2. Hydrogeologic Conditions

Current and historical hydrogeologic conditions in the SMVMA, including groundwater conditions, Twitchell Reservoir operations, and stream and climate conditions, are described in the following sections of this Chapter.

2.1 Groundwater Conditions

To provide a framework for discussion of groundwater conditions, geology of the SMVMA, including geologic structure and the nature and extent of geologic formations comprising the aquifer system, is described in the following section. Current groundwater levels are then described in relation to historical trends in groundwater levels and flow directions in the SMVMA, as well as in context of Stipulation protocol for defining conditions of severe water shortage. Current and historical groundwater quality conditions are also discussed, including general groundwater quality characteristics as well as groundwater quality degradation, specifically due to elevated nitrate concentrations.

2.1.1 Geology and Aquifer System

The SMVMA is underlain by unconsolidated alluvial deposits that comprise the aquifer system, primarily gravel, sand, silt and clay that cumulatively range in thickness from 200 to 2,800 feet. The alluvial deposits in turn overlie and fill a natural trough, which is composed of older folded and consolidated sedimentary and metamorphic rocks with their deepest portions beneath the Orcutt area. The consolidated rocks also flank the Valley and comprise the surrounding hills and mountains; typically, the consolidated rocks do not yield significant amounts of groundwater to wells. The geologic formations comprising the alluvial deposits and the geologic structure within the study area are illustrated in a generalized geologic map (Figure 2.1-1a) and two geologic cross sections (Figures 2.1-1b and 2.1-1c).

The alluvial deposits are composed of the Careaga Sand and Paso Robles Formation (Fm.) at depth, and the Orcutt Fm., Quaternary Alluvium, and river channel, dune sand, and terrace deposits at the surface (USGS, Worts, G.F., 1951). The Careaga Sand, which ranges in thickness from 650 feet to a feather edge, is identified as being the lowermost fresh water-bearing formation in the basin (DWR, 1970), resting on the above-mentioned consolidated rocks (specifically, the Tertiary-aged Foxen Mudstone, Sisquoc Fm., and Monterey Shale and the Jurassic/Cretaceous-aged Franciscan Fm., descriptions of which may be found in USGS, Worts, G.F., 1951). Overlying the Careaga Sand is the Paso Robles Fm., which comprises the greatest thickness of the alluvial deposits (from 2,000 feet to a feather edge); the thickest portion of this formation is located beneath the Orcutt area. Both the Careaga Sand and Paso Robles Fm. underlie the great majority of the SMVMA (see Figures 2.1-1b and 2.1-1c). The Careaga Sand is mainly composed of white to yellowish-brown, loosely-consolidated, massive, fossiliferous, medium- to fine-grained sand with some silt and is reported to be predominantly of marine origin (USGS, Worts, G.F., 1951). The Paso Robles Fm. is highly variable in color and texture, generally composed of yellow, blue, brown, grey, or white lenticular beds of: boulders and coarse to fine gravel and clay; medium to fine sand and clay; gravel and sand; silt; and clay

(USGS, Worts, G.F., 1951). This formation is reported to be primarily fluvial (stream-laid) in origin and there is no areal correlation possible between the individual beds, with the exception of a coarse basal gravel of minor thickness in the Santa Maria Valley oil field, generally in the southeast part of the SMVMA.

Above the Paso Robles Fm. and comprising the Orcutt Upland is the Orcutt Fm., which is typically 160 to 200 feet thick; in the remainder of the SMVMA, the Paso Robles Fm. is overlain by the Quaternary Alluvium, which comprises the majority of the Valley floor and is typically 100 to 200 feet thick. Further north in the adjacent NMMA, the Paso Robles Fm. is overlain by the Older Dune Sand, which comprises the Nipomo Mesa and ranges in thickness from approximately 400 feet to a feather edge. Along the northeast edge of the Sisquoc plain, the Paso Robles Fm. is overlain by terrace deposits approximately 60 feet thick. The Orcutt Fm. is composed of conformable upper and lower units ("members"), both reported to be mainly of fluvial origin that become finer toward the coast. The upper member generally consists of reddish-brown, loosely-compacted, massive, medium-grained clean sand with some lenses of clay, and the lower member is primarily grey to white, loosely-compacted, coarse-grained gravel and sand (USGS, Worts, G.F., 1951).

The Quaternary Alluvium is also composed of upper and lower members that are reported to be mainly fluvial in origin. The composition of the upper member becomes progressively finer toward the coast, with boulders, gravel, and sand in the Sisquoc plain area; sand with gravel in the eastern/central Valley area; sand with silt from the City of Santa Maria to a point approximately halfway to Guadalupe; and clay and silt with minor lenses of sand and gravel from that area westward. The lower member is primarily coarse-grained boulders, gravel and sand with minor lenses of clay near the coast. The Older Dune Sand is composed of loosely- to slightly-compacted, massive, coarse- to fine-grained, well-rounded, cross-bedded quartz sand that is locally stained dark reddish-brown (California DWR, 1999). The terrace deposits, in general, are similar in composition to the coarse-grained parts of the Quaternary Alluvium.

Two geologic cross sections illustrate several points about the geologic structure and variable aquifer thickness throughout the SMVMA. Longitudinal geologic cross section A-A' (see Figure 2.1-1b) begins in the area near the mouth of the Santa Maria River, traverses the Orcutt Upland, and terminates in the Sisquoc plain area near Round Corral, immediately southeast of the SMVMA. It shows the relative thicknesses of the various geologic formations and their general "thinning" from the central valley area toward the Sisquoc plain. This cross section also shows the Quaternary Alluvium and Orcutt Fm., essentially adjacent to each other and comprising the uppermost aquifer in the SMVMA, divided into the above-described upper and lower members.

Transverse geologic cross section B-B' (see Figure 2.1-1c) begins in the Casmalia Hills, traverses the western portion of the Valley (near the City of Guadalupe) and the southern Nipomo Mesa, and terminates at Black Lake Canyon. It shows the prominent asymmetrical syncline (folding of the consolidated rocks and Paso Robles Fm.) within the SMVMA and adjacent NMMA, with the deepest portion of Paso Robles Fm. toward the southern edge of the SMVMA, gradually becoming thinner and more shallow toward the north where it extends beneath the NMMA. This cross section also shows that both the upper and lower members of the Quaternary Alluvium extend north to the Santa Maria River, but only the upper member extends beyond the River to the southern edge of the Nipomo Mesa, and neither member extends northward beneath the Mesa.

Several faults have been reported to be located in the SMVMA and adjacent portion of the NMMA. The Santa Maria and Bradley Canyon faults, located in the Valley in the area between the City of Santa Maria and Fugler Point (at the confluence of the Cuyama and Sisquoc Rivers to form the Santa Maria River), are concealed and they are reported to be northwest-trending, high-angle faults, that vertically offset the consolidated rocks, Careaga Sand, and Paso Robles Fm., but not the overlying Quaternary Alluvium or Orcutt Fm. (USGS, Worts, G.F., 1951). The Oceano and Santa Maria River faults are of a similar nature (the latter fault also has a significant strike-slip component of movement), but they are primarily located in the southern Nipomo Mesa. The maximum vertical offset on the Oceano fault is reported to be in the range of 300 to 400 feet within the Careaga Sand and Paso Robles Fm.; on the other faults, it is reported to be much less, within the range of 80 to 150 feet (USGS, Worts, G.F., 1951; California DWR, 1999). However, these faults do not appear to affect groundwater flow within the SMVMA, based on the review of historical groundwater level contour maps (USGS, Worts, G.F., 1951; LSCE, 2000).

There is no know structural (e.g., faulting) or lithologic isolation of the alluvial deposits from the Pacific Ocean; i.e., the Quaternary Alluvium, Orcutt Fm., Careaga Sand, and Paso Robles Fm. aquifers continue beneath the Ocean. Thus, the potential exists for salt water to intrude into the coastal (landward) portions of the aquifers if hydrologic conditions within them were to change.

The aquifer system in the SMVMA is comprised of the Paso Robles Fm., the Orcutt Fm., and the Quaternary Alluvium (USGS, Worts, G.F., 1951). The upper member of the Quaternary Alluvium is consistently finer-grained than the lower member throughout the Valley. Further, the upper member becomes finer grained toward the Ocean such that it confines groundwater in the lower member from the approximate area of the City of Santa Maria's waste water treatment plant westward (approximately eight miles inland from the coast). The result of this has been artesian conditions in the western valley area (historically, flowing artesian wells were reported until the early 1940s in the westernmost portion of the Valley) (USGS, Worts, G.F., 1951). In addition, many wells belonging to local farmers in the western valley area, specifically in the Oso Flaco area, began flowing again during winter 1999.

Analysis of the geology, groundwater levels, and groundwater quality indicates that the aquifer system varies across the area and with depth, and this variation was the basis for the shallow and deep aquifer zone designations of the SMVMA monitoring program (LSCE, 2008). In the central and major portion of the SMVMA, there is a shallow unconfined zone comprised of the Quaternary Alluvium, Orcutt Fm., and uppermost Paso Robles Fm., and a deep semi-confined to confined zone comprised of the remaining Paso Robles Fm. and Careaga Sand. In the eastern portion of the SMVMA where these formations are much thinner and comprised of coarser materials, particularly in the Sisquoc Valley, the aquifer system is essentially uniform without distinct aquifer depth zones. In the coastal area where the surficial deposits (upper members of Quaternary Alluvium and Orcutt Fm.) are extremely fine-grained, the underlying formations (lower members of Quaternary Alluvium and Orcutt Fm., Paso Robles Fm., and Careaga Sand) comprise a deep confined aquifer zone.

2.1.2 Groundwater Levels

Groundwater levels within the SMVMA have fluctuated greatly since the 1920's, when historical water level measurements began, with marked seasonal and long-term trends, as illustrated by a collection of representative groundwater level hydrographs from various areas throughout the SMVMA (Figure 2.1-2). The historical groundwater level hydrographs illustrate that widespread decline in groundwater levels, from historical high to historical low levels, occurred between 1945 and the late 1960's. The decline ranged from approximately 20 to 40 feet near the coast, to 70 feet near Orcutt, to as much as 100 feet further inland (in the area just east of downtown Santa Maria). This decline was observed in both the shallow and deep aquifer zones, and is interpreted today to have been the combined result of progressively increasing agricultural demand, as well as increasing smaller municipal pumping, and long-term drier than normal climatic conditions during this period.

Since then, the basin has alternately experienced significant recharge (recovery) and decline which, collectively, reflect a general long-term stability as groundwater levels in both aquifer zones have fluctuated between historical-low and near historical-high levels over alternating five- to 15-year periods. Groundwater levels throughout the SMVMA have shown this trend, but with different ranges of fluctuation (see Figure 2.1-2); and groundwater levels have repeatedly recovered to near or above previous historical-high levels, including as recently as 2002. In the areas along the Santa Maria River, groundwater level fluctuations are greater in the shallow aquifer zone than the deep (see Twitchell Recharge Area, Central Agricultural Area, and Oso Flaco Area hydrographs). Conversely, in the Municipal Wellfield and Coastal Areas, groundwater level fluctuations are greater in the deep aquifer zone. Hydrographs from wells along the coastal portion of the SMVMA show that groundwater elevations have remained above sea level, with deep (confined) groundwater levels rising enough to result in flow at the ground surface, throughout the historical period. The periodic groundwater level fluctuation since the late 1960's (with a long-term stability) have apparently been due to intermittent wet and dry climatic conditions, with natural recharge during wet periods complemented by supplemental recharge along the Santa Maria River from the Twitchell Reservoir project (since becoming fully operational in the late 1960's). Long-term stability would also appear to be partially attributable to a general "leveling-off" of the agricultural demand on the basin since the early to mid-1970’s, as further described in Chapter 3.

Most recently, from 2002 through 2008, groundwater levels in both the shallow and deep zones have gradually declined. Recent groundwater level decline can be considered to be at least partially due to the fact that Twitchell Reservoir releases, for in-stream supplemental groundwater recharge, were well below the historical average, in most years since 2000 (including 2008), as discussed in Section 2.2. Importantly, 2008 groundwater levels do not trigger the Stipulation provisions for defining conditions of severe water shortage because, among other considerations, they remain well within the historical range of groundwater levels for the SMVMA. Also important is that coastal groundwater levels remain well above sea level through 2008 and, thus, conditions indicative of potential sea water intrusion are absent.

Groundwater beneath the SMVMA has historically flowed to the west-northwest from the Sisquoc area toward the Ocean, and this remained the case during 2008 as illustrated by two groundwater elevation contour maps for the shallow and deep aquifer zones (Figures 2.1-3a and 2.1-3b). One notable feature in both contour maps regarding hydrologic conditions in 2008 is the widening of groundwater level contours beneath the central-south and western portions of the SMVMA. This indicates a reduced groundwater gradient, tending slightly toward a local pumping depression, likely reflecting ongoing groundwater pumping in and around the municipal wellfield near the Santa Maria Airport and Town of Orcutt. In this area, both agricultural and numerous municipal water supply wells of the City of Santa Maria and the Golden State Water Company are operated, although municipal pumping in 2008 was notably lower than prior to the availability of State Water Project water as discussed in Chapter 3. The majority of municipal groundwater pumping is conducted from the purveyors' deep wells, and the two groundwater elevation maps show greater flattening of the gradient in the deep aquifer zone. Overall, this has had the effect of slowing (but not stopping or reversing) the movement of groundwater through that portion of the SMVMA. However, it should be noted that agricultural and/or municipal groundwater pumping has been conducted in this area for many decades, and a reduced groundwater gradient has been observed since about 1960 (USGS, Miller, G.A., and Evenson, R.E., 1966; USGS, Hughes, J.L., 1977; LSCE, 2000).

A second notable feature of the 2008 contour maps is some apparent residual effect of recharge from Twitchell Reservoir releases near the Santa Maria River from Garey to the confluence with Suey Creek. Shallow zone contour lines show a subtle convex-downstream shape and deep zone contours are in places parallel to and declining away from the River. Finally, notably to the west, a seaward gradient for groundwater flow is present in both aquifer zones in 2008 and coastal groundwater levels remain well above sea level.

2.1.3 Groundwater Quality

Groundwater quality conditions in the SMVMA have fluctuated greatly since the 1930's, when historical water quality sampling began, with marked short- and long-term trends. Groundwater quality in the SMVMA historically reflected the various natural sources of recharge to the aquifer system, most notably streamflows of the Cuyama and Sisquoc Rivers that provided recharge along the Santa Maria River. The great majority of groundwater in the SMVMA, primarily in the eastern and central portions of the Santa Maria Valley and in the Sisquoc Valley, had been of a calcium magnesium sulfate type originating from the Cuyama and Sisquoc River streamflows. Groundwater had historically been of better quality toward the Orcutt Upland, Nipomo Mesa, the City of Guadalupe, and coastal areas (Lippincott, J.B., 1931).

With development of the Valley and surrounding areas in the 1940's through 1970's, including expansion of the agricultural and urban areas and addition of the Twitchell Reservoir project, groundwater quality conditions changed within the SMVMA. The changes included improvement of the general groundwater quality in the eastern to central part of the Santa Maria Valley in and near the area of Twitchell Reservoir recharge, including the current-day municipal wellfield near the Town of Orcutt. Degradation in groundwater quality occurred further west and downgradient in the Valley, specifically with elevated general mineral and nitrate concentrations (USGS, Hughes, J.L., 1977).

Subsequently, from the 1970's through 2008, general mineral concentrations in groundwater have remained essentially unchanged, including the occurrence of better quality water in the SMVMA's eastern, central, and southern portions and poorer quality water to the west. Further, groundwater quality is slightly better in the deep aquifer zone compared to the shallow, as shown by the map with representative historical groundwater quality graphs from areas throughout the SMVMA (Figure 2.1-4). While groundwater quality data from 2008 for the SMVMA are extremely sparse (with none available for the Sisquoc Valley), assessment of those data indicates that, during 2008, specific conductance values in the shallow aquifer zone generally ranged between 650 and 1,450 umho/cm in the Twitchell Recharge and Municipal Wellfield Areas, while those further west exceeded 2,000 umho/cm. In comparison, specific conductance values in the deep zone, including in coastal monitoring wells (specifically those deeper than 600 feet), generally did not exceed 1,100 umho/cm.

In contrast to the stability in general groundwater quality concentrations observed during this recent period, nitrate concentrations in shallow groundwater have progressively increased, in some cases to the point where municipal purveyors have had to reduce or cease pumping from water supply wells with shallow zone completions in order to comply with drinking water standards. In 2008, nitrate-as-nitrate (NO3-NO3) concentrations in shallow groundwater remained elevated, in many areas above the primary drinking water standard of 45 mg/l. While the concentration in one shallow well north of the City of Santa Maria was 9.3 mg/l, and was non-detect (<0.18 mg/l) in the shallowest monitoring well along the coast, nitrate concentrations in the eastern, central, and southern portions of the SMVMA generally ranged between 34 and 62 mg/l. Some of the highest nitrate concentrations in 2008 were observed in shallow groundwater in the Municipal Wellfield Area (see Figure 2.1-4). In contrast to widespread elevated nitrate concentrations in shallow groundwater, however, nitrate concentrations in deep groundwater remain markedly lower, less than 10 mg/l and typically less than 5 mg/l across the SMVMA.

Review of groundwater quality data through 2008 from the two sets of coastal monitoring wells indicates that general mineral quality has remained stable, with no notable indication of sea water intrusion. Of note is that, during an investigation conducted in the late 1960's of the potential for sea water intrusion along the coast, for which the two sets of monitoring wells were constructed, localized areas of degraded shallow groundwater were identified but concluded at the time to be due to environmental factors other than intrusion (California DWR, 1970). Since then, including in 2008, some coastal shallow groundwaters, both unconfined and confined, have continued to show elevated but largely unchanging specific conductance values, as high as 2,000 umho/cm (well 11N/36W-35J4, 228 feet deep, confined) and 2,810 umho/cm (well 10N/36W-02Q4, 378 feet deep, confined). However, the general quality of coastal deep confined groundwater has remained stable with specific conductance values around 1,000 umho/cm (Figure 2.1-4).

Coastal shallow and deep confined groundwaters have both experienced degradation from nitrate, with a progressive increase in concentrations starting in the mid-1980's and continuing through 2008, as seen in wells 11N/36W-35J3, J4, and J5 (well depths of 495 to 135 feet). While some nitrate degradation was already present in the 1980's, with NO3-NO3 concentrations between 5 and 10 mg/l, concentrations have steadily risen since then to between 34 and 57 mg/l in 2008. Shallow confined groundwater near the second coastal monitoring well set has also shown elevated nitrate concentrations (20 mg/l NO3-NO3 in well 10N/36W-02Q4, 378 feet deep, confined). In contrast, the shallow unconfined groundwater had non-detectable levels of nitrate (well 10N/36W-02Q7, 44 feet deep). Nitrate concentrations in the deeper confined groundwater along the coast, specifically in coastal monitoring wells deeper than 600 feet, remain stable and unchanged with NO3-NO3 concentrations at 3 mg/l or less.

2.2 Twitchell Reservoir Operations

In order to describe Twitchell Reservoir operations, monthly records of reservoir stage, storage, and releases were updated and recorded observations of reservoir conditions were noted. The historical stage, storage, and releases, including through 2008, are described in relation to observed climatic conditions in the SMVMA.

2.2.1 Reservoir Stage and Storage

Review of the historical stage and storage in the Twitchell Reservoir, for which reliable records begin in 1967, indicate a typical seasonal rise and decline with winter and spring rain and subsequent spring and summer releases. Reservoir stage has risen to as high as about 640 feet msl, corresponding to storage of nearly 190,000 acre-feet, on several occasions, during the winter and spring months of years during which rainfall amounts were substantially higher than average. The rises in stage have been rapid, occasionally over one or two months, with subsequent declines gradually spread over the subsequent year or multiple years. During those years when releases have essentially emptied the reservoir for purposeful supplemental groundwater recharge through the Santa Maria River channel, the dam operator recorded the associated minimum reservoir stage, which have risen over time from about 480 feet msl in 1968, to 525 feet msl since 1986. This rise reflects the long-term filling of former dead pool storage (about 40,000 acre-feet below the reservoir outlet for release from conservation storage) with sediment that has naturally occurred with operation of the project (SMVWCD, 1968-2008). These seasonal fluctuations and long-term rise in minimum stage are illustrated in a graph of historical reservoir stage and storage (Figure 2.2.1a).

It is noteworthy that the siltation of the former dead pool storage below the conservation outlet in Twitchell Reservoir has not impeded the conservation of runoff for subsequent release for downstream groundwater recharge. Except for a few individual years over the life of the reservoir, accumulated storage in any year has been less than the designated active conservation pool of 109,000 af. In the infrequent wet years when greater storage could be conserved, e.g. 1969, 1978, 1983, 1995, and 1998, the SMVWCD has been permitted to temporarily utilize some of the dedicated flood control pool (89,000 af) to conserve those additional inflows and then shortly release them for downstream recharge. Total storage has never exceeded the combined conservation pool and flood control pool storage volume (198,000 af) and has never invaded the uppermost surcharge pool (159,000 af above the conservation and flood control pools) in the overall reservoir.

Reservoir storage has historically risen to between 150,000 and nearly 190,000 acre-feet (af) during the winter and spring months of years during which rainfall was substantially higher than average, with storage commonly below 50,000 af during most other years. As can be seen on Figure 2.2-1a, reservoir storage has repeatedly dropped to essentially zero during periods of below-average rainfall, including those associated with drought conditions in 1976-77 and 1987-90. Reservoir storage was also essentially zero during 2002 through 2004 as a result of a drier climatic period that began in 2001. About 50,000 af of storage were accrued in both 2005 and 2006, all of which was released for downstream groundwater recharge. There was essentially no storage in 2007. During 2008, reservoir storage reached a maximum of about 20,000 af in March; that water was almost entirely released for recharge by the end of the year, as can be seen in the series of progressive satellite images of the Reservoir surface area from 2008 in Appendix B.

2.2.2 Reservoir Releases

Twitchell Reservoir annual releases since 1967 have ranged from zero during low rainfall years and drought periods to a maximum of 243,660 af in 1998, as illustrated in a bar chart of annual reservoir releases (Figure 2.2-1b). In general, and most notably in the Twitchell Recharge Area, groundwater levels have tended to track Twitchell releases since the beginning of Reservoir operations (see Figure 2.1-2 and 2.2-1b). The long-term average annual release amount for the period 1967 through 2008 is 54,400 afy, with below-average releases during slightly more than half of those years. The five-year period from 1995 through 1999 is notable for continual releases in amounts well above the annual average, reflecting a wetter climatic period from 1993 through 1998. Also notable are multiple year periods when releases dropped to zero, specifically from 1987 through 1990 and from 2002 through 2004, reflecting the drier climatic conditions during those periods of time. In 2008, releases amounted to just under 24,000 af, essentially half of the long-term annual average.

2.3 Streams

The surface water hydrology of the SMVMA is characterized, specifically the current conditions in relation to historical trends in stream discharge and quality.

2.3.1 Discharge

The main streams entering the SMVMA are the Cuyama and Sisquoc Rivers; these rivers join in the Santa Maria Valley floor near Garey and become the Santa Maria River, which drains the Valley from this point westward (see Figure 1.3-2). The headwaters of the Sisquoc River include a portion of the San Rafael Mountains and Solomon Hills, and the River’s main tributaries within the SMVMA are Foxen, La Brea, and Tepusquet Creeks. Streamflow in the Sisquoc River and its tributary creeks have remained unimpaired through the present. The Cuyama River drains a portion of the Sierra Madre Mountains, including the Cuyama Valley, and streamflow into the Santa Maria River has been controlled since construction of Twitchell Dam between 1957 and 1959. The Santa Maria River receives minor streamflows from two small tributaries, Suey and Nipomo Creeks, along its course toward the City of Guadalupe and

Pacific Ocean. In the southern portion of the SMVMA, Orcutt Creek drains a portion of the Solomon Hills and the Orcutt area before ending near Betteravia.

Stream discharge in the Cuyama River below the dam, recorded during the initial period of Twitchell project operations between 1959 and 1983, averaged 37,350 afy. As discussed above, Twitchell Reservoir releases averaged 54,400 afy from 1967 through 2008. The historical variation in reservoir releases and Cuyama River streamflow is shown in the bar chart of annual surface water discharge for the River (Figure 2.3-1a). Cuyama River stream discharge, which comprises the largest source of SMVMA groundwater recharge, has ranged over the historical period of record from no streamflow during several drought years to almost 250,000 af during 1998. Streamflow from the Cuyama River into the SMVMA in 2008 was on the order of 24,000 af.

Stream discharge in the Sisquoc River, recorded at gauges at the southeast end of the Sisquoc plain and further downstream near the town of Garey, averages 37,900 afy over the historical period of record from the early 1940s to the present. The downstream gauge provides a measure of the stream discharge entering the SMVMA from the Sisquoc plain, and it reflects inflow from the headwaters of the Sisquoc River and its tributaries, as well as gains from and losses to groundwater in the Sisquoc plain. The historical variation in Sisquoc River streamflow is shown in the bar chart of annual surface water discharge for the River (Figure 2.3-1b). Sisquoc River stream discharge, which comprises a large source of SMVMA groundwater recharge, has ranged over the historical period of record from no streamflow during several drought years to over 300,000 af during 1998; in 2008, streamflow into the SMVMA was about 40,000 af. Of note is that the upstream gauge (“near Sisquoc”) was non-operational, and thus no data are available, from 1999 through 2007. Further, discharge amounts in the tributaries Foxen, La Brea, and Tepusquet Creeks have not been recorded since the early 1970's (early 1980's for the latter creek), when gauge operations were discontinued. As a result, the net amount of groundwater recharge in the Sisquoc plain from the Sisquoc River currently cannot be calculated.

Streamflow in the Santa Maria River has been recorded at two gauges during varying periods of time (see Figure 1.3-2). At the Guadalupe gauge, which was operational between 1941 and 1987, stream discharge ranged from no streamflow during numerous years to almost 185,000 af during 1941, and averaged 26,800 afy prior to the commencement of Twitchell project operations compared to 17,600 afy during operations. The historical variation in Santa Maria River streamflow is shown in the bar chart of annual surface water discharge for the River (Figure 2.3-1c). The reduction in streamflow at Guadalupe is attributed to Twitchell project operations, which optimize recharge along the more permeable portion of the River streambed by managing reservoir releases to maintain a “wetline” (downstream extent of streamflow) near the Bonita School Road Crossing.

Supplemental recharge to the Santa Maria Valley from Twitchell project operations has been roughly estimated to be 32,000 afy based on comparison of pre- and post-project net losses in streamflow between Garey and Guadalupe (LSCE, 2000). The estimation does not account for changes in climatic conditions between the pre- and post-project periods or losses/gains along the River due to other processes, which could result in changes in the amount of water available for recharge over time. As a result of discontinued stream discharge measurements at

Guadalupe, combined with the lack of gauges on Suey and Nipomo Creeks, the net amount of groundwater recharge in the Santa Maria Valley from the Santa Maria River currently cannot be calculated.

Stream discharge in the Santa Maria River has also been recorded more recently at a gauge at Suey Crossing northeast of the City of Santa Maria. However, these data are reported only sporadically, as for years 1999 and 2006, or not at all, as in 2000 through 2005. The discharge data for 2008 were unavailable for review for this report (the data are currently listed as awaiting quantification by rating curve.

Stream discharge in Orcutt Creek, recorded from 1983 through the present (absent years 1992 through 1994), averages 1,700 afy, ranging from essentially no streamflow during several years to just over 10,000 af in 1995; in 2008, streamflow was about 2,000 af. The historical variation in streamflow is shown in the bar chart of annual surface water discharge for the creek (Figure 2.3-1d). While essentially all streamflow recorded at the gauge ultimately provides groundwater recharge to the SMVMA, it is not known how much groundwater recharge or discharge occurs upstream from the gauge, specifically between the point where the Creek enters the SMVMA and the gauge.

2.3.2 Surface Water Quality

The majority of recharge to the SMVMA has historically been derived from streamflow in the Santa Maria River originating from the Cuyama and Sisquoc Rivers. Thus, groundwater quality in much of the SMVMA has historically reflected the water quality of streamflows in the Cuyama and Sisquoc Rivers. Water quality in the rivers depends on the proportion and quality of the rainfall runoff and groundwater inflow contributing to streamflow in their respective watersheds above the Santa Maria Valley. The Cuyama River watershed includes the Cuyama Valley, which is reported to be underlain by geologic formations containing large amounts of gypsum; the Sisquoc River watershed is primarily steep terrain underlain by consolidated rocks (USGS, Worts, G.F., 1951).

The quality of the streamflow in both the Cuyama and Sisquoc Rivers has historically been of a calcium magnesium sulfate type, although the Sisquoc River contains slightly less sulfate and more bicarbonate than the Cuyama River. The Cuyama River quality has improved at two points in time during the historical period, specifically the mid-1940's and the late 1960's (USGS, Hughes, J.L., 1977). The improvement observed in the mid-1940's is thought to be due to agricultural development of the Cuyama Valley that was supported by increased groundwater pumping in the Valley for irrigation. The increased pumping lowered groundwater levels in the Cuyama Valley, in turn reducing groundwater inflow to the Cuyama River, thereby reducing the contribution of dissolved salts (sulfate in particular) to the River. The improvement observed in the late 1960's is thought to be due to implementation of Twitchell Reservoir project operations, which facilitated conservation of Cuyama River streamflow and augmented recharge to the Santa Maria Valley groundwater basin. Specifically, the higher streamflow events in the Cuyama River that previously discharged to the ocean are of a better quality due to dilution by greater rainfall runoff. Releases from Twitchell Dam therefore contain a lower amount of dissolved salts than the Cuyama River streamflows from the period preceding the project. The improvement in Cuyama River water quality from both of these developments is shown in Table 2.3-1. More recent water quality data for the River were unavailable for review for this report.

Table 2.3-1
Selected General Mineral Constituent Concentrations
Cuyama River below Twitchell Reservoir
(USGS, Hughes, J.L., 1977)

Constituent	Years 1906 and 1941	Years 1958 - 1966	Years 1967 - 1975
Specific Conductance (umho/cm)	1,700 - 4,500	1,300 - 2,400	750 - 2,100
Sulfate (mg/l)	700 - 1,700	450 - 700	190 - 550
Chloride (mg/l)	90 - 140	50 - 100	25 -85

Water quality in the Sisquoc River likely has remained relatively unchanged since 1906 although much fewer historical data are available for the River. The water quality concentrations measured between 1940 and 1975 are lower than observed in the Cuyama River during any of the above periods of time, with approximately 1,100 umho/cm specific conductance, 350 mg/l sulfate, and 20 mg/l chloride (USGS, Hughes, J.L., 1977). Review of more recent water quality data indicate that specific conductance values have remained essentially unchanged, ranging from 900 to 1,200 umho/cm, from 1975 through to the present, as seen in the graph of Sisquoc River water quality (Figure 2.3-2a). The latter data have been collected essentially monthly, and a slight seasonal increase in specific conductance is visible in most years. The Sisquoc River has also been monitored for nitrate since 1975 on an annual basis, with NO_3-NO_3 concentrations at or below reporting limits.

The Sisquoc River data described above were collected at the upstream gauge (near Sisquoc) at the point where the river enters the Sisquoc plain and, thus, do not fully describe the quality of flows entering the Santa Maria Valley further downstream near Garey. Limited historical water quality data for the Sisquoc River near Sisquoc and near Garey, and for its tributary streams, indicate that the quality of streamflows entering the Sisquoc plain are slightly improved by tributary inflows (USGS, Hughes, J.L., 1977).

In contrast to the quality of streamflows in the Cuyama and Sisquoc Rivers, the quality of Orcutt Creek flows is highly degraded, with specific conductance values typically fluctuating between 1,100 and 3,500 umho/cm, with values exceeding 5,500 umho/cm in 2005 and 2006. Subsequently, specific conductance values declined to the previous range, as seen in the graph of Orcutt Creek historical water quality (Figure 2.3-2b). Orcutt Creek flows are also highly degraded by nitrate, with NO_3-NO_3 concentrations remaining above the health-based standard of 45 mg/l since 2005 and exceeding 125 mg/l in 2007 and 2008.

2.4 Climate

The climatic data reported for the SMVMA are characterized, specifically the current conditions in relation to historical trends in precipitation and historical evapotranspiration data.

2.4.1 Precipitation

Three precipitation gauges are located throughout the SMVMA, specifically at Guadalupe, Santa Maria (currently at the Airport and previously downtown), and Garey (see Figure 1.3-2). The average annual rainfall measured at the Santa Maria Airport gauge, the most centrally located of the three gauges, is 12.85 inches, as shown in a bar chart of historical precipitation (Figure 2.4-1). Review of historical monthly records indicates that the majority of rainfall occurs during the months of November through April, and this was the case during 2008. As shown in Table 2.4-1, the annual rainfall total for calendar year 2008 was 12.49 inches, slightly less than the long-term average of 12.85 inches. Further, 7.01 inches fell during the month of January alone, comprising almost two-thirds of the annual total, with the balance primarily in February, November, and December.

Long-term rainfall characteristics for the SMVMA are shown in the cumulative departure curve of historical annual precipitation (see Figure 2.4-1), which indicates that the area has experienced periods of wetter than normal conditions alternating with periods of drier than normal to drought conditions. Wet conditions prevailed from the 1930's through 1944, followed by drier conditions from 1945 through the late 1960's. Subsequently, there have been shorter periods of alternating wet and dry conditions, including the most recent cycle of a wet period in the early-1990's to 1998, followed by the current period of slightly dry conditions that began in 2001. This pattern of fluctuations in climatic conditions closely corresponds to the long-term fluctuations in groundwater levels described in section 2.1.2, including the substantial decline observed between 1945 and the late 1960's and the subsequent repeating cycle of decline and recovery between historical-low and near historical or above historical-high groundwater levels.

2.4.2 Evapotranspiration

Three CIMIS climate stations were initially operated within the SMVMA for varying periods of time, specifically at Santa Maria, Betteravia, and Guadalupe between 1983 and 1997 (see Figure 1.3-2). Subsequently, CIMIS stations began operating near Sisquoc and on the southern Nipomo Mesa, the latter located just outside of the SMVMA, with climate data available for full calendar years beginning in 2001 and 2007, respectively. These five stations have recorded daily reference evapotranspiration (ETo) and precipitation amounts, with annual ETo values typically ranging between 44 and 53 inches and averaging 48.5 inches, as shown in a bar chart of the historical ETo values for the SMVMA (Figure 2.4-2).

Daily climate data for 2008 from the Nipomo and Sisquoc stations are listed in Table 2.4-2, which shows that annual ETo and precipitation amounts were 45.03 and 11.55 inches, respectively, at Nipomo and 50.57 and 9.79 inches, respectively, at Sisquoc. Evapotranspiration was highest during the months of April through August at both stations. The 2008 precipitation at the Nipomo station, 11.55 inches, was most similar to the amount recorded at the Santa Maria Airport precipitation gauge, 12.49 inches. For this reason, and as described in the next chapter, the 2008 precipitation and ETo data recorded at the Nipomo station were utilized in the estimation of agricultural water requirements for the SMVMA in 2008.