

SLVWD Water Supply Master Plan

Executive Summary

Introduction

This Water Supply Master Plan for the San Lorenzo Valley Water District (SLVWD or District), Santa Cruz County, California (Figure ES-1), achieves the following:

- Documents the District’s conjunctive use of diverted streamflow and pumped groundwater on a monthly basis for 1984-2008, where conjunctive is broadly defined as the optimized, sustainable use of multiple sources of water throughout annual and long-term climatic cycles.
- Evaluates the production potential of its available water resources as defined by climate, watershed hydrology, aquifer hydrogeology, water quality, water rights, and infrastructure (i.e., water collection, treatment, storage, and conveyance).
- Demonstrates alternatives for sustainably supplying monthly water demand projected for 2030 and a repeat of the 1984-2008 climatic cycle.
- On the basis of this analysis, recommends:
 - Implementation of an intertie between the northern and southern service areas.
 - Exercising its entitlement to a portion of the yield of Loch Lomond reservoir.
- Technically supports subsequent District efforts regarding planning, environmental assessment, design, and project implementation.

In 2008 the District annexed the Felton System previously operated by the California American Water Company. That system remains separate and is not evaluated in this report.

Within the 136 square-mile San Lorenzo River watershed, the District serves unincorporated communities including Boulder Creek, Brookdale, Ben Lomond, and portions of Felton within its Northern Service Area, and portions of the City of Scotts Valley and adjacent unincorporated areas within its Southern Service Area (including the Mañana Woods subdivision annexed in 2006).

The District’s legal boundaries encompass approximately 58 square miles. The District’s “current serviceable area” is defined as the area currently or potentially served by existing District infrastructure. This area encompasses approximately 22.2 square miles in the Northern Service Area and 0.8 square mile in the Southern Service Area and Mañana Woods.

SLVWD currently produces approximately 2.0 million gallons per day (mgd), on average, to meet the demand of nearly 6,000 service connections and a population of more than 20,000.¹ The District’s currently active water sources consist of five stream diversions and seven groundwater wells. The Northern Service Area is supplied by both streams and wells, the conjunctive use of which has provided a reliable supply through past drought cycles. The Southern Service Area relies solely on groundwater, although an inter-tie to the Northern Service Area is being considered. The District is entitled to a portion of the yield of Loch Lomond Reservoir operated by the City of Santa Cruz, but has not exercised this right since the 1976-77 drought.

¹ This and all following descriptions of SLVWD exclude the Felton System annexed in 2008.

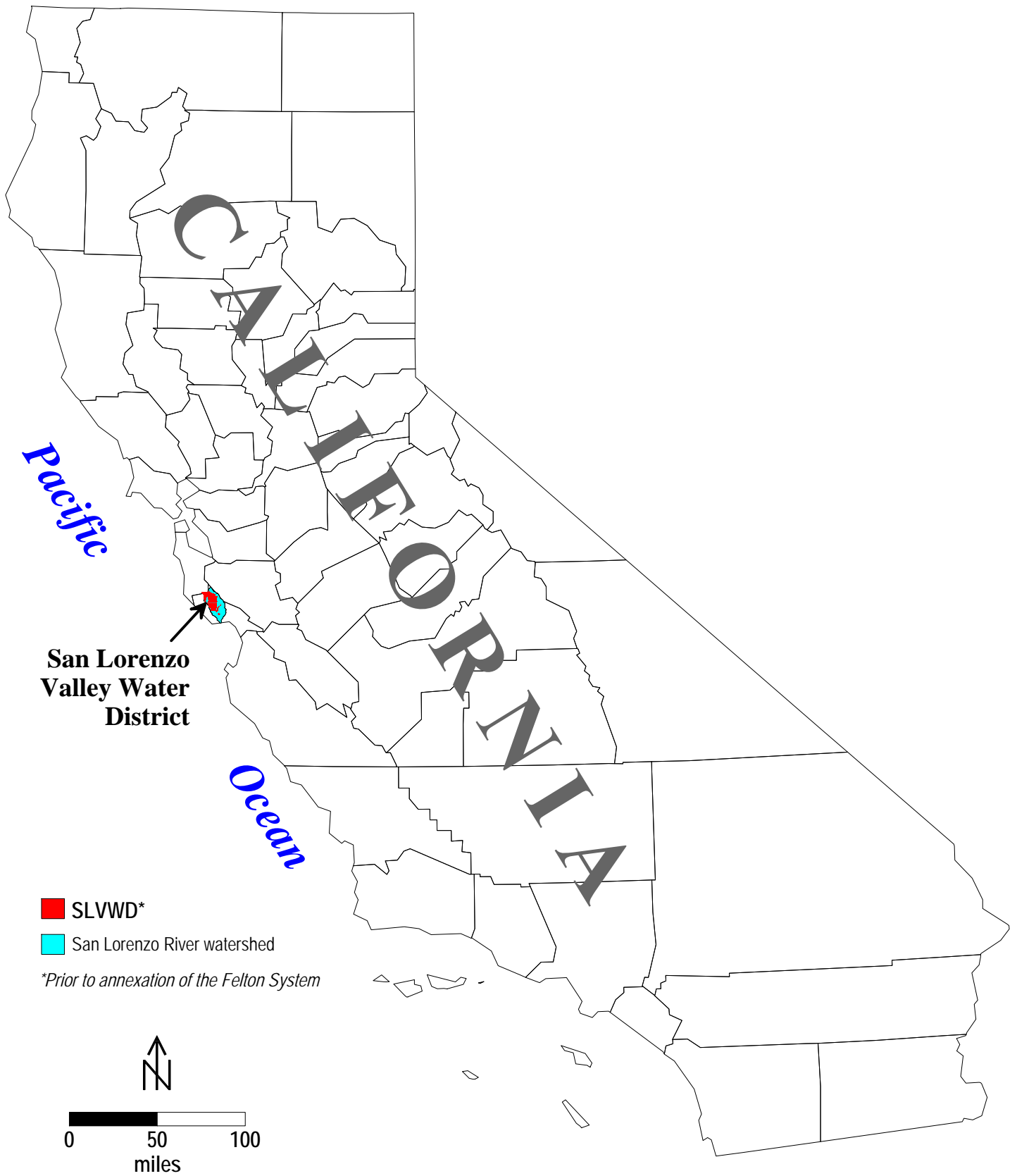
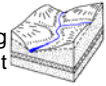


Figure ES-1

Location of San Lorenzo Valley Water District, Santa Cruz County, California



This report does not evaluate the following with respect to SLVWD's water supply:

- The feasibility of water collection, treatment, and conveyance on a less than monthly basis.
- The capacity, limitations, and losses of the water distribution system.
- Disinfection byproducts in the distribution system.
- Potential environmental constraints on water production.
- Conservation and demand-management measures.
- The use of recycled water.
- An independent assessment of projected 2030 water demand.

Additionally, this report does not attempt to estimate future water supplies as a function of currently uncertain projections of climate change. However, this report's approach and results do address this issue as follows:

- Provides a well-documented and thoroughly analyzed benchmark of the existing water supply as a function of climatic variability during the past quarter of a century.
- Formalizes recognition of SLVWD's conjunctive-use system and reliance on groundwater storage during drought. The flexibility and optimization of this system will be critical to responding successfully to the potential effects climate change.
- Supports major improvements to SLVWD's existing water supply system, i.e., a North-South Intertie and exercising SLVWD's entitlement to Loch Lomond, that will greatly enhance its capacity for managing the potential effects of climate change.
- Provides a procedure for updating these estimates once projections of climate change suitable for planning purposes become available.

This report gives water-supply volumes in units of both gallons and acre-feet (e.g., million gallons per year [MG/yr], acre-feet per year [AF/yr]). The results are also provided in terms of both the calendar year (CY) and the water year (WY) (e.g., 2009 extends from October 1, 2008 to September 30, 2009).²

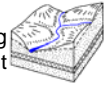
Water Demand

SLVWD raw-water production is closely correlated with customer demand due to the lack of substantial above-ground storage. Surface water is diverted and treated, and groundwater is pumped, in response to fairly immediate water demands. Monthly differences between water produced and water delivered largely represent system losses.

SLVWD water deliveries increased from about 1,000 AF/yr (325 MG/yr) in the late 1970s to an average of about 1,800 AF/yr (580 MG/yr) from 2001 through 2006, an average increase of 28 AF/yr (9 MG/yr). Total deliveries are proportioned about 75 percent to the Northern Service Area and 25 percent to the Southern Service Area. Average annual production is about 14 percent greater than total water deliveries due to various system losses that average about 300 AF/yr.

Water production and deliveries tend to be greatest in July (about 12 percent of annual) and least in February (5 percent or less of annual). About 60 to 65 percent of annual water deliveries occur from May through October. Residential water use comprises roughly 95 and 77 percent of all connections and deliveries, respectively. As of 2002, residential water use averaged about 225 gallons per day

² In this executive summary, most of the cited years refer to water years; however, for the sake of readability the prefix "WY" has been omitted, unlike in the main body of the report.



(gpd) in the Northern Service Area and 600 gpd in the Southern Service Area. Water use among SLVWD's commercial customers has averages nearly 1,000 gpd per connection.

Factors influencing SLVWD water demand include:

1. A population projected to increase at an annual rate of about 0.3 percent.
2. An increasing number of service connections at an annual rate of about 17 percent.
3. An increasing rate of water use per connection, from about 200 gpd in the early 1980s to about 280 gpd by 2000, an annual increase of about 3 gpd per connection and 20 AF/yr system-wide.
4. Variable rates of annual water loss, ranging from about 8 to 24 percent of total production.
5. Variable annual rainfall, with water use increasing and decreasing during individual years of below and above average rainfall, respectively. These trends reverse during sustained wet and dry conditions, e.g., in response to drought conservation, and include lag effects that last a year or more.

SLVWD projects its service connections and annual water production and deliveries through 2030 as follows:

- A 7.8 percent annual increase in service area population.
- An increase of 18 service connections per year, reaching more than 6,400 by 2030.
- An annual increases in water production and deliveries of 4 to 5 AF/yr (1 to 2 MG/yr), such that production reaches about 2,260 AF/yr (735 MG/yr) by 2030.

These projections assume that water use per connection will stabilize at about 280 gpd and system-wide losses will decline to about 10 percent by 2030.

Climate and Hydrology

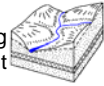
The climate and hydrology of the San Lorenzo Valley is characterized to help establish the following:

- The average and variable yield of SLVWD's diversion watersheds.
- Climatic factors controlling the amount and variability of groundwater recharge.
- A representative climatic cycle for evaluating conjunctive use.

SLVWD's water resources are derived solely from precipitation within the study area. This report refers to rainfall and precipitation synonymously, although on occasion some precipitation does occur as snow at higher elevations. Rainfall becomes either (1) evapotranspiration, (2) streamflow, or (3) pumped groundwater. The streamflow component can be subdivided further into stormflow and baseflow.

Rainfall and Evapotranspiration

Annual rainfall at Santa Cruz, Ben Lomond, and the top of Ben Lomond Mountain (Lockheed facility) averages approximately 30, 50, and 55+ inches per year (in/yr), respectively. SLVWD monitors rainfall at six stations including one at its main office. Based on an isohyetal map constructed from numerous stations in the region, SLVWD's streamflow diversion watersheds receive mean annual rainfall of up to 60 in/yr. On average, more than 90 percent of annual rainfall occurs during the half-year period from November through April. Approximately 80 percent of all days, and 50 percent of all weeks, have rainfall totaling less than 0.01 inches, reflecting the distinct dry season and recurrence of droughts.



Since 1973, the greatest one-day rainfall at Ben Lomond was 11.5 inches on January 4, 1982, equal to more than one-fifth mean annual rainfall. The greatest 30-day rainfall was nearly 33 inches during January and February, 1998. SLVWD measured rainfall greater than 30 inches at its office station during March 1983, January 1995, and February 1998. The Lockheed station received a maximum of 41 inches/month in January 1969, and has had season totals exceeding 100 inches five times during the past 117 years, with a maximum of 124 inches in 1890. Minimum seasonal rainfall of about 35 percent of average occurred at both the Santa Cruz and Lockheed stations in 1924.

Annual rainfall ranges between about 35 and 220 percent of average. Years of distinctly above or below average rainfall often occur consecutively and/or in clusters over periods ranging from 2 to 20 years and averaging about 7 years.

The two most recent significant droughts were 1975-77 and 1987-94, which had about 60 and 75 percent of average rainfall, respectively. A 19-year drought occurred during 1917-35 and a prolonged period of below average rainfall appears to have occurred prior to 1890. Currently, the region is experiencing a third year of drought that began in 2007.

The current drought follows a prolonged 12-year period from, 1995-2006, of near average to above average rainfall. Other significant wet periods were 1978-86, 1967-74, 1936-43, and 1890-1895. Long-term trend lines indicate that annual rainfall has been increasing slightly at a rate of about 0.1 to 0.2 percent.

Evapotranspiration from San Lorenzo Valley's forests is relatively constant at about 30 in/yr, regardless of rainfall. Thus, the portion of rainfall that becomes runoff and recharge increases significantly with increasing rates of average rainfall.

Evapotranspiration is only about 20 in/yr in the vicinity of SLVWD wells because of the low water-retention capacity of the area's sandy soils. Because these soils are also characterized by low runoff, groundwater recharge rates are particularly high.

Streamflow

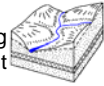
The streamflow hydrology of San Lorenzo Valley characterizes the source of SLVWD's stream diversions as well as baseflows discharged from local aquifers. The streams from which SLVWD diverts are ungaged, although known to flow equal to or more than the recorded rates of diversion.

The average unit streamflow of SLVWD's diversion watersheds is estimated to be 25 in/yr or more, a significantly high rate relative to a regional relation between gaged watershed average rainfall and streamflow.

On average, nearly 90 percent of annual streamflow occurs during the half-year period from December through May. The annual streamflow hydrograph lags behind the rainfall hydrograph by a month or more.

Streamflow was only 10 percent or less of average during 1977, the lowest year of record, and about 15 percent or less of average in 1976, the second driest year of record. The next four lowest streamflow years were 1961, 1988, 1990, and 1939, all of which were less than 25 percent of average. Streamflow was nearly 300 percent or more of average during 1983, the highest year of record. Other years with streamflow generally above 200 percent of average include 1941, 1952, 1958, 1969, 1982, 1998, and 2006.

Long-term records for streams gaged by the USGS indicate that annual flows vary between 5 and 400 percent of average, a significantly broader range of variability than annual rainfall. Streamflow records do not reveal clear trends in annual streamflow during the past 70 years.



During the two most recent droughts, 1975-77 and 1987-94, streamflow was about 35 and 40 percent of average, respectively. Flows were about 50 to 65 percent of average during the three earlier droughts that occurred during 1944-50, 1953-55, and 1959-66. Streamflow records do not exist for the prolonged 19-year drought that occurred during 1917-35.

Baseflow is the portion of streamflow that originates from groundwater. During the dry season, streamflow is essentially all baseflow. The contribution of baseflow to total streamflow increases throughout most of the wet season as groundwater pressures rise in response to rainfall recharge and diminished evapotranspiration. As the wet season ends, baseflow begins an exponential decline that continues throughout the dry season.

The proportion of baseflow relative to total flow is difficult to evaluate during stormflow periods. Stormflow-baseflow hydrograph separations for this study indicate that unit baseflows range from about 5 to 10 in/yr during an average year, comprising 35 to nearly 50 percent of total streamflow. Based on this analysis, typically about 35 to 40 percent of the “rainfall surplus” estimated from soil-water budgets becomes groundwater recharge. Most of the recharged groundwater becomes baseflow, although some is pumped from wells and lost to phreatophyte evapotranspiration.

In the case of well-drained soils, such as those in the vicinity of SLVWD wellfields, a much larger proportion of rainfall contributes to stream baseflow (~70 percent) because of the high rates of rainfall percolation that result from low runoff and low evapotranspiration.

Climatic Change

Globally since 1900, average near-surface air temperatures and ocean surface temperatures have increased about 0.15°F per decade, and precipitation appears to have increased about 0.2 percent per decade. Across the middle and high latitudes of the northern hemisphere, over-land precipitation and streamflow have increased at a rate of about 0.5 to 1 percent per decade (CDWR, July 2006).

Since the late 1800s in California, mean annual precipitation appears to have slightly decreased in the central and southern portions of the state while increasing in the north. Statewide, the overall trend has been relatively flat with a recent upward trend. The variability of statewide annual average precipitation within a moving 10-year period between 1890 and 2002 has about doubled, increasing from about 0.18 to 0.36.

Long-term records of mean annual daily minimum, maximum, and average temperatures among four stations in the Santa Cruz Mountains region exhibit similar trends: an increasing mean daily minimum temperature (0.4° to 0.9°F per decade); a decreasing mean daily maximum temperature (0.1° to 0.2°F per decade); and a resulting slight increase in average mean temperature (0.1° to 0.4°F per decade). The pattern of increased nighttime temperatures has been observed globally and attributed to climatic change.

As described above, there has been an apparent increase in mean annual rainfall of 1 to 2 percent of average per decade at two Santa Cruz County stations over the past 140 years. This range of increase is similar to the average hemispheric rate. Additionally, these local records exhibit an increasing trend in annual rainfall variability similar to the statewide trend. The observed trend of increasing rainfall is consistent with studies showing that precipitation has kept pace with increased humidity related to climatic change. Local streamflow records extend back only half as long and do not exhibit any trend.

The following climatic conditions are predicted statewide for California (references cited in main body of report):

- A 3 to 10°F temperature increase by 2100, with a greater proportion of this increase occurring in summer than in winter.
- A continuation of mostly winter precipitation, virtually all from North Pacific winter storms. Precipitation may increase in winter while decreasing in spring.
- Either relatively little change in overall precipitation statewide or a trend toward moderately decreased precipitation.
- A statewide 27 percent reduction in the average annual availability of water supplies, and a resulting 17 percent reduction in average annual water deliveries, mainly due to changes in the nature, spatial distribution, and timing of precipitation (e.g., decreased snow pack).
- A proportionately smaller increase in evapotranspiration assuming that most of the temperature increase is nocturnal.
- In Santa Cruz County during the next 50 to 100 years, local scientists have estimated that temperatures will rise 8° to 9°F, rainfall will decrease by nearly half between February and April, and summers will be hotter with increased water demand.
- Although unlikely, the possibility of sudden climatic change exists, as evidenced by pre-historic droughts lasting several decades. Sudden cooling could be brought on by volcanic eruptions or other causes of atmospheric debris.
- Significant uncertainty remains about the nature and magnitude of potential climatic change in California.

California's most significant expected impact from climate change, reduced snow pack, will not directly impact coastal areas relying solely on local water supplies. However, the central coast appears to be roughly within the boundary between an increasingly dry south and a possibly wetter north. Furthermore, increased spring and summer temperatures will result in increased water demand.

The increased variability of annual rainfall suggests a potentially greater frequency of extremely wet and/or dry years. Thus, even if little change in mean annual rainfall occurs, it may become more difficult to effectively capture and/or store the increased proportion of average rainfall that occurs during very wet years. Increased variability also suggests the potential for a reduced occurrence of extended droughts, given that one period of lowest historical variability was the prolonged drought of 1917-35.

Design Climatic Cycle

The reliability of SLVWD's water supply system is qualified largely by its capacity to sustain adequate production during the annual dry season and through the recurrence of expected multi-year droughts. As such, this study requires a design climatic cycle suitable for evaluating SLVWD's ability to meet expected future water demand through the conjunctive use of its surface water and groundwater sources. Alternative definitions of a design climatic cycle include:

1. A repetition of the well-documented hydrologic conditions of recent decades, during which two droughts occurred; complete SLVWD water production records are available since 1984.
2. An approximation of the more severe but poorly documented 1917-35 drought.
3. A hypothetical period representing future conditions under climatic change.

This study elected the first approach because the recent data record contributes significantly to reducing analytical uncertainties, given the many other assumptions and interpolations required to evaluate SLVWD's streamflow and groundwater sources. This analysis can be extrapolated to address the potential effects of climate change as they become better understood.

Stream Diversions

SLVWD's active water supply sources include direct diversions on Peavine, Silver, Foreman, Clear, and Sweetwater creeks. The diversion watersheds are situated along the steep northeast facing slopes of Ben Lomond Mountain.

Since 1984, production from SLVWD stream diversions has ranged from about 500 to 1,200 AF/yr (160 to 400 MG/yr), averaging nearly 900 AF/yr (290 MG/yr or 0.8 mgd). These diversions satisfy more than half of SLVWD's Northern Service Area average annual water demand.

Watershed Land Use, Hydrology, and Water Quality

SLVWD currently diverts from a total of seven stream intakes with a combined contributing watershed area of approximately 1,400 acres, or 2.2 square miles. The configuration of diversions allows gravity conveyance to SLVWD's Lyon Water Treatment Plant completed in 1994.

Peavine, Silver, and Foreman creeks drain directly to Boulder Creek, which has a watershed area of nearly 12 square miles upstream of its confluence with the San Lorenzo River. The combined watershed of these three diversions encompasses about 10 percent of the Boulder Creek watershed, about 2 percent of the 55-square-mile San Lorenzo River watershed above Clear Creek, and 1 percent of the river's 106-square-mile watershed above Big Trees.

Clear Creek and its tributary Sweetwater Creek drain directly to the San Lorenzo River. Their combined diversion watershed is about 60 percent of the Clear Creek watershed upstream of the river, about 2 percent of the river's watershed above Clear Creek, and 1 percent of the watershed above Big Trees. SLVWD's total of 1,400 acres of diversion watershed is about 4 percent of the river watershed above Clear Creek and 2 percent of the watershed above Big Trees.

The distribution of land uses within SLVWD's diversion watersheds is summarized as follows:

Diversion Watershed	SLVWD Land	State Park	Timber Production	Timber-Residential	Residential & Rural Residential
	Percent of Area				
Watershed Above Intake					
Peavine Ck	65	0	18	11	6
Silver Ck	100	0	0	0	0
Foreman Ck	58	0	3	19	20
Clear Ck	65	11	6	0	18
Sweetwater Ck	15	34	0	0	51
Overall	55	9	6	8	22

A contiguous block of SLVWD parcels occupies nearly 1,700 acres in the vicinity of the diversion watersheds. District lands comprise more than half (774 acres) of the total watershed area upstream of the diversion intakes. About one-fifth of the overall watershed consists of residential and rural-residential parcels. The remaining areas are split between State Park land and timber production parcels with and without residential use.

Perennial streamflow upstream of SLVWD's diversions occurs entirely within SLVWD land, with the exception of a portion of Sweetwater Creek. Additionally, the raw-water pipelines that extend between the diversion intakes and the water treatment plant are almost entirely on District land.

No timber harvesting is conducted on SLVWD’s watershed properties. These and other State Park and timber lands comprising SLVWD's watersheds are generally roadless wilderness. The diversion watersheds are not fenced although access roads are gated. SLVWD-owned land provides a considerable buffer around the diversion intakes. Residential development does occur along the crest of the watershed that relies on wells and individual wastewater disposal systems.

Parcels with hazardous-material permits within SLVWD’s stream diversion source areas include Camp Ben Lomond operated by the California Youth Authority, a tree farm, a utility station, and a radio or television broadcast site. Roadway accidents along Empire Grade could result in hazardous material spills into SLVWD's diversion watersheds.

The available diversion record for SLVWD’s surface-water sources dates back to January 1984. The amount of streamflow that bypasses the diversion intakes is not measured, and thus there is no record of total streamflow for these streams. SLVWD has found site conditions difficult for establishing permanent gages on these streams.

The following table provides water-budget estimates of average annual total streamflow for SLVWD’s diversion watersheds:

Diversion Watershed	Watershed Above Intake (acres)	Adjacent Recharge Area (acres)	Estimated Average Annual Water Budget					
			Rain-fall (in/yr)	Evapo-trans-pira-tion (in/yr)	Streamflow Derived from:			
					Watershed Rainfall (AF/yr)	Recharge Area* (AF/yr)	Total (rounded)	
Peavine Ck	230	180	60	31	29	560	150	700
Silver Ck	30	0	58	30	28	70	20	100
Foreman Ck	480	115	60	31	29	1,160	220	1,400
Subtotal	740	295				1,790	390	2,200
Clear Ck	435	345	60	31	29	1,050	250	1,300
Sweetwater Ck	225	70	60	31	29	540	70	600
Subtotal	660	415				1,590	320	1,900
Total	1,400	710				3,380	710	4,100

*Roughly apportioned based on watershed and recharge areas, assuming 12 in/yr average recharge rate.

On average, rainfall of about 60 in/yr within SLVWD’s diversion watersheds is estimated to split about equally between evapotranspiration (31 in/yr) and unit streamflow (29 in/yr).

The combined average streamflow of SLVWD’s diversion watersheds is estimated to be about 4,100 AF/yr. This is about 8 percent of the estimated average flow of the San Lorenzo River at Clear Creek, and about 4 percent of the river’s average flow at Big Trees. The combined estimated average annual flow of the Peavine, Silver, and Foreman creek diversion watersheds comprises about 17 percent of Boulder Creek’s estimated average flow. The estimated average annual flows of SLVWD’s individual watersheds range from about 100 AF/yr for Silver Creek to 1,400 AF/yr for Foreman Creek. Compared to the gaged records for the San Lorenzo River and several of its tributaries, a greater proportion of these streams’ annual flow occurs as dry-season baseflow.

The total dissolved mineral concentration of SLVWD diversions is low, usually less than 150 milligrams per liter (mg/L). Samples meet all drinking water standards except for infrequent exceedances of secondary standards for iron and manganese.

Elevated turbidity occurs primarily in wet winter months as a result of sediment transport. The District stops diverting during periods of significantly elevated turbidity. As a result, the turbidity of its combined raw-water diversions exceeds 1 nephelometric turbidity units (NTU) only about 5 percent of the time.

Infrastructure

The direct-diversion intake structures on Peavine, Silver, and Foreman creeks were rebuilt in 1983 following damage from the January 1982 storm. The direct-diversion structures on Clear and Sweetwater creeks were reconstructed at upstream locations in 1995 to allow gravity drainage to the Lyon WTP.

SLVWD's direct-diversion intake structures consist of a low notched dam with redwood flashboards, a stilling basin, a stainless steel screen, a diversion pipe and valve through the dam face, and a concrete splash apron on the downstream side of the dam. The screens require cleaning up to several times a day during early wet-season storms. The flashboards at each diversion must be manually removed and replaced before and after non-diversion periods. During stormy periods of intermittent peak flow, the flashboards might be removed and replaced several times a day. However, at the less accessible diversions (e.g., Clear Creek), the flashboards may be removed for long periods during the wet season given low seasonal demand and inconvenient site access. A raw-water sample intake just upstream of the Foreman diversion is piped to a turbidity meter, allowing diversions to be automatically stopped when exceeding 15 NTU.

The diversion structures have been damaged in the past by streamflow and sediment transport during extreme events (e.g., January 1982). However, the repaired structures and those constructed in 1995 are believed to be less vulnerable to storm damage than previously. The capacity of the diversion intakes has not been established, but generally exceeds raw-water conveyance capacities, and thus is not a factor limiting diversions under most circumstances.

SLVWD uses more than 6 miles of high-density polyethylene (HDPE) pipeline to convey raw water from the diversion intakes to the Lyon WTP. The Foreman/Peavine Supply Line is nearly 1 mile long. The Five-Mile Pipeline conveys diversions from the Clear and Sweetwater creek intakes. It had a design rate of 550 gpm (74 AF/month) and has conveyed in excess of 500 gpm during certain months of record. Recent hydraulic testing, however, indicates a flow capacity of approximately 400 gpm (54 AF/month) as a result of persistent backpressure.

SLVWD operates a centralized water treatment facility for its stream diversions in compliance with the U.S. Environmental Protection Agency's (USEPA) 1989 Surface Water Treatment Rule (SWTR) and subsequent SWTR enhancements. This set of regulations seeks to limit the occurrence of water-borne pathogenic microorganisms, including *Giardia lamblia*, viruses, *Legionella*, and *Cryptosporidium*, through the required use of disinfection and filtration, and strict limits on finished-water turbidity. The WTP was sized based on past and expected water demand, not hydrologic estimates of available flows.

The Lyon WTP was completed in 1994 and consists of three Neptune Trident Microfloc package units that perform adsorption, clarification, and two stages of filtration. Each unit has a 350-gpm design capacity and a 420-gpm maximum-rated capacity. Tests conducted by SLVWD in early 2006 demonstrated that the plant's effective, sustainable maximum capacity is approximately 1,200 gpm. The maximum monthly rate of WTP production is 1,010 gpm, which occurred in July 1998.

These units use automated pre- and post-filter chlorinators and an automated floc delivery system. The turbidity of the plant influent and filter-unit outflow are also monitored automatically. Inflow to the plant shuts off when its turbidity exceeds 10 NTU. Chlorinated outflow from the filter units collects in the WTP sump and is piped to tanks to achieve required disinfection times. The WTP's filters must be regularly flushed and backwashed. This water is fed back into the WTP at rates no greater than 10 percent of total inflow, per DHS regulations.

Diversions are discontinued during high turbidity stormflows for a total of roughly 40 hours during an average winter, 24 hours during a dry year, and 60 hours during particularly wet years.

The WTP's maximum yield based on typical rates of flushing, backwashing, and bypassing turbid stormflows is estimated at about 155 AF/month (51 MG/month or 1,100 gpm). Production capacities representative of dry, average, and wet years are approximately:

- 930 to 1,220 AF/yr (300 to 400 MG/yr) during average years
- 700 to 1,020 AF/yr (230 to 330 MG/yr) during dry years
- 990 to 1,350 AF/yr (320 to 440 MG/yr) during wet years

1984-2008 Production

This section presents and analyzes the diversion record; evaluates various operational constraints and procedures; describes the quality of water produced post-treatment; and estimates potential monthly and annual rates of diversion under various climatic and demand conditions. SLVWD's potential to divert streamflows is carefully considered given its inverse relation to the need and timing for groundwater production, and its potential to provide some additional supply to the Southern Service Area.

Since 1997, the diversion record is based on three separately metered raw-water flows: (1) outflow from the Peavine and Silver creek diversion pipeline into the Foreman mixing vault, (2) outflow from the Five-Mile Pipeline into the Foreman mixing vault, and (3) total inflow to the WTP.

Total annual diversions have ranged from about 400 to 1,200 AF/yr (150 to 390 MG/yr) since 1977, and averaged about 880 AF/yr (290 MG/yr) since 1984.³ Monthly diversions have ranged up to nearly 140 AF/month (45 MG/month), and thus have yet to be limited by an estimated WTP capacity of 155 AF/month (51 MG/month). To date, diversions have not been shut down due to lack of flow, although SLVWD has limited drought experience with the current Clear and Sweetwater creek intakes since they were relocated in 1995.

Since the 1997 reconfiguration of the diversion intakes and raw-water conveyance, the average contribution of each source as a percentage of total diversions is as follows:

Peavine and Silver Creeks	13%
Foreman Creek	60%
Clear and Sweetwater Creeks (Five-Mile Pipeline)	27%

The 1984-2008 diversion record mimics the climatic cycle. During the 1987-94 drought, diversions were 73 percent of average overall and as low as 56 percent of average. During the 1995-2000 wet period, annual diversions were 125 percent of average and as high as 135 percent. The climatic variability of the annual diversion record is similar to the variability of the Ben Lomond rainfall record, and less variable than the San Lorenzo River at Big Trees record. Regression analysis indicates that water-year diversions correlate significantly with the current year's and two previous years' rainfall. The variability of annual diversions is only weakly correlated to annual water demand.

Diversions supply nearly all of the Northern Service Area's water demand during typical, non-drought winter and early spring months. However, given the lack of significant surface-water storage capacity, a large dry-season gap occurs between surface-water supplies and peak demand that must be supplied by groundwater pumping. Monthly diversions from Foreman Creek tend to correlate with the hydrologic cycle whereas diversions from Peavine, Silver, Clear, and Sweetwater

³ Excluding diversions from Harmon Creek and Earl and Manson springs.

creeks tend to peak during late spring and summer, and may be entirely bypassed in winter. Monthly diversions often dip sharply in February as a result of low water demand and the shortness of the month. A daily or hourly record would be needed to evaluate the diversion record in relation to stormflow events.

On average, Foreman Creek diversions peak in March in response to cumulative seasonal rainfall. Diversions from the other streams peak in June when seasonal water demand surpasses the Foreman Creek diversion. Total diversions peak in May.

SLVWD's ten highest total monthly diversions range between approximately 120 and 140 AF/month (40 to 45 MG/month). These generally occur during spring and summer. The WTP has not produced at its estimated monthly capacity (~155 AF/month or 51 MG/month) because of the need to bypass turbid stormflow, low water demand during winter months, and physical constraints that limit the simultaneous conveyance of high flows from each intake. Since 1984, monthly diversions have been 30 percent or more below the WTP's estimated capacity about 85 percent of all months.

On average, diversions from Peavine, Silver, Clear, and Sweetwater creeks are less than 20 percent of estimated total flow, and diversions from Foreman Creek are slightly more than 40 percent of total flow. SLVWD's water rights do not specify required bypass flows except to provide for a downstream water right of 30 gpm on Clear Creek.

Diversion Watershed	Average Annual		
	Total Stream-flow above Intake	SLVWD Diversions (since 1998)	SLVWD Diversions as Percent of Total Streamflow
	(AF/yr)		
Peavine & Silver Cks	800	140	18%
Foreman Ck	1,400	620	44%
Clear & Sweetwater Cks	1,900	280	15%
Total	4,100	1,040	25%

Raw-water production is closely correlated to short-term water demand, given that the operable storage capacity of the northern distribution system is only 25 AF (about a 3- to 8-day supply, depending on season). Low seasonal demand is typically the limiting factor for diversions during periods of high flow. The Five-Mile Pipeline and its contributing diversions typically are shut down during mid-winter when seasonal high flows available from Peavine and Foreman creeks exceed low seasonal water demand. Thus, SLVWD has little experience operating its diversions and WTP at near capacity.

Since 1984, diversions have fulfilled the entire monthly water demand of the Northern Service Area about 3 percent of the time (about one month every three years). Although total diversions tend to parallel demand during winter and spring, they typically run about 10 AF/month (3.3 MG/month) below demand, due to a combination of factors including storm timing, turbid-stormflow bypass, conveyance limitations, and WTP operations. This results in an average need for about 10 AF/month of groundwater production, even when streamflows are plentiful.

High turbidity streamflow events typically last from hours to days. SLVWD's diversion intakes are shut off once a specified level of turbidity is reached, e.g., 5 NTU. Although the WTP can handle higher turbidity, it is usually unnecessary in terms of water demand, and is undesirable in terms of WTP operations. In practice, remote monitoring and control of the diversion intakes has been problematic.

At times the WTP's clarifier basins become full with backwash water, making it difficult to recycle and causing water color problems. Alternative means for emptying the clarifier basins are needed at such times.

Production Potential

Quantifying SLVWD's potential to divert streamflow is a function of several key but weakly defined constraints. This study characterizes SLVWD's surface-water supply by constructing a 1984-2006 hydrograph of total streamflow available for diversion based on extrapolation of the monthly diversion record. The diversion record reflects total, practically available diversions consistent with operational constraints, with the exception of times when available flows exceed demand. This is because stream diversions are preferred over groundwater pumping. Stream diversions cannot be stored, whereas groundwater is essentially stored until pumped.

Hydrographs of available streamflow are constructed by extrapolating the monthly diversion record above levels imposed by low winter demand. Extrapolating flows above the maximum expected capacity of the conveyance and treatment system is unnecessary. Monthly rainfall and water-demand records help guide the extrapolation. To estimate monthly diversions, these hydrographs are evaluated against (a) the estimated capacity of the diversion system and (b) assumed monthly water demand.

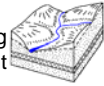
The analysis presented here assumes that the effective capacity of the combined diversion conveyance and treatment system is 155 AF/month (51 MG/month), i.e., the estimated WTP capacity. This exceeds the highest monthly rates of recorded total diversion by nearly 20 AF/month (7 MG/month). Additionally, it assumes that the hydraulic capacity of the conveyance system is no less than that of the WTP. The actual system capacity may remain poorly defined until tested by higher rates of demand at times when such flows are available.

If an intertie between service areas existed, an average of approximately 60 AF/yr (20 MG/yr) and range of 5 to 135 AF/yr (2 to 44 MG/yr) are estimated to have been available for use in the Southern Service Area during the period of record, after serving the production needs of the Northern Service Area. Estimated annual diversions for the period of record constitute 80 to 94 percent of estimated potential annual diversions within the system capacity.

Under 2030 demand, the average rate of diversion estimated for the Northern Service Area is nearly 100 AF/yr (33 MG/yr) greater than average actual diversions during 1984-2006. This represents about a 6 percent increase in the use of estimated potential diversions as limited by system capacity. However, these estimates rely on a significantly greater rate of maximum diversion (>1,500 AF/yr or >500 MG/yr) than has occurred historically (i.e., <1,200 AF/yr or <390 MG/yr). If annual diversions are limited to 1,200 AF/yr, estimated average 2030 diversions are lower by 24 AF/yr for the Northern Service Area and 35 AF/yr for the Southern Service Area.

Summary

Differences between diversion estimates reflecting current versus 2030 demand are relatively minor and within the range of overall uncertainty, given other variables and assumptions. SLVWD's expected supply of stream diversions is estimated in the following table, assuming the Northern Service Area has priority of use. On average, diversions are estimated to supply slightly more than 50 percent of demand in the Northern Service Area. Potential diversions in excess of this amount could provide an average of about 15 percent of demand in the Southern Service Area. In this case, diversions would supply slightly less than 50 percent of SLVWD's District-wide demand on average.



Year Type	Service Area						Total in Excess of Northern Service Area Demand	
	Northern		Available to Southern		Northern & Southern			
	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)
Average	950	310	50+	16+	1,000	330	150	50
Drought	650	200	<10	<3	650+	200+	25	8
Wet-period	1,200	400	<100	<33	1,200+	400+	200	65

The drought- and wet-period estimates represent expected averages for such periods. Individual years with diversions as low as 400 AF/yr (130 MG/yr) should be expected (e.g., 1977), especially given the upstream relocation of some intakes and discontinuation of others since 1996. Maximum annual diversions of as much as 1,500 AF/yr (490 MG/yr) are expected if the diversion system can sustain operation at capacities approaching 155 AF/month (51 MG/month) for periods of several months during the wettest years.

Potential diversions estimated to be available for use in the Southern Service Area are small relative to total estimated diversions, and thus have a relatively high degree of uncertainty. On average, about 90 percent of estimated diversions available to the Southern Service Area occur from December through April. Maximum monthly rates of diversion would be about 30 AF/month (10 MG/month), requiring a service-area intertie capacity of 250 gpm or more. Diversions available to the Southern Service Area would supply less than 10 percent of annual demand during about 35 percent of all years, and up to 30 percent of annual demand during other years. The diversion estimates for the Southern Service Area are highly dependent on the system operating at near capacity during the wettest months and periods.

The diversion estimates are sensitive to the system's assumed capacity and efficiency as follows:

- Assuming an effective system capacity of only 140 AF/month (46 MG/month) reduces the estimated average annual total diversion by about 10 to 20 AF/yr (3 to 7 MG/yr) and reduces estimated maximum-year total diversions by about 100 AF/yr (33 MG/yr).
- Assuming a 20 rather than 10 AF/month reduction in divertible flows during stormflow periods (3 to 7 MG/month) reduces estimated annual total diversions by 50 AF/yr (16 MG/yr).
- Potential improvements in WTP and conveyance efficiency could render all of the presented diversion estimates as conservatively low.

As stated in the introduction, this water-supply assessment does not address potential environmental constraints on raw water production. Also, it does not project changes in water supply as a result of climate change given considerable uncertainty about such trends.

Groundwater Sources

SLVWD's active groundwater supply sources consist of two wells at each of its Quail Hollow, Olympia, and Pasatiempo wellfields, and the Mañana Woods well. All of SLVWD's wells are associated at least partially with the Santa Margarita Sandstone aquifer. The Pasatiempo and Mañana Woods wells also draw from the underlying Lompico Sandstone aquifer.

The Quail Hollow and Olympia wells supply water to the Northern Service Area in conjunction with SLVWD's stream diversions. The Pasatiempo wells are the sole water supply for the Southern Service Area, and two Mañana Woods well comprise that subdivision's sole source of water.

Since 1984, production from all SLVWD wells has ranged from about 600 to 1,200 AF/yr (200 to 400 MG/yr), and averaged about 1,000 AF/yr (325 MG/yr or 0.9 mgd). Groundwater production

satisfies nearly half of the average annual water demand of SLVWD’s Northern Service Area and all of the Southern Service Area and Mañana Woods demand. Since 2001, groundwater production has averaged about 750 AF/yr (245 MG/yr) in the Northern Service Area and 410 AF/yr (135 MG/yr) in the Southern Service Area. Production from the Mañana Woods wells previously averaged about 70 AF/yr (23 MG/yr), but has decline to about 55 AF/yr (17 MG/yr) in response to SLVWD metering each connection.

Groundwater Subareas

The following groundwater subareas are defined for the purpose of characterizing SLVWD's groundwater resources:

<u>Subarea</u>	<u>sq. miles</u>	
Quail Hollow	3.0	
Olympia	2.9	
Pasatiempo	1.9	(adjacent areas of exposed
Camp Evers	0.9	Monterey Formation excluded)
Mission Springs	2.3	
Scotts Valley	~8	

With the exception of Quail Hollow, the subareas are somewhat arbitrary defined inasmuch as continuous aquifer zones extend between.⁴ Across these areas, mean annual rainfall trends from a high of 50 in/yr near the base of Ben Lomond Mountain to a low of slightly above 40 in/yr in eastern Scotts Valley.

Quail Hollow is a hillslope area of exposed Santa Margarita Sandstone encompassing about 3.0 square miles (1,940 ac) between the communities of Ben Lomond, Glen Arbor, Felton, Zayante, and Lompico. It is bounded on the west by the San Lorenzo River and Love Creek and on the east by Lompico and Zayante creeks; it is crossed by Newell Creek. Nearly the entire Quail Hollow area lies within SLVWD's current serviceable area.

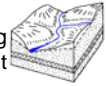
Quail Hollow groundwater supplies SLVWD, residential, and quarry wells, and discharges to springs and streams that contribute to the local and regional water supply. This area of exposed sandstone is overlain by several neighborhoods of single-family homes that are supplied water by either SLVWD or private wells, and all of which rely on septic tanks. The area also includes the 200-acre Quail Hollow sand quarry operated by Granite Rock; Quail Hollow Ranch County Park (nearly 280 acres); and the closed Santa Cruz County Ben Lomond Landfill west of Newell Creek (24 acres). The quarry captures and percolates both on-site runoff and used process water supplied from its well.

Active and former SLVWD wells are located within about 2,000 ft of each other near Quail Hollow Road on the hillslopes leading down to the east bank of Newell Creek. The two active wells are located on adjacent SLVWD-owned parcels with a combined area of nearly 3 acres.

SLVWD monitors five non-pumping wells in the Quail Hollow area and the quarry and closed landfill each have their own monitoring-well networks.

The **Olympia** groundwater subarea, as defined for the purpose of this study, lies between the communities of Mount Hermon, Zayante, and Scotts Valley. It is a hillslope area of partially exposed Santa Margarita Sandstone that covers 2.9 square miles (1,825 ac) between Zayante Creek to the west and north, Bean Creek to the south, and Lockhart Gulch to the east.

⁴ The term groundwater “subarea” is used instead of “subbasin” for this reason.



The Olympia and Mission Springs subareas, along with portions of the Camp Evers and Scotts Valley subareas, comprise more or less a single groundwater subbasin. SLVWD's Olympia wells are located toward the western edge of this subbasin and are unlikely to significantly influence groundwater conditions in Mission Springs or areas further east.

Olympia groundwater supplies SLVWD and residential wells, flows into adjoining groundwater subareas, and discharges to springs and streams that contribute to both local and regional water supplies. The sandstone aquifer extends beneath Lockhart Gulch and Bean Creek into the adjacent Mission Springs and Camp Evers subareas. Three closed sand quarries are located along the southeastern margin of the Olympia area.

SLVWD's three Olympia wells are located within about 1,000 ft of each other. The two active wells are located on a 61-acre parcel. SLVWD also owns four adjoining parcels with a combined area of _ ac. SLVWD's Olympia wells are located at the southeastern edge of its Northern Service Area.

The **Pasatiempo** groundwater area, as defined here, is a plateau and hillslope area of exposed sandstone between the communities of Felton, Mount Hermon, and Camp Evers in southern Scotts Valley. This 1,200-acre (1.9-square-mile) area encompasses SLVWD's active and former Pasatiempo wells; a large portion of SLVWD's Southern Service Area; most of the Mañana Woods subdivision; most of the Mount Hermon community and its three production wells; the nearly 300-acre Hanson Quarry undergoing closure; and large tracts of undeveloped land to the west and southwest. The area is bound by Bean Creek to the north, the San Lorenzo River to the west, Eagle Creek to the southwest, and small tributaries to Bean and Carbonera creeks to the east and southeast.

In the Pasatiempo area, the Santa Margarita Sandstone is underlain by the Lompico Sandstone at relatively shallow depths and productive zones in older formations at greater depths. These aquifers supply groundwater to SLVWD, Mount Hermon, and formerly quarry wells; subsurface flow into the adjoining Camp Evers subarea; and baseflow to springs and streams that contribute to both local and regional water supplies.

The former Hanson sand quarry is undergoing closure. The reclaimed quarry is expected to remain mostly open space and most runoff will continue to be retained on site. Roaring Camp and private undeveloped land adjacent to Henry Cowell State Park occupy a significant portion of the remaining recharge area.

SLVWD's two active production wells are located within 1,200 ft of each other within a 28-ac parcel shared with the Santa Cruz County Probation Center. SLVWD operations encompass inset parcels totaling 1.2 acres. SLVWD has a shallow and deep monitoring-well pair adjacent to one of its production wells. Two wells actively operated by Mount Hermon Association (MHA) are about 500 and 2,500 ft northwest of the nearest SLVWD well.

Camp Evers refers to the south-central portion of Scotts Valley near the intersection of Mount Hermon Road and Scotts Valley Drive. It occupies a small alluvial plain between Bean and Carbonera creeks that became highly developed since the 1970s.

As defined here, the Camp Evers groundwater subarea encompasses a total of about 550 acres (0.9 sq mi). It is bordered by the Pasatiempo subarea to the west and southwest, the Olympia and Mission Spring subareas to the north across Bean Creek, and the remainder of the Scotts Valley groundwater area to the east and northeast. A granitic outcrop limits groundwater movement across Camp Evers' southeastern boundary.

Camp Evers is an area of significant historical and ongoing groundwater production from wells operated by SVWD, mutual water companies, businesses, residences, and remedial operations.

SLVWD operates a well in the Camp Evers area since its 2006 annexation of the area formerly served by the Mañana Woods Mutual Water Company. It is located on a 0.21-acre parcel near Mount Hermon Road and Kings Village Shopping Center, about 0.5 mi north of the Mañana Woods residential area (which lies mostly within the Pasatiempo subarea). Groundwater pumped at this location requires treatment due to the well's interception of one or more contaminant plumes beneath Camp Evers.

Two currently active SVWD wells and are about 1,000 north and 1,300 ft west of the Mañana Woods well. Recycled water delivered by SVWD is an additional source of water within Camp Evers. Since 2005, more than 100 AF/yr (33 MG/yr) has been delivered for use within the greater Scotts Valley area.

Hydrogeology

The hydrogeology of the groundwater subareas defined above has been evaluated and described by several prior studies. The geologic formations exposed in this area are as follows:

Geologic Unit ^a	Geologic Period ^a	Approximate Local ^b Maximum Thickness (ft)	Locally ^b Significant		
			Aquifer	Aquitard	
Alluvium & terrace deposits	Quaternary	<100			
Purisima Formation	Tertiary	Pliocene			
Santa Cruz Mudstone		Miocene	250		×
Santa Margarita Sandstone			450	×	
Monterey Formation			~1,200		×
Lompico Sandstone			400	×	
Vaqueros Sandstone ^c		Oligiocene	~2,000+		
Zayante Sandstone ^c					
Butano Sandstone		Eocene	>2,000	×	
Locatelli Formation		Paleocene	300?		
granitic rocks		pre-Tertiary			×
schist					

^aModified after Clark, 1981.

^bSouth of Zayante fault, east of Ben Lomond fault, and west of Carbonera Creek.

^cNot apparent south of Zayante fault.

The Santa Margarita Sandstone is hydrogeologically important within each subarea, whether as the primary aquifer, a leaky shallow aquifer, and/or prime recharge area. The Lompico Sandstone is an aquifer of equal or greater importance in the Pasatiempo, Camp Evers, and Scotts Valley areas. Where present, the Monterey Formation forms a major aquitard between these sandstones. Relatively new, deep municipal wells have encountered deeper sandstone units interpreted as Butano Sandstone and possibly other formations.

The San Lorenzo Valley consists of three geologic terranes: 1) the exposed granitic basement rock of Ben Lomond mountain uplifted west of the Ben Lomond fault; 2) a thick, down-dropped sequence of sharply folded older Tertiary formations north of Zayante fault; and 3) south of Zayante fault and east of Ben Lomond fault, a thinner sequence of gently folded, younger Tertiary rocks uplifted on granitic basement. The subareas associated with SLVWD's groundwater sources lie within this third terrane, which is dominated by the Scotts Valley syncline, the axis of which extends from Boulder Creek southeast through Scotts Valley. The synclinal fold is most developed in the Lompico Sandstone and Monterey Formation and the Santa Margarita Sandstone is thickest along the syncline axis. These and other formations are draped over a structural high of granitic basement rock that forms the southeastern boundary of the Camp Evers subarea. This report presents structural contour

maps of the estimated bottom of the Santa Margarita Sandstone and top of the Lompico Sandstone, as well as four hydrogeologic cross sections.

SLVWD's groundwater resources occur within various hydrogeologic boundaries. The most common boundary occurs where exposed aquifer formation is truncated by erosion. In the absence of underlying rock of significant permeability, little groundwater flow may continue beyond these boundaries, causing groundwater to discharge to springs and streams. The Santa Margarita Sandstone has been removed by erosion along the circumference of nearly the entire area. Boundaries also occur along major faults.

The following table provides aquifer property estimates for the groundwater subareas. Groundwater conditions tend to be unconfined in the Santa Margarita Sandstone and leaky in the Lompico Sandstone, although conditions vary from unconfined to confined in the latter.

Hydro-geologic Unit	Subarea		Trans-missivity (ft ² /day)	Tested Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Storage Coefficient	
						Specific Yield	Storativity
						(dimensionless)	
Santa Margarita Sandstone	Quail Hollow	range	400 - 1,500	40 - 120	2 - 40	0.12 - 0.20	d
		average ^a	700	90	6+	0.18	
	Olympia	range	2,000 - 4,000	118 - 155	13 - 34	0.17 - 0.25	d
		average ^a	2,500	130	20	0.20	
	Camp Evers ^b	max	≥6,000	60	>100	0.18	d
	Monterey Formation	Olympia ^c	range	50 - 500	150 - 270	0.05 - 3	0.01 - 0.03
average ^a			e	e	0.15	e	e
Lompico Sandstone	Pasatiempo, Camp Evers, Scotts Valley	range	300 - 2,500	175 - 430	1 - 7	0.04 - 0.08	1E-5 - 0.02
		average ^a	2,000	400	5	0.06	e

^aInterpreted representative average.

^dNon-applicable given unconfined conditions.

^bWatkins-Johnson groundwater remediation site. ^eVariable as a function of aquifer conditions.

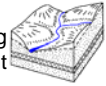
^cPlum Valley site.

Groundwater Occurrence and Storage

Estimated water table contours are informed and constrained by the topography and elevations of perennial streams and springs. The orientation of multiple production-zone piezometric surfaces deep within the Lompico and Butano sandstones differs substantially from the water table, but is poorly known away from a few monitored production wells. Although groundwater is always moving, it is thought of as stored because of its slow velocity. Estimates of groundwater storage do not represent extractable volumes of water.

The **Quail Hollow** groundwater occurs within the Santa Margarita Sandstone under unconfined conditions. Groundwater in the Lompico Sandstone is confined deeply beneath Quail Hollow, is probably of poor water quality, and has little if any interaction with shallow aquifer zones in the Santa Margarita Sandstone and upper Monterey Formation.

The water table mimics the topography as a result of mounded rainfall recharge and groundwater discharge to surrounding springs and streams. As a result, the water table has a saddle-like shape, descending from north and south along the limbs of the Scotts Valley Syncline, and descending to streams and springs to the east and west. Groundwater moves toward the center of Quail Hollow from the north and south, toward springs and streams to the east and west, and toward pumping wells. A groundwater divide separates flow east toward Zayante Creek from flow west toward



Newell Creek, the San Lorenzo River, and SLVWD wells. Groundwater discharges directly from the aquifer into Newell Creek, and from adjacent valley-floor alluvium into the San Lorenzo River. Under drought conditions, groundwater flows beneath portions of Newell Creek toward the river.

Quail Hollow springs occur where the water table intersects the ground surface. Most area springs occur where the sandstone pinches out west of Zayante Creek, forcing groundwater mounded above the Monterey Formation to emerge. From north to south, springs along the far east side of Quail Hollow include Quail Hollow Circle, Azalea, Olympia Circle, McHenry, and Arcadia springs. Each of these springs has contributed to local domestic water supplies.

Rough estimates of the average contribution of Quail Hollow groundwater to stream and spring baseflow are as follows: 1.5 cfs (700 gpm) to Newell Creek; 1.1 cfs (500 gpm) to the San Lorenzo River; and 2.1 cfs (900 gpm) to Zayante and Lompico creeks and their tributary springs.

Average annual production from SLVWD's Quail Hollow wells is equivalent to the continuous production of about 200 gpm. Whereas SLVWD's wells are toward the center of the subarea, many residential wells occur along the aquifer perimeter where the sandstone's saturated thickness is limited, thus requiring well completions into the underlying Monterey Formation. These residential wells are typically capable of producing 1 to 20 gpm. Groundwater discharging to springs and wells from Quail Hollow is generally of good quality with very low concentrations of total dissolved solids. Nuisance concentrations of some water quality constituents include those for nitrate.

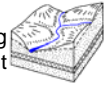
Saturated Santa Margarita Sandstone underlies about 1,100 acres of the Quail Hollow area; has an average and maximum thickness of about 60 and 120 ft, respectively. Assuming a porosity of about 20 percent, total groundwater storage in the sandstone aquifer averages nearly 14,000 AF. SLVWD's Quail Hollow groundwater model simulates a groundwater storage fluctuation of approximately $\pm 5,000$ AF during 1984-2008.

Groundwater also occurs under unconfined conditions within the Santa Margarita Sandstone aquifer of the **Olympia** subarea. Although partially overlain by younger formations, the Santa Margarita Sandstone is not fully saturated and groundwater remains unconfined. The saturated aquifer is not in direct contact with lower Bean Creek or Zayante Creek except where a small isthmus of sandstone connects to Quail Hollow. The Santa Margarita Sandstone aquifer extends south Lockhart Gulch into the Mission Springs and Scotts Valley areas, and beneath Bean Creek into Camp Evers area.

Groundwater in the Olympia and Mission Springs subareas is recharged by rainfall and runoff percolation, especially where the Santa Margarita Sandstone is exposed. The direction of groundwater flow is generally from the north and northeast to the south and southwest. The groundwater gradient is relatively gentle across the southern portions of these subareas due to high aquifer transmissivity, structural containment, and the spread of the Camp Evers pumping depression.

Groundwater movement is primarily toward the gaining reaches of Bean Creek and its tributaries downstream of Ruins Creek, SLVWD's Olympia wells and other wells serving local water needs, and the Camp Evers pumping depression centered south of Bean Creek. The groundwater contribution to Bean Creek baseflow downstream of Scotts Valley has been estimated to total nearly 4 cfs (1,700 gpm), of which a significant portion originates from the Olympia and Mission Springs subareas.

The combined average annual production of SLVWD's Olympia wells is equivalent to a continuous 260 gpm. Other wells serve individual residences and the Mission Springs Conference Grounds. The quality of groundwater in the Olympia Santa Margarita Sandstone aquifer is generally good, although upward leakage from the Monterey Formation is suspected to contribute high iron and



manganese. As in Quail Hollow, Lompico Sandstone groundwater is confined deep beneath the Monterey Formation, is likely of poor quality, and has little interaction with shallow aquifer zones.

Saturated Santa Margarita Sandstone occurs beneath an estimated 2,000 or more acres of the combined Olympia and Mission Springs area. The estimated average and maximum saturated thickness is 130 and 250 ft, respectively. Assuming an aquifer porosity of 20 percent, total groundwater storage is roughly 56,000 AF, of which about 52 percent (29,000 AF) occurs within the Olympia subarea. The saturated aquifer continues east into portions of Scotts Valley. Past fluctuations in groundwater storage within the Olympia and Mission Springs subareas are difficult to estimate from available data. A long-term groundwater level decline of nearly 1 ft/yr is apparent in SLVWD's longest operating and most heavily pumped Olympia well. However, such a trend is less apparent in a monitored former production well. An expanded groundwater monitoring network is needed to better define fluctuations and trends in the groundwater storage of the Olympia subarea.

The **Pasatiempo** subarea is underlain by a broad groundwater mound that is sustained by rainfall recharge into more than 1,000 acres of exposed Santa Margarita Sandstone. SLVWD's former Pasateimpo wells produced at least partially from the unconfined Santa Margarita Sandstone. Its current wells no longer produce from this aquifer because it has been largely dewatered, has yielded groundwater with significantly elevated nitrate concentrations, and SLVWD established deeper wells that produce an adequate groundwater quantity and quality from the underlying Lompico Sandstone.

Since 1990, groundwater levels in the Santa Margarita Sandstone have been relatively stable within the structural trough that extends north along the top of the Monterey Formation beneath Pasatiempo. The estimated volume of groundwater storage in the Pasatiempo Santa Margarita Sandstone is less than 3,000 AF.

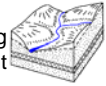
SLVWD's current Pasatiempo wells produce groundwater from the Lompico Sandstone, which is partially overlain by the Monterey Formation in the area. Well tests indicate that the Lompico Sandstone's productive aquifer zones are replenished by leakage from the overlying Santa Margarita Sandstone. This leakage must pass through the Monterey Formation, where present, and the uppermost units of the Lompico Sandstone. Since 2001, production from SLVWD's Pasatiempo wells has averaged about 250 gpm on a continuous basis.

MHA wells are located 400 to 2,000 ft north and northwest of the nearest SLVWD production well. The combined annual production of MHA wells has averaged about 120 gpm on a continuous basis since 2001.

Groundwater flow within the Lompico Sandstone is predominantly toward SLVWD and MHA production wells, and east and northeast toward the Camp Evers pumping depression. Static groundwater levels in SLVWD's two active Pasatiempo wells have declined about 130 ft since 1991, an average decline of about 8 ft/yr. The semi-confined Lompico Sandstone remains fully saturated at one SLVWD well and has partially dewatered at the other. The lowered groundwater levels result from the gradient needed to induce leakage from overlying zones, local groundwater production, and the gradient imposed by groundwater outflow to the Camp Evers pumping depression.

The water quality of the Santa Margarita and Lompico sandstone aquifers in the Pasatiempo subarea is generally good with low mineral concentrations. The generally similar water-quality of the two aquifers is consistent with the interpretation that groundwater in the Lompico Sandstone is derived largely from Santa Margarita Sandstone leakage.

The nearly 2-square-mile Pasatiempo subarea has roughly 3,000 AF of groundwater storage in the exposed Santa Margarita Sandstone, most of which occurs in the structural trough leading to Ferndell and Redwood springs. The volume of groundwater within the Lompico Sandstone underlying the



Pasatiempo subarea may approach roughly 10,000 AF assuming an average effective saturated thickness of 200 ft and a porosity of 6 percent. However, much of this occurs within deep, semi-confined and confined zones, and thus cannot be considered operable storage available for use during drought. Groundwater pumping has reduced groundwater storage by one to several thousand acre-feet in areas where the Lompico Sandstone has become less than fully saturated.

Developed aquifer zones within the **Camp Evers** subarea include the largely dewatered Santa Margarita Sandstone, the Lompico Sandstone, and sandstone interbeds within the Monterey and Locatelli formations. The Santa Margarita Sandstone directly overlies the Lompico Sandstone across much of southern Camp Evers, similar to the Pasatiempo subarea. The two sandstones are separated by an increasing thickness of Monterey Formation across the northern half of Camp Evers. Groundwater within the Santa Margarita Sandstone is unconfined whereas groundwater within deeper units tends to be partially to fully confined.

Groundwater originating from recharge, aquitard leakage, and subsurface inflow from adjoining subareas flows radially inward into the Camp Evers pumping depression. The influence of pumping wells on the pattern of groundwater flow is demonstrated by the control and interception of contaminant plumes by several of the major production wells, including the Mañana Woods well.

Groundwater levels within the Camp Evers pumping depression have declined as much as 150 ft since 1980. As a result, the Santa Margarita Sandstone is completely dewatered within much of the area. Groundwater levels are currently within the Lompico Sandstone at elevations below 325 ft msl near the pumping depression's center. Cemented zones within the Santa Margarita Sandstone and possibly alluvium appear to perch or mound shallow groundwater, which may help sustain Bean Creek baseflow despite the underlying pumping depression.

The Mañana Woods well operated by SLVWD in the Camp Evers area draws from the Lompico Sandstone. It produce at an average continuous rate of about 35 gpm during recent years. SVWD's Camp Evers wells have produced at a combined average rate of about 240 gpm since 2000. Additional users of Camp Evers groundwater include the Spring Lakes, Vista Del Lago, Valley Gardens, and Monteville developments, and groundwater remediation operations.

The natural quality of Camp Evers groundwater is good, with slightly higher concentrations of total dissolved solids than in the Quail Hollow, Olympia, and Pasatiempo subareas. However, Camp Evers groundwater has been significantly impacted by chemical releases from several facilities. Additionally, the influence of poor quality groundwater originating from the Monterey Formation has increased as groundwater levels have fallen.

Groundwater storage in the Santa Margarita Sandstone aquifer has declined by an estimated 7,000 to 8,000 AF in the Camp Evers and Pasatiempo subareas since the 1980s. Probably less than 2,000 AF of groundwater storage remains within the Santa Margarita Sandstone in the Camp Evers area.

Within the nearly 1-square-mile Camp Evers subarea, the volume of groundwater in the Lompico Sandstone is roughly 8,000 AF, assuming an average saturated thickness of 250 ft and a porosity of 6 percent. Groundwater pumping has reduced storage by as much as 2,000 AF in areas where the Lompico Sandstone appears to have become unconfined. The Camp Evers area also draws on groundwater stored in adjacent subareas.

Infrastructure and Operations

SLVWD's seven active production wells are summarized as follows:

Well Abbreviation	Well Nam	Date Drilled	Depths			Maximum Monthly Production			
			Completed Well	Sanitary Seal	Screened Interval (ft bgs)	(gpm)	(MG/mth)	(AF/mth)	(mth-yr)
QH-4A	Quail Hollow 4A	Jun-01	260	120	180 - 250	360	16	50	Jul-05
QH-5A	Quail Hollow 5A	Feb-00	174	112	124 - 164	185	8	25	Jul-05
Oly-2	Olympia 2	May-81	310	160	230 - 250	495	22	68	Aug-87
					280 - 300				
Oly-3	Olympia 3	Sep-90	310	160	230 - 300	430	19	59	Jul-93
Pas-6	Pasatiempo 6	Jul-90	790	381	560 - 580	285	13	39	Aug-05
					600 - 620				
					710 - 770				
Pas-7	Pasatiempo 7	Jul-90	540	260	380 - 440	280	12	38	Aug-92
					495 - 525				
MWd-2	Mañana Woods 2	Feb-88	380	160	190 - 210	60	3	8	Jul-06
					240 - 280				
					320 - 360				

Production from the Quail Hollow wells is often restricted by limited available drawdown given that pumping water levels are typically about 10 ft or more below the top of well screens and minimum pumping levels have been only a few feet above the suction intakes. Prior to 1995, SLVWD operated wells at three additional Quail Hollow locations. SLVWD is considering construction of a third Quail Hollow production well in the vicinity of Quail Hollow Ranch in order to minimize interference with the existing two active wells.

The pumping water levels of both of the active Olympia wells are sometimes drawn down below the top of their respective well screens. Minimum pumping water levels have been within 35 to 15 ft of the suction intakes. Minimum pumping levels in Pasatiempo Well 6 have remained more than 100 ft above the top of the well screens whereas minimum pumping water levels have come within 11 ft of the *bottom* of the Pasatiempo Well 7 screens. Its instantaneous pumping capacity of Mañana Woods Well 2 is about 130 gpm; water levels are commonly drawn down below the upper screened interval.

SLVWD's wells run automatically on demand as determined by water levels in certain storage units. Modest changes in discharge can be achieved manually by valving to adjust back pressure. For example, pumping rates can be reduced as water levels approach the suction intake; however, no power is saved.

The replacement of each well's pump and motor can be reasonably expected about every three years. However, earlier replacement is often required because of worse than expected wear resulting from power-supply irregularities and non-optimal pumping conditions. Downtimes associated with pump and motor replacement range from 3 to 5 days, or 1 to 2 days in an emergency.

Production from SLVWD's Quail Hollow wells is chlorinated at the wellhead as it is pumped directly into the distribution system. In addition to chlorination, production from the Olympia wells is treated at the wellhead for high iron and manganese by the addition of poly-phosphate. This method of treatment is suitable for combined iron and manganese concentrations of less than 3 mg/L; SLVWD Olympia well maximum is 1.7 mg/L. Because this treatment does not actually remove these minerals, the water still may have a metallic taste and the minerals may precipitate from the water once heated.

Chlorinated groundwater is pumped directly into SLVWD’s northern distribution system under pressure from 60 horse power (hp) pumps in each Olympia well, 20 hp Quail Hollow well pumps, and the two Quail booster pumps (700 gpm capacity). The Quail Hollow and Olympia wells are within the system’s Quail pressure zone and operate in response to water levels in the Quail tanks (capacity of 0.45 MG or 1.4 AF).

The need for additional groundwater production is indicated when storage in the Quail tanks declines below a threshold level. Production from the Olympia wells is constrained by the capacity of a segment of 6-inch pipeline along Quail Hollow Road that leads most directly to the Quail tanks.

The two Quail Hollow wells operate regularly throughout the dry season beginning when stream diversions decline to below Northern Service Area demand. The two Olympia wells operate when demand exceeds the combined production of stream diversions and the Quail Hollow wells; thus, their use is more seasonal and coincident with periods of peak demand.

Production from SLVWD's Pasatiempo wells is pumped directly into SLVWD's South System under pressure from the 60 hp pumps in each of the two wells. Production is chlorinated at the wellhead and treated with poly-phosphate for iron. Maximum untreated iron concentrations have reached 1.1 mg/L. As the sole water source for the South System, these wells operate throughout the year, and continuously during periods of high demand. Storage in the South System is limited to three tanks with 0.3 MG (0.9 AF) total capacity.

Groundwater pumped from the active Mañana Woods well is treated for volatile organic compounds using a series of three granular activated carbon (GAC) adsorption beds. The treatment capacity is 36.5 MG/yr, with a maximum daily rate of 0.17 mgd and a peak hourly rate of 130 gpm. The lead adsorption bed must be replaced three to nine times per year. The Mañana Woods water system currently remains separate from SLVWD’s South System.

Historical Groundwater Production and Water Levels

Recent average groundwater production from SLVWD wells is approximately as follows:

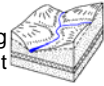
	Northern Area		Southern Area		SLVWD Total
	Quail Hollow	Olympia	Pasatiempo	Mañana Woods	
AF/yr	325	420	410	65	1,220
MG/yr	105	135	135	20	395

During drought periods, groundwater production in the Northern Service Area is about 10 to 15 percent greater than average due to reduced stream diversions. Whereas in the Southern Service Area, conservation causes production to be 10 to 20 percent lower than average during extended drought periods.

Approximate annual minimum and maximum production may be summarized as follows:

	Northern Area				Southern Area			
	Quail Hollow		Olympia		Pasatiempo		Mañana Woods	
	min.	max.	min.	max.	min.	max.	min.	max.
AF/yr	110	515	150	550	205	445	55	75
MG/yr	35	170	50	180	65	145	18	25
(year)	(1998)	(1980)	(1986)	(2001)	(1984)	(2002)	(2006-07)	(1999)

Recent average groundwater production by selected other major users in the area is as follows:



	Mt. Hermon Assoc.	Hanson Quarry (pre-2004)	SVWD			
			Camp Evers	Scotts Valley	N. Scotts Valley	Total
AF/yr	195	350	380	590	950	1,920
MG/yr	65	115	125	190	310	625

Other groundwater producers include Spring Lakes, Vista Del Lago, Montevalle, Valley Gardens, and several remediation sites, all of which are in the Camp Evers area.

Annual groundwater production by SLVWD's Quail Hollow and Olympia wells has cycled up and down since the 1980s, whereas groundwater production by SLVWD's Pasatiempo wells has trended upward. The majority of SVWD's groundwater production has shifted northeastward as Scotts Valley water demand increased and groundwater levels declined.

Since the 1980s, static groundwater levels have trended both up and down in the Quail Hollow production wells, declined slightly in the Olympia production wells (~1 ft/yr), and declined significantly in SLVWD's Pasatiempo production wells (6 to 8 ft/yr) and the Mañana Woods and other Camp Evers production wells (~6 to 15 ft/yr). Pumping levels in SVWD's north Scotts Valley wells have declined at even greater rates (>20 ft/yr).

SLVWD relies on its Quail Hollow wells during a greater portion of time than its Olympia wells, due in part to the more favorable quality of Quail Hollow groundwater. Also, years of peak Quail Hollow production have generally occurred during or immediately following average to wet periods. During dry years, when SLVWD relies most on production from groundwater storage, Quail Hollow production rates have declined due to falling water levels. Efforts to save more Quail Hollow groundwater for drought periods might be offset partially by increased losses to springs and streams. Strategies for optimizing Quail Hollow groundwater storage and production during expected climatic cycles can be explored using SLVWD's Quail Hollow groundwater model. Distributing production to a third active well would reduce drawdown in the existing wells, help sustain production during sustained drought conditions, and possibly increase the sustainable average rate of production.

Annual water-level fluctuations in the Olympia production wells are relatively small considering that peak seasonal production is nearly twice that of the Quail Hollow wells. During the 1987-94 drought, groundwater levels remained fairly constant while production ranged from about 300 to 500 AF/yr (100 to 165 MG/yr), indicative of the area's favorable groundwater storage and relatively high transmissivity. Although highly variable from year to year, production from the Olympia wells has been trending upward by about 3 AF/yr (1 MG/yr), on average, indicating that these wells help satisfy the long-term increase in Northern Service Area water demand. Fairly stable Olympia groundwater levels suggest that long-term average production equal to or greater than 400 AF/yr (130 MG/yr) is sustainable.

Water levels of SLVWD's Pasatiempo wells have a complex and varied history as influenced by multiple aquifer zones and proximity to other groundwater pumping in the Pasatiempo and Camp Evers areas. Total production from the Lompico Sandstone in the Pasatiempo area roughly doubled between the late 1980s and the early 2000s, resulting in fairly steady water level declines in all Lompico Sandstone wells. Since 1984, production from SLVWD's Pasatiempo wells has trended upward by an average of approximately 11 AF/yr (3.5 MG/yr) and now total about 350 to 450 AF/yr (115 to 150 MG/yr). Meanwhile, total recorded pumping in the Pasatiempo, Camp Evers, and Scotts Valley areas increased by about 100 AF/yr (33 MG/yr) between the mid-1970s and the early 2000s, reaching a peak of more than 3,000 AF/yr (1,000 MG/yr). Cessation of quarry pumping and reductions in municipal production during wet 2005-06 have contributed to some recent stabilization

of water levels. Whether or not SLVWD's current rates of production from its Pasatiempo wells are sustainable under future average and drought conditions is uncertain.

Groundwater production in the Camp Evers area increased substantially after SVWD construction two wells in 1980. By the early 1990s, production by SVWD in Camp Evers was about 2.5 times greater than SLVWD production in Pasatiempo, and about 1.5 times greater than SLVWD and Mount Hermon Pasatiempo production combined.

Pumping from SLVWD's Pasatiempo and Mañana Woods wells has averaged roughly 17 percent of total recorded production in the Pasatiempo, Camp Evers, and Scotts Valley areas. This percentage is smaller if production by other private wells is included. Although Pasatiempo and Camp Evers water levels appear to have stabilized in recent years, the water level history and long-term increase in total pumping suggest that additional water-level declines may occur as the regional aquifer continues to adjust to these conditions.

It is possible that Pasatiempo and Camp Evers groundwater levels may stabilize as a result of Hanson Quarry closure and reduced production from SVWD wells. Although groundwater storage has been reduced significantly since the 1980s, groundwater gradients may now be sufficient to sustain groundwater flow to major pumping wells without significant further declines in water levels.

Produced Groundwater Quality

The quality of water pumped from wells typically represents a blend of multiple groundwater zones. The overall mineral concentration, ionic water type, and constituents of concern for each well group may be summarized as follows:

Groundwater Subarea	SLVWD Wells	TDS (mg/L)	Water Type	Detected Constituents of Concern	Treatment (other than chlorination)
Quail Hollow	QH-4A & -5A	very low 70-130	calcium-bicarbonate	QH-5A: nitrate, trace TCE, MTBE	none
Olympia	Oly-2 & -3	moderate to moderately high 300-600	calcium-sulfate	iron, manganese, sulfate, TDS	phosphate, blending
Pasatiempo	Paso-6	very low ~100	calcium-bicarbonate	iron, arsenic	phosphate, blending
	Paso-7		sodium-bicarbonate	none	none
Mañana Woods	MWd-2	moderate 400	calcium-sulfate	benzene, MTBE, & trace of other gasoline compounds	GAC package plant

Nitrate concentrations trended upward in several of SLVWD Quail Hollow wells from the 1970s through the early 1990s. This has been correlated to the number of septic tanks in each well's capture zone. Nitrate concentrations have been fairly stable in recent years, averaging less than 3 mg/L in QH-4A and about 11 mg/L in QH-5A. Concentrations have the potential to spike again to previous peak levels.

The solvent trichloroethylene (TCE) has been detected in groundwater pumped from QH-5 and QH-5A since 1994. Concentrations have been generally below the 5 µg/L MCL and appear to be declining. The TCE probably originated from spills or septic-tank disposal of cleaning products by one or more local residences.

In 2006, the gasoline additive methyl tert-butyl ether (MTBE) was detected at concentrations up to 1.6 µg/L in seven monthly samples of QH-5A discharge. The California primary and secondary MCLs for MTBE are 5 and 13 µg/L, respectively. The MTBE may have originated from residential automobile maintenance and may be linked to the TCE source.

Groundwater produced from SLVWD’s Olympia wells is hard with moderate TDS concentrations and elevated concentrations of sulfate, iron, and manganese. About 300 ft apart, the two wells roughly split the radial groundwater flow into their essentially shared pumping depression. As such, Olympia Well 2 receives low-TDS groundwater flow from the south and southwest and Olympia Well 3 receives more mineralized groundwater from the east and northeast. Groundwater from SLVWD's Olympia wells has concentrations of iron and sulfate that approach and sometimes exceed secondary drinking water standards and manganese concentrations nearly always above the secondary standard. In response, SLVWD introduces a poly-phosphate additive to the discharge at each wellhead to bring iron and manganese concentrations into compliance. These and other groundwater quality concerns (e.g., hardness, taste, and order) are also addressed through the blending that occurs in the Quail tanks and elsewhere in the system. The Olympia wells are not impacted by high nitrate, consistent with the small amount of development in the subarea.

Concentrations of iron in groundwater produced from Pasatiempo Well 6 range up to 1 mg/L, typically exceeding the secondary standard of 0.3 mg/L. SLVWD introduces poly-phosphate into the flow at the Pasatiempo Well 6 wellhead in order to achieve compliance with the iron standard. Groundwater pumped from SLVWD's Pasatiempo wells does meet the secondary standard for manganese.

The federal MCL for arsenic was lowered from 50 to 10 µg/L in 2006. During that year, arsenic concentrations in water produced from Pasatiempo Well 6 ranged from 6 to 11 µg/L, sometimes exceeding the MCL. Compliance with the standard is achieved through blending with production from Pasatiempo Well 7, which has arsenic concentrations ranging from 1 to 3 µg/L.

Groundwater TDS concentrations in the Camp Evers area range from 100 to 1,000 mg/L. Groundwater produced from the Mañana Woods well has a TDS of approximately 400 mg/L and acceptable concentrations of iron, manganese, nitrate, and arsenic. However, it intercepts one or more VOC-contaminant plumes, as do other wells in the Camp Evers area. Groundwater produced from Mañana Woods Well 2 is run through a granular activated carbon (GAC) treatment system to reduce VOC concentrations to below MCLs.

The following VOCs were detected in groundwater pumped from Mañana Woods Well 2 in 2007:

VOCs Detected in MWd-2 Prior to Treatment	2007	MCL
	(µg/L)	
benzene	5.8	1 primary
MTBE	37	5 secondary
		13 primary
ethylbenzene	0.1	300 primary
tertiary butyl alcohol	5.0	not established
toluene	0.6	150 primary

These chemicals derive from gasoline and its breakdown products. Mañana Woods Well 2’s GAC treatment system was constructed and now operates through a settlement with by the responsible companies. This treatment system reduces contaminant concentrations to below MCLs. It is included in SLVWD’s annexation of the Mañana Woods system.

Groundwater Management and Protection

Drinking Water Source Assessment and Protection (DWSAP) reports have been prepared for each active SLVWD well as mandated by the California Department of Health Services. These reports delineate each well's area of contributing groundwater flow and recharge (i.e., capture zone) and identify potential contaminating activities within them.

SLVWD's Quail Hollow, Olympia, and Pasatiempo wells are susceptible to the effects of potential landuse changes associated with closing quarries. Quarry closures could significantly alter patterns of runoff, evapotranspiration, and percolation. On-site runoff retention may no longer be required and the regrading of stockpiled fine-grained material could reduce the percolation of rainfall and runoff.

Production Potential

Estimates of groundwater storage and production from SLVWD active wells may be summarized as follows:

Groundwater Subarea	Aquifer	Storage		Average Recharge	Subsfc. Inflow	SLVWD Production			
		Total*	Change			Average		Maximum	
		(AF)		(AF/yr)		(AF/yr)	(MG/yr)	(AF/yr)	(MG/yr)
Quail Hollow	S. Margarita	14,000	±5,000	~4,000	0	300+	100+	517	168
Olympia		29,000	?	~2,000	0	400+	130+	550	179
Pasatiempo	S. Margarita	<3,000	-8,000	~1,800	0	<400	<130	444	145
	Lompico	~10,000							
Camp Evers	S. Margarita	~2,000		500	~500	50+	17+	51	17
	Lompico	~8,000	-2,000						
Mission Springs	S. Margarita	17,000	?	900	~300	0	0	0	0

SLVWD's Quail Hollow wells provide a reliable summer water supply during average and wet years, and a diminished water supply during drought, with an average annual production of 300 to 400 AF/yr (100 to 130 MG/yr). Optimization of the Quail Hollow groundwater supply might require reduced production during some years in order to sustain higher production during drought. Currently, the wellfield is not operated this way because of the preferred quality of Quail Hollow groundwater compared to that produced from SLVWD's Olympia wells.

SLVWD's Olympia wells provide a dependable supply of relatively low quality groundwater compared to its other sources, in large part due to the subarea's relatively large volume of groundwater storage and long groundwater residence times. Average and drought-year production exceeding 400 and 500 AF/yr (130 and 160 MG/yr), respectively, appears sustainable. Greater production could be achieved with increased pumping and treatment capacity, although a long-term imbalance with groundwater inflows could occur unless recharge was somehow augmented. Optimization of the Olympia groundwater supply may require increased treatment capacity and a reduced need for blending.

SLVWD may be able to sustain its more than 400 AF/yr (130 MG/yr) of groundwater production from the Pasatiempo subarea for a number of years. However, historical trends suggest that total production rates from Pasatiempo and the adjoining Camp Evers subarea may not be sustainable, such that supplemental sources and/or reduced production may become necessary.

Similar to the Pasatiempo subarea, groundwater levels in the Camp Evers subarea appear to have stabilized in recent years, in large part due to decreased total production. As such, production from SLVWD Mañana Woods well appears generally sustainable at its relatively modest current rate of 50

to 60 AF/yr (16 to 20 MG/yr). This rate of production reflects recent reductions in demand following SLVWD's metering of each Mañana Woods connection. Continued treatment for VOC contamination in Mañana Woods Well 2 produced groundwater will be needed for the foreseeable future.

Potential Other Sources

Other sources of water potentially available to SLVWD include SLVWD's existing entitlement to a portion of the raw-water yield from Loch Lomond reservoir or an equivalent amount of finished-water purchased from the Santa Cruz City Water Department (SCCWD). Significant use of recycled water is infeasible because San Lorenzo Valley lacks centralized wastewater collection and treatment. Existing on-site wastewater disposal contributes significantly to soil moisture and stream baseflow, however.

Loch Lomond Reservoir

In 1958, SLVWD sold 2,500 acres of its property in the vicinity of the Newell Creek watershed to the City of Santa Cruz with the agreement that SLVWD would be entitled to purchase 12½ percent of the annual safe yield from a future Newell Creek reservoir, up to a maximum of 500 AF/yr. This percentage was roughly equivalent to the portion of the reservoir project area owned by SLVWD.

The City created Loch Lomond Reservoir with the completion of Newell Creek Dam in 1960. The drainage area above the dam is approximately 8.3 square miles. The reservoir capacity was recently estimated at about 9,000 AF. At capacity, the reservoir has a water surface area of about 180 acres and a length of up to 3 miles. Impounded water first ran over the spillway in March 1963.

Based on the 1958 agreement, SLVWD began receiving deliveries of Loch Lomond water from the City in 1963. In 1965 SLVWD constructed the Glen Arbor treatment plant for treating its Loch Lomond deliveries.

The City stipulated in 1965 that SLVWD was entitled to 313 AF/yr (102 MG/yr), or 12.5 percent of 2,500 AF/yr. This was based on Loch Lomond's estimated annual yield of 3,230 AF/yr minus the required constant release of 1 cfs (724 AF/yr).

The only record of Loch Lomond deliveries to SLVWD is for 1976-1977. Monthly deliveries to SLVWD ranged from 4 to 60 AF/month (1-20 MG/month). Total deliveries for the year were 353 AF/yr (115 MG/yr).

Toward the end of the 1976-77 drought the City lowered SLVWD's allocation first to 165 AF/yr and then to 250 AF/yr. This in turn led to several years of water-right disputes, ending in 1981 when SLVWD began developing its Olympia wellfield as an alternative supplemental supply. Since then, SLVWD has lacked the infrastructure to treat Loch Lomond water in compliance with current federal standards. Thus, SLVWD has not included Loch Lomond among its active water supply sources.

In 1996 the City provided SLVWD with a draft agreement that (a) acknowledged SLVWD's right to purchase 313 AF/yr (102 MG/yr) of raw Loch Lomond water and (b) offered to sell SLVWD the same amount of treated City water with the exception that it would be interruptible during declared water-shortage emergencies.

System Production

The actual potential supply provided by SLVWD's individual sources relies on their conjunctive use within the constraints of the climatic cycle and existing and planned infrastructure.

Existing and Planned System Infrastructure and Operation

The SLVWD water distribution system consists of 22 individual pressure zones within the North System, 2 pressure zones in the South System, and the Mañana Woods system. The 23 storage facilities supplying the North System have a combined capacity of approximately 8 MG or 25 AF. Nearly 90 percent of this total is provided by the 8 largest facilities, those with capacities greater than 200,000 gallons each. The South System is served by three tanks with a combined capacity of 0.3 MG or 0.9 AF. The District's constructed storage capacity is small relative to its rate of use. Storage equals about five times mean daily production in the North System and only one day's production in the South System. These low storage-to-use ratios illustrate the District's reliance on groundwater storage whenever direct stream diversions are insufficient. The storage capacity of the North System is of practical use to the District for helping to avoid diversions when stream turbidities are highest and seasonal demand is low.

The scale and complexity of SLVWD's water distribution system reflect the San Lorenzo Valley's demanding geography with regard to topography, patterns of development, and distribution of raw water sources. In addition to gravity flow from the Lyon WTP and pumping wells, the District employs 24 booster-pump stations to distribute water among the 22 North-System pressure zones. Water distribution among the southern system's two pressure zones requires a single booster station.

A key aspect of the North System is its capacity to reverse gradient as a function of seasonal changes in raw water supplies. During the wet season, the entire North System is supplied by stream diversions from the Lyon WTP. During dry conditions, a large portion of system demand is supplied by the Quail Hollow and Olympia wells near the southeastern, downgradient end of the system. The District acknowledges and intends to address distribution constraints that limit its ability to optimally convey treated water within the North System in response to seasonal water-supply availability and demand.

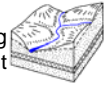
Typically, SLVWD operates the Olympia wells only when the combined production from stream diversions and the Quail Hollow wells is insufficient for maintaining adequate storage within the North System's storage facilities south of Boulder Creek.

SLVWD draws on storage within its North System to help limit the diversion of turbid stormflows. Additionally, SLVWD draws down on its North-System storage during some dry-season periods of peak demand when available sources cannot maintain constant storage. Given the system's limited storage capacity, such conditions can only be successfully handled for up to several days at a time.

North-South System Intertie

The concept of an intertie between SLVWD's North and South Systems stems from recognition of the following water-supply conditions:

- Static groundwater levels in SLVWD's Pasatiempo wells have fallen 150 feet since 1985. The sustainability of the current rate of production is uncertain.
- Potential stream diversions in excess of current North-System demand are estimated to average about 170 AF/yr (56 MG/yr) and range up to 200 AF/yr (65 MG/yr)—assuming repetition of the 1984-2006 climatic cycle with the existing diversion and WTP capacity.
- SLVWD has the right to purchase 313 AF/yr (102 MG/yr) of raw water from Loch Lomond reservoir.



An intertie between the North and South Systems would allow deliveries of excess available stream diversions and Loch Lomond water to the Southern Service Area to offset apparent over pumping in the groundwater subarea encompassing the District's Pasatiempo wells. Under current levels of seasonal demand, the Southern Service Area could utilize about 75 AF/yr (25 MG/yr) on average, ranging from 0 to 100 AF/yr (33 MG/yr). Maximum year conveyance to the South System via an intertie potentially could reach 250 AF/yr with access to excess available stream diversions and diversions from Loch Lomond under projected future demand. This would require maximum monthly conveyance of 35 AF, equivalent to average continuous rates of 260 gpm or 0.38 mgd. The feasibility and actual amount of needed instantaneous conveyance capacity has not been estimated, and a formal conceptual design for a North-South Intertie has not been prepared.

The North-South Intertie concept has the following caveats:

- Estimated amounts of stream diversion potentially available for conveyance to the Southern Service Area are relatively small compared to the total estimated volume of diversions. Thus, there is a proportionately higher degree of uncertainty associated with these relatively small amounts of potentially excess available diversions (i.e., they are roughly similar to the potential margin of error).
- On average, about 90 percent of the estimated available diversions occur from December through April. Actualizing these diversions requires the system to operate at near capacity during the wettest months, including storm periods.
- Excess diversions available to the Southern Service Area are highly variable, equaling 10 percent or less of annual demand during about 35 percent of all years, and up to 30 percent of annual demand during other years.

Loch Lomond Diversion

SLVWD is entitled to 313 AF/yr (102 MG/yr) of Newell Creek streamflow stored in Loch Lomond, or an equivalent amount of treated water, purchased from the City of Santa Cruz. Delivery of treated water, however, would be interruptible during declared water-shortage emergencies. SLVWD's maximum seasonal need from a supplemental source of water such as Loch Lomond could range up to 80 AF/month, equal to a continuous rate of nearly 600 gpm or 0.85 mgd. A conceptual design for the diversion, treatment, and conveyance of Loch Lomond water within the SLVWD system has not been prepared.

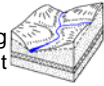
Expanded Groundwater Production Capacity and Treatment

SLVWD is considering construction of an additional production well in the Quail Hollow area so as to regain the capacity it had previously from multiple area wells. Furthermore, hydrogeologic conditions indicate that additional groundwater production capacity could be developed in the Olympia area. Such new wells could improve pumping performance and enhance production capacity. However, whether or not such wells would provide a significant supply increase is unlikely in the case of Quail Hollow and uncertain in the case of Olympia. Increased groundwater production from the Olympia area probably would require increased treatment capacity for iron and manganese.

Past and Current Conjunctive Use

Conjunctive use refers to the optimized, sustainable use of multiple sources of water throughout annual and long-term climatic cycles. Access to both stream diversions and groundwater allows SLVWD to practice conjunctive use in its Northern Service Area. Factors controlling this practice include:

- The seasonal and year-to-year variability of streamflows available for diversion.



- Limited surface-water storage (equal to only a few days' average use).
- Rates of groundwater extraction that can be sustained by the volume of useable groundwater storage and average rate of recharge.
- The limited availability of supplemental water sources.

Past and current infrastructure does not allow for conjunctive use in the Southern Service Area or Mañana Woods, which instead rely solely on groundwater.

The District's recent and historical use of surface-water and groundwater supplies may be summarized approximately as follows:

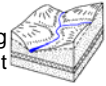
	<u>Annual Production (AF/yr)</u>	
	<u>2000-08</u>	<u>1984-2008</u>
	<u>Average</u>	<u>Range</u>
<u>Northern Service Area</u>		
Stream Diversions	935	500 - 1,200
Foreman, Peavine, & Silver Cks	660	305 - 955
5-Mile Pipeline (Clear & Sweetwater Cks)	275	90 - 380
Groundwater	760	330 - 1,000
Quail Hollow Wells	315	125 - 515
Olympia Wells	450	170 - 555
North System Total	1,700	1,330 - 1,800
<u>Southern Service Area</u>		
Pasatiempo Wells	410	205 - 445
<u>Mañana Woods</u>	50	(data unavailable)
<u>SLVWD Total</u>	2,120	1,595 - 2,210

Since 2000, total stream diversions have averaged 935 AF/yr (305 MG/yr) and groundwater pumping from the North and South System wells has averaged 760 and 410 AF/yr (250 and 135 MG/yr), respectively. Since SLVWD annexed the Mañana Woods system in 2006, groundwater production has been about 50 AF/yr (17 MG/yr). Total SLVWD production has ranged from approximately 1,600 to 2,200 AF/yr (520 to 720 MG/yr) since 1984 and has averaged 2,120 AF/yr (690 MG/yr) since 2000.

Since 1984, SLVWD's North System has obtained an average of 55 percent of its annual water supply from stream diversions and 45 percent from groundwater pumping. During any given year, stream diversions have supplied between 35 and 80 percent of North System demand, whereas groundwater has supplied between 20 and 65 percent annually. The complimentary use of these sources has resulted in a relatively smooth upward trend in total North System use since 1984.

The effective yield of SLVWD's North System is largely controlled by its ability to divert available streamflows. The North System is estimated to use 80 percent of available diversions, on average, and never less than 70 percent. When streamflows are limited by season or drought, SLVWD meets its North System water demand by pumping more from groundwater storage. Under sustainable conditions, groundwater storage is allowed to recover at times when streamflow and recharge are plentiful and demand is lower. During all years, groundwater satisfies at least 20 percent of North System demand and is currently the only supply that ensures North System demand can be met under most expected conditions.

To date, SLVWD's groundwater extractions from its Quail Hollow and Olympia wells have not resulted in substantial net declines in groundwater levels. This suggests that the average yields of the Quail Hollow and Olympia wellfields are sustainable at somewhat more than 300 and 400 AF/yr (100 and 135 MG/yr), respectively, given the current configuration of wells.



SLVWD's stream and groundwater sources have been in balance with demand when averaged over the past 2½ decades. However, as droughts of historical or worse magnitude occur under current and increasing rates of demand, it appears that SLVWD's North System will require some type of supplemental supply combined with increased conservation.

The groundwater levels of aquifers supplying the South System, Mañana Woods, and surrounding areas of Camp Evers and Scotts Valley have declined significantly since the mid-1980s. These aquifers comprise the sole potable water source for these communities. The ongoing sustainability of SLVWD's recent average rate of extraction from its Pasatiempo wells, slightly more than 400 AF/yr (135 MG/yr), is questionable.

Production from the Mañana Woods well, about 50 AF/yr (17 MG/yr), appears relatively sustainable given that other area wells pumping at substantially higher rates (e.g., SVWD wells 9 & 10) will experience declines in production first as a result of depressed groundwater levels. Santa Cruz County has obtained State funding to study potential conjunctive-use solutions to the Scotts Valley area's water supply deficit.

Potential Future Conjunctive Use

SLVWD's ability to meet expected future water demand through future climatic cycles will depend on the optimal conjunctive use of its available supplies throughout its served area.

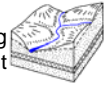
Estimates of SLVWD's potential for future conjunctive is a function of the following assumptions:

- Average demand projected for 2030, varied annually as a function of an assumed climatic cycle.
- Streamflows available for diversion, as estimated for the 1985-2008 climatic cycle.
- Sustainable rates of groundwater production from the current Quail Hollow and Olympia wellfields, as indicated by historical record.
- A goal of lowering production from the Pasatiempo wellfield as needed to stabilize and partially recover groundwater levels.
- The potential for an intertie between the North and South systems.
- The potential to obtain water from the City of Santa Cruz under SLVWD's right to up to 313 AF/yr of Newell Creek streamflow stored in Loch Lomond.

SLVWD's estimates of 2030 demand reflect significant expectations for improved water-use and conveyance efficiency as a result of reductions in system losses and per-connection usage.

The climatic cycle of the past several decades is well supported by the available data record and encompasses a wide range of drought and wet-period conditions. Although worse droughts have occurred, their rainfall and streamflow records are deficient. The future, local consequences of global climate change are poorly understood. For these reasons, the goal of this study has been to establish a firm estimate of SLVWD's future water supply as constrained by the climatic cycle of the past several decades. Because this has been a period of ongoing development and growth in water demand, it is important to evaluate the entire period against projected future demand. With this as a benchmark, subsequent analysis can evaluate the potential impacts of climate change to SLVWD's water supply as projections suitable for planning purposes become available.

SLVWD's water-demand response to the climatic cycle includes increased water use during single dry years, at the beginning of a drought, and one or two years following the end of a drought; and decreased water use during wet years and in response to requests for conservation during extended drought. Annual water demand is assumed to fluctuate ± 5 percent from projected 2030 demand in



response to the climatic cycle. Under these assumptions, the cumulative response to a drought is a water-use reduction of up to 10 percent.

In this assessment, the potential contribution of each SLVWD wellfield to future production demand is limited by maximum-monthly and sustainable-average pumping rates inferred from the historical record. As a base case, groundwater is assumed to contribute the following amounts once North System demand exceeds available stream diversions:

- Quail Hollow wellfield – maximum production of 35 AF/month (2.8 mgd or 260 gpm continuously) while maintaining average annual production of about 300 AF/yr (100 MG/yr).
- Olympia wellfield – maximum production of 75 AF/month (6 mgd or 560 gpm) once Quail Hollow wellfield reaches its maximum, while maintaining average annual production of about 400 AF/yr (135 MG/yr).

An alternate case allows higher pumping rates during dry periods offset by supplemental water use during wet periods.

Without any supplemental source, 2030 average demand in the Southern Service Area will require production of 440 AF/yr (145 MG/yr) from the Pasatiempo wells, a rate that currently does not appear sustainable. To the extent that one or more supplemental sources of water become available to the Southern Service Area, it is assumed that the Pasatiempo wellfield would benefit from a production rate roughly 100-AF/yr lower than projected for the purpose of sustainability.

An intertie between the North and South Systems would allow delivery of excess available stream diversions, and a portion of SLVWD's entitlement to Loch Lomond, to the Southern Service Area. This would help offset apparent groundwater overdraft in the subarea encompassing SLVWD's Pasatiempo wells. This analysis considered intertie conveyance rates up to approximately 40 AF/month (equivalent to continuous rates of 0.43 mgd and 300 gpm).

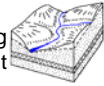
Use of SLVWD's entitlement to a portion of the yield of Loch Lomond is considered with and without a North-South Intertie in the analysis of potential future conjunctive use. Use rates up to a maximum of about 80 AF/month (0.85 mgd or 600 gpm continuous) are considered, although the feasibility of treating, conveying, and integrating this source into SLVWD's existing system has not been evaluated.

Historical levels of mainly voluntary conservation during drought are incorporated into the assumptions of demand variability described above. In the evaluated scenarios, higher levels of mandatory conservation are interchangeable with supplemental water use. In other words, the estimated need for supplemental water is equivalent to the amount of conservation needed if no supplemental source is developed. A more thorough analysis of conservation and demand management is beyond the scope of this report but needs to be addressed in subsequent work.

Alternate 2030 Conjunctive-Use Scenarios

Two conjunctive use scenarios under 2030 demand conditions are evaluated, referred to as Scenarios A and B. Both consider a North-South Intertie and access to a "supplemental" source of water, i.e., Loch Lomond. Scenario A uses supplemental water only when needed by the North System, whereas Scenario B is a trial-and-error optimization of all sources for both systems. Each scenario represents multiple subscenarios given the exchangeability of additional conservation and/or increased groundwater production (including overdraft) for a North-South Intertie and supplemental source of water. The two scenarios are further defined as follows:

- **Scenario A** – SLVWD has the option to utilize a supplemental supply when its North System is otherwise unable to fulfill demand under the constraints of sustainability. The North-South



Intertie is used to convey excess available stream diversions to the South System. In this base case, groundwater production by the District's three wellfields is as described above. Under worst-case drought conditions, purchases of supplemental water from the City of Santa Cruz could be interrupted at times when SLVWD needs it most.

- **Scenario B** – SLVWD routinely accesses a supplemental water supply for (a) “in-lieu” groundwater recharge⁵ in both Service Areas and (b) when needed to meet North System demand. This has the advantage of exercising a portion of SLVWD’s entitlement to Loch Lomond during periods when deliveries from the City of Santa Cruz are much less likely to be interrupted. In this case, the North-South Intertie delivers supplemental water as well as excess available stream diversions to the South System. In-lieu recharge allows higher monthly production rates from the wellfields during dry periods.
 - Supplemental water of up to 20 AF/month (0.21 mgd or 150 gpm continuously) for in-lieu recharge in each of the North and South Systems during non-stormflow months of years with above average rainfall. These conditions represent times when SLVWD demand is above seasonal lows, SLVWD stream diversions are below peak levels, and deliveries from Loch Lomond may be most feasible.
 - Quail Hollow wellfield – supply demand in excess of diversions up to a maximum of 47 AF/month (0.5 mgd or 350 gpm) during dry years; up to 20 AF/month (0.21 mgd or 150 gpm) during other years; average annual production maintained at about 300 AF/yr (100 MG/yr).
 - Olympia wellfield – supply demand in excess of diversions and Quail Hollow production up to a maximum of 80 AF/month (0.86 mgd or 600 gpm) during dry years; 60 AF/month (0.64 mgd or 445 gpm) otherwise; maintain average annual production at about 400 AF/yr (135 MG/yr).

These scenarios are evaluated on a monthly basis. This monthly time-step analysis is essential to an accurate assessment of conjunctive-use feasibility.

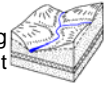
Scenario A: North-South Intertie and Supplemental Source for North System

Under this scenario:

- The North System requires a supplemental source and/or additional conservation⁶ when assumed maximum rates of wellfield production do not satisfy demand during the dry-season months of greater than half of all years. This has the disadvantage of relying on Loch Lomond as a supplemental source of last resort during drought when competition for stored water is greatest and deliveries from the City may be interrupted.
- During wet-periods, excess available streamflow diversions are conveyed to the South System via the North-South Intertie, allowing the complete resting of the Pasatiempo wellfield during some wet-season months of more than half of all years. Without the Intertie, the sustainability of groundwater supplies in the vicinity of the Pasatiempo wellfield would be further threatened by increased South System demand and production in 2030.
- Maximum monthly conveyance of excess available stream diversions via the North-South Intertie is 32 AF/month, equivalent to 0.34 mgd or 240 gpm. Instantaneous rates would be significantly larger but have not been estimated or evaluated for conveyance feasibility.

⁵ In-lieu recharge refers to the direct use of an alternative water supply in lieu of pumping groundwater.

⁶ Additional in the sense that up to 10 percent conservation is already factored into the assumed variation in demand as a function of the climatic cycle.



- The maximum monthly use of supplemental water is 65 AF/month, equivalent to 0.70 mgd or 485 gpm. Again, the instantaneous rates would be larger but have not been estimated or evaluated for conveyance feasibility.

On an annual basis, the average and range of water-supply contributions from each source under Scenario A are as follows:

	<u>2030 Demand</u>	
	<u>Scenario A, 1985-2008</u>	
	<u>AF/yr</u>	
<u>Northern Service Area</u>	<u>Average</u>	<u>Range</u>
Production Demand	1,760	1,660 - 1,835
Stream Diversions	960	535 - 1,385
Groundwater	710	340 - 1,010
Quail Hollow Wells	310	235 - 405
Olympia Wells	400	100 - 640
Add'l Conservation / Supplemental Source	90	0 - 265
<u>Southern Service Area</u>		
Production Demand	440	415 - 460
Pasatiempo Wells	440	415 - 460
Pasatiempo Wells If Intertie	365	285 - 460
Stream Diversions Via Intertie	75	0 - 140
<u>Mañana Woods Well</u>	60	55 - 65
<u>Total Production Demand</u>	2,260	2,132 - 2,355
Total Stream Diversions	1,035	535 - 1,505
Total Groundwater	1,135	685 - 1,515
Total Add'l Conservation/Supplemental Source	90	0 - 265
Unused Divertible Streamflows	65	0 - 125
Unused Loch Lomond Entitlement	225	50 - 315

The results of Scenario A are summarized on an annual-percentage basis and discussed as follows:

- Use of a supplemental source and/or additional conservation provides 5 percent of North System demand on average, ranging from zero to 14 percent. As a result, production from the Quail Hollow and Olympia wellfields provides 5 percent less of the North System supply, on average, compared to historical averages.
- If the entire need for supplemental water were offset by additional conservation, this would represent average and maximum conservation increases of approximately 5 and 15 percent of the water supply, over and above as much as 10 percent of drought conservation already factored into the 2030 demand projections.
- Excess available streamflow diversions delivered via a North-South Intertie provide 16 percent of South System demand on average, ranging from zero to 33 percent, with a corresponding decline in Pasatiempo wellfield production.
- On average, the North and South Systems under Scenario A use 95 percent of available stream diversions, whereas historically the North System has utilized only 80 percent. One quarter of this increase is due to greater North System demand in 2030, with the remainder a result of the Intertie.
- The use of a supplemental water source averages 28 percent of SLVWD's entitlement to Loch Lomond, ranging up to 84 percent of the entitlement in some years. As mentioned above, the potential disadvantage of this scenario is that it relies on Loch Lomond as a supplemental source of last resort during drought when competition for stored water may be greatest and deliveries from the City could be interrupted.

- Groundwater pumping for Mañana Woods represents 3 percent of total system production.

Scenario B: North-South Intertie and Supplemental Source for North and South Systems

Under this scenario:

- The North System receives a supplemental source as both (1) in-lieu recharge during non-drought years and (2) a source of last resort during drought. As a result, the Quail Hollow and Olympia wellfields are able to produce at higher peak-month rates. This has the advantage of using some of SLVWD's Loch Lomond entitlement when both supply and demand are adequate, and reducing usage during drought when competition for stored water is greatest and deliveries from the City of Santa Cruz may be interrupted.
- Via the North-South Intertie, the South System receives (1) excess available streamflow diversions and (2) supplemental water (i.e., from Loch Lomond), both of which constitute in-lieu recharge by allowing the Pasatiempo wellfield to recover. Whereas the conveyed stream diversions offset some wet-season pumping, the delivered supplemental water offsets dry-season pumping during years of above average rainfall.
- Maximum monthly conveyance via the North-South Intertie increases to 35 AF/month. Equivalent continuous rates are 0.38 mgd or 260 gpm; however, actual instantaneous rates would be greater and have not been estimated.
- The maximum monthly use of supplemental water is 80 AF/month, equivalent to 0.84 mgd or 585 gpm.

On an annual basis, the average and range of water-supply contributions from each source under Scenario B are as follows:

	2030 Demand Scenario B, 1985-2008	
	Average	Range
<u>Northern Service Area</u>		
Production Demand	1,760	1,660 - 1,835
Stream Diversions	960	535 - 1,385
Groundwater	660	225 - 1,105
Quail Hollow Wells	300	145 - 515
Olympia Wells	365	80 - 605
Supplemental Source	130	17 - 305
In-Lieu Recharge	50	0 - 160
Add'l Conserv. / Deficit Makeup	80	0 - 205
<u>Southern Service Area</u>		
Production Demand	440	415 - 460
Pasatiempo Wells	440	415 - 460
Pasatiempo Wells If Intertie	335	170 - 460
Stream Diversions Via Intertie	75	0 - 140
Add'l Conserv./Supplemental Source	35	0 - 125
Total Intertie	105	0 - 255
<u>Mañana Woods Well</u>	60	55 - 65
<u>Total Production Demand</u>	2,260	2,130 - 2,355
Total Stream Diversions	1,035	535 - 1,505
Total Groundwater	1,060	455 - 1,615
Total Add'l Conserv./Supplemental Source	160	17 - 310
Unused Divertible Streamflows	65	0 - 125
Unused Loch Lomond Entitlement	150	2 - 295

Compared to Scenario A, average annual production from the Olympia wellfield is reduced 10 percent; Quail Hollow wellfield peak production increases; supplemental water use during drought is

reduced; production from the Pasatiempo wellfield is reduced an additional 30 AF/yr, on average, achieving a 100 AF/yr reduction compared to 2030 demand; such that is maintained at historically sustainable averages.

On an annual-percentage basis, the results of Scenario B are summarized and differ from Scenario A as follows:

- Average annual use of supplemental water increases 2 percent to a total of 7 percent of North System demand, ranging up to 17 percent. Supplemental water use is roughly split between in-lieu recharge and drought supply when the wellfields are producing at their planned maximum capacity. The combined production of the North System wellfields decreases by a corresponding few percent, but increases in variability, providing from 13 to 65 percent of North System annual usage. Peak-year production from the Quail Hollow wellfield is able to increase under these conditions, while peak-year production from the Olympia wellfield is allowed to decrease.
- Delivery of supplemental water via the North-South Intertie reduces the Pasatiempo wellfield's contribution to demand in the Southern Service Area by another 8 percent, over-and-above the 16 percent reduction provided by conveyance of excess available streamflow diversions via the Intertie. The Intertie supplies up to 60 percent of South System annual demand during some years.
- Average annual supplemental water use increases to more than 50 percent of SLVWD's entitlement to Loch Lomond, ranging up to nearly 100 percent during some years. On average, about half this amount is used during non-drought conditions when competition for stored water is low and the City is least likely to interrupt the transfer of water under SLVWD's entitlement to a portion of the yield of Loch Lomond.

Conclusions

SLVWD's ability to meet expected future water demand through future climatic cycles will depend on the optimal conjunctive use of its available supplies throughout its served area.

Factors currently controlling the production potential of SLVWD's water supply system include:

- Seasonal and year-to-year variability of streamflows available for diversion (as evaluated in this report for 1984-2008).
- Seasonal and year-to-year variability of water demand, fluctuating ± 5 percent as a function of the climatic cycle (i.e., up to 10 percent reduction in response to drought).
- Limited surface-water storage (equal to only five times mean daily use of the North System).
- Large volumes of groundwater storage (roughly 50 times greater than total average annual wellfield production).
- Sustainable groundwater production as a function of useable groundwater storage and average recharge (Quail Hollow and Olympia wellfields)
- Potentially unsustainable groundwater production from the Pasatiempo wellfield, with no current means to convey excess available streamflow diversions from the Northern to the Southern Service Areas.
- No means to exercise SLVWD's entitlement to Newell Creek streamflow stored in Loch Lomond.

The annual yield of SLVWD's existing water system is summarized as follows:

	<u>Annual Production (AF/yr)</u>	
	<u>Recent</u> <u>Average</u>	<u>Range</u> <u>Period of Record</u>
Stream Diversions	935	500 - 1,200
Quail Hollow & Olympia Wellfields	760	330 - 1,000
North System Total	1,700	1,330 - 1,800
South System – Pasatiempo Wellfield	410	205 - 445
Mañana Woods	50	(data unavailable)
SLVWD Total	2,150	1,600 - 2,210

On average throughout a representative hydrologic cycle, the system utilizes about 80 percent of the streamflows available for diversion, and never less than 70 percent. As noted previously, these estimates do not reflect potential environmental constraints, uncertain projections of climate change, or SLVWD’s recently annexed Felton system.

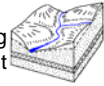
Groundwater storage is currently SLVWD’s only reliable source for satisfying water demand during periods of low streamflow. Because groundwater storage is many times greater than annual use, several years of above average groundwater production can be sustained with relatively limited consequences. However, if not balanced by long-term average recharge, a significant potential for groundwater overdraft exists (e.g., as has occurred in the Camp Evers and Scotts Valley areas). The potential for overdraft is exacerbated by the difficulty of accurately measuring and/or estimating groundwater storage and recharge.

Groundwater level records indicate that production from the Quail Hollow and Olympia wellfields has been effectively balanced by recharge during the last 24 years, largely because of conjunctive use practices. Depressed groundwater levels in the vicinity of the Pasatiempo wellfield indicate that its recent rates of production may not be sustainable. As SLVWD integrates its water supply systems to address this and other aspects of the system, it is critical that it evaluate the viability of its conjunctive use through a representative climatic cycle and reflecting realistic demand projections.

Conjunctive use has provided the North System with an apparently balanced supply over the past 24 years, as indicated by the little or no cumulative decline in Quail Hollow and Olympia groundwater levels. However, current demand is 16 percent greater than average demand for the 1984-2008 period of record. Under repetition of 1976-77 and 1987-94 droughts, SLVWD's water system could not supply demand as it did previously, relying instead on potentially unsustainable groundwater production and/or unprecedented rates of demand management.

The monthly analysis presented above for SLVWD’s projected 2030 demand indicates that successful future conjunctive use will require supplemental water and expanded conveyance. As demonstrated, this can be accomplished by exercising SLVWD’s entitlement to Loch Lomond and providing supplemental water to the Southern Service Area via a North-South Intertie.

The results of estimating SLVWD conjunctive use under projected 2030 demand and a repeat of the 1984-2008 climatic cycle is as follows, assuming (1) excess available stream diversions are conveyed to the south system to supplement the Pasatiempo wellfield and (2) diversions from Loch Lomond (and/or additional conservation) are used to supplement the North System at times when sustainable groundwater withdrawals are insufficient to meet demand:



2030 Demand
Scenario A, 1985-2008

	<u>AF/yr</u>	
	<u>Average</u>	<u>Range</u>
Stream Diversions	960	535 - 1,385
Quail Hollow & Olympia Wellfields	710	340 - 1,010
Add'l Conservation / Supplemental Source	90	0 - 265
North System Total	1,760	1,660 - 1,835
Pasatiempo Wells If Intertie	365	285 - 460
Stream Diversions Via Intertie	75	0 - 140
South System Total	440	415 - 460
Mañana Woods Well	60	55 - 65
Total Production Demand	2,260	2,132 - 2,355

In this future-case scenario, stream diversions provide 17 percent of demand in the Southern Service Area via a North-South Intertie, on average, allowing a 50 AF/yr reduction in average Pasatiempo wellfield production compared to recent years. As a result, about 95 percent of streamflows available for diversion are used on average, compared to about 80 percent currently. In the Northern Service Area, diversions from Loch Lomond (or an equivalent amount of treated water from the City of Santa Cruz, and/or additional conservation) provide up to 265 AF/yr during drought conditions, allowing production from the Quail Hollow and Olympia wellfields to decrease slightly (7 percent) compared to recent years and remain sustainable over the long term. However, the City is more likely to interrupt water transfers to SLVWD under worst-case drought conditions.

Offsetting supply deficits entirely through conservation would require average and maximum conservation increases equal to 5 and 15 percent of the water supply, respectively, over and above up to 10 percent drought conservation already factored into the 2030 demand projections.

In the alternate scenario summarized below, supplemental water from Loch Lomond (or an equivalent amount of treated City water) is used more routinely, and in both service areas, in order to maintain groundwater storage and allow more intensive groundwater production during drought.

2030 Demand
Scenario B, 1985-2008

	<u>AF/yr</u>	
	<u>Average</u>	<u>Range</u>
Stream Diversions	960	535 - 1,385
Quail Hollow & Olympia Wellfields	660	225 - 1,105
In-Lieu Recharge	50	0 - 160
Add'l Conserv./ Deficit Makeup	80	0 - 205
Total Supplemental Use	130	17 - 305
North System Total	1,760	1,660 - 1,835
Pasatiempo Wells If Intertie	335	170 - 460
Stream Diversions Via Intertie	75	0 - 140
Add'l Conserv./Supplemental Source	35	0 - 125
Total Intertie	105	0 - 255
South System Total	440	415 - 460
Mañana Woods Well	60	55 - 65
Total Supplemental Source	160	17 - 310
Total Production Demand	2,260	2,130 - 2,355

In this case:

- Supplemental water provides 24 percent of the South System supply, on average, allowing a 105 AF/yr reduction in average Pasatiempo wellfield production compared to recent years.

- Use of up to 300 AF/yr of supplemental water by the North System allows lowering average Quail Hollow and Olympia wellfield production by about 13 percent compared to recent years and increasing their production capacity during drought.
- Use of supplemental water increases to more than 50 percent of SLVWD's entitlement to Loch Lomond, on average, ranging up to nearly 100 percent of its entitlement during some years.
- About half of the supplemental water is used during non-drought conditions when competition for stored water is low and diversions from Loch Lomond, or an equivalent supply of City treated water, are least likely to be interrupted.
- Maximum monthly conveyance via the North-South Intertie is 35 AF/month, equivalent to continuous rates of 0.38 mgd or 260 gpm.
- The maximum monthly use of supplemental water by both service areas is 80 AF/month, equivalent to 0.84 mgd or 585 gpm.

These future cases assume:

- Feasible conveyance and treatment of the instantaneous flows implicit to the projected use of a North-South Intertie and supplemental water.
- SLVWD will address critical conveyance limitations within the existing system.
- SLVWD will achieve the significant reductions in system losses and per-connection usage that underlie its projected demand for 2030.
- Potential water supply limitations imposed by environmental constraints will be addressed by studies subsequent to this report.

Additionally, this report does not attempt to estimate future water supplies as a function of currently uncertain projections of climate change. However, this report's approach and results do address this issue as follows:

- Provides a well-documented and thoroughly analyzed benchmark of the existing water supply as a function of climatic variability during the past quarter of a century.
- Formalizes recognition of SLVWD's conjunctive-use system and reliance on groundwater storage during drought. The flexibility and optimization of this system will be critical to responding successfully to the potential effects climate change.
- Supports major improvements to SLVWD's existing water supply system, i.e., a North-South Intertie and exercising SLVWD's entitlement to Loch Lomond, that will greatly enhance its capacity for managing the potential effects of climate change.
- Provides a procedure for updating these estimates once projections of climate change suitable for planning purposes become available.

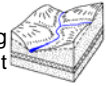
Recommendations

Consistent with the conclusions presented above, it is recommended that SLVWD recognize the following:

- SLVWD's Northern and Southern Service Areas both require a supplemental source of water in order to avoid continued and/or potential groundwater overdraft under current and projected future demand, and/or unprecedented rates of conservation. Specifically:
 - A North-South Intertie is needed to provide the Southern Service Area with a supplemental supply of water in order to lower Pasatiempo wellfield production to sustainable rates and replenish groundwater storage.
 - SLVWD will need to begin exercising its entitlement to a portion of the yield of Loch Lomond in order to avoid overproduction from the Quail Hollow and Olympia wellfields and contribute supplemental water to the South System via an intertie.
 - Relying on conservation alone would require unprecedented reductions in use of up to 15 percent over and above the 10 percent drought conservation already factored into the 2030 demand projections.
- SLVWD's demand projections for 2030 rely on ambitious reductions in system losses and per-connection usage; these assumptions should be confirmed or revised when possible.
- Optimizing conjunctive use in real time is more difficult than done conceptually for this report with perfect knowledge of an assumed climatic cycle. As such, SLVWD may need to formalize its conjunctive use practices, e.g.,
 - Maximize the use of stream diversions when available given SLVWD's limited capacity for surface-water storage. Achieving the average rates of stream diversion estimated in this report will not be possible without highly efficient diversion and treatment operations during periods of high flow.
 - Maintain groundwater storage at high levels when possible in anticipation of future drought.
 - Initiate demand management at the earliest signs of a potential drought so as to conserve groundwater storage.
 - Utilize available supplemental water (i.e., Loch Lomond) on a regular basis so as to conserve groundwater storage for drought use.

The following actions are recommended:

- Prepare a conceptual engineering design for a North-South Intertie in order to confirm its feasibility, including peak rates of conveyance implicit to the monthly analysis performed for this report.
- Similarly, prepare a conceptual engineering design for receiving a supplemental supply of water under SLVWD's entitlement to a portion of the yield of Loch Lomond. Confirm the feasibility of conveyance, needed treatment, and integration into SLVWD's existing system.
- Negotiate an agreement with the City of Santa Cruz consistent with SLVWD's entitlement to Loch Lomond and the feasibility assessment recommended above. Re-analyze the monthly conjunctive use scenarios presented in this report once the parameters of a supplemental supply are better defined.



- Address conveyance “bottlenecks” of the existing system that may limit SLVWD’s ability to fully exercise conjunctive use.
- Improve the groundwater monitoring network in the Olympia subarea in order to better document changes in groundwater storage as a function of groundwater production and recharge. Consider acquiring property in the vicinity of the proposed potential sites for additional Olympia wells.
- In the Quail Hollow area, work with the Santa Cruz County Planning Department and Graniterock to maintain high rates of groundwater recharge during the final stages of quarry operation and subsequent reclamation.
- Negotiate an agreement with Santa Cruz County Parks and Recreation to site a third Quail Hollow production well within Quail Hollow Ranch County Park. While providing a marginal gain in total sustainable yield, this well would provide the District needed flexibility for optimally managing this critical resource.
- Re-analyze the monthly conjunctive use scenarios presented in this report once projections of climate change suitable for planning purposes becomes available.