December 30, 2010

Mr. Rick Viergutz
Manager, Groundwater Section
Ventura County Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93009-1600

Re: Final Report
Groundwater Budget and Approach to a Groundwater Management Plan,
Upper and Lower Ventura River Basin

Dear Rick:

I am pleased on behalf of Daniel B. Stephens & Associates Inc. (DBS&A) to deliver the attached final report *Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin* (ULVRB), dated December 30, 2010 to Ventura County Watershed Protection District (VCWPD). We believe that this report represents an important step forward in developing an understanding of the ULVRB. The groundwater budget section of the report estimates, based on available data and hydrogeologic analyses, the magnitude of groundwater inputs and outputs, and arrives at an estimated final groundwater budget. The approach to a groundwater management plan (GWMP) provides a preliminary framework for management of groundwater to insure long-term sustainable, reliable, and good-quality water supply.

We appreciate comments provided by VCWPD on the 75% and 90% draft versions of the ULVRB report and the previous November 15, 2010 submittal of the 100% complete report. We have responded to specific comments by VCWPD and other stakeholders by revising our quantitative methods for certain components of the groundwater budget, adding additional references, modifying figures and tables where requested, generating new figures, incorporating a new section regarding groundwater consumption by riparian vegetation, and incorporating a new appendix that reproduces existing geologic maps and a generalized geologic cross section. Specific responses to all comments submitted on the previous versions of the report are provided in an appendix to the report.

As stated in your letter of November 2, 2010, DBS&A has not incorporated all additions to the report suggested by VCWPD. The following list presents the specific additions suggested by VCWPD that have not been included, and the justification:

- *Generation of original geologic cross sections:* VCWPD has requested in comments on the 75% and 90% draft report for DBS&A to generate new geologic cross sections of the Subbasins. To address this comment, DBS&A has used existing geologic cross sections and maps to present our conceptual model of the Subbasins and provide relevant data. We have cited the literature references throughout the report and provided reproductions of the maps and a regional cross section in an appendix to the final report. DBS&A would be pleased to

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create original geologic cross sections of the area, but this relatively time-intensive task is not included in our specific contracted scope of work and budget. Furthermore, DBS&A considers the data we have provided and/or cited to be adequate for estimation of the groundwater budget consistent with accepted methods.

- *Detailed information regarding agricultural extraction rates:* VCWPD requested in comments on the 75% report the addition of "detailed GIS data that describes crop and water use changes over time with better water application figures." Such detailed data is apparently not readily available. For example, as discussed in the report, agricultural well users currently do not report extraction data. This component of the budget was estimated from available data on crop coverage, crop-specific water usages for Ventura County from California Department of Water Resources, and the location of agricultural wells in the Subbasins. We have also included two 'checks' on our agricultural extraction estimate, based on reported extractions rates in the adjacent Ojai Basin, and water delivery trends by Casitas Municipal Water District (CMWD). The method is consistent with accepted methods used in the groundwater literature. The method is also appropriate given the data gaps that exist regarding this information in the ULVRB.

- *Verification of the number of septic systems:* VCWPD also requested in comments on the 75% draft report, and subsequent correspondence, that DBS&A contact staff at the County of Ventura Environmental Health Division to verify the number of septic systems in the ULVRB that was provided by the County of Ventura Individual Sewage Disposal System Applications/Permits Database. DBS&A contacted several staff at the Environmental Health Division, who informed us that the database we used provides the most accurate information regarding septic tanks in this area. Environmental Health Division staff also reported that the database is the same source of information used by Ventura County for submittals to the Regional Water Quality Control Board. However, we have added a discussion of the possible limitations of this database to the final report based on VCWPD comments.

Thank you again for the opportunity to perform this study. If you have any additional questions or would like further clarification, please feel free to contact me at (805) 681-2986 or gschnaar@dbstephens.com.

Sincerely,

DANIEL B. STEPHENS & ASSOCIATES, INC.

G. Schnaar

Gregory Schnaar, Ph.D.
Senior Environmental Scientist

GS/et
Attachments

Groundwater Budget and Approach to a Groundwater Management Plan Upper and Lower Ventura River Basin

Prepared for **Ventura County Watershed Protection District**

December 30, 2010

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Groundwater Budget and Approach to a Groundwater Management Plan Upper and Lower Ventura River Basin

December 30, 2010

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Executive Summary

The Upper and Lower Ventura River Groundwater Subbasins (the Subbasins) extend along the Ventura River Valley from the mouth of the river at the Pacific Ocean to just south of Matilija Canyon. Water users in the Ventura River Watershed have no access to imported water, and are therefore dependent upon maintaining an adequate supply of usable quality local water resources. For this reason, protection of local groundwater is vital, and an adequate understanding of groundwater storage volume and water quality trends is necessary. This report presents a groundwater budget for the Subbasins and an approach to a groundwater management plan (GWMP), which constitute the first steps in building a sufficient understanding of groundwater resources and planning for long-term protection.

The general approach for the groundwater budget is to estimate, based on available data and hydrogeologic analyses, the magnitude of all groundwater inputs and outputs within each of the Subbasins. The resulting budget provides an estimate of the net gain or loss of the volume of groundwater in storage within the Subbasins per year. For the Upper Subbasin, a net annual gain of 1,466 acre-feet per year (ac-ft/yr) is estimated for the budgeted time period (water years 1997 through 2007). The primary inputs to groundwater in this Subbasin are infiltration and surface water recharge from Lake Casitas and the Ventura River, while the primary outputs are municipal and agricultural extractions. The estimated net gain in groundwater storage is relatively small, and is consistent with long-term hydrographs of wells within the Upper Subbasin that indicate stable groundwater levels with 5- to 10-year rise and decline cycles.

For the Lower Subbasin, a net annual loss of 2,423 ac-ft/yr is estimated for the budgeted time period. The primary inputs are infiltration and inflow from the Upper Subbasin, while the primary outputs are groundwater discharge to surface water and discharge to the Pacific Ocean. There are currently no water levels monitored by Ventura County within the Lower Subbasin for comparison to the budget.

The intention of a GWMP is to provide a framework to manage groundwater to ensure a long-term sustainable, reliable, good-quality water supply suitable to the political, legal, institutional, hydrogeologic, and economic conditions and constraints that exist in a groundwater basin. This report presents an approach to development of a GWMP for the Subbasins, including specifications for public participation, interagency involvement, coordination with the Ventura River Watershed Council, literature review and technical analysis, establishment of management objectives, and development of a monitoring program.

1. Introduction

The County of Ventura Watershed Protection District (VCWPD), in cooperation with the Watersheds Coalition of Ventura County (WCVC), has received funding in the form of a Proposition 50 grant, intended for implementation of priority projects to address water supply reliability, water quality improvement, and habitat protection. The top priority project for the Ventura River Watershed is the Ventura River Watershed Protection Plan, also known as the V-1 Project, as defined in the Ventura County Integrated Water Management Program (VCIRWMP) that served as the basis for the Proposition 50 Grant Funding. One identified priority project component of the V-1 Project is the development of a groundwater budget for the Ventura River Valley Groundwater Basin, which is subdivided into the Upper Ventura River and Lower Ventura River Subbasins (the Subbasins) (Figure 1). Other V-1 components include water supply reliability, groundwater recharge, habitat restoration, water quality, and flood management. As part of the V-1 Project, Daniel B. Stephens & Associates, Inc. (DBS&A) has produced this groundwater budget and an approach for creation of a groundwater management plan (GWMP) for these two groundwater Subbasins. Section 2 of this report presents and describes the groundwater budget for the Subbasins. Section 3 discusses the approach for a GWMP.

1.1 Background

The Subbasins extend along the Ventura River Valley for approximately 15 miles from the mouth of the river at the Pacific Ocean to just south of Matilija Canyon. The delineation of the Subbasins is not consistent among various reports, including California Department of Water Resources (CDWR) Bulletin 118 (CDWR, 2003), VCWPD annual groundwater reports (e.g., VCWPD, 2009), and previous modeling reports for the Ventura River watershed (Tetra Tech, 2009). As discussed below, the delineation used for this report is consistent with the previous modeling studies, and includes the area surrounding the main stem of the Ventura River below Matilija Dam, portions of Coyote Creek drainage and Lake Casitas, and the southerly reach of San Antonio Creek (Figure 1).

Ventura County nomenclature defines the Upper and Lower basins as separate; however, for consistency with California State nomenclature (CDWR, 2003), this report refers to the system as a single basin consisting of two subbasins. Portions of the cities of Ventura, Oak View, Mira Monte, Meiners Oaks, and Ojai are located within the Subbasins.

The Upper Subbasin includes the main stem of the Ventura River above Foster Park and the Coyote Creek drainage, which includes Lake Casitas and drains into the Ventura River at Foster Park. North of Foster Park, outcropped bedrock exists between the Ventura River and the Coyote Creek drainage, separating the Upper Subbasin into two distinct eastern and western sections (Figure 1). The hydrogeologic systems are markedly different for the eastern and western portions of the Upper Subbasin, as are relevant data sources for calculation of the groundwater budget. The Upper East Subbasin consists of the main stem of the Ventura River above Foster Park; the Upper West Subbasin consists of Lake Casitas and the Coyote Creek drainage. All calculations for the groundwater budget were summed for the Upper East and Upper West Subbasins in order to arrive at a final groundwater budget for the Upper Subbasin.

The Upper Subbasin is bounded on the south by the Lower Subbasin, on the east by the Ojai Valley Basin, and throughout the rest of its area by the Santa Ynez Mountain Range. The Coyote, Matilija, and San Antonio Creeks flow into the Ventura River, which drains the Upper Subbasin. The Lower Subbasin is bounded on the north by the Upper Subbasin, on the south by the Pacific Ocean, and on the east and west by the foothills of the local southern mainland portion of the transverse ranges, and is drained by the Ventura River. The alluvial groundwater subbasins consist of unconfined Holocene and Pleistocene age deposits (CDWR, 2004). Several bedrock aquifer formations underlie the alluvial Subbasins, as described in Section 2.2.5. These bedrock aquifers may be confined, semi-confined, or unconfined.

Surface water and groundwater flows in the Subbasins have been influenced by several major engineering projects. The Ventura River Project of the U.S. Bureau of Reclamation was completed in 1959, and is one of several projects designed to capture seasonal floodwaters that would otherwise ”waste to the sea” (USBR, 2009). The Ventura River Project includes Casitas Dam and Lake Casitas on Coyote Creek, the Robles Diversion Dam on the Ventura River, and the Robles-Casitas Conduit (Figure 1). Casitas Dam is the main component of the project, and is located on Coyote Creek about 2 miles above the junction of the creek and the Ventura River. Lake Casitas, created by the dam and located along Coyote Creek, is a storage reservoir that is also fed by the Robles-Casitas Conduit, which diverts water from the Ventura River at the Robles Diversion Dam. Lake Casitas regulates flows along the lower reach of Coyote Creek, and supplies municipal and irrigation water to the Casitas Municipal Water District (CMWD).

The Foster Park Submerged Dam was constructed in 1907 at Casitas Narrows, along the Ventura River (Figure 1). The dam was built to intercept groundwater flow through alluvium below the river and bring it to the surface such that it would be available for diversion to municipal supply. The reinforced concrete dam contacts bedrock along its length, from depths of 6 to 50 feet below ground surface. Due to construction difficulties, a 300-foot gap exists in the dam at the eastern end of the alluvium (SBRA, 2002).

1.2 Groundwater Quantity Issues

Groundwater is extracted from the Subbasins for municipal, industrial, agricultural, and domestic uses. In the Upper Ventura Subbasin, the City of Ventura, Ventura River County Water District (VRCWD), CMWD, and Meiners Oaks County Water District (MOCWD) extract groundwater for municipal use. Hydrographs from wells within the Upper Subbasin indicate that groundwater levels are generally stable over relatively long time periods, and fluctuate seasonally by about 5 to 20 feet. Gradual groundwater level decline and rise can also be observed for dry and wet weather cycles, of lesser amplitude compared to seasonal cycles.

Ventura County regularly monitors several wells in the Upper Eastern Subbasin (Figure 1), and water level data are available beginning in 1949 (VCWPD, 2009). Groundwater level data from representative wells were smoothed through the use of a trailing 5-year average, which provides the average groundwater level over the previous 5-year period (Figures 2a and 2b). Analysis of the trailing 5-year average groundwater levels indicate that overall levels have remained generally stable since measurements began. Water levels for the Lower Subbasin are not currently monitored by Ventura County.

1.3 Groundwater Quality Issues

Historically, the Subbasins have both had generally good water quality, with the exception of elevated concentrations of total dissolved solids (TDS) above the U.S. Environmental Protection Agency (EPA) secondary maximum contaminant level (MCL) of 500 milligrams per liter (mg/L) and nitrate concentrations in excess of the state MCL of 45 mg/L (as NO_3). TDS concentrations within the Upper Subbasin are reported to range from 500 to 1,240 mg/L (CDWR, 2004; VCWPD, 2009). For the Lower Subbasin, TDS concentrations are reported to typically range from 760 to 784 mg/L, but become elevated to as high as 3,000 mg/L during extended dry periods when there is less recharge of lower-TDS surface waters. Nitrate concentrations reach a maximum approaching 70 mg/L in the central portion of the Upper Subbasin. The Lower Subbasin has also exhibited elevated levels of hydrogen sulfide, hydrocarbons associated with oil seepage, sulfate, iron, and nitrate (CDWR, 2004; VCWPD, 2009). In sampling conducted by VCWPD in 2009, no samples from either of the Subbasins exhibited levels of metals (i.e., Title 22 metals) above the EPA or state MCLs (VCWPD, 2009).

2. Groundwater Budget

Water users in the Ventura River Watershed have no access to imported water, and are therefore dependent upon maintaining an adequate supply of usable quality local water resources. For this reason, protection of local groundwater is vital, and an adequate understanding of groundwater storage volume and water quality trends is necessary. DBS&A has prepared a groundwater budget for the Upper and Lower Subbasins, with the objective to gain a better understanding of the groundwater inputs and withdrawals that govern groundwater availability.

2.1 Approach to the Groundwater Budget

The general approach for the groundwater budget is to estimate, based on available data and hydrogeologic analyses, the magnitude of all groundwater inputs and outputs within each of the Subbasins. The resulting budget provides an estimate of the net gain or loss of the volume of groundwater in storage within the Subbasins per year, over the time period of analysis. A general schematic of the hydrologic cycle and factors driving the groundwater budget is shown in Figure 3.

Groundwater inputs for a subbasin include infiltration of precipitation and irrigation water (I_p, I_i), inflow of groundwater from upgradient adjacent subbasins (GW_i), recharge of surface water to groundwater (SW_i), recharge of water from domestic septic systems (S), and flux of groundwater from bedrock into the alluvium (B_i). Groundwater outputs include extractions for municipal (E_m), domestic (E_d), irrigation of agriculture (E_a), and industrial (E_p) uses, groundwater outflow to downgradient basins or the ocean (GW_o), flux of groundwater in the alluvium to bedrock (B_o), discharge to surface water (SW_o), and consumption via evapotranspiration by riparian vegetation (R). Mathematically, the net groundwater budget (ΔGW_s) is represented by the following equation:

$$\Delta GW_s = \left[I_p + I_i + GW_i + SW_i + S + B_i\right] - \left[E_m + E_d + E_a + E_p + GW_o + R + B_o + SW_o\right] \quad (1)$$

In order to calculate the groundwater budget, additional watershed processes must be quantified. For example, the amount of infiltration to groundwater is a function of the amount of precipitation and irrigation. In addition, quantifying surface water/groundwater interactions (SW_i, SW_o) requires budgeting of surface water inputs and outputs, including diversions, point sources of surface water (e.g., from wastewater treatment plants), and surface water evaporation.

As described below, the annual average magnitude of each of the parameters listed on the righthand side of Equation 1 was estimated or obtained from literature references for each of the Subbasins. Several of the groundwater budget estimates or calculations presented in this report are derived from data presented in documentation of the Ventura River Watershed Hydrology Model (VRWHM), an existing hydrologic routing model of the Subbasins and surrounding Ventura River Watershed (Tetra Tech, 2009). This earlier study was also sponsored by the VCWPD and funded under a Proposition 50 grant. The model represents the surface water balance of the watershed and gaged flows.

Results of the watershed balance are presented in the VRWHM report (Tetra Tech, 2009) for water years 1997 through 2007 (i.e., October 1996 to September 2007). The range of the annual amount of streamflow in the Ventura River and precipitation in the study area during this period are generally representative of the longer-term record of 1950 to present (Figures 4 and 5). Similarly, long-term hydrographs show that groundwater levels within the Subbasins from 1997 to 2007 are generally representative of the longer-term record of 1950 to present (Figure 2a and 2b). For these reasons, and to maintain consistency with the VRWHM, the same time period of water years 1997 to 2007 was used in this report for determination of the groundwater budget (henceforth referred to as the budgeted time period). In addition, the delineation of the Subbasins is also consistent with the VRWHM (Figure 1).

2.2 Groundwater Inputs

This section describes estimated inputs to groundwater within the Subbasins, including infiltration from precipitation and irrigation, surface water recharge to groundwater, recharge from septic systems within the basins, and influx from bedrock into the alluvial aquifers. As described below, these inputs were estimated using available data and hydrogeologic analyses.

The final results of the groundwater budget for each of the Subbasins are provided in Section 2.4. Limitations are discussed below and summarized in Section 2.5.

2.2.1 Infiltration from Precipitation

Estimates of precipitation are required in order to estimate infiltration rates for each of the Subbasins. Total precipitation over the budgeted time period for the Subbasins was determined from annual rain contours for water years 1997-2007 that were generated for use in the VRWHM (Tetra Tech, 2009). Precipitation rates were calculated by summing the area contribution of each precipitation isocontour within each of the Subbasins (Figure 6). Annual average precipitation rates over the budgeted period were 3,661 acre-feet per year (ac-ft/yr) for the Upper West Subbasin, 18,597 ac-ft/yr for the Upper East Subbasin, and 4,947 ac-ft/yr for the Lower Subbasin (Table 1).

The amount of precipitation that infiltrated to groundwater was estimated using the modified Maxey-Eakin approach. The Maxey-Eakin method is the most widely used empirical approach for estimating infiltration to groundwater in the southwest (Scanlon, 2004). The Maxey-Eakin method estimates infiltration to groundwater as a percentage of total precipitation, based on five distinct precipitation regimes (0 percent infiltration for <3.9 inches per year [in/yr] precipitation, 3 percent for 3.9 to 12.0 in/yr, 7 percent for 12.0 to 15.0 in/yr, 15 percent for 15.0 to 20.0 in/yr, and 25 percent for >20 in/yr). The modified method uses a continuous exponential curve fit through the original Maxey-Eakin precipitation regimes, while maintaining a maximum 25 percent infiltration (e.g., Hevesi et al., 2002). The area covered by the Subbasins received an average precipitation of 16 to 28 in/yr during the budgeted time period (Figure 6). Potential infiltration for each precipitation isohyetal was calculated using the modified Maxey-Eakin method (Table 1).

Due to urban development, the actual infiltration in the area of the Subbasins is impacted by the amount of impervious surfaces (e.g., pavement) that route precipitation directly into storm drains and eventually to surface water bodies, referred to as the effective impervious area (EIA). EIA differs from total impervious area (TIA) because certain impervious surfaces route precipitation water onto the soil surface, where it is available to infiltrate into groundwater (e.g., building roofs). Land use coverage was analyzed using data for each of the Subbasins available from the Southern California Association of Governments (SCAG) for the year 2005 (as cited in Tetra Tech, 2009) (Figures 7a and 7b). Land use types include vacant, irrigated agricultural, orchards and vineyards, parks/golf courses, and developed areas, which are further delineated as residential, commercial, industrial, or institutional areas. The EIAs for the relevant land types were obtained from Brabec et al. (2002), and are presented in Table 2.

The Subbasin-wide EIA for each of the Subbasins was determined by summing the EIA for each land use component and dividing by the total land area for the Subbasin (Table 2). Infiltration from precipitation for each of the Subbasins was then calculated by applying the Subbasin EIA to the potential infiltration (Table 1). The resulting infiltration from precipitation was 4,181 ac-ft/yr for the Upper East Subbasin, 893 ac-ft/yr for the Upper West Subbasin (total 5,073 ac-ft/yr in Upper Subbasin), and 616 ac-ft/yr for the Lower Subbasin.

2.2.2 Infiltration from Irrigation

Irrigation estimates within each of the Subbasins were developed using the SCAG land use data. Irrigated SCAG land use types included irrigated agricultural, orchards and vineyards, parks/golf courses, and developed areas, which are further delineated as residential, commercial, industrial, or institutional areas. The total area for each SCAG land use type within each of the Subbasins was estimated using graphical analysis (Figures 7a and 7b; Table 3). As explained below, average irrigation water application rates for the various land use types for Ventura County for 1998-2001 were obtained from CDWR (2010). Annual irrigation volumes for each of the Subbasins were then obtained by multiplying the land use type-specific water application rates and the irrigated land use area within each Subbasin (Table 3).

Developed areas were assumed to only be irrigated at areas of vegetated coverage. The fraction of vegetative coverage for developed areas was determined from the TIA for each land use type, and ranges from 12 percent for commercial land use to 72 percent for low-density residential use (Brabec et al., 2002). The fraction of vegetative coverage for each developed land use within each of the Subbasins was multiplied by the total area for that land use to determine the irrigated area. A limitation of this approach is that it is assumed that all vegetated coverage within developed areas is irrigated, while in reality certain vegetated areas (e.g., low-impact landscaping) are not irrigated. This assumption will tend to overestimate irrigation and resulting estimates of infiltration. Water application rates for the vegetated areas of developed land uses and the park/golf course land use type were based on application rates for grasses (i.e., pasture) in Ventura County (CDWR, 2010).

Based on review of the crop designations used in the VRWHM (Tetra Tech, 2009), and crop data specific to the Subbasins obtained from the Farm Bureau of Ventura County (2010), the orchard/vineyard land use areas were determined to consist of citrus and avocado crops. The irrigated agriculture land use areas were determined to consist of truck produce crops (e.g., various row crops, bush berries, strawberries) based on review of these same sources. Water application rates for these crops were obtained from CDWR (2010). The total estimated irrigation rates, including all land use types, are 12,865 ac-ft/yr for the Upper East Subbasin, 670 ac-ft/yr for the Upper West Subbasin (total of 13,535 ac-ft/yr for the Upper Subbasin), and 2,822 ac-ft/yr for the Lower Ventura Subbasin (Table 3).

The amount of applied irrigation water that infiltrates to groundwater was determined by the irrigation efficiency, which describes the percentage of applied water that is retained within the root zone and is available for evapotranspiration. For the orchard/vineyard and irrigated agriculture land uses, irrigation efficiencies for each crop type in Ventura County were obtained from CDWR (2010). Irrigation efficiency for developed land areas was assumed to be 80 percent based on evaluation of irrigation systems in Ventura County (Tetra Tech, 2009). The amount of irrigation water that infiltrates to groundwater was determined for each land use within each of the Subbasins by assuming that all applied water that was not retained within the root zone infiltrates to groundwater (Table 3). The total infiltration from irrigation application for each of the Subbasins was determined by summing the contributions of each land use type. Estimated infiltration for irrigation was 2,891 ac-ft/yr for the Upper East Subbasin, 222 ac-ft/yr for the Upper West Subbasin (total 3,113 ac-ft/yr for Upper Subbasin), and 655 ac-ft/yr for the Lower Subbasin.

2.2.3 Surface Water Recharge to Groundwater

Surface water bodies within the Subbasins, including Lake Casitas and portions of the Ventura River and San Antonio Creek, recharge groundwater. For analysis of surface water/ groundwater interactions, the Upper West Subbasin, which contains Lake Casitas, was analyzed separately from the Upper East Subbasin, which contains sections of the Ventura River and San Antonio Creek, and the Lower Subbasin, which contains a section of the Ventura River. Discussion of surface water/groundwater interactions for the Lower Subbasin are included in Section 2.3.5, as calculations indicated that there is a net flux of groundwater discharging to surface water in the Lower Subbasin. The Upper East Subbasin estimate is discussed below.

The VRWHM provides modeled estimates of reservoir loss from Lake Casitas in the Upper West Basin, which includes recharge to groundwater and the net precipitation balance (Tetra Tech, 2009). The Casitas Reservoir Inventory Annual Summary, provided by CMWD (2010), was used herein to determine average annual lake evaporation and direct precipitation onto the lake in order to calculate the net precipitation balance. The net precipitation balance was then subtracted from the VRWHM-calculated annual average reservoir loss in order to estimate surface water recharge to groundwater at Lake Casitas. The estimated annual average recharge from the lake to groundwater over the budgeted time period is 2,003 ac-ft/yr (Table 4). Limitations of using the VRWHM estimates for the groundwater budget are discussed in Section 2.5.

For the Upper East Subbasin, the estimated surface water/groundwater balance of the Ventura River was estimated from an accounting of surface water flows within the river. The difference between inputs and outputs to the river along this section is assumed to recharge to groundwater. Inputs and outputs from the river are accounted for as follows:

$$\Delta SW = \left(Q_o + E + D_o\right) - \left(R + D_i + P + Q_i\right) \quad (2)$$

where ΔSW = the net surface water/groundwater balance

Q_o = the surface water flow at the downstream boundary of the Subbasin

E = evaporation from the river

D_o = diversions out of the river

R = surface runoff into the river along the reach of the Subbasin

D_i = point sources of water into the river

P = direct precipitation into the river

Q_i = the surface water flow at the upstream boundary of the Subbasin

For the section of the Ventura River within the Upper East Subbasin, there are no point sources into the river, and evaporation is considered negligible according to the VRWHM; therefore, Equation 2 simplifies to the following:

$$\Delta SW = (Q_o + D_o) - (R + P + Q_i) \tag{3}$$

Calculation of the net recharge to groundwater for the Upper Subbasin is presented in Table 5. VRWHM modeled flows at U.S. Geological Survey (USGS) Gage 608 were used to provide river flow rates at the downstream boundary of the Upper Subbasin, and modeled flows from the VRWHM were used at the upstream boundary. Gage 608 is located downstream of the Foster Park Dam (Figure 1). Estimates of surface runoff, direct precipitation, and diversions were also taken from the VRWHM. The calculated surface water recharge to groundwater for the Ventura River within the Upper East Subbasin is 1,321 ac-ft/yr.

A section of San Antonio Creek is also located within the Upper East Subbasin (Figure 1). Use of Equation 2 for determination of the groundwater/surface water balance was not applicable, however, because there are not sufficient stream flow gages present along the reach at this location. Therefore, a simpler approach was used based on the results of the VRWHM within the San Antonio Creek drainage. The VRWHM predicts a net recharge from the creek to groundwater of 2,204 ac-ft/yr along the entire length of the creek (Table 5). It was estimated based on graphical analysis that 44 percent of San Antonio Creek is located within the Upper East Subbasin. Therefore, it was assumed that 44 percent of the total San Antonio Creek recharge to groundwater, or 970 ac-ft/yr, occurs in the Upper East Subbasin. A limitation of this approach is that groundwater recharge and discharge rates may not be constant over the length of the Creek, as assumed here. As discussed in Section 2.5, obtaining model data from the

VRWHM that is specific to the area of San Antonio Creek in the Upper East Subbasin will reduce uncertainty associated with this estimate.

2.2.4 Recharge from Domestic Septic Systems

For domestic water users that use individual septic systems, some of the household-consumed water is eventually recharged to groundwater. The amount of septic system recharge for each of the Subbasins was estimated using data from the County of Ventura Individual Sewage Disposal System Applications/Permits Database (CVEHD, 2010) (Table 6). This database provides approved septic systems listed by the assessor's parcel number (APN), from 1977 to present. Geographical information system (GIS) parcel data were obtained from Ventura County, and were overlaid with the boundaries of the Subbasins to determine APNs within the boundaries of each of the Subbasins (Figure 8). This list was then cross-referenced against the Sewage Disposal System Applications/Permits Database in order to determine the number of approved septic systems within each of the Subbasins. The recharge rate for individual septic systems was assumed to be 143.5 gallons per day (gpd), or 0.16 ac-ft/yr, assuming 50 gpd per person based on a study of septic system recharge within southern California (Hantzche and Finnemore, 1992), and an average population of 2.87 persons per household in California (U.S. Census Bureau, 2010). The resulting total recharge from all septic systems was 120 ac-ft/yr for the Upper East Subbasin, 18 ac-ft/yr for the Upper West Subbasin (total of 138 ac-ft/yr for the Upper Subbasin), and 5 ac-ft/yr for the Lower Subbasin. Septic system recharge values may be underestimated, as additional septic systems may be present that are not listed in the Individual Sewage Disposal System Applications/Permits Database.

2.2.5 Inflow from Bedrock to the Alluvial Aquifer

Several tertiary (Eocene to Pliocene) bedrock formations underlie the Quaternary alluvium that comprises the aquifers of the Upper and Lower Subbasins (Appendix A). These formations also comprise a significant portion of the larger Ventura River Watershed. Geologic descriptions of the bedrock formations include siliceous, diatomaceous, and micaceous shales, sandstones, siltstones, and claystones, as described below, which typically have low groundwater flow rates compared to the alluvial material of the Subbasins (Freeze and Cherry, 1979; Fetter, 2001). A previous USGS groundwater modeling study of the nearby Santa Clara–Calleguas Basin states that these same bedrock formations are virtually non-water-bearing, and vertical flow between bedrock and the surficial aquifer materials was assumed to be zero in that study (Hanson et al., 2003). Several domestic, agricultural, and industrial wells extract groundwater from these bedrock formations within the Ventura River watershed; therefore, the formations do have some capacity for groundwater flow. For this reason, groundwater flux from the bedrock formations to the alluvial aquifers was estimated as described below.

Because most water users near the Subbasins have access to the alluvial groundwater or water from another source (e.g., CMWD), few wells exist within the Subbasins that extract groundwater exclusively from bedrock. Therefore, detailed hydrogeologic data for the bedrock formations from wells in the direct vicinity of the Subbasins is generally not available. Calculation of vertical groundwater flux between two units (e.g., bedrock and alluvium) typically requires a nested pair of groundwater wells or piezometers that are located relatively near each other horizontally and are screened in the separate formations (Fetter, 2001). Groundwater elevations measured in the two wells, and the vertical distance between the two screened intervals, are then used to measure a vertical hydraulic gradient. With knowledge of the hydraulic conductivity, Darcy's Law can be used to estimate vertical groundwater flux. Nested groundwater wells in the Subbasin alluvium and bedrock formations are not present in this area for accurate calculation of the vertical hydraulic gradient; therefore, as discussed below, a unit hydraulic gradient was assumed to develop a preliminary flux estimate. It is recognized that an assumed unit gradient may be substantially different that actual gradients; however, in the absence of site-specific data, this assumption can be used to provide a preliminary flux estimate. The resulting estimated groundwater flux into the alluvial aquifers is prone to significant uncertainty.

Available well and literature data were reviewed to estimate inflow from bedrock to alluvial aquifers using estimated parameters and accepted methods (Table 7). Regional geologic maps (Tan et al., 2003; Tan and Jones, 2006; Dibblee, 1987 and 1988) (see Appendix A, Plates 1 and 2) and cross sections (CDOG, 1991; Rockwell et al., 1984) (see Appendix A, Plate 3) were used to develop a general conceptual model of the bedrock formations. It is recognized that geologic structure can influence groundwater flux, but DBS&A has not identified a source of specific data for the area regarding this factor. For example, the Red Mountain Fault Zone located in the Upper Subbasin (Rockwell et al., 1984) (see Appendix A, Plate 2) may comprise a barrier to groundwater flow in the bedrock formations. In addition, upright synclines generally accept recharge into the limbs of the structure, directing it toward the syncline axis. However, DBS&A has not identified specific data regarding the influence of these and other structural features on groundwater flux.

Formation names used here and primary geologic structures identified in the area follow AAPG (1956) and Dibblee (1987 and 1988). The bedrock formations that underlie the Upper Ventura River Basin are the Cozy Dell shale, Coldwater sandstone, Sespe Formation, Vaqueros sandstone, Rincon shale, and Monterey Formation. South of the Red Mountain Fault Zone, beneath the Lower Ventura River Basin, the younger Pico Formation, Las Posas sand, and Saugus Formation are present. Wells within the Ventura River Watershed screened exclusively in bedrock were identified for several of the formations. Available data from these wells were used to assist in estimation of representative groundwater flow rates between bedrock and the alluvial aquifers. However, these wells are generally located several miles from the Subbasins, and therefore were used only for general information.

The northernmost bedrock formation underlying the Upper Subbasin is the Cozy Dell shale (Appendix A, Plate 2), which is structurally a part of the Matilija Overturn. This formation is described as micaceous shale with sandstone interbeds (Tan and Jones, 2006). A hydraulic conductivity of $3 \cdot x\ 10^{-5}$ feet per day (ft/d) was assumed for this formation, which is in the higher end of the range reported for shales and the lower end of the range reported for sandstones (Freeze and Cherry, 1979). The groundwater well 05N22W28M03S, located north of the Ojai Basin, was identified as the closest well relative to the Subbasins with available data and screened exclusively within the Cozy Dell shale. Water levels measured in this well correspond to a groundwater elevation of approximately 1,500 feet above mean sea level (msl), significantly greater than groundwater elevations measured in wells screened in alluvium. Groundwater elevations in alluvium wells that are located in the portion of the Upper Subbasin underlain by the Cozy Dell shale are generally in the range of 775 to 850 feet above msl (Turner, 1971; VCWPD, 2010b). It was thus inferred that the general direction of groundwater flux is from the Cozy Dell shale into the alluvial aquifer. A vertical hydraulic gradient calculated using well

05N22W28M03S between the Cozy Dell shale and the alluvium is greater than 1, which may be possible given the permeability contrast between the formations (Hart et al., 2008). However, due to the large distance between this well and the Subbasins, the calculated vertical gradient was inferred as a general estimate, and a gradient of 1 (i.e., unit gradient) was assumed to estimate flux.

Moving southward, the next bedrock formation is the Coldwater sandstone (Appendix A, Plate 2), which is also structurally a component of the Matilija Overturn. This formation is described as hard sandstone, with siltstone and shale interbeds (Tan and Jones, 2006). A hydraulic conductivity of $1 \cdot x\ 10^{-3}$ ft/d was assumed for this formation, which is in the middle of the range reported for sandstones (Freeze and Cherry, 1979). The groundwater well 05N22W33R01S, located in the Ojai Basin, was identified as the closest well relative to the Subbasins with available data and screened exclusively within the Coldwater sandstone. Water levels measured in this well correspond to a groundwater elevation of approximately 1,250 feet above msl, significantly greater than groundwater elevations measured in wells screened in alluvium. Groundwater elevations in alluvium wells that are located in the portion of the Upper Subbasin underlain by the Coldwater sandstone are generally in the range of 775 to 825 feet above msl (Turner, 1971; VCWPD, 2010a). It was thus inferred that the general direction of groundwater flux is from the Coldwater sandstone into the alluvial aquifer. The calculated vertical hydraulic gradient is greater than 1; therefore, a unit gradient was assumed for groundwater flux calculations.

The Sespe Formation, structurally a component of the Ojai Syncline and Red Mountain Anticline, is the next bedrock formation moving southward, and underlies a significant portion of the Upper Subbasin (Appendix A, Plate 2). The Sespe Formation is described as sandstone, siltstone, and claystone (Tan and Jones, 2006). Driller's logs for wells identified to be completed in the Sespe Formation (05N23W35Q02S, 04N23W01D02S) generally indicate poor yields, and the Sespe is also known to be cemented at depth, with a large clay shale fraction. A hydraulic conductivity of $1 \cdot x\ 10^{-4}$ ft/d was assumed for this formation, which is in the lower range reported for sandstones (Freeze and Cherry, 1979). Water levels measured in the identified Sespe wells correspond to groundwater elevations of approximately 900 and 1,100 feet above msl, greater than groundwater elevations measured in wells screened in alluvium. Groundwater elevations from alluvium wells that are located in the portion of the Upper Subbasin underlain by the Sespe Formation generally range from 450 to 800 feet above msl (Turner, 1979; VCWPD, 2010a). It was thus inferred that the general direction of groundwater flux is from the Sespe Formation into the alluvial aquifer. The calculated vertical hydraulic gradients are greater than 1; therefore, a unit gradient was assumed for groundwater flux calculations.

The Vaqueros sandstone, Rincon shale, and Monterey shale, which structurally are components of the Oak View folds and flexural slip faults and the Red Mountain Fault Zone, comprise the remaining bedrock formations underlying the Upper Subbasin. Wells with available information screened exclusively in these formations were not able to be identified. However, based on evaluation of the other bedrock formations discussed above, it was assumed that an upward vertical gradient exists in these formations, and a unit gradient was assumed. A spring sourced from the Monterey Formation has also been observed in the area where the Monterey Formation outcrops near Oak View, further supporting an upward vertical gradient. A hydraulic conductivity of $1 \cdot x\ 10^{-3}$ ft/d was assumed for the Vaqueros sandstone, which has been reported to yield water to wells in the region. A hydraulic conductivity of $3 \cdot x\ 10^{-5}$ ft/d was assumed for the Rincon shale, which is described as shale and siltstone. The Monterey shale is described as a brittle siliceous and diatomaceous shale, indicating significant fracturing, with sandstone and limestone. A hydraulic conductivity was therefore assumed of $1 \cdot x\ 10^{-4}$ ft/d, which is at the higher end reported for shales (Freeze and Cherry, 1979).

In the Lower Subbasin, the primary bedrock formation is the Pico Formation, which structurally is a component of the Ventura Anticline (Appendix A, Plate 1). This formation is described as claystone, siltstone, and sandstone, and is known to yield groundwater. A hydraulic conductivity of $1 \cdot x\ 10^{-3}$ ft/d was assumed for the Pico Formation, which is in the middle of the range reported for sandstones (Freeze and Cherry, 1979). Industrial wells associated with oil and gas production were identified that are screened exclusively within the Pico Formation and are located in the vicinity of the Lower Subbasin (3N-23W-32 [A.P.I. 111-05937]; 3N-23W-27 [A.P.I. 111-20358]). Flowing artesian conditions have been observed at these wells (Aera, 2003 and 2008), from which it is inferred that there is an upward vertical gradient. Because no static water levels or pressure measurements are available from these wells, a unit hydraulic gradient was assumed.

The remaining formations that underlie the Lower Subbasin are the Las Posas sand and the Saugus Formation, which are of a younger age (Quaternary). Each of these units comprises an aquifer unit that is a component of the Santa Clara–Calleguas Basin. A USGS modeling study of the Santa Clara–Calleguas Basin estimated groundwater elevations in these units in the vicinity of the Lower Subbasin (Hanson et al., 2003). Groundwater elevations were estimated to be in the range of 0 to 20 feet above msl, which is similar to the general range of groundwater elevations in the southern portion of the Lower Subbasin underlain by these formations (H2 Environmental, 2008). It was therefore assumed that no significant gradient exists between these formations and the Lower Subbasin, and that groundwater flux is zero.

The estimated length (primarily north to south) and width (primarily east to west) of the Ventura River Basin alluvium above the bedrock formations was estimated from Dibblee (1987 and 1988), Tan et al. (2003), Tan and Jones (2006), and AAPG (1956). The estimated area of the bedrock formations beneath the alluvium was then calculated. Darcy's Law was used to estimate the vertical flow of groundwater from the bedrock formations to the alluvial aquifers, using the parameters as described above (Table 7). The inflow calculations result in an estimate of 114 ac-ft/yr to flow from bedrock aquifers to the Upper Ventura River Subbasin and 319 ac-ft/yr from bedrock aquifers to the Lower Ventura River Subbasin.

2.2.6 Groundwater Inflow from Upgradient Subbasins

The majority of groundwater flow in the alluvium between the Upper and Lower Subbasins is intercepted by the Foster Park Submerged Dam (Figure 1). However, a 300-foot gap exists in the dam on the eastern side (SBRA, 2002). The groundwater flux within the 300-foot channel comprises an inflow to the groundwater budget for the Lower Subbasin and an outflow for the groundwater budget of the Upper Subbasin. Groundwater flux was calculated using Darcy's Law, as follows:

$$GW_i = A_a \cdot K_a \cdot \frac{dh_a}{dl} \qquad (5)$$

where A_a = the cross-sectional area of the alluvium in the gap, taken as the product of the thickness (b) and the width (w)

K_a = the hydraulic conductivity of the alluvium

dh_a/dl = the hydraulic gradient across the gap

The hydraulic conductivity for the alluvium above Foster Park Dam was obtained from aquifer test data associated with the Foster Park well field summarized by Hopkins (2007). The saturated alluvial thickness was also obtained from Hopkins (2007), while the hydraulic gradient for the Casitas Narrows was obtained from Turner (1971) and the width of the gap was estimated by San Buenaventura Research Associates (SBRA) (2002) at 300 feet. Groundwater flux into the Lower Subbasin from the Upper Subbasin was calculated to be 535 ac-ft/yr (Table 8).

The Ojai Groundwater Basin is located directly to the east of the Upper Ventura River Subbasin. A groundwater divide exists at the boundary of the Upper Ventura River Subbasin and Ojai Basin, as evidenced by analysis of potentiometric surface maps (Turner, 1971; SGD, 1992); therefore, it is assumed that there is no significant direct flow of groundwater between the basins. Within the Ojai Basin, groundwater flow is generally toward Thacher and San Antonio Creeks, which drain into the Ventura River (CDWR, 2004).

2.3 Groundwater Outputs

This section describes calculations of outputs to groundwater within the Subbasins, including extractions, discharge to surface water, outflow of groundwater from the Upper Subbasin to the Lower Subbasin, and outflow from the Lower Subbasin to the ocean. As described below, these outputs were estimated using available data and hydrogeologic analyses. The final results of the groundwater budget for each of the Subbasins are provided in Section 2.4. Limitations are discussed below, and are summarized in Section 2.5.

2.3.1 Municipal Groundwater Extractions

Several active municipal groundwater extraction wells exist within the Upper East Subbasin (Figure 9). Municipal groundwater extractions were provided by water purveyors for the Upper East Subbasin, and annual average withdrawals over the budgeted period were calculated (Table 9). The City of Ventura extracts groundwater for municipal use at the Foster Park well field, which is located at the southern terminus of the Upper East Subbasin. Additionally, the VRCWD, CMWD, and MOCWD extract groundwater in the Upper East Subbasin. A total average extraction rate of 7,385 ac-ft/yr was estimated over the budgeted time period from the Upper East Subbasin. Extraction rates were relatively stable over the budgeted time period for VRCWD, CMWD, and MOCWD, but decreased significantly for the City of Ventura since 2005. This decrease in municipal extraction rates represents a significant change in the groundwater budget that would result in a more positive groundwater budget for the time period since 2005 (Section 2.4). No municipal groundwater extractions occur within the Lower Subbasin or Upper West Subbasin.

2.3.2 Domestic Groundwater Extractions

The locations of active domestic groundwater wells were obtained from the Ventura County Well Database (VCWPD, 2010a), and GIS was used to determine how many active wells exist within each of the Subbasins (Figure 9; Table 10). A total of 86 active domestic wells are located within the Upper East Subbasin, 8 within the Upper West Subbasin, and 5 within the Lower Subbasin. An average annual domestic water use per household for domestic well users of 163 gpd (0.18 ac-ft/yr) was obtained from analysis of Ventura County water usage data (USGS, 2000). It was assumed that each domestic well serves one household, with an average population of 2.87 persons per household in California (U.S. Census Bureau, 2010). The resulting calculated domestic groundwater extraction was 15.7 ac-ft/yr for the Upper East Subbasin, 1.5 ac-ft/yr for the Upper West Subbasin (total of 17.2 ac-ft/yr for Upper Subbasin), and 1 ac-ft/yr for the Lower Subbasin (Table 10). A limitation of this approach is that certain wells designated as domestic in the Ventura County Well Database may also be used for agricultural purposes as a secondary use, and therefore extract additional groundwater.

2.3.3 Agricultural Groundwater Extractions

Irrigation water supply within the Subbasins (Section 2.2.2) is supplied from both groundwater and surface water sources. Agricultural groundwater withdrawals from individual wells are not currently available. For the purpose of the groundwater budget, agricultural extraction was estimated from existing SCAG land use data (as cited in Tetra Tech, 2009) and the locations of active agricultural wells within the Subbasins, available from the Ventura County Well Database. Active agricultural well locations were overlaid on the land use map for the Subbasins (Figures 7a and 7b). Those land use areas designated as irrigated agriculture or orchard/vineyard, for which active agricultural wells were either co-located or reasonably proximal, were assumed to provide all irrigation via groundwater extraction. These land use areas were then multiplied by water application rates for the land use types available from CDWR, as described in Section 2.2.2 (Table 11). Estimated agricultural extraction rates using this method are 1,898 ac-ft/yr for the Upper East Subbasin and 522 ac-ft/yr for the Lower Subbasin. There are no active agricultural wells located in the Upper West Subbasin. The total agricultural extraction for the Subbasins is 2,420 ac-ft/yr.

A limitation of this approach is that active agricultural wells that are not located near agricultural land uses were assumed to extract no groundwater from the Subbasins. This may be a reasonable assumption considering that wells are listed as "active" within the Ventura County database if employed as little as 8 hours per year. In addition, this method assumes that all irrigation for those areas co-located or proximal to agricultural wells is supplied by groundwater, while both surface water and groundwater supplies may be used. Therefore, agricultural extractions comprise a source of uncertainty for the groundwater budget.

For this reason, alternative approaches were also used to estimate agricultural extraction within the Subbasins as a check. First, local agricultural withdrawal rates were assessed in the adjacent Ojai Groundwater Basin; these withdrawal rates are required to be reported to the Ojai Basin Groundwater Management Agency (OBGMA) (SGD, 1992). Irrigation practices are similar in the Ojai Basin and Ventura River Subbasins, and are often conducted by the same management teams. Based on this review, a representative annual average extraction of 79 ac-ft/yr was applied to each active agricultural well within the Subbasins. The resulting alternative estimates of agricultural extraction were 3,397 ac-ft/yr for the Upper East Subbasin and 474 ac-ft/yr for the Lower Subbasin (Table 11). Although the estimated extraction rates compare well for the two different methods for the Lower Subbasin, the estimated extraction rate for the Upper East Subbasin is significantly greater using the alternative approach. The discrepancy in the Upper East Subbasin is due to the large number of active agricultural wells that are not co-located with agricultural land uses in that Subbasin (Figures 7a and 7b).

Second, CMWD annual water delivery trends were assessed (Merckling, 2010). During relatively dry years, CMWD observes significant increases in water demand from Lake Casitas due to lowering of groundwater levels and concomitant decrease in availability of groundwater for irrigation. For the period 1984-2008, the average annual CMWD deliveries for water years with less than 10 inches of rainfall were 21,718 ac-ft/yr. During this same time period, average annual CMWD deliveries for water years with rainfall of 10 to 30 in/yr were 19,652 ac-ft/yr. The difference of 2,066 ac-ft/yr is assumed to be caused by increased agricultural surface water demands throughout the CMWD service area (including Ventura and Ojai Basins) during dry periods, when groundwater levels may be too low for pumpage from some agricultural wells. This difference of 2,066 ac-ft/yr is not directly comparable to agricultural extractions in the Ventura Subbasins presented above because (1) the CMWD service area includes both Ventura and Ojai Basins, and (2) it is not anticipated that all agricultural extractions would end during drier years, as analysis of groundwater fluctuations (e.g., Figure 2) indicates that groundwater levels do not decline so much during dry periods that all alluvial wells become dry. However, this comparison provides an order-of-magnitude check on the estimated groundwater extraction of 2,420 ac-ft/yr provided above for the Subbasins.

2.3.4 Industrial Groundwater Extraction

Groundwater is extracted from the alluvium of the Lower Subbasin during oil extraction by Aera Energy LLC (Aera) and its predecessors, including Shell Oil, from deeper zones (i.e., bedrock) (Figure 9). However, groundwater extraction rates associated with oil extraction by Aera are not currently available, and therefore were not included in the groundwater budget. This is identified as a current limitation of the groundwater budget, although effects are anticipated to be relatively small, as major groundwater extraction from these wells appears to have ceased several years ago following the cessation of steam/waterflood injection practices in the Ventura Oil Field. There are no active industrial wells within the Upper Subbasin.

2.3.5 Groundwater Discharge to Surface Water

Calculations of surface water/groundwater interaction, as described in Section 2.2.3, indicate that there is a net discharge of groundwater to surface water within the Lower Subbasin. Similar to the Upper East Subbasin, the estimated surface water/groundwater balance for the Lower Subbasin was estimated from an accounting of surface water flows within the Ventura River at the upstream and downstream boundaries of the subbasin, while also accounting for other inputs and outputs from the river (Table 5).

For the Lower Subbasin, because there are no diversions out, and evaporation is considered negligible according to the VRWHM, Equation 2 simplifies to the following:

$$\Delta SW = Q_o - \left(R + D_i + P + Q_i\right) \qquad (6)$$

Calculation of the net groundwater discharge to surface water for the Lower Subbasin is presented in Table 5. VRWHM modeled flow at USGS Gage 608 was used to provide river flow rates at the upstream boundary of the Subbasin, and modeled flows from the VRWHM were used at the downstream boundary. Estimates of surface runoff, direct precipitation, and input to the river from the Ojai Wastewater Treatment Plant (Figure 1) were also taken from the VRWHM. The calculated groundwater discharge to surface water in the Lower Subbasin is 1,254 ac-ft/yr.

2.3.6 Groundwater Outflow

Groundwater flow into downgradient subbasins or the Pacific Ocean is an important groundwater output. As discussed in Section 2.2.7, groundwater flows out of the Upper Subbasin and into the Lower Subbasin at an estimated rate of 535 ac-ft/yr (Table 8).

For the Lower Subbasin, Darcy's Law (Equation 5), was used to estimate the groundwater flux to the Pacific Ocean (Table 8). The saturated alluvium thickness was obtained from evaluation of well logs summarized by Hopkins (2007) and Turner (1971). Additional local well logs from several regulated facilities within the Lower Subbasin were also evaluated to determine the representative lithologic characteristics of the alluvium (PWE, 2006; EPI, 1996; Pacific, 1997; EnviroSolve, 2008; HEI, 2006). Boring logs describe the saturated alluvium as mostly silty sands and gravels, and sandy silt. A hydraulic conductivity was assumed of 300 ft/d, which is representative of gravels, coarse sands, and silty sands (Fetter, 2001; Freeze and Cherry, 1979).

Publically available water level measurements from two of the regulated facilities within the Lower Subbasin were used to calculate the hydraulic gradient. Water level measurements from AT Systems, Inc. (188 W. Santa Clara [H2 Environmental, 2008]) and Former BJ Services (2509 N. Ventura Ave [EnviroSolve, 2010]) were used because groundwater level measurements were collected contemporaneously (September 2008), and the sites are placed favorably within the Lower Subbasin for estimation of the hydraulic gradient (Figure 1). Groundwater flux out of the Lower Subbasin was calculated to be 2,412 ac-ft/yr (Table 8).

This estimate has a significant impact on the calculated groundwater budget for the Lower Subbasin, and is recognized as a source of uncertainty in the budget. For example, varying hydraulic conductivity within reasonable ranges varies the estimated outflow from the Lower Subbasin.

2.3.7 Groundwater Consumption by Riparian Vegetation

During the dry season, riparian vegetation in arid and semiarid environments such as the Subbasins access groundwater at the water table via deep roots called tap roots, and redistribute it to shallower depths where it is available for evapotranspiration (e.g., Lubczynski, 2009; Baird et al., 2005). This moisture redistribution by deep-rooted species also provides water for evapotranspiration by shallower-rooted riparian vegetation. Trees form deep tap roots and access groundwater in both riparian scrub/shrub and forested areas (Lubczynski, 2009), both of which exist in the Subbasins. Areal coverage of riparian vegetation in the Subbasins was obtained from the U.S. Fish and Wildlife Service (USFWS, 2010) (Figures 10a and 10b).

Non-native riparian species, namely *Arundo donax* (also known as giant reed), are known to have higher evapotranspiration rates compared to native species. *Arundo donax* evapotranspiration in southern California has been reported to be an estimated 5.62 feet per year (ft/yr), and evapotranspiration for native vegetation has been reported to be an estimated 1.87 ft/yr (Iverson, 1994). *Arundo donax* removal has been considered in the Ventura River Watershed, including along the main stem of the Ventura River and San Antonio Creek in the Subbasins, but no large-scale removal projects have been initiated within the Subbasins to date (VCWPD, 2007). The extent of *Arundo donax* coverage within riparian areas along the Ventura River within the Subbasins has also not been systematically mapped. However, a recent study mapped *Arundo donax* coverage in San Antonio Creek, including the reach within the Upper Ventura Subbasin, and upstream in the adjacent Ojai Basin (Wildscape Restoration, 2008). From this analysis of *Arundo donax* coverage in San Antonio Creek within the Upper Ventura Subbasin, it was assumed that there is a 10 percent *Arundo donax* coverage within riparian areas of the Subbasins, including both scrub/shrub and forested areas.

Based on the estimated evapotranspiration rates for *Arundo donax* and native species (Iverson, 1994), and the estimated 10 percent coverage by *Arundo donax*, the overall average evapotranspiration rate for riparian vegetation in the Subbasins was estimated to be 2.25 ft/yr (Table 12). This estimate agrees well with previous estimates of evapotranspiration by riparian vegetation in the nearby Santa Clara–Calleguas Basin, which range from 1.1 to 5.2 ft/yr (Hanson et al., 2003). Water consumed for evapotranspiration by riparian vegetation is sourced from shallower soil moisture during the wet season, and from groundwater only during the dry season (Lubczynski, 2009). Based on analysis of precipitation data in the Subbasins (VCWPD, 2010b), the dry season (rainfall less than 1 inch per month) was determined to generally extend from May through October. Reference evapotranspiration data for the area of the Subbasins obtained from the California Irrigation Management Information System (CIMIS, 2010) indicate that 65 percent of reference evapotranspiration occurs during these dryer months. It was therefore estimated that 65 percent of the total riparian evapotranspiration, or 1.46 ft/yr, is sourced from groundwater during the dry season, while the remaining 35 percent is sourced from shallower soil moisture during the wet season.

The areas of riparian vegetation, either as scrub/shrub or forests, were determined by GIS analysis of Figures 10a and 10b to be 980 acres in the Upper Ventura Subbasin, and 250 acres in the Lower Ventura Subbasin. Based on these coverage areas and the estimated groundwater consumption rate, it was estimated that 1,430 ac-ft/yr of groundwater is consumed by riparian vegetation in the Upper Subbasin, and 365 ac-ft/yr of groundwater is consumed by riparian vegetation in the Lower Subbasin (Table 12).

2.4 Results of the Groundwater Budget

Final results of the groundwater budget for the Upper and Lower Subbasins are provided in Tables 13 and 14, respectively. These budgets represent reasonable estimates based on available data and hydrogeologic analyses. Limitations to the analyses and resulting uncertainty are discussed in Section 2.5.

For the Upper Subbasin, because there are assumed to be no significant inputs from upgradient alluvial subbasins, industrial extractions, net groundwater discharge to surface water, or loss of alluvial groundwater to bedrock, Equation 1 simplifies to the following:

$$\Delta GW_s = \left[I_p + I_i + SW_i + S + B_i\right] - \left[E_m + E_d + E_a + R + GW_o\right] \qquad (7)$$

A net annual gain of 1,466 ac-ft/yr is estimated for the budgeted time period for the Upper Subbasin (Table 13). The primary inputs to groundwater are infiltration and surface water recharge from Lake Casitas and the Ventura River, while the primary outputs are municipal and agricultural extractions. The estimated net gain in groundwater storage is relatively small, and is consistent with long-term hydrographs of wells within the Upper Subbasin that indicate stable groundwater levels with 5- to 10-year rise and decline cycles (Figure 2). Over the budgeted time period, hydrographs within the Upper Subbasin exhibit both net increasing and decreasing trends, with fluctuation (Figures 11a through 11g).

For the Lower Subbasin, because there is no net surface water recharge to groundwater, municipal or industrial extractions, or net loss of alluvial groundwater to bedrock, Equation 1 simplifies to the following:

$$\Delta GW_s = \left[I_p + I_i + GW_i + S + B_i\right] - \left[E_d + E_a + R + GW_o + SW_o\right] \quad (8)$$

A net annual loss of 2,423 ac-ft/yr for the Lower Subbasin is estimated for the budgeted time period (Table 14). The primary inputs are infiltration and inflow from the Upper Subbasin, while the primary outputs are groundwater discharge to surface water and discharge to the ocean. There are currently no Ventura County-monitored water levels within the Lower Subbasin for comparison to the budget.

It is expected that the results of the groundwater budget presented in this report are specific to the budgeted time period (water years 1997 through 2007); a different outcome would likely occur over an alternative time period. For example, the decrease in municipal extractions by the City of Ventura of about 4,000 ac-ft/yr since 2005 (Table 9) would result in a more positive groundwater budget for the Upper Subbasin. In addition, changes in the management of the Subbasins will impact the groundwater budget. Likewise, changes in management of the upgradient Ojai Basin will impact flow in San Antonio Creek, and therefore impact the groundwater budget of the Upper and Lower Ventura River Subbasins.

2.5 Limitations and Recommendations

As discussed above, there are several limitations to the groundwater budget presented in this report. The limitations are summarized here, along with an estimation of their potential impact on the final budget. These groundwater budgets constitute the first step in building a sufficient understanding of groundwater resources within the Subbasins; recommendations for further analyses are provided below.

- *Delineation of the Subbasins:* The delineation of the Subbasins is not consistent among various reports, including CDWR Bulletin 118 (CDWR, 2003), VCWPD annual groundwater reports (e.g., VCWPD, 2009), and previous modeling reports for the Ventura River watershed (Tetra Tech, 2009). The delineation used for this report is consistent with the previous modeling studies.

Recommendation: Determine a unified delineation of the Subbasins based on geologic maps of the extent of alluvium (e.g., Appendix A, Plates 1 and 2) along the Ventura River and associated creeks.

- *Use of the VRWHM:* Several calculations presented in this report rely on reported results of the VRWHM. As discussed in the VRWHM report (Tetra Tech, 2009), similar to any hydrologic model, the VRWHM is prone to uncertainty stemming from assumptions in the mathematical formulation, data uncertainty, and parameter specifications. Recommendations are provided in the VRWHM documentation for reducing uncertainty with the VRWHM (Tetra Tech, 2009).

  Recommendation: Following any revisions to the VRWHM that reduce model uncertainty, revise the groundwater budgets presented in this report to reflect those changes.

  Recommendation: Develop a groundwater flow model of the Subbasins. As discussed in the VRWHM documentation (Tetra Tech, 2009), uncertainty with the surface water hydrology model will be reduced via development of a groundwater model for the Subbasins, and coupling of the groundwater and surface water models. Development and application of a calibrated groundwater model could also be used to reduce uncertainty with estimation of the groundwater budget within the Subbasins.

- *Infiltration from Precipitation (Section 2.2.1):* The approach used in this report for estimation of infiltration from precipitation relies on the Maxey-Eakin method, which is the most often used empirical method for this purpose in the semiarid regions of the southwest. However, this approach has not been field-validated within the Subbasins, and does not account for area-specific factors that influence recharge rates, such as soil type and slope.

Recommendation: The VRWHM includes calculation of infiltration to groundwater from precipitation based on local factors, and the model has been calibrated (i.e., field validated) to streamflow data. However, the VWRHM has not currently been used to generate model data at a fine enough spatial scale to be applied to the area of the Subbasins. It is recommended that output from the VRWHM be generated that is specific to areas within the Subbasins, and that these data be used to reduce uncertainty associated with infiltration from precipitation. Additionally, data from the VRWHM could be used to reduce uncertainty with estimation of surface water recharge to groundwater (Section 2.2.3).

- *Selection of the Budgeted Time Period:* The time period used in this report is water years 1997-2007, to be consistent with the VRWHM, and because this period is generally representative of conditions over the last several decades (Figures 2, 4, and 5). However, selection of a different time period would result in a different estimated groundwater budget. For instance, a groundwater budget calculated during a period of relatively low precipitation would result in a more negative groundwater budget. Additionally, the decrease in municipal extractions by the City of Ventura since 2005 (Table 9) would result in a more positive groundwater budget for the Upper Subbasin.

- *Inflow from Bedrock to the Alluvial Aquifer (Section 2.2.5*): Estimates of groundwater inflow from the alluvial aquifer are prone to uncertainty due to a lack of hydrogeologic data regarding the bedrock formations. Perhaps most significantly, nested groundwater wells are not present for accurate calculation of a vertical hydraulic gradient. As described in Section 2.2.5, the geologic structure of the bedrock formations has also not been accounted for in this analysis, because DBS&A has not identified any specific data regarding the influence of geologic structure on groundwater flow in this area.

  Recommendation: Install nested groundwater monitoring wells or piezometers in the area of the Subbasins that are screened in both the alluvium and the bedrock formations. These wells may be used to estimate vertical hydraulic gradients and estimate additional hydrogeologic data.

- *Groundwater Flow Calculations (Sections 2.2.6 and 2.3.5):* Groundwater flow calculations using Darcy's Law are dependent on estimated values of hydraulic conductivity, hydraulic gradient, and aquifer cross-sectional area. Resulting uncertainty in these calculations may be significant, particularly for the Lower Subbasin, where groundwater discharge to the ocean is a primary component of the groundwater budget.

  Recommendation: Obtain additional local measurements of hydraulic conductivity via aquifer tests or other methods. Additionally, development of a calibrated groundwater model, as discussed above, could help reduce uncertainty with groundwater flow calculations.

- *Agricultural Groundwater Extractions (Section 2.3.3):* Because extraction data from agricultural wells within the Subbasins are not reported to a public agency, and are therefore not available, agricultural extraction was estimated based on co-location of active wells and agricultural land uses. Alternative methods were also used based on extraction rates per well in the adjacent Ojai Basin and CMWD water delivery trends.

  Recommendation: Obtain agricultural extractions from individual well owners within the Subbasins and invite well owners to participate in a groundwater monitoring program.

- *Industrial Groundwater Extraction (Section 2.3.4):* Groundwater extraction rates associated with oil production or other uses in the Lower Subbasin are not currently reported to a public agency, and are therefore not available.

  Recommendation: Encourage well owner participation to obtain extraction rates from wells associated with oil production in the Lower Subbasin.

- *Groundwater/Surface Water Balance Calculations (Sections 2.2.3 and 2.3.5):* The net groundwater/surface water balances presented for each of the Subbasins rely on estimates of surface water inputs and outputs for sections of the Ventura River Watershed that contain the Subbasins.

Recommendation: Obtain output from the VRWHM that is specific to model areas within the Subbasins that contain surface water bodies. With model output data specific to these specific reaches, uncertainty of the surface water/groundwater balance will be reduced.

Recommendation: Install additional surface water gages along San Antonio Creek within the area of the Subbasins, and upstream (including at the boundary between the Ventura River Basin and Ojai Basin) in order to better quantify groundwater/surface water interactions along that reach.

- *Comparison of the groundwater budget to observed groundwater levels (Section 2.4):* The estimated annual groundwater budget may be compared to the change in groundwater storage as estimated from changes in groundwater levels measured in monitoring wells within a basin. This quantitative comparison was not performed during this study and would entail detailed assessment of the annual change in groundwater levels throughout the Upper and Lower Subbasins from available groundwater level monitoring data. There are currently no Ventura County-monitored water levels within the Lower Subbasin for comparison to the budget (VCWPD, 2009). Water level measurements within the Lower Subbasin would also be important for development of a groundwater model, and water samples could also be collected from these wells to evaluate groundwater quality trends.

  Recommendation: Perform an assessment of the change in groundwater storage for comparison to the budget, as measured from monitoring of groundwater levels. Furthermore, identify several wells within the Lower Subbasin for inclusion in a groundwater level and groundwater quality monitoring program, including abandoned wells.

3. Approach to a Groundwater Management Plan (GWMP)

Groundwater management, as defined in CDWR Bulletin 118, Update 2003 (CDWR, 2003), is the planned and coordinated monitoring, operation, and administration of a groundwater basin or portion of a groundwater basin with the goal of long-term sustainability of the resource. Groundwater management needs are identified at the local water agency level and may be directly resolved at the local level. If groundwater management needs cannot be directly resolved at the local agency level, additional actions such as enactment of ordinances by local governments, passage of laws by the legislature, or decisions by the courts may be necessary to resolve the issues. The State's role is to provide technical and financial assistance to local agencies for their groundwater management efforts.

A managing entity can range from a users group to a court-appointed watermaster, following adjudication of the subject basin. For the Subbasins, a subcommittee of the Ventura River Watershed Council (VRWC) could convene and act as an amicable users group at the local level. Such a group could be generated by a minimal special act, perform as a special district, and perhaps could be named the Upper and Lower Ventura River Groundwater Management District (ULVRGMD).

Once a management entity is formed, a GWMP can be generated with the intention of providing a framework to manage groundwater to ensure a long-term sustainable, reliable, good-quality water supply suitable to the political, legal, institutional, hydrogeologic, and economic conditions and constraints that exist in the Subbasins. The following outline provides an approach to development of a GWMP; several parts have been adopted from CDWR (2003).

Component 1. Develop a map showing the area of the Basin, with the area that will be subject to the GWMP, as well as the boundaries of other local agencies that overlie any portion of the Basin. As a delineated groundwater basin with two delineated groundwater subbasins, maps of the basins have been developed by both the state and county agencies.

Component 2. Provide a written statement to the public describing the manner in which interested parties may participate in development of the GWMP. The statement should be provided to the public via local newspapers and/or other media, with distribution throughout the Basin. Documentation of public notification will be included in the GWMP.

Component 3. Establish a plan to involve other agencies whose boundaries overlie the Basin in development of the GWMP. This may include involvement via agency representative participation in the VRWC (see Component 4).

Component 4. Establish a process for the VRWC to serve as the designated advisory committee of stakeholders (interested parties) within the plan area that will help guide the development and implementation of the GWMP and provide a forum for resolution of controversial issues.

Component 5. Describe, in detail, the area to be managed under the GWMP, including (1) the physical structure and characteristics of the aquifer system underlying the plan area in the context of the overall basin, (2) a summary of the availability of historical data, (3) issues of concern, and (4) a general discussion of historical and projected water demands and supplies.

Component 6. Establish management objectives (MOs) for the groundwater basin that is subject to the plan. MOs are intended to contribute toward a more reliable supply for long-term beneficial uses of groundwater in the plan area. For example, MOs for a typical groundwater basin may include the installation of infiltration basins or reduction in groundwater extraction.

Component 7. For each MO in Component 6, describe how meeting the MO will contribute to a more reliable supply for long-term beneficial uses of groundwater in the plan area, and describe existing or planned management actions to achieve MOs.

Component 8. Adopt monitoring protocols for the monitoring and management of groundwater levels, groundwater quality, potential inelastic land surface subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality.

Component 9. Describe the monitoring program, including the following:

- A map indicating the general locations of any applicable monitoring sites for groundwater levels, groundwater quality, subsidence stations, or stream gages.
- A summary of monitoring sites indicating the type (groundwater level, groundwater quality, subsidence, stream gage) and frequency of monitoring. For groundwater level and groundwater quality wells, indicate the depth interval(s) or aquifer zone monitored and the type of well (public, irrigation, domestic, industrial, or monitoring).
- A quality assurance project plan (QAPP) for monitoring in the basin.
- Standard operating procedures (SOPs) for monitoring in the basin.

Component 10. Describe any current or planned actions by the local managing entity to coordinate with other land use, zoning, or water management planning agencies or activities.

Component 11. Provide for periodic report(s) summarizing groundwater basin conditions and groundwater management activities. The report(s), prepared annually or at other frequencies as determined by the WCVC, should include the following:

- Summary of monitoring results, including a discussion of historical trends
- Summary of management actions during the period covered by the report
- Discussion, supported by monitoring results, of whether management actions are achieving progress in meeting MOs
- Summary of proposed management actions for the future
- Summary of any plan component changes, including addition or modification of MOs, during the period covered by the report
- Summary of actions taken to coordinate with other water management and land use agencies, and other government agencies

Component 12. Provide for the periodic reevaluation and updating of the plan by the VRWC.

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Figures

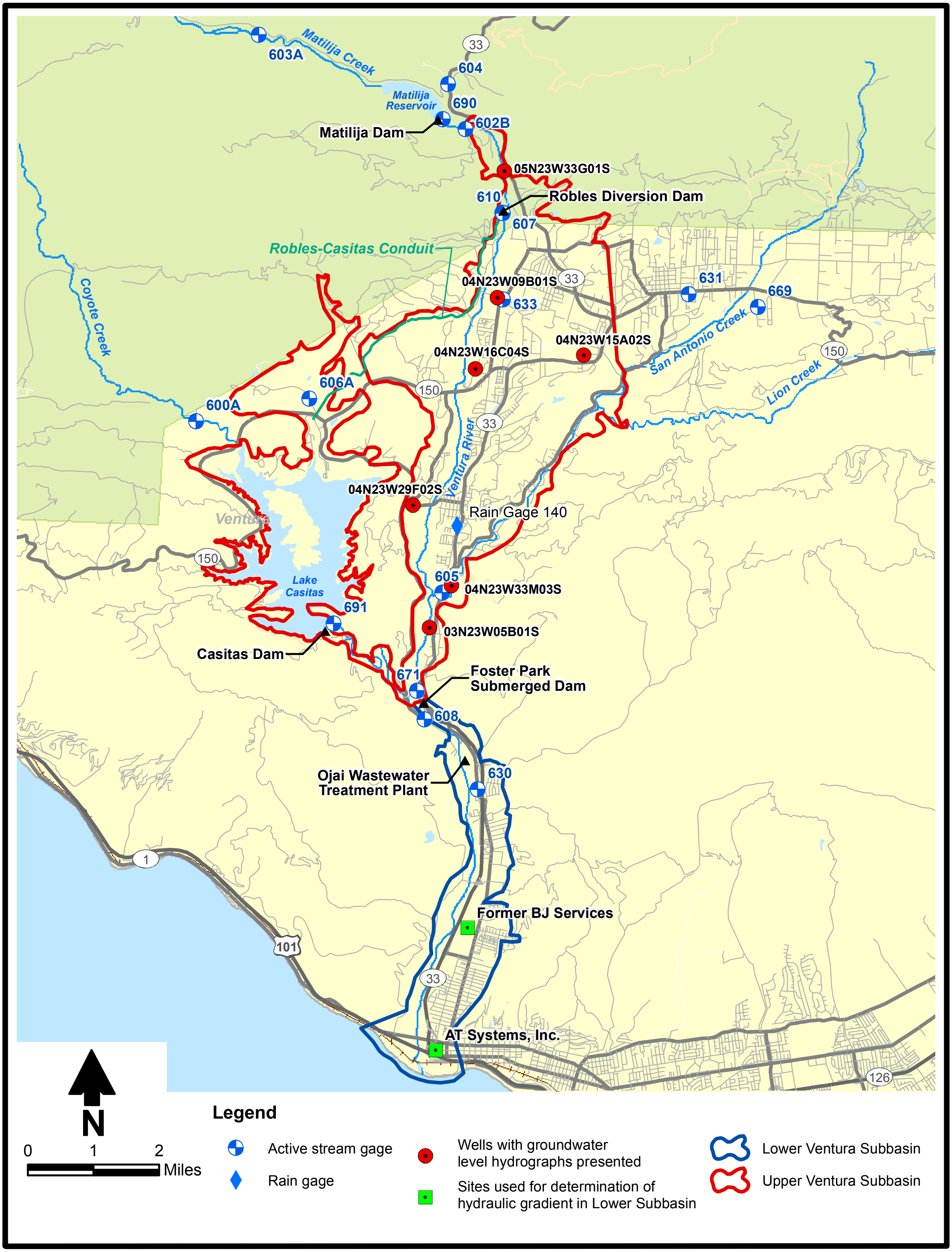

Figure 1: Study Area Location Map. The locations of various features that are relevant to the groundwater budget are shown. [Sources: Subbasin boundaries and stream gage locations from Tetra Tech, 2009; Well locations from VCWPD, 2010a; Rain gage location from VCWPD, 2010b]

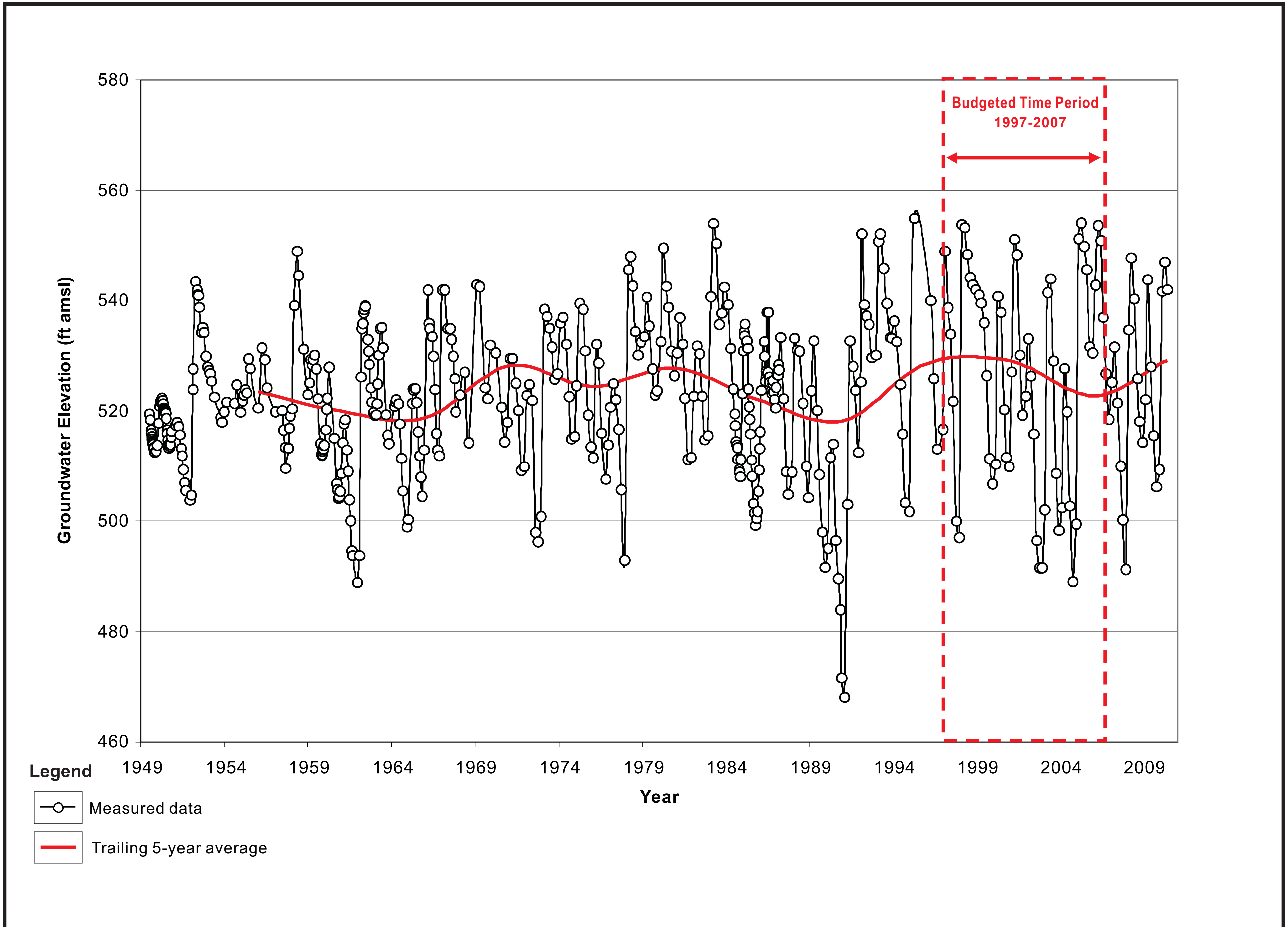

Figure 2a: Hydrograph for Upper Ventura River Groundwater Basin Key Well 04N23W16C04S (1949-2010). Measured groundwater elevation is shown. A trailing 5-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. The budgeted time period (water years 1997-2007) is also shown. [Source: VCWPD, 2010a]

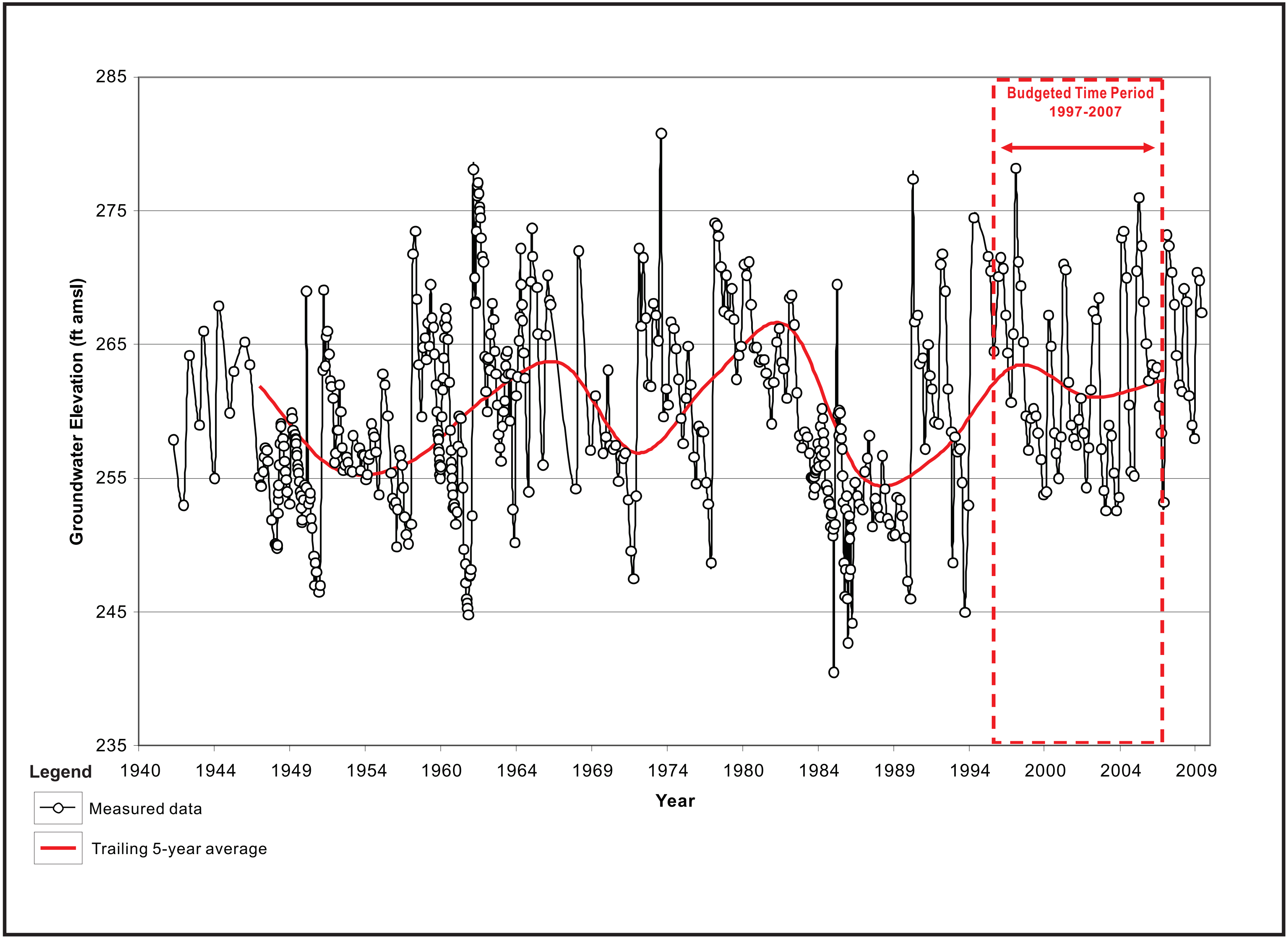

Figure 2b: Hydrograph for Upper Ventura River Groundwater Basin Well 03N23W05B01S (1942-2010). Measured groundwater elevation is shown. A trailing 5-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. The budgeted time period (water years 1997-2007) is also shown. [Source: VCWPD, 2010a]

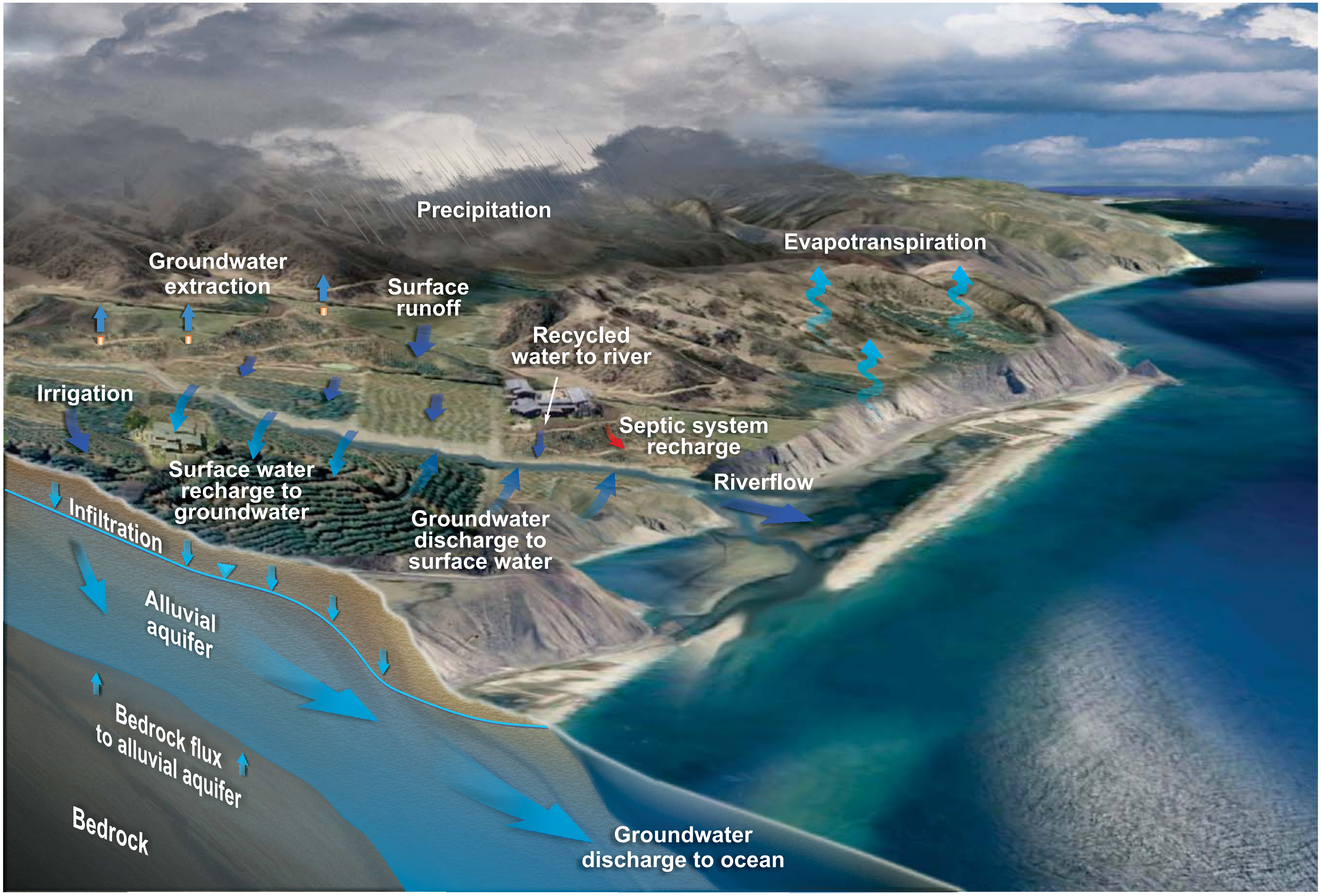

Figure 3: Schematic Hydrologic Cycle. A generalized hydrologic cycle is shown that includes major processes that impact the groundwater budget for the Upper and Lower Ventura River Subbasins.

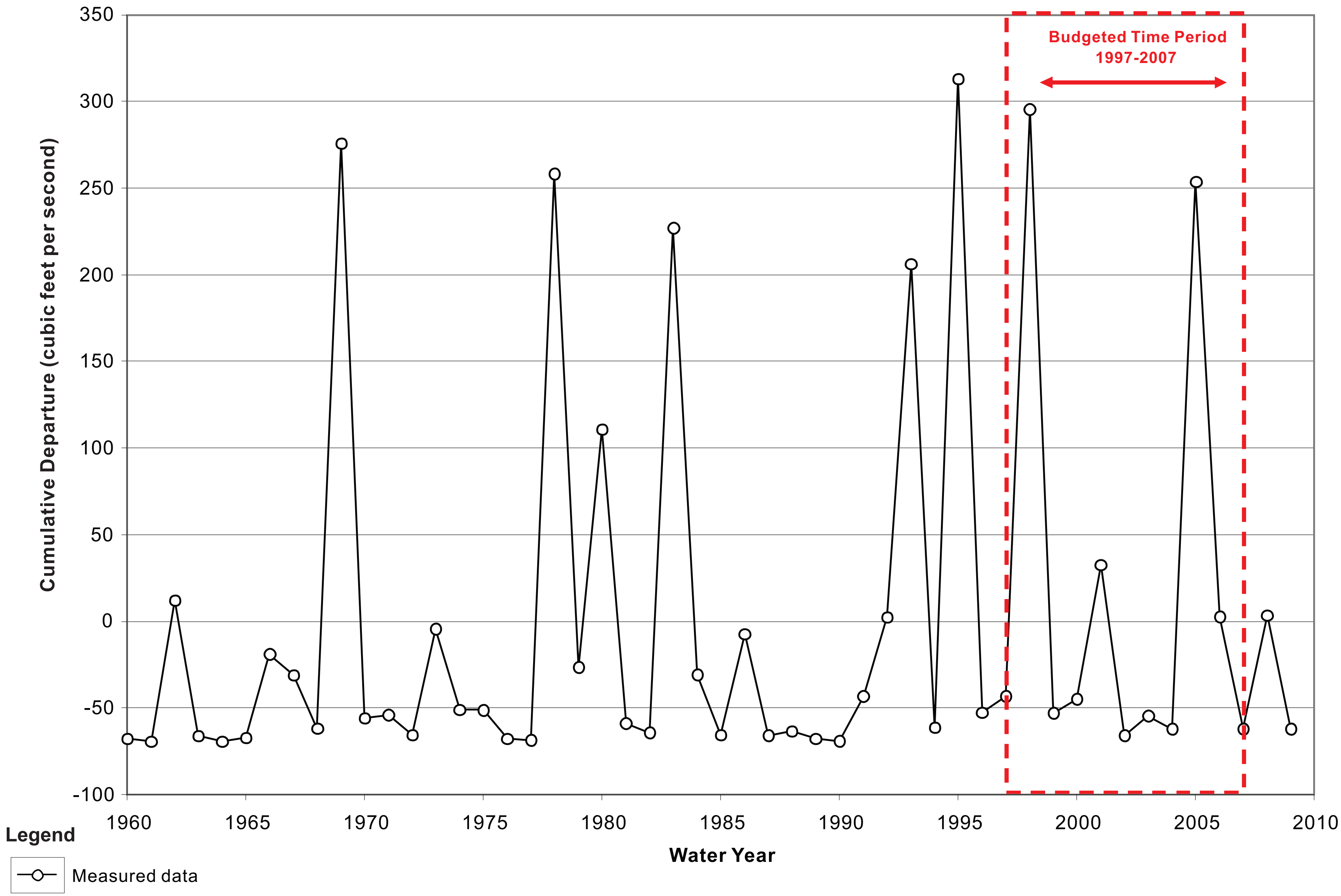

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Figure 4: Cumulative Departure Curve for Average Annual Streamflow in Ventura River, Stream Gage 608 (cubic feet per second), Water Years 1960-2009. The cumulative departure curve shows the variation from the average of all annual data, 1960-2009, which was 69.61 cubic feet per second. The budgeted time period (water years 1997-2007) is also shown. [Source: Average annual streamflow data from USGS, 2010]

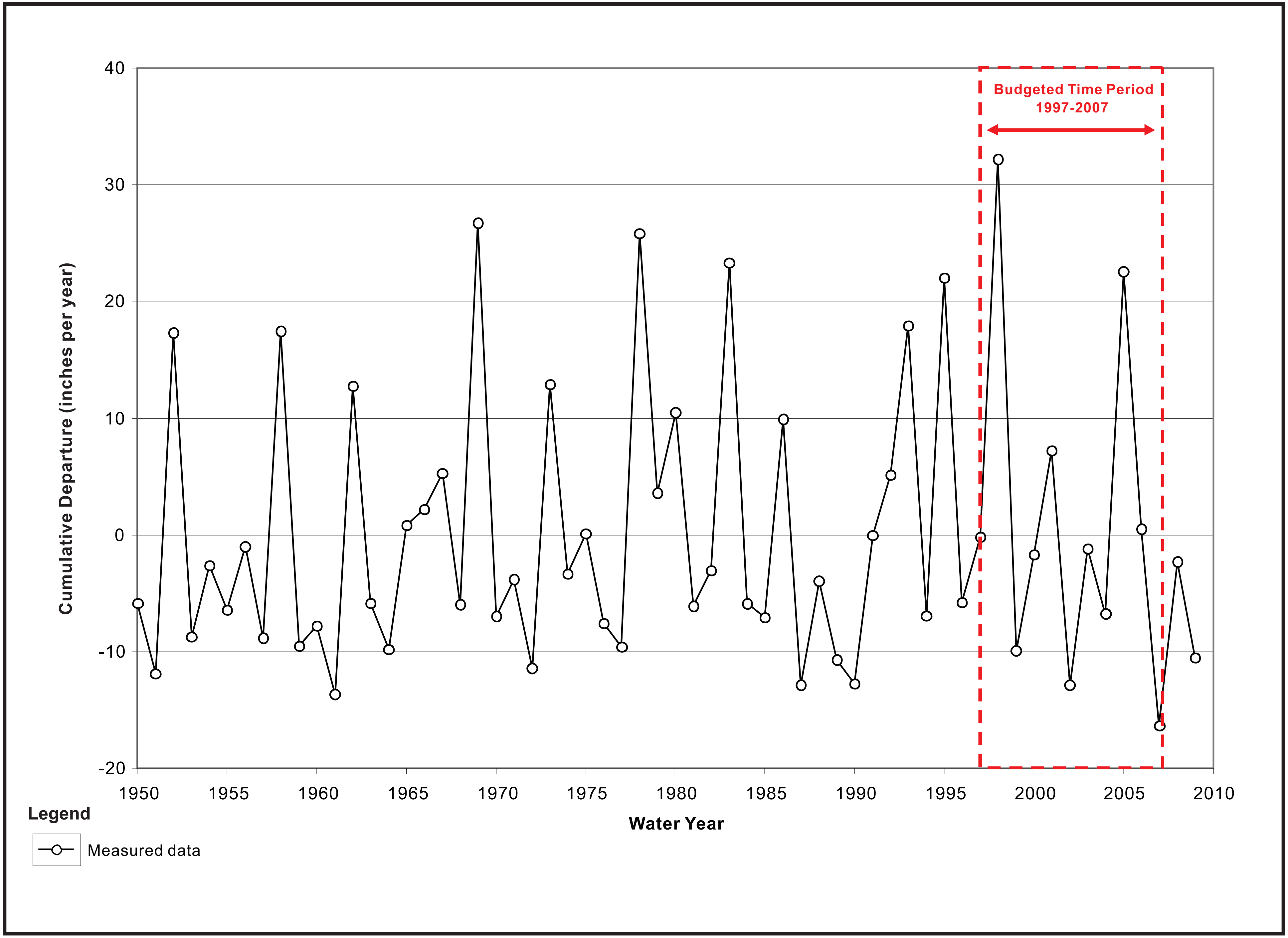


Figure 5: Cumulative Departure Curve for Annual Precipitation, Rain Gage 140 (inches per year), Water Years 1950-2009. The cumulative departure curve shows the variation from the average of all annual data, 1950-2009, which was 21.95 inches per year. The budgeted time period (water years 1997-2007) is also shown. [Source: Precipitation data from VCWPD, 2010b]

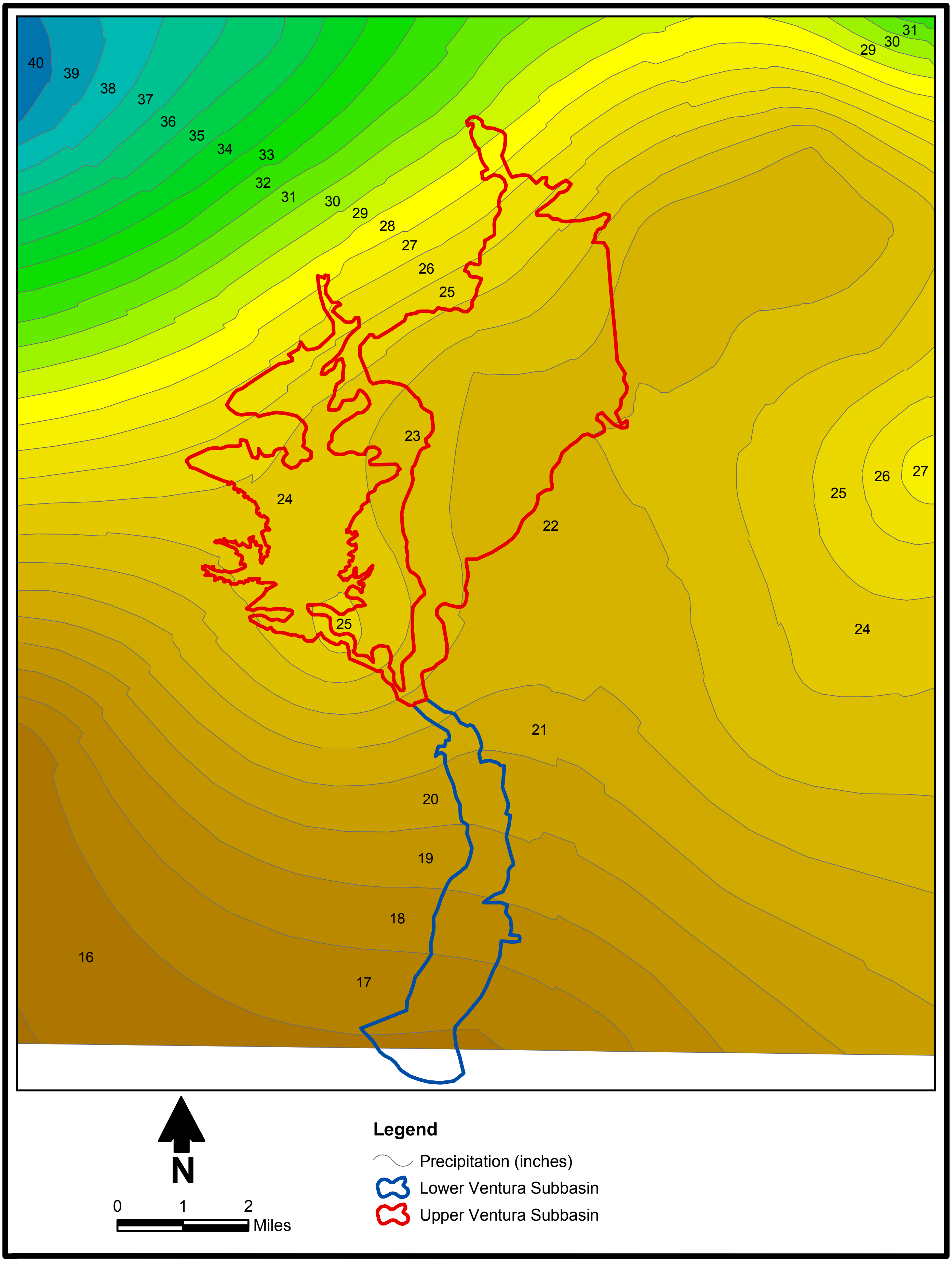


Figure 6: Isohyets of Annual Average Precipitation (inches). Annual average precipitation data are shown relative to the locations of the Subbasins. [Sources: Annual Rain Contours, 1997-2007, used in Tetra Tech, 2009; Subbasin boundaries from Tetra Tech, 2009]

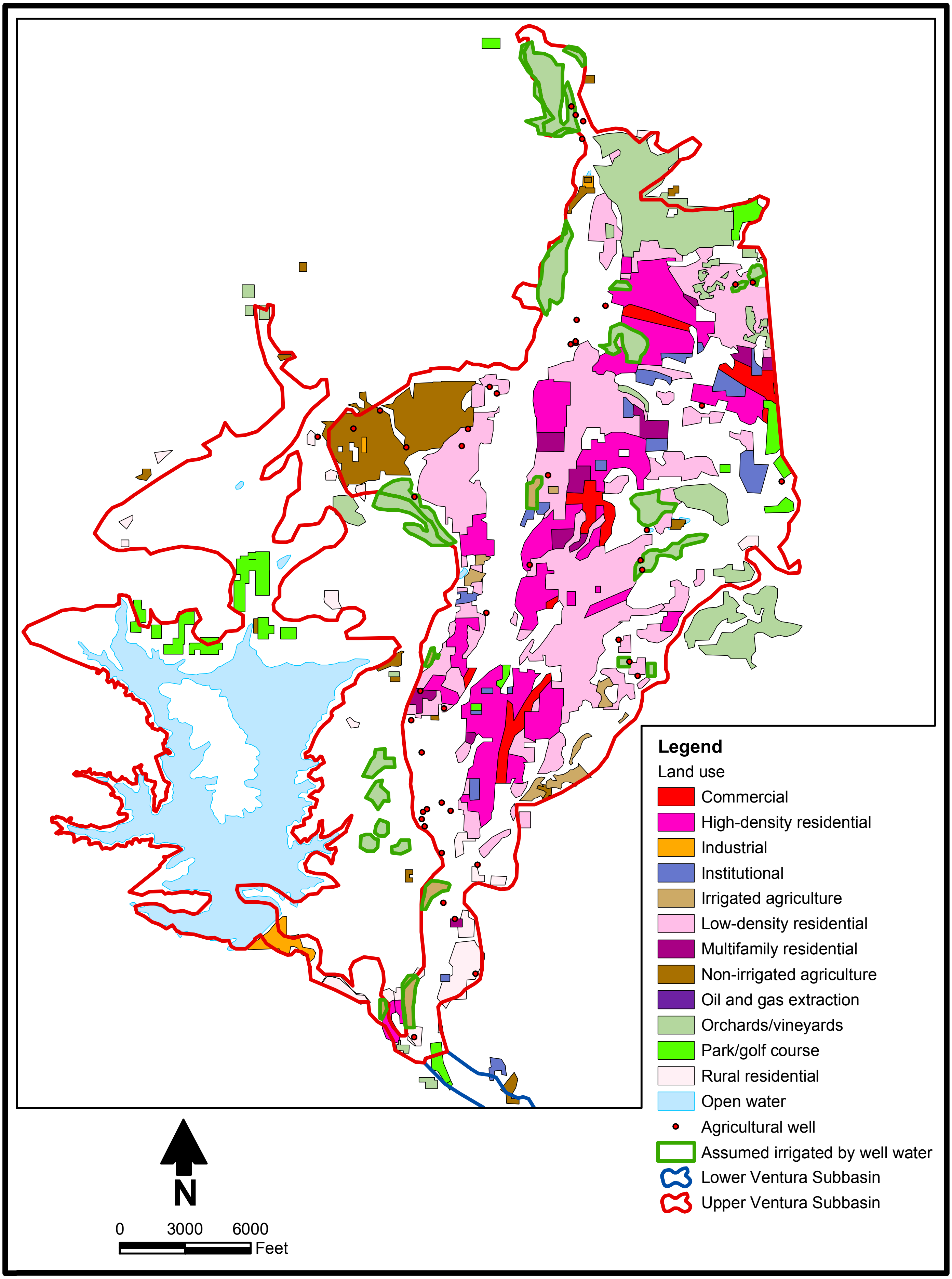


Figure 7a: Land Use, Upper Ventura River Subbasin. Land use coverage is shown for the Upper Ventura River Subbasin. [Sources: Southern California Association of Governments (SCAG) land use data, 2005, as cited in Tetra Tech, 2009; Subbasin boundaries from Tetra Tech, 2009]

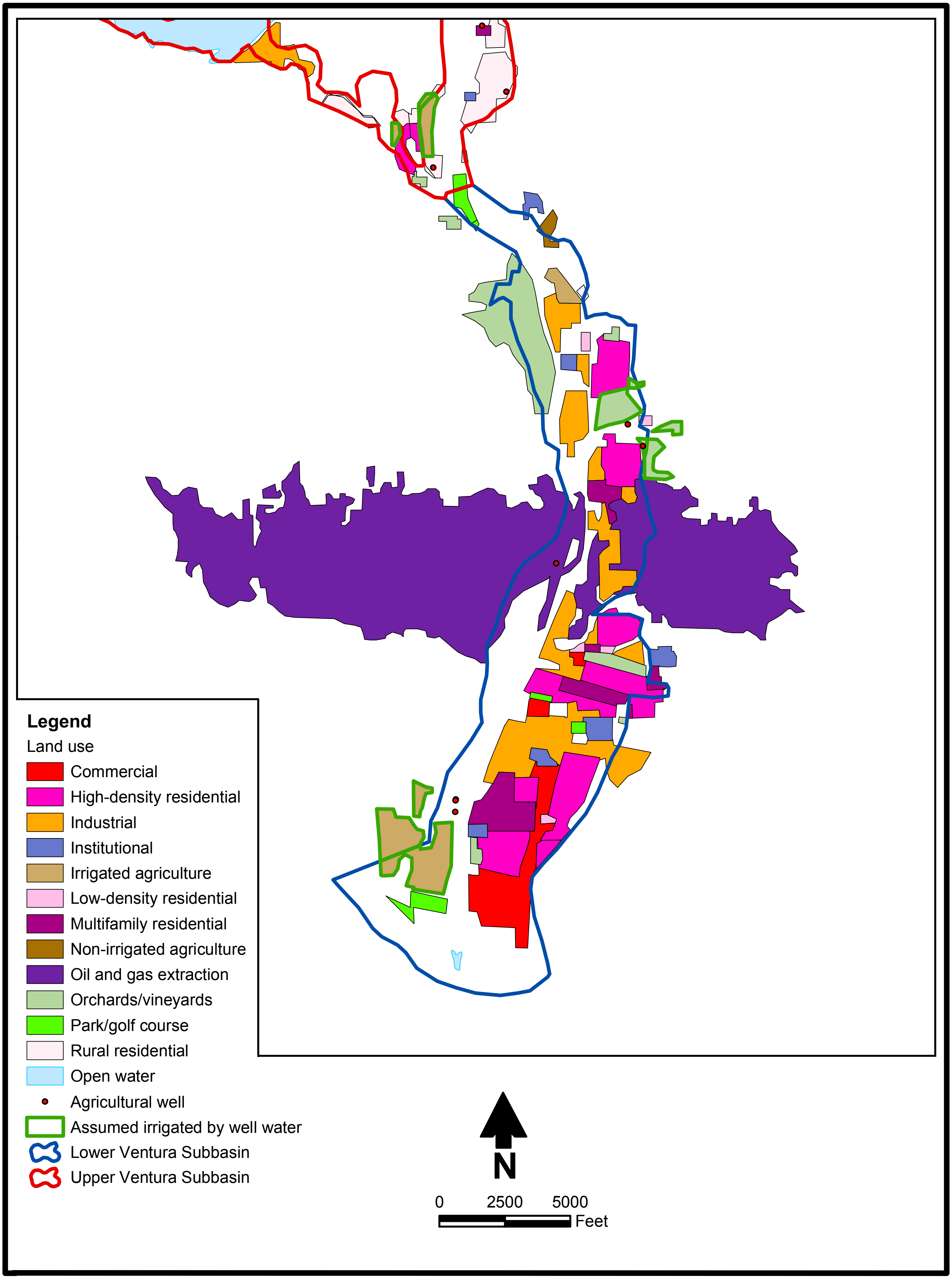


Figure 7b: Land Use, Lower Ventura River Subbasin. Land use coverage is shown for the Lower Ventura River Subbasin. [Sources: Southern California Association of Governments (SCAG) land use data, 2005, as cited in Tetra Tech, 2009; Subbasin boundaries from Tetra Tech, 2009]

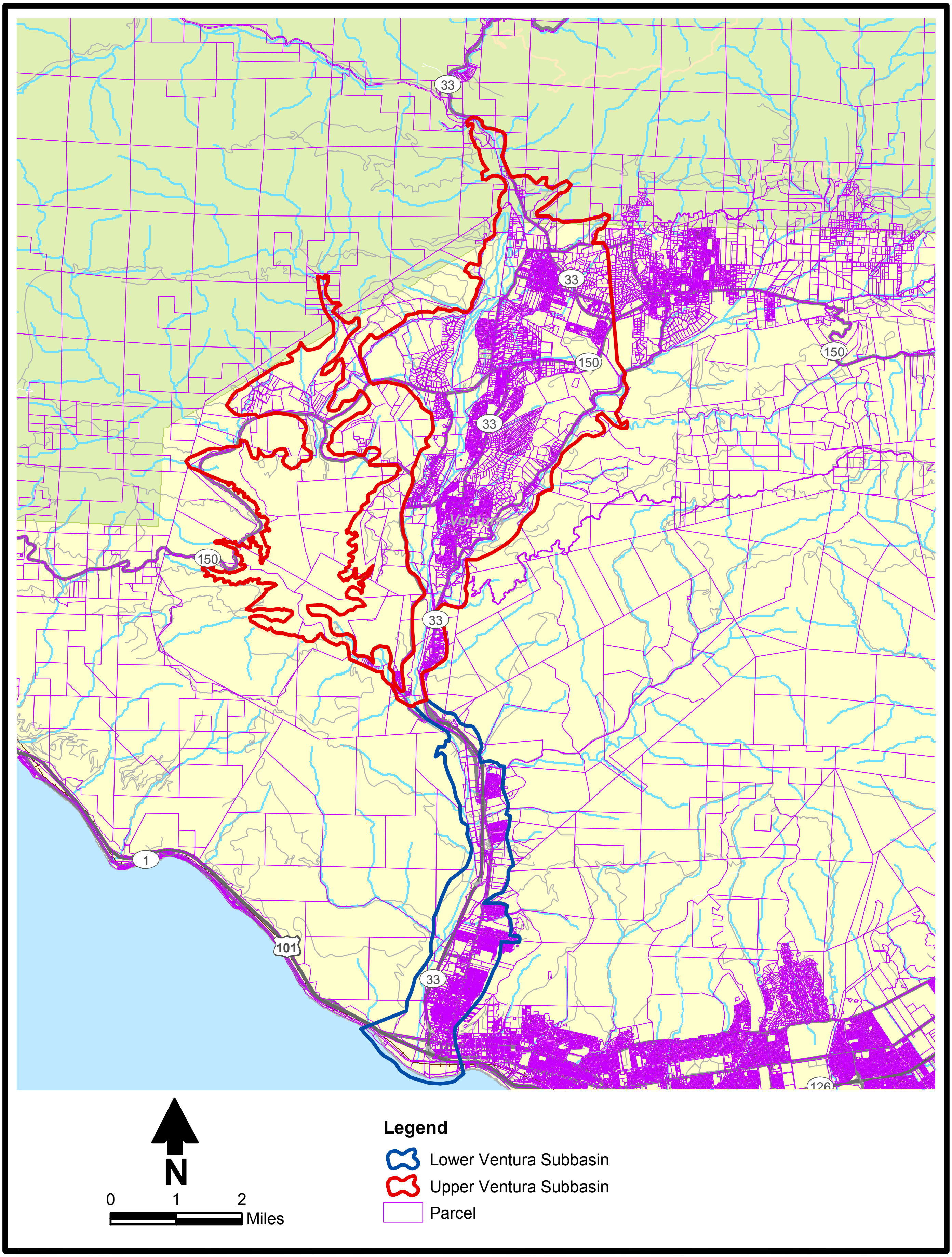


Figure 8: Parcel boundaries. Parcel boundaries are shown relative to the locations of the Subbasins. [Source: Parcel data, County of Ventura, http://gis.countyofventura.org/maps_data.htm; Subbasin boundaries from Tetra Tech, 2009]

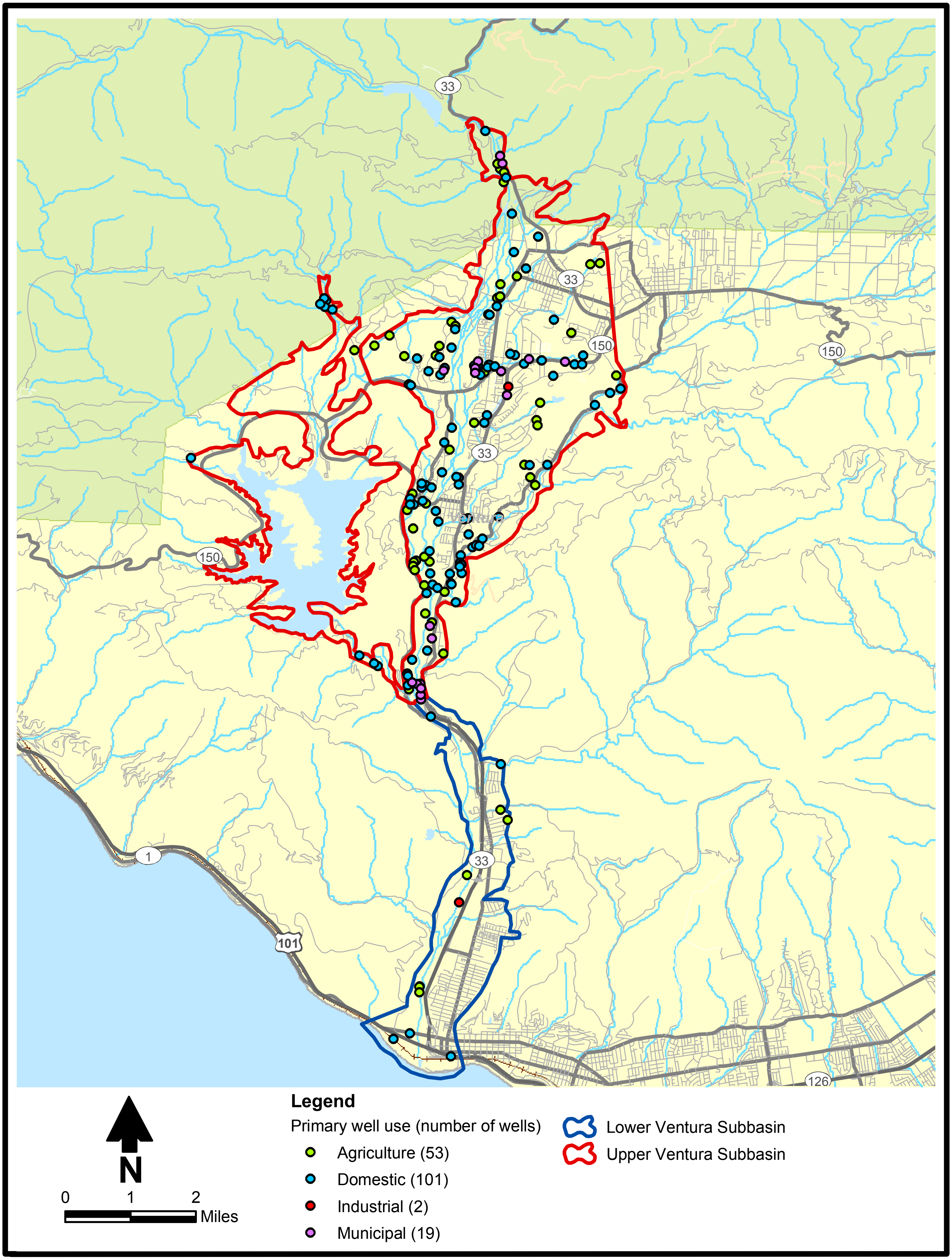


Figure 9: Well Locations. The locations of wells with the primary purpose of agricultural, domestic, industrial, and municipal supply are shown. [Source: Ventura County Well Database, 2010]

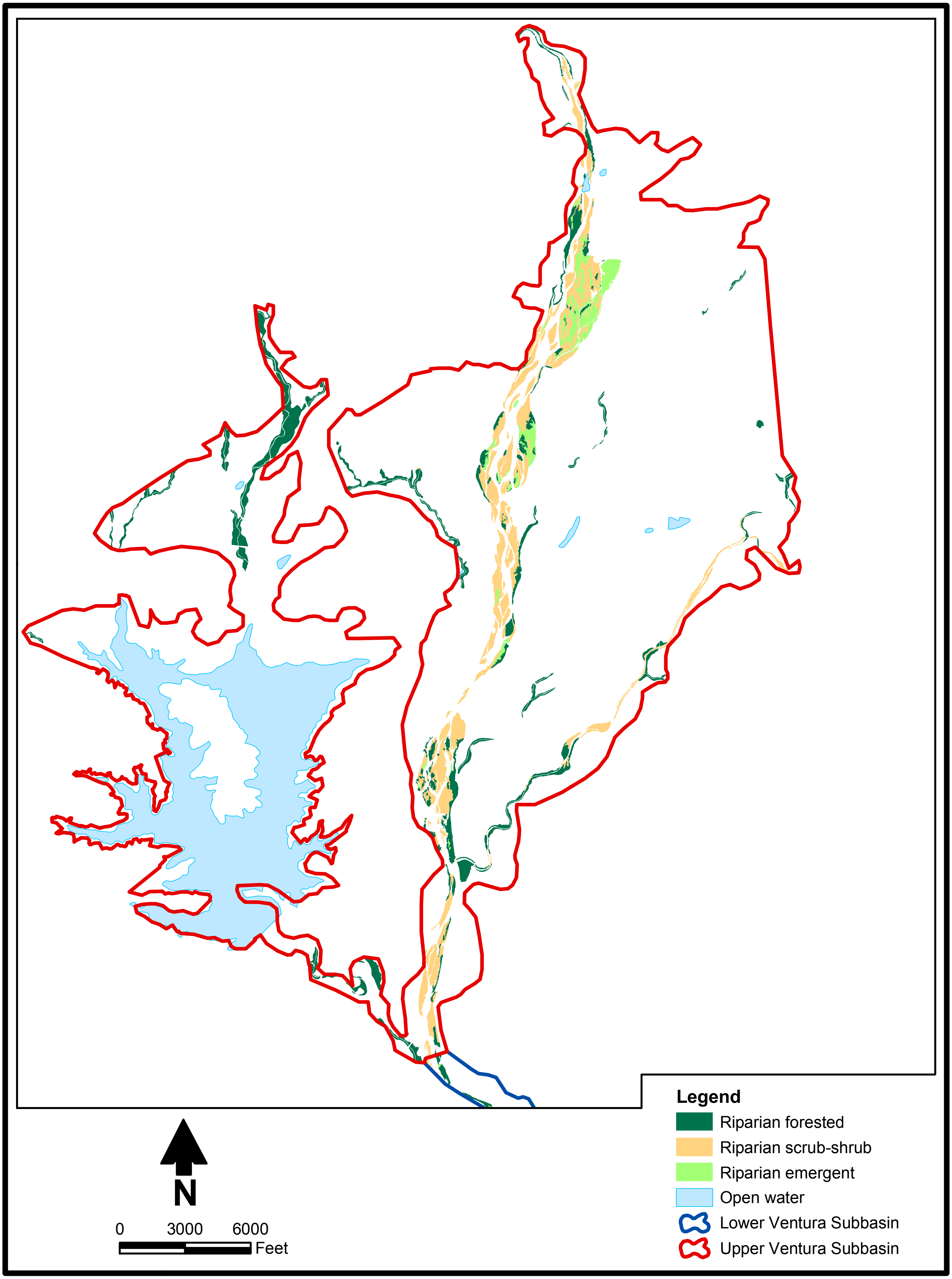


Figure 10a: Riparian Vegetation Coverage, Upper Ventura River Subbasin. The coverage of riparian habitat for 2009 is shown for the Upper Ventura River and associated tributaries within the Subbasin. [Sources: Riparian data from USFWS, 2010; Subbasin boundaries from Tetra Tech, 2009]

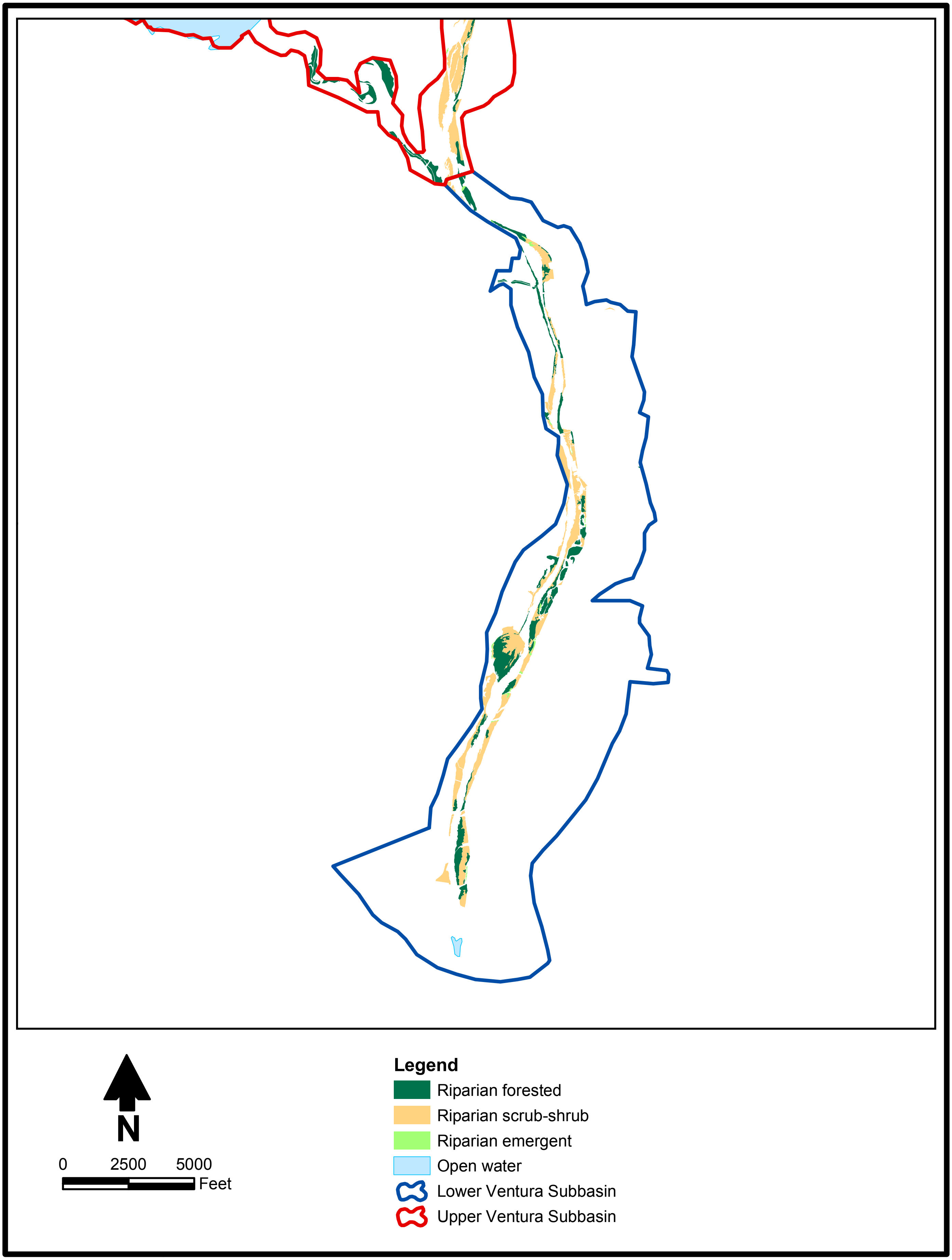


Figure 10b: Riparian Vegetation Coverage, Lower Ventura River Subbasin. The coverage of riparian habitat for 2009 is shown for the Lower Ventura River and associated tributaries within the Subbasin. [Sources: Riparian data from USFWS, 2010; Subbasin boundaries from Tetra Tech, 2009]

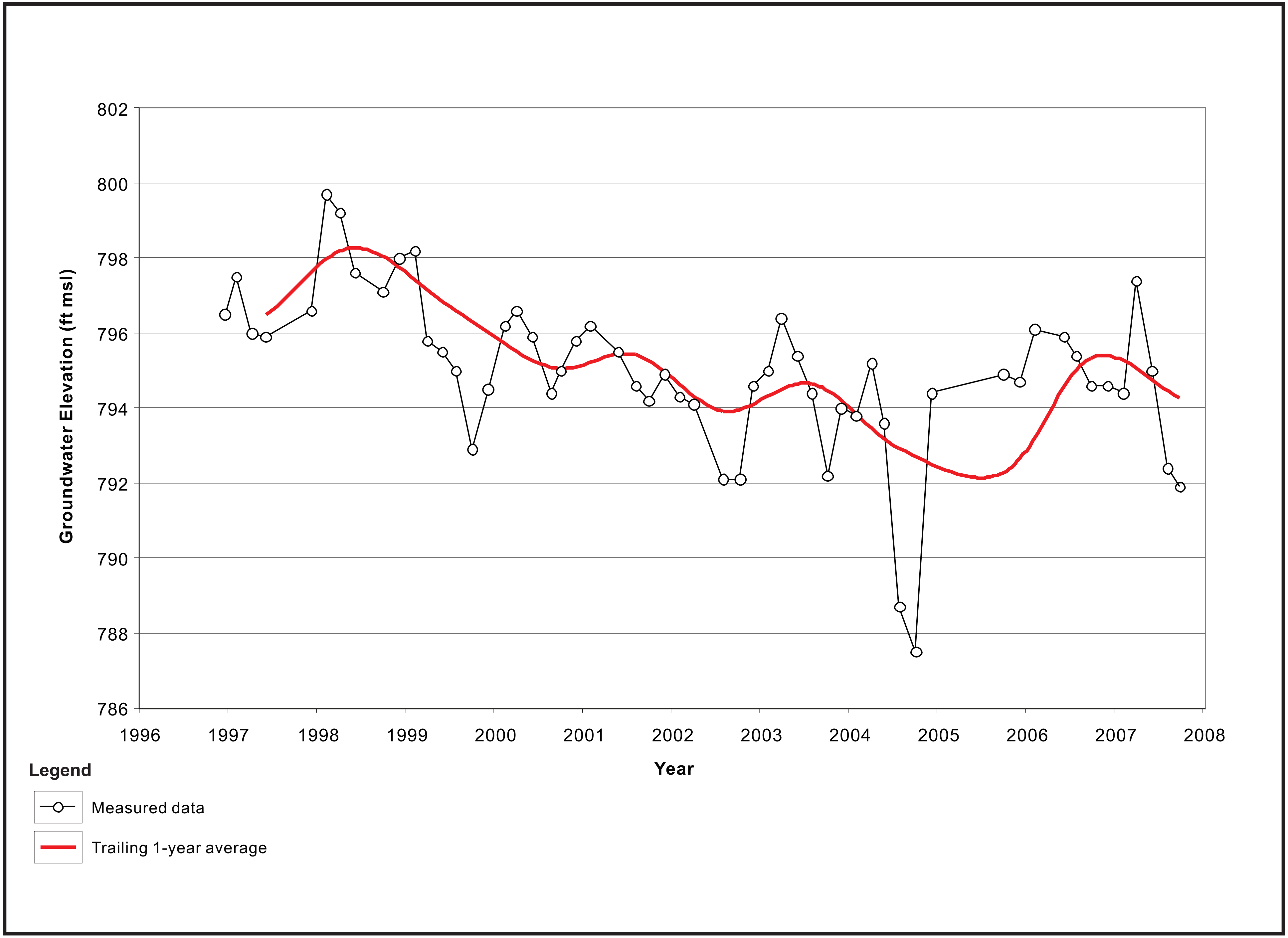


Figure 11a: Hydrograph for 05N23W33G01S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

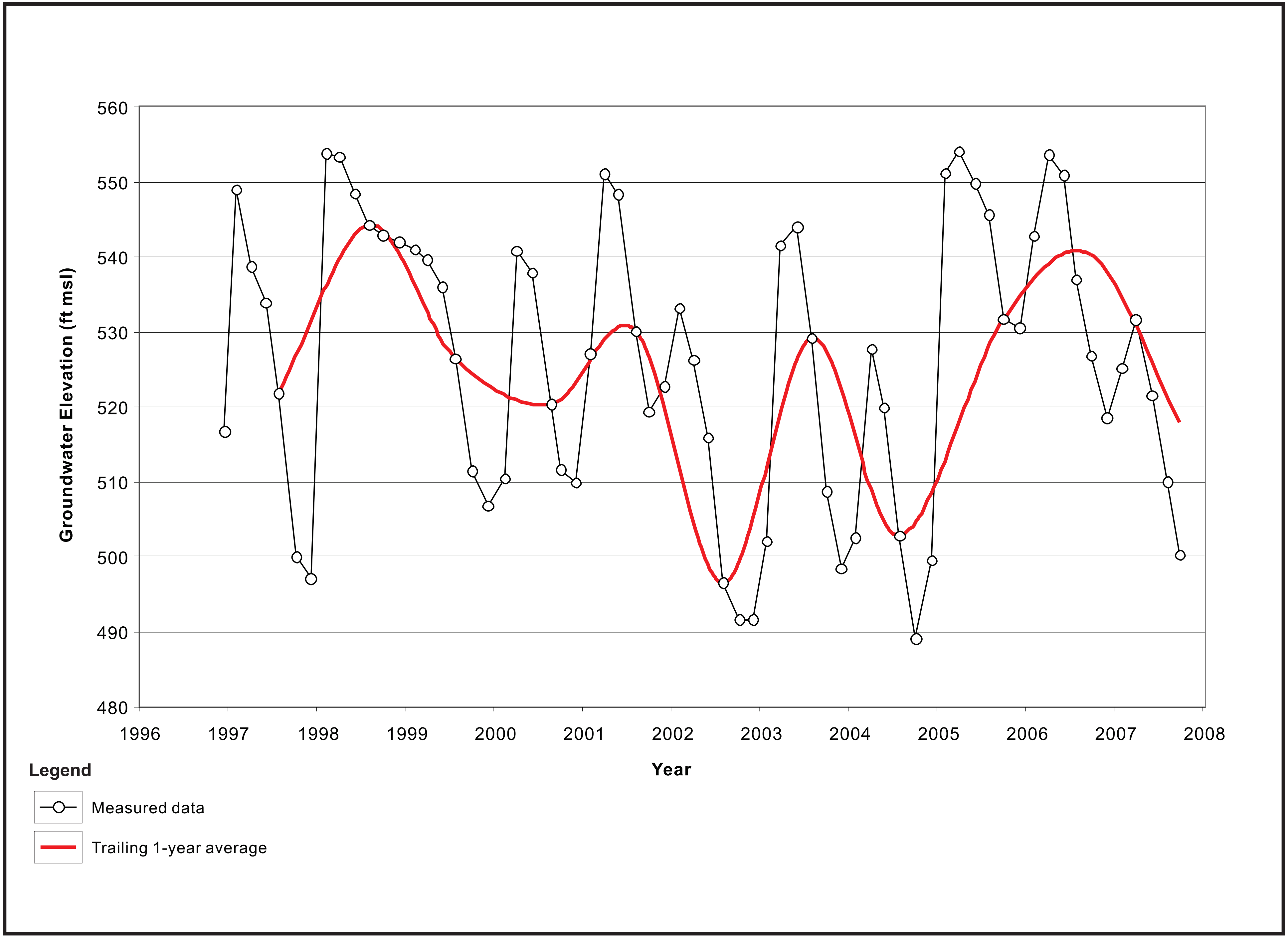


Figure 11b: Hydrograph for 04N23W16C04S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

Figure 11c: Hydrograph for 04N23W15A02S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

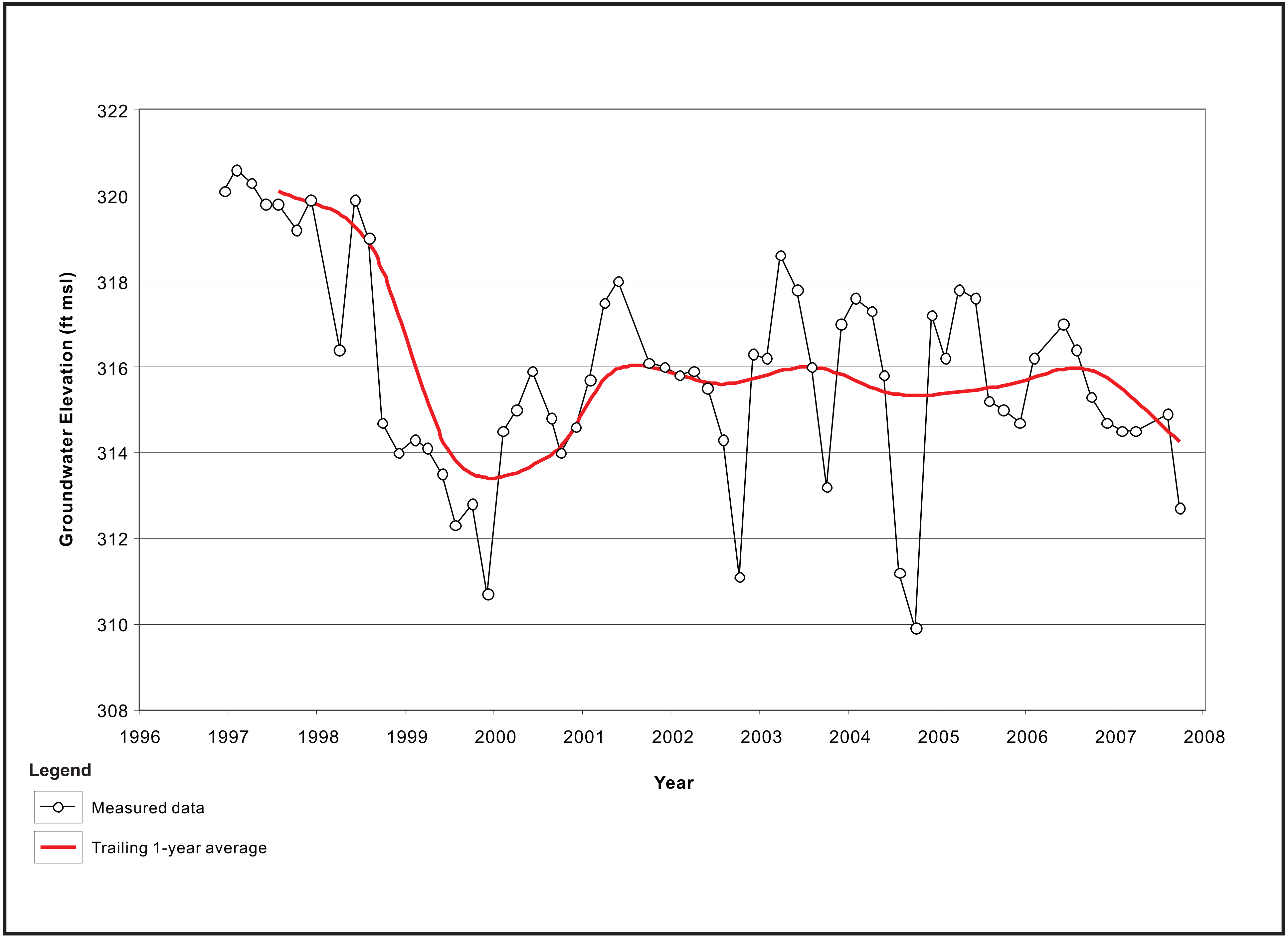


Figure 11d: Hydrograph for 04N23W33M03S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

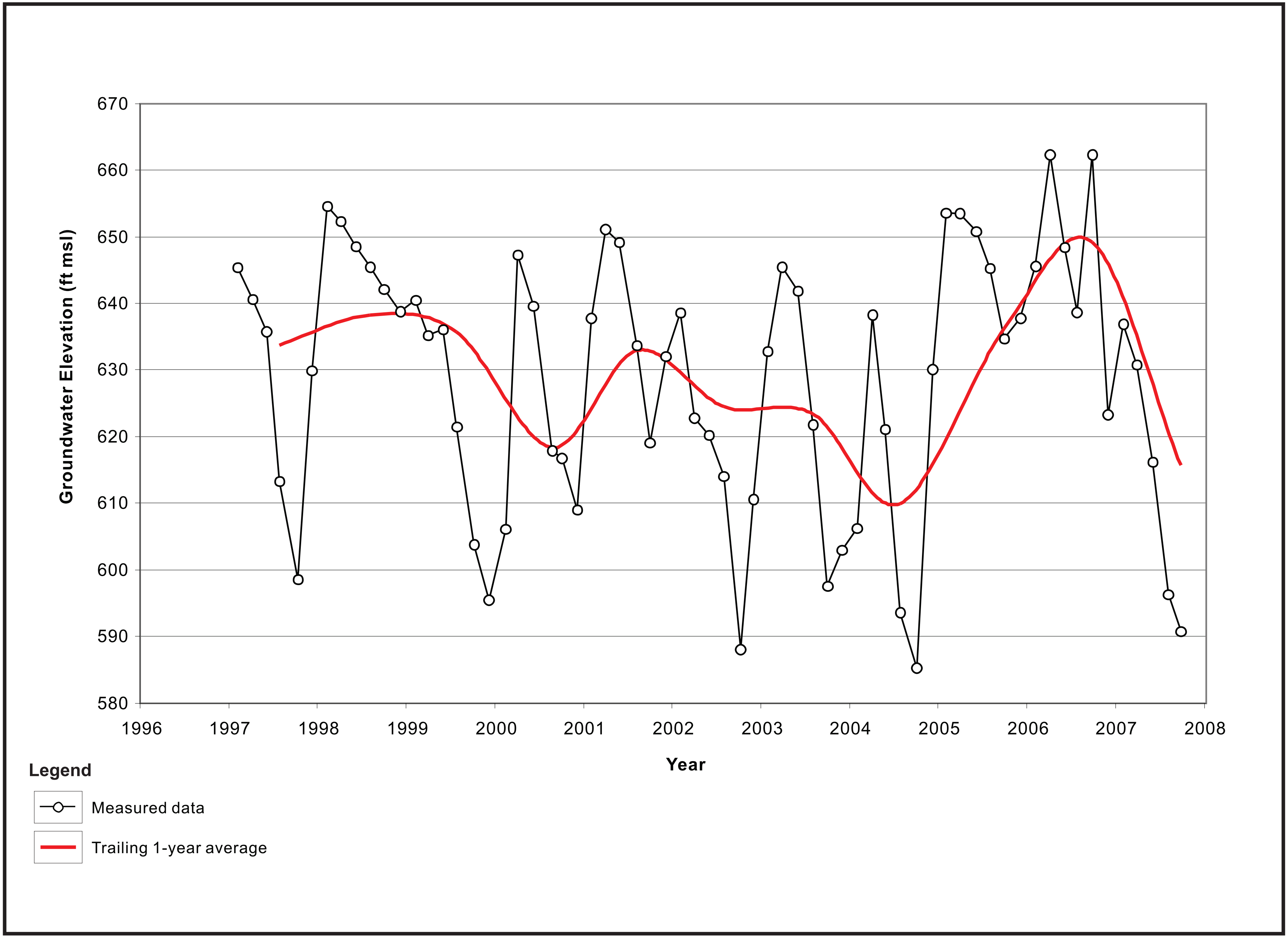


Figure 11e: Hydrograph for 04N23W09B01S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

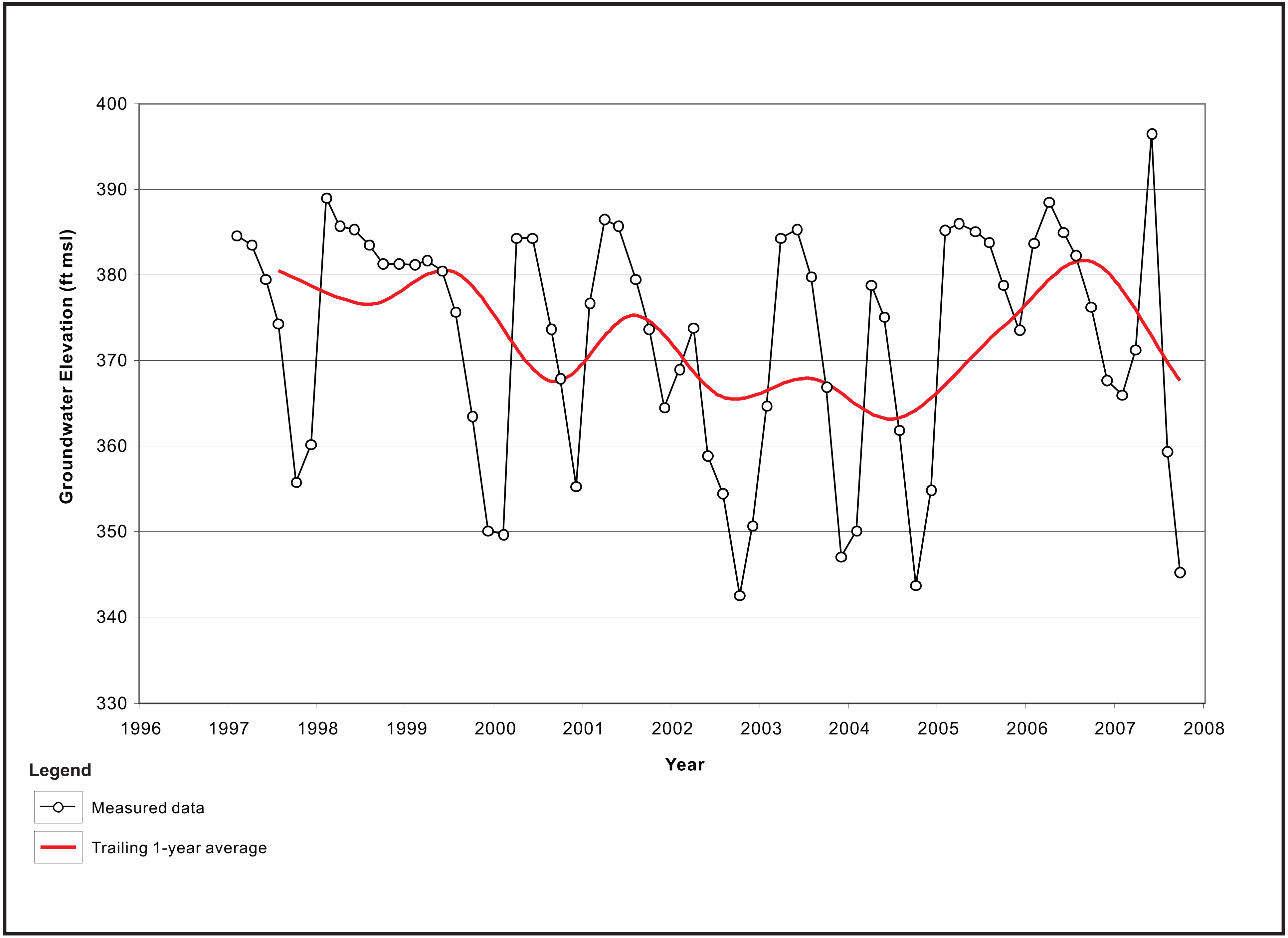


Figure 11f: Hydrograph for 04N23W29F02S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

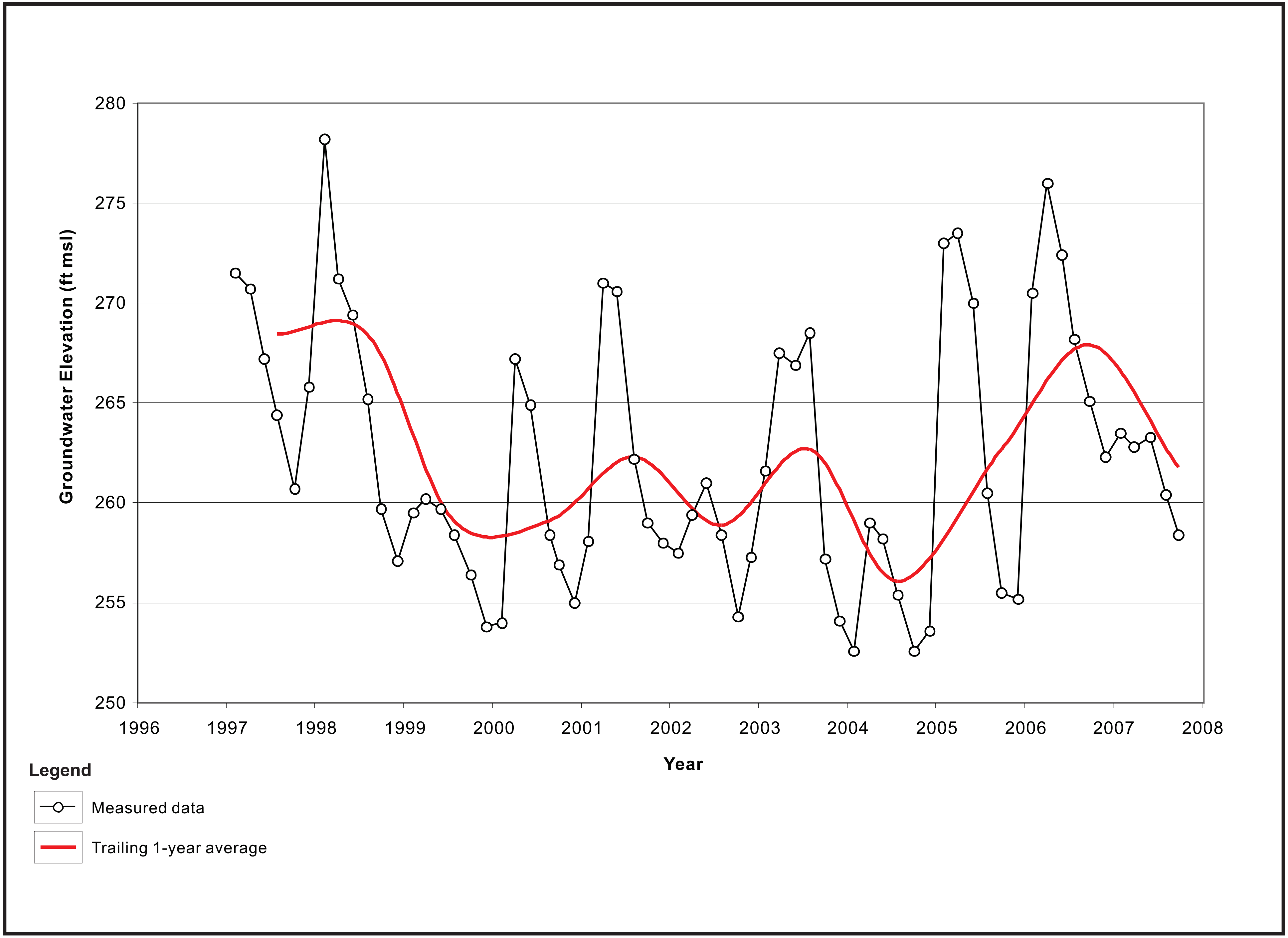


Figure 11g: Hydrograph for 03N23W05B01S, Water Years 1997-2007. Measured groundwater elevation is shown. A trailing 1-year average of the measured data, based on water year, is also provided for the purposes of data smoothing and interpretation. [Source: VCWPD, 2010a]

Tables

Table 1. Estimated Infiltration from Precipitation, Upper and Lower Subbasins

Groundwater Basin	Area (acres)	Annual Precipitation [a]		Potential Infiltration [b]		Effective Impervious Area [c] (%)	Infiltration [d] (ac-ft/yr)
		(in/yr)	(ac-ft/yr)	(%)	(ac-ft/yr)		
Lower Ventura	511	16.5	703	11.3	79		
	815	17.5	1,189	12.8	153		
	682	18.5	1,051	14.6	153		
	446	19.5	724	16.5	120		
	530	20.5	905	18.8	170		
	180	21.5	322	21.3	69		
	29	22.5	54	24.2	13		
Total Lower Ventura	3,192		4,947		756	19	616
Upper Ventura (east)	3,271	22.5	6,132	24.2	1,485		
	3,409	23.5	6,677	25.0	1,669		
	1,449	24.5	2,958	25.0	740		
	731	25.5	1,553	25.0	388		
	299	26.5	659	25.0	165		
	69	27.5	159	25.0	40		
	113	28.5	269	25.0	67		
	73	29.5	179	25.0	45		
	4	30.5	10	25.0	3		
Total Upper Ventura (east)	9,418		18,597		4,601	9	4,181

Sources:
[a] Average for water years 1997-2007, Tetra Tech (2009). See also Figure 6.
[b] Hevesi et al., 2002 (using modified Maxey-Eakin approach)
[c] Table 2
[d] Potential infiltration ∗ (1 – Effective impervious area)

in/yr = Inches per year
ac-ft/yr = Acre-feet per year

Table 1. Estimated Infiltration from Precipitation, Upper and Lower Subbasins

Groundwater Basin	Area (acres)	Annual Precipitation [a]		Potential Infiltration [b]		Effective Impervious Area [c] (%)	Infiltration [d] (ac-ft/yr)
		(in/yr)	(ac-ft/yr)	(%)	(ac-ft/yr)		
Upper Ventura (west)	13	22.5	25	24.2	6		
	198	23.5	387	25.0	97		
	138	24.5	281	25.0	70		
	720	25.5	1,531	25.0	383		
	150	25.5	318	25.0	80		
	463	26.5	1,023	25.0	256		
	28	27.5	63	25.0	16		
	13	28.5	31	25.0	8		
Total Upper Ventura (west)	1,723 [e]		3,661		915	2	893

Sources:
[a] Average for water years 1997-2007, Tetra Tech (2009). See also Figure 6.
[b] Hevesi et al., 2002 (using modified Maxey-Eakin approach)
[c] Table 2
[d] Potential infiltration ∗ (1 – Effective impervious area)
[e] Total area minus area of Lake Casitas

in/yr = Inches per year
ac-ft/yr = Acre-feet per year

Table 2. Effective Impervious Area, Upper and Lower Subbasins

Land Use	Area [a] (acres)	Effective Impervious Area [b] %	Effective Impervious Area [b] acres
Lower Ventura			
Commercial	184	62	114
High-density residential	431	32	136
Industrial	407	54	220
Institutional	50	32	16
Irrigated agriculture	104	1	1
Low-density residential	17	7	1
Multifamily residential	150	58	87
Orchards/vineyards	204	1	2
Park/golf course	36	5	2
Vacant	1,607	1	13
Total	3,192		591
Fraction effective impervious area		19	
Upper Ventura West			
Commercial	0	62	0
High-density residential	11	32	4
Industrial	34	54	18
Institutional	0	32	0
Irrigated agriculture	5	1	0
Low-density residential	0	7	0
Multifamily residential	0	58	0
Orchards/vineyards	11	1	0
Park/golf course	142	5	7
Vacant	1,520	1	13
Total [c]	1,723		42
Fraction effective impervious area		2	
Upper Ventura East			
Commercial	225	62	139
High-density residential	1,189	32	377
Industrial	8	54	4
Institutional	171	32	54
Irrigated agriculture	139	1	1
Low-density residential	1,987	7	146

Sources:
[a] SCAG (2005), as cited by Tetra Tech (2009)
[b] Brabec et al. (2002)

[c] Total area minus area of Lake Casitas

Table 2. Effective Impervious Area, Upper and Lower Subbasins

Land Use	Area [a] (acres)	Effective Impervious Area [b] %	Effective Impervious Area [b] acres
Upper Ventura East (cont.)			
Multifamily residential	153	58	89
Orchards/vineyards	966	1	8
Park/golf course	107	5	6
Vacant	4,473	1	37
Total	9,418		860
Fraction effective impervious area		9	

Sources:
[a] SCAG (2005), as cited by Tetra Tech (2009)
[b] Brabec et al. (2002)

Table 3. Estimated Infiltration from Irrigation, Upper and Lower Subbasins

Land Use	Area [a] (acres)	Fractional Coverage as Vegetation [b]	Water Application [c] (ac-ft/ac-yr)	Irrigation Efficiency [d] (%)	Irrigation [e] (ac-ft/yr)	Infiltration from Irrigation [f] (ac-ft/yr)
Lower Ventura						
Commercial	184	0.12	3.96	80	90	18
High-density residential	431	0.55	3.96	80	942	188
Industrial	407	0.26	3.96	80	412	82
Institutional	50	0.50	3.96	80	99	20
Irrigated agriculture	104	1.00	1.96	70	205	61
Low-density residential	17	0.72	3.96	80	48	10
Multifamily residential	150	0.33	3.96	80	196	39
Orchards/vineyards	204	1.00	3.36	73	687	185
Park/golf course	36	1.00	3.96	65	144	50
				Total	2,822	655
Upper Ventura West						
Commercial	0	0.12	3.96	80	0	0
High-density residential	11	0.55	3.96	80	24	5
Industrial	34	0.26	3.96	80	34	7
Institutional	0	0.50	3.96	80	0	0
Irrigated agriculture	5	1.00	1.96	70	10	3
Low-density residential	0	0.72	3.96	80	0	0
Multifamily residential	0	0.33	3.96	80	0	0
Orchards/vineyards	11	1.00	3.36	73	37	10
Park/golf course	142	1.00	3.96	65	564	197
				Total	670	222
Upper Ventura East						
Commercial	225	0.12	3.96	80	110	22
High-density residential	1,189	0.55	3.96	80	2,600	520
Industrial	8	0.26	3.96	80	8	2
Institutional	171	0.50	3.96	80	338	68
Irrigated agriculture	139	1.00	1.96	70	273	82
Low-density residential	1,987	0.72	3.96	80	5,667	1,133
Multifamily residential	153	0.33	3.96	80	200	40
Orchards/vineyards	966	1.00	3.36	73	3,247	877
Park/golf course	107	1.00	3.96	65	423	148
				Total	12,865	2,891

Sources:
[a] SCAG (2005), as cited by Tetra Tech (2009)
[b] Brabec et al. (2002), 1-total impervious area (TIA)
[c] CDWR (2010)
[d] Tetra Tech (2009) for non-agricultural uses; CDWR (2010) for agricultural uses
[e] Area ∗ Fractional Coverage as Vegetation ∗ Water Application
[f] Irrigation Rate ∗ (1 – Irrigation Efficiency)

ac-ft/ac-yr = Acre-feet per acre per year   ac-ft/yr = Acre-feet per year   — = Not applicable

Table 4. Surface Water/Groundwater Interaction Upper Ventura Subbasin (West)

Water Year	Component (ac-ft/yr)	
	Evaporation [a]	Precipitation [a]
1997	11,062	4,304
1998	9,503	12,632
1999	10,224	2,295
2000	9,801	5,134
2001	8,379	6,693
2002	8,286	2,718
2003	7,985	3,583
2004	7,783	4,897
2005	7,242	7,798
2006	7,649	5,534
2007	8,571	2,253
Average	8,771	5,258
Modeled reservoir loss	5,516	
Net precipitation [b]	–3,513	
Estimated recharge to water [c]	2,003	

[a] Source: CMWD (2010)
[b] Average precipitation minus average evaporation
[c] Modeled reservoir loss plus net precipitation

ac-ft/yr = Acre-feet per year

Table 5. Surface Water/Groundwater Interaction
Upper Ventura Subbasin (East) and Lower Ventura Subbasin

Designator	Parameter	Calculation	Value (ac-ft/yr [a])
A	Ventura River length, Upper East Subbasin	—	9.9 miles
B	Ventura River length, Lower Subbasin	—	6.1 miles
C	Fraction Ventura River length, Upper East Subbasin	A / (A+B)	0.62 [b]
D	Fraction Ventura River length, Lower Subbasin	B / (A+B)	0.38 [b]
E	Average modeled flows, USGS Gage 608 1997-2007	—	71,523
Reported total, Ventura River Mainstem			
F	Modeled runoff	—	25,013
G	Modeled upstream input	—	58,129
H	Modeled point source (Ojai WWTP)	—	2,491
I	Modeled direct precipitation	—	198
J	Modeled downstream out	—	84,880
K	Modeled diversions out	—	885
Estimated, Upper East Subbasin			
Ventura River			
L	Runoff	F ∗ C	15,477
G	Upstream input	—	58,129
M	Direct precipitation	I ∗ C	123
K	Diversions out	—	885
O	Estimated balance (net river to groundwater)	(E+K) – (L+G+M)	–1,321
San Antonio Creek			
P	Modeled groundwater to creek (entire creek)	—	349
Q	Modeled creek to groundwater (entire creek)	—	2,553
R	Modeled net creek to groundwater (entire creek)	Q – P	2,204
S	Fraction length of creek within Upper East Subbasin	—	0.44 [b]
T	Estimated balance (net creek to groundwater)	–(S ∗ R)	–970
Total Upper East Subbasin			
U	Estimated balance (net surface water to groundwater)	T + O	–2,290
Estimated, Lower Subbasin (Ventura River)			
V	Runoff	F ∗ D	9,536
W	Point source (Ojai WWTP)	—	2,491
X	Direct precipitation	I ∗ D	76
Y	Estimated balance (net groundwater to river)	J – (V+W+X+E)	1,254

Source: Modeled data (Tetra Tech, 2009)
[a] Unless otherwise noted
[b] Unitless

ac-ft/yr = Acre-feet per year
USGS = U.S. Geological Survey
WWTP = Wastewater treatment plant

Table 6. Estimate of Recharge from Septic Systems

Basin	Number of Approved Septic Systems [a]	Recharge (ac-ft/yr)
Estimated average recharge per septic system [b]		0.16 [c]
Upper Ventura West	115	18
Upper Ventura East	749	120
Lower Ventura	34	5

[a] Source: CVEHD (2010)
[b] Source: Hantzche and Finnemore (1992)
[c] 143.5 gallons per day

ac-ft/yr = Acre-feet per year

Table 7. Bedrock Inflow to Alluvial Subbasins

Formation (North to South)	Structure	Description [a]	Length Under Subbasins [a] (feet)	Width Under Subbasins [a] (feet)	Area under Subbasins (ft^2)	Hydraulic Conductivity [b] (ft/d)	Flux to Basin [c] (ft^3/d)	Flux to Basin (ac-ft/yr)
Upper Subbasin								
Cozy Dell shale	Matilija Overturn	Micaceous shale with sandstone interbeds	5,500	1,000	5,500,000	3×10^{-5}	165	1
Coldwater sandstone	Matilija Overturn	Hard arkosic sandstone with siltstone, shale interbeds	5,000	500	2,500,000	1×10^{-3}	2,500	21
Sespe Formation	Ojai Syncline	Sandstone, siltstone and claystone	19,000	4,000	76,000,000	1×10^{-4}	7,600	64
Vaqueros sandstone	Oak View folds and flexural slip faults	Sandstone, locally calcareous	500	2,000	1,000,000	1×10^{-3}	1,000	8.4
Rincon shale	Oak View folds and flexural slip faults	Shale and siltstone	3,000	2,000	6,000,000	3×10^{-5}	180	2
Monterey shale	Oak View folds and flexural slip faults	Platy, brittle siliceous and diatomaceous shale, some sandstone and limestone	3,000	2,000	6,000,000	1×10^{-4}	600	5
Rincon shale	Oak View folds and flexural slip faults	Shale and siltstone	1,000	2,000	2,000,000	3×10^{-5}	60	0.5
Monterey shale	Oak View folds and flexural slip faults	Platy, brittle siliceous and diatomaceous shale, some sandstone and limestone	5,000	1,000	5,000,000	1×10^{-4}	500	4

[a] Source: Dibblee (1987 and 1988); AAPG (1956). Length refers to generally north-to-south direction, width refers to generally east-to-west direction.
[b] Source: Freeze and Cherry, 1979
[c] Darcy's Law, assuming a unit hydraulic gradient

ft^2 = Square feet
ft/d = Feet per day
ft^3/d = Cubic feet per day
ac-ft/yr = Acre-feet per year

Table 7. Bedrock Inflow to Alluvial Subbasins

Formation (North to South)	Structure	Description [a]	Length Under Subbasins [a] (feet)	Width Under Subbasins [a] (feet)	Area under Subbasins (ft^2)	Hydraulic Conductivity [b] (ft/d)	Flux to Basin [c] (ft^3/d)	Flux to Basin (ac-ft/yr)
Upper Subbasin (cont.)								
Rincon shale	Oak View Folds and Flexural Slip faults	Shale and siltstone	4,000	1,000	4,000,000	3×10^{-5}	120	1
Vaqueros sandstone	Oak View Folds and Flexural Slip faults	Sandstone, locally calcareous	300	1,000	300,000	1×10^{-3}	300	3
Sespe Formation	Red Mountain Anticline	Sandstone, siltstone and claystone	6,000	800	4,800,000	1×10^{-4}	480	4
Vaqueros sandstone		Sandstone, locally calcareous	100	500	50,000	1×10^{-3}	50	0.4
Rincon shale	Red Mountain Fault Zone	Shale and siltstone	1,000	800	800,000	3×10^{-5}	24	0.2
Total (Upper Subbasin)								114
Lower Subbasin								
Pico Formation	Ventura Anticline	Claystone, siltstone, and sandstone	19,000	2,000	38,000,000	1×10^{-3}	38,000	319
Total (Lower Subbasin)								319

[a] Source: Dibblee (1987 and 1988); AAPG (1956). Length refers to generally north-to-south direction, width refers to generally east-to-west direction.
[b] Source: Freeze and Cherry, 1979
[c] Darcy's Law, assuming a unit hydraulic gradient

ft^2 = Square feet
ft/d = Feet per day
ft^3/d = Cubic feet per day
ac-ft/yr = Acre-feet per year

Table 8a. Groundwater Flux Between Subbasins

Designator	Parameter	Calculation	Value	Units
A	Hydraulic conductivity of alluvium at Foster Park [a]	—	922	ft/d
B	Thickness of saturated alluvium [a]	—	33	feet
C	Width of alluvium (gap in Foster Park Dam) [b]	—	300	feet
D	Hydraulic gradient [c]	—	0.0070	unitless
E	Groundwater flux	B ∗ C ∗ A ∗ D	63,894.6	ft^3/d
			535	ac-ft/yr

Sources:
[a] Hopkins (2007)
[b] SBRA (2002)
[c] Turner (1971)

— = Not applicable
ft/d = Feet per day
ft^3/d = Cubic feet per day
ac-ft/yr = Acre-feet per year

Table 8b. Groundwater Flux to Pacific Ocean

Designator	Parameter	Calculation	Value	Units
A	Hydraulic conductivity of alluvium [a]	—	300	ft/d
B	Thickness of saturated alluvium [b]	—	33	feet
C	Average groundwater elevation, AT Systems, Inc, 9/2008 [c]	—	6.86	ft msl
D	Average groundwater elevation, Former BJ Services, 9/2008 [d]	—	64.78	ft msl
E	Distance, AT Systems, Inc to Former BJ Services	—	10,138	feet
F	Width of alluvium (Lower Subbasin) [e]	—	5,089	feet
G	Hydraulic gradient	(D – C) / E	0.0057	unitless
H	Groundwater flux	F ∗ B ∗ A ∗ G	287,851.8	ft^3/d
			2,412	ac-ft/yr

Sources:
[a] Fetter (2001) and Freeze and Cherry (1979) value for silty sands, silty gravels, and sandy gravels
[b] Hopkins (2007); Turner (1971)
[c] H2 Environmental (2008)
[d] EnviroSolve (2010)
[e] USGS (1951)

— = Not applicable
ft/d = Feet per day
ft msl = Feet above mean sea level
ft^3/d = Cubic feet per day
ac-ft/yr = Acre-feet per year

Table 9. Municipal Groundwater Withdrawals (Upper East Subbasin) 2000 Through 2007

Year	Extraction Rate (ac-ft/yr)				
	City of Ventura Foster Park	Ventura River County Water District	Casitas Municipal Water District Mira Monte Well	Meiners Oaks County Water District	Total
2000	6,779	1,512	250	1,197	9,739
2001	5,727	1,416	197	1,128	8,467
2002	5,951	1,359	57	1,243	8,610
2003	6,722	1,415	236	1,115	9,487
2004	6,118	1,362	282	1,209	8,971
2005	1,293	1,481	118	1,088	3,980
2006	2,233	1,470	204	1,166	5,074
2007	2,000	1,176	304	1,271	4,751
Average	4,603	1,399	206	1,177	7,385

Source: Pumping records provided by applicable water districts
ac-ft/yr = Acre-feet per year

Table 10. Domestic Groundwater Withdrawals

Basin	Number of Active Domestic Wells [a]	Extraction (ac-ft/yr)
Estimated average domestic withdrawals per well [b]		*0.18* [c]
Upper Ventura West	8	1.5
Upper Ventura East	86	15.7
Lower Ventura	5	0.9

[a] Source: VCWPD (2010a)
[b] Source: USGS (2000) for domestic well users in Ventura County, California
[c] 163 gallons per day

ac-ft/yr = Acre-feet per year

Table 11a. Agricultural Groundwater Withdrawals Based on Land Use and Agricultural Well Placement Within Subbasins

Basin	Land Use Type	Land Use Area [a] (acres)	Water Application [b] (ac-ft/ac-yr)	Irrigation (ac-ft/yr)
Lower Ventura River	Irrigated agriculture	147.6	1.96	289
	Orchards/vineyards	69.4	3.36	233
			Total irrigation	522
Upper Ventura East	Irrigated agriculture	70.3	1.96	138
	Orchards/vineyards	523.9	3.36	1,760
			Total irrigation	1,898

[a] SCAG (2005), as cited by Tetra Tech (2009)
[b] Source: CDWR (2010)

ac-ft/ac-yr = Acre-feet per acre per year
ac-ft/yr = Acre-feet per year

Table 11b. Agricultural Groundwater Withdrawals Based on Number of Agricultural Wells and an Average Extraction Rate

Basin	Number of Active Wells [a]	Withdrawals (ac-ft/yr)
Estimated average agricultural withdrawals per well [b]		*79*
Lower Ventura River	6	474
Upper Ventura East	43	3,397

[a] Source: VCWPD (2010a)
[b] Estimated from SGD (1992)

ac-ft/yr = Acre-feet per year

Table 12. Groundwater Consumption by Riparian Vegetation

Basin	Riparian Vegetated Cover [a] (acres)	Riparian Evapotranspiration
Evapotranspiration rate, Arundo donax		5.62 ft/yr [b]
Evapotranspiration rate, native trees		1.87 ft/yr [b]
Estimated total evapotranspiration rate		2.25 ft/yr [c]
Estimated average groundwater consumption rate		1.46 ft/yr [d]
Upper Ventura	980	1,430 ac-ft/yr
Lower Ventura	250	365 ac-ft/yr

[a] Source: USFWS (2010)
[b] Source: Iverson (1994)
[c] Assumes 10% of riparian forested areas occupied by *Arundo donax*, based on review of Wildscape Restoration (2008).
[d] Assumes 65% of evapotranspiration sourced from groundwater, see text for explanation.

ft/yr = Feet per year
ac-ft/yr = Acre-feet per year

Table 13. Groundwater Balance
Upper Ventura Subbasin

Category	Parameter	Value (ac-ft/yr)		
		Upper West	Upper East	Upper (Combined) [a]
Groundwater inputs	Infiltration from precipitation	893	4,181	5,073
	Infiltration from irrigation	222	2,891	3,113
	Net surface water to groundwater	2,003	2,290	4,293
	Septic system recharge	18	120	139
	Bedrock to alluvial [b]			114
Groundwater outputs	Extractions (domestic)	1	16	17
	Extractions (municipal)	0	7,385	7,385
	Extractions (agricultural)	0	1,898	1,898
	Groundwater outflow to Lower Subbasin [b]			535
	Consumption by riparian vegetation [b]			1,430
			Final balance [c]		+1,466

Source: Tables 3 through 12
[a] Numbers may not add exactly because of rounding to nearest whole number.
[b] Values not calculated independently for East and West Subbasins.
[c] Sum of groundwater inputs minus sum of groundwater outputs.

ac-ft/yr = Acre-feet per year

Table 14. Groundwater Balance Lower Ventura Subbasin

Category	Parameter	Value (ac-ft/yr)
Groundwater inputs	Infiltration from precipitation	616
	Infiltration from irrigation	655
	Septic system recharge	5
	Bedrock to alluvial	319
	Groundwater inflow from Upper Subbasin	535
Groundwater outputs	Groundwater discharge to surface water	1,254
	Extractions (domestic)	1
	Extractions (agricultural)	522
	Downgradient out	2,412
	Consumption by riparian vegetation	365
	Final balance [a]	–2,423

Source: Tables 3 through 12

[a] Sum of groundwater inputs minus sum of groundwater outputs. Numbers may not add exactly because of rounding to nearest whole number.

ac-ft/yr = Acre-feet per year

Appendix A

Reproduced Geologic Maps and Cross Section

Appendix A. Reproduced Geologic Maps and Cross Section

Plate 1. Geologic Map of the Ventura 7.5' Quadrangle (Reproduced from Tan et al., 2003)

This plate provides a geologic map of the area surrounding the Lower Subbasin, and was used in conjunction with other references for estimation of water inflow from bedrock to the alluvial aquifer (Section 2.2.5). DBS&A has modified the original figure to add the delineation of the Lower Subbasin (blue) and Upper Subbasin (red). Subbasin boundaries are from Tetra Tech (2009).

Plate 2. Geologic Map of the Matilija 7.5' Quadrangle (Reproduced from Tan and Jones, 2006)

This plate provides a geologic map of the area surrounding the Upper Subbasin, and was used in conjunction with other references for estimation of water inflow from bedrock to the alluvial aquifer (Section 2.2.5). DBS&A has modified the original figure to add the delineation of the Upper Subbasin (red). Subbasin boundaries are from Tetra Tech (2009).

Plate 3: Generalized Cross Section, Central Ventura Basin (Reproduced from CDOG, 1991)

This plate provides a general conceptual diagram of bedrock units that exist within the area of the Ventura River Watershed, and was used in conjunction with other references for estimation of water inflow from bedrock to the alluvial aquifer (Section 2.2.5). DBS&A has modified the original figure to add the delineation of the Lower Subbasin (blue) and Upper Subbasin (red) to the reference map, and to add a reference above the cross section for the location of the cross section relative to the Subbasins. The cross section crosses through the eastern edge of the Upper Subbasin, but otherwise is located external to the Subbasins (see map inset). Shaded areas on the map inset represent known oil and gas reservoirs. Subbasin boundaries are from Tetra Tech (2009).

Preliminary Geologic Map available from:
http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm

CALIFORNIA GEOLOGICAL SURVEY
MICHAEL S. REICHLE, ACTING STATE GEOLOGIST

STATE OF CALIFORNIA - GRAY DAVIS, GOVERNOR
THE RESOURCES AGENCY - MARY NICHOLS, SECRETARY FOR RESOURCES
DEPARTMENT OF CONSERVATION - DARRYL YOUNG, DIRECTOR

Prepared in cooperation with the U.S. Geological Survey,
Southern California Areal Mapping Project

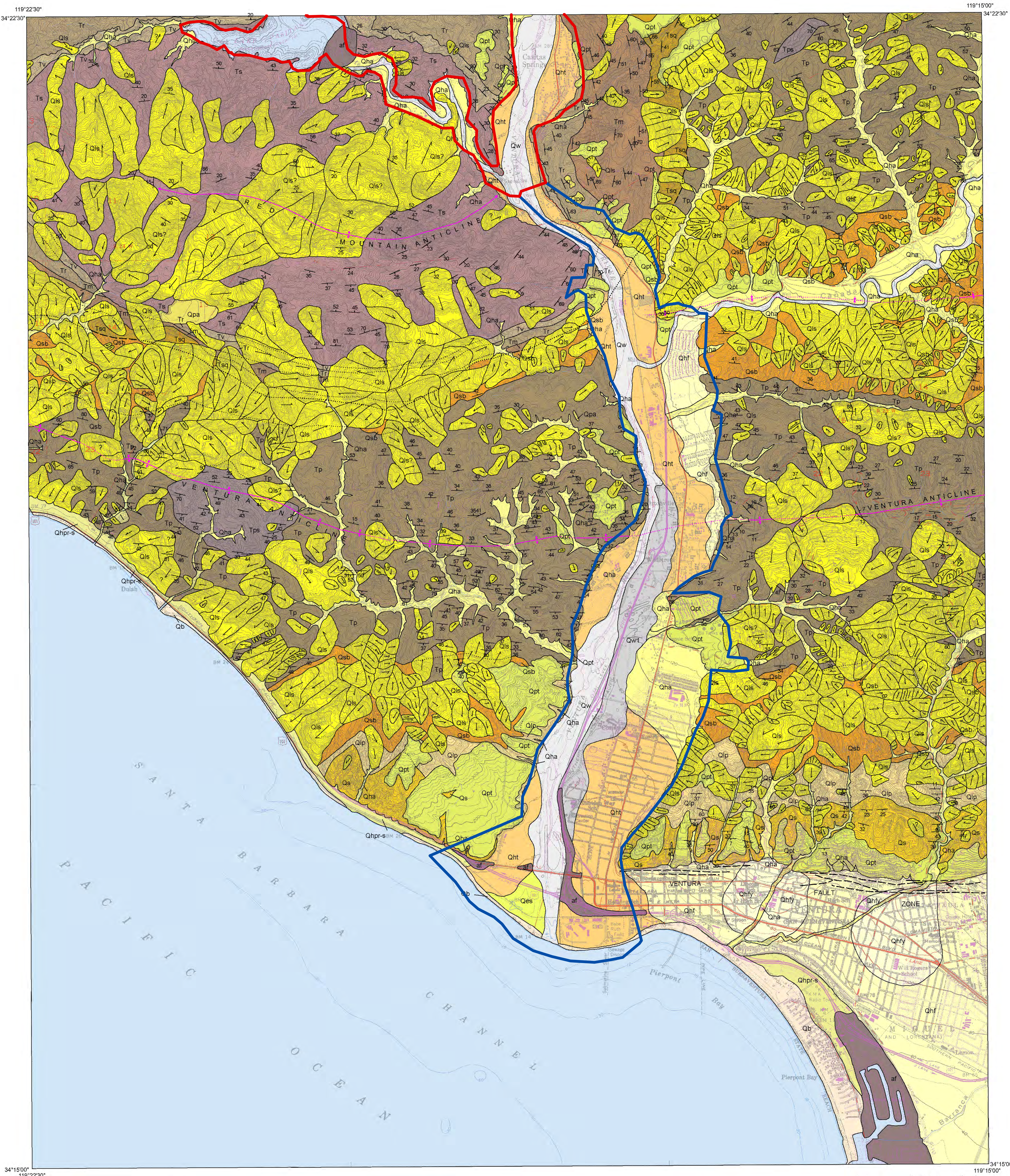
GEOLOGIC MAP OF THE VENTURA 7.5' QUADRANGLE VENTURA COUNTY, CALIFORNIA: A DIGITAL DATABASE

VERSION 1.0

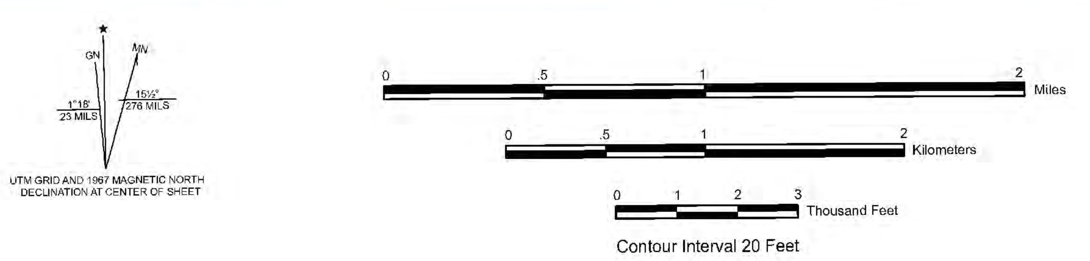
By
Siang S. Tan[1], Terry A. Jones[1] and Kevin B. Clahan[2]

Digital Database by:
Kelly Corriea[3]
2003

1. California Geological Survey, Los Angeles, CA
2. California Geological Survey, San Francisco, CA
3. U.S. Geological Survey, Riverside, CA

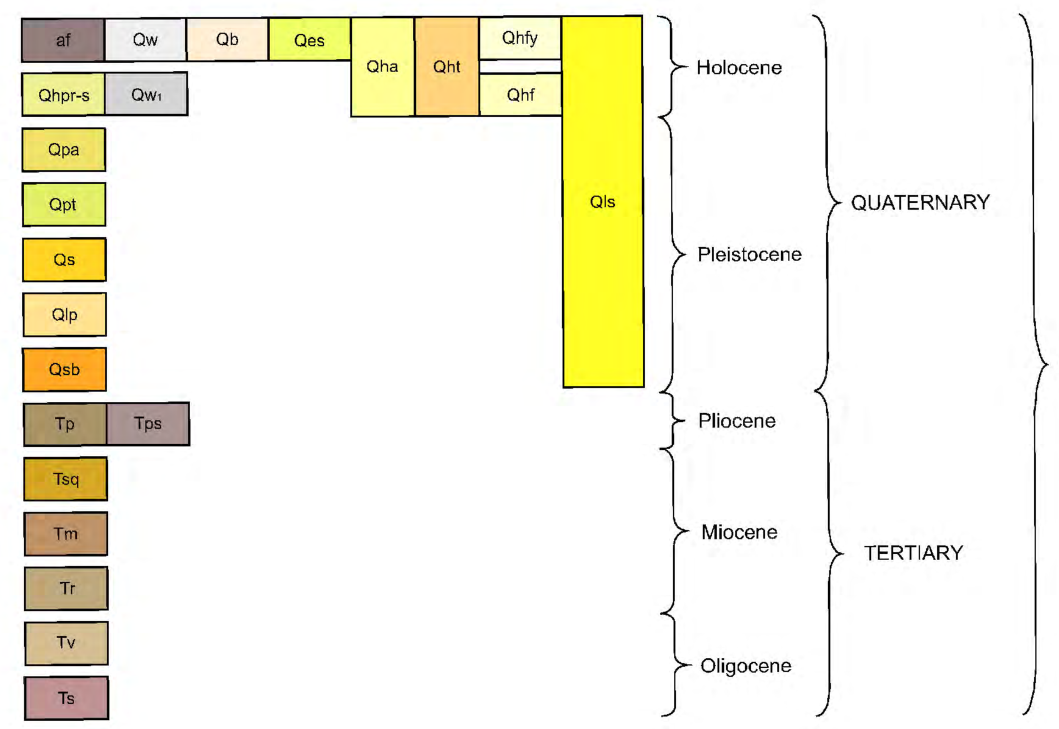


Topographic base from the U.S. Geological Survey. Polyconic Projection.



This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program, Statemap Award no.02HQAG0018

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact between map units; generally approximately located or inferred; dotted where concealed.

Fault; approximately located or inferred, querried where location is uncertain; dotted where concealed.

Landslide; arrow indicates principal direction of movement, querried where existence is questionable (some geologic features are drawn within questionable landslides); hachured where headscarp is mappable.

Strike and dip of bedding.

Axis of anticline; dotted where concealed; arrow indicates direction of plunge.

Axis of syncline; dotted where concealed.

EXPLANATION OF MAP UNITS

af	Artifical fill material; may be engineered and/or non-engineered.
Qw	Active wash deposits within major river channels; composed of unconsolidated sand, gravel and silt.
Qb	Active beach deposits; consist mainly of loose sand, fine to coarse-grained.
Qes	Active coastal estuarine deposits; composed of saturated silty clay with some fine sand.
Qhfy	Latest Holocene alluvial fan deposits, deposited by streams emanating from mountain canyons onto alluvial calley floors; deposits originate as debris flows, hyperconcentrated mudflows, or braided stream flows; composed of moderately to poorly sorted, and moderately to poorly bedded sandy clay with some gravel.
Qw1	Historically active wash deposits adjacent to active channel; composed of unconsolidated sand, silt and gravel.
Qha	Undivided Holocene alluvial and colluvial deposits on the floors of valleys, includes active stream deposits in hill slope areas; composed of unconsolidated sandy clay with some gravel.
Qht	Holocene stream terrace deposits, deposited in point bar and overbank settings; composed of unconsolidated clayey sand and sandy clay with gravel.
Qhf	Holocene alluvial fan deposits; deposited by streams emanating from mountain canyons onto alluvial valley floors; deposits originate as debris flows, hyperconcentrated mudflows, or braided stream flows; composed of moderately to poorly sorted, and moderately to poorly bedded, sandy clay with some gravel.
Qls	Holocene to Pleistocene landslide deposits, include numerous active landslides; composed of weathered broken up rocks; extremely susceptible to renewed landsliding.
Qhpr-s	Holocene paralic deposits of the Sea Cliff marine terrace 1800 to 5800 years old (Lajoie, and others, 1982); composed of semi-consolidated sandy clay with some gravel.
Qpt	Undivided Pleistocene stream terrace deposits, consists of consolidated clay sand, gravel, cobble and some boulder size material.
Qpa	Pleistocene undivided alluvial deposits, consist of consolidated slit, sand, clay, and gravel.
Qs	Pleistocene Saugus Formation; weakly consolidated alluvial deposits composed of sandstone and siliceous shale gravel and cobbles in sandy matrix; highly susceptible to landsliding.
Qlp	Pleistocene Las Posas Sandstone; weakly indurated sand, with some gravelly sand units; highly susceptible to landsliding.
Qsb	Pleistocene Santa Barbara claystone; locally contains Monterey Formation shale fragments; highly susceptible to landsliding.
Tp	Pliocene undivided Pico Formation, composed of claystone, siltstone, sandstone, locally pebbly; generally susceptible to landsliding.
Tps	Pliocene Pico Formation portion containing sandstone; generally resistant to landsliding.
Tsq	Pliocene-Miocene Sisquoc Shale; silty shale and claystone; generally susceptible to landsliding
Tm	Miocene Monterey Formation; consists of siliceous and diatomaceous shale and some sandstone and limestone; generally susceptible to landsliding.
Tr	Miocene Rincon Shale; composed of shale and siltstone; generally susceptible to landsliding.
Tv	Early Miocene Vaqueros Sandstone; consists of sandstone, locally calcareous.
Ts	Oligocene Sespe Formation, composed of sandstone; locally pebbly, with some siltstone and claystone.

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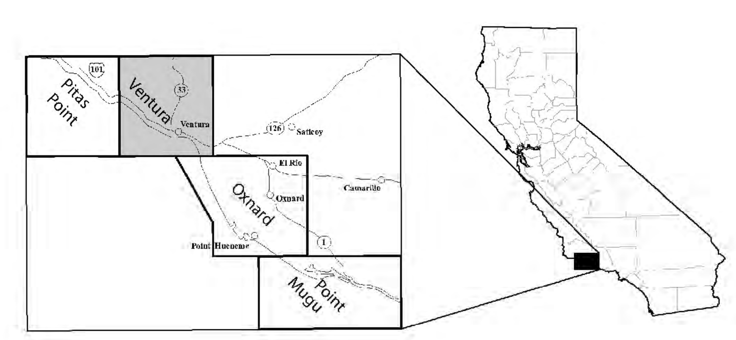

Plate 1

Preliminary Geologic Map available from:
http://www.conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm

CALIFORNIA GEOLOGICAL SURVEY
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DEPARTMENT OF CONSERVATION - BRIDGETT LUTHER, DIRECTOR

Prepared in cooperation with the U.S. Geological Survey, Southern California Areal Mapping Project

GEOLOGIC MAP OF THE MATILIJA 7.5' QUADRANGLE VENTURA COUNTY, CALIFORNIA: A DIGITAL DATABASE

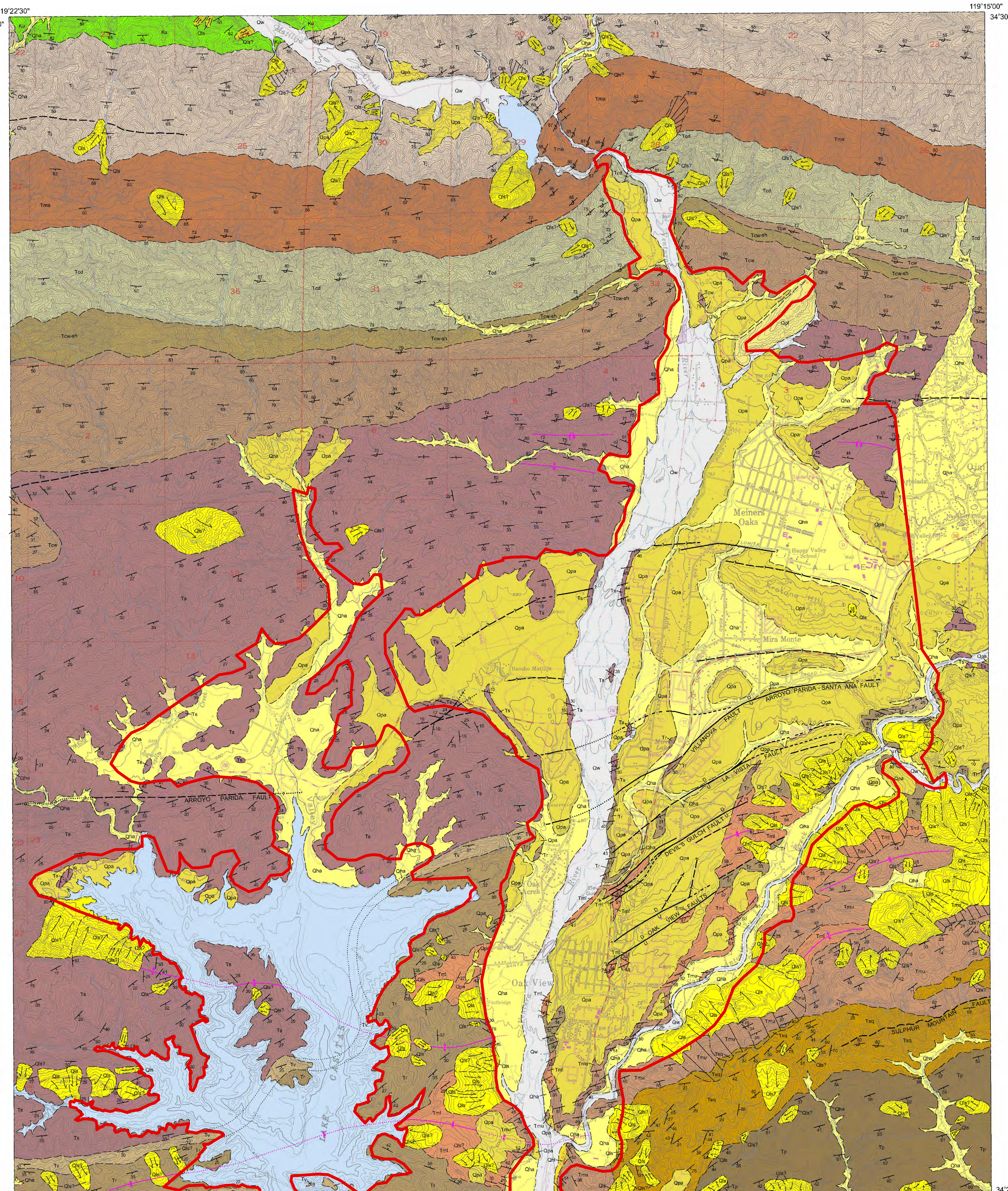
VERSION 1.0

By
Siang S. Tan[1] and Terry A. Jones[1]

Digital Database
by
Carlos I. Gutierrez[2]
2006

1. California Geological Survey, 888 South Figueroa Street, Suite 475, Los Angeles, CA 90017
2. California Geological Survey, 801 K Street, MS 12-32, Sacramento, CA 95814

119°22'30"
34°30'00"



119°15'00"
34°22'30"

Topographic base from U.S. Geological Survey
Matilija 7.5-minute Quadrangle, 1988
UTM projection, North American Datum 1927

Scale 1:24,000

0 .5 1 2 Miles
0 .5 1 2 Kilometers
0 1 2 3 Thousand Feet

Contour Interval 40 Feet
Dotted Lines Represent Half-Interval Contours

GN MN 1°18' 23 MILS 14° 249 MILS
UTM GRID AND 1988 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program, STATEMAP Award no. 05HQAG0080

Unit Explanation

Qw — **Active wash deposits within major river channels (Holocene)** - Composed of unconsolidated silt, sand and gravel.

Qha — **Alluvial and colluvial deposits, undivided (Holocene)** - Located on the floors of valleys; includes active stream deposits in hill slope areas; composed of unconsolidated sandy clay with some gravel.

Qhf — **Alluvial fan deposits (Holocene)** - Deposited by streams emanating from mountain canyons onto alluvial valley floors; deposits originate as debris flows, hyper-concentrated mudflows, or braided stream flows; composed of moderately to poorly sorted, and moderately to poorly bedded, sandy clay with some gravel.

Qls — **Landslide deposits (Holocene to late Pleistocene)** - Includes numerous active landslides, composed of weathered, broken up rocks; extremely susceptible to renewed landsliding, including their head scarp areas.

Qpa — **Alluvial deposits, undivided (late Pleistocene)** - Consists of semi-consolidated silt, sand, clay, and gravel.

Qpf — **Alluvial fan deposits (late to middle Pleistocene)** - Semi-consolidated poorly sorted gravel, boulder, sand, silt and clay; often form elevated, slightly tilted, terraces on hill slope areas.

Tp — **Pico Formation, undivided (Pliocene)** - Composed of claystone, siltstone, and sandstone; locally pebbly; generally susceptible to landsliding.

Tsq — **Sisquoc Shale (Pliocene-Miocene)** - Silty shale and claystone; generally susceptible to landsliding. Locally contains siliceous shale similar to the Monterey Formation.

Tmu / Tml — **Monterey Formation (middle and late Miocene)** - Consists of siliceous and diatomaceous shale and some sandstone and limestone; generally susceptible to landsliding. Tml = lower section, containing punky thin-bedded shale; Tmu = upper section, composed of platy brittle siliceous thin-bedded shale.

Tr — **Rincon Shale (early Miocene)** - Composed of shale and siltstone; generally susceptible to landsliding.

Tv — **Vaqueros Sandstone (early Miocene)** - Consists of sandstone, locally calcareous.

Ts — **Sespe Formation (Oligocene)** - Composed of sandstone; locally pebbly, siltstone and claystone; rocks are generally reddish in color.

Tcw / Tcw-sh — **Coldwater Sandstone (late Eocene)** - Composed of hard arkosic sandstone with siltstone and shale interbeds; locally reddish in color, similar to appearance of Sespe Formation. Tcw-sh consists predominantly of shale.

Tcd — **Cozy Dell Shale (late Eocene)** - Consists of micaceous shale with arkosic sandstone interbeds; generally susceptible to landsliding.

Tma — **Matilija Sandstone (middle to late Eocene)** - Composed of hard arkosic sandstone with micaceous shale interbeds.

Tj — **Juncal Formation (early to middle Eocene)** - Consists of micaceous shale with arkosic sandstone interbeds; generally susceptible to landsliding.

Ku — **Unnamed conglomerate (late Cretaceous)** - Conglomerate with arkosic sandstone and micaceous shale interbeds.

Unit Correlation

Qw, Qha, Qhf, Qls	Holocene	QUATERNARY	CENOZOIC
Qpa, Qpf, Qls	Pleistocene	QUATERNARY	CENOZOIC
Tp, Tsq	Pliocene	TERTIARY	CENOZOIC
Tmu, Tml, Tr, Tv	Miocene	TERTIARY	CENOZOIC
Ts	Oligocene	TERTIARY	CENOZOIC
Tcw, Tcw-sh, Tcd, Tma, Tj	Eocene	TERTIARY	CENOZOIC
Ku		CRETACEOUS	MESOZOIC

Symbol Explanation

Contact between map units - Dashed where approximately located or inferred; dotted where concealed.

Fault - Solid where accurately located; long dash where approximately located; short dash where inferred; dotted where concealed; queried where location is uncertain. U = upthrown block, D = downthrown block. Arrow and number indicate direction and angle of dip of fault plane.

Axis of anticline - Approximately located; dotted where concealed. Arrow indicates direction of plunge.

Axis of syncline - Approximately located; dotted where concealed.

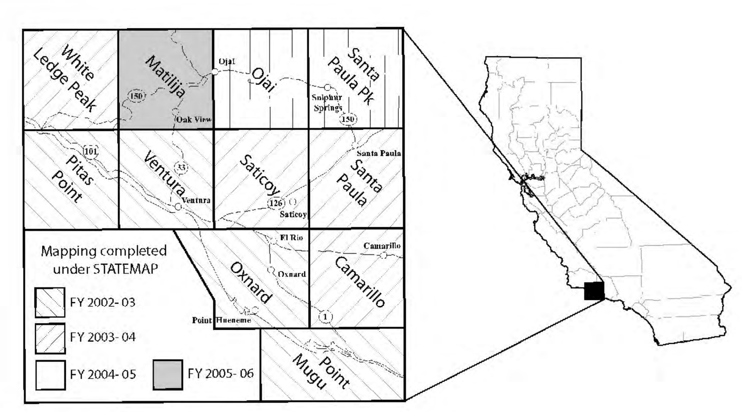
Axis of overturned syncline - Approximately located; dotted where concealed.

Strike and dip of bedding.

Vertical bedding.

Strike and dip of overturned bedding.

Landslide - Arrows indicate principal direction of movement, queried where existence is questionable; hachured where headscarp is mappable; some geologic features are drawn within headscarp.



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Revised: 11/06/2006

Plate 2

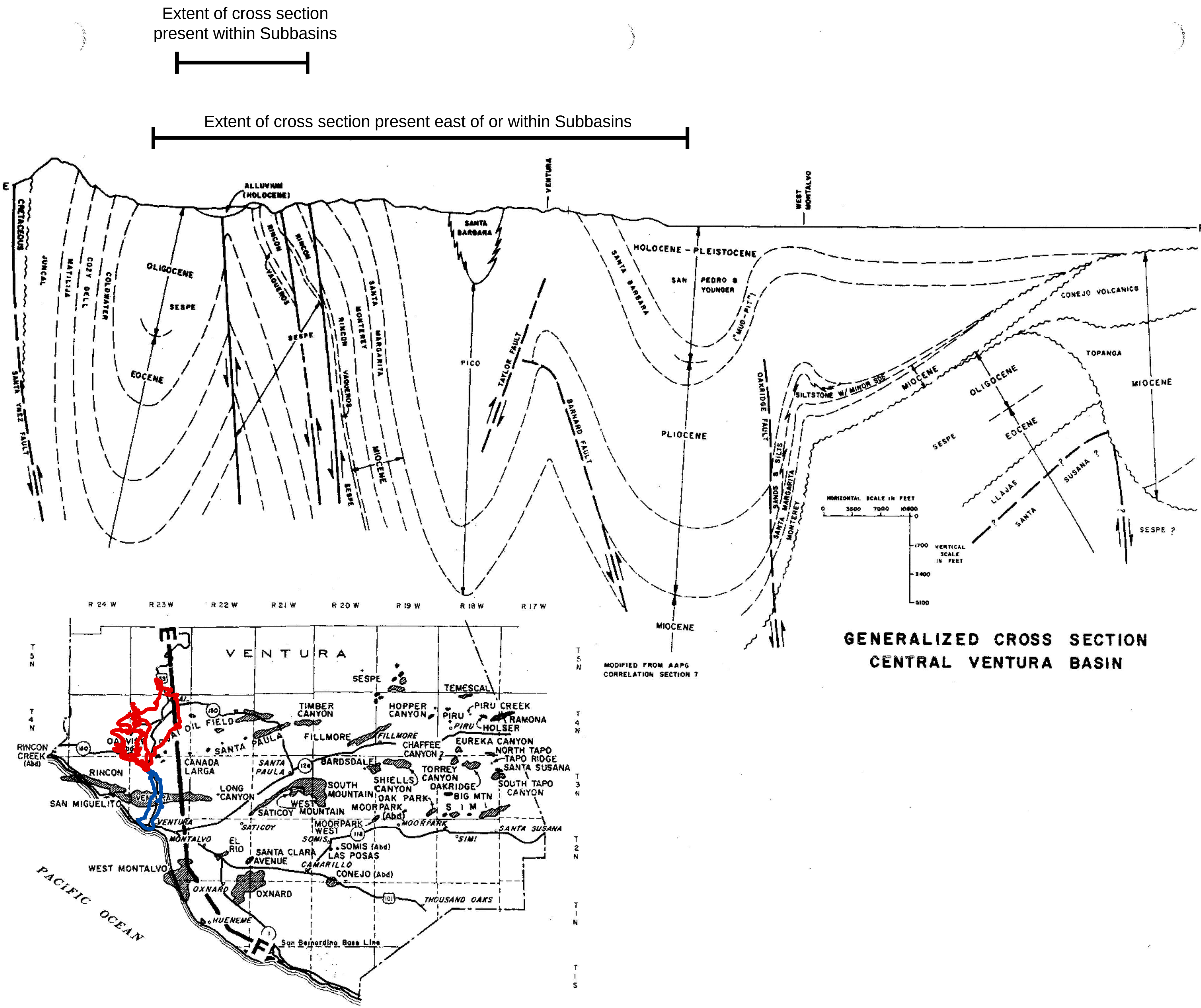
Extent of cross section present within Subbasins
Extent of cross section present east of or within Subbasins
GENERALIZED CROSS SECTION
CENTRAL VENTURA BASIN
MODIFIED FROM AAPG CORRELATION SECTION 7
HOLOCENE - PLEISTOCENE
SAN PEDRO & YOUNGER
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
SESPE
PICO
TOPANGA
CONEJO VOLCANICS
OAKRIDGE FAULT
BARNARD FAULT
TAYLOR FAULT
SANTA YNEZ FAULT
VENTURA
WEST MONTALVO
HORIZONTAL SCALE IN FEET
VERTICAL SCALE IN FEET
VENTURA
PACIFIC OCEAN
San Bernardino Base Line

Plate 3

Appendix B

Response to Comments

Response to Comments
DRAFT Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (75% Complete), dated August 20, 2010

This document provides responses to comments received by Daniel B. Stephens & Associates, Inc. (DBS&A) from the Ventura County Watershed Protection District (VCWPD), Hawks & Associates/City of Ojai, and Hopkins Groundwater Consultants/City of Ventura on the draft report *Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (75% Complete).*

VCWPD Comments Dated September 16, 2010

1. *In describing basin boundaries, DBSA separates the Upper Ventura River Basin into two subbasins. Please explain DBSA's decision to divide the basin in this manner. We note that earlier reports (Turner 1971) did not comment on the portion DBSA calls the Upper West Subbasin. Based on the geology and hydrology, should it in fact be part of the Upper Ventura River Basin?*

DBS&A appreciates VCWPD comments on this section. DBS&A has added text to Section 1.1 explaining the reasoning behind separating the Upper Subbasin into eastern and western sections. Regarding the Upper West Subbasin, DBS&A notes that this area is included within the Upper Basin in VCWPD reports (e.g., the groundwater section annual reports) and earlier reports, such as the Tetra Tech report. A discussion has also been added regarding the inconsistency of Subbasin delineation among various sources.

2. *The report relies heavily on the HSPF model that was developed to model surface water runoff at the watershed scale. We understand the importance of relying on particular information in the HSPF model, but there seems to be some disagreement on the ability of the model data to be directly useful to the groundwater budget evaluation. The model uses a parameter, that is updated periodically to represent the surface water contribution to groundwater. Please contact Scott Holder (805) 477-7121 for information regarding limitations of the model and add a discussion to your report that clearly states the limitations of information and data referenced in the model as it is used in reference to the groundwater budget. The report should include a statement that provides an indication of your level of confidence in the reported values i.e., 20%, 50%, 100% of actual value.*

DBS&A appreciates VCWPD comments on calculation of infiltration to groundwater from precipitation. Based on feedback from VCWPD, and the inability to refine the spatial output of the HSPF model, DBS&A has limited the use of the HSPF model. In the 90% and 100% reports, the HSPF model calculations are used only in estimation of surface water/groundwater interaction. Calculation of infiltration from precipitation and irrigation have therefore been revised significantly in the 90% and 100% reports.

In addition to the surface water modeling component of the HSPF TetraTech report, the authors compiled useful information necessary for a groundwater budget, including data from personal communications with VCWPD. DBS&A has distinguished cases where we use data from the HSPF TetraTech report from cases where we actually base calculations on HSPF model results.

DBS&A has contacted VCWPD staff regarding limitations of the model as requested, but have not received a reply regarding the limitations discussed in the comment. DBS&A has included a general discussion of the limitations of the Tetra Tech model in Section 2.5.

3. *Several discussions focus on structural geology and hydrogeology. It is important to include a geologic map of the area, and all pertinent geologic cross sections. A cross section was included in the "Approach to a GWMP" section of your presentation in the Watershed Council Meeting; however, the cross section was not included in the report. The alignment was not included, the labels were not legible, and were very general in nature. We suggest construction of a geologic cross section along the alluvial filled valleys where bedrock reportedly yields water to the more recent/quaternary sediments. The geologic map should include location of the water wells used to estimate hydraulic parameters for the aquifer and if possible those wells should be projected onto the cross section. If after drafting the cross section, it is found that the wells are too far from or much shallower than the aquifer yielding water to the alluvium, it may be appropriate to adjust the hydraulic properties obtained from the well to account for more consolidation of the rock at depth. The cross section should clearly show the water yielding units. Cross sections could be constructed from information contained on a geologic map such as Dibblee's, other maps, and Field data. In addition, Turner's 1971 report has some cross sections that might be helpful.*

DBS&A appreciates VCWPD comments in this section, and agrees that cross sections and geologic maps of these areas can be useful for providing a graphical basis for calculations in the groundwater budget. Geologic maps prepared by the California Geological Survey in association with the USGS (Tan and Jones, 2006; Tan et al., 2003) have been incorporated into Appendix A of the 100% report. Measurements of bedrock section length and width were taken along the Subbasins from these maps to include in the calculations for contributions of water from the bedrock. A geologic cross section in the general vicinity of the Subbasins was incorporated, as published by the Division of Oil and Gas (CDOG, 1991), to indicate general structural trends and regional stratigraphic relationships. In other areas of the groundwater budget where data from additional cross sections that have been previously developed (Turner, 1971), DBS&A has cited these sources.

DBS&A considers construction of an original geologic cross section to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited to be adequate for estimation of the groundwater budget. In addition, DBS&A would be pleased to construct cross sections in this area; however, this relatively time-intensive task is outside of our contracted scope of work and budget.

4. *Section 1. Please include an explanation of what a multi-year running average is and why it was used on the hydrographs; what is the logic? Inclusion of a few more hydrographs would be helpful for interpreting short and long-term trends. The County has water level data beginning in 1972 on at least five or six wells that were not included in your report.*

Additional text has been added to Section 1.2 to explain the use of multiyear trailing averages—it is a common technique that smooths the graphed data over time to facilitate trend review. Additional hydrographs have been added to the 100% report.

5. *2.2.1 Precipitation - Even though the report focuses on conditions during water years 1997 to 2007, it would be more meaningful if it included more long-term data. Water quality, water level, and precipitation data is easily accessible and would support long-term trends and show how the conditions during the 1997 to 2007 time period compare with the long-term trends.*

DBS&A has included graphs of long-term precipitation data and additional long-term hydrographs in the 100% report.

6. *2.2.2 Irrigation - At first glance the report seems to indicate that agricultural acres and crop types were arrived at independently, but later it indicates that the values came from the Tetratech model. Are the water use figures from the same time frame as the study? How many of the irrigated areas use a water source from outside of the basin? We understand that water application rates do not tell us how much water passes through the root zone and enters groundwater. Many growers have calculated their irrigation rates so that no more water is used than is absolutely necessary. Energy rates have a significant impact on pumping. It would probably require a much more detailed study than time permits.*

DBS&A appreciates VCWPD comments on this section and has added clarifying text to Section 2.2.2 to address these questions and clarify the sources of different data used in the calculations. Importantly, the approach for infiltration of irrigation water has been significantly revised, and relies on irrigation efficiency estimates, which represent the amount of irrigation water that passes through the root zone and infiltrates to groundwater. Data from the Tetra Tech report are used in the revised calculations, but their model calculations are not used.

7. *Importantly, there are additional current resources that can be used to evaluate irrigated agriculture. A few months back, we mentioned to Mr. Kear that the County of Ventura Agricultural Commissioner's office has a database (and GIS) called Crops Now which contains good information of crop patterns throughout the County. Dale Zurawski of the Farm Bureau also mentioned that she has greater than 90% coverage of crop types and acreage in the area. Use of those two sources would allow a better estimate of crop types and any changes over time can be made. In the southern part of the County, citrus crops have been replaced with berries. We have found water use for berries is greater on a per acre basis than citrus and a move towards berry crops will result in an increasing the groundwater extractions on an acre per acre basis.*

DBS&A appreciates comments regarding these additional references, and agrees that these resources are useful as a 'check' on the irrigation estimates. The initial assumed crop types were verified based on review of data obtained from the Farm Bureau of Ventura County, and this reference has been added to the text. Water application rates for the crop types are based on data for Ventura County obtained from CDWR.

8. *We encourage DBSA to incorporate Casitas Municipal Water District's data on agricultural water use; both as validation of per-acre/per-crop usage estimates, and as a subtractive validation of estimates of total agricultural groundwater use (Le.: total agricultural use - Casitas agricultural water = ag groundwater use).*

DBS&A has received this data from CMWD and used it as a check on agricultural extraction rates, as discussed in the revised Section 2.3.3. Thank you for your comment.

9. *The County does not keep data on quantity of extractions from wells in the Ventura River Basin area, but well owners could be contacted for that information based on flow meter or electrical use. We request that the agricultural evaluation include detailed GIS data that describes crop and water use changes over time with better water application figures. The Farm Bureau can assist you with some of this information.*

DBS&A agrees, as discussed in the limitations section of the report, that additional data regarding agricultural water use would be useful for refining the groundwater budget. Water application rates are based on crop-specific data obtained for Ventura County from CDWR. DBS&A has also provided two ‘checks’ on estimates of agricultural water use, based on reported extraction rates by well owners in the adjacent Ojai Basin, and by analysis of CMWD water delivery trends, and the three methods generally agree (see Sec 2.3.3).

DBS&A considers a detailed year-by-year analysis of agricultural application rates to be outside the scope of the current project, and also considers the data we have provided and/or cited to be adequate for estimation of agricultural extraction rates. DBS&A notes that comments from Hawks & Assoc./City of Ojai state that “Estimates of agricultural extractions by crop and unit water use are acceptable.”

10. *Again, this report needs to be very clear in explaining how the HSPF model results are used to determine infiltration rates and the limitations of using that data in this report for groundwater budget calculations.*

In the 90% and 100% report, estimates of infiltration have been revised significantly. Infiltration rates from precipitation and irrigation are not based on calculations with the HSPF model in the 90% or 100% report, but the rate estimates are based on data compiled in the TetraTech report. Section 2.2.1 and 2.2.2 have been rewritten, and the former Section 2.2.3 has been removed.

11. *2.2.5 Septic System Recharge - The number of septic systems needs to be verified by DBSA. The County of Ventura Individual Sewage Disposal System Applications/Permits Database only goes back to 1977. There are many more septic systems in the county than those listed on the database. Please contact VC Environmental Health Division to obtain an estimate of the total number of septic systems in the area. The amount of recharge from septic systems reported by DBSA appears to be the same rate of flow regardless of the number of people relying on the septic system or the septic system type. That value should be explored and described in more detail. Also, please include the source information for the Sewage Disposal database in the references page.*

DBS&A appreciates VCWPD comments regarding the number of septic systems assumed in the groundwater budget. DBS&A has contacted staff at Ventura County Environmental Health Division regarding this issue, who have informed us that the database we have used represents the best available data regarding the number of septic systems. Section 2.2.4 (formerly Section 2.2.5) has been revised to note this limitation. The database citation has been added to the references list.

12. 2.2.6 Inflow from Bedrock - Please include a labeled diagram and/or cross section illustrating method of calculation of thickness of various formations in your discussion regarding inflow from bedrock. It is difficult to picture relationships between formation thickness and width and the alluvial aquifer. The last paragraph beginning on the first page of this letter describes methods that will be helpful to better illustrate and quantify inflow from bedrock. A description of the method used to estimate specific capacity should be included.

DBS&A appreciates comments from VCWPD regarding bedrock inflow calculations, and this section has been significantly revised in the 100% report based in part on these comments. The length (primarily north-to-south) and width (primarily east-to-west) of the bedrock formations that underlie the alluvial aquifers were estimated based on geologic maps that are cited in the report and reproduced in Appendix A. These calculated dimensions were used in conjunction with additional estimated parameters to provide a preliminary calculation of the influx of water from the bedrock formations to the alluvial aquifers. DBS&A has discussed the data gaps that exist regarding these calculations, and the associated limitations. The revised approach does not rely on specific capacity estimates.

DBS&A considers construction of an original geologic cross section in this area to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited to be adequate for interpretation and evaluation of the bedrock calculations. In addition, DBS&A would be pleased to construct cross sections in this area; however, this relatively time-intensive task is outside of our contracted scope of work and budget.

13. This section states, "Hydraulic gradient. .. was estimated from typical grade elevations and groundwater levels ... including flowing artesian conditions ... " A footnote in Table 7 indicates Kear Consulting as the source for hydraulic conductivity for the bedrock aquifers. Please include a discussion in the text that explains Mr. Kear's method of obtaining data and explain how hydraulic conductivity was calculated. Include a diagram and references.

Based on feedback from VCWPD, this section has been revised significantly. In the revised approach, the hydraulic conductivity is estimated from geologic descriptions of the bedrock formations and reported values in Freeze and Cherry (1979). Because the approach was revised significantly and simplified, DBS&A determined that an explanatory block diagram is not necessary for description of these calculations.

14. 2.2.7 Inflow from upgradient subbasins - is discussed, but no mention is made of the Ojai Valley Basin even though there is a significant contact between the two basins. The Report should include a discussion of the Ojai Valley Basin contributions even if it is zero inflow. This could also be described in a geologic cross section or a diagram (you may consider reviewing Turner 1971 for this).

DBS&A appreciates VCWPD comments regarding the influence of the Ojai Basin. A discussion regarding the Ojai Basin has been added to Section 2.2.6 (formerly Section 2.2.7). Based on review of potentiometric surface maps (Turner, 1971; SGD, 1992), groundwater within the Ojai Basin is interpreted to flow towards San Antonio and Thacher creeks, and it is assumed that there is no significant net flow of groundwater between the basins.

DBS&A considers construction of an original geologic cross section in this area to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited, including the cross sections in Turner (1971) to be adequate for interpretation of inflow from upgradient basins.

15. *There is a discussion of the flow of water past Casitas Narrows through the 300 foot gap in the subsurface dam and the hydraulic parameters (Fetter reference) of saturated strata. A cross section through the narrows showing the gap should be included. Well logs for several wells near the area might assist in constructing the cross section and in determining the hydraulic characteristic of the area, and as a double check on Fetter's numbers.*

DBS&A has revised this calculation based on data in the Foster Park well field design report (Hopkins, 2007), cited by Hawks & Assoc./City of Ojai in their comments on the report. This report has been cited as a data source in this section.

DBS&A considers construction of an original geologic cross section in this area to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited, including cross sections in Turner (1971) and hydrogeologic data from this area summarized in Hopkins (2007) to be adequate for interpretation of inflow from upgradient basins.

16. *2.3.2 Domestic Extractions - Some of the wells listed as domestic, may in fact also be used for irrigation. Either double check well use if a domestic well is on a large rural parcel with no other water supply; or on a developed property such as the Ventura River RV Park, etc. The number of wells with dual uses may be so small as to be negligible. If so, please include a statement to that effect.*

DBS&A appreciates comments from VCWPD regarding secondary well uses for wells located in the Subbasins. DBS&A has based estimated water use on the primary water use given for each well within the VCWPD database, which does not list secondary uses. DBS&A has provided discussion of this point, as a limitation, within the report.

17. *2.3.3 Agricultural Extractions - See discussion in 2.2.2 above.*

DBS&A has added clarifying text to Section 2.2.2 to address these questions and clarify the sources of different data used in the calculations.

18. *2.3.4 Industrial Extractions - Contact industrial users such as Aera and obtain water use records and also confirm the year water use ceased. Include results of your inquiry in the report.*

Although we have tried, DBS&A has been unable to obtain this information from Aera, and have included discussion of this in the limitations section (Section 2.5) of the report. Importantly, operators of industrial water wells are not required to report extraction data to the public.

19. *2.3.6 - The discussion regarding outflow to the Pacific using Fetter's numbers for hydraulic conductivity should include subsurface descriptions from well logs to confirm aquifer thickness and composition as a cross check to Fetter's classification.*

DBS&A appreciates VCWPD comments regarding the need to reference subsurface descriptions from well logs. Data from well logs from five regulated sites, Turner (1971), and Hopkins (2007), were used to revise the estimates of hydraulic conductivity and thickness in the 90% and 100% reports.

20. *Section 3 Some of the wording in this section is taken directly from Chapter 3 of DWR Bulletin 118. It should be referenced. Component 6. Please define the term "management objectives" and include a few examples.*

DBS&A appreciates VCWPD comments on this section. A reference to Bulletin 118 has been added at the beginning of the section, and this component has been revised as requested.

21. *All Figures: Please change the title of the table included on each figure that gives the definitions of map symbols from 'Explanation' to 'Legend'.*

DBS&A appreciates VCWPD comments on the figures, which have been revised as requested.

22. *All figures would be easier to understand if a caption was included describing what is included in the figure and the purpose of the figure.*

The figures have been revised as requested.

23. *The source of data for all of the figures should be more visible with larger font. The information is hard to find on many of the figures. (It could be included in a figure caption.)*

The figures have been revised as requested.

24. *Please include the source of basin and watershed boundaries on figures that show those boundaries.*

The figures have been revised as requested.

25. *Figure 1 - Figure 1 does not show all items described on Page 2 middle paragraph of report. Given the scale it might be difficult. If all items cannot be included on the map as shown, please print figure on larger paper or split figure and put Upper and Lower basins on separate pages.*

All items listed in this paragraph are now shown in Figure 1.

26. *Figure 2 - Figure 2 is used to support the concept that overall water levels have remained stable in the basin, but one of the concluding tables in the report shows a net deficit of around 2000 acre feet per year. This appears internally inconsistent. Please include an explanation.*

The discussion regarding comparison of hydrographs and the results of the budget has been revised.

27. *Figure 4 - Please indicate the time period used for determining average rainfall shown by Figure 4. Please include the units for rainfall measurement. This could be included in a caption. Explanation of gap between isohyets and edges of basin and watershed boundaries (why colored part does not extend to edges of basin) should be included. (It was already mentioned during DBSA's presentation, but the basin boundaries between Upper and Lower do not meet and should).*

This figure has been edited as requested. The southern tip of the Lower Subbasin is not included in the original figure from Tetra Tech from which this figure was derived, but is assigned a precipitation of 16 in/yr due to the absence of another contour line.

28. *Figure 5 - Same comment as for Figure 1. Please print map on larger page or split into basin map Upper and Lower on two pages. Also, please include time span or year covered by the land use information.*

This figure has been split into two parts as requested.

29. *Figure 6 - If possible indicate on the figure which parcels actually have septic systems.*

DBS&A is not able to include this information as the individual parcels are not discernable on the original figure.

30. *Table 1 - Parameter values labeled "Bedrock to Alluvial" and "Groundwater Outflow to Lower Sub-basin" in the Upper West and Upper East columns contain a symbol that stands for "not applicable". Please enter a value in those cells or explain how the total in the Upper (Combined) is derived. Are the other cells labeled "not applicable" actually zero? If so, please enter the number or please explain why the value is "not applicable".*

This table has been revised as requested.

31. *Table 3 - Nine cells in the column labeled Fractional Coverage as Vegetation are listed as "not applicable". There has to be a number in that column for the calculation to work out correctly. Please enter a number, whether it is 100%, 1.00,0.1, etc.*

This table has been revised as requested.

32. *In addition, the units do not work out correctly when the calculations are performed. Please verify that the units for each column are correct. "Water Application" should be ac-ftlyr per acre. You can make that correction in the footnote if it is too awkward in the column heading.*

This table has been revised as requested.

33. *Table 4 - There should be some mention of limitations of using the Modeled reservoir loss value.*

DBS&A has contacted VCWPD staff regarding limitations of the model as requested, but have not received a reply regarding the limitations discussed in the comment. Limitations of the VRWHM are discussed, in a general sense, in Section 2.5. A reference is included in Section 2.2.3 following discussion of the reservoir loss calculation that refers to this.

34. *Table 5 - According to footnote "a" below the table, the numbers in the Value column are "acft/yr unless other noted." Values for C, D, and S are not in acre-feet per year. Please indicate what the units are for those values.*

This table has been revised as requested.

35. *Table 6 - As discussed above in the text, please verify with VCEHD the actual number of septic tanks as their database only goes back to 1977.*

DBS&A has contacted staff at Ventura County Environmental Health Division regarding this issue, who have informed us that the database we have used represents the best data regarding the number of septic systems available. Section 2.2.4 (formerly Section 2.2.5) has been revised to note this limitation of the approach.

36. Table 7 - Footnote "e" indicates source for Hydraulic Conductivity is Kear Groundwater, professional experience with wells in bedrock formations in region. This source is not referenced in report. As mentioned above, please include a discussion regarding Kear's methods in the text.

DBS&A has revised the approach used for these calculations and this table based on comments from VCWPD. This source is no longer used in the table.

37. Footnotes "f' and "g" below table 7 contain equations but "f' and "g" are not used anywhere on the table.

DBS&A has revised the approach used for these calculations and this table based on comments from VCWPD. These footnotes are no longer used in the table.

38. Table 11a - The units do not work out correctly when the calculations are performed. Please verify that the units for each column are correct. "Water Application" should be ac-ft/yr per acre and Irrigation appears to be the total for one year. Please indicate in the footnotes that Water Application is per acre and that Irrigation is the total for a period of one year.

Table 11 has been revised as requested by correcting the units.

Hawks & Associates/City of Ojai Comments Dated September 27, 2010

1. *Thank you for the opportunity to comment on this vital study. It is one of the missing links in our understanding of the watershed water balance. We appreciate the data collection efforts, especially noting the septic tank survey as a useful addition to understanding the watershed.*

Thank you for your comment.

2. *An average groundwater balance is not satisfying for our semi-arid/ arid zone hydrology. We strongly recommend this report show an annual balance with a summary of average, max., min. (range) at the end. We need to see the extremes, especially with water supply and fish passage concerns.*

DBS&A appreciates this comment, and acknowledges that a year-by-year groundwater budget may be useful for certain applications within the Subbasins. The budget presented in this report is intended to reflect the average conditions during the budgeted time period, which are generally representative of normal conditions. DBS&A notes that the methodology presented in this report could be applied to any given year based on data availability. DBS&A has also added a discussion of the budgeted time period to the limitations section of the report.

3. *We would like to see a more thorough development of the base period to have more confidence that the water budget is a long-term budget. Just having a recent period is great for having more data, but it is only part of the picture. A cumulative departure from the mean graph would show if the period selected was wet/dry or about right. We recommend you look at runoff departure from the mean as a better indicator of what is happening on the ground and groundwater recharge than precipitation.*

DBS&A has provided cumulative departure curves as requested in the 100% report. Thank you for your comment.

4. *Are there any groundwater level contours for snapshots in time to calculate change in storage that you could compare your budget to?*

Detailed groundwater contours of the Subbasins could be used as a check of the overall groundwater budget, with an understanding of the uncertainty that would be inherent to this analysis based on limitations of data availability. In lieu of this quantitative comparison, DBS&A has provided a qualitative comparison of the groundwater budget and hydrographs within the Subbasins. DBS&A notes that a quantitative analysis of the potentiometric surface over time may best be achieved through the development of a groundwater flow model of the Subbasins.

5. *The approach to a groundwater management plan will likely affect the Ojai Basin. This section (Section 3) needs to be reasonable. A specific sequence of authority (governance structure and funding source) should be laid out, starting with the most cooperative forms (voluntary groundwater user associations) and ending at stipulated court judgment with a Watermaster. The role of a GMA should be outlined because that is how the Ojai Valley is "governed". Attached is a pdf map of local water agencies – if you need any of this data please let us know.*

DBS&A appreciates comments from Hawks & Associates/City of Ojai regarding the approach to a GWMP section. "Governance" of the Ojai Basin has been successful via the GMA avenue, and a similar type of agency could be developed for the Ventura River Basins if adequate resources are available. However, a simpler type of group, such as an association, watershed council, or other special district with County supervision, may be ideal for the ULVRB such that grant funding for projects can be pursued. It may be prudent that the VRWC act as a lead in the groundwater management, possibly with a subcommittee dedicated to the matter. A discussion of this point has been added to the 100% report.

6. *Page 3: Groundwater is also used (extracted) by riparian habitat and should be listed as a user. This is one motivator for removing Arundo and Tamarisk.*

Extraction via riparian habitat has been quantified for the 100% report, as requested (see Section 2.3.7). Thank you for your comment.

7. *Page 9 and page 16. Comparing gage records with VRWHM results may not be as accurate as model to model and gage to gage comparisons.*

VRWHM modeled flow rates were used at gage locations, so this was a model-to-model comparison. DBS&A has edited the text to clarify this point.

8. *Page 12. What was the specific capacity estimated as and by what methods?*

DBS&A has significantly revised the approach in this section, and specific capacity estimates are no longer used.

9. *Page 12. How was the hydraulic gradient calculated?*

DBS&A has significantly revised the approach in this section. An accurate vertical hydraulic gradient cannot be calculated in the Subbasins because nested wells do not exist with screens in the bedrock and alluvial aquifers. As discussed in the 100% report, a unit hydraulic gradient was assumed because of this data gap. The associated limitations and uncertainty of this assumption are discussed in the report.

10. *Page 13. Try to get an annual extraction record from the City of Ventura and use that in the budget. They have changed their extraction rates, and average is not realistic.*

DBS&A appreciates this comment, and has added available yearly extraction data for each municipal district to Table 9 to show these trends. Additionally, discussion of the decrease in City of Ventura pumping since 2005 has been added to Sections 2.3.1 and 2.4. As noted above, the budget presented in this report is intended to be an average over water years 1997-2007.

11. *Page 14. Domestic Groundwater Extractions - please show a water balance for your household. Some of the 225 gpd is going back to groundwater due to deep percolation of irrigation or inefficiencies. If they are on a septic system, then this analysis assumes another 150 gpd recharging from the septic tank*

The septic system recharge and domestic water use numbers cited in the report are not directly comparable. The average domestic water use specific only to private well users in Ventura County of 163 gpd used in Section 2.3.2 of the 100% report (from USGS, 2000) is not directly comparable to the estimated 143.5 gpd of recharge from septic systems cited in Section 2.2.4 (from Hantzche and Finnemore, 1992), which is representative of all households, including those served by public supply.

12. *Page 13 and page 16. Aquifer testing (pumping tests) has been conducted in the Foster Park area. Reference: Preliminary Hydrogeological Study, Foster Park Wellfield Design Study Ventura , California prepared by Hopkins Groundwater Consultants for the City of Ventura—December 2007. The hydraulic conductivity value should be refined based on the local testing.*

This section has been revised, as requested, using the hydraulic conductivity values obtained from Hopkins (2007). DBS&A thanks Hawks & Associates for providing this report.

13. *Page 20. As part of the Agricultural Groundwater Extractions recommendation for a survey of individual well owners, also invite well owners to be part of the GWMP and request adding any abandoned wells to the monitoring program.*

This text has been added to the section, as requested.

14. *Estimates of agricultural extractions by crop and unit water use are acceptable.*

Thank you for your comment.

Hopkins Groundwater Consultants/City of Ventura Comments Dated September 23, 2010

1. *Changes in the water budget of up gradient groundwater basins (i.e., the Ojai Groundwater Basin) will impact the flow into the Ventura River Groundwater Basin(s) by affecting rising groundwater that supports surface flow in San Antonio Creek. We suggest this factor be considered along with the potential positioning of a stream flow gage at the basin boundary be mentioned (see Figure 1) to provide data for future management and modeling efforts.*

Thank you for your comment. Text has been added to Section 2.4 to address the point that changes in the management of the Subbasins, or the upgradient Ojai Basin, will impact the groundwater budget. In addition, the recommendation for a gage at the boundary of the basins has been added to Section 2.5.

2. *While the short base period used for the study was useful because it has a corresponding surface water budget, it is perhaps not an appropriate time period for use in calibrating a groundwater model.*

Thank you for your comment. DBS&A agrees that a longer base period would likely be necessary for calibration of a groundwater model. Calibration targets for a groundwater model would likely include long-term groundwater elevation hydrographs with the Subbasins and surface flows. The groundwater budget may also be useful for constraining the calibration during the budgeted time period.

3. *Evaporation was appropriately ignored in the groundwater budget; however we noticed that the list of groundwater outputs does not include transpiration from plants within the riparian corridor along the Ventura River and its tributaries. Summertime consumption of mature trees and riparian vegetation can be large. The groundwater budget used to support a groundwater model should consider the acreage of mature vegetation (trees, Arundo, etc.) that have deep root systems (to depths up to 20 feet) that extract groundwater from the alluvial basin.*

Extraction via riparian habitat has been quantified for the 100% report, as requested (see Section 2.3.7). Thank you for your comment.

Response to Comments
DRAFT Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (90% Complete), dated October 8, 2010

VCWPD Comments Dated November 2, 2010

This document provides responses to comments received by Daniel B. Stephens & Associates, Inc. (DBS&A) from the Ventura County Watershed Protection District (VCWPD) on the draft report *Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (90% Complete).*

1. *Executive Summary and Section 1.1: The second sentence of the Executive Summary and second sentence of Section 1.1, both state that the subbasins are "delineated by the California Department of Water Resources (2004)", but the basin boundaries on Figure 1 are not the same as those delineated by CDWR (2004). So there is an inconsistency there. The CDWR (2004) boundary descriptions do not include the area around Lake Casitas but do include Canada Larga. It is not until last sentence of section 2.1 that the report indicates, "the delineation of the Subbasins is also consistent with the VRWHM (Figure 1)". Please be clear about which basin boundaries are used in this report and be consistent.*

DBS&A has modified the text to clarify the source of the delineation of the Subbasins in this report. Additionally, DBS&A has added a discussion to Section 1.1 and Section 2.5 regarding the inconsistency of the Subbasin delineation from these various reports.

2. *Section 1.2 Groundwater Quantity Issues - Kennedy Narrows is referred to in the first paragraph but does not appear to be on Figure 1.*

Reference to "Kennedy Narrows" has been removed from the text.

3. *Section 2.2.1 Infiltration from Precipitation – The second paragraph indicates that precipitation infiltrated to groundwater was estimated using the Modified Maxey-Eakin approach and references Scanlon, 2004. The Scanlon paper is from a book about Groundwater Recharge in A Desert Environment and discusses several methods for estimating recharge in the semi-arid and arid southwest, specifically the basin and range physiographic region such as Death Valley and Nevada. Scanlon refers to modifications of the Maxey-Eakin method made by Flint et al (2002) and D'Agnese et al (1999) but does not discuss those modifications or how the method could be used in non-desert areas. Other authors who reference the Maxey-Eakin method stressed that it is derived from practical experience and not basic theory and that the Maxey-Eakin method needs to be field validated. The field-validated model for one basin does not necessarily translate to another. Please include an explanation regarding modifications made to the Maxey-Eakin method that allow this empirical approach to be applicable to the Ventura River Valley Basin.*

The Maxey-Eakin method is accepted in the groundwater literature as the most widely used empirical method for use in estimating groundwater recharge from precipitation in semiarid regions of the southwest (e.g., Scanlon, 2004). The Scanlon reference is a review article, and is titled 'Evaluation of Methods of Estimating Recharge in Semiarid and Arid Regions in the Southwestern U.S.' Based on several definitions of semiarid that can be found in the scientific literature (for example, guidance provided by the Food and Agriculture Organization; http://www.fao.org/docrep/t0122e/t0122e03.htm), DBS&A has determined that the area of the

Subbasins fits within the definition of semiarid. The Maxey-Eakin method is based on quantitative groundwater budgets of alluvial basins in arid and semiarid regions of the Southwest, and is used extensively. DBS&A has reviewed the modifications of D'Agnese (1999) and Flint et al. (2002), and these are not widely cited in the groundwater literature. As described in the text of the report, a commonly used modification to the Maxey-Eakin method that recognizes an exponential relationship between infiltration and precipitation was used. Additionally, the approach used in the report included a modification that accounted for the effects of paved surfaces on runoff and infiltration.

DBS&A agrees with VCWPD that the ideal method for estimation of recharge from precipitation would involve a more site-specific, field-validated methodology that accounts for soil type, slope, and other factors that influence infiltration rates. The most robust methodology available involves development of a watershed hydrology model, and calibration (i.e., field validation) to available data, including streamflow data. The Ventura River Watershed Hydrology Model (VRWHM) (Tetra Tech, 2009), submitted to VCWPD, provides this exact type of model for the study area, was calibrated to streamflow data, and calculates recharge from precipitation while accounting for soil type, slope, and other factors.

Because this model has previously been developed, and development of another similar model is outside the scope of the current groundwater budgeting project, DBS&A has previously recommended that VCWPD use this model for estimation of recharge from precipitation. Estimated infiltration rates from the VRWHM were used in the 75% report. However, the current reports of the VRWHM model output data are not discretized at a fine enough scale to be specific to the area of the Subbasins. DBS&A has communicated to VCWPD the limitation of the report of model output data in the current VRWHM documentation. VCWPD has communicated to DBS&A that data at a finer discretization from the VRWHM will not be made available. Therefore, VRWHM model output could not be credibly used for the groundwater budget.

For this reason, DBS&A has relied on the Maxey-Eakin approach for the 100% report. This approach provides a reasonable estimation of groundwater recharge from precipitation that is consistent with methods widely cited in the groundwater literature. DBS&A has added a discussion to the Limitations section of the report (Section 2.5) regarding this issue, and the recommendation to use the VRWHM to improve these estimates.

4. *Section 2.2.2 Infiltration from Irrigation -Third paragraph - first sentence references data "obtained from personal communication with VCWPD as cited in Tetra Tech, 2009". Please just reference Tetra Tech, 2009.*

This edit has been made, as requested.

5. *Fourth paragraph – states that the term irrigation efficiency "describes the percentage of applied water that is retained within the root zone and is available for evapotranspiration". The discussion states that irrigation efficiency was used to determine the amount of applied irrigation water that infiltrates to groundwater and also uses irrigation efficiency of 80% for developed land areas…and again references "personal communication with VCWPD as cited in Tetra Tech, 2009". It's important that the report clearly defines irrigation efficiency in each case as used in the report because the term irrigation efficiency often means different things to different people. For example, the Fox Canyon Groundwater Management Agency has a groundwater allocation system based on what it calls irrigation efficiency; however its measure of irrigation efficiency is not technically a measure of*

irrigation efficiency as defined in the literature. We believe its term may have been used in the Tetra Tech, 2009 report. The Fox Canyon Groundwater Management Agency's irrigation efficiency terminology is actually a non standard term, and is efficiency relative to an "allowed water value." Other users of the term irrigation efficiency are researchers and growers that use a standard definition, such as Irrigation Efficiency= [(Volume of irrigation water beneficially used) / (Volume of irrigation water applied – Change in root zone water storage)] X 100 . The reason this is an important distinction is that this section describes irrigation efficiencies as obtained from CDWR (2010), and Tetra Tech, 2009. We believe the Tetra Tech 2009 reference is for a non-standard measure of irrigation efficiency.

DBS&A appreciates VCWPD comments on the irrigation calculations in the report. DBS&A has reviewed the Tetra Tech (2009) report and CDWR (2010) data to verify the definitions of irrigation efficiency are consistent. The Tetra Tech (2009) report references the WUCOLS III manual in its discussion of irrigation efficiency, and provides a range reference from that manual of 65 to 90 percent (p. 28). The WUCOLS III manual defines irrigation efficiency as "(beneficially used water/total water applied) * 100", a standard definition, and functionally equivalent to the CDWR (2010) definition. Because the Tetra Tech (2009) report references the WUCOLS III manual in discussion of irrigation efficiency, DBS&A assumes that this is the definition used in the Tetra Tech (2009) report.

6. *Section 2.2.5 Inflow from Bedrock - A quantification of inflow from bedrock is described in this section; however, it appears to contain a number of assumptions, which should either be narrowed down, or described in better detail. The discussion does not contain a generalized geologic cross section describing the areas where bedrock inflow is occurring.*

DBS&A appreciates VCWPD comments on calculation of inflow from bedrock in the 75% and 90% reports, and has significantly revised this section based on these comments. Geologic maps and a regional cross section, cited and included in an appendix, were used to develop a general conceptual model of the bedrock in this area, and were also used in the calculations of inflow from bedrock.

DBS&A considers construction of an original geologic cross section to be outside the contracted scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited to be adequate for estimation of the groundwater budget.

DBS&A agrees that the approach used in the report is based on several assumptions, which are necessary given the lack of specific data regarding the bedrock formations in this area. DBS&A has discussed these limitations in the revised 100% report.

7. *Even though a site specific geologic cross section isn't necessarily required for this evaluation, a conceptual cross section showing the rock types discharging groundwater to the overlying Quaternary alluvium, and showing the gradients and general structure would be beneficial. The analysis provided doesn't describe the regional trend of the formations, structure, or the degree of their interconnectivity. A cross section is provided that trends roughly north south along the boundary between the Ojai basin and the Upper Ventura Subbasin, but the degree of faulting in that section seems to be significantly less than the Quaternary faults cutting across the alluvial filled Upper Ventura sub basin. In other words, the cross section provided does not appear to fully reflect the structure, at least in terms of faulting, in the Upper Ventura Subbasin.*

DBS&A has provided the generalized cross section because it supports the development of a conceptual model of the bedrock formations and alluvium. DBS&A has also added a citation to a paper with additional cross sections that includes fault zones of the Upper Ventura Subbasin (Rockwell et al., 1984). These references are only used to describe the regional trends of the formations, and are used to determine where the bedrock formations are in relation to the alluvium. DBS&A agrees that structural features of the bedrock formations may influence basin groundwater flow rates. However, DBS&A has not identified meaningful data regarding hydrogeologic characteristics of the bedrock formations underlying the Subbasins, such as could be used to calculate a vertical gradient.

DBS&A considers construction of an original geologic cross section to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature. Furthermore, DBS&A considers the data we have provided and/or cited to be adequate for estimation of the groundwater budget, with the limitations and assumptions given.

8. *The Red Mountain Fault zone is mentioned in the text but not shown on the cross section. Faults can be barriers or conduits to groundwater flow so the presence of faults can have an effect on the discharge of groundwater.*

The Red Mountain fault zone is described in detail in a reference cited in the 100% report, which includes additional cross sections (Rockwell et al., 1984). The Red Mountain Fault Zone may be a barrier to groundwater flow, and this has been stated in the revised Section 2.2.5.

9. *How is the geologic structure (folding, faulting, etc.) taken into account in determining groundwater discharge to the alluvial aquifer? The report identifies various geologic structures in the text and Table 7. Please discuss the significance of those structures on groundwater inflows. The table also includes bed thicknesses; it appears these may be apparent thicknesses. If so, does this have an effect on the calculation of inflow?*

This section has been revised significantly for the 100% report. Each of the geologic bedrock formations are discussed in the revised section, and general statements are included regarding the possible influences of structure given the lack of specific data regarding regional structure and groundwater flux. The approach used, and Table 7, no longer include thickness or apparent thickness.

10. *The third paragraph indicates that numerous domestic, agricultural and industrial wells extract groundwater from aquifers within the bedrock formations. Is it known which formations these wells are screened in? If so, please name them. The section goes on to state that "Hydrogeologic data from these wells can be used to characterize the quantity of groundwater available in each formation". Was this done?*

The revised Section 2.2.5 lists wells (given by T/R/S number) that have been identified that are screened exclusively in the bedrock formations, along with relevant water level data obtained from driller's logs of these wells. Additional detailed information regarding these wells, such as the driller's logs, have not been included in the report due to confidentiality of groundwater well information in California. However, DBS&A can provide copies of the driller's logs for these wells to VCWPD upon request.

11. *Last sentence indicates DBS&A completed a review of available well data with literature data… Please reference the literature data.*

Literature data has been cited throughout this section, and references include Turner (1971), Freeze and Cherry (1979), Fetter (2001), Tan et al. (2003), Tan and Jones (2006), Dibblee (1987 and 1988), CDOG (1991), Rockwell et al. (1984), AAPG (1956), and Hanson et al. (2003).

12. *The second sentence indicates that the percentage of bedrock formation that is potential primary and/or secondary aquifer material was estimated from several hundred geophysical logs of water wells and oil wells in the region. How, exactly, was this estimation conducted? Please define the term primary and/or secondary aquifer material. Where were the values required for the calculations in footnote "f" of Table 7 obtained?*

This section has been significantly revised, and there is no longer reference to geophysical well logs.

13. *The last sentence of the paragraph indicates that geophysical logs, published cross sections, and oil field data sets were used to estimate the areal extent of bedrock aquifers and the base of fresh water, but the geographic locations of these data sets are not defined. What is the geographic location of the published cross sections, logs and oil field data and how were they used to determine the extent of bedrock aquifers and base of fresh water?*

This section has been significantly revised. Geologic maps, both cited and included as Appendix A, were used to determine the areal extent of the bedrock formations that underlie the alluvial aquifers. Cross sections, both cited and included in Appendix A, were used to develop a general conceptual model of the bedrock formations and alluvial aquifer.

14. *Please explain the method used to estimate typical specific capacity. The text indicates methods such as Driscol (1986) and GRA (2004) but Table 7 indicates the source as Kear Groundwater. What maps were used to measure typical grade elevation and what wells were used to determine groundwater levels?*

This section has been significantly revised based on comment from VCWPD, and no longer uses specific capacity estimations. Rather, hydraulic conductivity is estimated based on geologic descriptions of each of the bedrock formations and associated values reported in Freeze and Cherry (1979).

15. *Flux to the basin was calculated using hydraulic conductivity, bedrock aquifer area, and head. Should the value labeled "head" actually be the gradient between the bedrock aquifer and the alluvial? The same value for head (0.03 feet) is used for the Sespe, Vaqueros, Rincon, and Monterey formations for over 6.5 miles along the Ventura River Basin. How was head or gradient normal to the alluvial river valley in so many locations determined over such a long transect along the river valley?*

This section has been revised significantly, including Table 7. In the revised approach, a unit hydraulic gradient was assumed. It is recognized that an assumed unit gradient may be substantially different that actual gradients; however, in the absence of site-specific data, this assumption can be used to provide a preliminary flux estimate. The resulting estimated groundwater flux into the alluvial aquifers is prone to significant uncertainty, as stated in the report.

16. *The last sentence – isn't it Thacher Creek, not Thacker?*

This correction has been made.

17. *Section 2.3.2 Domestic Extractions – page 16 second sentence discusses domestic water use of 163 gpd for private well users vs. recharge from septic systems of 150 gpd. Please clarify the significance of this discussion and why was it included in this section.*

DBS&A appreciates VCWPD comments on this section. The referenced text was added to this section in the 90% report based on a comment by the City of Ojai. For the 100% report, DBS&A has removed this discussion, as it does not pertain to the topic of the section. This discussion is retained in the response to comments for the 75% report, which are included in this appendix.

18. *Section 2.4 Results of the Groundwater Budget - The first sentence indicates there are no inputs from upgradient alluvial subbasins… Should this instead say that the assumption is there are no inputs, or no significant inputs? We know that cross sections provided by Turner, indicate there is an interconnectedness to the basin that exists when water levels in the Ojai Basin rise sufficiently.*

The text has been modified to 'assumed to be no significant inputs,' as requested.

19. *DBSA provided two USGS geologic maps by e-mail after we received the 90% draft. Neither has a figure number or figure caption so please reference in the 100% text. Due to the scale of the geologic maps, they are difficult to read at the 8.5" x 11" size. Please reproduce at 11" x 17". The basin boundaries overlaid on the map includes a section of Matilija Sandstone but the report does not include any mention of it. Please adjust boundaries or explain why discussion of Matilija Sandstone was excluded.*

These reproduced geologic maps have been incorporated within the 100% report in Appendix A, and a cover sheet to the appendix provides explanatory captions. These maps were provided to VCWPD in their original format, which is 42 in. x 32 in., not 8.5 in. x 11 in., and have been retained in their original formatting.

The overlay of the Subbasin boundaries is consistent with all other delineations in the report, and was taken from Tetra Tech (2009). As discussed in the 100% report, the delineation of the Subbasins is not consistent among various reports. A recommendation has been added to the report to determine a unified delineation of the Subbasins based on geologic maps of the extent of the alluvium along the Ventura River and associated creeks.

20. *A "Generalized Geologic Cross Section Central Ventura Basin" was also provided by e-mail. The figure does not have a figure number or figure caption and is not referenced in the text. Please modify this figure for inclusion in the 100% report The term "Basin" on the cross section does not have the same meaning as groundwater basin. It may be helpful for the report to clarify the oil field basin terminology relative to the groundwater basin terminology. The groundwater basin boundary locations should be included on the cross section where it crosses the study area. Please be clear in your discussion that only a small portion of the cross section is applicable to the Ventura River Valley Basin.*

This reproduced geologic cross section has been incorporated within the 100% report as a plate in Appendix A, and a cover sheet to the appendix provides an explanatory caption. DBS&A is not aware of the term 'Basin' on this cross section. The boundaries of the Subbasins have been provided on the map inset on the lower lefthand side of the plate. A sentence has been added to the explanatory caption regarding the overlap between the Subbasins and the cross section, as requested.

21. We understand the block diagram figure recently emailed to us will be included in the 100% report. The three dimensional perspective of the drawing contains a bed shown as a 2 dimensional "ribbon" that twists in the block diagram. This is incorrect and the bed should be re-drawn to show the three dimensional perspective. Should the spring in the block diagram be located at the point where the confined aquifer becomes unconfined, in this case near the ground surface? The potentiometric surface should curve down when the confined aquifer transitions to unconfined. The potentiometric surface should probably continue to curve down to meet the water table aquifer in the alluvial aquifer. The block diagram shows two separate water table conditions above the unconfined aquifer, and this doesn't appear to be correct.

DBS&A appreciates comments on this block diagram provided by VCWPD. The approach used in the bedrock section has been significantly revised based on feedback by VCWPD, and the block diagram emailed earlier by DBS&A is no longer applicable to the approach. Therefore, this block diagram has not been included in the 100% report.

22. Table 7 - Footnote "e" indicates the source is Kear Groundwater, professional experience with wells in bedrock formations in region… but the text indicates method came from Driscoll (1986) and GRA (2004). As mentioned above, please include a discussion explaining how specific capacity was estimated.

DBS&A appreciates VCWPD comments on this table. As discussed above, this section and Table 7 have been revised significantly, and no longer include the references discussed in this comment.

23. Figures 2a-b, 8a-f, 9 and 10 are not referenced in the text. We are sure they will be in the final report.

These figures have been added to the 100% report, as requested.

Response to Comments
Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (100% Complete), dated November 15, 2010

VCWPD Comments Dated December 14, 2010

This document provides responses to comments received by Daniel B. Stephens & Associates, Inc. (DBS&A) from the Ventura County Watershed Protection District (VCWPD) on the draft report *Groundwater Budget and Approach to a Groundwater Management Plan, Upper and Lower Ventura River Basin (100% Complete).*

1. *Section 1.1 Background - please define "State-indicated" requirements.*

The referenced text has been modified to read "Ventura County nomenclature defines the Upper and Lower basins as separate; however, for consistency with California State nomenclature (CDWR, 2003), this report refers to the system as a single basin consisting of two subbasins." As provided in the CDWR reference, the State refers to the study area as a single basin consisting of two subbasins.

2. *It appears that the alluvial basins are unconfined and the bedrock aquifers may be confined or unconfined. Please briefly detail the aquifer confining conditions.*

Text has been added to Section 1.1, as requested.

3. *DBS&A's Response to Comments (90% Complete) states, "Because the Tetra Tech (2009) report references the WUCOLS III manual in discussion of irrigation efficiency, DBSA assumes that this is the definition used in the Tetra Tech (2009) report." Please confirm which definition the Tetra Tech report uses.*

DBS&A has confirmed that the Tetra Tech report uses the WUCOLS II manual definition of irrigation efficiency, by contacting the report authors.

4. *Section 2.2.2 Infiltration from Irrigation -Third paragraph - first sentence references data "obtained from personal communication with VCWPD as cited in Tetra Tech, 2009". Please just reference Tetra Tech, 2009.*

The text has been modified, as requested.

5. *Fourth 2.2.5 Inflow from Bedrock - Section 2.2.5 has been substantially revised in the 100% report. We commented on the 90% report asking for more detail on the percentage of bedrock formation that is potential primary and/or secondary aquifer material estimated from several hundred geophysical logs of water wells and oil wells in the region. Your response to comments states the reference to the several hundred geophysical well logs has been removed and Section 2.2.5 has been significantly revised. Revisions include removal of the reference to the geophysical well logs and information that stems from that including primary and secondary porosity of aquifer material. Also the discussion of groundwater gradients has been changed to remove calculation of a gradient between two wells spaced laterally apart (approach in the 90% report) and replaced with the use of a vertical upward unit gradient.*

   This change in approach seems unusual given the effort that went into the description in the 90% report re well logs and primary and secondary porosity and what appeared to be a potential for the *data to really improve this study. Please describe why the reference to geophysical well logs and other data that stemmed from that was removed. We are concerned that the revised approach, including the use of a unit gradient, appears even more generalized. The caveat on page 13 states the estimated groundwater flux into the alluvial aquifers based on the new approach is prone to significant uncertainty. The limitation is mentioned in the limitations section with key uncertainty related to lack of nested groundwater wells.*

As noted by VCWPD, the technical approach regarding this section was modified from the 90% to the 100% draft report. These modifications were in response to VCWPD comments, with the objective of providing a more reproducible analysis with sufficient citations for the data used in the estimates. DBS&A does not believe that the revised approach is more general; rather, a significant amount of detail was added to the report regarding the bedrock formations and the wells that are screened in those formations. DBS&A believes that the final approach is the more scientifically reproducible approach. In addition, DBS&A has sought to be very clear regarding the inherent uncertainty and limitations of this analysis due to the absence of nested wells. The use of a vertical hydraulic gradient is also appropriate, as the analysis aims to calculate vertical groundwater flow from the underlying bedrock formations to the alluvial aquifer. DBS&A notes that bedrock contributions to the total groundwater budget are relatively minor and have even been assumed to be insignificant in previous USGS modeling of groundwater alluvial basins in this area (Hanson et al., 2003).

6. *The new approach for calculating inflow from bedrock has resulted in a reduction of bedrock inflows listed in the 90% report of about 862 AFlYear to 463 AFlYear in the 100% report. It also mentions that geologic structure exists in the area that can affect groundwater discharge to the alluvial valley; however the geologic structure's effect was not taken into account. Please also include in the limitations section that geologic structure was not taken into account re groundwater discharge from bedrock to the alluvial aquifer. In cases such as this where the geologic structure's effect on water flow is not well described in the subject report, conceptual cross sections showing generalized structure can be very helpful, but were not provided.*

Text has been added to the limitations section, as requested. DBS&A reiterates that we consider development of generalized cross sections to be not within the scope and budget of this project. DBS&A also notes that bedrock contributions to the total groundwater budget are relatively minor and have even been assumed to be insignificant in previous USGS modeling of groundwater alluvial basins in this area (Hanson et al., 2003).

7. *DBS&A's response to comment #7, second paragraph, states, "DBS&A considers construction of an original geologic cross section to be outside the scope of development of a groundwater budget consistent with methods used in the groundwater literature." The Watershed Protection District met with DBS&A and stated that a generalized cross section through the study area would suffice. We are disappointed one was not provided. One cross section (Plate 3) is provided from earlier researcher's work, but it doesn't trend through the main study area, but exists in a in a localized area on the east near what is expected to be a no flow boundary under typical water conditions. A careful review of the plate indicates that the cross section E to F is approximately 25.9 miles long, and that only about 2.9 miles of it actually goes through the study area, but that 2.9 mile stretch is not indicated on the cross section. That geologic cross section is included as Plate 3 in the subject report and we again request that DBS&A show on that section the limits of the study area (along the cross section alignment). That plate, plus the geologic maps should have a legend defining these blue and red areas (upper and lower sub basins).*

The geologic cross section plate has been modified, as requested, to show the extent of the study area relative to the cross sections. DBS&A has previously stated in the cover page for Appendix A that the cross section presented crosses through the eastern edge of the Upper

Subbasin, but otherwise is located external to the Subbasins. Additionally, DBS&A has provided an explanation of modifications of the figures (i.e., addition of the delineation of the Upper and Lower Subbasins in red and blue) on this cover page.

The AAPG cross section presented, along with an additional cross section referenced in the report (Rockwell et al., 1984), provide a general conceptual model of the vertical spatial relationship between the alluvial aquifers and the bedrock formations. As described in detail in Section 2.2.5, geologic maps were used to provide estimates of the area of the bedrock formations that underlie the alluvial aquifers. DBS&A understands that VCWPD requested inclusion of a generalized geologic cross section and reiterates that development of such a cross section is outside the budgeted scope of this project. DBS&A also notes that bedrock contributions to the total groundwater budget are relatively minor and have even been assumed to be insignificant in previous USGS modeling of groundwater alluvial basins in this area (Hanson et al., 2003).

8. *We note that the inflow, if any, from the Matilija sandstone has still not been included, despite our comment on the 90% draft.*

As discussed in the 100% complete report and response to comments on the 90% report, delineation of the Subbasins is not consistent among various reports. The overlay of the Subbasin boundaries on Plate 2 is consistent with all other delineations in the report and was taken from Tetra Tech (2009). A recommendation has been added to the report to determine a unified delineation of the Subbasins based on geologic maps of the extent of the alluvium along the Ventura River and associated creeks. However, a small section on the northern tip of the delineated Upper Subbasin overlies an area mapped as Matilija Sandstone in the geologic map presented by Tan and Jones (2006). This stems from an apparent inconsistency in the mapping of the Upper Basin alluvium between Tan and Jones (2006) and Tetra Tech (2009). For the purposes of the present study, this very small section is assumed to be a component of the delineated Upper Ventura Subbasin. DBS&A notes that this is an extremely small area, approximately 0.04% of the total area of the Upper Subbasin, and therefore is not expected to represent a significant amount of uncertainty in the overall analysis.

9. *Page 13, last sentence states "It is recognized that geologic structure can influence groundwater flux, but no source of specific data for the area was identified regarding this factor." Page 14 lines 4-6 from the top of the page states "However, no specific data were identified regarding the influence of these and other structural features on groundwater flux." By who was no source of specific data, or no specific data, identified?*

The referenced text has been modified to clarify that DBS&A has not identified this data.

10. *2.4 Results of the Groundwater Budget - This section describes that a relatively small net gain in groundwater storage exists in the upper sub basin. It appears that the change in storage value was arrived at without the benefit of cross checking changes in groundwater elevations and resulting changes in storage in the studied aquifer(s). The limitations section makes mention of this.*

This has been added to the limitations section, as requested.