5.58E+02	2.93E+03	4.09E+04	1.08E+04	2.31E+02
11	Upper Love Creek - Monterey	7.22E+01	4.03E+03	2.85E+04	9.66E+03	3.37E+02	7.22E+03	3.30E+04	9.44E+03	3.01E+02	1.58E+03	2.20E+04	5.82E+03	1.24E+02
12	Fitch Creek	4.26E+02	2.18E+04	1.66E+05	5.65E+04	2.05E+03	3.88E+04	1.93E+05	5.31E+04	1.69E+03	8.40E+03	1.27E+05	3.22E+04	6.61E+02
13	Middle Love Creek	7.36E+02	3.52E+04	2.34E+05	7.76E+04	3.61E+03	6.26E+04	2.70E+05	7.10E+04	2.81E+03	1.35E+04	1.78E+05	4.25E+04	1.05E+03
14	Lower Love Creek	3.16E+02	1.51E+04	1.00E+05	3.33E+04	1.55E+03	2.68E+04	1.16E+05	3.04E+04	1.20E+03	5.77E+03	7.62E+04	1.82E+04	4.51E+02
15	Lower Newell - Monterey	4.60E+02	2.51E+04	2.00E+05	6.18E+04	2.16E+03	4.48E+04	2.32E+05	6.00E+04	1.90E+03	9.77E+03	1.54E+05	3.69E+04	7.77E+02
16	Lower Newell - Santa Margarita	8.98E+02	4.37E+04	2.10E+05	6.93E+04	4.36E+03	7.79E+04	2.43E+05	6.44E+04	3.50E+03	1.68E+04	1.60E+05	3.88E+04	1.35E+03
17	Lompico Creek - Butano	4.56E+02	2.24E+04	9.19E+04	3.15E+04	2.05E+03	4.03E+04	1.07E+05	3.23E+04	2.02E+03	8.90E+03	7.19E+04	2.04E+04	8.87E+02
18	Lompico Creek - Monterey	4.45E+02	2.08E+04	1.09E+05	3.56E+04	2.01E+03	3.73E+04	1.26E+05	3.62E+04	1.95E+03	8.22E+03	8.48E+04	2.27E+04	8.49E+02
19	Lower Lompico - Monterey	4.45E+02	2.08E+04	1.09E+05	3.56E+04	2.01E+03	3.73E+04	1.26E+05	3.62E+04	1.95E+03	8.22E+03	8.48E+04	2.27E+04	8.49E+02
20	Unnamed Creek #2 off Zayante Creek - Butano	5.63E+01	3.21E+03	2.07E+04	6.98E+03	2.53E+02	5.77E+03	2.39E+04	7.17E+03	2.49E+02	1.27E+03	1.62E+04	4.51E+03	1.09E+02
21	Unnamed Creek #3 off Zayante Creek - Butano	1.31E+02	7.49E+03	4.82E+04	1.63E+04	5.90E+02	1.35E+04	5.59E+04	1.67E+04	5.81E+02	2.97E+03	3.77E+04	1.05E+04	2.55E+02
22	Unnamed Creek #4 off Zayante Creek - Santa Margarita	5.93E+02	2.65E+04	1.44E+05	4.51E+04	2.79E+03	4.74E+04	1.67E+05	4.36E+04	2.44E+03	1.03E+04	1.11E+05	2.68E+04	9.96E+02
23	Unnamed Creek #5 off Zayante Creek - Santa Margarita	5.93E+02	2.65E+04	1.44E+05	4.51E+04	2.79E+03	4.74E+04	1.67E+05	4.36E+04	2.44E+03	1.03E+04	1.11E+05	2.68E+04	9.96E+02
24	Zayante - Mountain House Gulch	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Upper Zayante - Butano	1.88E+02	1.07E+04	6.89E+04	2.33E+04	8.42E+02	1.92E+04	7.98E+04	2.39E+04	8.31E+02	4.24E+03	5.39E+04	1.50E+04	3.64E+02
26	Upper Zayante - Monterey	8.10E+02	4.08E+04	2.68E+05	8.15E+04	3.64E+03	7.33E+04	3.11E+05	8.37E+04	3.59E+03	1.62E+04	2.10E+05	5.27E+04	1.57E+03
27	Middle Zayante - Monterey	4.45E+02	1.99E+04	1.08E+05	3.38E+04	2.09E+03	3.56E+04	1.25E+05	3.27E+04	1.83E+03	7.74E+03	8.34E+04	2.01E+04	7.47E+02
28	Middle Zayante - Monterey	2.96E+02	1.33E+04	7.21E+04	2.25E+04	1.39E+03	2.37E+04	8.34E+04	2.18E+04	1.22E+03	5.16E+03	5.56E+04	1.34E+04	4.98E+02
29	Lower Zayante - Monterey	1.04E+03	4.64E+04	2.52E+05	7.89E+04	4.88E+03	8.30E+04	2.92E+05	7.64E+04	4.27E+03	1.81E+04	1.95E+05	4.69E+04	1.74E+03
30	Upper Lockhart Gulch - Monterey	8.23E+01	6.43E+03	6.70E+04	1.45E+04	3.70E+02	1.16E+04	7.77E+04	1.49E+04	3.64E+02	2.55E+03	5.25E+04	9.41E+03	1.60E+02
31	Upper Lockhart Gulch - Santa Margarita	1.23E+02	9.65E+03	1.01E+05	2.18E+04	5.54E+02	1.73E+04	1.17E+05	2.24E+04	5.47E+02	3.83E+03	7.87E+04	1.41E+04	2.40E+02
32	Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	8.23E+00	6.43E+02	6.70E+03	1.45E+03	3.70E+01	1.16E+03	7.77E+03	1.49E+03	3.64E+01	2.55E+02	5.25E+03	9.41E+02	1.60E+01
33	Middle Lockhart Gulch - Santa Margarita	8.23E+01	6.43E+03	6.70E+04	1.45E+04	3.70E+02	1.16E+04	7.77E+04	1.49E+04	3.64E+02	2.55E+03	5.25E+04	9.41E+03	1.60E+02
34	Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	8.23E+00	6.43E+02	6.70E+03	1.45E+03	3.70E+01	1.16E+03	7.77E+03	1.49E+03	3.64E+01	2.55E+02	5.25E+03	9.41E+02	1.60E+01
35	Lower Lockhart Gulch - Santa Margarita	1.07E+02	8.36E+03	8.72E+04	1.89E+04	4.81E+02	1.50E+04	1.01E+05	1.94E+04	4.74E+02	3.32E+03	6.82E+04	1.22E+04	2.08E+02
36	Upper Ruins Creek - Santa Margarita	6.80E+01	5.10E+03	5.33E+04	1.12E+04	3.06E+02	9.16E+03	6.18E+04	1.15E+04	3.01E+02	2.02E+03	4.17E+04	7.27E+03	1.32E+02
37	Middle Ruins Creek - Santa Cruz Mudstone	2.38E+02	1.78E+04	1.87E+05	3.94E+04	1.07E+03	3.21E+04	2.16E+05	4.04E+04	1.05E+03	7.08E+03	1.46E+05	2.55E+04	4.62E+02
38	Lower Ruins Creek - Santa Margarita	3.40E+01	2.55E+03	2.67E+04	5.62E+03	1.53E+02	4.58E+03	3.09E+04	5.77E+03	1.51E+02	1.01E+03	2.09E+04	3.64E+03	6.61E+01
39	Mackenzie Creek - Monterey	1.41E+02	8.90E+03	7.22E+04	1.94E+04	6.32E+02	1.60E+04	8.36E+04	1.99E+04	6.23E+02	3.53E+03	5.65E+04	1.25E+04	2.73E+02
40	Mackenzie Creek - Santa Margarita	1.41E+02	8.90E+03	7.22E+04	1.94E+04	6.32E+02	1.60E+04	8.36E+04	1.99E+04	6.23E+02	3.53E+03	5.65E+04	1.25E+04	2.73E+02
41	Unnamed Creek #8 off Bean Creek - Butano	2.16E+02	1.34E+04	8.92E+04	3.02E+04	1.01E+03	2.40E+04	1.03E+05	2.95E+04	9.01E+02	5.25E+03	6.89E+04	1.82E+04	3.72E+02
42	Bean Creek Inflow - Butano	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	Upper Bean Creek - Butano	2.16E+02	1.34E+04	8.92E+04	3.02E+04	1.01E+03	2.40E+04	1.03E+05	2.95E+04	9.01E+02	5.25E+03	6.89E+04	1.82E+04	3.72E+02
44	Upper Bean Creek - Monterey	4.14E+02	2.32E+04	1.77E+05	5.23E+04	1.86E+03	4.17E+04	2.05E+05	5.37E+04	1.83E+03	9.21E+03	1.38E+05	3.38E+04	8.04E+02
45	Upper Bean Creek - Santa Margarita	1.77E+02	9.95E+03	7.57E+04	2.24E+04	7.98E+02	1.79E+04	8.77E+04	2.30E+04	7.86E+02	3.95E+03	5.92E+04	1.45E+04	3.44E+02
46	Middle Bean Creek - Santa Margarita	2.38E+02	1.36E+04	1.28E+05	3.03E+04	1.07E+03	2.44E+04	1.48E+05	3.11E+04	1.05E+03	5.38E+03	1.00E+05	1.96E+04	4.62E+02
47	Middle Bean Creek - Santa Margarita	1.02E+02	5.81E+03	5.49E+04	1.30E+04	4.58E+02	1.04E+04	6.36E+04	1.33E+04	4.52E+02	2.31E+03	4.29E+04	8.40E+03	1.98E+02
48	Lower Bean Creek - Santa Margarita	4.65E+02	2.13E+04	1.14E+05	3.66E+04	2.11E+03	3.82E+04	1.32E+05	3.72E+04	2.03E+03	8.42E+03	8.91E+04	2.33E+04	8.81E+02
49	Lower Bean Creek - Monterey	4.65E+02	2.13E+04	1.14E+05	3.66E+04	2.11E+03	3.82E+04	1.32E+05	3.72E+04	2.03E+03	8.42E+03	8.91E+04	2.33E+04	8.81E+02

Runoff Coefficient (C) Fact Sheet

What is It?

The runoff coefficient (C) is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavement, steep gradient), and lower for permeable, well vegetated areas (forest, flat land).

Why is It Important?

It is important for flood control channel construction and for possible flood zone hazard delineation. A high runoff coefficient (C) value may indicate flash flooding areas during storms as water moves fast overland on its way to a river channel or a valley floor.

How is It Measured?

It is measured by determining the soil type, gradient, permeability and land use. The values are taken from the table below. The larger values correspond to higher runoff and lower infiltration.

Land Use	C	Land Use	C
		Lawns:	
		Sandy soil, flat, 2%	0.05 - 0.10
Business:		Sandy soil, avg., 2-7%	0.10 - 0.15
Downtown areas	0.70 - 0.95	Sandy soil, steep, 7%	0.15 - 0.20
Neighborhood areas	0.50 - 0.70	Heavy soil, flat, 2%	0.13 - 0.17
		Heavy soil, avg., 2-7%	0.18 - 0.22
		Heavy soil, steep, 7%	0.25 - 0.35
		Agricultural land:	
		Bare packed soil	
		*Smooth	0.30 - 0.60
		*Rough	0.20 - 0.50
Residential:		*Cultivated rows*	
Single-family areas	0.30 - 0.50	*Heavy soil, no crop	0.30 - 0.60
Multi units, detached	0.40 - 0.60	*Heavy soil, with crop	0.20 - 0.50
Munti units, attached	0.60 - 0.75	*Sandy soil, no crop	0.20 - 0.40
Suburban	0.25 - 0.40	*Sandy soil, with crop	0.10 - 0.25
		Pasture	
		*Heavy soil	0.15 - 0.45
		*Sandy soil	0.05 - 0.25
		Woodlands	0.05 - 0.25

Industrial: Light areas Heavy areas	0.50 - 0.80 0.60 - 0.90	*Streets:* Asphaltic Concrete Brick	0.70 - 0.95 0.80 - 0.95 0.70 - 0.85
Parks, cemeteries	0.10 - 0.25	Unimproved areas	0.10 - 0.30
Playgrounds	0.20 - 0.35	Drives and walks	0.75 - 0.85
Railroad yard areas	0.20 - 0.40	Roofs	0.75 - 0.95

Note: The designer must use judgment to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest "C" values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should assigned the highest "C" values.

http://water.me.vccs.edu/courses/CIV246/table2b.htm accessed 11/19/09

	Runoff Coefficient, C					
	Soil Group A			Soil Group B		
Slope :	< 2%	2-6%	> 6%	< 2%	2-6%	> 6%
Forest	0.08	0.11	0.14	0.10	0.14	0.18
Meadow	0.14	0.22	0.30	0.20	0.28	0.37
Pasture	0.15	0.25	0.37	0.23	0.34	0.45
Farmland	0.14	0.18	0.22	0.16	0.21	0.28
Res. 1 acre	0.22	0.26	0.29	0.24	0.28	0.34
Res. 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36
Res. 1/3 acre	0.28	0.32	0.35	0.30	0.35	0.39
Res. 1/4 acre	0.30	0.34	0.37	0.33	0.37	0.42
Res. 1/8 acre	0.33	0.37	0.40	0.35	0.39	0.44
Industrial	0.85	0.85	0.86	0.85	0.86	0.86
Commercial	0.88	0.88	0.89	0.89	0.89	0.89
Streets: ROW	0.76	0.77	0.79	0.80	0.82	0.84
Parking	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.65	0.67	0.69	0.66	0.68	0.70

Rational Method Runoff Coefficients - Part I

	Runoff Coefficient, C					
	Soil Group C			Soil Group D		
Slope :	< 2%	2-6%	> 6%	< 2%	2-6%	> 6%
Forest	0.12	0.16	0.20	0.15	0.20	0.25
Meadow	0.26	0.35	0.44	0.30	0.40	0.50
Pasture	0.30	0.42	0.52	0.37	0.50	0.62
Farmland	0.20	0.25	0.34	0.24	0.29	0.41
Res. 1 acre	0.28	0.32	0.40	0.31	0.35	0.46
Res. 1/2 acre	0.31	0.35	0.42	0.34	0.38	0.46
Res. 1/3 acre	0.33	0.38	0.45	0.36	0.40	0.50
Res. 1/4 acre	0.36	0.40	0.47	0.38	0.42	0.52
Res. 1/8 acre	0.38	0.42	0.49	0.41	0.45	0.54
Industrial	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.89	0.89	0.90	0.89	0.89	0.90
Streets: ROW	0.84	0.85	0.89	0.89	0.91	0.95
Parking	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.68	0.70	0.72	0.69	0.72	0.75

Rational Method Runoff Coefficients - Part II

Figure 819.2A

Runoff Coefficients for Undeveloped Areas

Watershed Types

	Extreme	High	Normal	Low
Relief	.28 -.35 Steep, rugged terrain with average slopes above 30%	.20 -.28 Hilly, with average slopes of 10 to 30%	.14 -.20 Rolling, with average slopes of 5 to 10%	.08 -.14 Relatively flat land, with average slopes of 0 to 5%
Soil Infiltration	.12 -.16 No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity	.08 -.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity, imperfectly or poorly drained	.06 -.08 Normal; well drained light or medium textured soils, sandy loams, silt and silt loams	.04 -.06 High; deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover	.12 -.16 No effective plant cover, bare or very sparse cover	.08 -.12 Poor to fair; clean cultivation crops, or poor natural cover, less than 20% of drainage area over good cover	.06 -.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	.04 -.06 Good to excellent; about 90% of drainage area in good grassland, woodland or equivalent cover
Surface Storage	.10 -.12 Negligible surface depression few and shallow; drainageways steep and small, no marshes	.08 -.10 Low; well defined system of small drainageways; no ponds or marshes	.06 -.08 Normal; considerable surface depression storage; lakes and pond marshes	.04 -.06 High; surface storage, high; drainage system not sharply defined; large floodplain storage or large number of ponds or marshes

Given	An undeveloped watershed consisting of; 1) rolling terrain with average slopes of 5%, 2) clay type soils, 3) good grassland area, and 4) normal surface depressions.	Solution: Relief 0.14 Soil Infiltration 0.08 Vegetal Cover 0.04 Surface Storage <u>0.06</u> C = 0.32
Find	The runoff coefficient, C, for the above watershed.	

Table 819.2B

Runoff Coefficients for Developed Areas

Type of Drainage Area	Runoff Coefficient
Business:	
Downtown areas	0.70 - 0.95
Neighborhood areas	0.50 - 0.70
Residential:	
Single-family areas	0.30 - 0.50
Multi-units, detached	0.40 - 0.60
Multi-units, attached	0.60 - 0.75
Suburban	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial:	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90
Parks, cemeteries:	0.10 - 0.25
Playgrounds:	0.20 - 0.40
Railroad yard areas:	0.20 - 0.40
Unimproved areas:	0.10 - 0.30
Lawns:	
Sandy soil, flat, 2%	0.05 - 0.10
Sandy soil, average, 2-7%	0.10 - 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil, flat, 2%	0.13 - 0.17
Heavy soil, average, 2-7%	0.18 - 0.25
Heavy soil, steep, 7%	0.25 - 0.35
Streets:	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs:	0.75 - 0.95

use in California are given in Figure 819.2C and Table 819.7A. These equations are based on regional regression analysis of data from stream gauging stations. The equations in Figure 819.2C were derived from data gathered and analyzed through the mid-1970's, while the regions covered by Table 819.7A are reflective of a more recent (1994) study of the Southwestern U.S, which has been supplemented by a 2007 Study of California Desert Region Hydrology. Nomographs and complete information on use and development of this method may be found in "Magnitude and Frequency of Floods in California" published in June, 1977 by the U.S. Department of the Interior, Geological Survey.

The Regional Flood-Frequency equations are applicable only to sites within the flood-frequency regions for which they were derived and on streams with virtually natural flows. For example, the equations are not generally applicable to small basins on the floor of the Sacramento and San Joaquin Valleys as the annual peak data which are the basis for the regression analysis were obtained principally in the adjacent mountain and foothill areas. Likewise, the equations are not directly applicable to streams in urban areas affected substantially by urban development. In urban areas the equations may be used to estimate peak discharge values under natural conditions and then by use of the techniques described in the publication or HDS No. 2, adjust the discharge values to compensate for urbanization. Further limitations on the use of USGS Regional Flood-Frequency equations are:

Table 1 Runoff Coefficients for the Rational Method

	FLAT	ROLLING	HILLY
Pavement & Roofs	**0.90**	**0.90**	**0.90**
Earth Shoulders	0.50	0.50	0.50
Drives & Walks	0.75	0.80	**0.85**
Gravel Pavement	**0.85**	**0.85**	**0.85**
City Business Areas	0.80	**0.85**	**0.85**
Apartment Dwelling Areas	0.50	0.60	0.70
Light Residential: 1 to 3 units/acre	0.35	0.40	0.45
Normal Residential: 3 to 6 units/acre	0.50	0.55	0.60
Dense Residential: 6 to 15 units/acre	0.70	0.75	0.80
Lawns	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay & Loam	0.50	0.55	0.60
Cultivated Land, Sand & Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	**0.90**
Parks & Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland & Forests	0.10	0.15	0.20
Meadows & Pasture Land	0.25	0.30	0.35
Unimproved Areas	0.10	0.20	0.30

Note:

- ***Impervious surfaces in bold***
- *Rolling = ground slope between 2 percent to 10 percent*
- *Hilly = ground slope greater than 10 percent*

Appendix F: Historical 1985 to 2012 SMGB Model calibration results

SMGB Model Calibration Summary by Well									
Well	Measurements	Area	Original Aquifer	Updated Aquifer	Orig RM	Orig ABS	TR36_RM	**TR36_ABS**	ABS Difference
BCW-2	54	BC	1	1	-3.42	3.91	-3.70	4.25	-0.34
BCW-3	103	BC	1	1	-4.00	4.00	-4.30	4.32	-0.33
BCW-6	53	BC	1	1	2.19	2.55	-0.10	2.20	0.35
BCW-7	71	BC	1	1	5.38	5.38	1.99	1.99	3.39
BCW-8	26	BC	1	1	5.89	5.89	1.99	1.99	3.89
BOWMAN_PIT_TEST_#1	84	BC	1	1	-0.98	1.04	-0.54	0.80	0.24
Lonestar_#1	45	BC	1	1	8.79	8.79	24.85	24.85	-16.06
Lonestar_#2	45	BC	1	1	-1.99	2.73	13.59	13.59	-10.86
MISSION_SPRINGS	35	BC	1	1	-5.66	5.66	-10.06	10.06	-4.39
RMC-2	49	BC	1	1	-59.87	59.87	-4.03	4.04	55.83
RMC-5	2	BC	1	1	-26.28	26.28	-9.25	9.25	17.03
RMC-6	61	BC	1	1	-1.41	3.00	13.63	13.63	-10.62
SK-1	67	BC	1	1	-1.30	4.80	-3.19	4.34	0.46
SK-2	53	BC	1	1	0.01	3.68	-2.54	3.94	-0.26
WJ-32	8	BC	1	1	13.97	13.97	18.22	18.22	-4.25
WJ-32A	25	BC	1	1	3.90	3.90	10.61	10.61	-6.71
WJ-44	13	BC	1	1	2.48	2.48	0.96	0.96	1.53
WJ-45	14	BC	1	1	3.40	3.40	1.14	1.14	2.26
WJ-46	58	BC	1	1	0.92	2.21	-1.58	1.99	0.22
CHAMPION	38	PS	1	1	27.58	27.58	22.22	22.22	5.37
HIDDEN_GLEN	231	PS	1	1	22.32	22.32	12.58	12.58	9.74
KAISER_#2	186	PS	1	1	5.13	9.02	11.61	11.75	-2.73
KAISER_#3	79	PS	1	1	-15.64	32.30	18.76	18.89	13.41
NEW_PROBATION	377	PS	1	1	-10.85	11.32	-15.38	15.53	-4.20
OLD_PROBATION	145	PS	1	1	4.24	12.00	-13.60	13.94	-1.94
Pasatiempo_MW-2	247	PS	1	1	0.68	5.36	-4.46	5.85	-0.49
SV1-MW	57	PS	1	1	8.75	8.75	3.58	4.44	4.31
SV3-MW_B	73	PS	1	1	-9.49	15.38	-13.69	15.62	-0.24
SV4-MW	80	PS	1	1	-1.22	5.32	22.86	23.07	-17.75
SV5-MW_A	6	PS	1	1	-7.43	12.24	12.67	12.67	-0.43
SV5-MW_B	87	PS	1	1	-7.80	9.02	-2.08	10.44	-1.42
SVWD_MW-3B_(SHALLOW)	4	PS	1	1	-16.12	25.26	7.69	12.63	12.63
VISTA_DEL_LAGO_#1	58	PS	1	1	29.92	29.92	3.33	7.41	22.51
BL_Ashram	90	QH	1	1	0.90	1.29	-1.00	1.47	-0.18
BL_Machlis	78	QH	1	1	5.33	6.27	2.85	5.03	1.24
BL_MW-01	86	QH	1	1	11.24	11.24	12.11	12.11	-0.86
BL_MW-02	98	QH	1	1	1.33	2.53	-3.60	4.30	-1.77
BL_MW-03	98	QH	1	1	-1.22	2.22	-7.15	7.15	-4.93
BL_MW-04	99	QH	1	1	2.52	2.75	-4.67	4.69	-1.94
BL_MW-05	88	QH	1	1	3.41	3.96	-0.24	3.50	0.46
BL_MW-06	90	QH	1	1	-1.20	1.80	-5.98	6.32	-4.51
BL_MW-07	82	QH	1	1	4.41	4.41	-0.34	1.13	3.29
BL_MW-08	84	QH	1	1	5.70	5.87	3.42	3.65	2.23
BL_MW-09	85	QH	1	1	-2.18	2.27	0.22	0.62	1.66
BL_MW-10	76	QH	1	1	8.66	8.66	6.24	6.24	2.42
BL_MW-11	74	QH	1	1	2.04	2.09	-6.55	6.80	-4.71
Olympia_1	353	QH	1	1	-13.39	13.57	15.48	18.27	-4.70
Olympia_2	443	QH	1	1	-30.74	30.75	-3.96	13.87	16.89
Olympia_3	308	QH	1	1	-31.84	31.93	-8.76	11.97	19.96
QHQ_Active_Well	2	QH	1	1	31.61	31.61	52.12	52.12	-20.50
QHQ_Inactive_Well	141	QH	1	1	22.08	22.08	27.77	27.77	-5.69
QHQ_MW-2	122	QH	1	1	8.15	8.52	19.33	19.33	-10.81
QHQ_MW-4	136	QH	1	1	11.15	12.94	5.75	9.36	3.58
QHQ_MW-5	139	QH	1	1	18.59	18.59	1.10	4.12	14.47
QHQ_MW-6B	151	QH	1	1	17.28	17.30	-13.53	14.47	2.83
QHQ_MW-7	87	QH	1	1	-13.07	14.49	-8.11	9.95	4.54

SMGB Model Calibration Summary by Well

Well	Measurements	Area	Original Aquifer	Updated Aquifer	Orig RM	Orig ABS	TR36_RM	**TR36_ABS**	ABS Difference
Quail_#3	68	QH	1	1	17.52	18.72	27.62	28.69	-9.97
Quail_#4	295	QH	1	1	-2.96	13.73	5.42	16.22	-2.49
Quail_#4A	186	QH	1	1	7.57	13.83	7.85	13.67	0.16
Quail_#5	247	QH	1	1	3.00	11.29	7.94	14.76	-3.47
Quail_#5A	221	QH	1	1	4.25	13.92	0.42	12.48	1.44
Quail_#8	329	QH	1	1	6.72	11.94	-0.21	6.05	5.88
Quail_MW-A	171	QH	1	1	-4.99	4.99	-5.99	5.99	-1.00
Quail_MW-B	170	QH	1	1	7.43	8.79	-0.02	5.89	2.90
Quail_MW-C	161	QH	1	1	20.04	20.09	3.96	10.04	10.06
#12_GLENWOOD_MONITOR	30	SV	1	1	11.38	11.38	-18.34	18.34	-6.96
AP-1	98	SV	1	1	-3.03	3.05	-2.15	2.26	0.79
AP-2	86	SV	1	1	-0.79	1.26	-0.93	1.30	-0.04
AP-3	59	SV	1	1	-1.76	2.32	-2.01	2.55	-0.23
AP-3N	12	SV	1	1	1.80	1.80	-0.02	0.64	1.15
BILLAWALLA	28	SV	1	1	10.82	10.82	-12.79	12.79	-1.98
CASA_WAY	66	SV	1	1	-5.98	5.99	-35.38	35.38	-29.39
DH-9	74	SV	1	1	29.61	29.61	32.80	32.80	-3.19
GRACE_WAY_MONITOR	16	SV	1	1	27.57	27.57	15.61	15.61	11.95
KV-1	9	SV	1	1	-61.77	61.77	-52.42	52.42	9.35
KV-2	9	SV	1	1	-61.26	61.26	-63.67	63.67	-2.42
KV-4	9	SV	1	1	-56.39	56.39	-69.56	69.56	-13.16
MW-1_Chevron	64	SV	1	1	-29.23	29.23	1.12	1.79	27.45
MW-2_Chevron	62	SV	1	1	-29.28	29.28	0.81	1.67	27.61
MW-2_Shell	47	SV	1	1	-26.22	26.22	-1.84	2.36	23.86
MW-3_Chevron	62	SV	1	1	-29.18	29.18	0.26	1.32	27.86
MW-3_Shell	66	SV	1	1	-27.09	27.09	-7.30	7.30	19.79
MW-4_Chevron	66	SV	1	1	-29.95	29.95	-1.71	1.74	28.21
MW-4_Shell	34	SV	1	1	-27.52	27.52	-1.91	2.44	25.08
MW-5_Chevron	66	SV	1	1	-28.94	28.94	-0.31	1.28	27.66
MW-5_Shell	65	SV	1	1	-28.65	28.65	-1.18	1.85	26.80
MW-6_Chevron	38	SV	1	1	-24.33	24.33	8.11	8.11	16.22
MW-6_Shell	12	SV	1	1	-10.92	11.94	15.68	15.68	-3.74
MW-7_Chevron	38	SV	1	1	-25.18	25.18	9.43	9.43	15.75
MW-8_Chevron	63	SV	1	1	-31.22	31.22	4.12	4.35	26.86
OB-1	113	SV	1	1	-4.89	4.96	-1.60	2.29	2.67
OB-2	114	SV	1	1	-3.50	3.59	1.14	2.47	1.12
OB-3	111	SV	1	1	-2.87	3.08	1.01	1.76	1.32
RA-1	121	SV	1	1	-6.58	6.64	-2.85	3.40	3.24
RA-2	105	SV	1	1	-9.06	9.14	-5.03	5.29	3.85
RA-3	110	SV	1	1	-3.83	3.84	-0.11	2.01	1.83
RA-4	91	SV	1	1	-4.38	5.35	-1.74	2.93	2.42
SKYPARK	3	SV	1	1	-5.37	5.37	-17.56	17.56	-12.18
SKYPARK_M-1	113	SV	2	1	-46.24	46.24	-0.62	1.25	44.99
SKYPARK_M-2	13	SV	1	1	-1.27	1.27	-2.83	2.83	-1.56
SUPPLY_WELL	79	SV	1	1	-2.95	2.95	-21.18	21.18	-18.23
SV_ROCKERY	78	SV	1	1	-11.45	14.25	-2.56	3.63	10.62
SVWD_AB303_MW-1	3	SV	1	1	-28.27	28.27	-6.05	6.05	22.22
TW-18	105	SV	1	1	-20.13	20.13	17.74	17.74	2.39
WATKINS_JOHNSON	13	SV	1	1	-1.67	1.75	-14.13	14.13	-12.38
Wescosa_Well	6	SV	1	1	-1.65	2.04	5.25	5.71	-3.67
WJ-11	127	SV	1	1	-2.84	3.09	-15.99	15.99	-12.91
WJ-21	59	SV	1	1	-2.92	2.92	-1.00	1.57	1.36
WJ-22	114	SV	1	1	-2.49	2.49	-0.36	1.41	1.08
WJ-23	50	SV	1	1	0.22	2.95	0.30	2.87	0.08
WJ-25A	117	SV	1	1	-2.60	2.69	1.49	3.42	-0.73
WJ-26	111	SV	1	1	-13.68	13.68	-13.07	13.07	0.61

SMGB Model Calibration Summary by Well

Well	Measurements	Area	Original Aquifer	Updated Aquifer	Orig RM	Orig ABS	TR36_RM	**TR36_ABS**	ABS Difference
WJ-27A	102	SV	1	1	-5.27	5.27	-4.40	4.40	0.87
WJ-28	56	SV	1	1	-3.32	3.56	0.45	1.50	2.06
WJ-29A	110	SV	1	1	-2.49	4.60	-1.20	3.37	1.23
WJ-29B	15	SV	1	1	-1.14	2.15	-0.73	1.57	0.57
WJ-29C	2	SV	1	1	0.71	0.71	0.39	0.39	0.32
WJ-30	32	SV	1	1	-0.07	0.69	-0.10	0.72	-0.03
WJ-30A	37	SV	1	1	-0.22	0.73	-0.25	0.77	-0.04
WJ-37A	110	SV	1	1	-3.46	3.55	-2.61	2.74	0.81
WJ-40	73	SV	1	1	-3.17	3.17	-1.90	1.91	1.26
WJ-41	122	SV	1	1	-2.14	2.28	-3.20	3.20	-0.92
WJ-43	116	SV	1	1	-3.07	4.60	-12.87	14.19	-9.59
WJ-48	72	SV	1	1	-5.43	5.43	-2.50	2.66	2.78
#9_MONITOR_WELL	200	SV	1	2	-38.02	42.28	-1.37	23.51	18.78
HARMONY_FOODS	48	SV	2	2	6.92	15.49	45.78	48.29	-32.80
KV-3	9	SV	1	2	-18.11	18.11	14.48	14.48	3.63
MONTEVALLE_#2	33	SV	1	2	20.13	23.61	52.80	52.93	-29.32
MONTEVALLE_#3	76	SV	1	2	16.61	25.44	18.93	19.63	5.81
SK-3	21	SV	2	2	-15.62	15.62	-8.40	8.40	7.22
SK-4	5	SV	2	2	11.02	11.02	4.36	4.36	6.66
SKYPRK_SUPLY	33	SV	2	2	-40.55	40.55	-4.27	5.27	35.28
SVWD_#9	245	SV	1	2	-8.63	20.88	-1.29	29.53	-8.65
WJ-49	74	SV	1	2	-68.27	68.27	1.00	1.84	66.43
ESTRELLA	117	PS	3	3	-15.05	27.35	-8.90	21.21	6.14
KAISER_#4	100	PS	3	3	128.75	128.75	51.90	51.90	76.85
KAISER_#4A	17	PS	5	3	61.84	61.84	52.94	52.94	8.91
MT._HERMON_#1	17	PS	3	3	29.74	31.87	3.74	8.89	22.98
MT._HERMON_#2	22	PS	3	3	21.99	29.96	-3.35	17.41	12.55
MUSHROOM_FARM	42	PS	3	3	50.29	50.29	30.46	30.46	19.84
Pasatiempo_#6	467	PS	3	3	16.73	28.88	3.04	14.59	14.29
Pasatiempo_#7	349	PS	3	3	25.59	38.96	-9.33	20.47	18.50
Pasatiempo_MW-1	249	PS	3	3	21.69	31.03	0.24	13.17	17.85
SPRING_LAKES_#3	28	PS	3	3	36.26	36.26	12.87	13.57	22.69
SPRING_LAKES_#4	104	PS	3	3	3.60	24.88	-16.14	19.93	4.96
SPRING_LAKES_#5	48	PS	3	3	-15.19	20.70	-35.87	35.87	-15.17
SPRING_LAKES_#6	10	PS	3	3	-65.76	65.76	-71.69	71.69	-5.93
SV3-MW_C	74	PS	3	3	-10.94	16.53	33.32	33.80	-17.27
SVWD_MW-3A_(DEEP)	4	PS	3	3	16.49	16.49	10.43	11.04	5.44
#11_MONITOR	136	SV	3	3	-18.66	23.74	8.02	14.14	9.59
#13_MONITOR	14	SV	3	3	11.16	11.39	-30.32	30.32	-18.92
#3_EL_PUEBLO	3	SV	3	3	-3.44	3.44	-8.57	8.57	-5.12
#3A_EL_PUEBLO	22	SV	3	3	4.56	13.14	0.05	10.28	2.85
#6_SVWD	40	SV	3	3	9.81	13.35	-6.94	8.77	4.58
CEEW-1	33	SV	1	3	3.19	6.83	-18.02	18.70	-11.86
CEMW-11	9	SV	1	3	22.85	22.85	7.40	8.55	14.30
CEMW-12	34	SV	1	3	-17.86	17.86	-2.66	2.68	15.17
CEMW-15	45	SV	1	3	0.20	12.86	-37.11	37.11	-24.24
CEMW-17B	37	SV	1	3	-33.24	33.24	26.56	26.56	6.67
CEMW-18C	36	SV	1	3	-52.89	52.89	16.32	16.32	36.57
CEMW-19B	33	SV	1	3	-53.53	53.53	14.89	14.89	38.64
CEMW-20A	29	SV	1	3	-52.49	52.49	13.77	13.77	38.72
CEMW-20B	36	SV	1	3	-54.01	54.01	13.22	13.22	40.79
CEMW-21C	36	SV	3	3	-22.95	22.95	-13.60	14.70	8.25
CEMW-22A	33	SV	1	3	-61.63	61.63	14.00	14.00	47.63
CEMW-22B	34	SV	1	3	-61.66	61.66	14.14	14.14	47.52
CEMW-22C	34	SV	2	3	-53.28	53.28	9.54	9.78	43.50
CEMW-23B	34	SV	1	3	-64.49	64.49	11.89	11.89	52.60

SMGB Model Calibration Summary by Well

Well	Measurements	Area	Original Aquifer	Updated Aquifer	Orig RM	Orig ABS	TR36_RM	**TR36_ABS**	ABS Difference
CEMW-23C	34	SV	2	3	-54.54	54.54	10.14	10.30	44.24
CEMW-9	59	SV	1	3	9.13	14.12	-28.19	28.19	-14.08
DC_MW-13B	48	SV	3	3	10.76	15.32	15.30	16.19	-0.87
EL_PUEBLO_WELL_FIELD	2	SV	3	3	-18.96	18.96	-12.95	12.95	6.00
FLOREA	77	SV	1	3	-18.09	18.23	12.42	12.57	5.66
HIDDEN_OAKS	84	SV	1	3	31.79	31.79	40.54	40.54	-8.74
Lompico_Test	84	SV	3	3	-7.75	11.77	35.30	35.52	-23.75
MANANA_WOODS_#2	105	SV	3	3	-8.20	10.48	-8.58	9.55	0.93
OLD_MANANA_WOODS	55	SV	1	3	-14.14	18.58	-8.59	10.80	7.78
SVWD_#10	255	SV	3	3	-1.88	16.24	-6.13	15.69	0.56
SVWD_#10A	21	SV	3	3	8.37	13.21	1.76	10.68	2.53
SVWD_#11	125	SV	3	3	-17.89	23.51	10.00	21.05	2.46
SVWD_#11A	109	SV	3	3	-23.92	25.93	2.90	18.75	7.17
SVWD_#11B	119	SV	3	3	-50.18	61.58	-4.23	46.98	14.60
SVWD_#7	210	SV	3	3	-34.83	37.46	-26.57	28.24	9.22
SVWD_AB303_MW-2	2	SV	3	3	40.62	40.62	46.56	46.56	-5.94
TW-19	95	SV	3	3	-43.20	43.20	-12.37	16.14	27.06
#15_MONITOR	138	SV	4	4	-39.48	46.32	-0.85	34.16	12.16
Canham_Well	1	SV	4	4	-31.82	31.82	58.90	58.90	-27.09
Stonewood	1	SV	4	4	346.93	346.93	75.78	75.78	271.15
SVWD_#3B	105	SV	4	4	-64.06	68.04	-12.59	27.09	40.95
SVWD_#7A	93	SV	4	4	-52.33	56.11	0.91	33.17	22.94
Oly-10	38		3	4	9.77	9.77	21.65	21.65	-11.88
Oly-9	38		3	4	7.12	7.12	20.81	20.81	-13.69
CEMW-13	21	SV	5	5	-16.93	16.93	2.02	7.13	9.80
CEMW-20C	1	SV	3	5	37.79	37.79	-2.88	2.88	34.91
CEMW-4	47	SV	1	5	6.31	16.10	-12.26	12.39	3.71
INDIAN_SPRING_#2	133	SV	5	5	-35.05	35.05	6.22	8.77	26.28

MODFLOW Streamflow Summary by SFR1 Package Segment													
		AVERAGE				MAXIMUM				MINIMUM			
	Segment	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
		cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
Upper Blackburn Gulch	1	0.18	0.97	0.22	0.05	0.37	2.28	0.44	0.12	0.08	0.36	0.10	0.02
Lower Blackburn Gulch	2	0.79	4.10	0.89	0.12	1.86	9.12	1.78	0.28	0.29	1.35	0.37	0.01
Carbonera Creek - Butano	3	0.00	0.37	0.01	0.00	0.01	1.13	0.09	0.00	0.00	0.00	0.00	0.00
Carbonera Creek - Monterey	4	0.10	1.44	0.18	0.00	0.39	3.71	0.58	0.00	0.00	0.22	0.02	0.00
Carbonera Creek - Monterey	5	0.15	2.47	0.31	0.00	0.71	6.26	1.03	0.00	0.00	0.39	0.00	0.00
Carbonera Creek - Santa Cruz Mudstone	6	0.87	5.80	0.94	0.01	2.62	13.82	2.42	0.07	0.07	1.29	0.24	0.00
Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	7	1.10	5.02	0.97	0.03	2.89	11.36	2.10	0.13	0.13	1.37	0.37	0.00
Carbonera Creek - Santa Margarita	8	2.67	13.21	2.35	0.01	7.64	30.76	5.67	0.15	0.14	3.20	0.68	0.00
Carbonera Creek - Lompico	9	2.66	13.39	2.31	0.00	7.78	31.29	5.71	0.05	0.04	3.17	0.60	0.00
Upper Love Creek - Butano	10	0.00	0.25	0.00	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.00	0.00
Upper Love Creek - Monterey	11	0.02	0.52	0.04	0.00	0.09	2.31	0.14	0.00	0.00	0.04	0.00	0.00
Fitch Creek	12	0.23	1.75	0.41	0.03	0.65	4.32	1.03	0.04	0.03	0.43	0.12	0.02
Middle Love Creek	13	0.72	4.79	1.09	0.09	1.87	12.89	2.68	0.16	0.12	1.15	0.36	0.06
Lower Love Creek	14	1.05	6.01	1.50	0.24	2.50	15.74	3.50	0.36	0.27	1.56	0.58	0.18
Lower Newell - Monterey	15	1.75	9.07	2.58	0.34	4.07	20.43	5.32	0.50	0.49	2.70	1.16	0.28
Lower Newell - Santa Margarita	16	3.29	12.52	4.24	1.31	6.86	27.68	8.33	1.95	1.07	3.99	1.97	0.80
Lompico Creek - Butano	17	0.51	2.44	0.68	0.12	1.43	5.58	1.52	0.21	0.10	0.68	0.26	0.06
Lompico Creek - Monterey	18	0.75	3.61	0.96	0.12	2.07	8.25	2.15	0.23	0.10	1.00	0.36	0.04
Lower Lompico - Monterey	19	1.03	4.82	1.28	0.17	2.76	10.97	2.82	0.30	0.17	1.35	0.50	0.07
Unnamed Creek #2 off Zayante Creek - Butano	20	0.06	0.15	0.09	0.06	0.11	0.36	0.17	0.09	0.03	0.05	0.04	0.03
Unnamed Creek #3 off Zayante Creek - Butano	21	0.00	0.05	0.00	0.00	0.00	0.26	0.01	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #4 off Zayante Creek - Santa Margarita	22	0.33	1.60	0.47	0.10	1.04	4.14	1.25	0.27	0.00	0.26	0.10	0.00
Unnamed Creek #5 off Zayante Creek - Santa Margarita	23	0.27	1.49	0.33	0.03	0.83	3.75	0.89	0.08	0.03	0.29	0.06	0.02
Zayante - Mountain House Gulch	24	1.79	10.93	2.70	0.31	4.29	25.55	5.91	0.49	0.41	3.07	1.11	0.21
Upper Zayante - Butano	25	2.04	11.94	3.05	0.42	4.84	27.73	6.61	0.64	0.59	3.49	1.36	0.25
Upper Zayante - Monterey	26	2.74	15.10	3.93	0.65	6.34	34.76	8.26	0.91	0.84	4.50	1.82	0.45
Middle Zayante - Monterey	27	4.08	21.14	5.53	0.89	9.78	48.55	11.76	1.31	1.11	6.22	2.48	0.58
Middle Zayante - Monterey	28	4.61	23.55	6.21	1.04	11.28	54.58	13.46	1.64	1.18	6.74	2.68	0.66
Lower Zayante - Monterey	29	5.23	27.53	6.87	0.78	13.35	64.59	15.50	1.50	1.08	7.54	2.67	0.37
Upper Lockhart Gulch - Monterey	30	0.00	0.41	0.00	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00	0.00
Upper Lockhart Gulch - Santa Margarita	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle Lockhart Gulch - Santa Margarita	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Lockhart Gulch - Santa Margarita	35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Ruins Creek - Santa Margarita	36	0.00	0.03	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00
Middle Ruins Creek - Santa Cruz Mudstone	37	0.20	2.00	0.29	0.00	0.53	4.90	0.66	0.01	0.01	0.53	0.11	0.00
Lower Ruins Creek - Santa Margarita	38	0.20	0.42	0.29	0.20	0.31	0.87	0.54	0.33	0.12	0.17	0.16	0.13
Mackenzie Creek - Monterey	39	0.01	0.61	0.03	0.00	0.12	1.59	0.17	0.00	0.00	0.05	0.00	0.00
Mackenzie Creek - Santa Margarita	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #8 off Bean Creek - Butano	41	0.15	0.96	0.21	0.01	0.42	2.31	0.56	0.04	0.01	0.26	0.04	0.01
Bean Creek Inflow - Butano	42	0.67	5.09	0.91	0.04	1.72	12.16	2.11	0.09	0.09	1.36	0.34	0.01
Upper Bean Creek - Butano	43	1.17	7.24	1.56	0.21	2.80	17.04	3.50	0.45	0.27	2.11	0.64	0.09
Upper Bean Creek - Monterey	44	1.57	9.27	2.10	0.33	3.65	21.47	4.53	0.56	0.41	2.74	0.90	0.20
Upper Bean Creek - Santa Margarita	45	0.35	8.59	0.92	0.00	2.36	22.55	3.90	0.00	0.00	1.23	0.00	0.00
Middle Bean Creek - Santa Margarita	46	0.42	9.57	1.30	0.26	2.46	26.24	5.01	0.53	0.04	0.31	0.23	0.09
Middle Bean Creek - Santa Margarita	47	1.13	11.25	2.31	0.84	3.61	29.31	6.69	1.52	0.12	0.83	0.66	0.25
Lower Bean Creek - Santa Margarita	48	3.96	15.81	5.49	3.37	7.30	36.69	11.02	4.50	2.09	3.55	3.11	2.29
Lower Bean Creek - Monterey	49	4.53	17.37	6.11	3.69	8.29	39.84	11.98	4.84	2.45	4.32	3.56	2.63

MODFLOW Streamflow Summary Over Time by SFR1 Package Segment									
	Period	1985-1991		1991-1998		1998-2005		2005-2012	
		Annual	Summer	Annual	Summer	Annual	Summer	Annual	Summer
	Segment	cfs	cfs	cfs	cfs	cfs	cfs	cfs	cfs
Upper Blackburn Gulch	1	0.33	0.09	0.48	0.06	0.34	0.04	0.29	0.03
Lower Blackburn Gulch	2	1.22	0.22	1.95	0.15	1.46	0.06	1.33	0.05
Carbonera Creek - Butano	3	0.06	0.00	0.16	0.00	0.09	0.00	0.08	0.00
Carbonera Creek - Monterey	4	0.28	0.00	0.64	0.00	0.44	0.00	0.41	0.00
Carbonera Creek - Monterey	5	0.46	0.00	1.08	0.00	0.75	0.00	0.70	0.00
Carbonera Creek - Santa Cruz Mudstone	6	1.29	0.01	2.65	0.02	1.99	0.01	1.83	0.02
Unnamed Creek #1 off Carbonera Creek - Santa Cruz Mudstone	7	1.26	0.02	2.38	0.04	1.88	0.03	1.72	0.05
Carbonera Creek - Santa Margarita	8	3.14	0.00	6.22	0.01	4.82	0.00	4.38	0.02
Carbonera Creek - Lompico	9	3.14	0.00	6.28	0.00	4.86	0.00	4.40	0.01
Upper Love Creek - Butano	10	0.05	0.00	0.15	0.00	0.05	0.00	0.02	0.00
Upper Love Creek - Monterey	11	0.10	0.00	0.28	0.00	0.13	0.00	0.10	0.00
Fitch Creek	12	0.39	0.02	0.88	0.03	0.62	0.03	0.58	0.03
Middle Love Creek	13	1.10	0.07	2.51	0.10	1.71	0.10	1.55	0.10
Lower Love Creek	14	1.47	0.20	3.22	0.26	2.25	0.26	2.06	0.27
Lower Newell - Monterey	15	2.50	0.32	4.57	0.36	3.54	0.35	3.37	0.37
Lower Newell - Santa Margarita	16	3.79	0.96	6.98	1.45	5.65	1.46	5.29	1.43
Lompico Creek - Butano	17	0.68	0.13	1.27	0.15	0.98	0.12	0.89	0.10
Lompico Creek - Monterey	18	0.98	0.13	1.84	0.16	1.43	0.12	1.29	0.11
Lower Lompico - Monterey	19	1.32	0.17	2.46	0.20	1.91	0.16	1.74	0.16
Unnamed Creek #2 off Zayante Creek - Butano	20	0.07	0.04	0.12	0.07	0.10	0.06	0.09	0.06
Unnamed Creek #3 off Zayante Creek - Butano	21	0.01	0.00	0.03	0.00	0.01	0.00	0.01	0.00
Unnamed Creek #4 off Zayante Creek - Santa Margarita	22	0.31	0.02	0.91	0.14	0.71	0.13	0.63	0.13
Unnamed Creek #5 off Zayante Creek - Santa Margarita	23	0.31	0.02	0.77	0.04	0.57	0.03	0.52	0.04
Zayante - Mountain House Gulch	24	2.75	0.26	5.45	0.36	4.04	0.33	3.81	0.34
Upper Zayante - Butano	25	3.15	0.43	6.02	0.50	4.46	0.41	4.17	0.39
Upper Zayante - Monterey	26	4.09	0.65	7.62	0.72	5.73	0.63	5.38	0.63
Middle Zayante - Monterey	27	5.76	0.89	10.73	1.01	8.15	0.87	7.59	0.87
Middle Zayante - Monterey	28	6.29	0.95	12.07	1.19	9.19	1.04	8.52	1.04
Lower Zayante - Monterey	29	7.01	0.66	13.96	0.96	10.53	0.80	9.72	0.81
Upper Lockhart Gulch - Monterey	30	0.06	0.00	0.17	0.00	0.10	0.00	0.09	0.00
Upper Lockhart Gulch - Santa Margarita	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #6 off Lockhart Gulch - Santa Margarita	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle Lockhart Gulch - Santa Margarita	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #7 off Lockhart Gulch - Santa Margarita	34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Lockhart Gulch - Santa Margarita	35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Ruins Creek - Santa Margarita	36	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Middle Ruins Creek - Santa Cruz Mudstone	37	0.44	0.00	0.87	0.00	0.63	0.00	0.60	0.00
Lower Ruins Creek - Santa Margarita	38	0.23	0.17	0.33	0.22	0.30	0.21	0.26	0.19
Mackenzie Creek - Monterey	39	0.10	0.00	0.25	0.00	0.16	0.00	0.16	0.00
Mackenzie Creek - Santa Margarita	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unnamed Creek #8 off Bean Creek - Butano	41	0.24	0.02	0.47	0.01	0.34	0.01	0.31	0.01
Bean Creek Inflow - Butano	42	1.15	0.03	2.39	0.04	1.71	0.04	1.61	0.04
Upper Bean Creek - Butano	43	1.88	0.25	3.54	0.23	2.58	0.19	2.39	0.17
Upper Bean Creek - Monterey	44	2.45	0.36	4.53	0.34	3.38	0.31	3.15	0.31
Upper Bean Creek - Santa Margarita	45	1.51	0.00	3.78	0.00	2.53	0.00	2.31	0.00
Middle Bean Creek - Santa Margarita	46	1.76	0.20	4.48	0.32	2.97	0.29	2.69	0.26
Middle Bean Creek - Santa Margarita	47	2.53	0.66	5.61	0.93	4.04	0.92	3.75	0.93
Lower Bean Creek - Santa Margarita	48	5.39	2.96	9.16	3.51	7.44	3.52	7.12	3.59
Lower Bean Creek - Monterey	49	6.05	3.30	10.09	3.83	8.21	3.82	7.86	3.90

Appendix H: SMGB Model scenario Water balance results

APPENDIX H: Historical Calibration Model
Water Balance Summary

Calibrated Model	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge		Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge		Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY		AFY	AFY	AFY	AFY	AFY	AFY	AFY		AFY
1985	7,582	0	3,858	134	11,574		2,901	4,167	864	895	447	7,244	16,518		-4,944
1986	9,901	0	6,289	135	16,325		3,123	3,934	857	819	432	7,402	16,567		-242
1987	4,802	0	3,539	145	8,486		3,835	3,197	725	581	408	5,588	14,334		-5,847
1988	5,245	0	3,528	148	8,921		3,718	2,878	670	504	392	4,911	13,074		-4,153
1989	6,102	0	3,826	148	10,076		3,438	2,806	643	440	377	4,742	12,446		-2,370
1990	4,654	0	3,798	152	8,605		3,267	2,516	603	346	360	4,235	11,326		-2,722
1991	6,195	0	4,761	150	11,106		3,550	2,585	607	370	349	4,536	11,997		-891
1992	7,887	0	5,033	146	13,066		3,602	2,899	634	444	341	5,041	12,962		104
1993	10,722	0	6,212	139	17,073		3,490	3,483	707	565	337	6,155	14,736		2,338
1994	6,599	0	4,087	144	10,830		4,079	3,152	650	450	300	5,377	14,009		-3,179
1995	12,169	0	6,900	136	19,204		3,639	3,825	749	623	241	6,835	15,912		3,292
1996	10,331	0	5,859	136	16,325		3,960	3,935	766	615	158	6,931	16,366		-40
1997	10,399	0	4,821	134	15,353		4,409	4,096	776	651	101	6,948	16,980		-1,626
1998	13,093	0	7,218	131	20,442		3,901	4,363	850	741	55	7,887	17,796		2,646
1999	8,822	0	4,906	135	13,864		3,957	4,065	777	624	21	7,067	16,511		-2,647
2000	9,293	0	6,016	149	15,459		4,241	3,876	748	607	0	6,980	16,452		-993
2001	7,694	0	4,674	176	12,544		4,455	3,613	695	551	0	6,310	15,623		-3,078
2002	8,421	0	4,295	189	12,905		4,336	3,618	675	545	0	6,158	15,332		-2,427
2003	8,754	0	4,764	189	13,708		4,393	3,507	660	517	0	5,959	15,037		-1,330
2004	8,709	0	4,363	193	13,265		4,117	3,520	651	506	0	5,830	14,624		-1,359
2005	11,651	0	5,995	196	17,842		3,431	3,890	715	581	0	6,581	15,197		2,645
2006	12,921	0	5,962	188	19,070		3,736	4,331	787	670	0	7,248	16,772		2,298
2007	5,980	0	3,514	219	9,712		4,025	3,474	646	481	0	5,705	14,330		-4,617
2008	7,233	0	4,638	215	12,086		3,820	3,225	610	444	0	5,441	13,539		-1,454
2009	8,068	0	4,645	220	12,932		3,430	3,248	612	455	0	5,433	13,178		-245
2010	10,609	0	5,563	193	16,365		2,927	3,644	665	537	0	6,108	13,882		2,483
2011	12,298	0	5,972	172	18,443		2,694	4,236	748	630	0	7,051	15,359		3,084
2012	7,456	0	4,506	189	12,150		3,084	3,676	662	493	0	6,111	14,027		-1,877
Average	**8,700**	**0**	**4,984**	**164**	**13,848**		**3,698**	**3,563**	**705**	**560**	**154**	**6,136**	**14,817**		**-970**
Total	**243,590**	**0**	**139,543**	**4,600**	**387,733**		**103,557**	**99,761**	**19,751**	**15,684**	**4,320**	**171,812**	**414,885**		**-27,152**

Note: All Units are in Acre-feet per year

APPENDIX H: Base Case Model Scenario
Water Balance Summary

Base Case	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1985	7,582	0	3,973	188	11,744	2,834	3,533	632	452	0	5,772	13,223	-1,479
1986	9,901	0	6,571	181	16,653	2,835	3,712	673	491	0	6,528	14,238	2,414
1987	4,802	0	3,590	197	8,589	2,832	3,126	580	324	0	5,249	12,111	-3,522
1988	5,245	0	3,493	200	8,939	2,829	2,945	554	293	0	4,702	11,323	-2,385
1989	6,102	0	3,912	201	10,215	2,827	2,917	542	262	0	4,617	11,166	-951
1990	4,654	0	3,753	209	8,616	2,824	2,622	514	194	0	4,089	10,243	-1,627
1991	6,195	0	4,847	205	11,247	2,823	2,746	526	237	0	4,446	10,778	469
1992	7,887	0	5,107	197	13,191	2,825	3,067	564	327	0	5,002	11,785	1,407
1993	10,722	0	6,310	183	17,216	2,828	3,624	641	461	0	6,132	13,687	3,529
1994	6,599	0	4,136	195	10,929	2,829	3,275	595	360	0	5,371	12,430	-1,501
1995	12,169	0	6,967	175	19,311	2,831	3,965	702	544	0	6,886	14,928	4,384
1996	10,331	0	5,901	174	16,407	2,834	4,020	725	546	0	6,995	15,120	1,287
1997	10,399	0	4,848	168	15,415	2,837	4,200	739	591	0	7,047	15,415	1
1998	13,093	0	7,246	159	20,498	2,840	4,474	820	689	0	8,007	16,830	3,668
1999	8,822	0	4,929	167	13,919	2,842	4,110	753	581	0	7,143	15,428	-1,510
2000	9,293	0	6,035	169	15,498	2,841	3,953	729	572	0	7,080	15,175	323
2001	7,694	0	4,678	173	12,545	2,840	3,721	683	523	0	6,450	14,216	-1,671
2002	8,421	0	4,290	170	12,881	2,840	3,765	669	525	0	6,305	14,103	-1,222
2003	8,754	0	4,755	171	13,679	2,840	3,663	661	503	0	6,112	13,780	-100
2004	8,709	0	4,336	168	13,213	2,840	3,675	658	499	0	6,016	13,687	-474
2005	11,651	0	5,948	157	17,756	2,842	4,035	729	581	0	6,802	14,989	2,767
2006	12,921	0	5,911	147	18,978	2,848	4,460	807	676	0	7,483	16,273	2,705
2007	5,980	0	3,463	168	9,611	2,848	3,622	664	492	0	5,939	13,565	-3,954
2008	7,233	0	4,574	173	11,979	2,845	3,421	629	458	0	5,698	13,050	-1,071
2009	8,068	0	4,584	170	12,822	2,843	3,459	630	473	0	5,667	13,072	-250
2010	10,609	0	5,494	160	16,263	2,844	3,821	683	558	0	6,317	14,224	2,039
2011	12,298	0	5,916	147	18,361	2,849	4,318	766	652	0	7,235	15,821	2,540
2012	7,456	0	4,455	163	12,074	2,850	3,721	678	516	0	6,237	14,002	-1,928
Average	**8,700**	**0**	**5,001**	**176**	**13,877**	**2,837**	**3,642**	**662**	**478**	**0**	**6,119**	**13,738**	**139**
Total	**243,590**	**0**	**140,023**	**4,937**	**388,549**	**79,440**	**101,971**	**18,544**	**13,379**	**0**	**171,326**	**384,660**	**3,889**

Note: All Units are in Acre-feet per year

APPENDIX H: Base Case Model Scenario
Water Balance Summary

GWMgmt #1	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge		Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge		Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY		AFY	AFY	AFY	AFY	AFY	AFY	AFY		AFY
1985	7,582	0	3,975	190	11,747		3,273	3,521	630	452	0	5,750	13,625		-1,878
1986	9,901	0	6,582	186	16,668		3,288	3,677	667	490	0	6,451	14,573		2,095
1987	4,802	0	3,603	205	8,610		3,509	3,053	570	323	0	5,134	12,589		-3,979
1988	5,245	0	3,505	212	8,961		3,493	2,830	542	290	0	4,551	11,706		-2,745
1989	6,102	0	3,927	216	10,245		3,380	2,793	528	258	0	4,451	11,411		-1,166
1990	4,654	0	3,764	228	8,646		3,461	2,489	502	189	0	3,927	10,567		-1,921
1991	6,195	0	4,880	228	11,302		3,435	2,605	515	230	0	4,278	11,063		240
1992	7,887	0	5,150	223	13,260		3,416	2,935	551	318	0	4,825	12,046		1,214
1993	10,722	0	6,355	212	17,290		3,361	3,505	628	451	0	5,942	13,886		3,404
1994	6,599	0	4,177	226	11,001		3,458	3,162	582	348	0	5,193	12,742		-1,741
1995	12,169	0	7,018	209	19,395		3,170	3,869	685	530	0	6,713	14,968		4,427
1996	10,331	0	5,939	210	16,481		3,135	3,966	710	531	0	6,877	15,220		1,261
1997	10,399	0	4,879	207	15,485		3,300	4,163	725	574	0	6,959	15,722		-237
1998	13,093	0	7,279	199	20,571		3,052	4,448	806	671	0	7,925	16,902		3,670
1999	8,822	0	4,961	210	13,993		3,199	4,102	741	562	0	7,088	15,691		-1,698
2000	9,293	0	6,073	215	15,581		3,337	3,935	715	552	0	7,006	15,545		36
2001	7,694	0	4,722	221	12,637		3,517	3,674	666	502	0	6,339	14,697		-2,060
2002	8,421	0	4,342	220	12,983		3,431	3,695	648	502	0	6,154	14,431		-1,448
2003	8,754	0	4,813	223	13,790		3,417	3,591	640	479	0	5,945	14,072		-282
2004	8,709	0	4,386	223	13,318		3,520	3,597	635	474	0	5,834	14,058		-741
2005	11,651	0	6,005	214	17,871		3,309	3,959	703	555	0	6,599	15,124		2,747
2006	12,921	0	5,973	206	19,100		3,344	4,393	779	648	0	7,305	16,469		2,631
2007	5,980	0	3,515	230	9,725		3,633	3,539	639	463	0	5,764	14,038		-4,314
2008	7,233	0	4,638	237	12,108		3,582	3,309	603	429	0	5,489	13,412		-1,304
2009	8,068	0	4,653	237	12,958		3,550	3,341	604	442	0	5,441	13,378		-420
2010	10,609	0	5,578	228	16,415		3,276	3,727	657	526	0	6,103	14,290		2,125
2011	12,298	0	5,980	217	18,496		3,145	4,263	740	620	0	7,063	15,831		2,665
2012	7,456	0	4,515	236	12,206		3,363	3,687	656	483	0	6,118	14,307		-2,100
Average	**8,700**	**0**	**5,042**	**217**	**13,959**		**3,370**	**3,565**	**645**	**460**	**0**	**5,972**	**14,013**		**-54**
Total	**243,590**	**0**	**141,186**	**6,067**	**390,843**		**94,354**	**99,828**	**18,067**	**12,890**	**0**	**167,223**	**392,362**		**-1,519**

Note: All Units are in Acre-feet per year

APPENDIX H: Groundwater Management Scenario #2
Water Balance Summary

GWMgmt #2	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1	7,582	0	3,972	189	11,744	2,447	3,559	633	452	0	5,780	12,872	-1,128
2	9,901	0	6,565	184	16,650	2,389	3,784	677	491	0	6,566	13,907	2,743
3	4,802	0	3,582	202	8,586	2,640	3,207	584	325	0	5,306	12,061	-3,475
4	5,245	0	3,488	208	8,941	2,673	3,011	558	295	0	4,751	11,287	-2,346
5	6,102	0	3,903	211	10,217	2,618	2,983	545	265	0	4,661	11,073	-856
6	4,654	0	3,751	222	8,627	2,692	2,690	518	198	0	4,135	10,233	-1,606
7	6,195	0	4,836	220	11,251	2,666	2,808	529	242	0	4,488	10,733	518
8	7,887	0	5,095	212	13,194	2,580	3,134	568	333	0	5,043	11,657	1,537
9	10,722	0	6,295	197	17,215	2,390	3,712	647	468	0	6,190	13,407	3,807
10	6,599	0	4,119	207	10,925	2,518	3,376	603	367	0	5,445	12,309	-1,384
11	12,169	0	6,947	185	19,301	2,257	4,086	712	553	0	6,975	14,582	4,718
12	10,331	0	5,877	182	16,390	2,243	4,172	739	556	0	7,113	14,823	1,567
13	10,399	0	4,824	174	15,397	2,297	4,366	758	602	0	7,186	15,209	188
14	13,093	0	7,220	163	20,476	2,209	4,653	843	702	0	8,168	16,574	3,901
15	8,822	0	4,900	170	13,892	2,311	4,292	776	595	0	7,307	15,281	-1,388
16	9,293	0	5,999	170	15,463	2,292	4,127	751	587	0	7,244	15,002	461
17	7,694	0	4,642	173	12,509	2,466	3,877	703	539	0	6,604	14,188	-1,679
18	8,421	0	4,256	169	12,846	2,366	3,908	689	541	0	6,445	13,949	-1,103
19	8,754	0	4,712	168	13,634	2,356	3,804	682	521	0	6,260	13,623	11
20	8,709	0	4,305	165	13,178	2,421	3,808	679	517	0	6,171	13,596	-419
21	11,651	0	5,909	153	17,712	2,266	4,179	753	600	0	6,965	14,764	2,948
22	12,921	0	5,869	141	18,931	2,280	4,630	836	696	0	7,654	16,096	2,835
23	5,980	0	3,430	162	9,572	2,521	3,776	688	512	0	6,097	13,594	-4,022
24	7,233	0	4,537	167	11,936	2,514	3,547	649	479	0	5,833	13,022	-1,086
25	8,068	0	4,548	164	12,781	2,494	3,579	650	494	0	5,798	13,015	-235
26	10,609	0	5,453	154	16,216	2,341	3,962	706	579	0	6,456	14,044	2,172
27	12,298	0	5,875	141	18,314	2,242	4,497	794	674	0	7,406	15,614	2,700
28	7,456	0	4,411	158	12,025	2,343	3,908	704	539	0	6,416	13,910	-1,885
Average	**8,700**	**0**	**4,976**	**179**	**13,854**	**2,423**	**3,765**	**678**	**490**	**0**	**6,231**	**13,587**	**268**
Total	**243,590**	**0**	**139,321**	**5,013**	**387,923**	**67,836**	**105,433**	**18,971**	**13,723**	**0**	**174,464**	**380,427**	**7,495**

Note: All Units are in Acre-feet per year

APPENDIX H: Artificial Recharge Scenario #1
Water Balance Summary

E-Rch #1	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Injection	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1	7,582	0	3,971	188	1,000	12,741	2,453	3,560	635	453	0	5,781	12,881	-139
2	9,901	0	6,559	180	1,000	17,640	2,405	3,787	682	494	0	6,572	13,940	3,700
3	4,802	0	3,569	195	1,000	9,566	2,658	3,212	595	334	0	5,319	12,118	-2,551
4	5,245	0	3,468	198	1,000	9,912	2,693	3,020	576	310	0	4,775	11,374	-1,463
5	6,102	0	3,875	198	1,000	11,175	2,641	2,995	571	287	0	4,698	11,192	-16
6	4,654	0	3,719	206	1,000	9,579	2,717	2,703	550	227	0	4,186	10,383	-804
7	6,195	0	4,794	201	1,000	12,189	2,692	2,825	569	278	0	4,551	10,915	1,274
8	7,887	0	5,046	189	1,000	14,122	2,604	3,157	615	375	0	5,123	11,875	2,248
9	10,722	0	6,240	171	1,000	18,133	2,411	3,753	703	517	0	6,298	13,682	4,451
10	6,599	0	4,058	178	1,000	11,835	2,537	3,430	663	421	0	5,574	12,626	-792
11	12,169	0	6,880	153	1,000	20,202	2,273	4,181	781	612	0	7,133	14,979	5,223
12	10,331	0	5,806	147	1,000	17,285	2,254	4,304	815	620	0	7,295	15,287	1,998
13	10,399	0	4,747	137	1,000	16,283	2,302	4,540	844	669	0	7,393	15,749	534
14	13,093	0	7,142	131	1,000	21,366	2,211	4,873	948	772	8	8,409	17,220	4,146
15	8,822	0	4,819	135	1,000	14,776	2,312	4,530	884	667	7	7,567	15,967	-1,191
16	9,293	0	5,915	138	1,000	16,346	2,293	4,372	861	661	11	7,519	15,717	629
17	7,694	0	4,553	141	1,000	13,388	2,466	4,116	810	614	13	6,889	14,909	-1,521
18	8,421	0	4,168	139	1,000	13,728	2,366	4,161	799	618	18	6,743	14,706	-977
19	8,754	0	4,615	140	1,000	14,509	2,357	4,057	793	598	21	6,570	14,397	112
20	8,709	0	4,222	140	1,000	14,070	2,422	4,070	793	596	25	6,495	14,400	-330
21	11,651	0	5,821	134	1,000	18,606	2,267	4,483	879	680	33	7,312	15,654	2,953
22	12,921	0	5,775	128	1,000	19,824	2,281	5,014	979	776	39	8,007	17,096	2,728
23	5,980	0	3,343	140	1,000	10,464	2,522	4,089	817	592	31	6,443	14,493	-4,029
24	7,233	0	4,445	143	1,000	12,821	2,515	3,832	771	559	30	6,179	13,885	-1,064
25	8,068	0	4,457	142	1,000	13,668	2,495	3,857	769	574	33	6,147	13,875	-207
26	10,609	0	5,356	137	1,000	17,102	2,342	4,268	833	659	39	6,818	14,958	2,145
27	12,298	0	5,782	130	1,000	19,211	2,244	4,874	936	754	45	7,776	16,628	2,583
28	7,456	0	4,315	139	1,000	12,909	2,344	4,233	838	617	37	6,772	14,842	-1,932
Average	**8,700**	**0**	**4,909**	**157**	**1,000**	**14,766**	**2,431**	**3,939**	**761**	**548**	**14**	**6,441**	**14,134**	**632**
Total	**243,590**	**0**	**137,462**	**4,400**	**28,000**	**413,451**	**68,077**	**110,296**	**21,308**	**15,333**	**389**	**180,344**	**395,747**	**17,704**

Note: All Units are in Acre-feet per year

APPENDIX H: Artificial Recharge Scenario #2
Water Balance Summary

E-Rch #2	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Injection	Total Recharge		Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge		Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY		AFY	AFY	AFY	AFY	AFY	AFY	AFY		AFY
1	7,582	0	3,968	189	98	11,839		2,448	3,560	633	452	0	5,793	12,886		-1,047
2	9,901	0	6,558	184	98	16,741		2,390	3,784	677	491	0	6,589	13,932		2,809
3	4,802	0	3,569	202	202	8,775		2,642	3,208	584	325	0	5,341	12,100		-3,325
4	5,245	0	3,475	208	64	8,991		2,674	3,011	558	295	0	4,785	11,324		-2,333
5	6,102	0	3,889	211	38	10,239		2,620	2,984	546	266	0	4,686	11,101		-862
6	4,654	0	3,754	221	78	8,707		2,693	2,691	518	199	0	4,168	10,269		-1,562
7	6,195	0	4,828	219	15	11,256		2,667	2,809	530	243	0	4,508	10,758		499
8	7,887	0	5,085	211	79	13,262		2,581	3,134	568	334	0	5,063	11,681		1,581
9	10,722	0	6,283	196	93	17,294		2,391	3,713	648	470	0	6,220	13,442		3,852
10	6,599	0	4,104	206	162	11,070		2,521	3,377	604	369	0	5,484	12,356		-1,286
11	12,169	0	6,932	184	50	19,334		2,259	4,088	713	555	0	7,018	14,632		4,702
12	10,331	0	5,862	180	189	16,562		2,247	4,176	740	559	0	7,164	14,886		1,676
13	10,399	0	4,805	172	134	15,510		2,301	4,370	760	605	0	7,246	15,282		228
14	13,093	0	7,201	161	158	20,612		2,211	4,659	845	705	0	8,239	16,659		3,953
15	8,822	0	4,879	167	210	14,078		2,313	4,299	778	598	0	7,383	15,370		-1,292
16	9,293	0	5,977	168	118	15,555		2,293	4,133	754	591	0	7,317	15,088		468
17	7,694	0	4,618	170	152	12,634		2,467	3,883	706	543	0	6,670	14,268		-1,634
18	8,421	0	4,235	166	87	12,908		2,366	3,914	692	545	0	6,507	14,024		-1,116
19	8,754	0	4,686	165	128	13,734		2,357	3,809	685	525	0	6,323	13,700		34
20	8,709	0	4,286	161	112	13,268		2,422	3,814	683	522	0	6,235	13,675		-407
21	11,651	0	5,889	149	111	17,800		2,267	4,187	757	605	0	7,030	14,846		2,954
22	12,921	0	5,846	138	181	19,085		2,281	4,643	840	701	0	7,729	16,193		2,892
23	5,980	0	3,406	159	209	9,753		2,522	3,787	692	517	0	6,180	13,699		-3,945
24	7,233	0	4,527	163	35	11,957		2,514	3,555	653	484	0	5,935	13,141		-1,184
25	8,068	0	4,528	161	96	12,853		2,495	3,586	654	499	0	5,853	13,088		-235
26	10,609	0	5,432	150	89	16,279		2,342	3,971	710	585	0	6,514	14,121		2,158
27	12,298	0	5,856	137	130	18,421		2,243	4,509	798	680	0	7,475	15,706		2,715
28	7,456	0	4,387	154	184	12,180		2,344	3,920	708	544	0	6,493	14,009		-1,829
Average	**8,700**	**0**	**4,959**	**177**	**118**	**13,954**		**2,424**	**3,770**	**680**	**493**	**0**	**6,284**	**13,651**		**302**
Total	**243,590**	**0**	**138,860**	**4,952**	**3,297**	**390,699**		**67,876**	**105,573**	**19,032**	**13,808**	**0**	**175,949**	**382,237**		**8,462**

Note: All Units are in Acre-feet per year

APPENDIX H: Climate Variability Scenario #1
Water Balance Summary

Climate #1	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1985	9,495	0	5,093	181	14,769	2,835	3,773	680	530	0	6,335	14,153	616
1986	9,495	0	5,069	177	14,741	2,836	3,813	689	537	0	6,399	14,274	466
1987	9,495	0	5,058	175	14,727	2,837	3,830	694	544	0	6,433	14,339	388
1988	9,495	0	5,051	172	14,718	2,838	3,840	698	549	0	6,457	14,382	336
1989	9,495	0	5,046	170	14,711	2,839	3,847	700	554	0	6,473	14,413	298
1990	9,495	0	5,041	169	14,704	2,840	3,851	702	558	0	6,485	14,435	269
1991	9,495	0	5,037	167	14,698	2,841	3,854	704	561	0	6,494	14,453	246
1992	9,495	0	5,033	165	14,694	2,842	3,856	705	564	0	6,501	14,467	227
1993	9,495	0	5,030	164	14,689	2,842	3,858	706	566	0	6,507	14,479	210
1994	9,495	0	5,028	163	14,685	2,843	3,859	707	568	0	6,512	14,489	196
1995	9,495	0	5,025	161	14,681	2,844	3,860	708	570	0	6,517	14,499	183
1996	9,495	0	5,023	160	14,678	2,845	3,861	709	572	0	6,521	14,507	171
1997	9,495	0	5,021	159	14,675	2,845	3,862	710	573	0	6,525	14,515	160
1998	9,495	0	5,019	158	14,672	2,846	3,863	710	574	0	6,529	14,522	149
1999	9,495	0	5,018	157	14,669	2,846	3,864	711	575	0	6,532	14,529	140
2000	9,495	0	5,016	156	14,666	2,847	3,865	712	576	0	6,535	14,535	131
2001	9,495	0	5,015	155	14,664	2,847	3,865	712	577	0	6,538	14,541	123
2002	9,495	0	5,013	154	14,661	2,848	3,866	713	578	0	6,541	14,546	115
2003	9,495	0	5,012	153	14,659	2,848	3,867	713	579	0	6,544	14,551	108
2004	9,495	0	5,011	152	14,657	2,849	3,867	714	580	0	6,546	14,556	101
2005	9,495	0	5,010	151	14,655	2,849	3,868	714	580	0	6,549	14,560	95
2006	9,878	0	4,998	150	15,026	2,850	3,934	718	608	0	6,604	14,714	312
2007	9,878	0	4,992	149	15,019	2,852	3,971	721	612	0	6,636	14,792	227
2008	9,878	0	4,989	148	15,015	2,853	3,987	723	613	0	6,655	14,831	184
2009	9,878	0	4,986	147	15,011	2,854	3,996	724	614	0	6,666	14,854	157
2010	9,878	0	4,984	146	15,008	2,855	4,000	725	615	0	6,673	14,869	140
2011	9,878	0	4,983	145	15,006	2,855	4,004	726	616	0	6,679	14,879	127
2012	9,878	0	4,981	144	15,004	2,855	4,006	726	617	0	6,683	14,887	117
Average	**9,590**	**0**	**5,021**	**159**	**14,770**	**2,846**	**3,885**	**710**	**577**	**0**	**6,538**	**14,556**	**214**
Total	**268,533**	**0**	**140,582**	**4,446**	**413,562**	**79,681**	**108,785**	**19,875**	**16,163**	**0**	**183,068**	**407,573**	**5,989**

Note: All Units are in Acre-feet per year

APPENDIX H: Climate Variability Scenario #2
Water Balance Summary

Climate #2	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1985	7,086	0	3,777	190	11,053	2,834	3,471	618	432	0	5,662	13,016	-1,963
1986	9,966	0	6,855	182	17,003	2,834	3,684	667	480	0	6,550	14,215	2,788
1987	3,972	0	3,408	201	7,581	2,831	3,001	561	285	0	5,111	11,790	-4,209
1988	4,397	0	2,902	206	7,505	2,827	2,775	529	246	0	4,349	10,725	-3,221
1989	5,341	0	3,727	207	9,275	2,825	2,719	510	205	0	4,219	10,478	-1,203
1990	3,594	0	3,180	217	6,992	2,820	2,350	479	120	0	3,575	9,345	-2,353
1991	5,531	0	5,011	213	10,755	2,821	2,497	494	172	0	4,277	10,261	494
1992	7,608	0	5,134	204	12,947	2,823	2,897	538	281	0	4,643	11,181	1,765
1993	10,948	0	6,605	188	17,742	2,827	3,558	628	437	0	5,993	13,442	4,299
1994	5,928	0	3,978	202	10,108	2,827	3,140	573	312	0	5,113	11,965	-1,857
1995	12,706	0	7,370	179	20,255	2,830	3,972	696	535	0	6,935	14,968	5,287
1996	10,589	0	6,094	177	16,860	2,833	4,059	727	543	0	7,089	15,250	1,609
1997	10,480	0	4,828	171	15,480	2,836	4,252	742	592	0	7,123	15,544	-65
1998	13,801	0	7,671	160	21,632	2,838	4,590	841	710	0	8,297	17,277	4,355
1999	8,642	0	4,874	170	13,686	2,840	4,147	757	579	0	7,222	15,546	-1,860
2000	9,252	0	6,235	173	15,660	2,840	3,964	728	568	0	7,173	15,273	387
2001	7,328	0	4,603	178	12,109	2,838	3,685	674	509	0	6,406	14,113	-2,004
2002	8,047	0	4,119	175	12,342	2,838	3,717	653	506	0	6,202	13,916	-1,574
2003	8,450	0	4,734	176	13,360	2,837	3,588	646	480	0	5,963	13,514	-154
2004	8,395	0	4,315	174	12,884	2,837	3,599	641	475	0	5,943	13,496	-612
2005	11,965	0	6,116	160	18,241	2,840	4,032	724	577	0	6,794	14,967	3,274
2006	13,503	0	6,093	148	19,744	2,846	4,545	820	688	0	7,610	16,509	3,235
2007	5,118	0	3,163	174	8,455	2,846	3,536	649	463	0	5,779	13,273	-4,818
2008	6,818	0	4,535	179	11,532	2,842	3,314	611	429	0	5,506	12,701	-1,170
2009	7,784	0	4,533	176	12,494	2,840	3,371	614	448	0	5,500	12,773	-280
2010	10,736	0	5,569	164	16,468	2,842	3,790	675	547	0	6,239	14,092	2,376
2011	12,639	0	6,027	149	18,815	2,847	4,357	769	655	0	7,281	15,910	2,906
2012	7,029	0	4,365	167	11,562	2,848	3,662	666	497	0	6,128	13,801	-2,239
Average	**8,488**	**0**	**4,994**	**181**	**13,662**	**2,835**	**3,581**	**651**	**456**	**0**	**6,024**	**13,548**	**114**
Total	**237,653**	**0**	**139,822**	**5,062**	**382,536**	**79,386**	**100,273**	**18,231**	**12,770**	**0**	**168,682**	**379,342**	**3,194**

Note: All Units are in Acre-feet per year

APPENDIX H: Climate Variability Historical Comparison #1
Water Balance Summary

Sensitivity #1	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1985	9,495	0	4,781	131	14,407	2,910	4,421	917	964	451	7,830	17,493	-3,086
1986	9,495	0	4,856	135	14,485	3,124	4,044	874	845	435	7,263	16,586	-2,100
1987	9,495	0	4,955	136	14,585	3,869	3,928	847	782	422	6,807	16,655	-2,070
1988	9,495	0	4,971	137	14,603	3,847	3,806	826	743	410	6,624	16,255	-1,653
1989	9,495	0	4,989	137	14,620	3,572	3,764	812	716	398	6,579	15,841	-1,221
1990	9,495	0	4,987	137	14,618	3,458	3,765	803	697	386	6,558	15,668	-1,049
1991	9,495	0	4,982	137	14,614	3,726	3,699	793	682	375	6,533	15,808	-1,194
1992	9,495	0	4,981	137	14,613	3,714	3,696	784	669	364	6,507	15,734	-1,121
1993	9,495	0	4,981	137	14,613	3,555	3,732	776	658	354	6,513	15,588	-975
1994	9,495	0	4,982	137	14,614	4,154	3,745	766	649	324	6,511	16,148	-1,535
1995	9,495	0	4,998	137	14,629	3,674	3,729	755	639	254	6,453	15,504	-875
1996	9,495	0	5,001	137	14,633	3,968	3,782	748	631	170	6,452	15,751	-1,117
1997	9,495	0	5,007	137	14,639	4,402	3,764	742	624	110	6,423	16,064	-1,425
1998	9,495	0	5,016	137	14,648	3,890	3,762	735	617	57	6,392	15,453	-805
1999	9,495	0	5,005	137	14,637	3,941	3,819	731	611	28	6,440	15,570	-934
2000	9,495	0	5,012	141	14,648	4,244	3,786	726	605	0	6,422	15,782	-1,134
2001	9,495	0	5,020	163	14,678	4,472	3,753	721	599	0	6,381	15,926	-1,248
2002	9,495	0	5,025	177	14,697	4,343	3,713	715	594	0	6,375	15,740	-1,043
2003	9,495	0	5,032	176	14,703	4,401	3,704	707	588	0	6,373	15,772	-1,070
2004	9,495	0	5,046	181	14,721	4,122	3,705	702	582	0	6,342	15,453	-731
2005	9,495	0	5,059	195	14,748	3,431	3,718	697	576	0	6,315	14,738	10
2006	9,878	0	5,054	195	15,127	3,730	3,804	699	598	0	6,370	15,200	-73
2007	9,878	0	5,055	203	15,136	4,030	3,816	698	598	0	6,379	15,520	-384
2008	9,878	0	5,060	193	15,132	3,829	3,780	697	595	0	6,367	15,268	-137
2009	9,878	0	5,054	199	15,132	3,437	3,773	698	593	0	6,407	14,909	222
2010	9,878	0	5,047	183	15,108	2,932	3,816	702	592	0	6,452	14,495	613
2011	9,878	0	5,043	174	15,095	2,696	3,919	706	592	0	6,495	14,407	687
2012	9,878	0	5,036	173	15,087	3,087	3,954	708	592	0	6,545	14,885	202
Average	**9,590**	**0**	**5,001**	**157**	**14,749**	**3,734**	**3,811**	**753**	**651**	**162**	**6,539**	**15,651**	**-902**
Total	**268,533**	**0**	**140,036**	**4,401**	**412,970**	**104,558**	**106,698**	**21,086**	**18,231**	**4,537**	**183,105**	**438,214**	**-25,244**

Note: All Units are in Acre-feet per year

APPENDIX H: Climate Variability Historical Comparison #2
Water Balance Summary

Sensitivity #2	Recharge	Recharge from Rivers	Recharge from Streams	Subsurface Inflow	Total Recharge	Wells	Springs	Evapotrans-piration	Discharge to River	Subsurface Outflow	Discharge to Streams	Total Discharge	Change in Aquifer Storage
Units	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY
1985	7,086	0	3,662	135	10,882	2,898	4,101	849	875	445	7,118	16,287	-5,405
1986	9,966	0	6,567	136	16,669	3,122	3,903	851	810	431	7,426	16,543	126
1987	3,972	0	3,345	146	7,463	3,820	3,065	704	545	405	5,435	13,974	-6,511
1988	4,397	0	2,979	150	7,527	3,678	2,705	643	459	389	4,536	12,409	-4,882
1989	5,341	0	3,645	150	9,135	3,401	2,608	611	384	372	4,372	11,748	-2,613
1990	3,594	0	3,204	155	6,953	3,227	2,246	565	274	354	3,685	10,350	-3,397
1991	5,531	0	4,886	153	10,570	3,499	2,341	570	306	343	4,424	11,483	-913
1992	7,608	0	5,057	148	12,814	3,581	2,731	606	399	336	4,703	12,356	457
1993	10,948	0	6,491	139	17,579	3,478	3,415	690	542	333	6,018	14,477	3,102
1994	5,928	0	3,921	146	9,994	4,064	3,015	625	405	295	5,118	13,522	-3,528
1995	12,706	0	7,295	135	20,136	3,631	3,831	743	617	238	6,885	15,945	4,191
1996	10,589	0	6,042	135	16,766	3,958	3,973	769	614	156	7,024	16,492	274
1997	10,480	0	4,795	133	15,409	4,408	4,146	779	653	99	7,024	17,110	-1,701
1998	13,801	0	7,640	130	21,571	3,901	4,478	872	763	54	8,183	18,251	3,320
1999	8,642	0	4,848	135	13,625	3,959	4,101	783	624	19	7,148	16,634	-3,008
2000	9,252	0	6,213	152	15,616	4,239	3,888	748	605	0	7,075	16,555	-939
2001	7,328	0	4,596	180	12,103	4,450	3,578	687	538	0	6,269	15,522	-3,419
2002	8,047	0	4,123	192	12,362	4,334	3,572	659	528	0	6,059	15,152	-2,789
2003	8,450	0	4,743	193	13,386	4,391	3,433	646	495	0	5,814	14,780	-1,394
2004	8,395	0	4,345	197	12,937	4,115	3,446	636	483	0	5,740	14,420	-1,482
2005	11,965	0	6,161	199	18,324	3,430	3,888	711	578	0	6,578	15,184	3,140
2006	13,503	0	6,141	188	19,832	3,736	4,417	801	682	0	7,377	17,014	2,818
2007	5,118	0	3,212	223	8,553	4,023	3,389	632	453	0	5,550	14,047	-5,494
2008	6,818	0	4,594	220	11,632	3,818	3,119	593	416	0	5,254	13,200	-1,568
2009	7,784	0	4,592	224	12,601	3,429	3,160	597	431	0	5,271	12,888	-287
2010	10,736	0	5,638	196	16,570	2,926	3,614	658	527	0	6,033	13,757	2,813
2011	12,639	0	6,090	174	18,903	2,693	4,277	752	633	0	7,103	15,458	3,445
2012	7,029	0	4,412	193	11,634	3,083	3,619	651	474	0	6,005	13,832	-2,198
Average	**8,488**	**0**	**4,973**	**166**	**13,627**	**3,689**	**3,502**	**694**	**540**	**152**	**6,044**	**14,621**	**-994**
Total	**237,653**	**0**	**139,238**	**4,657**	**381,547**	**103,294**	**98,058**	**19,430**	**15,114**	**4,269**	**169,226**	**409,390**	**-27,843**

Note: All Units are in Acre-feet per year