San Jacinto Watershed Model Update (2010) - Final

Submitted to:

Lake Elsinore & San Jacinto Watersheds Authority

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Contents

Tables

Figures

1 Introduction and Objectives

In partnership with the Santa Ana Watershed Protection Authority (SAWPA), Tetra Tech Inc. completed a watershed assessment and modeling study in 2003 to support management initiatives and development of Total Maximum Daily Loads (TMDLs) for the San Jacinto River watershed, specifically, Lake Elsinore and Canyon Lake. The results of the study are presented in the Lake Elsinore and Canyon Lake Nutrient Source Assessment – Final Report (January 2003). The nutrient modeling results were subsequently used to develop TMDLs for Lake Elsinore and Canyon Lake by the California Regional Water Quality Control Board (RWQCB).

Since the original development of the watershed model that supported the nutrient source assessment and TMDL calculation effort, new datasets have been collected that provide additional information on nutrient sources within the watershed and local watershed processes. This information was used to update the original model in order to re-assess the nutrient load contribution from the watershed and ultimately the TMDL calculations which will require updating the lake models in the future. Funding for this effort was provided by the Lake Elsinore and San Jacinto Watershed Authority (LESJWA). The objectives of the project included:

- Compile and review available data to determine the model updates and technical approaches that are needed. Provide recommendations to the watershed stakeholders on data use and modeling assumptions.
- Update the watershed model based on additional data collected, including updated land use information, monitoring data, nutrient loading rates, stormwater conveyance systems, and other key datasets. Model updates will provide the watershed stakeholders with a better understanding of nutrient sources, the transport of loads through the watershed, and loading to the lakes.
- Perform additional model runs to assess nutrient loading characteristics and sources for current and pre-development conditions.
- Calculate annual and cumulative nutrient loads based on stakeholder jurisdiction
- Extend the modeling period to allow for 20-year estimation of nutrient loads.
- Develop a simplified Lake Management Spreadsheet Tool that includes model output data from various simulation runs. This tool will be used to investigate the results of various modeling scenarios and facilitate management decisions. Linkage to the lake models for Lake Elsinore and Canyon Lake will be incorporated in the future.
- Develop Modeling Report and presentations to watershed stakeholders.

This report provides detailed information on the data compilation effort, the technical approaches and assumptions used to update the watershed model, review of model calibration/validation, and a summary of the nutrient loading results. Although this report focuses on the model updates and data/assumptions used, key information from the 2003 Nutrient Assessment Report was included to highlight important changes in source data and updates to model configuration. Note that the Lake Management Spreadsheet Tool and associated documentation was provided as a separate deliverable.

2 Technical Approach

This section provides an overview of the current modeling effort that builds upon the 2003 modeling study that supported the development of Total Maximum Daily Loads (TMDL) for nutrients for Lake Elsinore and Canyon Lake (SAWPA 2003). The following discussion covers nutrient sources and the model simulated transport of nutrients throughout the San Jacinto River watershed, including an overview of the watershed model, and details regarding model configuration, calibration, and validation. The current modeling effort was designed to update the 2003 watershed model to incorporate new datasets that have the potential to affect the 2003 load calculations to Canyon Lake and Lake Elsinore.

2.1 Model Background

A Loading Simulation Program C++ (LSPC) watershed model was developed in 2003 to represent the San Jacinto River watershed. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate naturally occurring land-based processes over an extended period of time, including hydrology and pollutant transport.

The San Jacinto River watershed is a complex system that presents multiple challenges for the development of an accurate and representative model. The original selection of LSPC as the appropriate watershed model to address these challenges was based on the consideration of multiple selection criteria, including technical, regulatory, and user criteria detailed in Section 4.1 of the 2003 nutrient modeling report (SAWPA 2003). The 2003 model was developed to meet the objectives defined for the Lake Elsinore and Canyon Lake Nutrient Assessment Project including the development of appropriate Total Maximum Daily Loads (TMDLs), wasteload allocations (WLAs) and load allocations (LAs) for the watershed; and to provide stakeholders with a tool to assist in the management of both lakes.

The previously developed watershed model was used as the basis for the model updates detailed in this report that improve the simulation of stormwater runoff and transport of nutrients as a result of rainfall events (and direct, non-storm loadings to water bodies). Updates were made to incorporate new datasets that have the potential to affect load calculations to Canyon Lake and Lake Elsinore and associated TMDLs. The accuracy of model predictions is based on the quality and completeness of the data used to develop the model. Although there were significant improvements to several key datasets that were used to build the model, there are inherent uncertainties in any modeling study due to data limitations and other factors. Additional information on data sources and modeling assumptions is included in the project data memos that were provided to LESJWA and the watershed stakeholders during the data collection phase (Appendix A). Some of the more important data limitations and model uncertainties are noted in the following sections.

In addition to updating the watershed load estimates , model output was incorporated into a spreadsheet tool that will ultimately be used by stakeholders in strategizing TMDL implementation efforts. The LSPC model allows for the testing of alternative scenarios and modifications produced by various management and environmental factors. Model output provides the underlying datasets to be analyzed by the tool. An overview of the LSPC model and technical challenges specific to the model updates are discussed in this section.

2.1.1 Watershed Model (LSPC)

Loading Simulation Program C++ was used to simulate watershed processes, including hydrology and pollutant accumulation and washoff in the San Jacinto watershed. LSPC is a component of the EPA's TMDL Modeling Toolbox (Toolbox), which has been developed through a joint effort between EPA and Tetra Tech, Inc. It integrates a geographical information system (GIS), comprehensive data storage and management capabilities, a dynamic watershed model (a re-coded version of EPA's Hydrological Simulation Program – FORTRAN [HSPF]), and a data analysis/post-processing system into a convenient PC-based windows interface.

Figure 2-1. Toolbox

The Toolbox (Figure 2-1) is a collection of models, modeling tools, and databases that have been utilized over the past decade in the determination of TMDLs for impaired waters. LSPC is the primary watershed loading/routing model in the Toolbox modeling package. The Toolbox takes these proven technologies and provides the capability to more readily apply the models, analyze the results, and integrate watershed and detailed hydrodynamic and water quality receiving water applications. The design of the toolbox is such that each of the models are stand-alone applications that do not rely on any other modules within the Toolbox to operate. The Toolbox provides an exchange of information between the models through common databases. Due to the modular design of the Toolbox, additional models can be added easily in a plug and play fashion. The 2003 nutrient modeling study took advantage of the Toolbox flexibility by linking the LSPC watershed model to an Environmental Fluids Dynamic Code (EFDC) receiving water model of Canyon Lake, which was linked back to the watershed model, which was then linked to a BATHTUB receiving water model of Lake Elsinore. For a detailed description of the model setup and linkages of the 2003 study, refer to Section 4.0 of the report (SAWPA 2003).

2.1.2 Technical Challenges

The watershed of the San Jacinto River presents a challenging system for modeling hydrology and pollutant loading and transport. The system involves various unique features including: hydraulic issues in the San Jacinto River (e.g., storage in Mystic Lake and regional BMPs, flow impediments, flow diversions), impacts of agricultural BMPs (CAFO waste storage), hydrology sinks (Perris Reservoir), and a Mediterranean climate that results in essentially no flow at various locations throughout the San Jacinto River and its tributaries during normal conditions. This section outlines key functions and processes that were considered for the development of the 2003 model and updated for this study.

2.1.2.1 Hydrology

Several influencing hydrologic factors in the San Jacinto watershed required proper attention to ensure that the system is modeled accurately. These are discussed below.

2.1.2.1.1 Groundwater Infiltration

A general characteristic that affects watershed model representation is dryness and the significance of losses to deep groundwater. During dry periods, the San Jacinto River generally transports no water and exhibits no sustained baseflow resulting from groundwater influence. The area has experienced serious reduction in groundwater levels due to excessive pumping and limited recharge. Therefore, the impact of groundwater flow to the San Jacinto River and the lakes is limited. The majority of water that infiltrates into the ground is understood to be lost from the system. Such infiltration losses can occur during transport processes of either watershed runoff or stream flow (personal communication with Steven Clark, Riverside County Flood Control and Water Conservation District).

2.1.2.1.2 Mystic Lake

Mystic Lake (Figure 2-2) is located roughly in the middle of the San Jacinto River watershed and impounds all San Jacinto River flow. River flow was once diverted around Mystic Lake via a low-flow channel constructed by local farmers, but the channel has received substantial siltation and is no longer active during low-flow periods. Therefore, all San Jacinto River flow is assumed impounded by Mystic Lake (personal communication with Stephen Stump, Riverside County Flood Control and Water Conservation District; and Tom Paulek, California Department of Fish and Game).

Once formed, the lake is relatively shallow and large in area, allowing for significant infiltration and groundwater recharge, but also a significant opportunity for evaporation losses. After filling, the lake has been observed to maintain a substantial amount of volume for over a year or more, with little or no transport back to the San Jacinto River. Therefore, most water stored in the lake is typically lost from the San Jacinto system. However, during torrential rainfall events or periods of extended rain, the storage capacity of Mystic Lake can be exceeded and the lake can overflow back to the San Jacinto River. Subsidence of the lake has also been noted in recent studies.

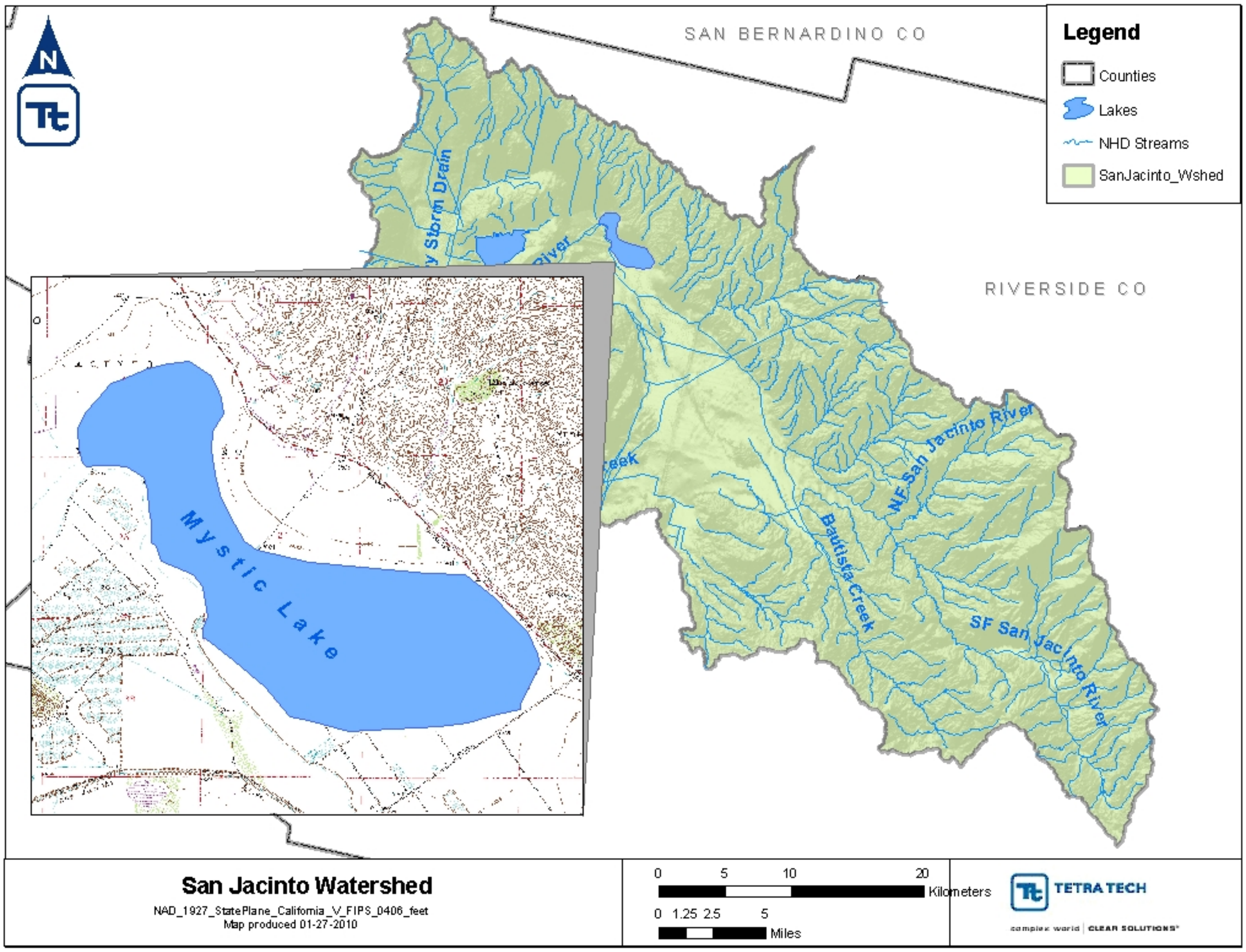

Figure 2-2. Mystic Lake

2.1.2.1.3 Lake Hemet

Lake Hemet is an artificial lake in the San Jacinto Mountains, 4,340 ft (1,323 m) above sea level (Figure 2-3). Lake Hemet is part of the San Bernardino National Forest and was created in 1895 with the construction of the

Hemet Dam, and is owned and operated by the Lake Hemet Municipal Water District (LHMWD). The LHMWD provides water from Lake Hemet to a geographically diverse service area in Riverside County, including portions of the cities of Hemet and San Jacinto, and to the San Jacinto Mountain community of Garner Valley.

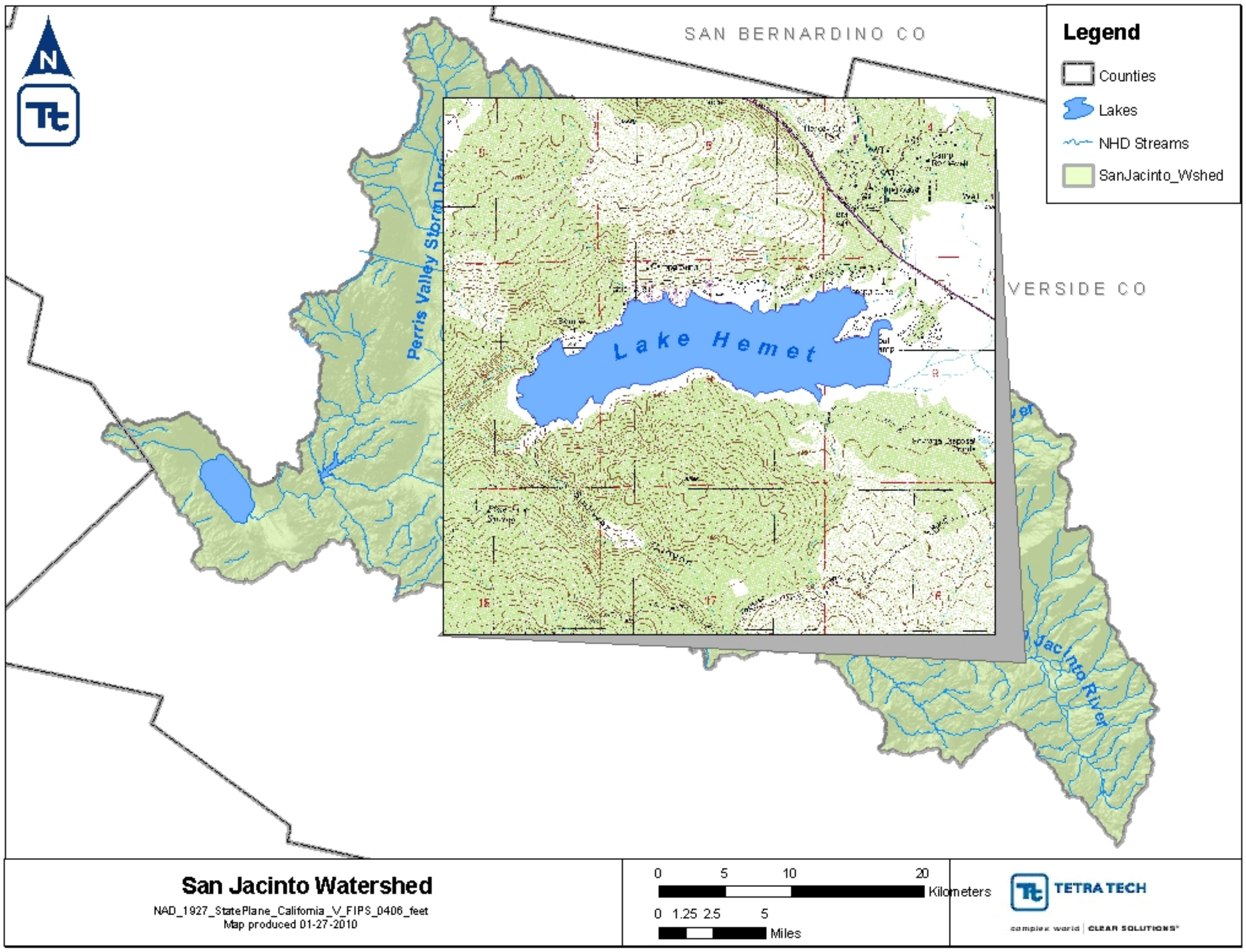

Figure 2-3. Lake Hemet

2.1.2.1.4 *Perris Reservoir*

Another major impoundment in the San Jacinto watershed, Perris Reservoir (Figure 2-4), acts essentially like a sink and allows no outflow to the San Jacinto River. Located on a northwest reach of the San Jacinto River, Perris Reservoir impounds runoff from a 10-square-mile watershed. Runoff from the entire watershed is considered lost to the San Jacinto system and is not to be included in the model system (personal communication with Steven Clark, Riverside County Flood Control and Water Conservation District).

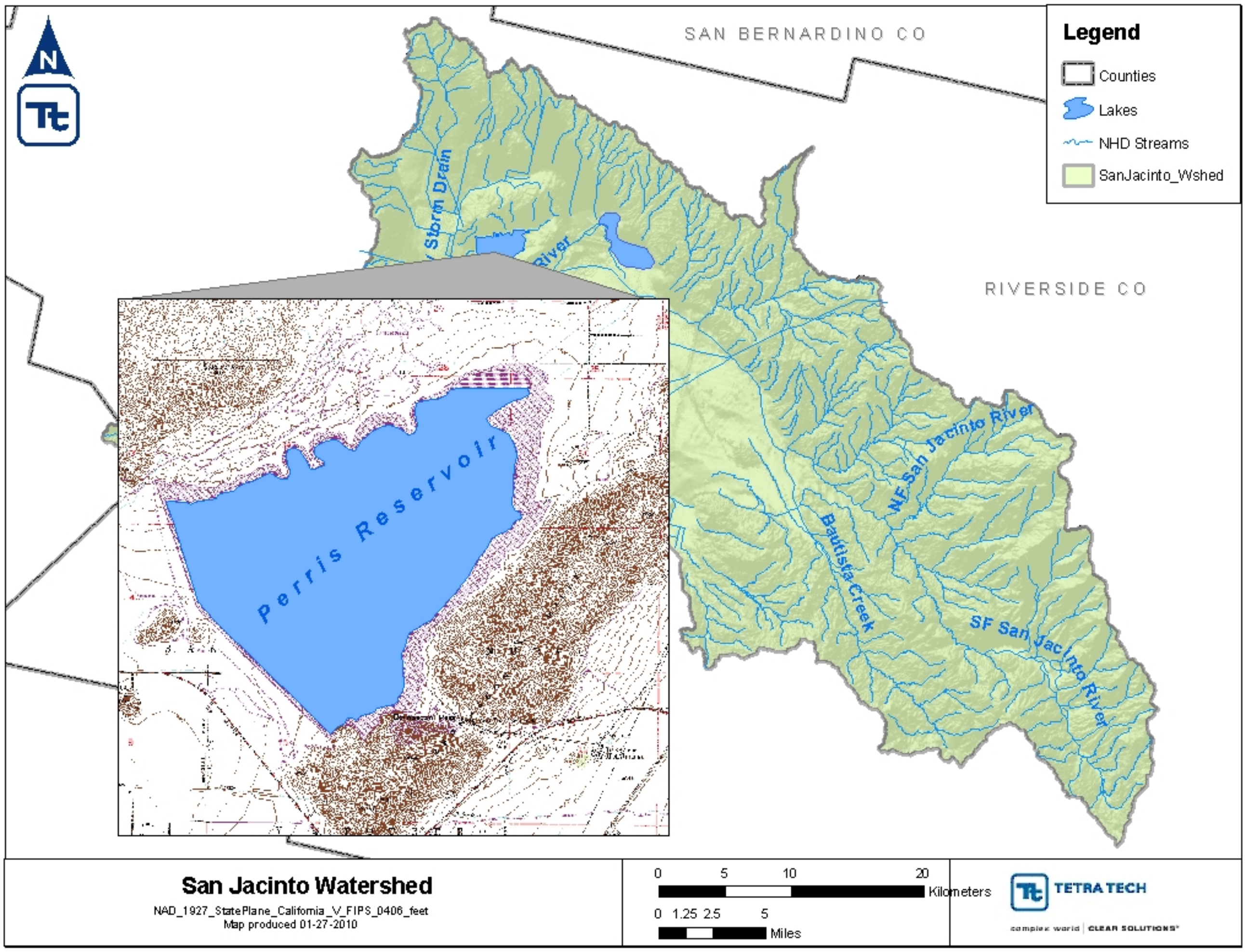

Figure 2-4. Perris Reservoir

2.1.2.1.5 Management Practices

During periods of rainfall, storage of runoff or stream flow in detention facilities or other planned or unplanned impoundments is an important consideration in modeling nutrient transport in the watershed. Planned impoundments include any BMPs, lakes, or other engineered systems that result in storage of stormwater runoff. Unplanned impoundments may result from under-designed culverts, natural landscape features, or other impediments to flow, and may create excessive ponding and storage during wet weather events. These impoundments can have major impacts on the quantity and quality of water that is transported through the watershed. Storage of water results not only in the attenuation of peak flows, but also in an increase in opportunity for soil infiltration and associated losses previously mentioned, as well as water quality impacts from settling, biological uptake, etc. For agricultural areas, the operation of stormwater detention ponds can have pronounced effects on the magnitude of peak runoff from the San Jacinto River watershed.

Model updates included the representation of four major flood control facilities (Figure 2-5) whose locations, stage-storage-discharge data available in as-built plans/rating curves, and drainage areas were provided by the Riverside County Flood Control and Water Conservation District (RCFCWCD). Communications with RCFCWCD found that the flood control facilities in the watershed serve only a water detention function (100-yr storms) and have no designed water quality impacts.

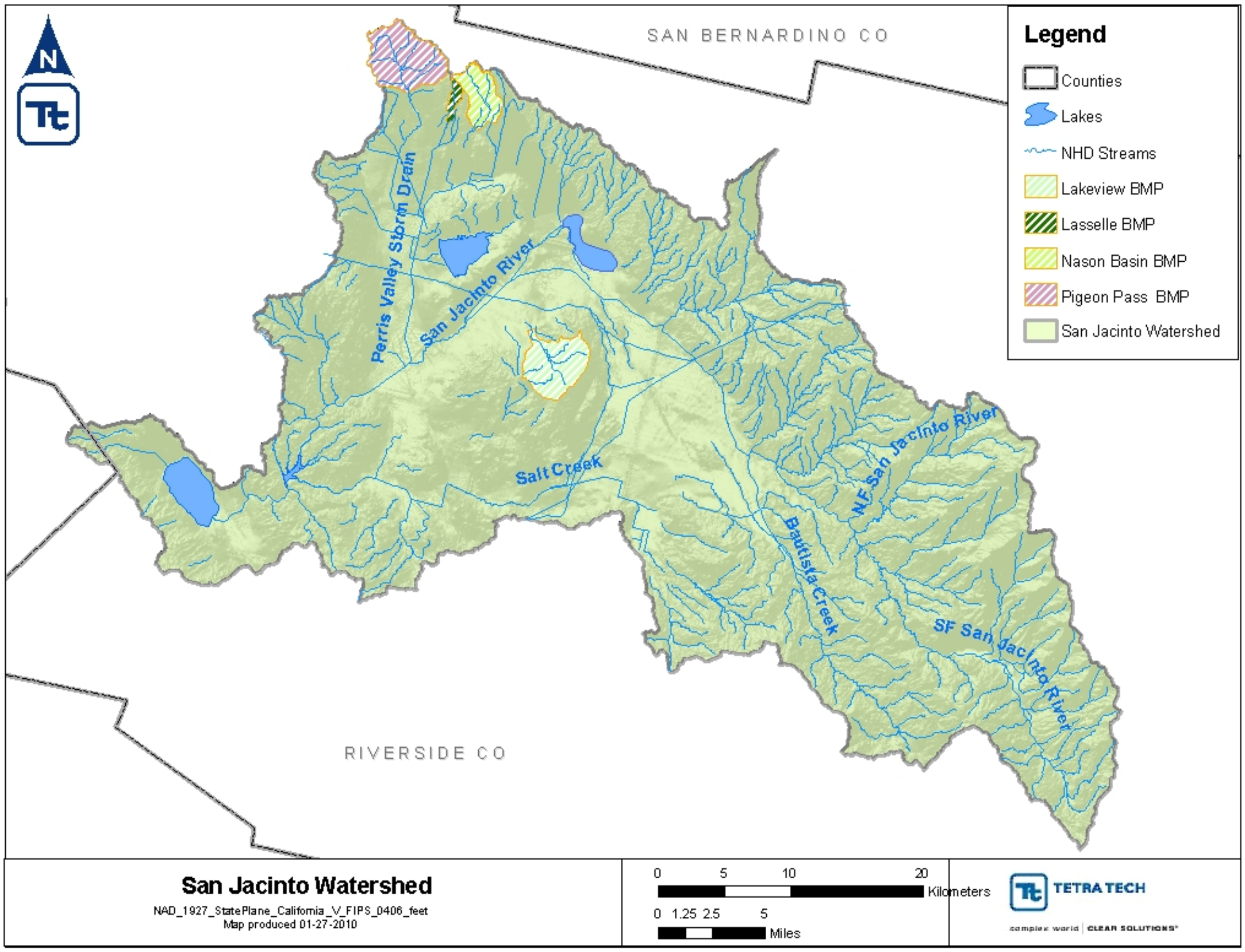

Figure 2-5. San Jacinto watershed regional BMPs identified by RCFCWCD

2.1.2.2 Water Quality

Many factors impact the water quality of the runoff of the San Jacinto watershed and inflows to Canyon Lake. These issues were defined and addressed in the LSPC model to ensure its accuracy and predictive capability. Key nutrient/water quality factors were discussed in Section 3.0 of the 2003 modeling report (SAWPA 2003).

2.1.2.3 Source Representation

General categories of nutrient sources (identified in Section 3.0 of the 2003 modeling report) in the San Jacinto River basin require special attention regarding estimation and transport. The following considerations were critical to source representation for the San Jacinto River watershed.

- The model should accurately represent the accumulation of pollutants during extended dry periods (as are exhibited in the watershed) prior to washoff.
- Rainfall intensity and volume play an important role in nonpoint source pollutant washoff estimation. The model must provide adequate time-step estimation of flow and not over-simplify storm events. It should provide accurate representation of rainfall events and resulting peak runoff.
- Different sources influence receiving waters in different ways and at different times (through different transport mechanisms). For example, surface runoff impacts water bodies differently than direct stream contributions. The model must be capable of simulating these transport mechanisms.

- Representation of the potential impacts of overflow from dairy wastewater detention facilities during torrential rainfall events, and associated loads to the San Jacinto River, should be addressed.
- The model should include the ability to include the potential impacts of BMPs to assess the relative benefits of alternative management scenarios, including water detention.
- Existing and future conditions are dependent on land use data; the model should use the most accurate land use data for nonpoint source estimation.
- Irrigation return flows and nutrients contributed from wastewater facilities were not explicity represented consistent with the 2003 study

2.2 Model Configuration

This section outlines the configuration of the updated watershed model (LSPC), and provides details regarding issues and assumptions made during development of the modeling system. Development and application of the watershed model to address the project objectives involved a number of important steps:

1) Watershed Segmentation
2) Configuration of Key Model Components
3) Model Calibration and Validation
4) Model Simulation for Existing Conditions and Scenarios

2.2.1 Watershed Segmentation

Watershed segmentation refers to the subdivision of the entire San Jacinto watershed into smaller, discrete subwatersheds for modeling and analysis. The original 2003 watershed segmentation primarily considered stream networks, locations of lakes, and topographic variability. The locations of flow and water quality monitoring stations, consistency of hydrologic factors, land use consistency, and existing watershed boundaries were also considered. Model segmentation was updated for this study based on the inclusion of large, regional BMPs identified by RCFCWCD, the availability of additional water quality monitoring stations, and analysis of 12-digit Hydrologic Unit Code (HUC) boundaries developed by the NRCS (NRCS 2004). Figure 2-6 depicts the updated subwatershed delineation for the San Jacinto River basin. The watershed was divided into 59 subwatersheds for model configuration.

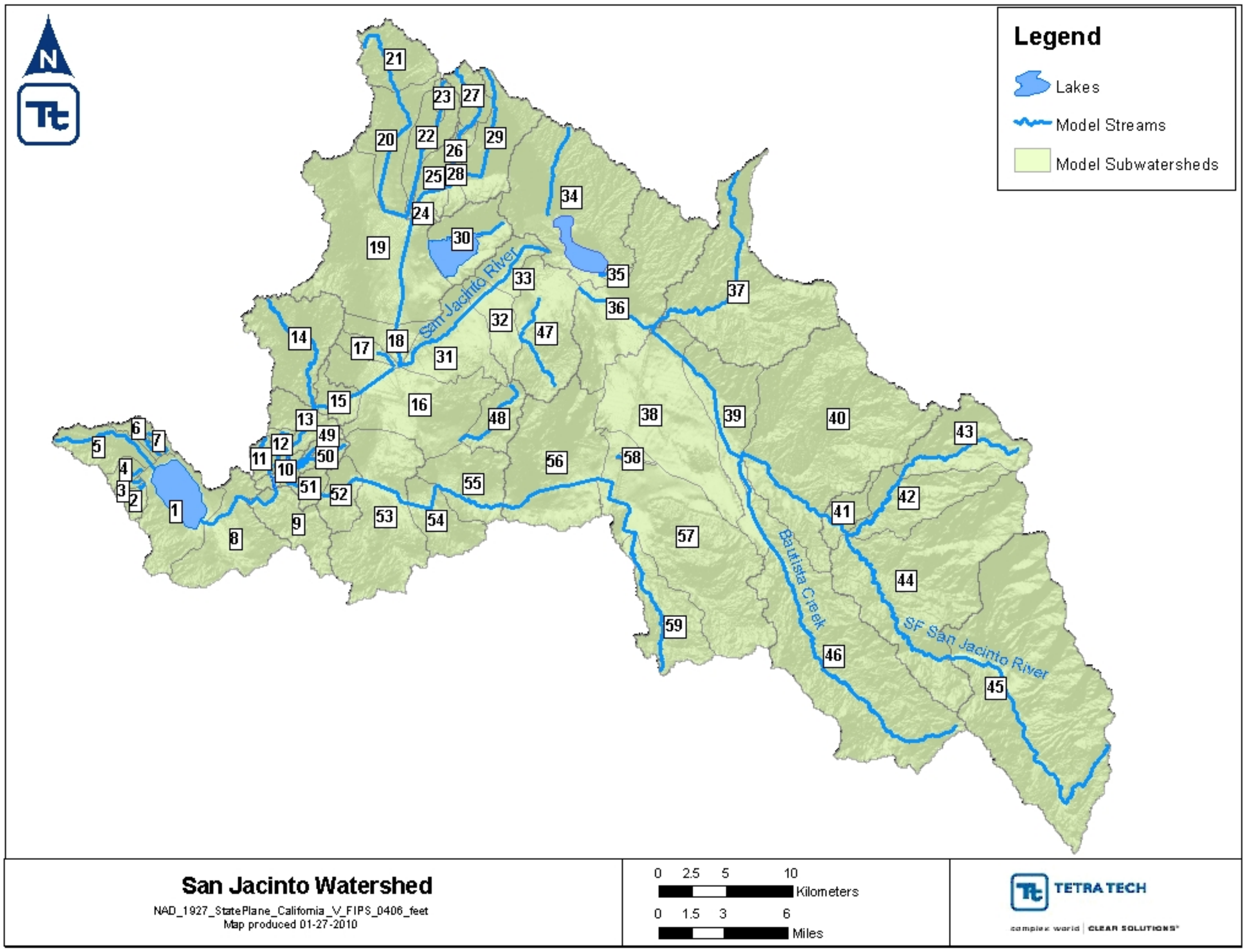

Figure 2-6. Model subwatersheds for the San Jacinto River basin

Model updates included providing the capability to estimate the nutrient loads contributed by stakeholder jurisdictions. Where possible, the subwatershed delineation was updated based on the location of municipal boundaries and other features. In most instances, the watershed jurisdictions do not follow natural breaks in topography and drainage. In order to estimate jurisdictional loads, the updated subwatershed delineation was overlain with the jurisdictional boundaries in order to estimate the load contributed by each jurisdiction through a model output post-processing step (see Section 5). Additional features, including Federal Lands, State Lands, Native American Reservations, U.S. Forests, and Wildlife Reserves were also considering during post-processing. Figure 2-7 and Figure 2-8 present the jurisdictional boundaries considered in the post-processing of model output. Note that GIS information for Caltrans right-of-ways and facilities was provided after development of the model land use coverage. This information can be used in the future to estimate load contributions from areas maintained by Caltrans.

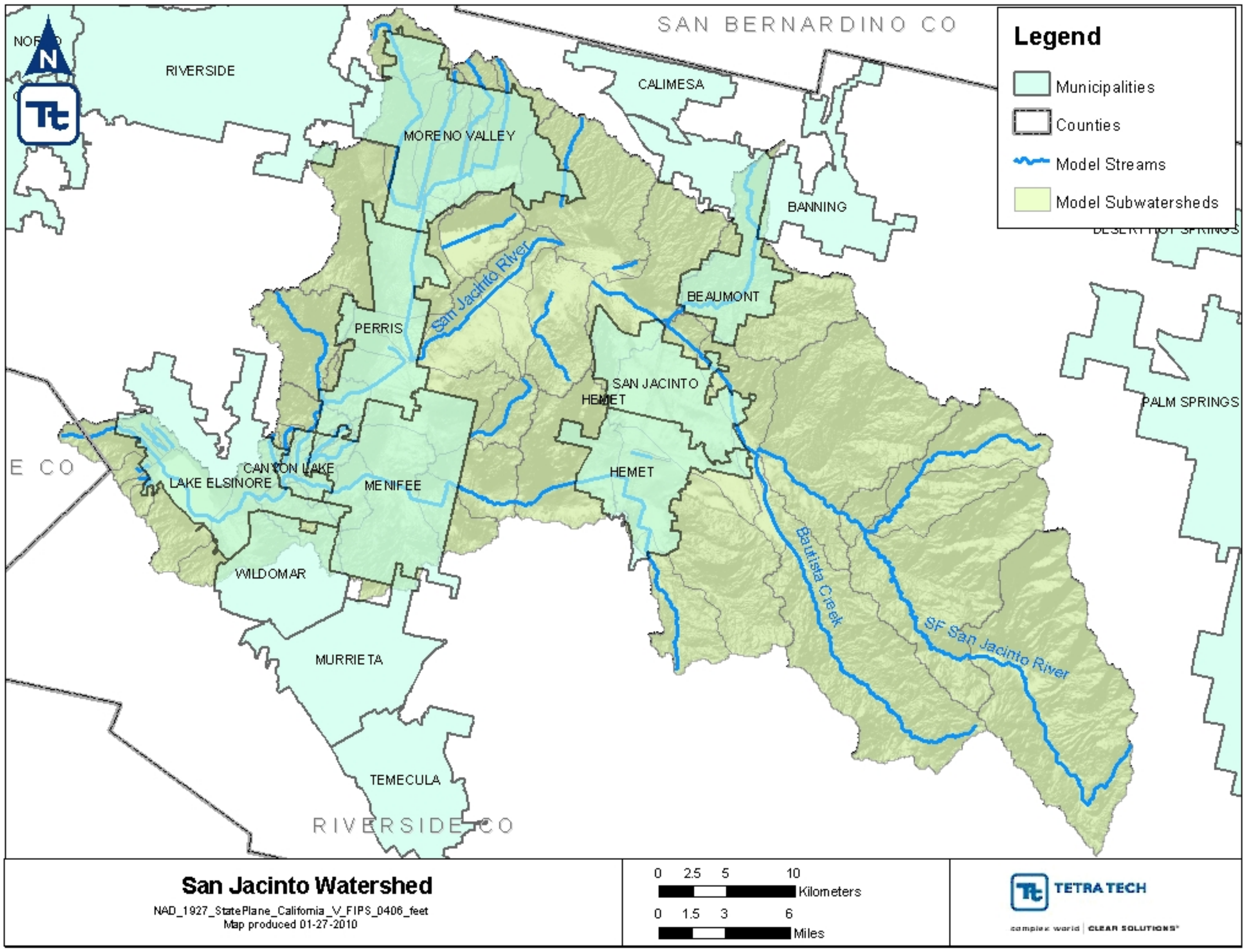

Figure 2-7. San Jacinto River basin municipalities

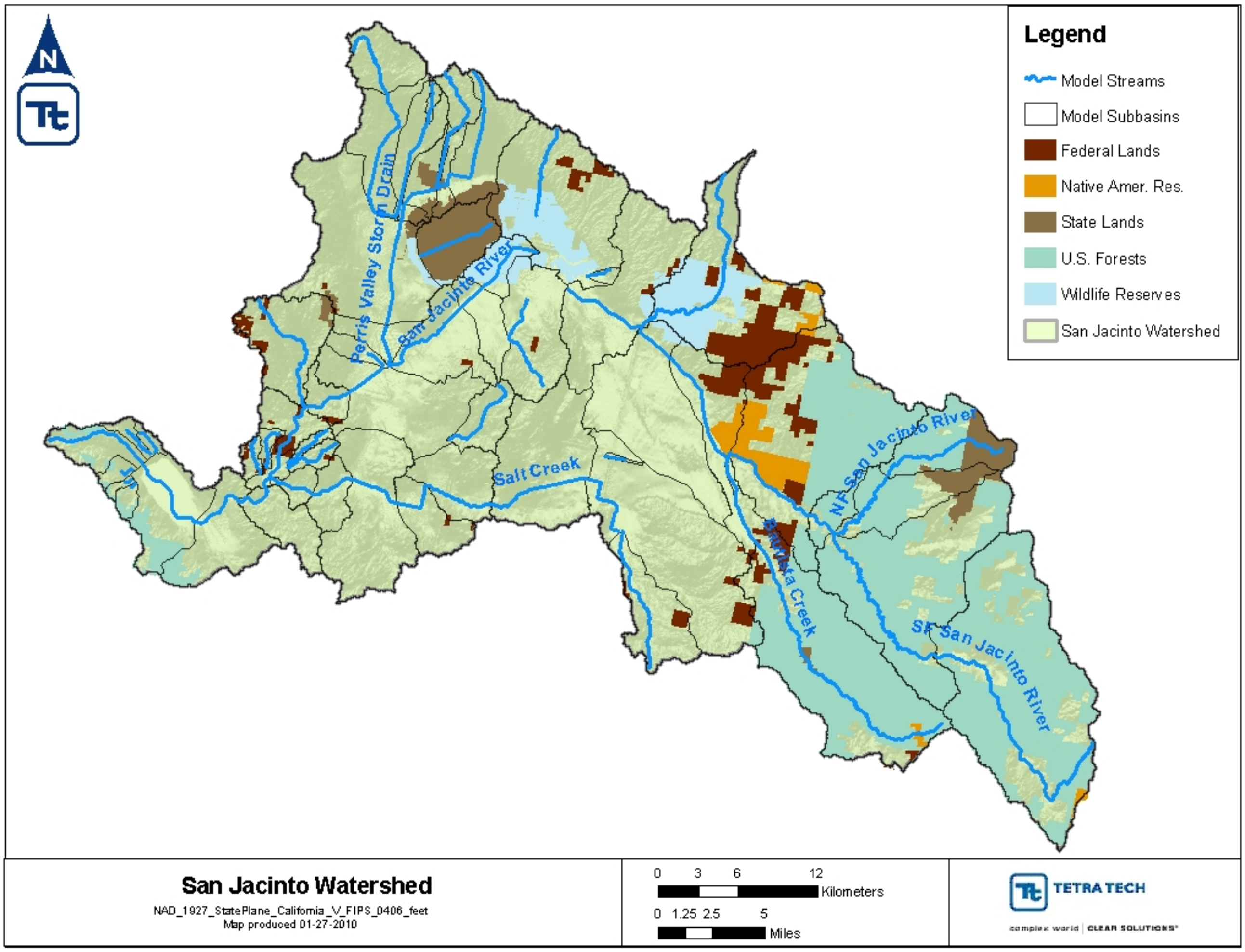

Figure 2-8. Other jurisdictions in the San Jacinto River basin

2.2.2 Configuration of Key Model Components

Configuration of the watershed model involved consideration of four major components: meteorological data, land use representation, hydrologic and pollutant representation, and water body representation. These components provided the basis for the model's ability to estimate flow and pollutant loadings. Meteorological data essentially drive the watershed model. Rainfall and other parameters are key inputs to LSPC's hydrologic algorithms. The land use representation provides the basis for distributing soils and pollutant loading characteristics throughout the basin. Hydrologic and pollutant representation refers to the LSPC modules or algorithms used to simulate hydrologic processes (e.g., surface runoff, evapotranspiration, and infiltration) and pollutant loading processes (primarily accumulation and washoff). Water body representation refers to LSPC modules or algorithms used to simulate flow and pollutant transport through streams and rivers.

2.2.2.1 Meteorology

Meteorological data are a critical component of the watershed model and have a significant impact on the accuracy of model predictions. Appropriate representation of precipitation and potential evapotranspiration (PEVT) are required to characterize watershed hydrology. Depending on the selected modules, temperature, wind speed, cloud cover, and dew point may also be required to develop a valid model, but this was not the case for the San Jacinto watershed. Meteorological data provide necessary input to LSPC algorithms for hydrologic and water quality representation. The 2003 modeling study simulated conditions in the San Jacinto watershed for a 10-year time period (1990–2000). To extend the modeling period for the watershed model updates, precipitation and PEVT data covering 20 consecutive years (7/1/1989–7/31/2009) were accessed from a number of sources in an effort to develop a representative dataset for the San Jacinto watershed. The 20-year time period includes the range of meteorological conditions associated with wet and dry periods in the watershed, including the extremely heavy winter rains associated with El Nino events.

Because non-point sources are typically driven by rainfall and runoff, precipitation data are an important input and hourly precipitation data are recommended for non-point source modeling. Therefore, only rainfall monitoring stations with hourly-recorded data were considered in the precipitation data selection process. Figure 2-9 shows the general distribution of precipitation totals in the San Jacinto watershed (PRISM 2010).

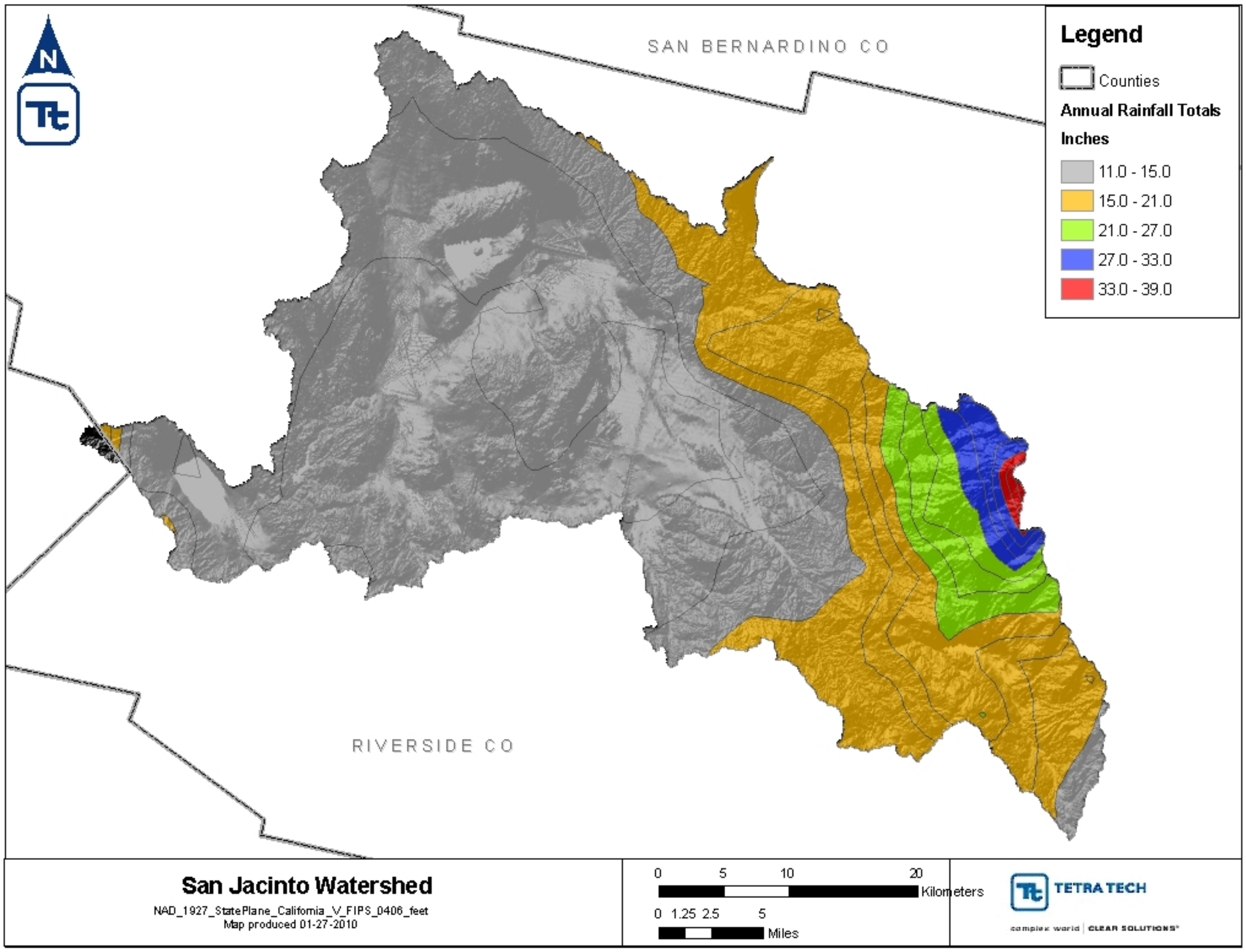

Figure 2-9. San Jacinto River basin historical annual rainfall totals

Long-term hourly precipitation data from six Riverside County Flood Control and Water Conservation District (RCFCWCD) rain gages located within or near the San Jacinto watershed were used in the watershed model. Figure 2-10 depicts the locations of the rainfall stations and the area of influence estimated using the Theissen polygon method. Rainfall-runoff processes for each of the subwatersheds in the model are driven by rainfall data from the selected stations (e.g., subwatersheds located predominately in the area of influence assigned by the Sun City station will be driven by this station’s data).

Long-term temperature and pan evaporation data are available for a number of weather stations in close proximity, but outside the watershed. After analyzing the data, two stations, the Camp Pendleton surface airways station (Station No. 03154) and the Los Angeles County Flood Control District (LACFC) Station No. 96D at Puddingstone Dam, representing temperature and pan evaporation data respectively, were selected as the most appropriate to represent PEVT conditions throughout the San Jacinto watershed (Figure 2-11). Data for the LACFC station was used for the time period 7/1/1989–12/31/2006 and the Camp Pendleton station was used for 1/1/2007–7/31/2009. These stations are summarized in Table 2-1 Data collected from these stations are assumed to be representative of conditions within the San Jacinto watershed given the location of these stations within the evapotranspiration zones that cover the watershed. Temperature and pan evaporation data collected within the watershed are also available from stations located within Riverside County, however, these data were not available for the entire modeling period. These data can be incorporated in future model updates depending on data availability.

The Hamon method (1963) was used to estimate PEVT from Station No. 03154 as a function of temperature. Pan evaporation data from Station No. 96D was transformed into PEVT using an appropriate pan coefficient. Table 2-2 shows monthly pan coefficients applied to the pan evaporation data (Aqua Terra 2008). The transformed daily PEVT estimates were then disaggregated to estimate hourly rainfall by fitting a sine curve distribution over the computed daylight hours. For each station, daylight hours (from sunrise and sunset) were uniquely derived as a function of latitude and the average curvature of Earth.

Table 2-1. Meteorological monitoring stations

Station code	Agency	Station name	Parameter	Period of record collected	Annual rainfall (inches)	Located within watershed?
67	RCFCWCD	Elsinore	Precipitation	7/1/1990 – 7/31/2009	10.6	Yes
212	RCFCWCD	Sun City	Precipitation	7/1/1990 – 7/31/2009	11.2	Yes
155	RCFCWCD	Pigeon Pass	Precipitation	7/1/1990 – 7/31/2009	12.8	Yes
124	RCFCWCD	Moreno East	Precipitation	7/1/1990 – 7/31/2009	12.1	Yes
248	RCFCWCD	Winchester	Precipitation	7/1/1990 – 7/31/2009	10.8	Yes
89	RCFCWCD	Hurkey Creek Park	Precipitation	7/1/1990 – 7/31/2009	18.7	Yes
96D	LACFC		Pan Evaporation	3/10/1945 - 5/14/1999		No
03154	NOAA	Camp Pendleton MCAS	Air temperature	7/1/1966 – 3/31/2002		No

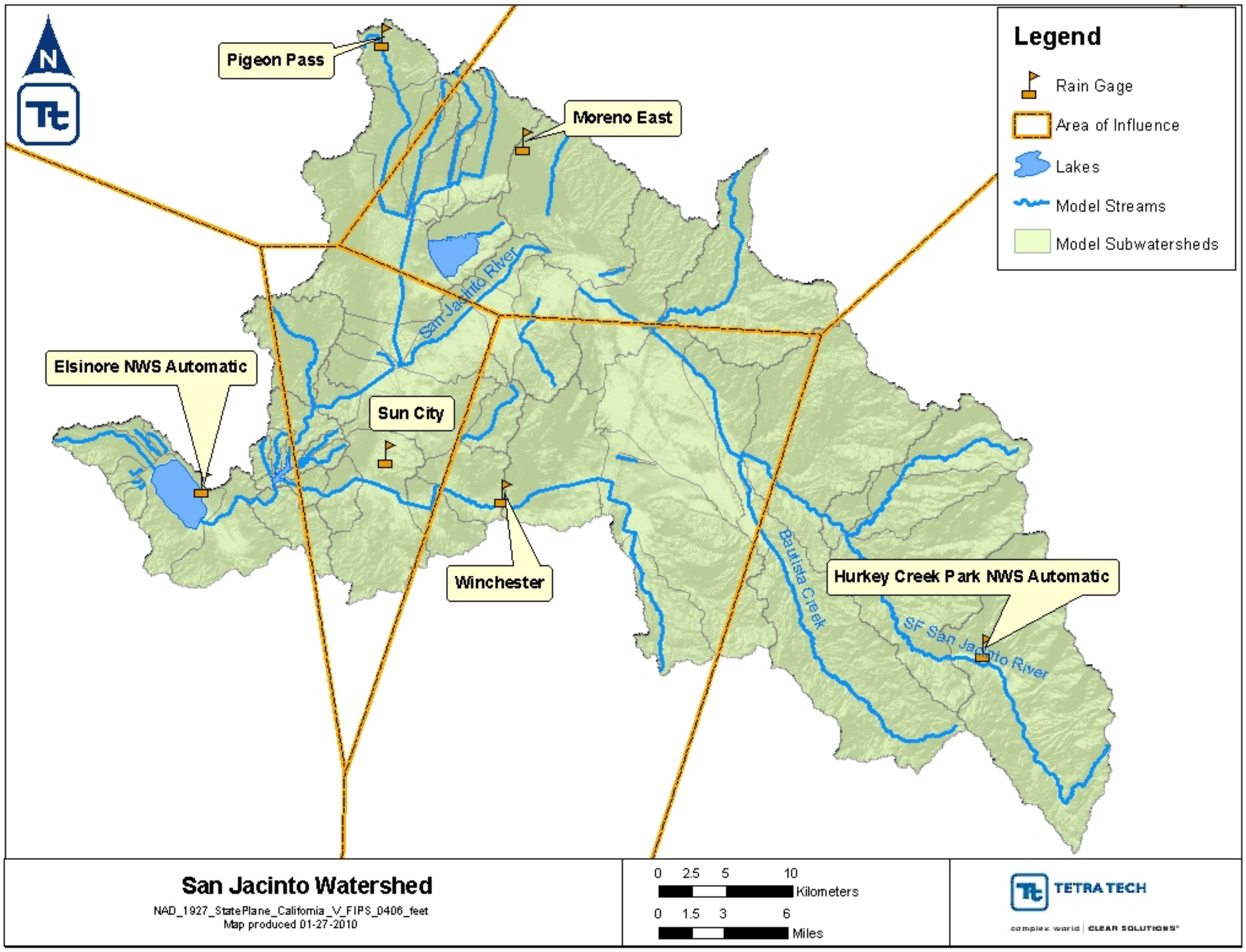

Figure 2-10. Rainfall gages in the San Jacinto River basin

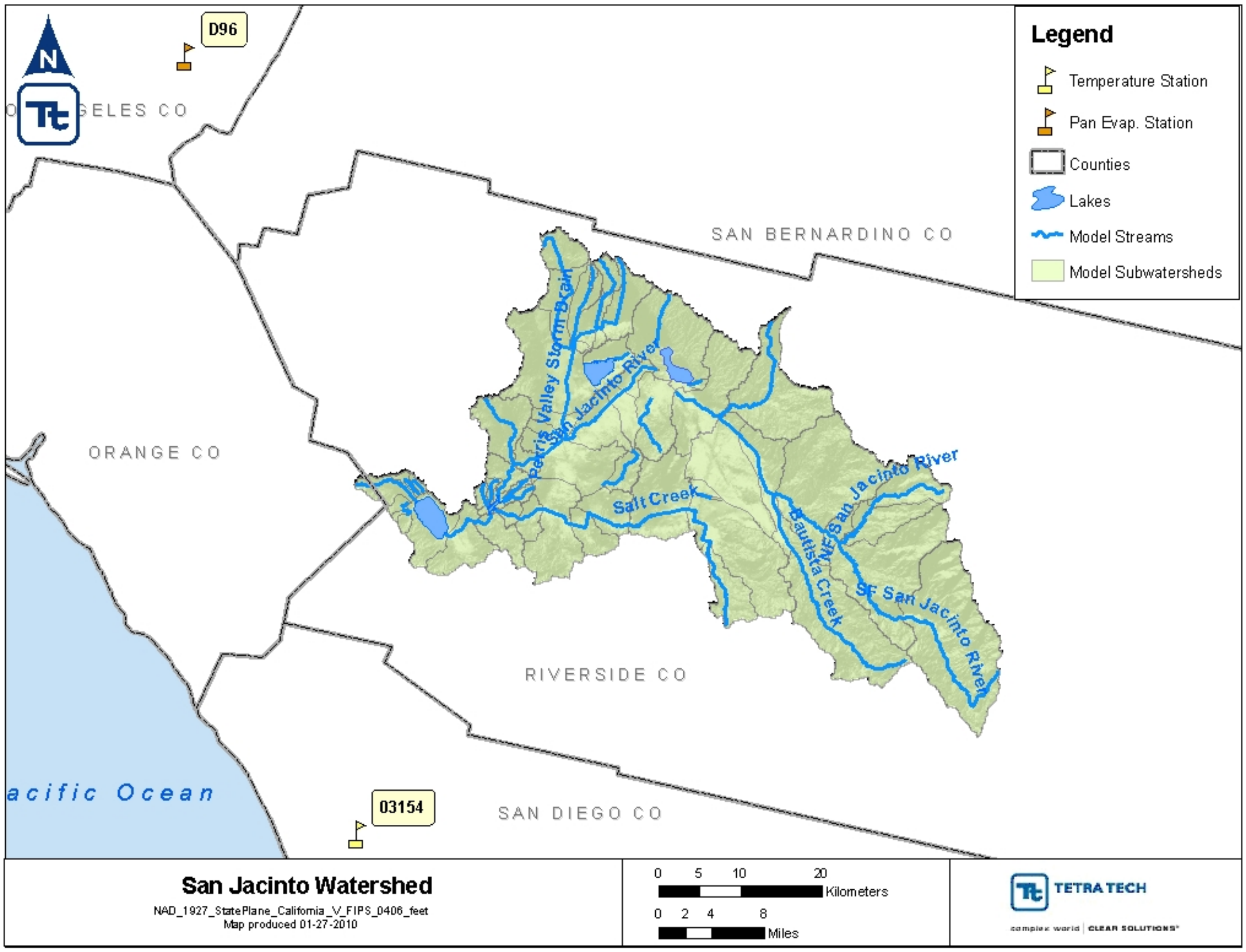

Figure 2-11. Temperature (03154) and pan evaporation (D96) monitoring stations

Table 2-2. Monthly pan coefficients for evaporation stations

Spring and Summer		Fall and Winter	
Month	**ET Coefficient**	**Month**	**ET Coefficient**
January	0.82	July	0.74
February	0.63	August	0.78
March	0.68	September	0.87
April	0.66	October	0.93
May	0.68	November	0.97
June	0.77	December	0.95

2.2.2.2 Land Use

The watershed model requires a basis for distributing hydrologic and pollutant loading parameters. This is necessary to appropriately represent hydrologic variability throughout the basin, which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated to land practices. The basis for this distribution is provided by land use coverage of the entire watershed.

Land use data updates for the San Jacinto watershed model utilized datasets similar to those used for the previous 2003 Nutrient Source Assessment study (SAWPA 2003). The 2005 Southern California Association of Governments (SCAG) land use dataset and the 2009 Western Riverside County Agriculture Coalition (WRCAC) agriculture land use data were selected to build the model input data.

The Southern California Aerial Land Use Consortium, an organization consisting of public and quasi-public agencies, headed by SCAG, originally contracted with Aerial Information Systems (AIS) to develop a region-wide land use data layer in 1990, which came to be known as the SCAG land use dataset. Land use data updates were completed in 1993, 2000, and 2005. Beginning in 2000, the updates were performed using computer interactive photo interpretation techniques and digital natural color imagery. Polygon attributes and boundaries were revised by the photo interpreters to reflect current conditions. Hard to identify photo signatures were flagged for on-site visits to ensure the accuracy of the interpretations. Land use categories available in the 2005 SCAG data and associated areas within the San Jacinto watershed are presented in Table 2-3. Table 2-3 also lists the model land uses (discussed below) assigned to the original SCAG categories.

Table 2-3. 2005 SCAG land use categories and areas

2005 SCAG land use description	Model land use	Area (acres)
Abandoned Orchards and Vineyards	Forested	112
Air Field	Urban	1,161
Airports	Urban	342
Base (Built-up Area)	Urban	948
Beaches (Vacant)	Open Space	1
Bus Terminals and Yards	Urban	15
Cemeteries	Open Space	83
Colleges and Universities	Urban	211
Commercial Recreation	Urban	185
Commercial Storage	Urban	309
Communication Facilities	Urban	23
Dairy, Intensive Livestock, and Associated Facilities	Dairy/Livestock	368
Developed Local Parks and Recreation	Open Space	873
Developed Regional Parks and Recreation	Open Space	493
Duplexes, Triplexes	High-Density Residential	507
Electrical Power Facilities	Urban	198
Elementary Schools	Urban	869
Fire Stations	Urban	71
Former Base (Built-up Area)	Urban	213
Former Base Vacant Area	Open Space	1,069
Freeways and Major	Urban	1,313
Mixed Transportation and Utility	Urban	22
Mixed Urban	Urban	21
Mobile Home Courts and Subdivisions, Low-Density	Low-Density Residential	1,204
Modern Strip Development	Urban	1,748
Natural Gas and Petroleum Facilities	Urban	25
Non-Irrigated Cropland and Improved Pasture Land	Non-Irrigated Cropland	9,169
Nurseries	Orchards/Vineyards	216
Older Strip Development	Urban	67
Open Storage	Urban	867
Orchards and Vineyards	Orchards/Vineyards	549
Other Agriculture	Cropland	724
Other Open Space and Recreation	Open Space	1,367
Other Public Facilities	Urban	161
Other Special Use Facilities	Urban	256
Packing Houses and Grain Elevators	Urban	10
Park-and-Ride Lots	Urban	2
Police and Sheriff Stations	Urban	24
Poultry Operations	Dairy/Livestock	42
Pre-Schools/Day Care Centers	Urban	33
Railroads	Urban	30
Religious Facilities	Urban	485

2005 SCAG land use description	Model land use	Area (acres)	2005 SCAG land use description	Model land use	Area (acres)
Roads					
Golf Courses	Open Space	2,049	Research and Development	Urban	2
Government Offices	Urban	162	Retail Centers (Non-Strip With Contiguous Interconnected Off-Street Parking	Urban	979
High-Density Single Family Residential	Med-Density Residential	27,837	Rural Residential, High-Density	Med-Density Residential	323
Horse Ranches	Dairy/Livestock	714	Rural Residential, Low-Density	Low-Density Residential	18,070
Hotels and Motels	Urban	93	Senior High Schools	Urban	672
Improved Flood Waterways and Structures	Urban	541	Solid Waste Disposal Facilities	Urban	736
Irrigated Cropland and Improved Pasture Land	Irrigated Cropland	6,284	Special Care Facilities	Urban	89
Junior or Intermediate High Schools	Urban	492	Trade Schools and Professional Training Facilities	Urban	60
Liquid Waste Disposal Facilities	Urban	395	Trailer Parks and Mobile Home Courts, High-Density	Med-Density Residential	2,618
Low- and Medium-Rise Major Office Use	Urban	226	Truck Terminals	Urban	13
Low-Density Single Family Residential	Low-Density Residential	7,712	Under Construction	Urban	6,255
Low-Rise Apartments, Condominiums, and Townhouses	High-Density Residential	1,241	Undeveloped Regional Parks and Recreation	Open Space	3,495
Maintenance Yards	Urban	119	Vacant Area	Open Space	1,448
Major Medical Health Care Facilities	Urban	82	Vacant Undifferentiated	Forested	279,823
Manufacturing	Urban	7	Vacant With Limited Improvements	Open Space	1,119
Manufacturing, Assembly, and Industrial Services	Urban	1,087	Water Storage Facilities	Urban	231
Medium-Rise Apartments and Condominiums	High-Density Residential	13	Water Transfer Facilities	Urban	229
Mineral Extraction - Other Than Oil and Gas	Urban	380	Water Within a Military Installation	Water	0
Mixed Commercial and Industrial	Urban	49	Water, Undifferentiated	Water	4,175
Mixed Multi-Family Residential	High-Density Residential	36	Wholesaling and Warehousing	Urban	364
Mixed Residential	High-Density Residential	343	Wildlife Preserves and Sanctuaries	Forested	919
Mixed Transportation	Urban	544			
Total Area (acres)					**398,414**

The 2009 WRCAC agricultural data were derived using methodologies presented in *A Land Use and Land Cover Classification System* for use with Remote Sensor Data (Anderson et al. 1976). Agricultural land use classifications derived from satellite imagery were refined based on stakeholder information regarding agricultural production and manual review of the satellite imagery. Using this information, a spatial coverage for portions of

Riverside County was developed which includes large areas in the western and central portions of the San Jacinto watershed. The 2009 WRCAC land use categories and associated areas in the San Jacinto watershed are presented in Table 2-4. Table 2-4 also lists the model land uses (discussed below) assigned to the original WRCAC categories.

Table 2-4. 2009 WRCAC land use categories and areas

WRCAC land use description	Model land use	Area (acres)
Abandoned Orchards Vineyards	Forested	15
Backyard Livestock	Dairy/Livestock	1,547
Christmas Tree Farms	Orchards/Vineyards	13
Citrus	Orchards/Vineyards	3,156
Dairies Intensive	Dairy/Livestock	1,004
Dairies Non Intensive	Dairy/Livestock	1,075
Flood Control	Water	2,413
Horses	Dairy/Livestock	2,782
Irrigated Agriculture	Irrigated Cropland	20,797
Manure Piles	Dairy/Livestock	147
Non Irrigated Agriculture	Non-Irrigated Cropland	15,510
Nurseries Undifferentiated	Orchards/Vineyards	929
Orchards Vineyards Undifferentiated	Orchards/Vineyards	170
Other Ag Undifferentiated	Cropland	349
Other Livestock	Dairy/Livestock	191
Poultry	Dairy/Livestock	329
Turf Farms	Pasture/Hay	1,130
Unknown Agriculture Placeholder	Open Space	2,178
Vacant Zoned Agriculture	Forested	11,595
Water	Water	2,715
Water Storage	Water	1,007
Water Transfer	Water	332
Wildlife Reserve	Forested	19,743
Total		**89,127**

Similar to the 2003 study, the two land use datasets were combined to create a custom composite coverage that takes advantage of the more detailed WRCAC agricultural data where it is available. Areas for which WRCAC data are not available were characterized using the 2005 SCAG land use dataset.

Although the multiple categories in the land use coverage provide much detail regarding spatial representation of land practices in the watershed, such resolution is unnecessary for watershed modeling if many of the categories share hydrologic or pollutant loading characteristics. Therefore, many land use categories were grouped into similar classifications, resulting in a subset of 14 categories for modeling. Selection of these land use categories was based primarily on the grouping of model land uses done for the original 2003 modeling study, which took into account the availability of monitoring data and literature values that could be used to characterize individual land use contributions and critical nutrient-contributing practices associated with different land uses. For example, multiple urban and agricultural categories were represented independently (such as dairy/livestock, cropland, and sewered residential land), whereas forest and other natural categories were grouped. The final subset of land use categories used in the watershed model is shown in Figure 2-12 and listed in Table 2-3 and Table 2-4 with their associated SCAG and WRCAC land use categories, respectively. The same model land use categories were used for the model update in order to be consistent with the 2003 study and the lake TMDLs. A summary of the model land use areas and a break-down of the source dataset (SCAG and WRCAC) composition are presented in Table 2-5. This static land use coverage was used to simulate nutrient load contributions from the watershed for the entire 20-year modeling period. Additional information on the land use datasets and methods used to develop the composite land use coverage is included in the Model Land Use Updates memo that was provided to LESJWA on 1/4/2010 (Appendix B). Note that GIS information for Caltrans right-of-ways and facilities was provided after development of the model land use coverage. This information can be used in the future to estimate load contributions from areas maintained by Caltrans.

Table 2-5. 2010 San Jacinto watershed model land use categories and source data composition

Land Use Description	SCAG Land Use	WRCAC Land Use	Aggregate Land Use
	Area (acres)		
Cropland	724	338	1,063
Irrigated Cropland	6,284	19,459	25,744
Non-Irrigated Cropland	9,169	13,855	23,024
Orchards and Vineyards	765	4,200	4,965
Pasture/Hay/Ranches	0	1,123	1,123
Dairy/Livestock	1,125	6,787	7,912
Agriculture Total	**18,067**	**45,763**	**63,831**
Low-Density Residential	26,988	0	26,988
Medium-Density Residential	30,778	0	30,778
High-Density Residential	2,140	0	2,140
Urban	23,414	0	23,414
Developed Total	**83,320**	**0**	**83,320**
Forest/Shrubland	280,855	31,353	312,210
Open Space/Bare Rock	11,997	5,545	17,542
Water	4,175	6,467	10,643
Undeveloped Total	**297,028**	**43,365**	**340,395**
Grand Total	**398,415**	**89,128**	**487,546**

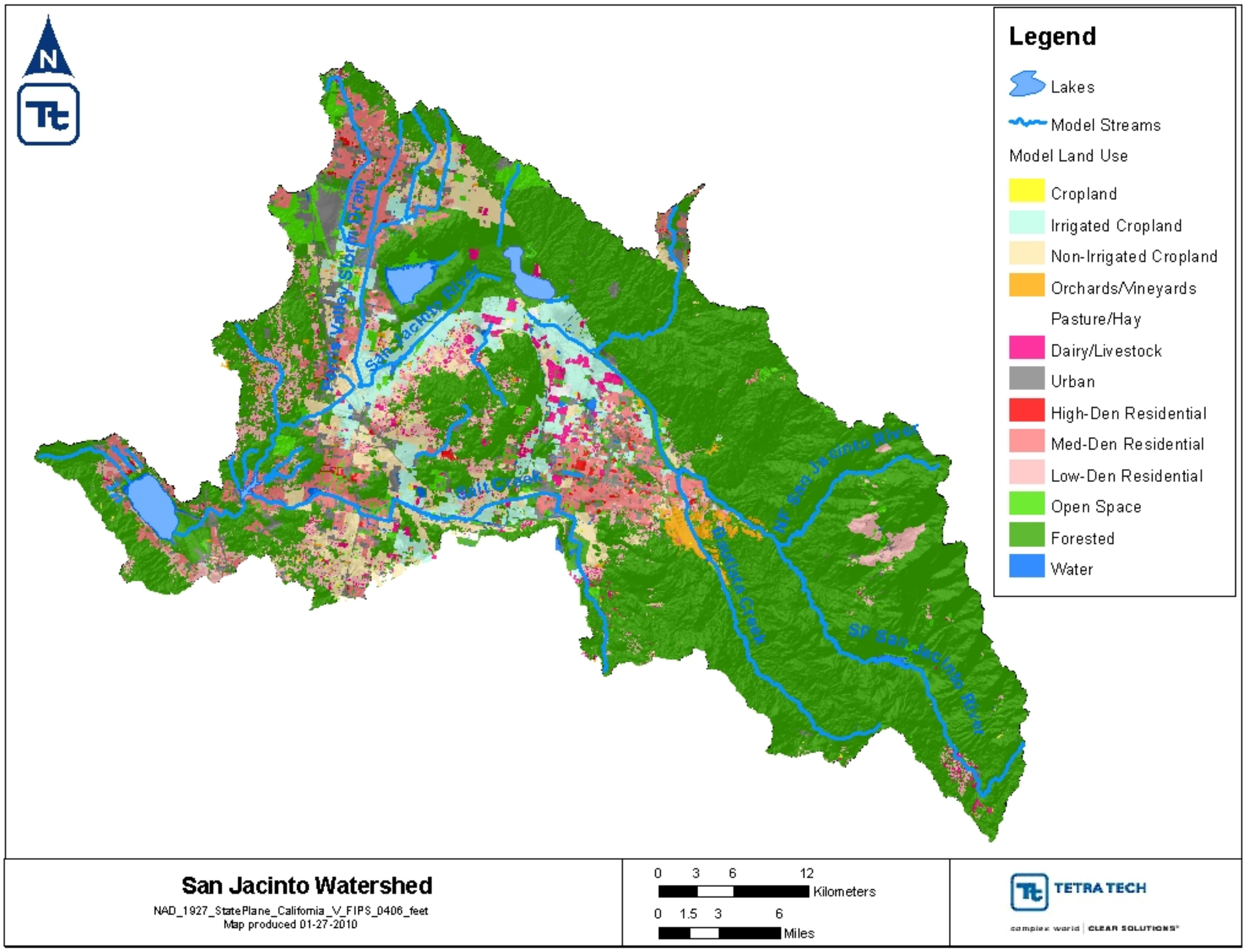

Figure 2-12. Land use categories used in watershed model

LSPC algorithms require that land use categories be divided into separate pervious and impervious land units for modeling. The original 2003 model based this division on typical impervious percentages associated with different land use types from the Soil Conservation Service's TR-55 Manual (Soil Conservation Service 1986). To improve on this general classification of land uses, land use imperviousness was derived from the Multi-Resolution Land Characteristics (MRLC) National Land Cover Database (NLCD), which includes a GIS data layer of land surface percent imperviousness at a 30-meter squared resolution (MRLC 2001). This data layer, therefore, provides actual estimated imperviousness for each 30-meter analysis unit giving greater spatial resolution to land use imperviousness classification than a literature value assigned generally to a land use category. Percent imperviousness of land cover in the San Jacinto watershed is presented in Figure 2-13.

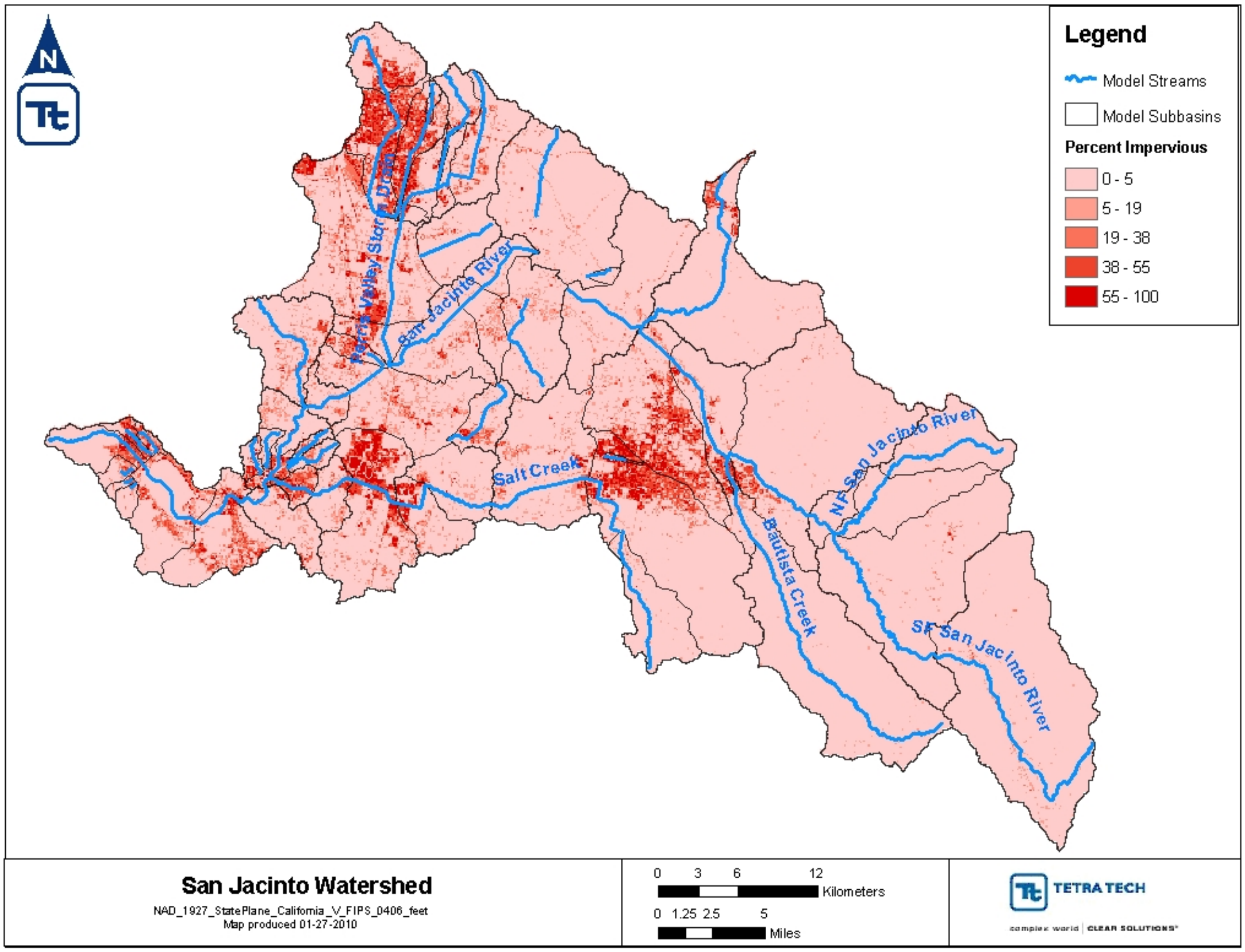

Figure 2-13. Percent imperviousness in the San Jacinto basin (MRLC 2001)

The model land use GIS data layer was overlain with the NLCD impervious layer to assign the impervious percentages to the model land uses. This division was made for developed land uses only (residential and urban) areas. It is assumed that impervious areas associated with pervious land uses are disconnected, meaning that runoff from these areas are captured by pervious lands. LSPC does not route runoff from land areas, therefore if a land area is classified as impervious the runoff volume and timing is delivered to the stream without consideration of land uses that surround it.

To test the validity of NLCD derived impervious areas, model hydrology simulations were run with only impervious land areas represented. The hydrology of impervious land uses is treated uniformly in LSPC, whereby all precipitation captured by these areas is converted into surface runoff and only limited adjustments can be made to the interception storage characteristics in the model.. Therefore, if impervious area runoff volumes are causing stream flow storm peaks to closely approach or exceed observed data it can be assumed that this area has been over-estimated.

Analysis of model simulated stream hydrographs found that storm peaks were being regularly equaled or exceeded with only impervious areas being represented. Figure 2-14 provides a comparison of simulated and observed stream flow for the period 10/1/2000–9/30/2002 at USGS gage 11070270 (see Figure 2-19) with only impervious areas being represented in the model. The comparison found that approximately 92 percent of total in-stream volume was being simulated with only impervious areas being represented for this time period. Therefore, it was determined that the 2001 NLCD land cover dataset was over estimating impervious areas in the San Jacinto watershed.

A comparison of the impervious area in the 2003 San Jacinto watershed model to the current model found that the old land use dataset had approximately 51 percent of the impervious area of the 2010 dataset. Using this percentage as a starting point, the area of impervious land in the current model, as estimated using the NLCD data, was reduced by 29 percent during the hydrology calibration process (see Section 2.2.3.1). This reduction in imperviousness allowed the model to retain the spatial accuracy of the imperviousness classification provided by the NLCD dataset, while adjusting for any uncertainty in the data itself as identified in the model simulation runs.

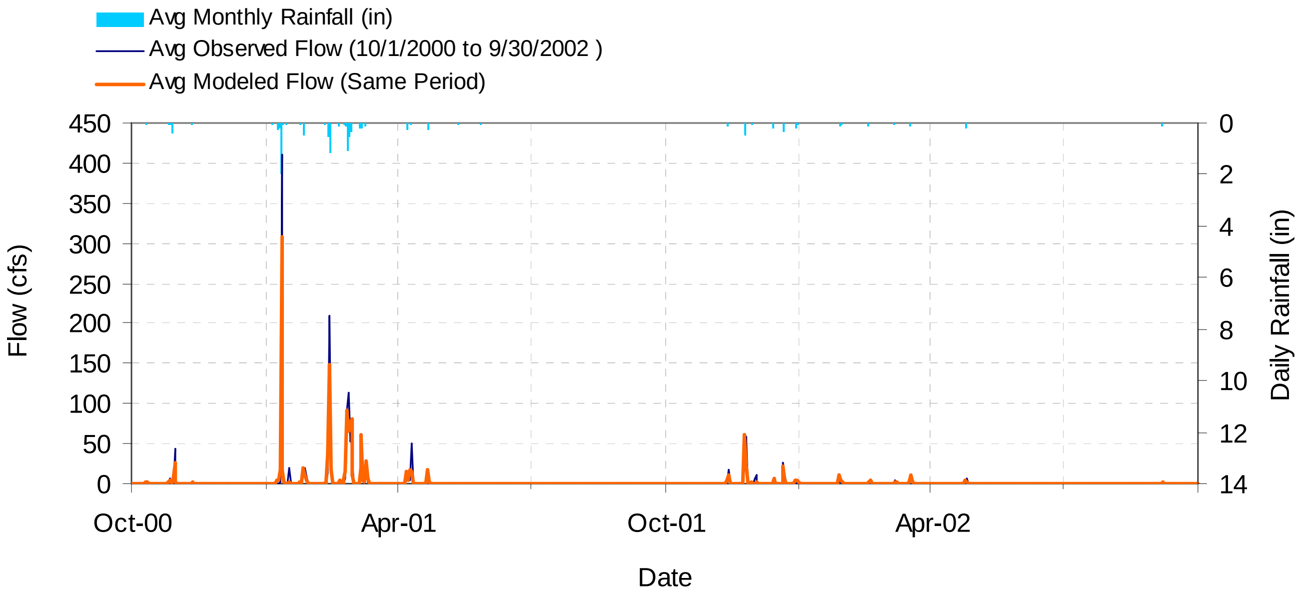

Figure 2-14. Comparison of observed and simulated in-stream flow at USGS gage 11070270 with only impervious areas represented in the model

2.2.2.3 Hydrology Representation

The LSPC PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) modules, which are identical to those in HSPF, were used to represent hydrology for all pervious and impervious land units (Bicknell et al. 1996). The LSPC model requires the designation of key hydrologic parameters in the PWATER and IWATER modules. These parameters are associated with infiltration, groundwater flow, and overland flow. The parameter values developed for the original 2003 model served as a starting point for designation of infiltration and groundwater flow parameters, which were based on the State Soil Geographic Database (STATSGO) and the Riverside County Hydrology Manual. Starting values were refined through the hydrologic calibration process (described in next section).

To account for the variability of hydrology characteristics throughout the watershed associated with different soil types or topography, five groups of hydrology parameters were configured for the updated model. The assignment of appropriate group parameters was dependent upon location and predominant SCS hydrologic soil groups of each subwatershed (Figure 2-15). The land use and soils data allow for the representation of hydrologic variability at the subwatershed level by taking into account both land surface and subsurface characteristics.

The Natural Resources Conservation Service (NRCS) has defined four hydrologic soil groups (Table 2-6) that classify soils according to their infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils (Group D) are poorly drained and have the lowest infiltration rates, while sandy soils (Group A) well drained and have the highest infiltration rates. As mentioned above, data for the study watersheds were obtained from STATSGO (USDA 1993) and were summarized by hydrologic soil groups.

Table 2-6. NRCS hydrologic soil groups

Hydrologic soils group	Description
A	Soils with high infiltration rates. Usually deep, well drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.

Source: (USDA 1993)

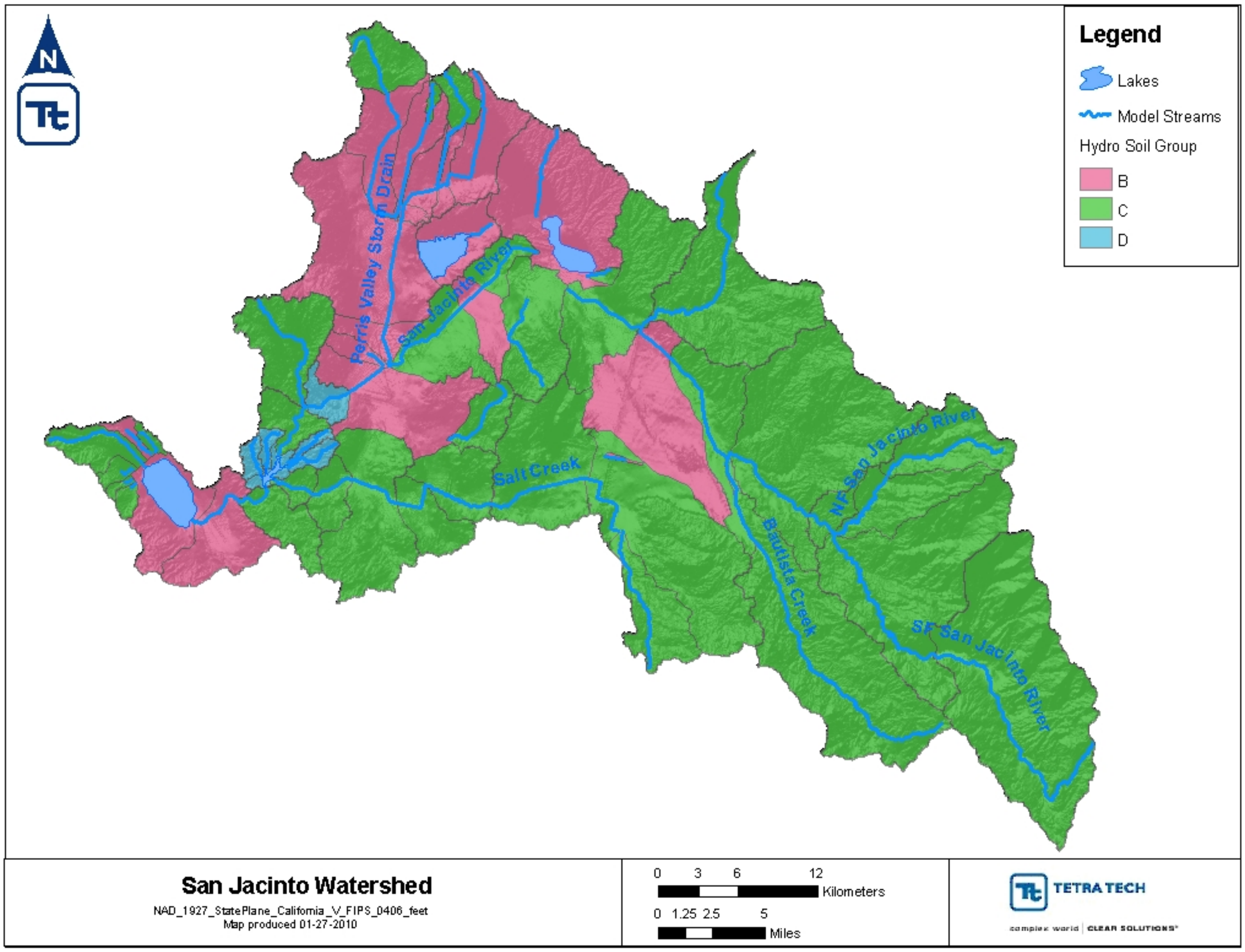

Figure 2-15. Hydrologic soil groups in the San Jacinto River basin

In addition to the general hydrologic soil groups, certain areas of the San Jacinto watershed required a hydrologic calibration specific to observed conditions that are discussed below. These areas included:

1) Areas located in the upper portion of the San Jacinto watershed (upstream of Mystic Lake) with soils classified as SCS soil type C.
2) Areas draining to Salt Creek in the lower portion of the San Jacinto watershed, with soils classified as SCS soil type C.

Areas located in the upper portion of the San Jacinto watershed, above Mystic Lake showed a distinctively different hydrologic signature than areas below the Lake. This area is predominantly forested and characterized by hydrologic group C soils. While the rest of the watershed is characterized by very little or no baseflow during dry-weather conditions and very quick recessions of ground water, the area above Mystic Lake shows more or less sustained baseflow throughout the year and gradual recession of groundwater. Based on observed flow data at USGS flow gage 11069500, located below Lake Hemet in the upper portion of the watershed, recession rates in this area average approximately 76 percent for the period 1/1/1990–4/6/2010. A recession rate of 76 percent means that after a peak storm flow event approximately 76 percent of the flow remains in the stream channel the next day. In contrast, observed flows at gaging stations in the rest of the watershed had an average recession rate of approximately 33 percent, meaning that little or no base flow exists after a rainfall event.

Figure 2-16 and Figure 2-17 show the hydrograph separation of observed stream flow for 10/1/2004–9/30/2005 at USGS gage 11069500 and USGS 11070270 using the Fixed Interval, Sliding Interval, and Local-Minimum methods (Pettyjohn and Henning 1979). All three methods are used to estimate the groundwater portion of total stream flow. As described above, USGS gage 11069500 is located in the area above Mystic Lake in the upper portion of the watershed and USGS 11070270 is located on the Perris Valley Storm Drain in a mixed land use area of the watershed (see Figure 2-19). As can be seen, flows at USGS 11069500 predominantly consist of ground water flow that gradually recedes over time. In contrast, flows at USGS 11070270 for the same time period show the majority of flow to be associated with storm water runoff that creates large flashy storm peaks with little or no associated ground water flow. Based on these and similar observations throughout the watershed, a separate set of hydrologic parameters (parameter group 6) was developed for C soils in the area above Mystic Lake. Separate hydrologic parameters were not developed for B soils in this area for two reasons:

1) The vast majority of the soils in this area are classified as hydrologic group C
2) The B soils in this area are characterized by significantly greater areas of developed land uses, which are associated with the quick groundwater recessions and flashy storm response observed throughout the rest of the watershed

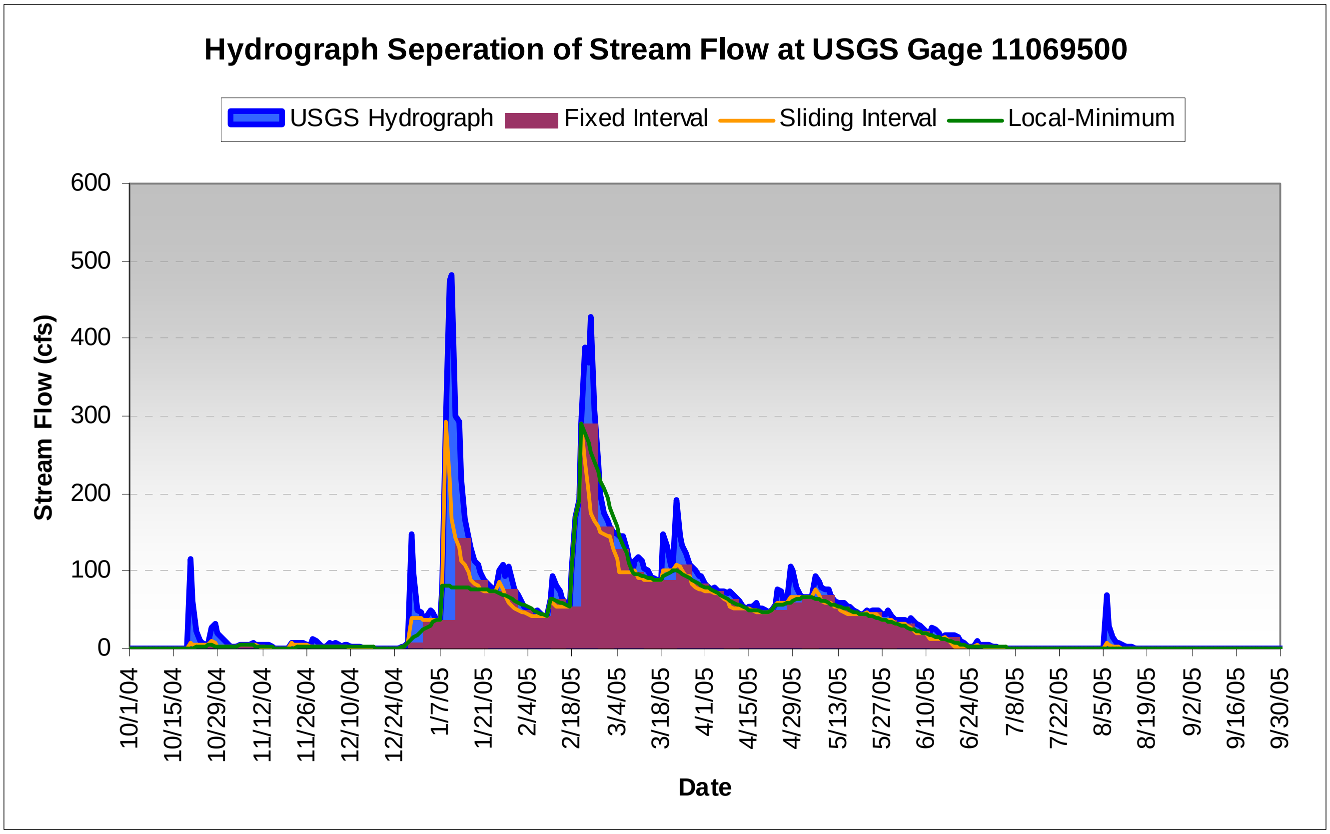

Figure 2-16. Hydrograph separation of stream flow at USGS 11069500

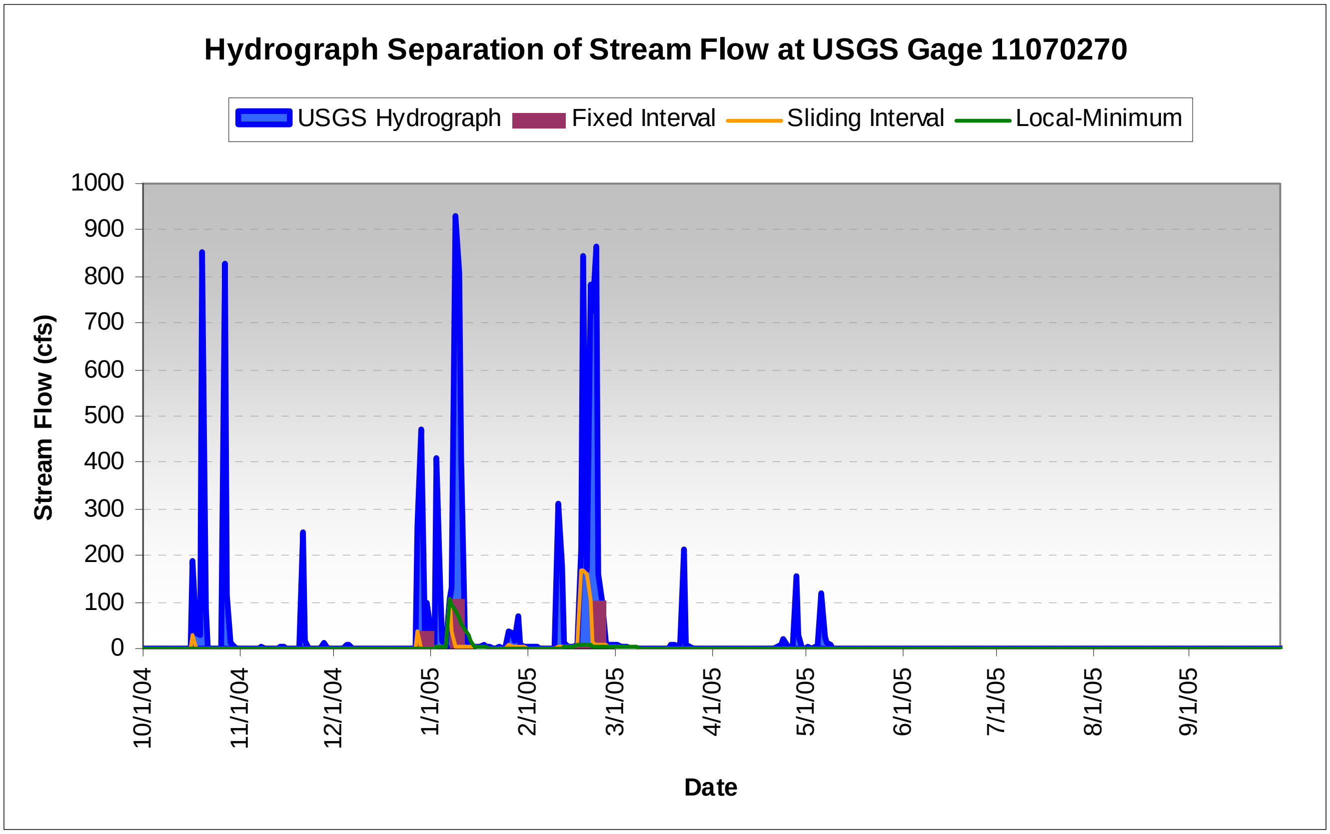

Figure 2-17. Hydrograph separation of stream flow at USGS 11070270

Areas draining to Salt Creek in the lower portion of the San Jacinto watershed also showed a distinctively different hydrologic signature than the remaining areas. Although the groundwater recession for this area is slightly lower than what is observed for other areas of the watershed (approximately 30 percent), the major difference is found in the unit-area flows for the area.

For the time period 1/1/2000–2/28/2010, the average unit area flows for USGS gages 11070270, 11070365, and 11069500 (see Figure 2-19) were between 44–59 acre-feet/mi^2/yr. For USGS 11070465 located on Salt Creek, the unit area flow for the same time period is approximately 18 acre-feet/mi^2/yr. It is not currently known what is causing the relatively low observed flows at Salt Creek. Note that the quality of the observed flow data collected at gage 11070465 was rated poor by the USGS. In addition, flow in the stream is partly regulated by the Paloma Valley Reservoir and diversions for irrigation and domestic use also occur at times. No data were available to represent these hydro-modifications during the time of model development. Based on the differences in unit-area flows and the influence of hydro-modifications in the area, a separate set of hydrologic parameters (parameter group 5) was developed for C soils in the area. This entire area is characterized by group C soils.

Including the two hydrological distinct areas described above, 5 sets of hydrologic parameters were used in the model. These are:

1) General hydrologic B type soils (parameter group 2)
2) General hydrologic C type soils (parameter group 3)
3) General hydrologic D type soils (parameter group 4)
4) Hydrologic C type soils in areas draining to Salt Creek (parameter group 5)
5) Hydrologic C type soils in the upper portion of the watershed draining to Mystic Lake (parameter group 6)

2.2.2.4 Pollutant Representation

The primary pollutants represented in the watershed model include total nitrogen and total phosphorus. These pollutants were originally modeled in the 2003 study. If deemed necessary to support future efforts, additional parameters may be added, including individual nutrient components, such as ammonia, nitrate-nitrite, inorganic nitrogen, total kjeldahl nitrogen, orthophosphate, and inorganic phosphorus, as well as sediment. Loading processes for all pollutants were represented for each land unit using the LSPC PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules, which are identical to those in HSPF. These modules simulate the accumulation of pollutants during dry periods and the washoff of pollutants during storm events. Similar to the 2003 modeling study, total nitrogen and total phosphorus were represented as conservative constituents with a constant decay rate. Pollutants were not simulated as associated with sediments, therefore, instream hydrodynamics do not significantly affect instream concentrations and estimated loads. This simplified approach was used initially in the 2003 study and was retained for the model updates.

2.2.2.4.1 Land Loads

Starting values for parameters relating to land-use-specific accumulation rates, buildup limits, and assigned interflow and groundwater concentrations were derived from literature (Haith and Shoemaker 1987; Novotny and Olem 1994; Maidment; U.S. Forest Service 2010) except for cropland areas where assumptions were made from regional data for land application of manure (described later in this section). Starting literature values for the applicable land uses were all taken from the 2003 modeling study except for forested areas. These were provided by the U.S. Forest Service, which compiled a range of nutrient accumulation rates for western forests (U.S. Forest Service 2010). Starting values served as baseline conditions for water quality calibration; the appropriateness of these values to the updated model representation of the San Jacinto River watershed was validated and refined through the calibration process. Although atmospheric deposition may be an issue in the watershed, it was not explicitly simulated in the watershed model. It was, however, represented implicitly in the model through use of the land use- and pollutant-specific accumulation rates.

As mentioned, local information was required to assist in the estimation of nitrogen and phosphorus loading attributed to the land application of manure in agricultural areas. Annual manure application to cropland areas is estimated at 12 dry tons per acre (SWQCB and UCR 2009). From updated data collected by the San Jacinto Basin Resource Conservation District, the content of the manure loads were estimated at 30 pounds total nitrogen per ton of manure and 9.6 pounds total phosphorus per ton of manure. The resulting annual loads attributed to land application of manure are estimated at 0.99 lbs/acre of total nitrogen and 0.32 lbs/acre of total phosphorus. Build-up limits for these agricultural loads were determined through analysis of build-up times required to reach the theoretical limit and the calibration process described in the next section.

2.2.2.4.2 Septic Loads

As discussed in Section 3.2.3 in the 2003 modeling report, failed septic systems are believed to be major contributors to nutrient loads in the San Jacinto River basin (SAWPA 2003). To quantify these impacts, the same assumptions and methodologies used in the 2003 modeling study were applied to the updated model so that loadings could be simulated dynamically. The discussion below reviews these assumptions and methodologies.

A crucial step in the quantification of septic loads was the identification of all septic systems in the San Jacinto River watershed that are at risk for failure and are in close proximity to water bodies where associated loads can be transported. Using a similar method to that used by the Elsinore Valley Municipal Water District (EVMWD) for identification of land parcels on septic systems in the vicinity of Lake Elsinore, septic systems outside of the EVMWD boundaries were assessed. Land parcel data was obtained from Riverside County and all vacant, non-residential, and non-urban parcels were removed from analysis. The sewer main coverage was provided by EVMWD for guidance in assessing sewered areas. However, the sewer main coverage did not provide detail regarding the layout and extent of the collection systems, so the sewer main was assumed to provide service to an area extending 1500 meters to either side of each sewer main (SAWPA 2003).

All parcels located within this 1500-m buffer zone were assumed to be sewered, while the remaining parcels were assumed to require septic systems for sewage disposal. Once assumptions were made regarding the location of septic systems, those systems located within 500 feet of streams (BASINS Reach file, version 3) were selected and identified as posing a potential risk to direct contamination of surface water (resulting from rainfall events). These results were combined with those systems identified by EVMWD to provide an overall spatial distribution of septic systems throughout the San Jacinto River basin that are at risk of failure and may result in transport of pollutants to Lake Elsinore and Canyon Lake during rainfall events (Figure 2-18) (SAWPA 2003).

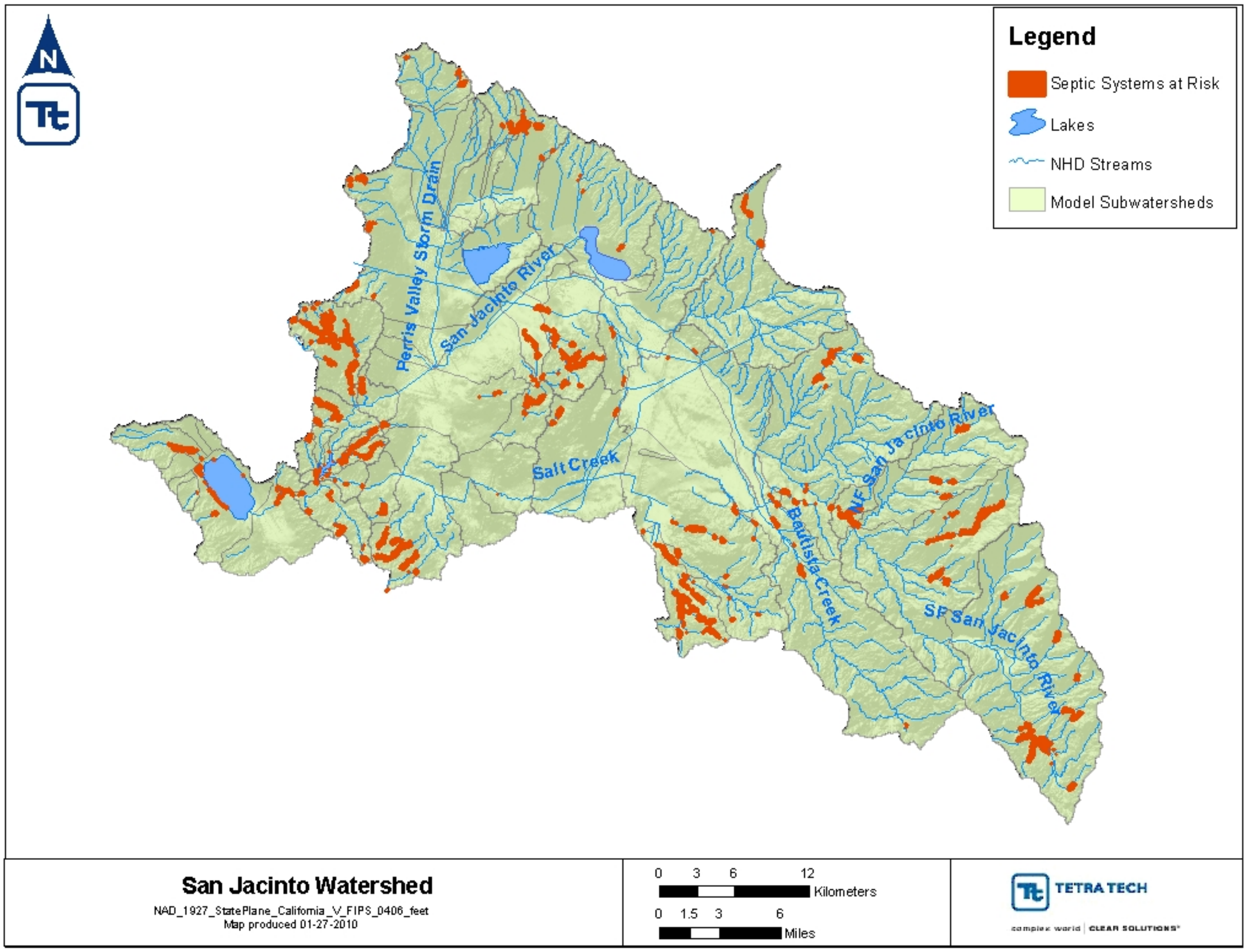

Figure 2-18. Septic systems at risk of failure and contamination of surface waters

To quantify the waste loads from failed septic systems, the following assumptions were gathered from previous studies, literature values, and local expertise (SAWPA 2003).

- Each system was assumed to provide service to a single household, with an average occupancy of 3.5 persons (Black & Veatch, 1994)
- Total wastewater flow per person is 50 gallons per day (Black & Veatch, 1994)
- 10 percent of parcels are vacant (Black & Veatch, 1994)
- Septic concentrations of 10 mg/L total phosphorus and 50 mg/L total kjeldahl nitrogen (Black & Veatch, 1994; verified by Mike Gardner, EMWD)
- 30 percent failure rate of septic systems (National Small Flows Clearinghouse, 1993)

- Ratio of total nitrogen to total kjeldahl nitrogen assumed 2.67 (estimated from typical waste concentrations reported in Metcalf and Eddy, 1991)

For each subwatershed shown in Figure 2-6, an annual load of total nitrogen and total phosphorus was estimated. Since transport of these loads is believed to occur primarily during rainfall periods when stream flow and groundwater are most prevalent, the annual septic loads were represented dynamically in the watershed model as a function of rainfall. For this to be accomplished, septic contributions were specified using an artificial land use, with all flow routed through the interflow routines of the PWATER functions of the model. Due to some changes in the LSPC algorithms since the time of the 2003 model development, a new calibration was developed to route all septic flows through interflow. Septic source contributions were calibrated by adjusting the artificial land use area and pollutant concentrations so that annual average loads over the 20-year simulation period matched the estimated loads. This approach is analogous to including a separate point source with time-variable flow and pollutant concentrations, however, it capitalizes on the rainfall-based processes simulated by the model.

Based on the changes in the septic land use calibration, the total septic land use area changed for the 2010 model updates. The new calibration routed flow through interflow much more efficiently, therefore, only 76 acres of the septic land use was required to achieve the calculated septic loads for each subwatershed. The 2003 model required 856 acres.

2.2.2.5 Water body Representation

Modeling the entire San Jacinto River watershed required routing flow and pollutants through numerous stream networks. These stream networks connect all of the subwatersheds represented in the watershed model. Routing required the development of rating curves for major streams in the networks for the model to simulate hydraulic processes. Hydraulic formulations typically estimate in-stream flow, water depth, and velocity using continuity and momentum equations. Stream characteristics were gathered from various USGS monitored streams in the region to develop rating curves for one representative stream in each subwatershed. Streams were assumed to be completely-mixed, one-dimensional segments with a trapezoidal cross-section. The rating curves consist of a representative depth-outflow-volume-surface area relationship. In-stream flow calculations are made using the HYDR (hydraulic behavior simulation) module in LSPC, which is identical to the HYDR module in HSPF. In-stream pollutant transport is performed using the ADCALC (advective calculations for constituents) and GQUAL (generalized quality constituent simulation) modules.

The representation of Mystic Lake was updated for the current study. Stage-storage data available for Mystic Lake provided by RCFCWCD were used to represent the storage characteristics of the lake up to a water surface elevation of 1,425 feet. The 1,425 foot threshold represents the maximum storage capacity of the lake, above which over-flows occur. Overflows above this point were estimated using the rectangular weir equation, while additional storage was estimated using a simplified trapezoidal flood plain. It is assumed that the data provided by RCFCWCD accounts for lake subsidence that has occurred over time.

The outflow channel dimensions of Mystic Lake were taken from HECRAS files provided by RCFCWCD and used as starting point to size the outfall for the weir equation. Infiltration losses from the lake were estimated based on the surface area of the lake and typical wet infiltration rates for hydrologic soil group B, which underlies the lake.

To represent Lake Hemet and outflows from the dam, the stream routing functions of LSPC were modified to allow storage and overflow of water using a simplified trapezoidal volume representative of the lake’s volume (8,100 acre-ft), with dam overflow calculated using simple weir equations. Lake volumes and weir overflow functions were adjusted during the hydrology calibration (see Section 2.2.3.1) to better match observed flows.

To represent the four regional storage BMPs in the watershed model, rating curves available from as-built design drawings provided by the RCFCWCD were used to establish the stage, storage, and outflow relationships. The rating curves were assigned to the model reaches of their respective subwatersheds (Figure 2-5).

2.2.3 Model Calibration and Validation

After reconfiguring the San Jacinto River watershed model, model calibration and validation were performed for the extended 20-year modeling period (7/1/1989–7/31/2009). Re-calibration of the watershed model was required because the updated datasets, particularly land use and weather data, significantly altered the model simulations. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Model calibration was performed at multiple locations throughout the watershed. This approach ensured that heterogeneities were accurately represented. Model validation was performed to test the calibrated parameters at different locations or for different time periods, without further adjustment. Upon completion of the calibration and validation at selected locations, a calibrated dataset containing parameter values for each modeled land use and pollutant was developed.

Calibration and validation were completed by comparing time-series model results to monitoring data. Output from the watershed model was in the form of daily average flow and concentrations for the modeled nutrients for each of the subwatersheds. Flow monitoring data are available at USGS flow gaging stations located throughout the watershed, while water quality monitoring data are available at these locations and additional locations where flow was not monitored.

2.2.3.1 Hydrology Calibration

Hydrology was the first model component calibrated and involved a comparison of observed data from in-stream USGS flow gaging stations to modeled in-stream flow. Key hydrologic parameters were adjusted to reproduce observed flow patterns and magnitudes as closely as possible. USGS gage stations considered for use in model calibration are shown in Figure 2-19.

The period of record for each gage varies, with stations 11070270, 11069500, and 11070500 having the most years, and stations 11070365, 11070210, and 11070465 (all three located just upstream of Canyon Lake) limited to data collected after water year (WY) 2001 (Table 2-7). Station 11070500, located below Canyon Lake, is greatly influenced by Canyon Lake dam overflows during storm flows, therefore, calibration to this gage was not used for the watershed model. Also, USGS gage 11070465, located on Salt Creek at Murrieta Rd. near Sun City, CA was rated as having poor record quality, therefore, the review of the calibrations and validations for this gage should be assessed accordingly.

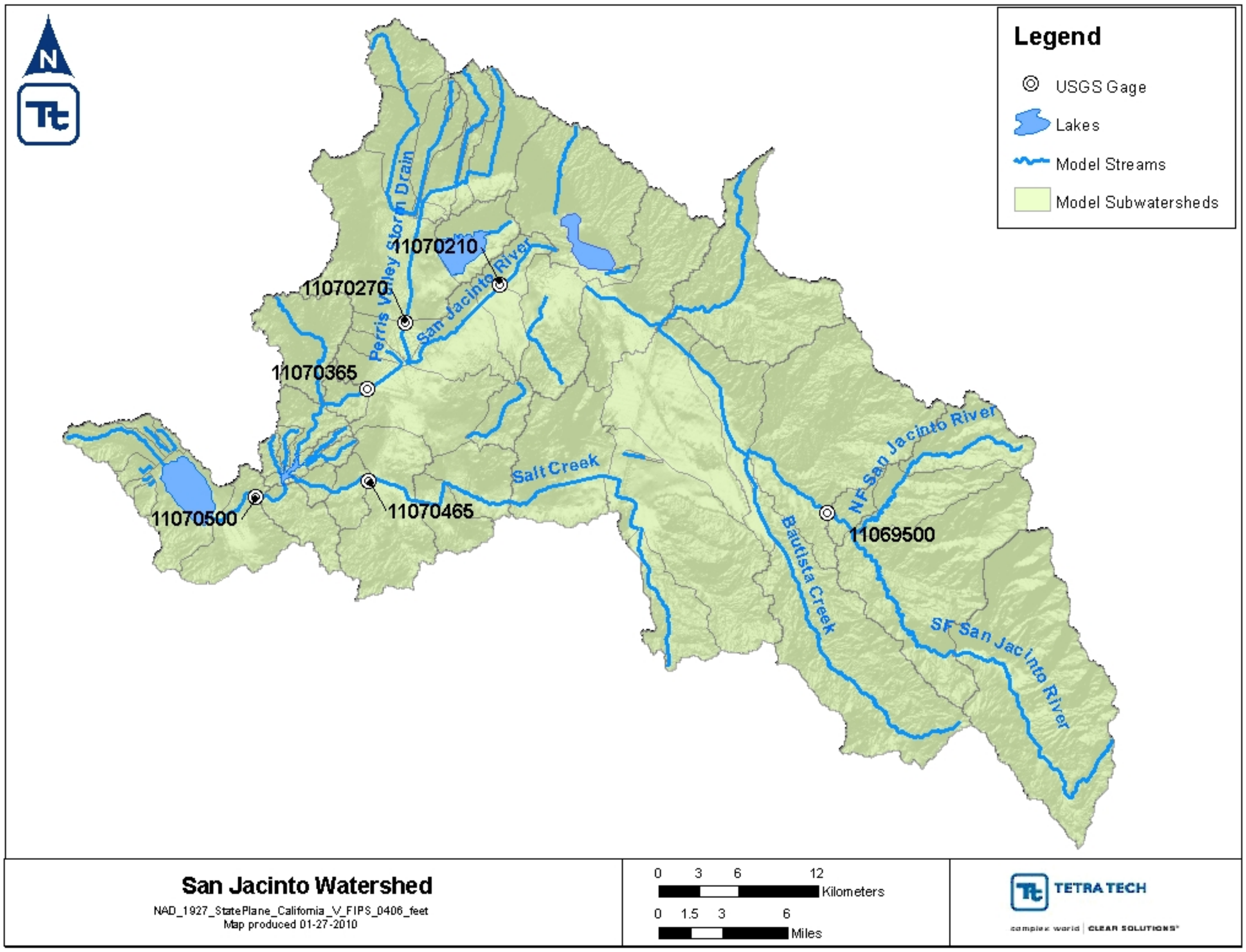

Figure 2-19. USGS stream flow gages

Calibration time periods were selected based on an examination of annual precipitation variability and the availability of observation data. In particular, the period 10/1/2004–9/30/2005 was selected as a calibration period because of the known El Nino storm that occurred during this time. This period captures hydrologic conditions associated with very heavy rainfall, which would represent the worst case scenario for nutrient loading in the watershed. The model was then validated for other time periods to ensure that the model calibration also accurately represented low and medium flow conditions as well. Details regarding location, period of historical record, and selected periods for calibration and validation are listed for each gage in Table 2-7.

Table 2-7. USGS station descriptions

Station Number	Station name	Historical record	Selected calibration period	Selected validation period
11070500	San Jacinto River near Elsinore, CA	1/1/1916–present	None (influenced by Canyon Lake overflow)	
11070365	San Jacinto River near Sun City, CA	8/25/2000–present	None	10/1/2000–9/30/2008
11070270	Perris Valley Storm Drain at Nuevo Rd. near Perris, CA	10/1/1969–9/30/1997; 10/1/1998–present	10/1/2004–9/30/2005	10/1/1993–9/30/1995
11070210	San Jacinto River at Ramona Expressway near Lakeview, CA	8/23/2000–9/30/2009	None	10/1/2001–9/30/2008

Station Number	Station name	Historical record	Selected calibration period	Selected validation period
11069500	San Jacinto River near San Jacinto, CA	10/1/1920–9/30/1991; 10/1/1996–present	10/1/2004–9/30/2005	10/1/2002–9/30/2004
11070465	Salt Creek at Murrieta Rd. near Sun City, CA	10/1/1983–9/30/1985; 10/1/2000–present	10/1/2004–9/30/2005	10/1/2005–9/30/2006

Key considerations in the hydrology calibration included the overall water balance, the high-flow/low-flow distribution, storm flows, and seasonal variation. Two criteria for goodness of fit were used for calibration: graphical comparison and the relative error method. Graphical comparisons are extremely useful for judging the results of model calibration; time-variable plots of observed versus modeled flow provide insight into the model's representation of storm hydrographs, baseflow recession, time distributions, and other pertinent factors often overlooked by statistical comparisons. The relative error method was used to further support the goodness of fit evaluation through a quantitative comparison. A small relative error indicates a better goodness of fit for calibration.

As in the 2003 study, after calibrating hydrology at multiple locations, independent sets of hydrologic parameters were developed and applied to the remaining subwatersheds in the basin. Validation of these hydrologic parameters was made through a comparison of model output to observed data at either separate time periods at calibration locations or additional locations in the watershed (USGS gages 11070365 and 11070210). The additional validation locations represented larger watershed areas and essentially validated application of the hydrologic parameters derived from the calibration of smaller subwatersheds. Validation was assessed in a similar manner to calibration.

In addition, the 2010 model calibration error statistics for the most recent continuous shared flow record made up of complete water years (referred to as the calibrated long-term simulation) at calibration stations were compared to error statistics for calibration periods selected for the 2003 watershed model at the same gages. An example of the most recent continuous shared flow record made up of complete water years would be 10/1/1996–9/30/2008 for USGS gage 11069500, since the most recent continuous observed flow record is 10/1/1996–present and the model simulation period is 7/1/1989–7/31/2009. This comparison can be thought of as a check as to whether the updated model maintained or improved on the quality of the original 2003 model simulations. If the updated calibrated long-term simulation results are comparable or better than 2003 calibration results, model performance can be said to have been maintained or improved.

Figure 2-20 shows the location of USGS gage 11069500 in the headwaters of the San Jacinto River. Note that calibration parameters specific to conditions in this area were developed based on the considerations discussed in Section 2.2.2.3. The predominant land use for this portion of the watershed is forested. This area represents the headwaters region (Group 6 hydrologic parameters) and was also descriptive of the hydrologic characteristics associated with a predominantly forested area. Note that a large portion of this drainage area is impounded by the Lake Hemet dam and the area also includes several diversions (USGS 2008). Dam storage and overflow characteristics have been estimated as discussed in Section 2.2.2.5 and no information was available concerning diversions at the time of model development. As would be expected, the technical uncertainty associated with these factors may have impacted the accuracy of the calibration.

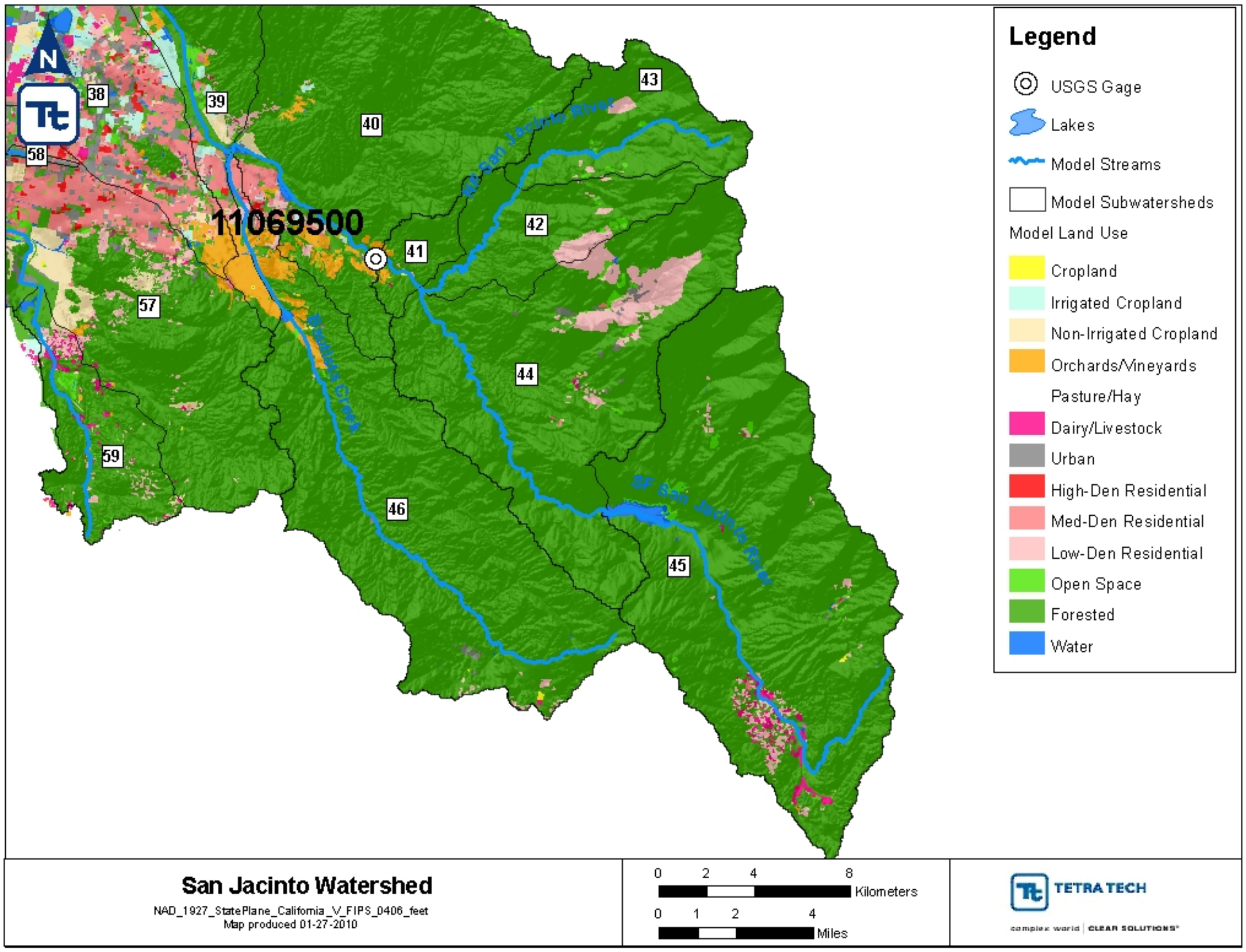

Figure 2-20. USGS gage 11069500 calibration area

Figure 2-21 depicts the time-variable plot used for model calibration at this gage (output from subwatershed 41). As can be seen from the plot, a large storm occurred in the winter of 2005 that required accurate prediction. This storm was associated with the cyclical El Nino event that tends to cause large precipitation events in southern California. The relative error of the model is reported in Table 2-8 for seasons and flow magnitudes, and it includes an overall comparison of predicted and observed flow volumes.

The percent error in predicted versus observed total volume was about 3.2 percent, with the model over-predicting the top 10 percent highest flows by 11.2 percent. Seasonal statistics show that the model over-predicts fall and winter flow volumes, while under-predicting spring and summer volumes, but, in general, errors are within or close to the recommended error percentage ranges. This discrepancy between the observed and modeled hydrographs is likely due to the difference between the magnitude of measured rainfall data used to drive the model and the amount of rain that actually fell in the watershed. The simplified representation of the Lake Hemet dam may also be impacting the model results.

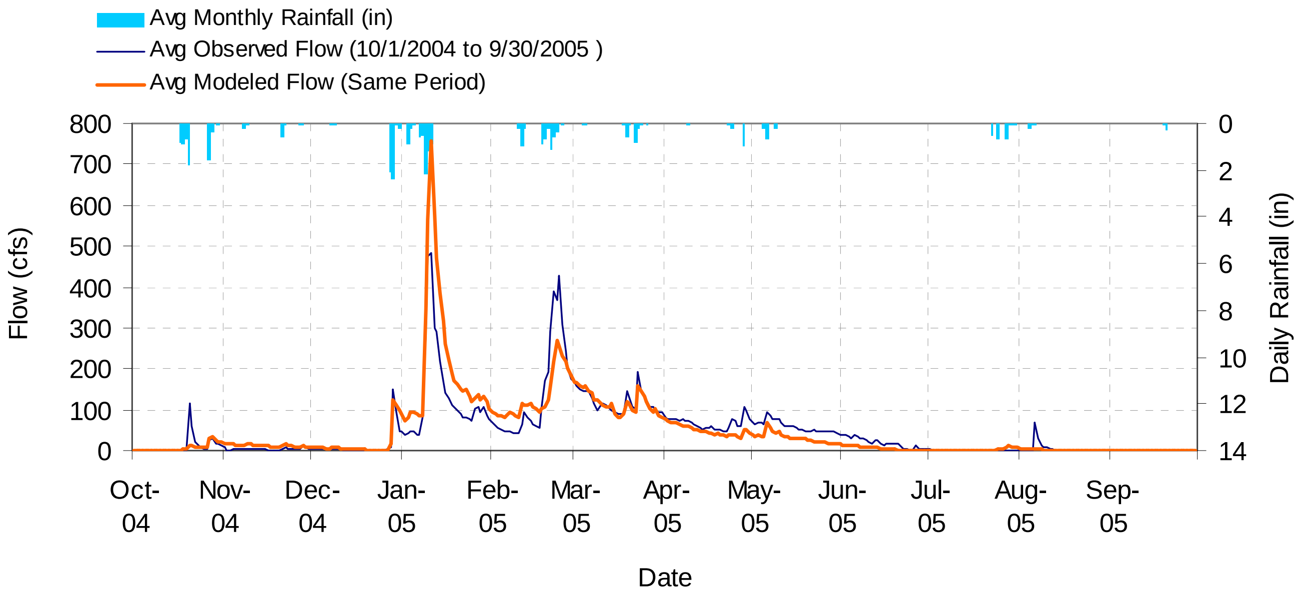

Figure 2-21. Graphical analysis of USGS 11069500 calibration period

Table 2-8. Relative error analysis of USGS 11069500 calibration period

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 41 1-Year Analysis Period: 10/1/2004 - 9/30/2005 Flow volumes are normalized, with total observed as 100		**USGS 11069500 San Jacinto River near San Jacinto, CA** Hydrologic Unit Code: 18070202 Latitude: 33 44 17 Longitude: 116 49 59 Drainage Area (sq-mi): 142	
Total Simulated In-stream Flow:	**103.21**	Total Observed In-stream Flow:	**100.00**
Total of simulated highest 10% flows:	**50.39**	Total of Observed highest 10% flows:	**45.31**
Total of Simulated lowest 50% flows:	**3.01**	Total of Observed Lowest 50% flows:	**2.29**
Simulated Summer Flow Volume (months 7-9):	**0.58**	Observed Summer Flow Volume (7-9):	**0.98**
Simulated Fall Flow Volume (months 10-12):	**6.16**	Observed Fall Flow Volume (10-12):	**4.87**
Simulated Winter Flow Volume (months 1-3):	**81.11**	Observed Winter Flow Volume (1-3):	**68.60**
Simulated Spring Flow Volume (months 4-6):	**15.36**	Observed Spring Flow Volume (4-6):	**25.55**
Total Simulated Storm Volume:	**7.83**	Total Observed Storm Volume:	**9.66**
Simulated Summer Storm Volume (7-9):	**0.11**	Observed Summer Storm Volume (7-9):	**0.41**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*1995-1999*	*2000-2004*
Error in total volume:	3.21	10	-1.43	7.35
Error in 50% lowest flows:	31.48	10	-1.60	-3.91
Error in 10% highest flows:	11.20	15	2.26	1.75
Seasonal volume error - Summer:	-40.63	30	13.27	-2.52
Seasonal volume error - Fall:	26.37	30	4.49	12.42
Seasonal volume error - Winter:	18.24	30	-18.21	13.31
Seasonal volume error - Spring:	-39.89	30	1.90	6.11
Error in storm volumes:	-18.95	20	1.13	12.07
Error in summer storm volumes:	-74.43	50	3.16	15.42

To validate the hydrologic parameters derived through the calibration process and to check the ability of the model to simulate smaller storms, a second time period was selected for comparison of model results. Figure 2-22 shows the results of the model validation for the period of 10/1/2002–9/30/2004. Although model results under-predicted peak flows for the storm, the general shape of the modeled hydrograph compared well with the observed storm hydrograph. The overall calibration process accounted for both hydrologic regimes without substantially causing a gross misrepresentation of either.

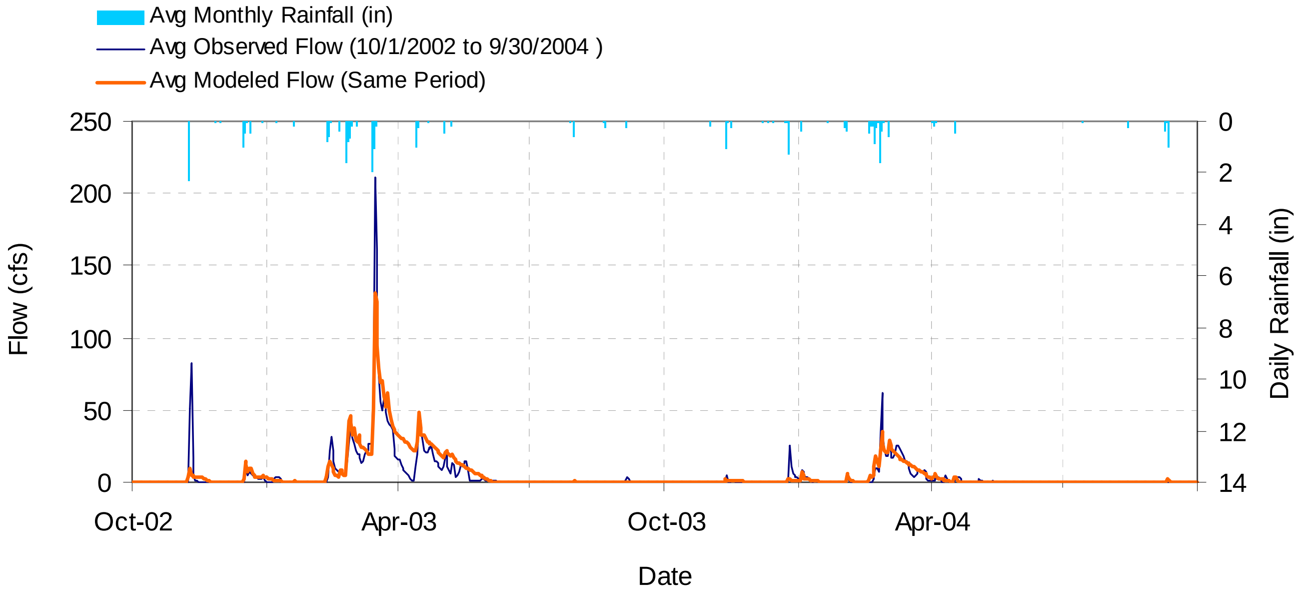

Figure 2-22. Graphical analysis of USGS 11069500 validation period

A comparison of the 2010 calibrated long-term simulation (10/1/1996–9/30/2008) and the 2003 calibration (10/1/1996–9/30/2001) error statistics for USGS 11069500 is presented in Table 2-9. Calibration errors that are statistically better are highlighted in yellow. In general the two calibrations are comparable. While the 2010 model shows a greater under prediction of total simulated volume, seasonal volumes are more accurately simulated for all seasons except spring which is slightly more accurately simulated by the 2003 model. Because summer volumes make up such a small percentage of overall flow, the major reason why the 2003 model shows better total volume simulations is its large over prediction of winter volumes, which make up the vast majority of total volume. The 2010 long-term simulation of winter volumes is fairly accurate, showing only a 5.7 percent error.

Table 2-9. Comparison of error statistics for the 2010 calibrated long-term simulation and the 2003 calibration simulation at USGS 11069500

USGS Gage	Errors (Simulated-Observed)	Error Statistics	
		2010 Long-term simulation	2003 Calibration simulation
11069500	Error in total volume:	-13.78	-0.25
	Error in 50% lowest flows:	-99.74	-98.25
	Error in 10% highest flows:	-17.84	4.03
	Seasonal volume error - Summer:	49.00	-86.47
	Seasonal volume error - Fall:	-22.78	-30.37
	Seasonal volume error - Winter:	5.66	44.13
	Seasonal volume error - Spring:	-41.97	-36.70
	Error in storm volumes:	-43.62	-18.75
	Error in summer storm volumes:	12.58	-86.08

Figure 2-23 depicts the location of USGS gage 11070270 on the Perris Valley Storm Drain in the northwest portion of the San Jacinto River watershed. As seen in the figure, the watershed (including subwatersheds 19–30) is relatively mixed with urban and residential areas in the headwaters and cropland areas in the bottom portion. The watershed is a mixture of Group 2 (Class B soils) and Group 3 (Class C soils) hydrologic parameters.

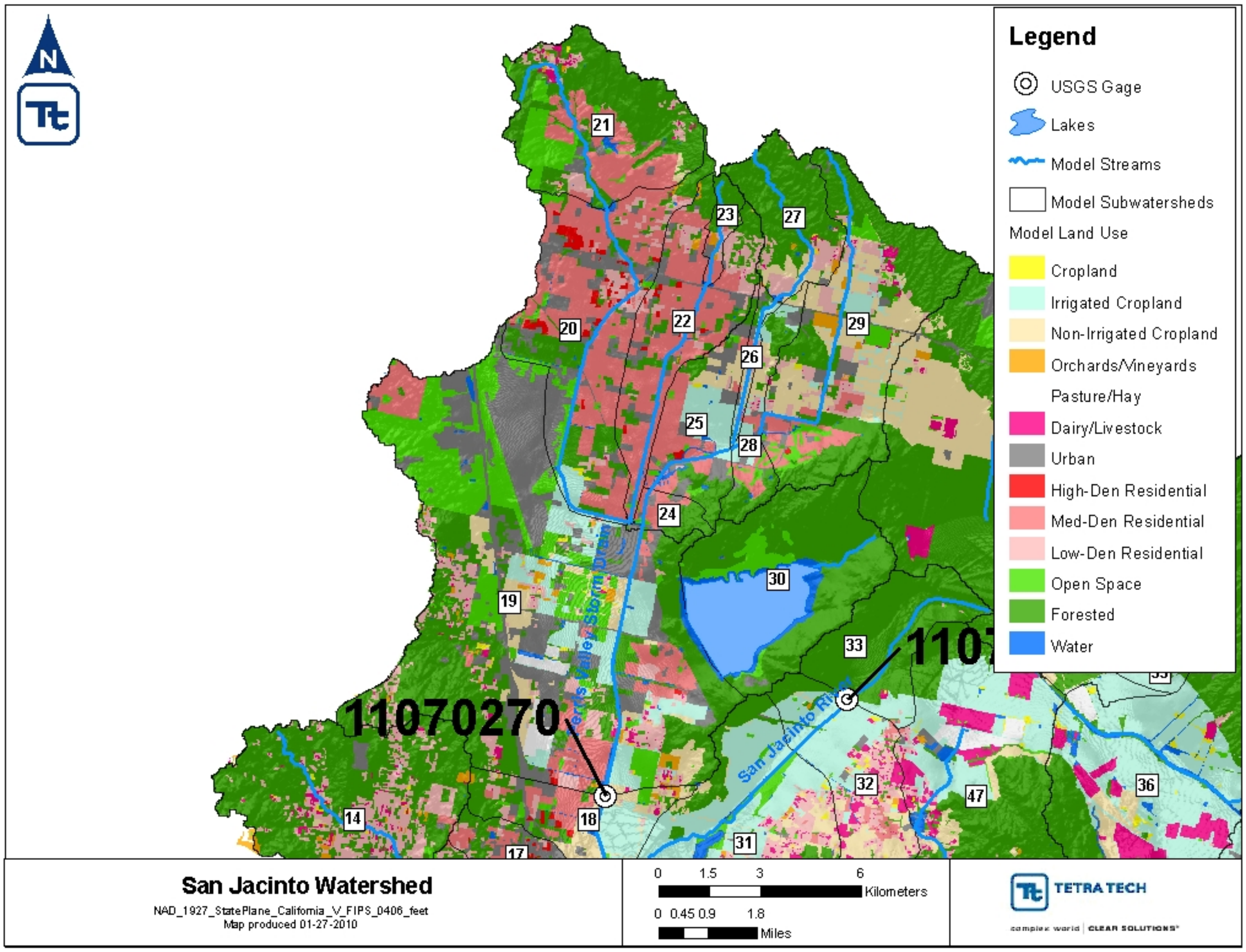

Figure 2-23. USGS gage 11070270 calibration area

Figure 2-24 depicts the time-variable plot used for model calibration at this gage (output from subwatershed 20). As can be seen from the plot, runoff from the region follows the hydrologic response seen throughout much of the San Jacinto watershed, where flow is flashy with sharp increases followed by equally sharp recessions. Flow is virtually non-existent for dry periods. The relative error analysis for calibration at this station is reported in Table 2-10, and showed only a 7.3 percent error between predicted and observed total volumes, and a 7.2 percent error in the highest 10 percent of predicted and observed stream flows. All seasonal volume errors were within the recommended ranges, except for summer. These flows are dominated by very low flows (0.16 percent of observed total flow for the calibration period), therefore small differences in flow volume are exaggerated in the error statistics.

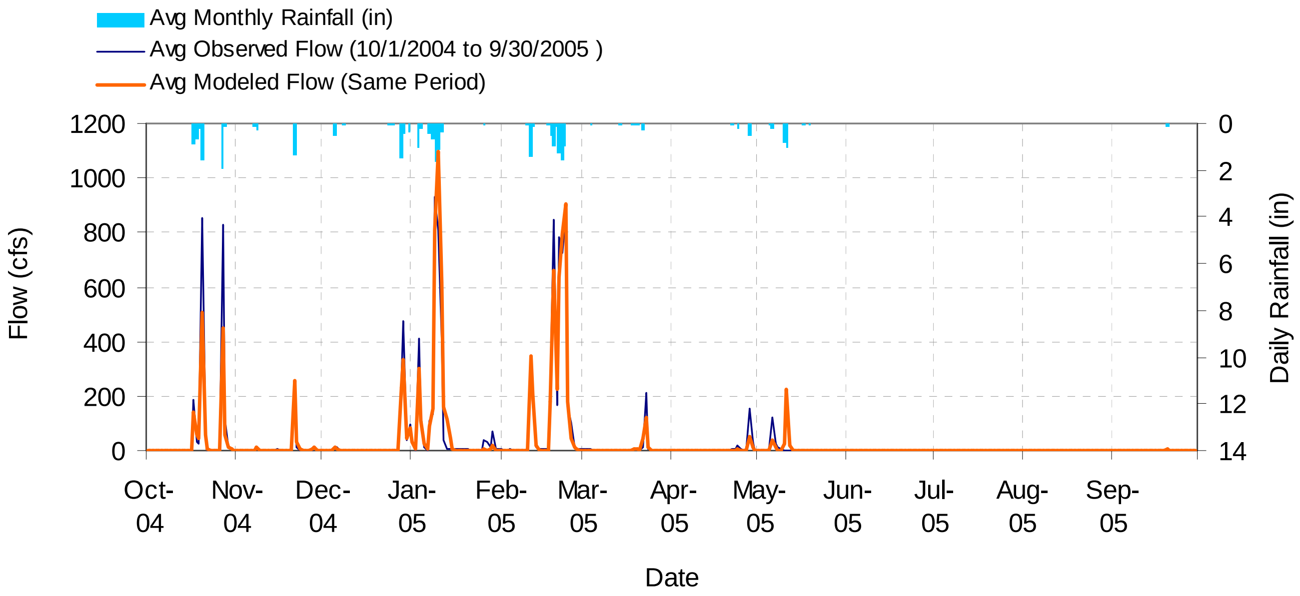

Figure 2-24. Graphical analysis of USGS 11070270 calibration period

Table 2-10. Relative error analysis of USGS 11070270 calibration period

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 19		**USGS 11070270 Perris Valley Storm Drain at Nuevo Rd., near Perris, CA**	
1-Year Analysis Period: 10/1/2004 - 9/30/2005 Flow volumes are normalized, with total observed as 100		Hydrologic Unit Code: 18070202 Latitude: 33 48 04 Longitude: 117 12 19 Drainage Area (sq-mi): 93.3	
Total Simulated In-stream Flow:	**92.68**	Total Observed In-stream Flow:	**100.00**
Total of simulated highest 10% flows:	**88.85**	Total of Observed highest 10% flows:	**95.78**
Total of Simulated lowest 50% flows:	**0.00**	Total of Observed Lowest 50% flows:	**0.11**
Simulated Summer Flow Volume (months 7-9):	**0.06**	Observed Summer Flow Volume (7-9):	**0.16**
Simulated Fall Flow Volume (months 10-12):	**20.49**	Observed Fall Flow Volume (10-12):	**28.50**
Simulated Winter Flow Volume (months 1-3):	**68.70**	Observed Winter Flow Volume (1-3):	**67.87**
Simulated Spring Flow Volume (months 4-6):	**3.43**	Observed Spring Flow Volume (4-6):	**3.48**
Total Simulated Storm Volume:	**44.97**	Total Observed Storm Volume:	**55.70**
Simulated Summer Storm Volume (7-9):	**0.05**	Observed Summer Storm Volume (7-9):	**0.04**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*1995-1999*	*2000-2004*
Error in total volume:	-7.32	10	-1.43	7.35
Error in 50% lowest flows:	-99.20	10	-1.60	-3.91
Error in 10% highest flows:	-7.24	15	2.26	1.75
Seasonal volume error - Summer:	-60.20	30	13.27	-2.52
Seasonal volume error - Fall:	-28.11	30	4.49	12.42
Seasonal volume error - Winter:	1.23	30	-18.21	13.31
Seasonal volume error - Spring:	-1.46	30	1.90	6.11
Error in storm volumes:	-19.25	20	1.13	12.07
Error in summer storm volumes:	18.73	50	3.16	15.42

The validation period 10/1/1993–9/30/1995 at station 11070270 also showed a good fit to the observed flow data. Figure 2-25 shows the comparison of modeled and observed stream flows for this period. In general, both medium and large storm events are simulated accurately and groundwater recession matches the overall trend well, with little or no groundwater flow observed after rainfall events.

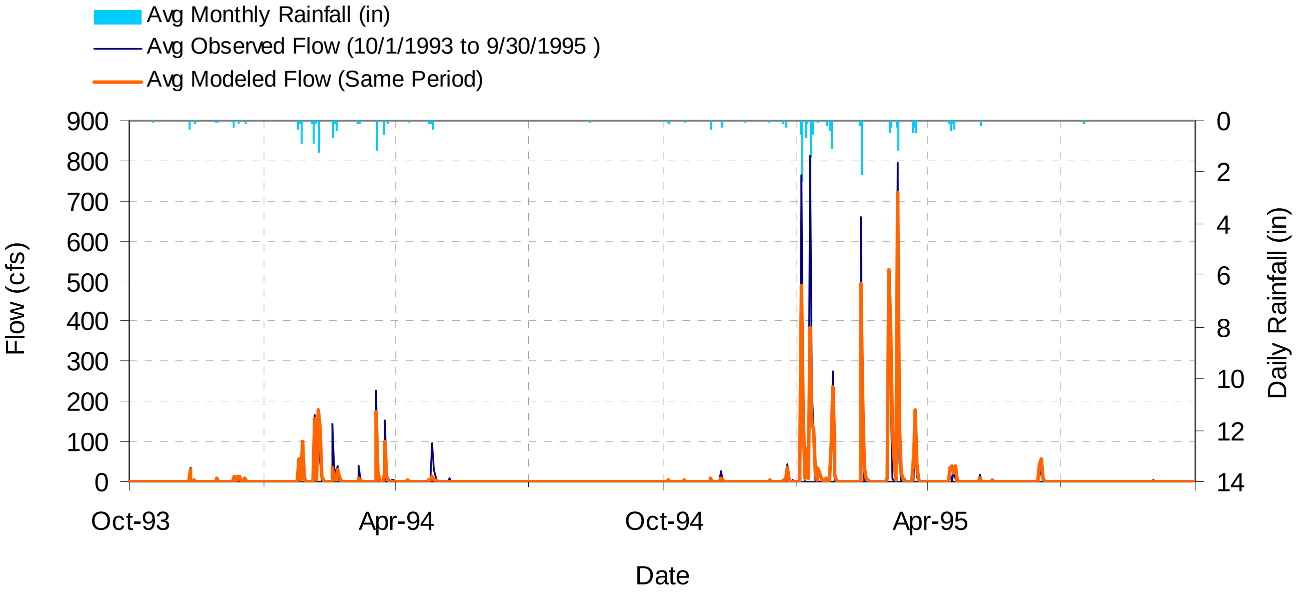

Figure 2-25. Graphical analysis of USGS 11070270 validation period

A comparison of the 2010 calibrated long-term simulation (10/1/1998–9/30/2008) and the 2003 calibration (1/1/1991–9/30/1997) error statistics for USGS 11070270 is presented in Table 2-11. Calibration errors that are statistically better are highlighted in yellow. In general, the 2010 long-term simulation results are significantly improved from the 2003 calibration simulation results. The 2010 model shows a more accurate simulation for every measure of model performance. The total volume error is only 3.8 percent and the 10 percent highest flows are also simulated within a 4 percent error. The greatest error percentage for the 2010 long-term simulation is for 50% lowest flows, which shows an error of approximately 100 percent. By comparison the error percentage for 50% flows in the 2003 calibrated simulation is orders of magnitude greater at over two million percent.

Table 2-11. Comparison of error statistics for the 2010 calibrated long-term simulation and the 2003 calibration simulation at USGS 11070270

USGS Gage	Errors (Simulated-Observed)	Error Statistics	
		2010 Long-term simulation	2003 Calibration simulation
11070270	Error in total volume:	3.80	9.98
	Error in 50% lowest flows:	-99.99	2141734.69
	Error in 10% highest flows:	3.87	4.96
	Seasonal volume error - Summer:	-49.77	70.21
	Seasonal volume error - Fall:	-10.30	-27.32
	Seasonal volume error - Winter:	5.43	10.65
	Seasonal volume error - Spring:	33.34	159.73
	Error in storm volumes:	-5.91	-32.24
	Error in summer storm volumes:	-24.80	-52.22

Figure 2-26 shows the location of USGS gage 1107465 on Salt Creek upstream of Canyon Lake at the base of the San Jacinto River watershed. Note that calibration parameters specific to conditions in this area were developed based on the considerations discussed in Section 2.2.2.3. The subwatersheds of this area (53–59) are characterized by a mix of land uses. This area represents a special area in the watershed (Group 5 hydrologic parameters) that had significantly lower unit-area flows than all other USGS flow gages and flow records for this gage were rated as poor by the USGS. In addition, flows in this area are influenced by diversions and the Paloma Valley

Reservoir, none of which data were available for at the time of model development. As would be expected, the technical uncertainty associated with these factors impacted the accuracy of the calibration.

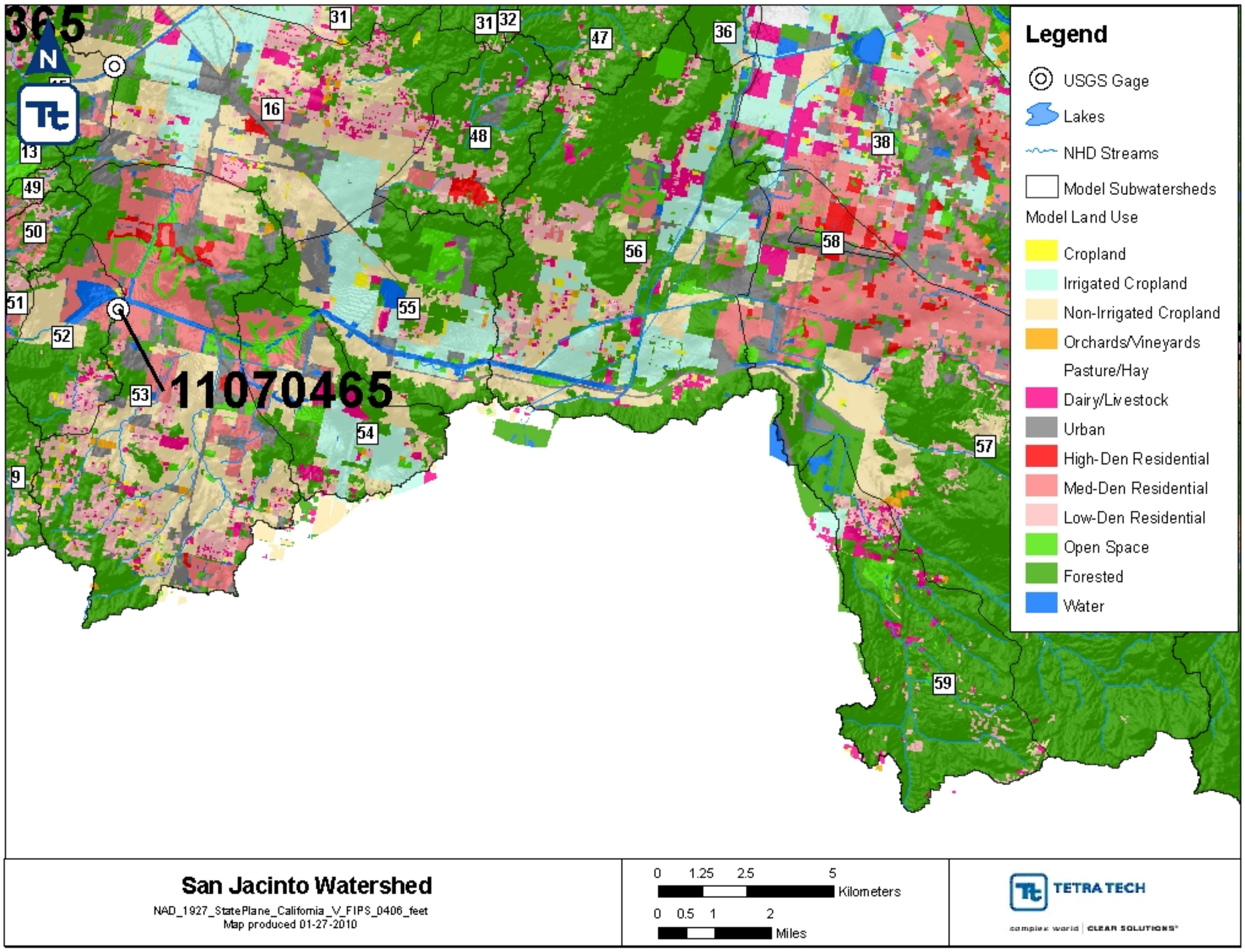

Figure 2-26. USGS gage 11070465 calibration area

Figure 2-27 depicts the time-variable plot used for model calibration at this gage (output from subwatershed 53). As can be seen from the plot, runoff from the region follows the flashy response seen at USGS 11070270 and the simulated flows match the observed trend well. Flow is very flashy with sharp increases followed by equally sharp recessions and flow is virtually non-existent for dry periods. The relative error analysis for calibration at this station is reported in Table 2-12, and shows a 21.8 percent error between predicted and observed total volumes, and a 28.5 percent error in the highest 10 percent of predicted and observed stream flows. Seasonal volume errors are similarly over-predicted, particularly spring volumes. Though these error values may seem high, compared with the previous model these volumes are a vast improvement (see Table 2-13). Flow data at this USGS gage are considered poor and unreliable, therefore the error statistics for the calibration at this gage should be considered tentative estimates based on the best available information.

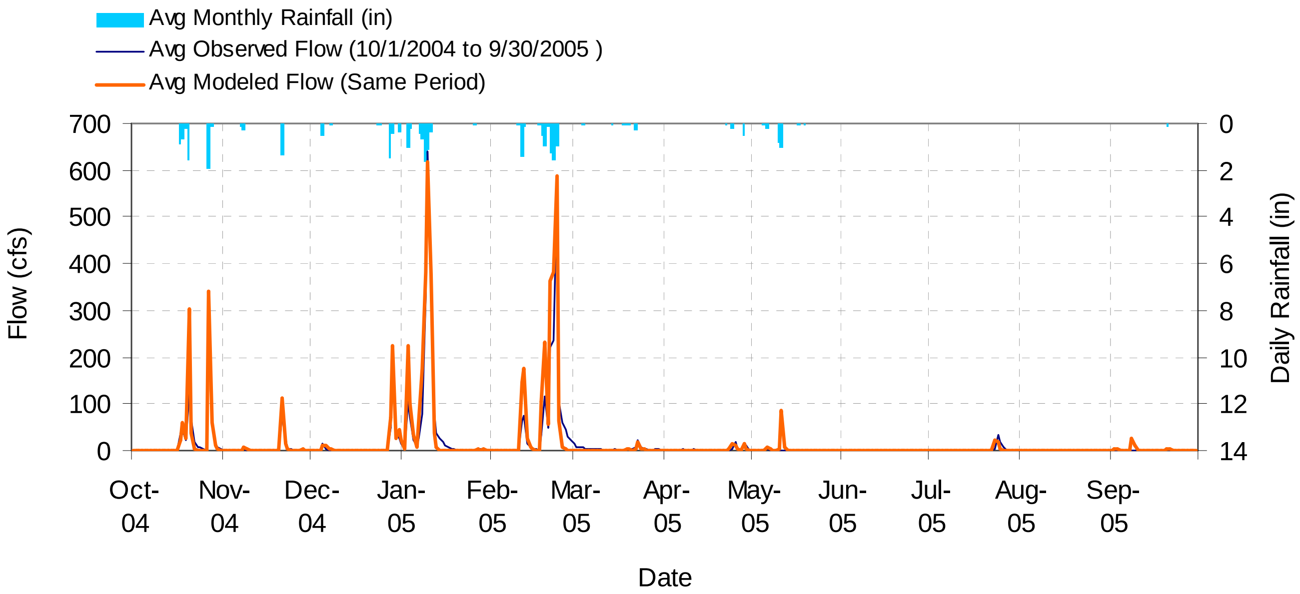

Figure 2-27. Graphical analysis of USGS 11070465 calibration period

Table 2-12. Relative error analysis of USGS 11070465 calibration period

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 53 1-Year Analysis Period: 10/1/2004 - 9/30/2005 Flow volumes are normalized, with total observed as 100		**USGS 11070465 USGS Home** Hydrologic Unit Code: Latitude: Longitude: Drainage Area (sq-mi):	
Total Simulated In-stream Flow:	**121.85**	Total Observed In-stream Flow:	**100.00**
Total of simulated highest 10% flows:	**116.01**	Total of Observed highest 10% flows:	**90.26**
Total of Simulated lowest 50% flows:	**0.00**	Total of Observed Lowest 50% flows:	**0.00**
Simulated Summer Flow Volume (months 7-9):	**2.01**	Observed Summer Flow Volume (7-9):	**1.34**
Simulated Fall Flow Volume (months 10-12):	**28.85**	Observed Fall Flow Volume (10-12):	**21.75**
Simulated Winter Flow Volume (months 1-3):	**87.49**	Observed Winter Flow Volume (1-3):	**75.32**
Simulated Spring Flow Volume (months 4-6):	**3.50**	Observed Spring Flow Volume (4-6):	**1.59**
Total Simulated Storm Volume:	**61.92**	Total Observed Storm Volume:	**44.22**
Simulated Summer Storm Volume (7-9):	**1.15**	Observed Summer Storm Volume (7-9):	**0.75**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*1995-1999*	*2000-2004*
Error in total volume:	21.85	10	-1.43	7.35
Error in 50% lowest flows:	44006.40	10	-1.60	-3.91
Error in 10% highest flows:	28.52	15	2.26	1.75
Seasonal volume error - Summer:	49.85	30	13.27	-2.52
Seasonal volume error - Fall:	32.67	30	4.49	12.42
Seasonal volume error - Winter:	16.16	30	-18.21	13.31
Seasonal volume error - Spring:	119.64	30	1.90	6.11
Error in storm volumes:	40.04	20	1.13	12.07
Error in summer storm volumes:	54.66	50	3.16	15.42

The validation period 10/1/2005–9/30/1995 at station 11070465 showed a very good fit to the observed flow data. Though not presented, the error in total volume for this time period is only 5.2 percent. Figure 2-28 shows the comparison of modeled and observed stream flows for this period. In general, both medium and large storm events are simulated accurately and groundwater recession matches the overall trend well, with little or no groundwater flow observed after rainfall events.

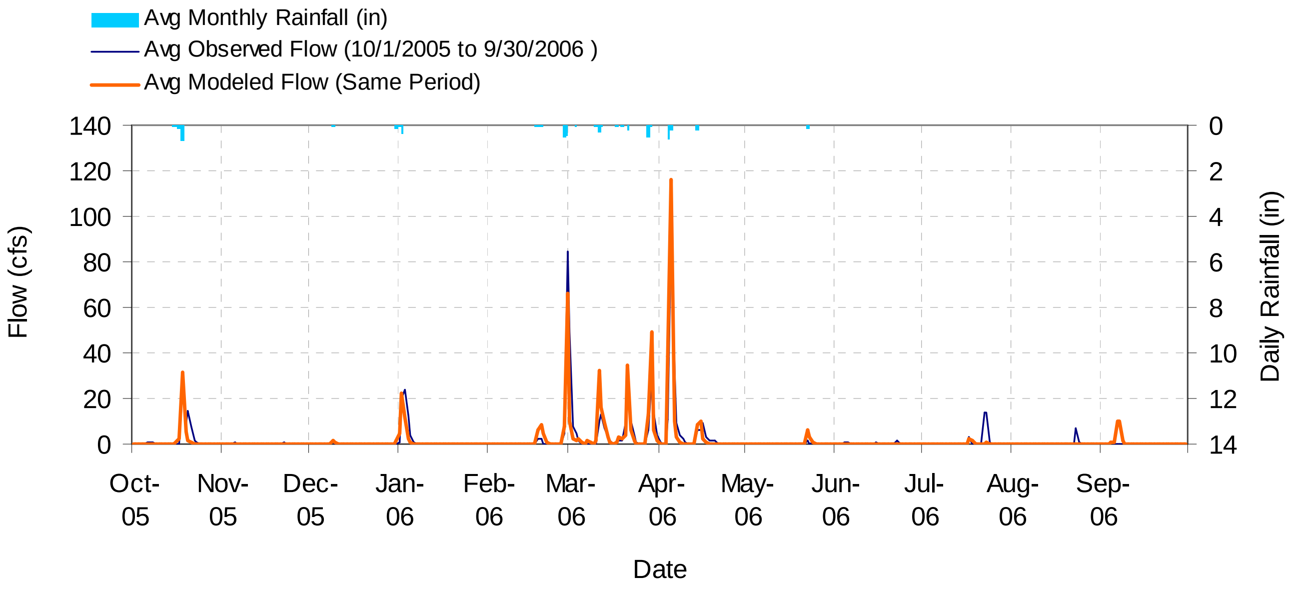

Figure 2-28. Graphical analysis of USGS 11070465 validation period

A comparison of the 2010 calibrated long-term simulation (10/1/2000–9/30/2008) and the 2003 validation (10/1/2000–6/29/2001) error statistics for USGS 11070270 is presented in Table 2-13. Calibration errors that are statistically better are highlighted in yellow. In general the 2010 long-term simulation results are significantly improved from the 2003 calibration simulation results. The 2010 model shows a more accurate simulation for every measure of model performance except summer seasonal volume and summer storms. The total volume error is 32.1 percent as compared to 187 percent for the 2003 simulations. Seasonal volume errors are generally below forty percent as well, with only the spring season exceeding. Again it should be noted the observed flow data at this gage was rated poor by the USGS and this gage showed unit-area flows significantly lower than all other gages in the watershed (see Section 2.2.2.3).

Table 2-13. Comparison of error statistics for the 2010 calibrated long-term simulation and the 2003 calibration simulation at USGS 11070465

USGS Gage	Errors (Simulated-Observed)	Error Statistics	
		2010 Long-term simulation	2003 Calibration simulation
11070365	Error in total volume:	32.11	187.00
	Error in 50% lowest flows:	0.00	7771153.62
	Error in 10% highest flows:	30.53	167.24
	Seasonal volume error - Summer:	36.91	0.00
	Seasonal volume error - Fall:	35.95	1999.86
	Seasonal volume error - Winter:	29.69	173.96
	Seasonal volume error - Spring:	47.62	181.37
	Error in storm volumes:	46.47	199.08
	Error in summer storm volumes:	15.69	0.00

Two other gages (11070365 and 11070210) located upstream of Canyon Lake were also selected for model validation (see Figure 2-19). Figure 2-29 and Figure 2-30 show graphical analysis of the validation periods for these gages. USGS 11070210 is located approximately 3.5 miles downstream of Mystic Lake and is the only gage that appears to distinctly capture outflows from the lake. For most of the observed monitoring record this gage shows little or no flow. During the WY 2005 El Nino period, flow was measured at the USGS gaging station downstream. Mystic Lake was not observed to overflow during the 2005 El Nino period, therefore, it is assumed that the flow measured at this station was from local runoff. The model does predict a minor overflow event from

Mystic Lake during this time period. Model predictions reflect the large amount of rainfall that occurred during the fall and winter which increased lake levels up to the overflow elevation. Additional data would be needed to further refine the representation of Mystic Lake in the future. Current data gaps include the lack of Mystic Lake overflow data to use for model calibration, storage or design data were not available for Lake Hemet Dam, information on water withdrawals or transfers, and possible deficiencies in the weather data that were used to drive the model simulations.

USGS 11070365 is located approximately 5 miles upstream of Canyon Lake and captures the majority of the flow entering the lake. Figure 2-29 shows a comparison of the observed and modeled hydrographs. The model captures the observed trends well, accurately predicting small and medium size storms, as well as low flows. The model does tend to slightly under-predict larger peak flows, particularly the WY 2005 El Nino event, but in general overall volume matches the observed data well.

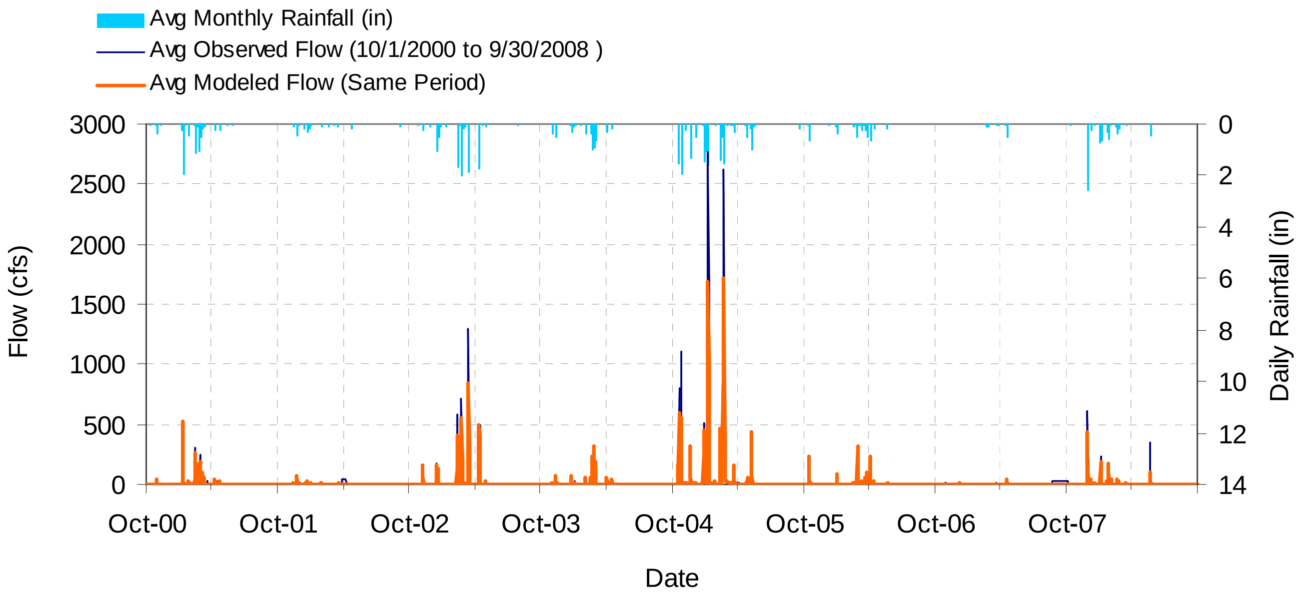

Figure 2-29. Graphical analysis of USGS 11070365 validation period

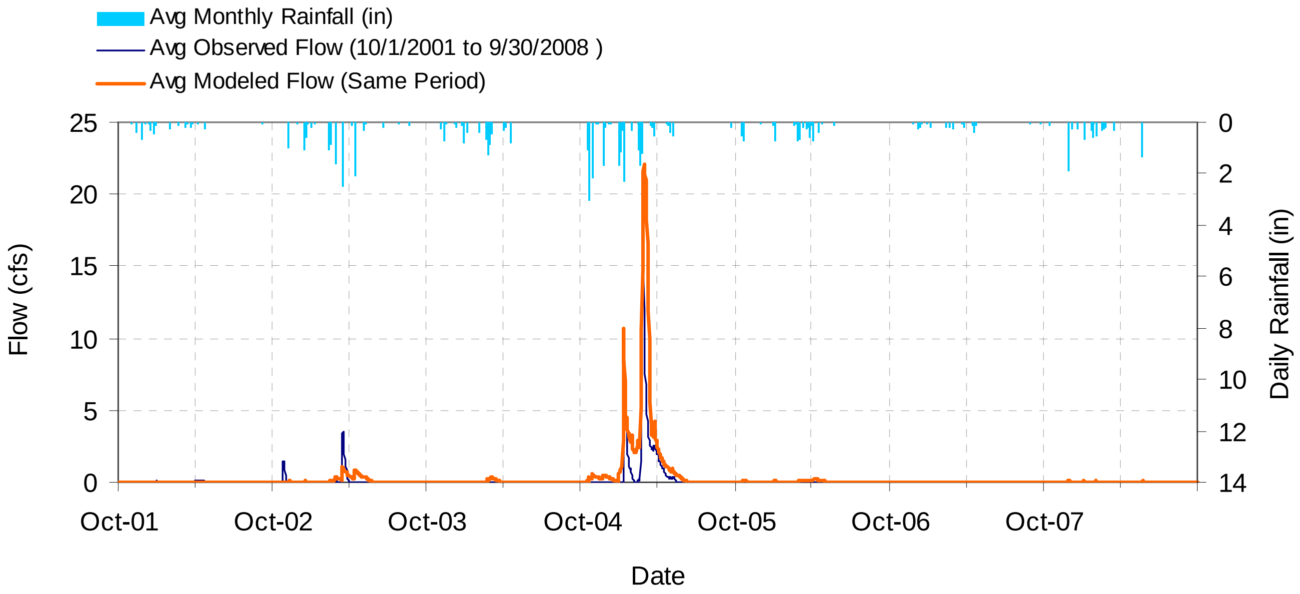

Figure 2-30. Graphical analysis of USGS 11070210 validation period

Meaningful calibration data was not available for the 2003 model simulations at USGS gage 11070210, so a comparison to the 2010 long-term simulation has been omitted. A comparison of the 2010 calibrated long-term simulation (10/1/2000–9/30/2008) and the 2003 calibration (10/1/2000–6/29/2001) error statistics for USGS 11070365 is presented in Table 2-14. Calibration errors that are statistically better are highlighted in yellow. In general the 2010 long-term simulation results are slightly improved from the 2003 calibration simulation results. The 2010 model shows a more accurate simulation for five of the nine model performance measures. The total volume is greatly improved with the updated calibration showing only 4.9 percent error. The 10 percent highest flows are also significantly improved showing only a 6.8 percent error. The greatest error percentage for the 2010 long-term simulation other than 50% lowest flows is for summer volume. Summer volumes consist of extremely low flows, however, and make up only a small fraction of total volume.

Table 2-14. Comparison of error statistics for the 2010 calibrated long-term simulation and the 2003 calibration simulation at USGS 11070270

USGS Gage	Errors (Simulated-Observed)	Error Statistics	
		2010 Long-term simulation	2003 Calibration simulation
11070365	Error in total volume:	-4.91	54.60
	Error in 50% lowest flows:	40682.63	22205662.35
	Error in 10% highest flows:	-6.75	40.34
	Seasonal volume error - Summer:	-94.82	0.00
	Seasonal volume error - Fall:	2.59	528.45
	Seasonal volume error - Winter:	-7.77	51.07
	Seasonal volume error - Spring:	51.59	23.96
	Error in storm volumes:	-13.57	-5.79
	Error in summer storm volumes:	42.55	0.00

2.2.3.2 Water Quality

After hydrology was sufficiently calibrated, the model water quality simulation was calibrated. Modeled versus observed in-stream concentrations were directly compared during model calibration. The water quality calibration consisted of comparing model water quality time series output to available water quality observation data, and adjusting pollutant loading and in-stream water quality parameters within a reasonable range. The objective was to best simulate concentrations occurring during low flow, mean flow, and storm peaks at water quality monitoring stations representative of different regions of the basin (and different land uses, in particular).

Adjusted water quality parameters included pollutant buildup, washoff, and subsurface concentrations. Water quality calibration adequacy was assessed through review of time-series plots and comparative statistical plots of the observed and modeled water quality. Looking at a time-series plots of modeled versus observed data provided insight into the timing and response of the system, while the statistical comparison gave further verification of the comparability of modeled and observed concentrations. Comparisons of model performance were not made to the 2003 model because the more recent water quality datasets compiled for the current study did not include time of collection in the data record. Therefore, 2010 model simulations were run at an average daily time step as opposed to the hourly time step used in the 2003 model simulations.

Table 2-15 lists the water quality station details and the respective calibration and validation periods used for analyses. Selection of calibration and validation periods was dependent on the availability of data at each station, but an effort was made to include WY 2005 as a validation period because of the El Nino influenced rainfall totals that occurred. Calibration of the 2003 model focused on the winter of 2001 with validation periods in the early to mid-1990s and the winter of 2000. Model calibration and validation for the updated model was performed for average daily model predictions of total nitrogen and total phosphorus. Water quality parameters for the watershed model were, then, further validated through a statistical comparison of observed water quality data to modeled in-stream values for each date that the observed data were collected. Statistics included median, 25th, 75th, 10th, and 90th percentile values.

Table 2-15. Water quality station calibration/validation periods

Station number	Station name	Period of Record	Sampling Dates	Selected Calibration Period	Selected Validation Period
759	San Jacinto River at Goetz Rd.	1/11/2001–2/17/2009	29	1/1/2001–3/10/2001	1/15/2008–1/31/2008
325	Perris Valley Channel at Nuevo Rd.	1/11/2001–3/23/2005	19	1/1/2001–3/10/2001	2/1/2005–3/31/2005
Cranston	Cranston Gaging Station	1/5/2008–4/21/2008	6	1/1/2008–4/21/2008	None (validated at station 792)
318	Hemet NPDES	1/11/2001–3/22/2005	11	1/1/2001–3/10/2001	2/1/2003–3/30/2005
792	San Jacinto River at Cranston	1/11/2001–3/23/2005	11	None (used as validation for Cranston station	1/1/2005–3/30/2005
834	Canyon Lake at Sierra Park	1/11/2001–10/27/2004	9	1/1/2001–3/10/2001	2/1/2003–10/31/2004

2.2.3.2.1 Urban

Figure 2-31 shows the land use of subwatershed 58 and the location of water quality station 318 at the base of the drainage area. Water quality calibration to this gage provided a unique opportunity to select appropriate parameters for the build-up and wash-off of nutrients in urban areas since subwatershed 58 is predominately urban. Such homogeneity for a watershed provides justification for parameterization of other land uses in more heterogeneous areas where contributions from individual land use types are difficult to isolate.

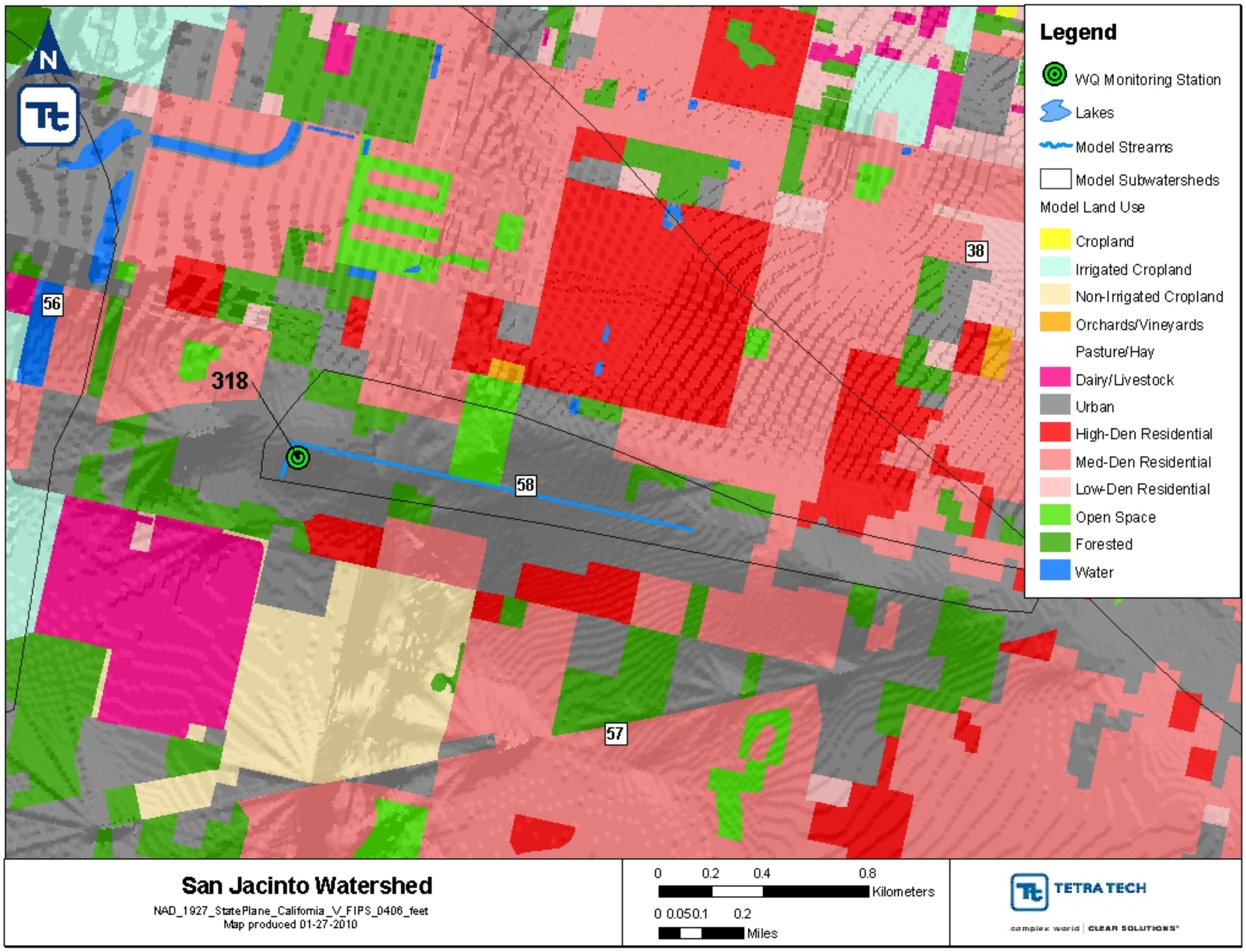

Figure 2-31. Location of water quality station 318

Calibration to water quality gage 318 was performed for total nitrogen and total phosphorus using average daily LSPC output as depicted in Figure 2-32 and Figure 2-33. Model predictions of nutrients are plotted with observed data to show the temporal calibration.

Model predictions of both total nitrogen and total phosphorus follow the temporal trend and magnitude of the observed concentrations well. Simulated total nitrogen concentrations are particularly accurate with the predicted values consistently equaling or nearly equaling observed values. Total phosphorus concentrations generally appear to be slightly over predicted, but are nearly equal to observed concentrations on multiple occasions. Differences between observed and predicted total phosphorus concentrations appear to be more an issue of timing as all observation appear to be collected on the rising or falling arm of the storm event, which tends to be more difficult to predict than peak flows.

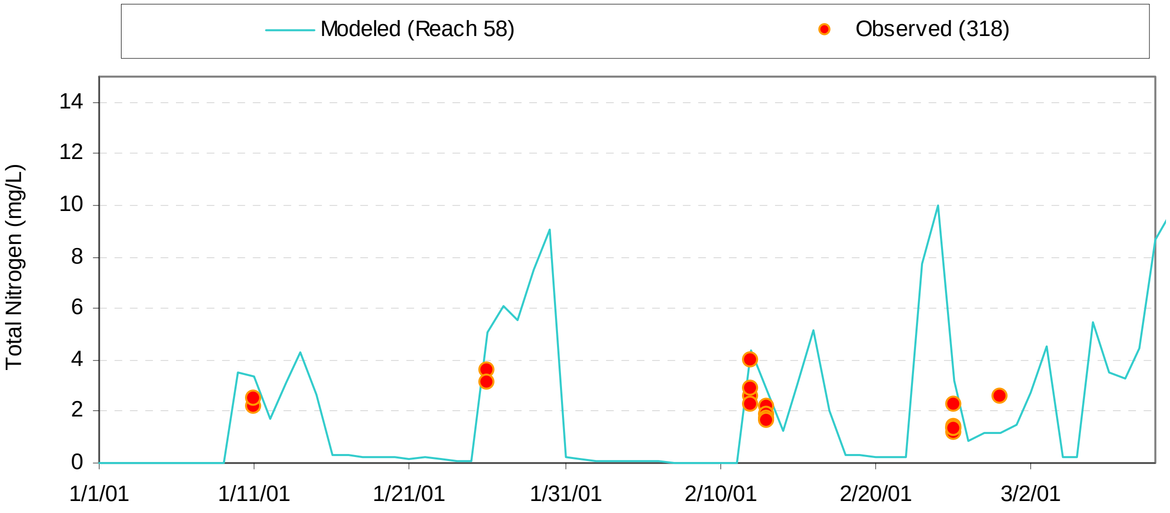

Figure 2-32. Model calibration of total nitrogen concentrations at water quality station 318

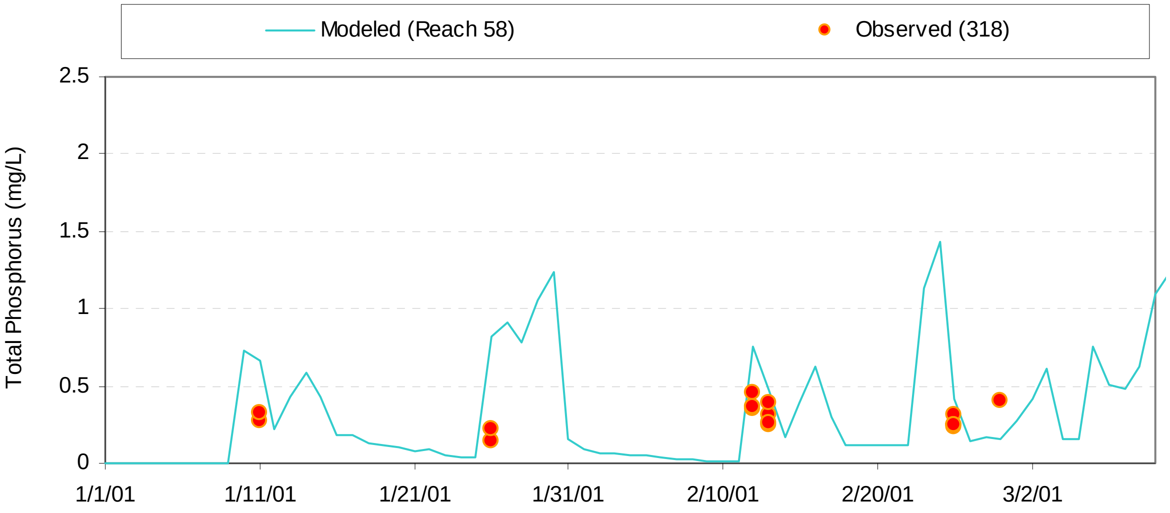

Figure 2-33. Model calibration of total phosphorus concentrations at water quality station 318

Model results for water quality station 318 were validated for the period from 2/1/2003–3/30/2005. Results of this validation period are shown in Figure 2-34 and Figure 2-35. As with the calibration, model results for this period compared well with observed data.

As further validation and to analyze the variability between model and observed water quality for the entire observed data record, Figure 2-36 is provided. This figure compares the median, 25th, 75th, 10th, and 90th percentile for the observed and modeled concentrations. The simulated concentrations included in the statistics are for all dates that observed data were collected. Median concentrations for the matched data are very similar, with modeled total nitrogen concentrations slightly higher than observed values and modeled total phosphorus concentrations nearly identical to the observed values. The range of the 25th and 75th percentile modeled concentrations are a bit larger than for the observed, particularly nitrogen, but in general the two are comparable, with the range differing by less than 2 mg/L for total nitrogen and less than 1 mg/L for total phosphorus.

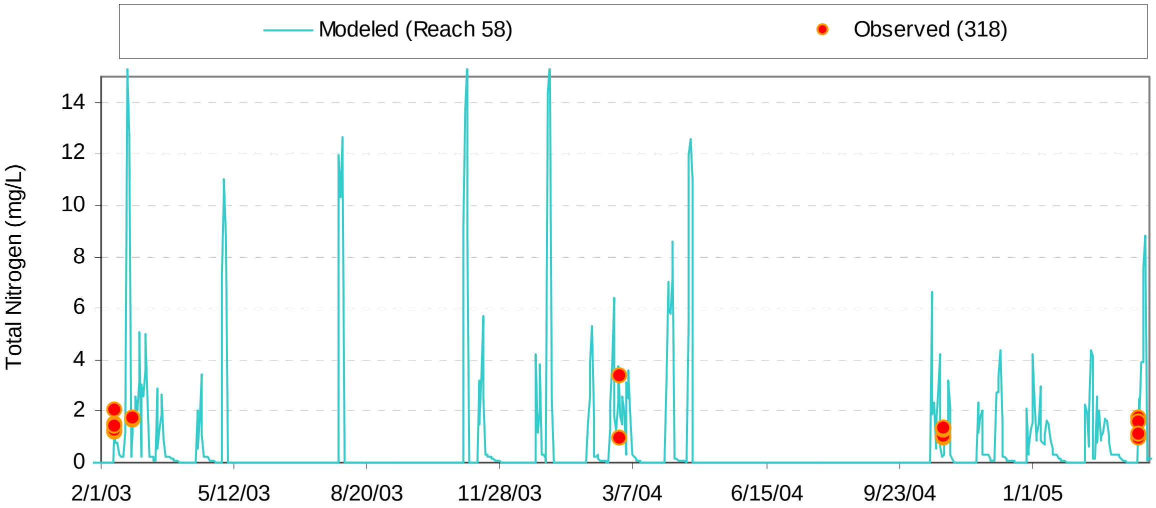

Figure 2-34. Model validation of total nitrogen concentrations at water quality station 318

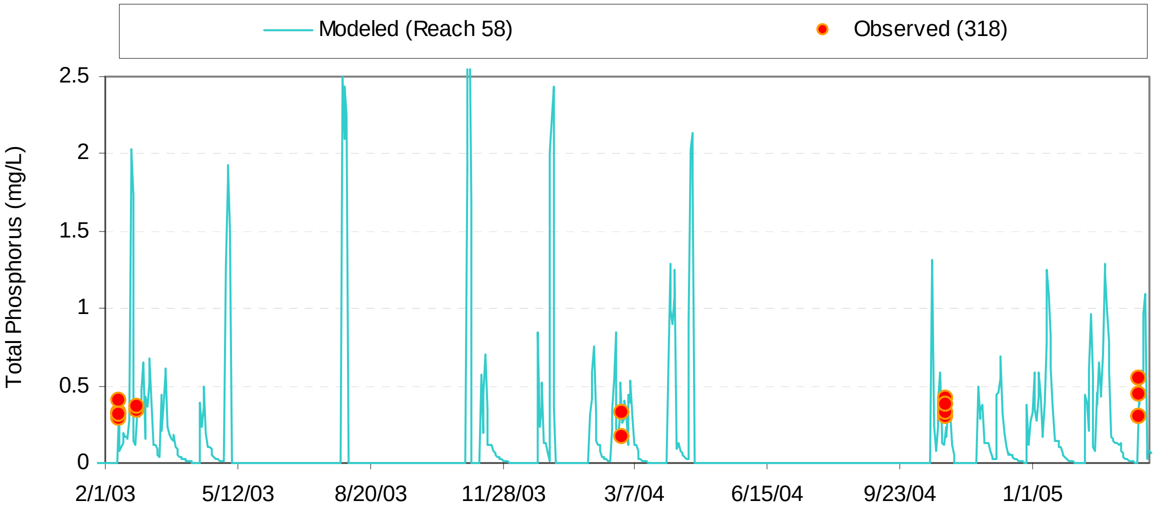

Figure 2-35. Model validation of total phosphorus concentrations at water quality station 318

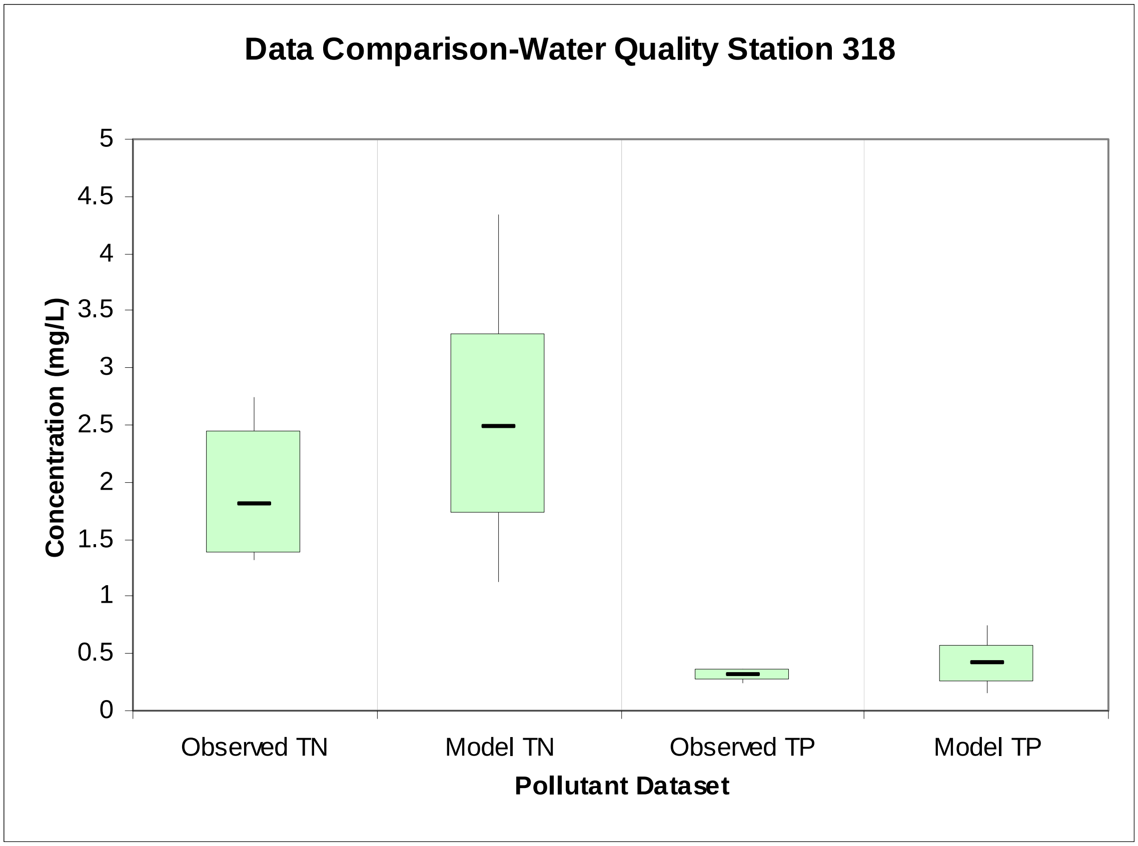

Figure 2-36. Statistical (median, 25th, 75th, 10th, and 90th percentile) comparison of modeled and observed nutrient concentrations at water quality station 318 (data included is for dates when observed data were collected)

2.2.3.2.2 Forested

Calibration of the watershed model output to the Cranston water quality station, located at the headwaters of the San Jacinto River watershed, was important to ensure that the forested headwaters were represented effectively (Figure 2-37). Since much of the flow at this gage was associated with interflow and groundwater, calibration to this gage provided a good check of the assigned background groundwater concentrations. It also helped assess the pollutant build-up rates for western forests derived from the U.S. Forest service data provided as part of the 2010 model updates (U.S. Forest Service 2010). Figure 2-38 and Figure 2-39 show the results of the water quality calibration for the period 1/1/2008–4/21/2008. In general, the model simulations match the observed data well. Peak total nitrogen and total phosphorus concentrations were well under-predicted by the model on 1/27/2008, but these observed concentrations look anomalous, as you would not expect in-stream concentrations of over 15 mg/L total nitrogen and 3.5 mg/L total phosphorus in a watershed that is 97 percent forested.

Due to a lack of data, water quality monitoring data collected at water quality station 792 was used to validate the Cranston calibration. This gage is also located in the headwaters of the San Jacinto watershed (co-located with USGS 11069500) and predominantly forested (Figure 2-19). Data for the period 1/1/2005–3/30/2005 were used for the validation (Figure 2-40 and Figure 2-41). The validation period in general shows a good match between modeled and observed nutrient concentrations. There is some slight over-prediction for the January storm, but all other observations are matched by the model simulation.

Figure 2-42 provides the comparison of the median, 25th, 75th, 10th, and 90th percentile for the observed and modeled concentrations at station 792. Median total phosphorus concentrations show a good match (0.16 mg/L for observed and 0.14 mg/L for modeled), while the median modeled total nitrogen concentration (0.91 mg/L) is slightly greater than the observed median (0.57 mg/L). In general the median and percentile values are comparable.

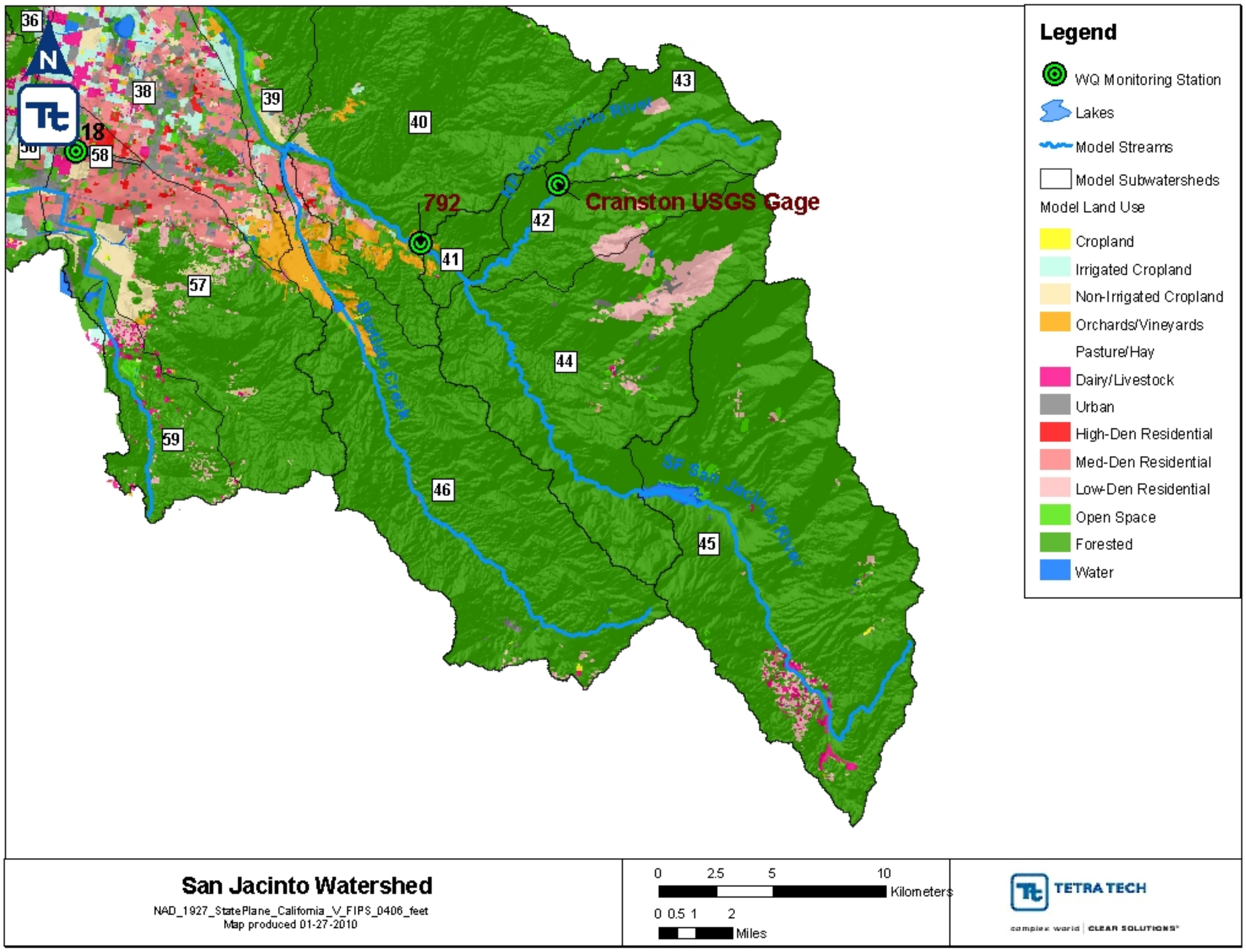

Figure 2-37. Location of water quality stations 792 and Cranston

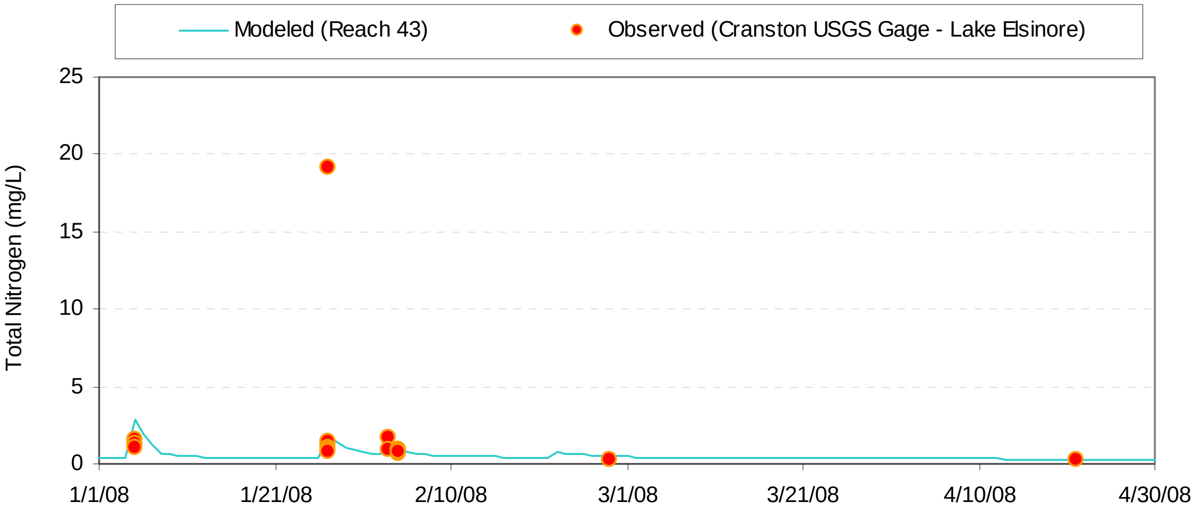

Figure 2-38. Model calibration of total nitrogen concentrations at water quality station Cranston

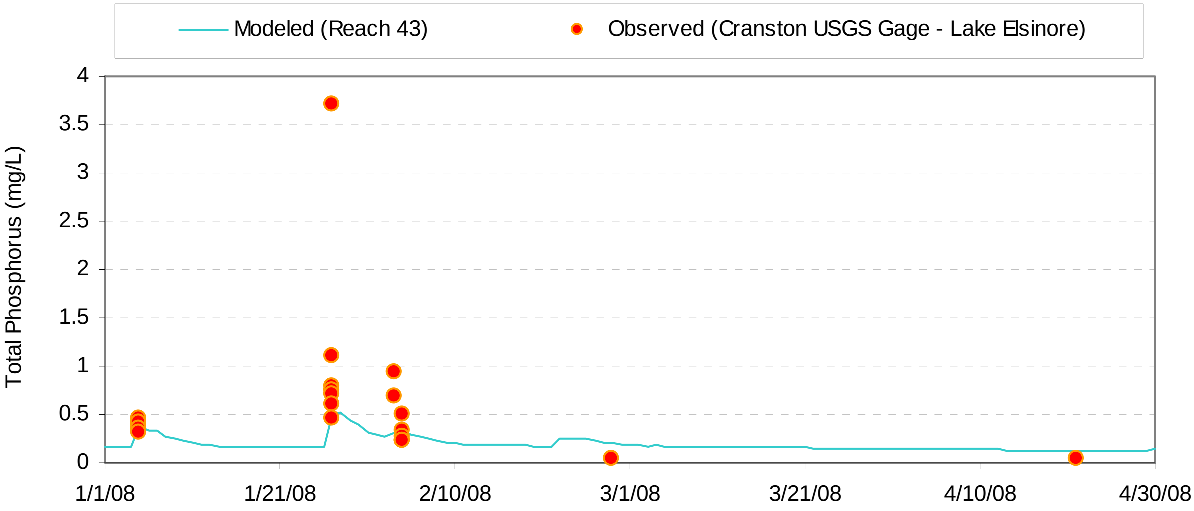

Figure 2-39. Model calibration of total phosphorus concentrations at water quality station Cranston

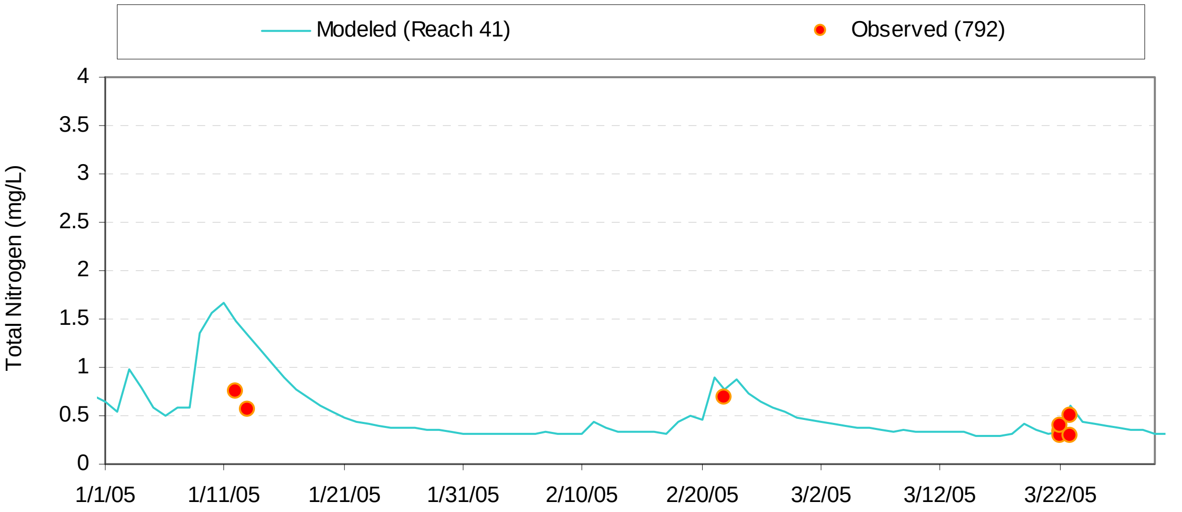

Figure 2-40. Model validation of total nitrogen concentrations at water quality station 792

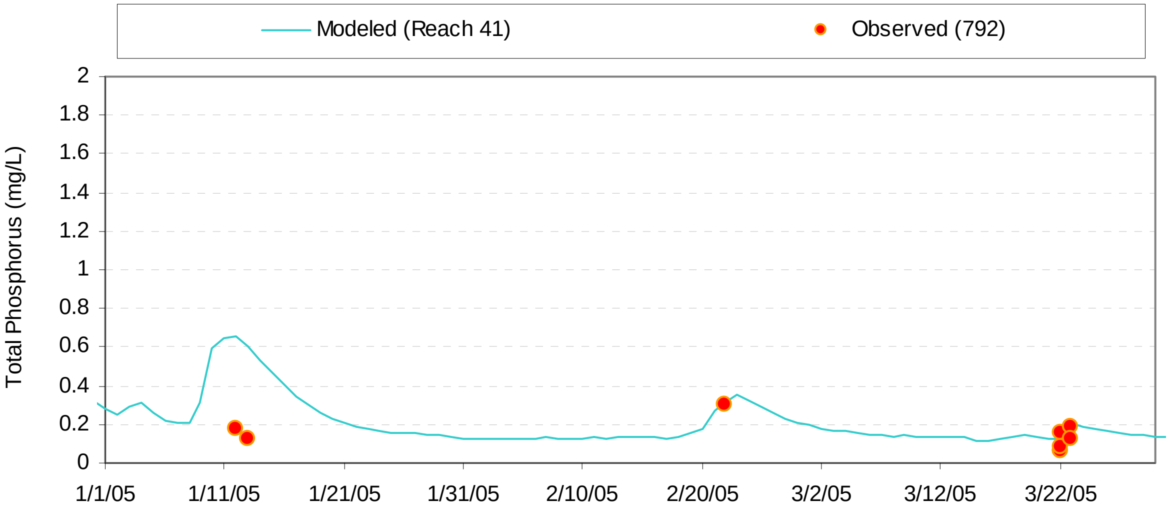

Figure 2-41. Model validation of total phosphorus concentrations at water quality station 792

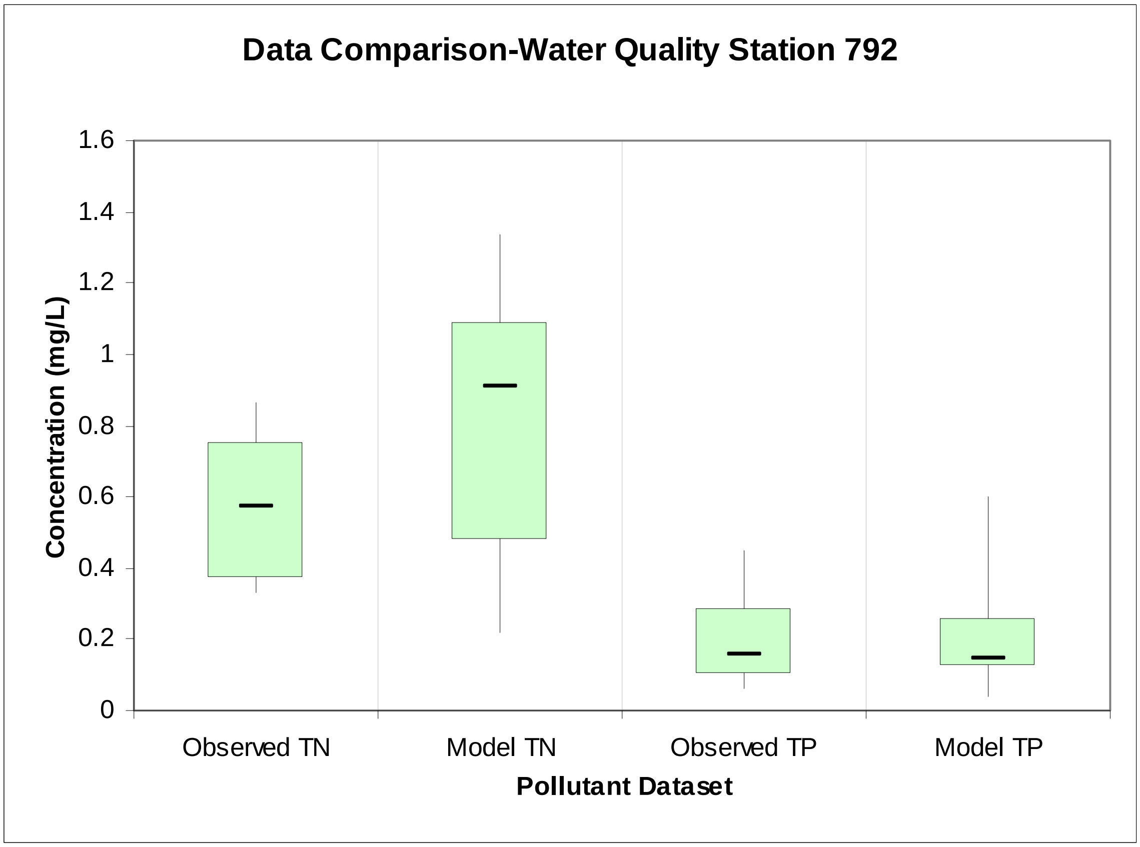

Figure 2-42. Statistical (median, 25th, 75th, 10th, and 90th percentile) comparison of modeled and observed nutrient concentrations at water quality station 792 (data included is for dates when observed data were collected)

2.2.3.2.3 Residential

Water quality station 834, located on the northwest side of Canyon Lake, provides water quality data for a watershed (subwatershed 49) that is dominated by residential land use (Figure 2-43). Comparison of model-predicted and observed water quality data for the calibration time period (1/1/2001–3/10/2001) showed a good match with all simulated concentrations being within less than 1 mg/L of all observed data points except for total nitrogen concentrations measured on 3/2/2001. As with the calibration, model validation results for the time period 2/1/2003–10/31/2004 compared well with observed data (Figure 2-44 through Figure 2-47). Comparison of the median, 25th, 75th, 10th, and 90th percentile for the observed and modeled concentrations also showed excellent matches with all model concentration percentiles within 1 mg/L of the same observed concentration percentile (Figure 2-48).

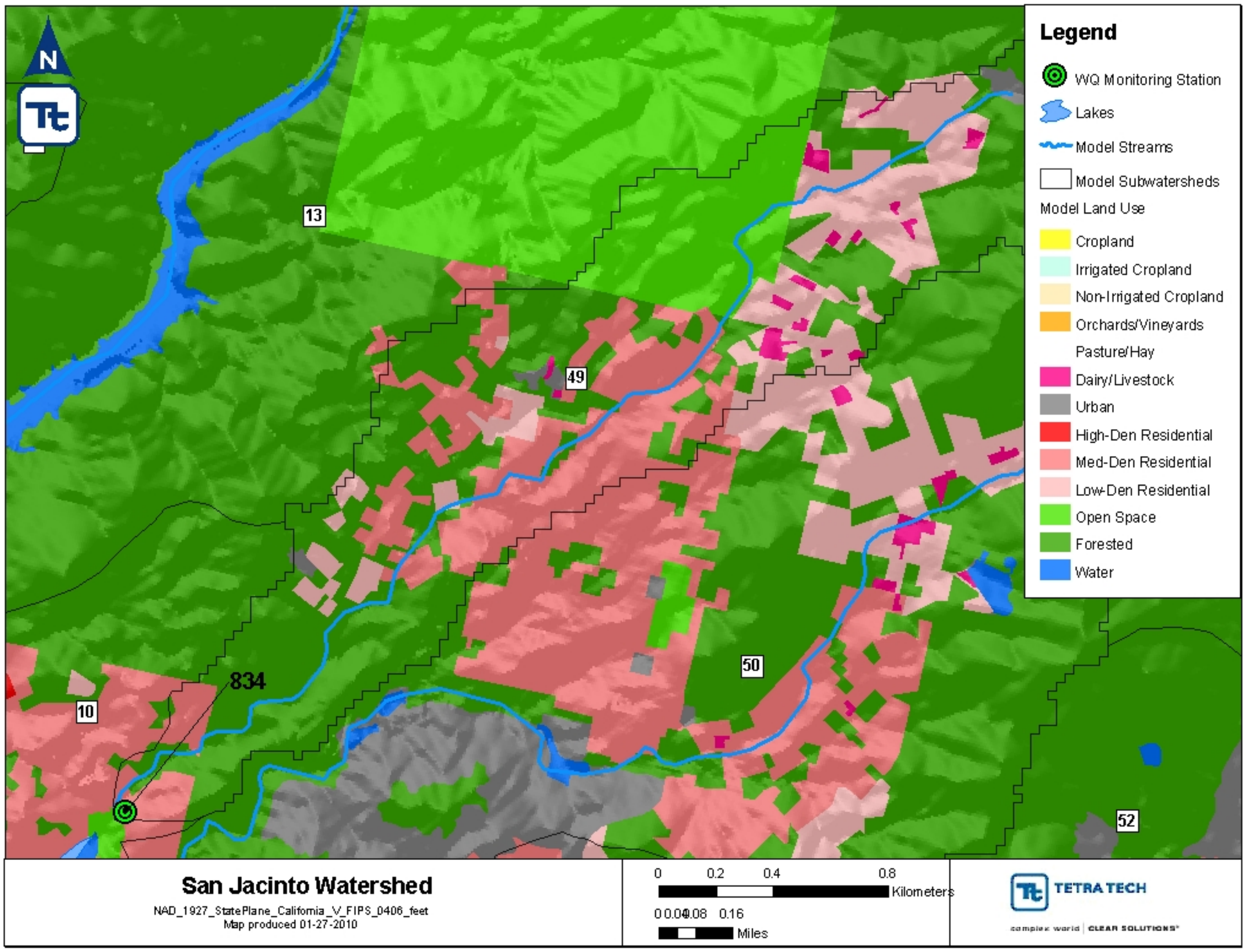

Figure 2-43. Location of water quality station 834

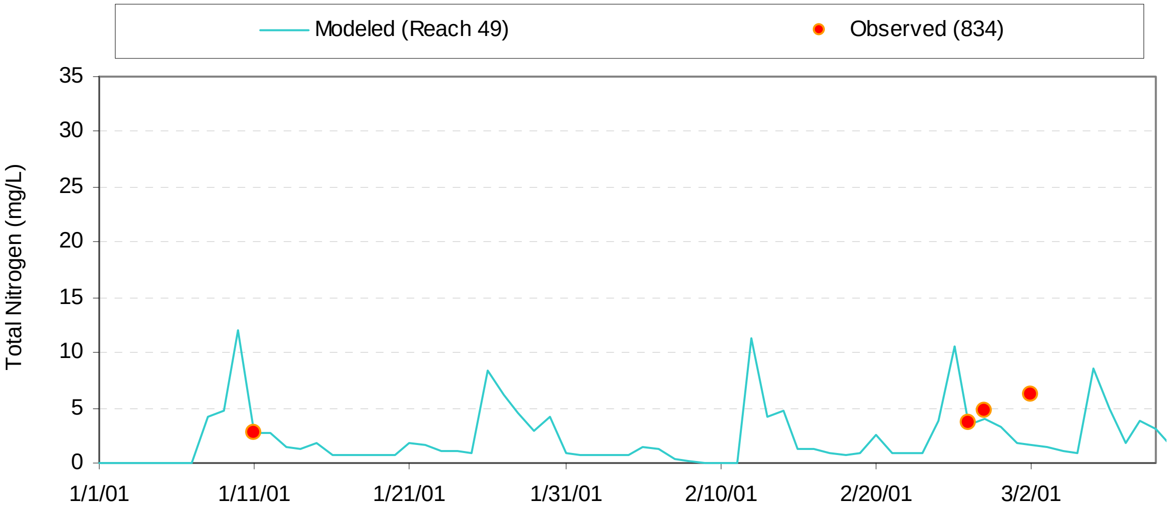

Figure 2-44. Model calibration of total nitrogen concentrations at water quality station 834

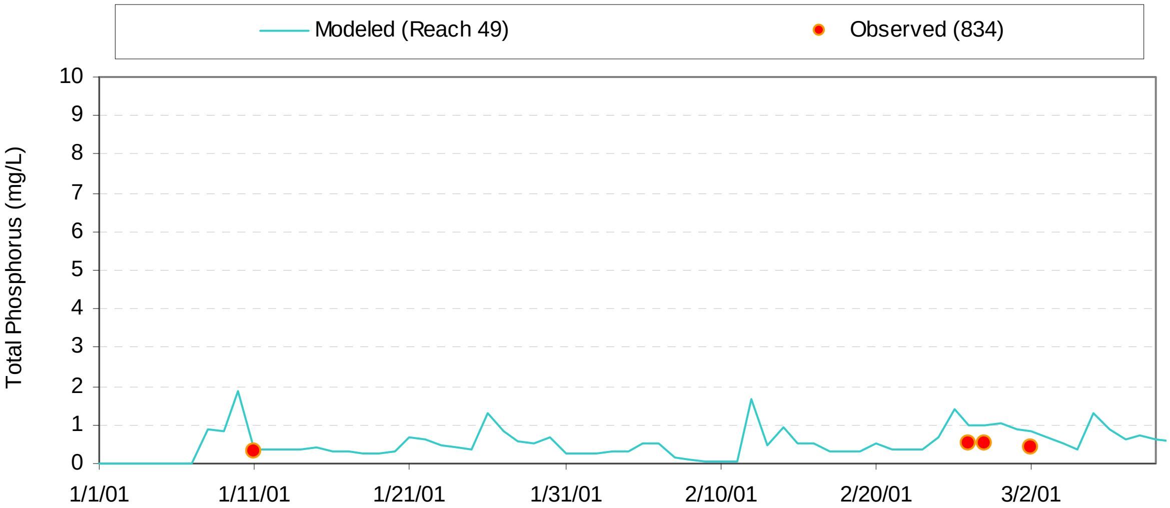

Figure 2-45. Model calibration of total phosphorus concentrations at water quality station 834

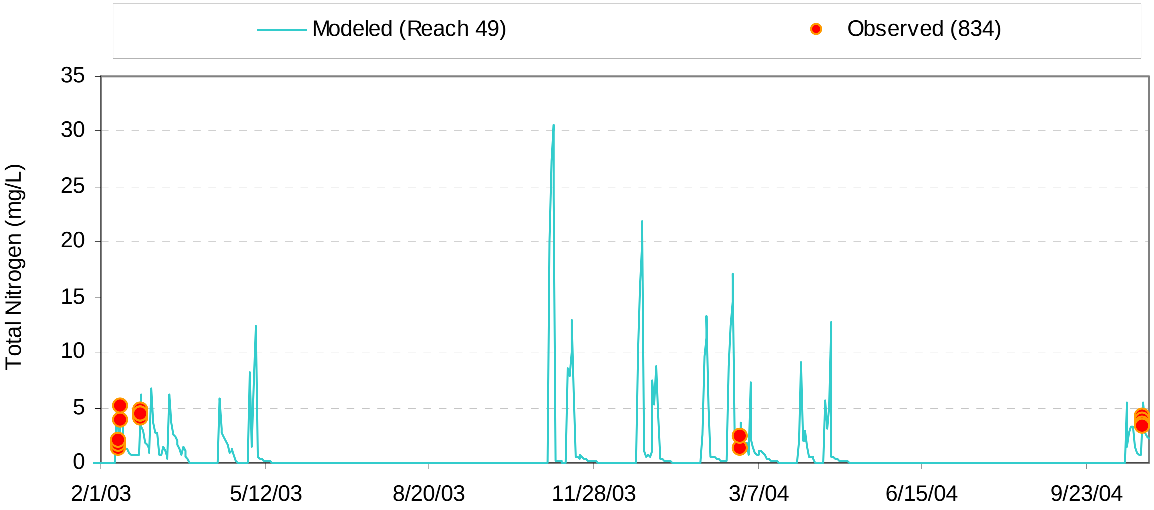

Figure 2-46. Model validation of total nitrogen concentrations at water quality station 834

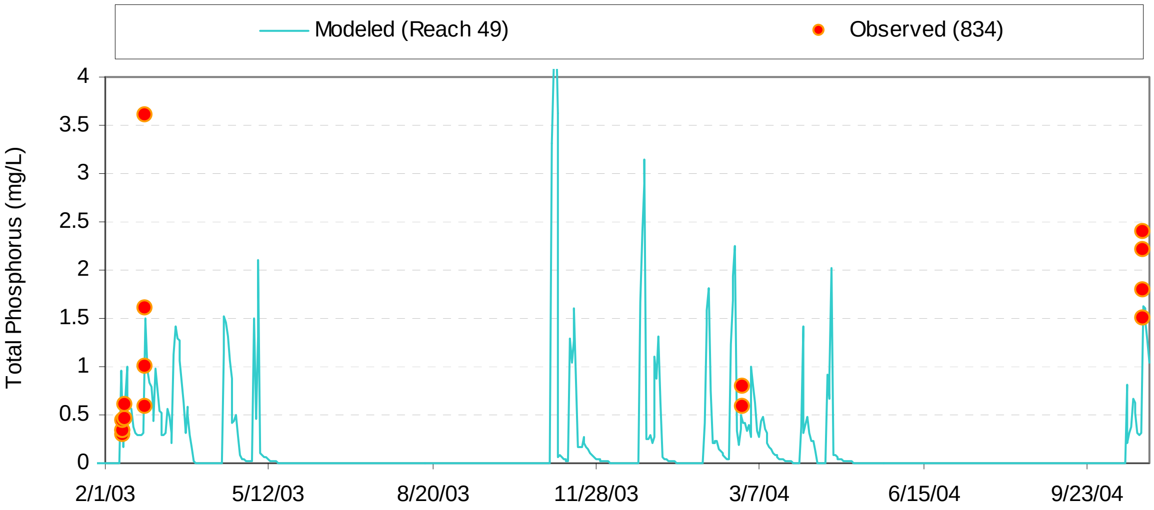

Figure 2-47. Model validation of total phosphorus concentrations at water quality station 834

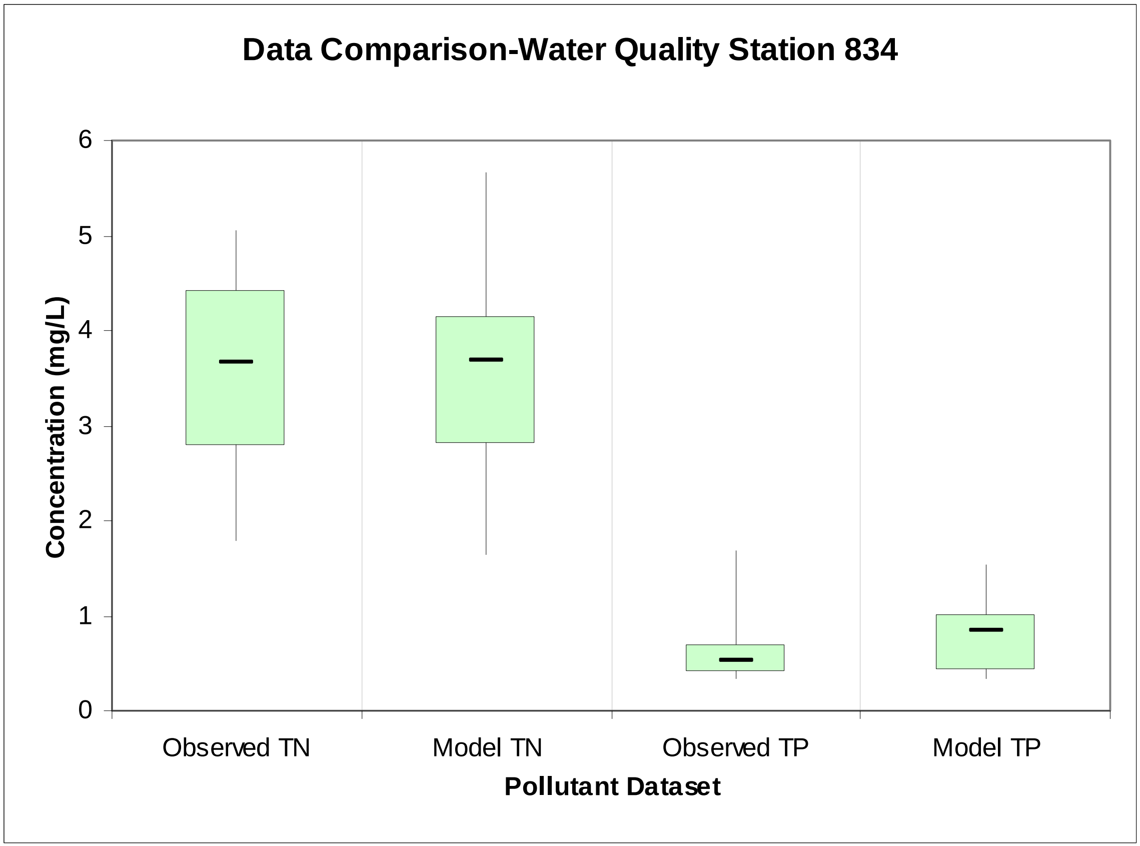

Figure 2-48. Statistical (median, 25th, 75th, 10th, and 90th percentile) comparison of modeled and observed nutrient concentrations at water quality station 834 (data included is for dates when observed data were collected)

2.2.3.2.4 Cropland

Water quality station 325, located at the same location as USGS stream flow gage 11070270 (Figure 2-49), included many of the land uses previously calibrated, but also included a substantial amount of cropland area for calibration of agricultural loading parameters. Figure 2-50 and Figure 2-51 depict the results of calibration to this water quality station for the period from 1/1/2001–3/10/2001.

Model calibration showed good matches between the observed and modeled concentrations with both storm flow and low flow modeled total nitrogen and total phosphorus concentrations close to observed values. To verify the appropriateness of the model calibration, validation of model performance was performed for 2/1/2005–3/31/2005 (Figure 2-52 and Figure 2-53). The validation showed better matches than the calibration results with modeled nutrient concentrations within 1 mg/L of observed values for total nitrogen and within 0.5 mg/L of observed values for total phosphorus, except for one outlier data point collected on 3/23/2005 that had a concentration (1.8 mg/L); nearly twice the concentrations of the other two samples collected that day (0.69 and 0.85 mg/L).

Comparison of the median, 25th, 75th, 10th, and 90th percentiles for the observed and modeled concentrations, in general showed an under-prediction of nutrient concentrations (Figure 2-54). However, the 10th and 90th percentile ranges were comparable for the observed and modeled data. The under prediction can like be attributed to two storms that occurred on 2/12/2004 and 10/27/2004 that were not captured in the model rainfall data. These two dates show some of the highest nutrient concentration s in the observed dataset.

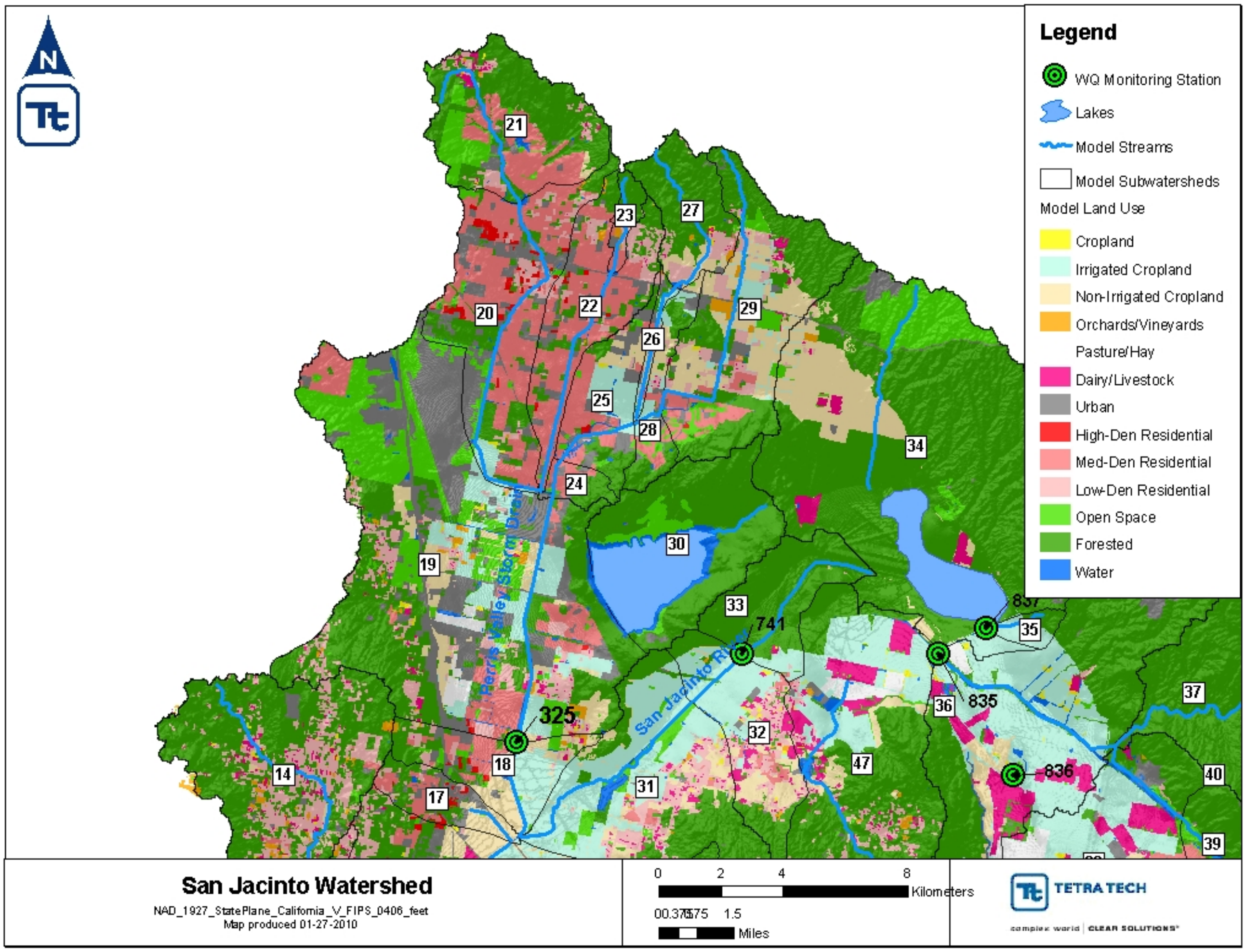

Figure 2-49. Location of water quality station 325

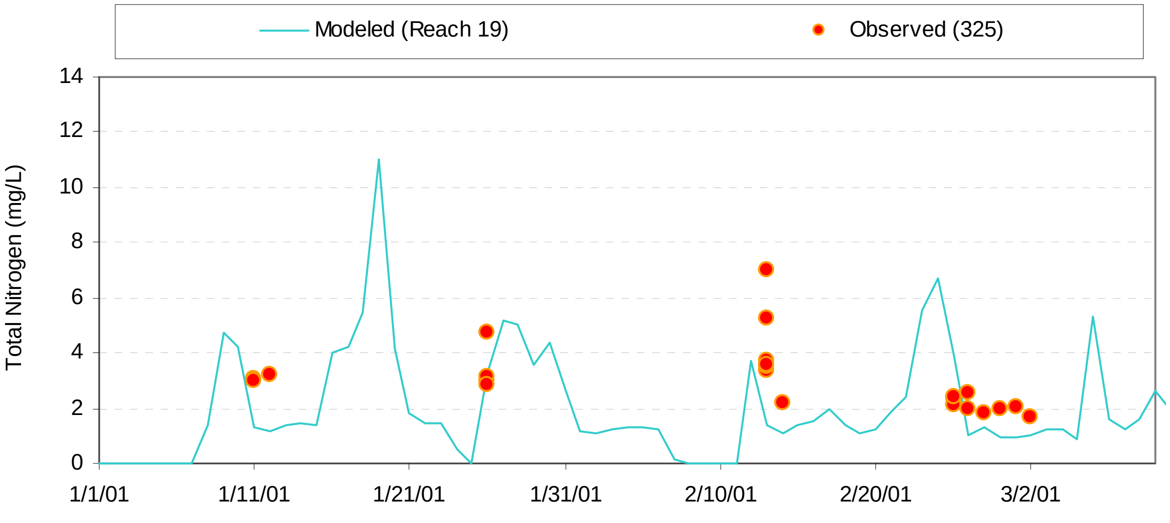

Figure 2-50. Model calibration of total nitrogen concentrations at water quality station 325

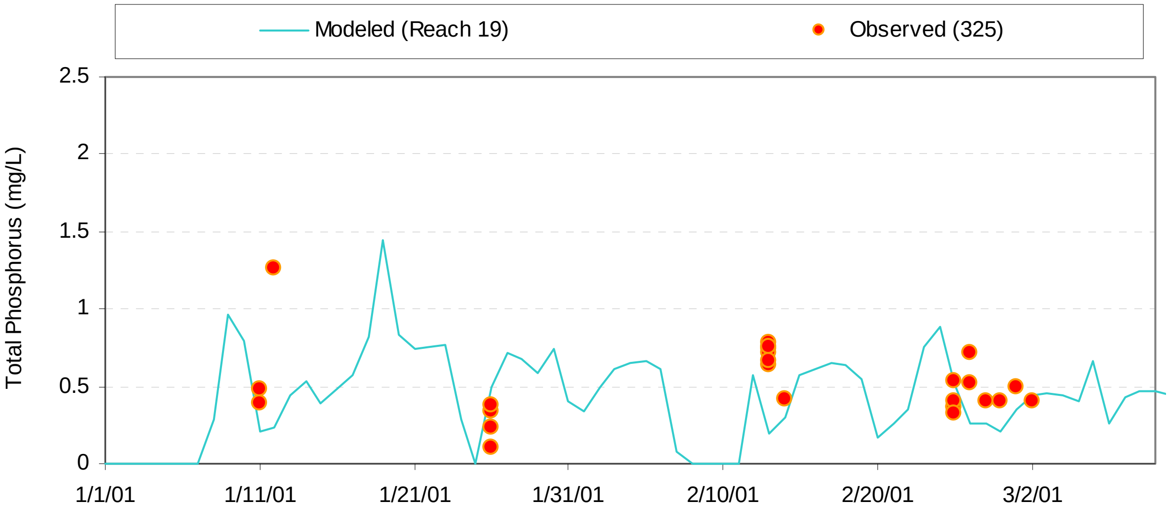

Figure 2-51. Model calibration of total phosphorus concentrations at water quality station 325

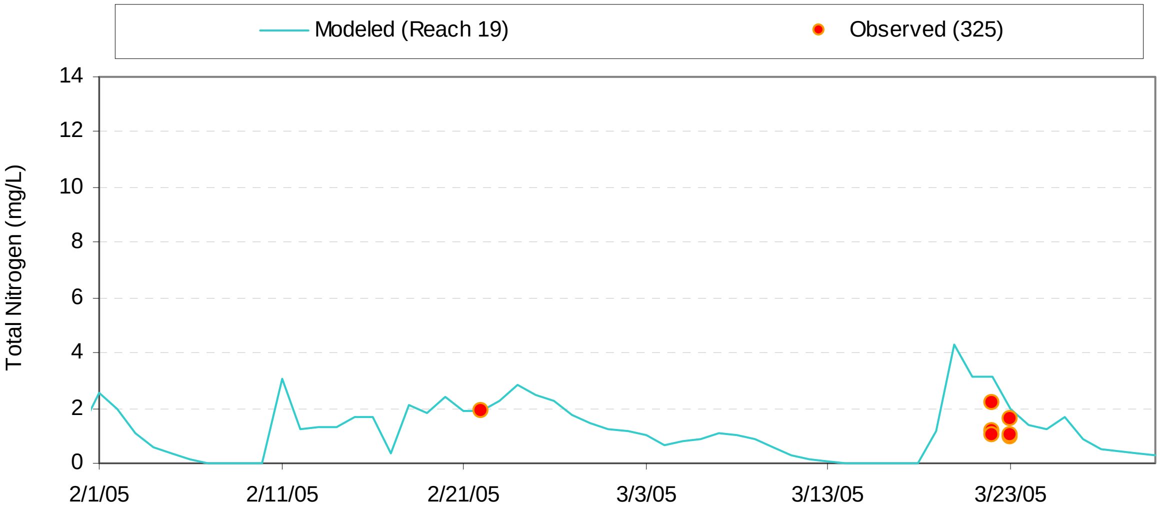

Figure 2-52. Model validation of total nitrogen concentrations at water quality station 325

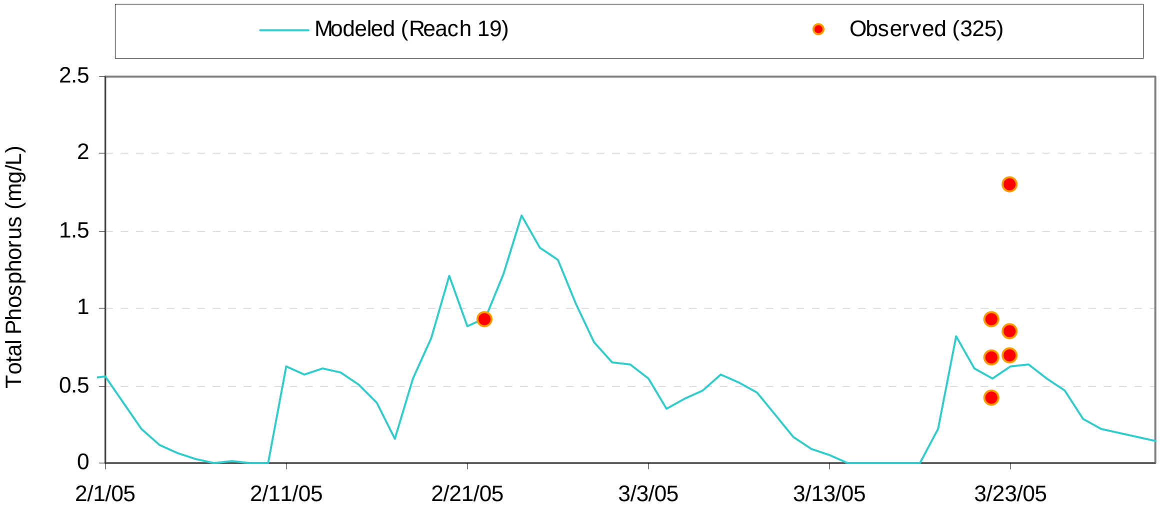

Figure 2-53. Model validation of total phosphorus concentrations at water quality station 325

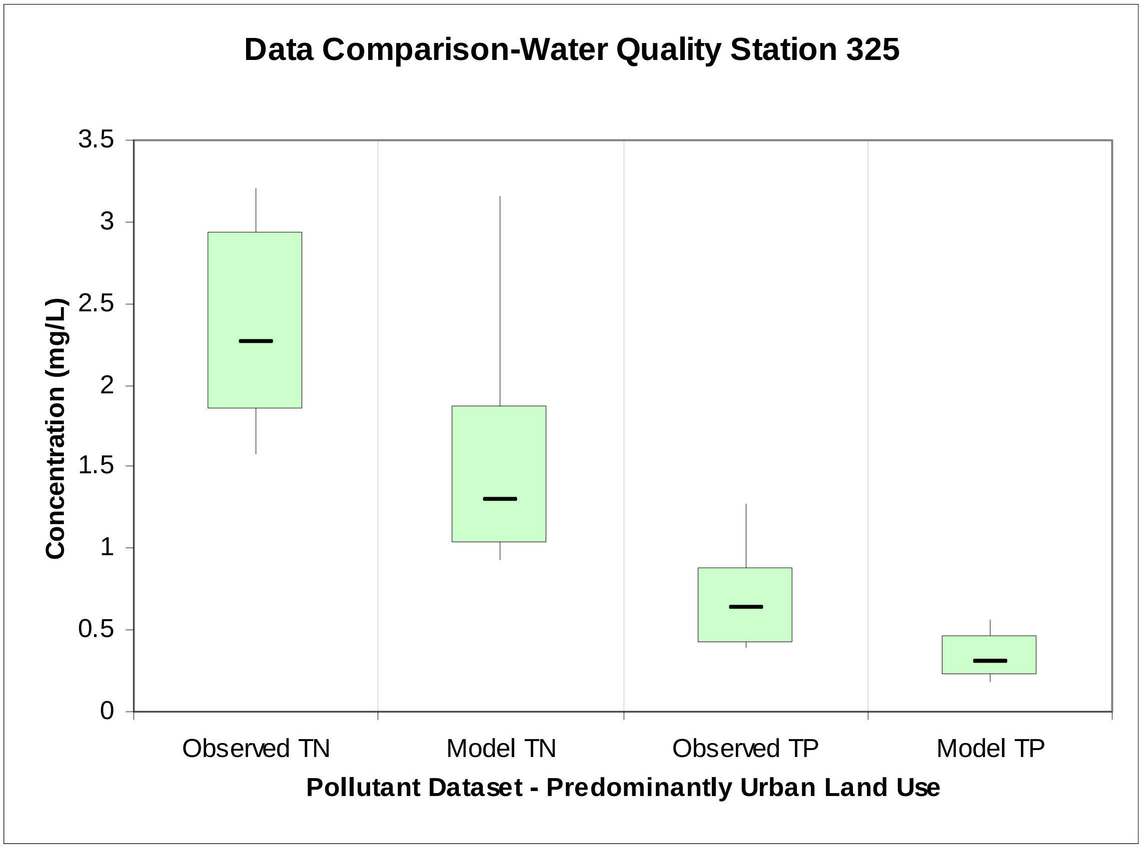

Figure 2-54. Statistical (median, 25th, 75th, 10th, and 90th percentile) comparison of modeled and observed nutrient concentrations at water quality station 325 (data included is for dates when observed data were collected)

2.2.3.2.5 Watershed Wide

Water quality station 759 is located on the San Jacinto River directly above Canyon Lake (Figure 2-56). These data served as a good check of the overall performance of the model for prediction of water quality and nutrient loads to Canyon Lake. Also, a significant amount of agricultural area is located just upstream of the station, so validation of the agricultural model parameters is possible through comparison of model results with observed data at these locations. Calibration and validation results are depicted for station 759 in Figure 2-57 through Figure 2-60. All calibration and validation plots showed excellent matches. Good correlation at this station provided confidence in model results, since hydrology was also validated at this location and the model showed good results for the entire simulation period meaning that model simulated loads to Canyon Lake should be accurate (flow x concentration = load).

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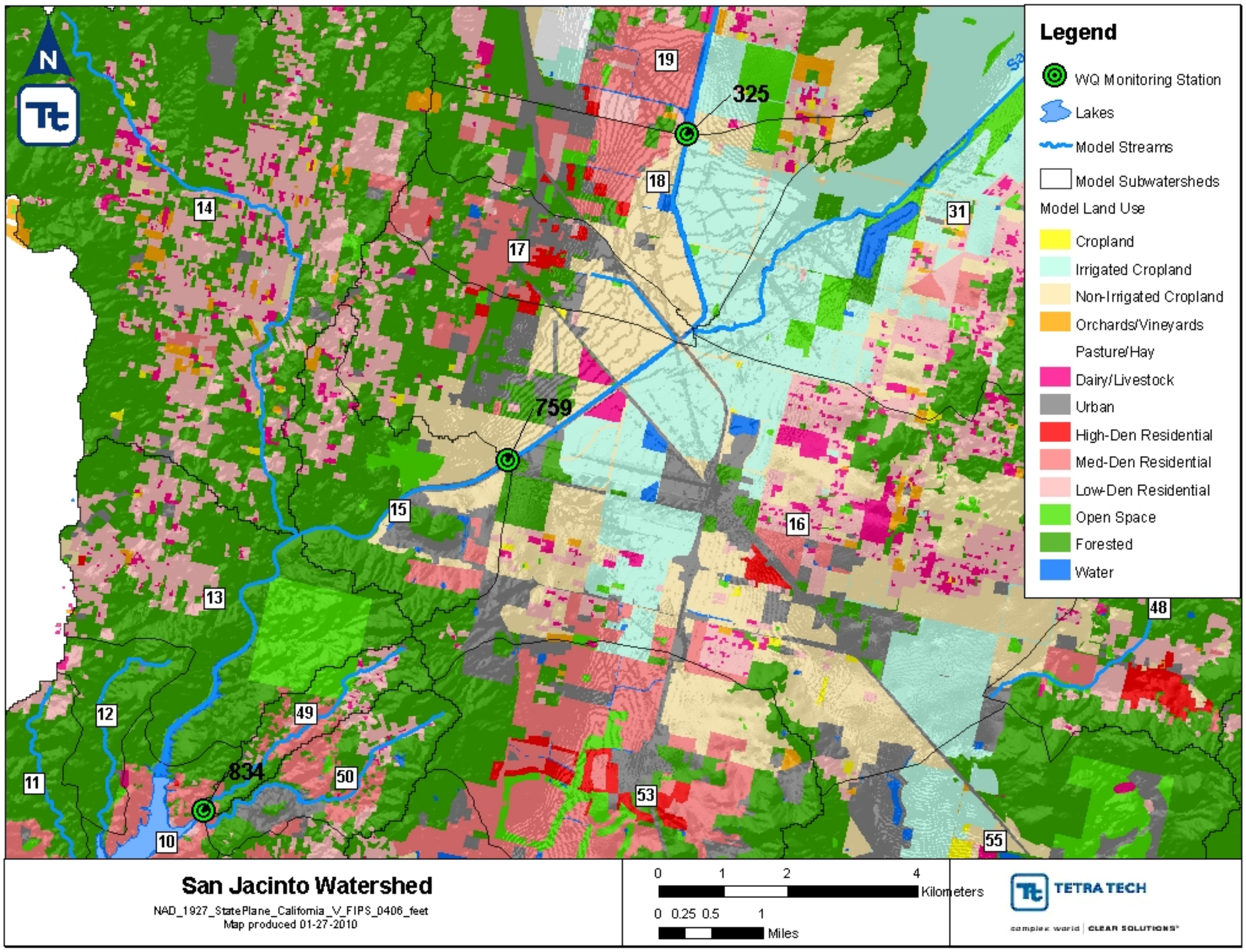

Figure 2-55. Location of water quality station 759

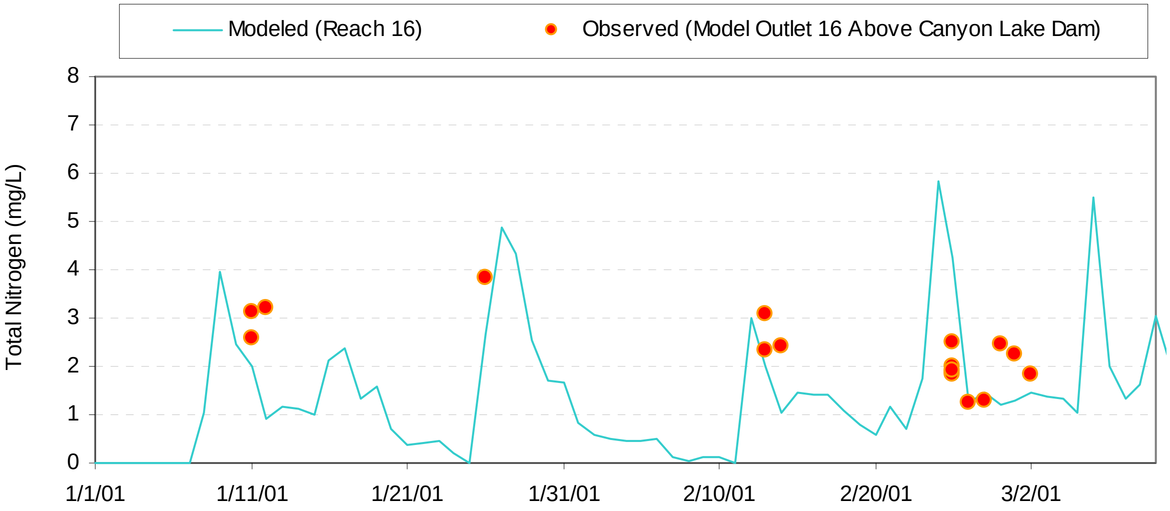

Figure 2-56. Model calibration of total nitrogen concentrations at water quality station 759

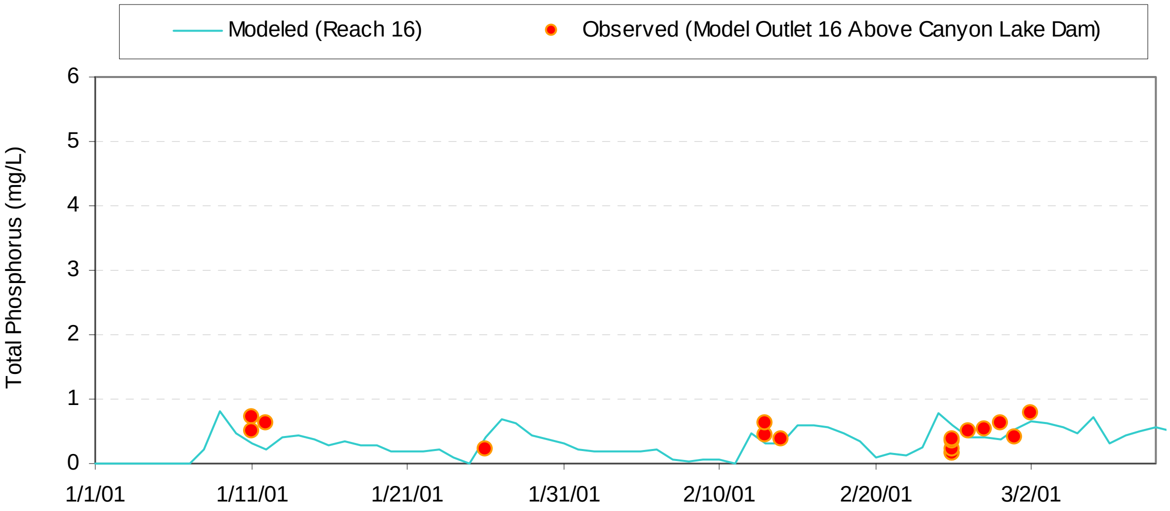

Figure 2-57. Model calibration of total phosphorus concentrations at water quality station 759

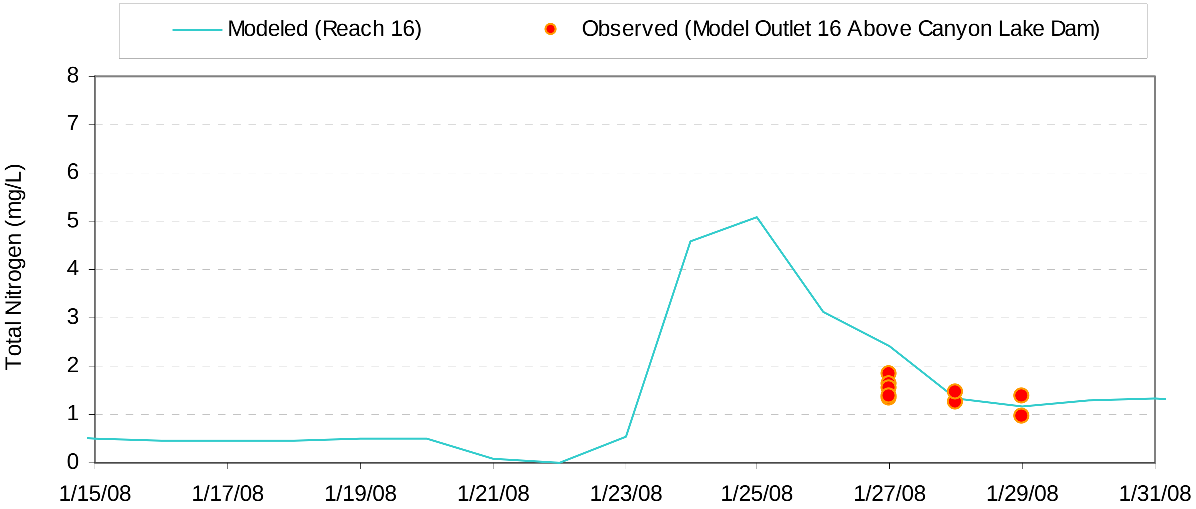

Figure 2-58. Model validation of total nitrogen concentrations at water quality station 759

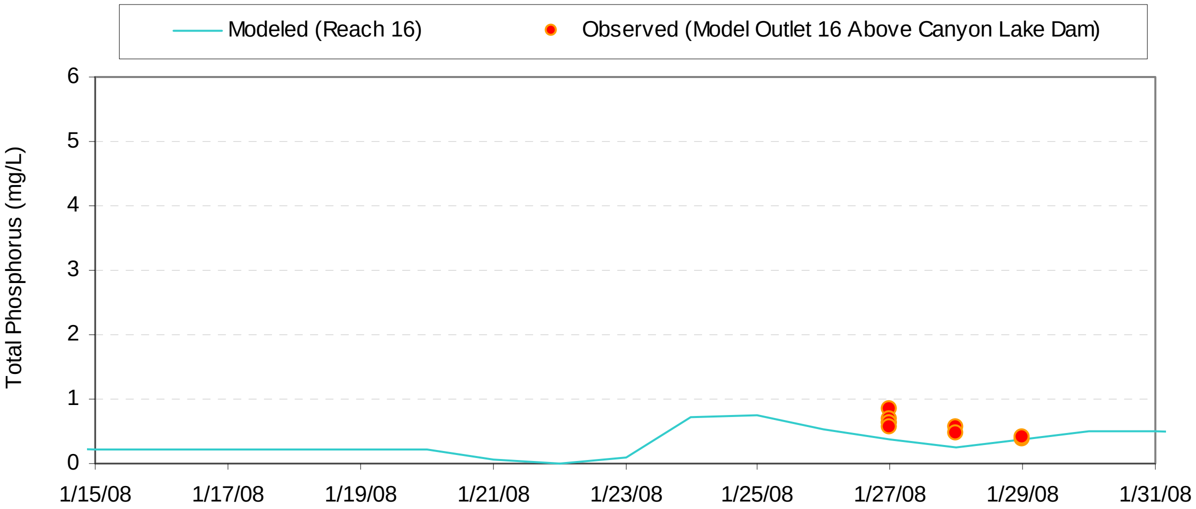

Figure 2-59. Model validation of total phosphorus concentrations at water quality station 759

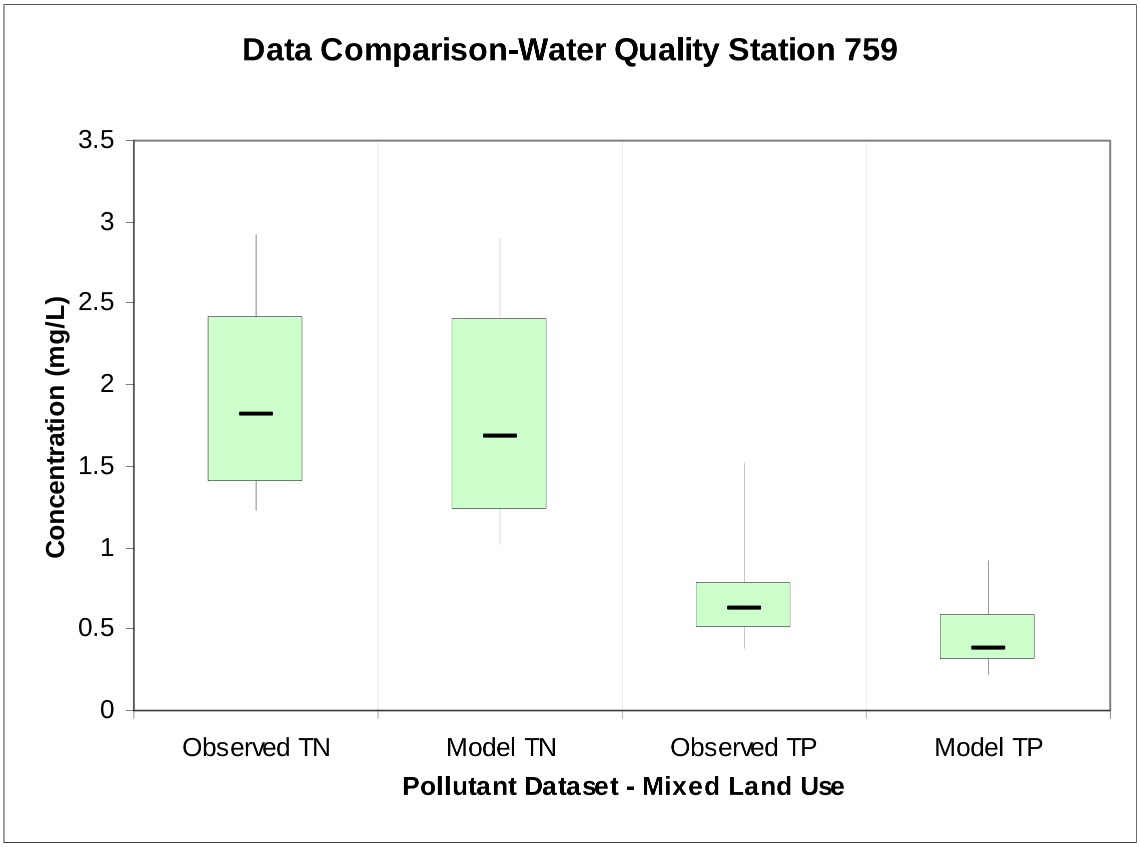

Figure 2-60. Statistical (median, 25th, 75th, 10th, and 90th percentile) comparison of modeled and observed nutrient concentrations at water quality station 359 (data included is for dates when observed data were collected)

2.3 Model Simulation for Existing Conditions and Scenarios

Model updates to the original 2003 watershed model for the San Jacinto River included the addition and revision of multiple datasets including, land use data, climatological data, lake representation, the representation of large regional BMPs, pollutant build-up rates, and updates to the model calibration and validation of hydrology and water quality. The model updates were designed to support the on-going management efforts in the San Jacinto watershed to meet applicable water quality criteria for nutrient concentrations in Canyon Lake and Lake Elsinore.

In general, the updated model maintained or improved on the performance of the 2003 watershed model simulations. In addition, the updated model land use is based on a detailed characterization of agricultural land uses in the watershed and offers significant flexibility in terms of assessing the relative contributions of agricultural sources in post-processing steps that will be incorporated into a spreadsheet tool being developed in tandem with the model, that will allow for the assessment of various management scenarios.

The fully calibrated model was run from July 1989 to August 2009 to generate flow and nutrient loadings under a variety of conditions for 20 full years. Model output was summarized to provide insight into monthly and annual loads for the simulation period. In addition, to compare loads simulated by the updated model to loads simulated by the 2003 model, the zonal analysis presented in Section 5 of the 2003 modeling report was recreated for the 2010 model output. In-stream loads for three water years (WY) representing a range of hydrologic conditions in the watershed were compared:

1) WY 1998 when both Mystic Lake and Canyon Lake overflowed
2) WY 1994 when only Canyon Lake overflowed
3) WY 2000 when neither Mystic Lake or Canyon Lake over flowed

As part of the ongoing watershed management efforts the model system will allow testing of multiple scenarios defined by SAWPA, RWQCB, and the Lake Elsinore/San Jacinto River Watershed Stakeholder TMDL Workgroup. The updated model output was also incorporated into a spreadsheet tool to be used by stakeholders in strategizing TMDL implementation efforts. The LSPC model allows for the testing of alternative scenarios and modifications produced by various management and environmental factors. The model configuration also allows for future applications and upgrades, such as explicit representation of BMPs using the BMP Module in LSPC.

3 Model Results

Assessing the total load of pollutants and characterizing the distribution of sources and loads for the 2010 San Jacinto watershed model was addressed through two techniques. The primary assessment method involved analyzing output from the watershed model and summarizing the output on a monthly and annual basis. The second technique involved assessment of the nutrient load distribution spatially and by land use. This analysis provides insight into the relative load contribution from different locations and will help guide future nutrient management efforts. Simulated annual loads to Canyon Lake were also compared to the 2003 model results to provide a comparison of the predicted loading. Note that model predictions are based on a static representation of land use within the watershed. As discussed in Section 2, the updated model was run for a 20-year time period based on a composite land use coverage that was developed using 2009 WRCAC and 2005 SCAG land use data. This land use snapshot was used to estimate nutrient loads for the entire simulation period, as was done for the 2003 study and TMDL development.

In addition to an analysis of existing conditions, the modeling system was used to predict relative nutrient loads to the lakes for pre-development land use conditions. For the pre-development condition, the entire watershed was represented by the “forested” land use category in the model consistent with the 2003 model analysis. Comparison of scenario results to the existing condition provides insight into the watershed and lakes’ sensitivity to land use-based load contributions. Future modeling tasks can include revising the pre-development scenario to retain areas that are currently classified as forest. All other land uses would be converted to open space to better represent natural conditions based on discussion with the watershed stakeholders. The 2005 SCAG land use dataset does not differentiate between open space-forested and open space-scrub/shrub categories, therefore, hydrologic and loading characteristics of these areas are likely comparable and significant changes are not expected.

The San Jacinto watershed model was updated with the goal of better representing loading conditions to the San Jacinto watershed system. Though LSPC includes a simple receiving water model that calculates in-stream pollutant fate and transport, it is not designed to simulate complex water column sediment interactions or dispersion and advection effects associated with lake modeling. The original 2003 modeling system included an Environmental Fluid Dynamics Code (EFDC) receiving model of Canyon Lake to represent these processes and to accurately simulate pollutant outflows and downstream loading to Lake Elsinore. Canyon Lake is the major source of pollutant loading to Lake Elsinore. Therefore, these model updates do not include estimates of loading to Lake Elsinore. The watershed model updates do, however, include the areas downstream of Canyon Lake that drain to Lake Elsinore. The 2010 watershed model updates can be linked to the existing EFDC Canyon Lake model to provide simulations of nutrient loading to Lake Elsinore.

3.1 Nutrient Loads to Canyon Lake

Nutrient loads from the watershed model were summarized to provide monthly and annual predictions to Canyon Lake over a 20-year period. Simulated annual loads were compared to the 2003 model results, as well, to provide a general comparison of the simulated pollutant loads between the two studies.

3.1.1 Canyon Lake

Monthly nutrient loads to Canyon Lake from 1990 through 2009 are presented graphically on log scales in Figure 3-1 through Figure 3-4. Figure 3-1 and Figure 3-3 present monthly average nutrient loads for the simulation period and Figure 3-2 and Figure 3-4 present the 10th, 25th, 50th, 75th, and 90th percentile loads by month for the simulation period. As seen in the figures, there is significant seasonal variability between the wet winter period and the summer. The wet winter period carries significantly more flow and higher nutrient loads, accordingly.

Monthly loads vary by up to 5 orders of magnitude from dry periods to wet periods. Note that the log scale used for these figures cannot display values that approach zero, which can be the case for summer and fall loads.

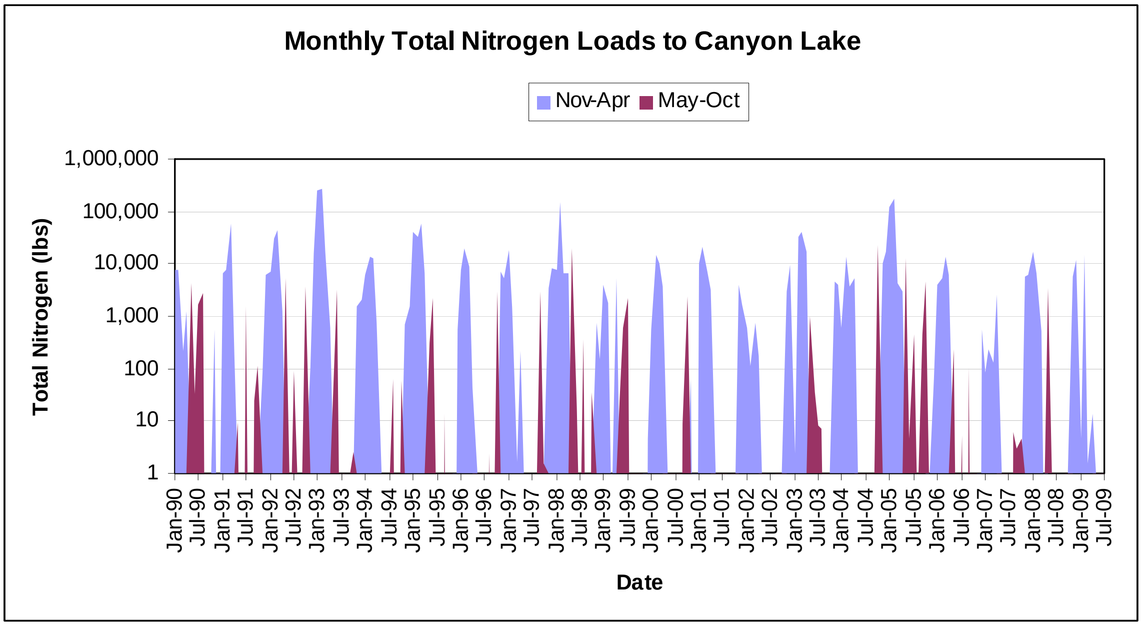

Figure 3-1. Monthly predicted total nitrogen loads to Canyon Lake

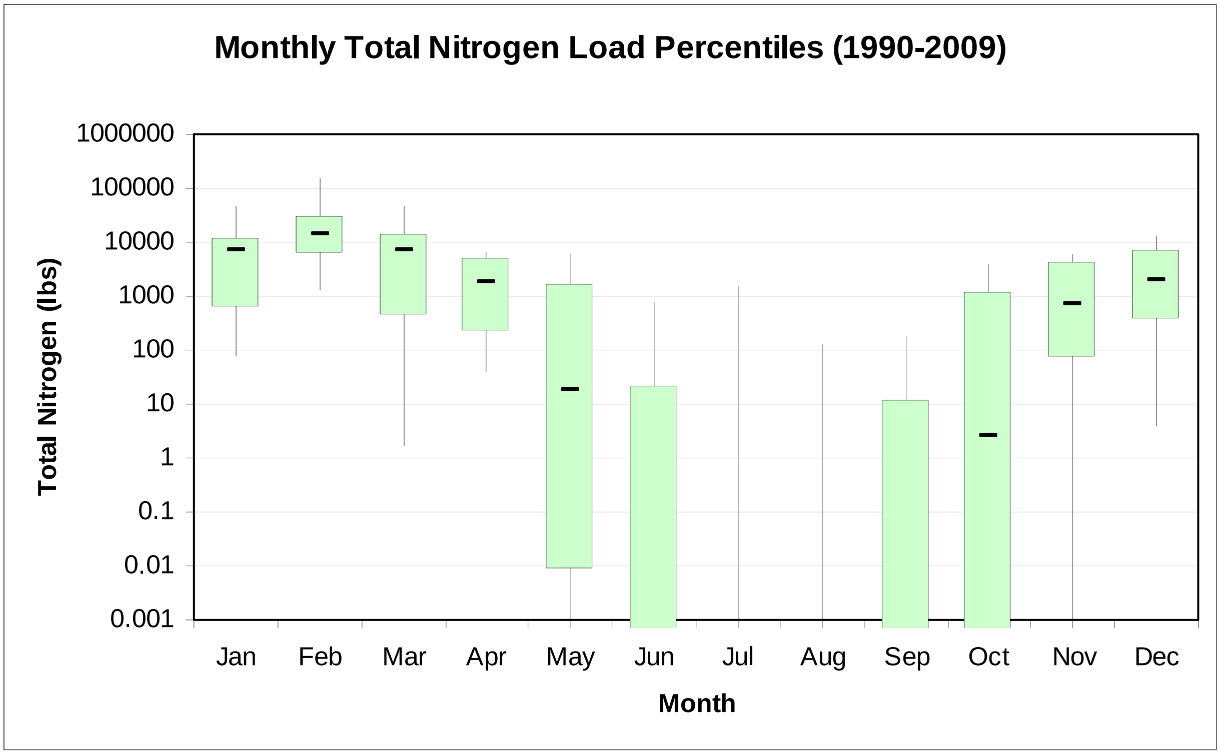

Figure 3-2. Monthly predicted percentiles (10th, 25th, 50th, 75th, and 90th) of total nitrogen loads to Canyon Lake. Note that values are presented on a log scale and values that approach zero are not depicted.

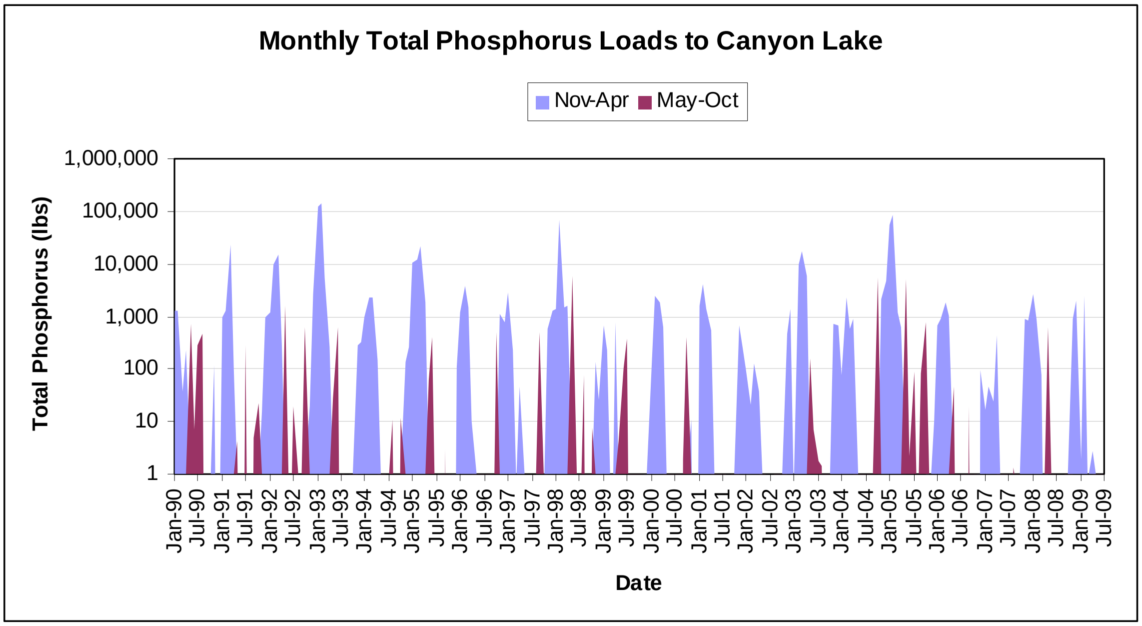

Figure 3-3. Monthly predicted total phosphorus loads to Canyon Lake

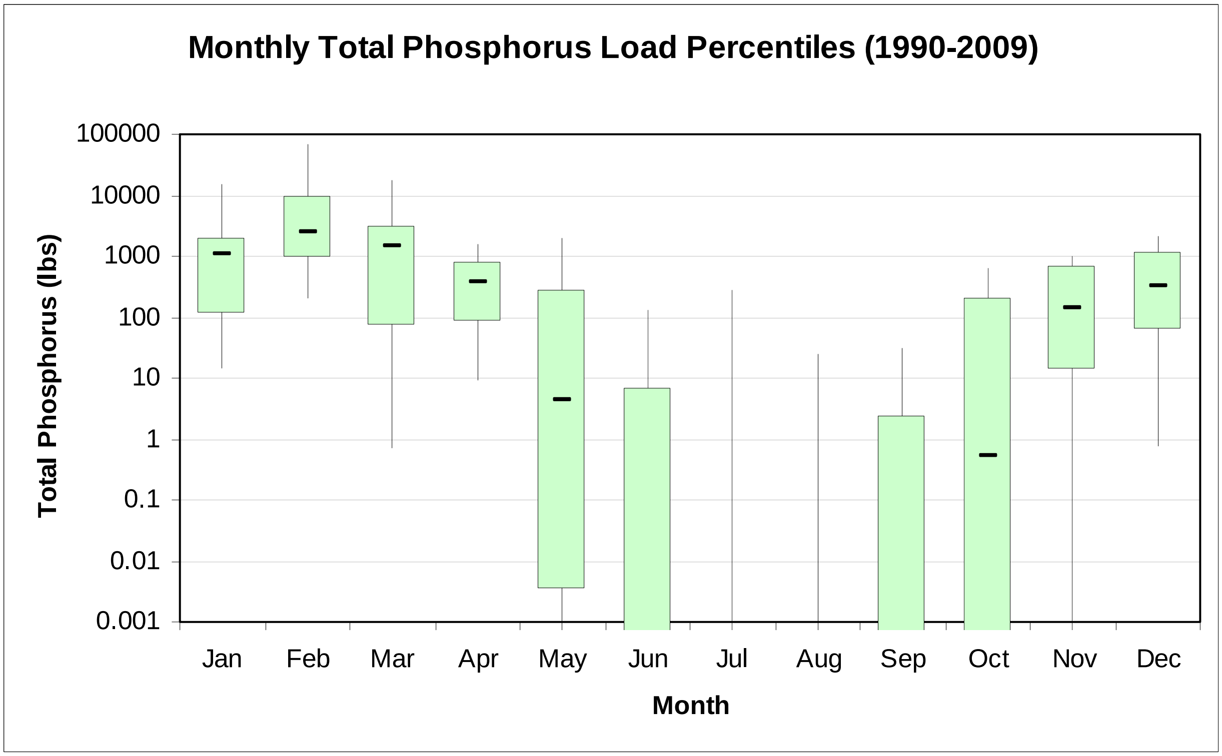

Figure 3-4. Monthly predicted percentiles (10th, 25th, 50th, 75th, and 90th) of total phosphorus loads to Canyon Lake. Note that values are presented on a log scale and values that approach zero are not depicted.

3.1.1.1 Comparison of 2010 and 2003 watershed model loads

Table 3-1 presents the annual loads to Canyon Lake for the 20-year period for the updated model and also presents the 2003 model results, which covered the 1991-2000 time period. Annual loads are shown for each water year (WY), which extends from October 1 through September 30. In general, the model results are comparable overall and have the same magnitude. A comparison of the average annual loads for shared simulation years shows that the updated model predicts larger loads overall for both total nitrogen (5.3%) and total phosphorus (18.1%).

Water year 1993 shows the greatest discrepancy in average annual total phosphorus loads between the 2010 and 2003 simulations. This was an El Nino year and had the highest total rainfall for the simulation period and the highest simulated nutrient loads. Interestingly, total nitrogen loads for the same year are very similar, with the 2010 model results showing only an 11 percent increase from the 2003 simulation. The trend is not necessarily consistent, however. An examination of WY 1999 shows a similar relationship with total nitrogen loads being much more similar between the models than total phosphorus loads. Rather than the updated model load being greater than the 2003 model load, as was the case in WY 1993, the 2003 model showed greater loads than the updated 2010 model. This result is indicative of the complexities of the watershed model and the multiple factors that can affect the simulation of pollutant loading.

Figure 3-5 and Figure 3-6 show a relative comparison of the total nitrogen and total phosphorus loads, respectively, by water year for the 2003 and 2010 models. The figures present the percent contribution of each model if their respective loads were totaled by water year. If both models predicted exactly the same load for a water year each would have a 50 percent contribution.

As shown in Table 3-1, in general the two models predict loads that are very similar. For total nitrogen loads, the updated 2010 model predicts a greater load for seven of the ten water years (WYs 1992, 1993, 1994, 1996, 1997, 1999, and 2000). For three of those years the relative percent contribution of the 2010 model does not exceed 55 percent. For the water years where the 2003 simulated a greater total nitrogen load (WYs 1991, 1995, and 1998), the relative percent contribution of the 2010 model does not fall below 40 percent.

Simulated total phosphorus loads are also similar between the updated and 2003 model. The 2010 model shows greater total phosphorus loads for five of the ten water years (1992, 1993, 1994, 1996, and 2000). Five of the ten water years also show the relative contribution of each model to be within 60 percent (WYs 1991, 1994, 1996, 1998, and 2000). The most dissimilar year is 1992, which shows the 2010 model accounting for approximately 71 percent of the theoretical combined load.

Table 3-1. Annual nutrient loads to Canyon Lake (water years)

	Total nitrogen load (lbs)			**Total phosphorus load (lbs)**		
Water Year	**2010 model**	**2003 model**	**Percent difference***	**2010 model**	**2003 model**	**Percent difference***
1990	25,710			4,308		
1991	77,123	80,833	-4.8%	25,199	29,591	-17.4%
1992	96,739	42,094	56.5%	28,444	11,396	59.9%
1993	562,151	500,020	11.1%	270,697	152,465	43.7%
1994	36,255	24,039	33.7%	6,416	5,951	7.2%
1995	141,061	163,029	-15.6%	47,074	71,913	-52.8%
1996	36,305	16,793	53.7%	6,502	5,554	14.6%
1997	38,271	18,696	51.1%	6,101	10,580	-73.4%
1998	206,755	287,720	-39.2%	78,723	94,865	-20.5%
1999	14,624	14,067	3.8%	2,340	4,454	-90.3%
2000	29,304	25,319	13.6%	5,061	3,691	27.1%
2001	43,666			8,162		
2002	7,415			1,213		
2003	106,562			35,062		
2004	32,573			5,150		
2005	374,163			163,129		
2006	34,023			5,306		

Water Year	Total nitrogen load (lbs)			Total phosphorus load (lbs)		
	2010 model	2003 model	Percent difference*	2010 model	2003 model	Percent difference*
2007	3,507			605		
2008	39,520			6,094		
2009	32,247			5,270		
Average	**96,899**	**117,261**	**5.3%**	**35,543**	**39,046**	**18.1%**

* Percent difference for average annual loads is calculated based on shared simulation years

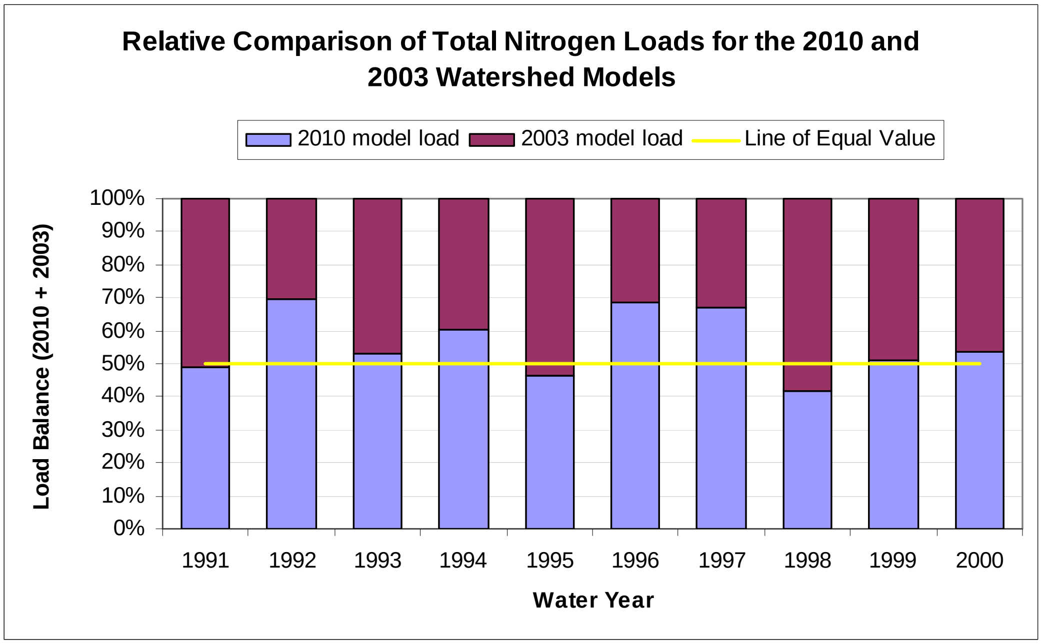

Figure 3-5. Annual total nitrogen load balance between the 2010 and 2003 watershed models

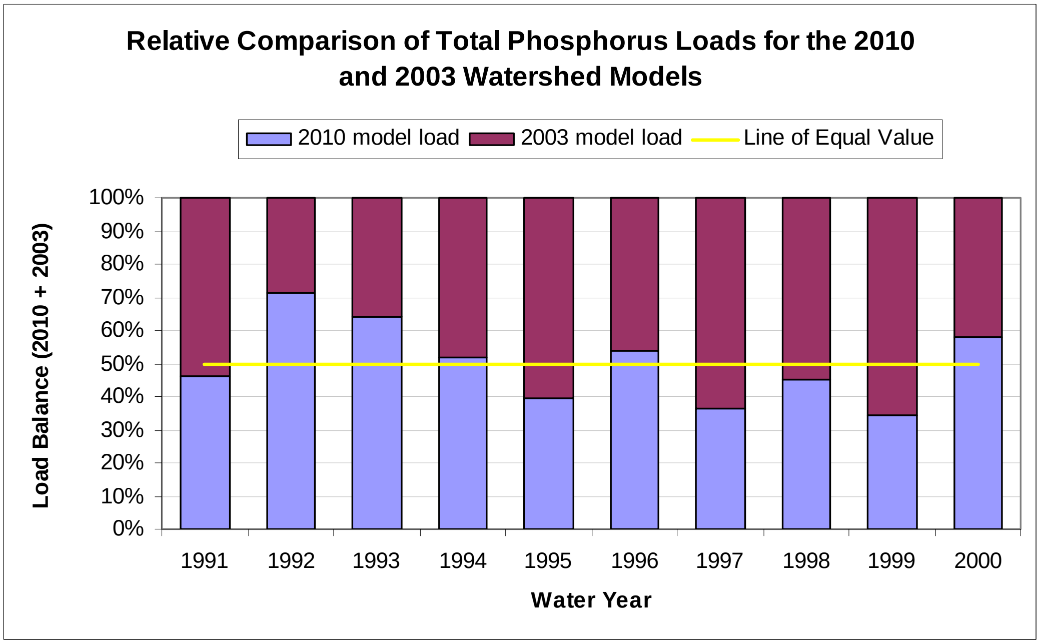

Figure 3-6. Annual total phosphorus load balance between the 2010 and 2003 watershed models

3.2 Assessment of Spatial and Land Use Loading Effects

The assessment of spatial and land use loading affects in the watershed was done in two ways. First, a zonal land use assessment was done that tracked nutrient pollutant loads through the San Jacinto watershed using a methodology established in the 2003 nutrient modeling report (SAWPA 2003). Secondly, the nutrient load contributions of municipalities and other jurisdictions located in the watershed were estimated. Both of these are discussed in the following section.

3.2.1 Zonal Land Use Load Assessment

The 2003 modeling study evaluated the variability in nutrient loading and its dependence on hydrologic conditions by examining three separate water years. These scenarios represented conditions when (1) Mystic Lake and Canyon Lake overflowed, (2) Canyon Lake overflowed but Mystic Lake did not, and (3) neither Mystic Lake nor Canyon Lake overflowed. Scenarios 1, 2, and 3 were represented using model results from WYs 1998, 1994, and 2000, respectively. The same scenarios were run using the updated 2010 watershed model to evaluate spatial and land use effects by dividing the watershed into zones, as was done in the 2003 modeling study (SAWPA 2003). Changes in watershed load estimates from the 2003 modeling study are based on updates to key datasets that were used to develop the current model and other factors that are discussed in Section 2. Significant changes include a more accurate representation of land uses in the watershed, improved representation of storage capacity in Mystic Lake, and re-calibration of the model to account for changes in model configuration and nutrient source data. These updates resulted in significant changes in estimated nutrient loads, such as an increase in the load contribution from developed areas because of a large increase in urban lands and total impervious area. In addition, agricultural land loads contributed downstream are lower, in part, due to the refined Mystic Lake representation. Open space/forest loading rates also were increased based on USFS data and model calibration results.

When Mystic Lake is not present and overflowing, the annual nutrient loads from the upper portions of the watershed do not typically reach Canyon Lake or Lake Elsinore. Likewise, unless Canyon Lake overflows, the nutrient loads from the entire San Jacinto River basin upstream of Canyon Lake will not reach Lake Elsinore (at least during the same year). Localized sources and contributions from areas downstream of Mystic Lake impact the lakes each year, however, they are most critical when Mystic Lake is not overflowing. Cumulative effects due to long-term nutrient contributions from the upper watershed are also expected.

Nutrient loads predicted by the updated watershed model were summarized both spatially and by land use to provide a useful assessment of the variability of nutrient loads throughout the watershed. To analyze the spatial variability of nutrient loads, the San Jacinto River watershed was divided into 9 zones of impact. Figure 3-7 depicts the locations and extent of these zones. Division of the zones was based on modeled subwatersheds and was selected to provide optimal assessment of the varying load distribution throughout the watershed.

To easily track the impact of Mystic Lake on nutrient transport, the load for Zone 7 is summarized as the load exported from Mystic Lake. As a result, if the load stated for Zone 7 is zero, then Mystic Lake did not overflow and no nutrient load could be transported to the bottom portion of the watershed. As an example, for scenarios 2 and 3 identified above, Zone 7 resulted in no net load because Mystic Lake did not overflow, although upstream loads are reported for Zones 8 and 9. For these scenarios, the loads exported from Zones 8 and 9 are stored in Mystic Lake and are not exported from Zone 7 as Mystic Lake overflow.

Also, Canyon Lake influences the nutrient load exported to Zone 1. Because the watershed model provides only a simplistic representation of Canyon Lake, loads to Zone 1 are not considered reliable and, therefore, are not included in the following analysis. Zone 2 is summarized as the load *to* Canyon Lake. Summary of loads *to* the lake instead of *from* the lake (as with Mystic Lake and Zone 7) was provided so that assessments can be made regarding impacts to the lake for possible management scenarios. Zone 2 includes the total load from Zones 3 through 9 (subject to losses through delivery), combined with local loads from the area within the Zone 2 boundary, and summarized as input into Canyon Lake.

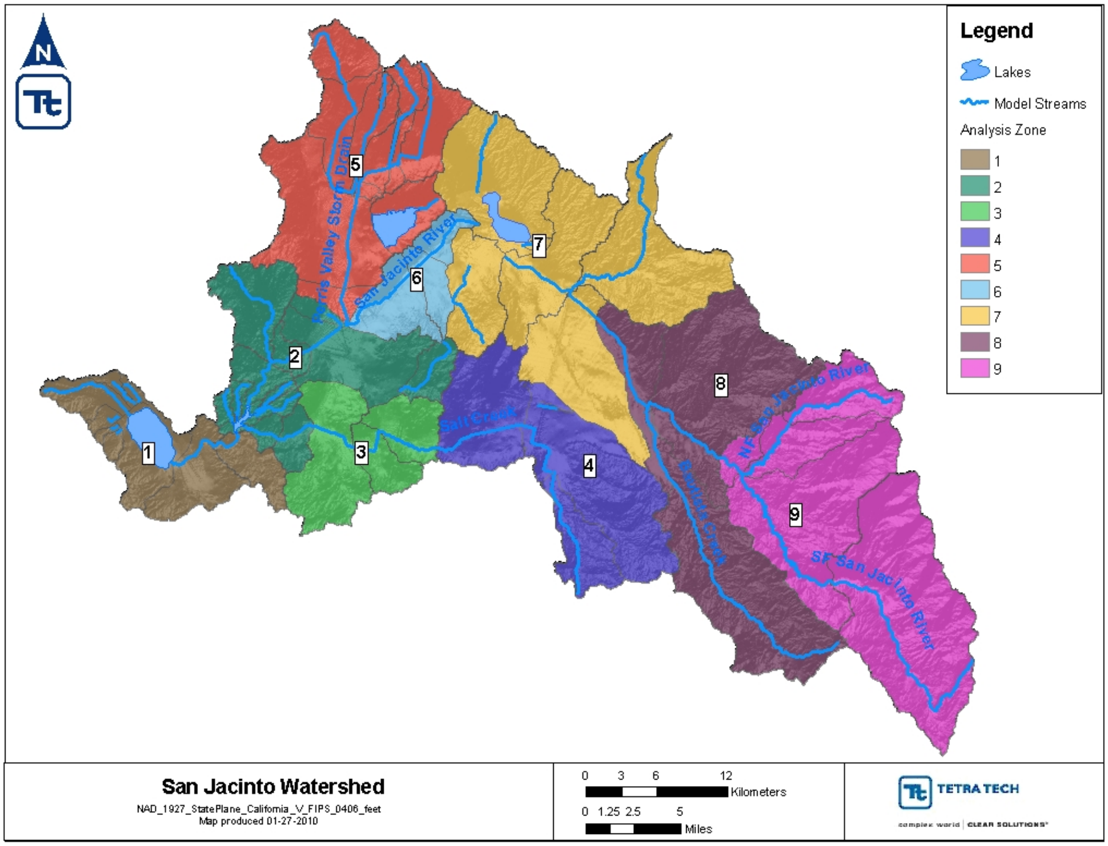

Figure 3-7. Watershed analysis zones

Summaries of model-predicted total nitrogen and total phosphorus loads for the all Zones are provided in Table 3-2 through Table 3-7 for each hydrologic scenario (WY 1994, 1998, and 2000) and land use represented in the updated model. The reported loads are the net loads exported from the zones, including loads transported from upstream zones (except for Zone 1 as described below). For example, the total nitrogen load exported from Zone 8 for WY 1994 is 14,458 lbs, which includes 5,575 lbs from Zone 9 subject to instream losses through Zone 8. Hence, distribution of loads by land use for Zone 8 is a composite of the source distribution for local loads in Zone 8, combined with the source distribution of the load transported from Zone 9 (load from Zone 9 distributed by land use percentages corresponding to Zone 9). Nutrient loads contributed by local land areas within Zone 1 are shown in Table 3-2 through Table 3-7. Exported loads are not shown for Zone 1 because nutrient processes within Lake Elsinore and Canyon Lake would need to be considered in estimating the loads exported from this zone.

Note that the Zone 2 loads *to* Canyon Lake presented in Table 3-2 through Table 3-7 are the same as the total annual loads to Canyon Lake presented in Table 3-1. A comparison of these total loads to the loads simulated by the 2003 model (also presented in Table 3-1) shows that the loads predicted by the two models are similar, as discussed in Section 3.1.1.1. The year that shows the most discrepancy is WY 1998, the year in which Mystic Lake overflowed. A comparison of the zonal loads simulated by the 2010 and 2003 models shows that the 2003 model predicted a much larger Mystic Lake overflow event than the 2010 model (SAWPA 2003).

Table 3-2. Total nitrogen loads (lbs) for Scenario 1 – both Mystic Lake and Canyon Lake overflowed (WY 1998)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
1998	Total Nitrogen (lbs)	Cropland	291	788	70	20	274	101	0	441	119
		Irrigated Cropland	363	15,638	927	478	5,598	2,517	1	851	3
		NonIrrigated Cropland	1,124	16,051	2,029	711	9,735	1,262	0	1,016	5
		Orchards / Vineyards	122	3,709	38	18	483	695	0	5,560	190
		Pasture / Hay	0	133	0	0	92	20	0	0	0
		Dairy / Livestock	1,907	48,241	3,410	2,082	7,330	7,417	3	29,782	22,131
		Low-Density Residential	4,800	10,194	1,301	836	5,453	915	0	5,636	3,312
		Med-Density Residential	8,348	23,428	11,426	5,830	26,181	981	0	3,014	66
		High-Density Residential	447	1,759	1,141	739	1,007	117	0	207	0
		Urban	4,737	11,945	2,893	1,719	14,481	581	0	1,182	395
		Forested	12,559	66,721	443	344	7,465	12,273	6	91,983	41,050
		Open Space	375	2,637	41	17	2,148	267	0	1,100	533
		Water	0	0	0	0	0	0	0	0	0
		Septic	1,695	5,513	1,433	921	2,443	546	0	2,855	1,808
		Total	**36,769**	**206,755**	**25,152**	**13,717**	**82,692**	**27,692**	**13**	**143,626**	**69,612**

Table 3-3. Total phosphorus loads (lbs) for Scenario 1 – both Mystic Lake and Canyon Lake overflowed (WY 1998)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
1998	Total Phosphorus (lbs)	Cropland	192	476	42	12	176	82	0	275	73
		Irrigated Cropland	240	9,478	556	287	3,518	2,077	1	525	2
		NonIrrigated Cropland	744	9,868	1,218	427	6,319	1,054	0	639	3
		Orchards / Vineyards	94	2,664	28	14	367	674	0	4,165	139
		Pasture / Hay	0	69	0	0	49	14	0	0	0
		Dairy / Livestock	1,037	21,053	1,138	695	3,617	4,295	2	13,538	9,859
		Low-Density Residential	1,407	3,279	221	134	1,365	489	0	2,647	1,656
		Med-Density Residential	1,948	4,115	1,551	792	4,953	243	0	698	26
		High-Density Residential	101	294	154	100	198	26	0	50	0
		Urban	1,400	2,884	521	304	3,462	217	0	491	175
		Forested	4,147	23,379	176	137	2,505	5,883	3	34,476	15,071
		Open Space	122	772	8	4	658	105	0	330	157
		Water	0	0	0	0	0	0	0	0	0
		Septic	127	392	107	69	183	53	0	212	132
		Total	**11,559**	**78,723**	**5,720**	**2,975**	**27,369**	**15,212**	**6**	**58,045**	**27,292**

Table 3-4. Total nitrogen loads (lbs) for Scenario 2 – Canyon Lake overflowed (WY 1994)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
1994	Total Nitrogen (lbs)	Cropland	2	62	7	2	10	3	0	45	11
		Irrigated Cropland	4	840	84	43	293	34	0	82	0
		NonIrrigated Cropland	11	707	202	65	251	14	0	86	0
		Orchards / Vineyards	2	386	4	2	13	23	0	459	14
		Pasture / Hay	0	5	0	0	3	0	0	0	0
		Dairy / Livestock	25	4,138	325	189	235	212	0	2,975	1,905
		Low-Density Residential	1,109	2,832	586	353	1,701	60	0	705	222
		Med-Density Residential	2,644	12,339	5,386	2,543	10,823	158	0	1,215	11
		High-Density Residential	149	979	538	322	419	20	0	80	0
		Urban	1,589	6,324	1,447	922	6,253	94	0	271	57
		Forested	111	6,789	44	34	131	399	0	8,027	3,086
		Open Space	3	111	4	2	48	4	0	73	31
		Water	0	0	0	0	0	0	0	0	0
		Septic	140	741	48	15	220	24	0	440	240
		Total	**5,788**	**36,255**	**8,675**	**4,491**	**20,402**	**1,045**	**0**	**14,458**	**5,575**

Table 3-5. Total phosphorus loads (lbs) for Scenario 2 – Canyon Lake overflowed (WY 1994)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
1994	Total Phosphorus (lbs)	Cropland	1	27	4	1	6	2	0	27	6
		Irrigated Cropland	2	366	50	26	176	20	0	49	0
		NonIrrigated Cropland	7	311	120	39	151	8	0	52	0
		Orchards / Vineyards	1	210	3	1	10	17	0	340	10
		Pasture / Hay	0	2	0	0	2	0	0	0	0
		Dairy / Livestock	9	1,035	108	63	78	73	0	1,024	665
		Low-Density Residential	152	364	84	51	234	14	0	219	103
		Med-Density Residential	353	1,213	729	351	1,442	22	0	176	2
		High-Density Residential	20	96	73	45	56	3	0	12	0
		Urban	274	796	243	156	1,047	17	0	64	16
		Forested	44	1,936	18	13	52	157	0	3,120	1,216
		Open Space	1	18	1	0	10	1	0	16	7
		Water	0	0	0	0	0	0	0	0	0
		Septic	10	40	4	1	16	2	0	33	18
		Total	**874**	**6,416**	**1,436**	**747**	**3,281**	**336**	**0**	**5,130**	**2,044**

Table 3-6. Total nitrogen loads (lbs) for Scenario 3 – neither Mystic Lake nor Canyon Lake overflowed (WY 2000)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
2000	Total Nitrogen (lbs)	Cropland	1	33	4	1	6	2	0	17	4
		Irrigated Cropland	1	548	51	26	170	31	0	31	0
		NonIrrigated Cropland	3	687	110	39	179	14	0	35	0
		Orchards / Vineyards	0	171	2	1	9	14	0	174	5
		Pasture / Hay	0	3	0	0	2	0	0	0	0
		Dairy / Livestock	8	2,339	186	114	159	146	0	1,134	732
		Low-Density Residential	766	2,698	460	312	1,338	81	0	532	131
		Med-Density Residential	1,835	12,054	4,244	2,250	8,516	239	0	1,130	9
		High-Density Residential	103	954	424	285	329	30	0	75	0
		Urban	906	5,041	1,062	691	4,146	101	0	250	59
		Forested	34	3,069	26	20	98	240	0	3,051	1,182
		Open Space	1	85	2	1	29	3	0	30	13
		Water	0	0	0	0	0	0	0	0	0
		Septic	138	1,622	256	160	534	60	0	455	250
		Total	**3,797**	**29,304**	**6,825**	**3,902**	**15,516**	**961**	**0**	**6,913**	**2,385**

Table 3-7. Total phosphorus loads (lbs) for Scenario 3 – neither Mystic Lake nor Canyon Lake overflowed (WY 2000)

Water Year	Pollutant	Land Use	Zone 1 Local Land Loads	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
2000	Total Phosphorus (lbs)	Cropland	1	17	2	1	4	1	0	10	2
		Irrigated Cropland	1	278	30	16	101	21	0	17	0
		NonIrrigated Cropland	2	361	65	23	107	9	0	20	0
		Orchards / Vineyards	0	108	2	1	7	12	0	122	4
		Pasture / Hay	0	1	0	0	1	0	0	0	0
		Dairy / Livestock	3	700	62	38	53	57	0	369	237
		Low-Density Residential	98	352	61	41	177	16	0	109	42
		Med-Density Residential	233	1,328	544	290	1,093	35	0	141	1
		High-Density Residential	13	104	54	37	42	4	0	10	0
		Urban	147	692	164	106	652	19	0	46	12
		Forested	13	1,000	10	8	39	105	0	1,108	427
		Open Space	0	17	0	0	6	1	0	6	3
		Water	0	0	0	0	0	0	0	0	0
		Septic	10	103	19	12	40	5	0	32	17
		Total	**522**	**5,061**	**1,015**	**573**	**2,322**	**285**	**0**	**1,991**	**745**

3.2.2 Municipality and Jurisdiction Load Assessment

In addition to the zonal spatial assessment, simulated loads to Canyon Lake (Zone 2) were also assessed by municipalities (including counties) and other jurisdictions in the watershed. Assessment at this level will also assist local stakeholders in identifying management scenarios to best address pollutant loading. Figure 3-8 shows the municipalities located in the San Jacinto watershed and Figure 3-11 presents other jurisdictions of interest located in the watershed. These include federal lands, state lands, Native American reservations, U.S. Forests, and wildlife reserves. In order to calculate municipality loads, these areas were overlain with the model land use and subwatershed layers to assign the areas to a modeling unit (subwatershed) and characterize the land use distribution in each. Model output is in the format of pollutant load by subwatershed and land use type. Once subwatershed and land use information were assigned to the municipality areas, they were linked to the model output to assign the appropriate load on a unit-area basis. This same methodology was used to assign loads to the other watershed jurisdictions. Municipality loads were only calculated for areas that were not also covered by another jurisdiction. Note that GIS information for Caltrans right-of-ways and facilities was provided after development of the model land use coverage. This information can be used in the future to estimate load contributions from areas maintained by Caltrans.

Table 3-8 and Table 3-9 present the total nitrogen and total phosphorus loads assigned to municipalities in the watershed. Figure 3-9 and Figure 3-10 present the relative contributions of each municipality to the average annual total nitrogen and total phosphorus load, respectively. Note that septics represent an artificial land use in the model and therefore are not assigned spatially beyond the subwatershed level. Table 3-10 and Table 3-11 present the total nitrogen and total phosphorus loads for the other jurisdictional areas in the watershed.

In general, the other jurisdictional areas are mutually exclusive, but there are some small areas where these five areas (federal lands, state lands, Native American reservations, U.S. Forests, and wildlife reserves) do overlap (no more than two overlap for the same area). This overlap does not affect the calculated municipality loads because these are calculated for areas that are not covered by the other jurisdictions. Also note that municipalities include county areas and, therefore, the watershed is completely covered by municipalities. Loads calculated for the other jurisdictions, however, were assessed on an individual basis, in areas where they overlapped, loads were double counted. This area is very small and barely impacted the average annual load if municipality and jurisdiction average annual loads are summed. The average annual load to Canyon Lake as presented in Table 3-1 is 96,899 lbs total nitrogen and 35,543 lbs total phosphorus. If average annual loads for municipalities and jurisdictions are summed (Table 3-8 through Table 3-11) the average annual load to Canyon Lake is 96,933 lbs total nitrogen and 35,555 lbs total phosphorus. If determined to be necessary, loads for overlapping jurisdictional areas can be separated out. Load estimates by land use type within each municipality/other jurisdiction are provided in the Spreadsheet Tool that was developed to summarize the model results and facilitate implementation planning.

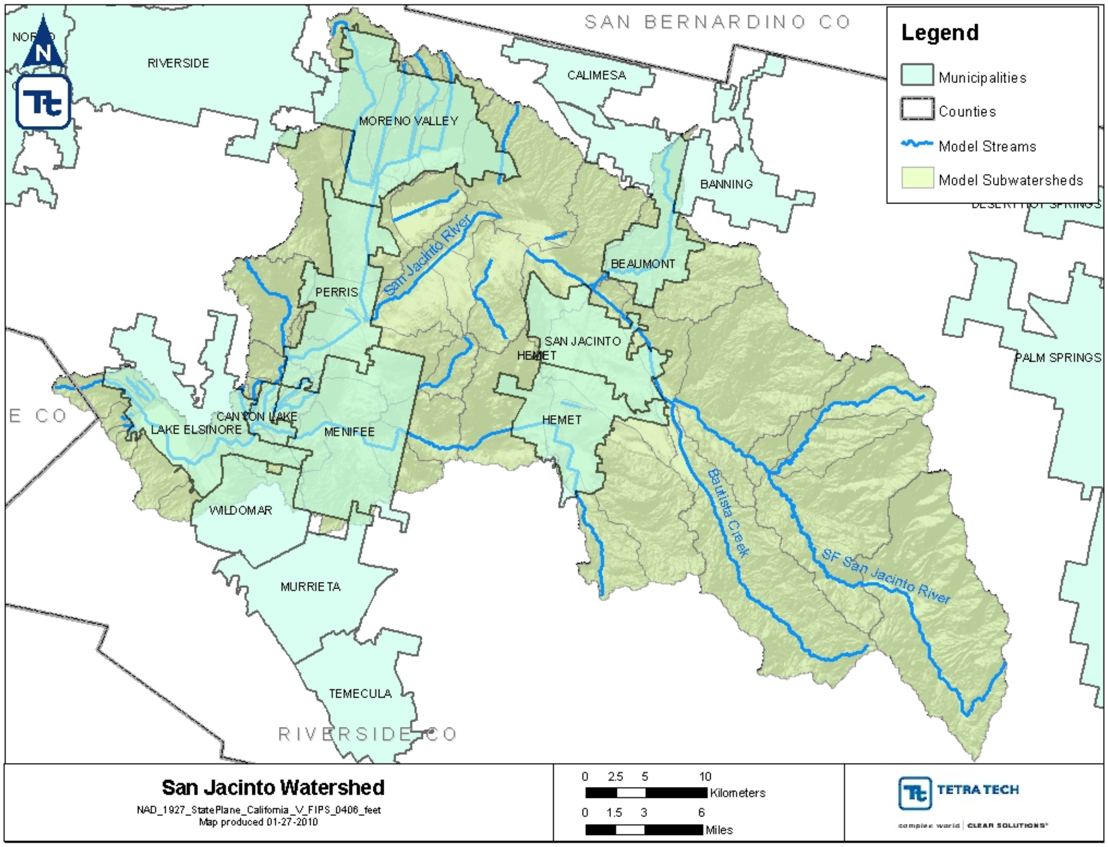

Figure 3-8. Municipalities within the San Jacinto watershed

Table 3-8. Total nitrogen loads for municipalities in the San Jacinto watershed

Water year	Total Nitrogen Load (lbs)														
	Banning	Beaumont	Canyon Lake	Hemet	Lake Elsinore	Menifee	Moreno Valley	Murrieta	Perris	Riverside	Riverside County	San Jacinto	Wildomar	Septic	Total
1990	103	304	603	3,948	173	3,646	6,049	21	2,160	240	5,676	1,683	0	186	**24,791**
1991	94	518	571	5,188	240	6,933	7,227	74	3,370	212	28,953	5,969	1	3,676	**63,026**
1992	180	763	1,142	9,069	361	11,005	13,065	102	5,691	440	33,429	8,533	0	3,806	**87,588**
1993	324	3,253	1,870	31,432	1,019	51,663	38,765	652	27,072	607	247,929	57,622	3	12,150	**474,363**
1994	105	348	618	4,295	195	4,276	6,411	28	2,405	244	10,205	2,526	0	741	**32,396**
1995	130	875	757	7,807	414	10,901	10,424	121	5,277	272	55,717	10,365	1	3,963	**107,024**
1996	97	322	623	4,141	190	4,275	6,230	26	2,254	246	10,351	2,604	0	1,236	**32,595**
1997	126	389	795	5,089	234	4,946	7,792	27	2,706	316	9,606	2,551	0	753	**35,332**
1998	209	1,398	1,225	13,134	564	18,871	17,811	224	9,723	444	82,360	17,421	2	5,513	**168,899**
1999	46	153	255	1,783	83	1,711	2,692	12	1,013	100	3,974	872	0	121	**12,817**
2000	94	293	595	3,823	173	3,766	5,870	22	2,055	236	7,041	1,924	0	1,622	**27,513**
2001	143	444	903	5,831	259	5,767	8,941	34	3,168	359	10,657	2,989	0	1,873	**41,368**
2002	36	105	170	1,259	51	1,080	1,889	7	755	67	1,451	457	0	1	**7,329**
2003	193	854	1,250	9,782	389	12,349	14,359	125	6,198	480	36,539	9,101	0	5,438	**97,058**

Water year	Total Nitrogen Load (lbs)													
	Banning	Beaumont	Canyon Lake	Hemet	Lake Elsinore	Menifee	Moreno Valley	Murrieta	Perris	Riverside	Riverside County	San Jacinto	Wildomar	Septic	Total
2004	124	362	779	4,878	219	4,614	7,549	24	2,578	311	7,207	2,145	0	623	**31,414**
2005	296	2,285	1,794	23,545	780	36,303	30,005	451	18,359	624	159,594	38,595	2	9,990	**322,622**
2006	100	319	633	4,088	195	4,047	6,205	23	2,150	251	9,335	2,261	0	551	**30,158**
2007	17	51	76	593	23	502	880	4	366	30	697	216	0	1	**3,456**
2008	113	360	734	4,638	225	4,591	7,089	25	2,389	291	10,411	2,483	0	1,704	**35,054**
2009	99	306	659	4,107	192	4,067	6,298	22	2,116	262	8,276	2,196	0	1,067	**29,665**
Avg	**132**	**685**	**803**	**7,422**	**299**	**9,766**	**10,278**	**101**	**5,090**	**302**	**36,970**	**8,626**	**1**	**2,751**	**83,223**

Table 3-9. Total phosphorus loads for municipalities in the San Jacinto watershed

Water year	Total Phosphorus Load (lbs)													
	Banning	Beaumont	Canyon Lake	Hemet	Lake Elsinore	Menifee	Moreno Valley	Murrieta	Perris	Riverside	Riverside County	San Jacinto	Wildomar	Septic	Total
1990	15	48	78	570	24	554	855	4	343	31	1,162	300	0	12	**3,998**
1991	17	158	93	1,363	54	2,264	1,802	28	1,093	31	11,050	2,224	0	248	**20,426**
1992	27	204	161	2,016	62	3,125	2,766	36	1,682	58	11,966	2,855	0	261	**25,220**
1993	97	1,576	549	14,683	345	26,843	18,130	340	14,856	150	127,232	30,061	1	946	**235,809**
1994	12	52	63	543	25	630	779	5	361	24	2,313	473	0	40	**5,320**
1995	24	272	131	2,192	102	3,697	2,780	46	1,781	41	20,909	3,926	0	260	**36,162**
1996	10	49	61	524	23	650	754	6	357	23	2,413	511	0	67	**5,449**
1997	14	55	82	615	28	669	914	5	379	32	1,983	432	0	42	**5,249**
1998	43	506	235	4,265	145	7,432	5,597	94	3,942	74	35,092	7,428	1	392	**65,247**
1999	5	20	27	217	10	228	313	2	131	10	808	158	0	6	**1,935**
2000	11	46	67	515	22	588	769	5	328	26	1,631	374	0	103	**4,484**
2001	19	76	110	860	35	987	1,283	8	563	43	2,637	636	0	124	**7,383**
2002	6	18	25	200	8	170	295	1	126	10	252	75	0	0	**1,186**
2003	34	264	206	2,525	75	4,063	3,537	49	2,069	73	14,722	3,515	0	399	**31,532**
2004	16	54	92	653	28	664	987	5	390	37	1,439	373	0	40	**4,776**
2005	75	1,001	439	9,404	229	16,751	11,834	220	8,954	132	75,471	18,159	1	752	**143,423**
2006	10	42	58	451	22	506	655	4	272	22	1,883	370	0	27	**4,321**
2007	3	9	11	99	4	82	144	1	65	4	128	37	0	0	**588**
2008	11	47	68	512	26	573	751	4	297	27	2,126	403	0	85	**4,931**
2009	11	43	68	502	23	561	740	4	301	27	1,785	393	0	60	**4,519**
Avg	**23**	**227**	**131**	**2,136**	**64**	**3,552**	**2,784**	**43**	**1,915**	**44**	**15,850**	**3,635**	**0**	**193**	**30,598**

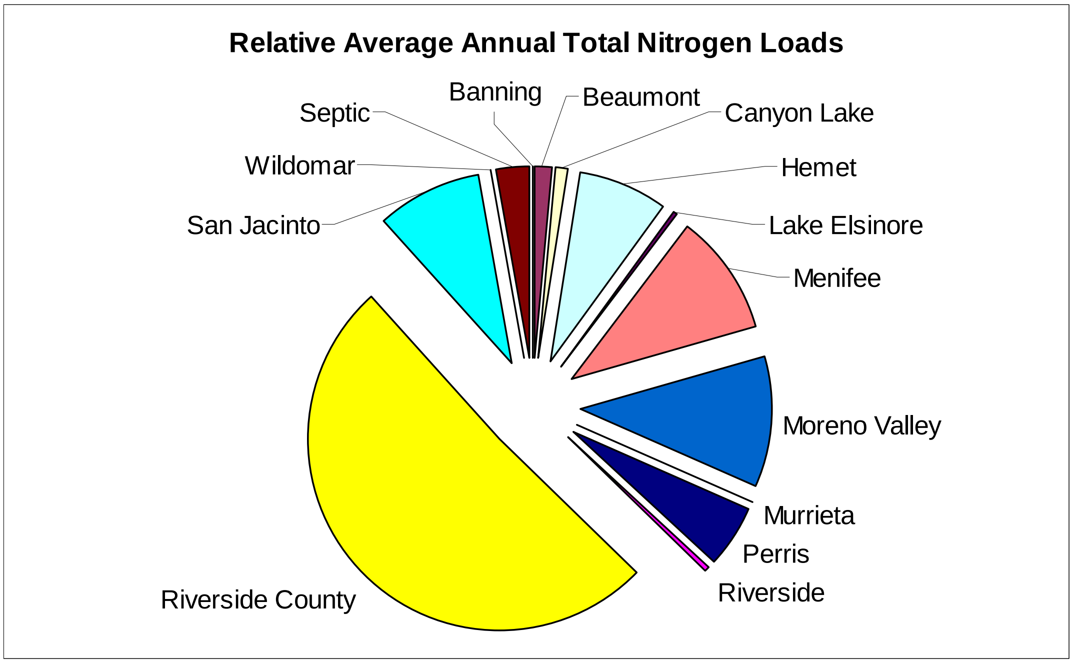

Figure 3-9. Relative total nitrogen loads from municipalities in the San Jacinto watershed

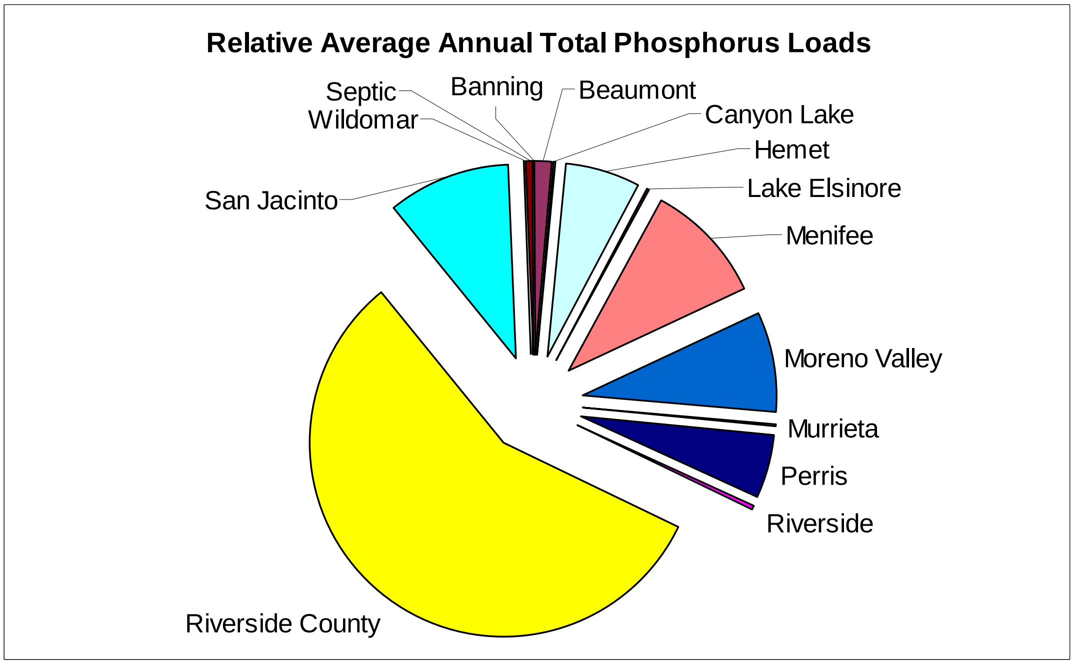

Figure 3-10. Relative total phosphorus loads from municipalities in the San Jacinto watershed

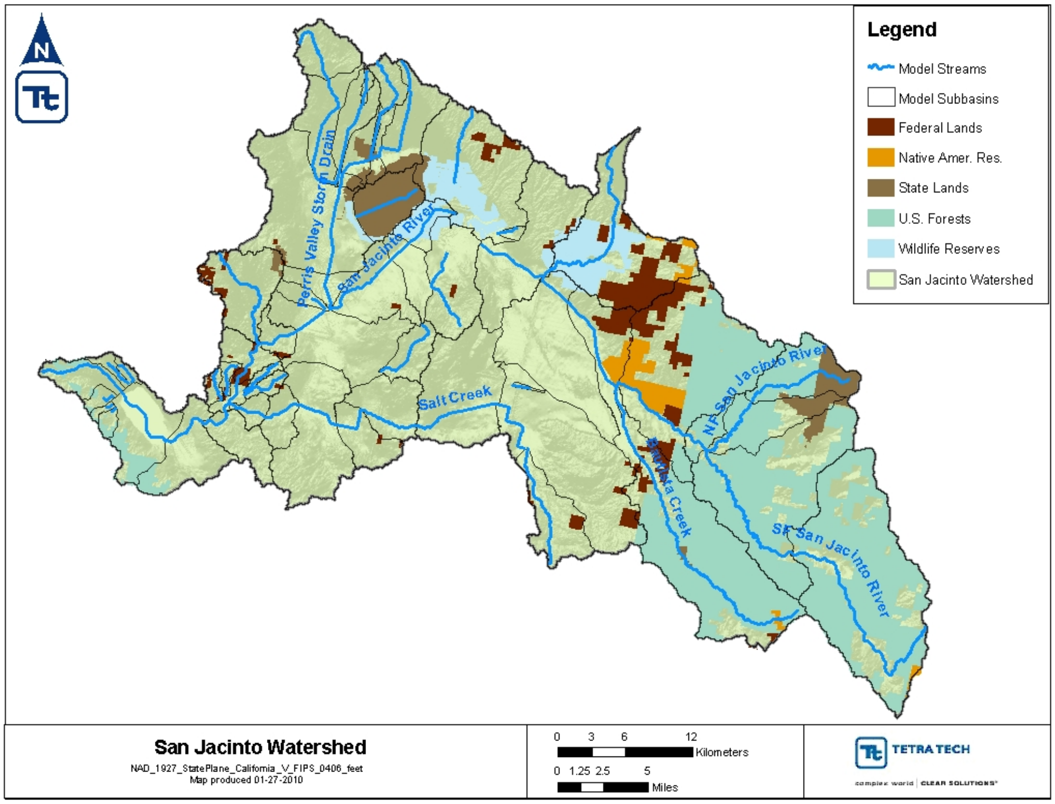

Figure 3-11. Jurisdictions within the San Jacinto watershed

Table 3-10. Total nitrogen loads for jurisdictions in the San Jacinto watershed

Water Year	Total Nitrogen Load (lbs)					
	Federal Lands	State Lands	Native American Reservations	US Forests	Wildlife Reserve	Total
1990	94	101	75	550	101	921
1991	1,558	1,176	641	9,080	1,679	14,133
1992	983	916	519	5,705	1,050	9,174
1993	9,533	8,534	4,405	55,327	10,213	88,011
1994	422	334	192	2,464	456	3,868
1995	3,784	2,742	1,425	22,084	4,090	34,126
1996	405	331	185	2,362	437	3,719
1997	318	268	160	1,858	343	2,947
1998	4,159	3,327	1,759	24,230	4,479	37,954
1999	199	148	87	1,163	215	1,812
2000	192	172	109	1,117	206	1,795
2001	242	237	152	1,413	260	2,304
2002	7	14	18	40	7	86
2003	1,015	962	572	5,897	1,083	9,528
2004	119	131	91	694	127	1,162
2005	5,584	5,055	2,665	32,393	5,974	51,671
2006	425	325	183	2,482	459	3,875
2007	4	7	9	26	5	51
2008	493	370	209	2,874	532	4,478
2009	281	234	135	1,636	302	2,588
Average	**1,491**	**1,269**	**679**	**8,670**	**1,601**	**13,710**

Table 3-11. Total phosphorus loads for jurisdictions in the San Jacinto watershed

Water Year	Total Nitrogen Load (lbs)					
	Federal Lands	State Lands	Native American Reservations	US Forests	Wildlife Reserve	Total
1990	33	30	20	193	36	311
1991	527	409	239	3,047	563	4,786
1992	344	343	201	1,979	365	3,231
1993	3,723	3,823	2,080	21,404	3,944	34,974
1994	121	93	53	702	130	1,099
1995	1,211	904	500	7,025	1,300	10,940
1996	116	93	52	671	124	1,055
1997	94	74	42	544	101	854
1998	1,470	1,263	710	8,498	1,569	13,511
1999	45	32	19	261	48	406
2000	63	53	32	363	67	578
2001	84	77	47	484	89	781
2002	3	3	4	15	3	27
2003	374	378	242	2,150	395	3,539
2004	40	38	24	231	43	374
2005	2,099	2,160	1,204	12,070	2,222	19,755
2006	109	80	45	635	118	987
2007	2	2	2	10	2	17
2008	130	92	53	752	139	1,166
2009	83	65	37	480	89	753
Average	**533**	**501**	**280**	**3,076**	**567**	**4,957**

3.3 Assessment of Pre-development and Existing Conditions

Comparison of model results for existing and pre-development conditions in the San Jacinto River watershed provides insight into the impact that urbanization has on Canyon Lake. A theoretical pre-development stage where the entire San Jacinto River watershed was assumed to have nutrient loading and hydrology characteristics respective of forested conditions was compared to the existing/calibrated conditions reported in Section 5. As mentioned above, all lands were represented as “forested” in the pre-development scenario consistent with the 2003 model analysis. Future modeling tasks can include revising the pre-development land use to include open space areas, although significant differences are not expected because the 2005 SCAG land use dataset does not differentiate between the open space-forested and open space-scrub/shrub categories.

For the pre-development scenario, hydrology and nutrient loading characteristics were assigned using land use-specific parameters developed for forested lands in the areas of the watershed above Mystic Lake (parameter group 6). These parameters are likely most indicative of the hydrology of forested lands in pre-development conditions. The model was run for the entire simulation period, allowing comparison of model results for varying hydrology conditions.

Figure 3-12 and Figure 3-13 present the relative total nitrogen and total phosphorus loads for the simulation period. Nutrient loads from the pre-development and existing scenario are listed in Table 3-12. As can be seen in the comparisons of model results, urbanization has varying impacts on model-predicted nutrient loads, with relative loading characteristics dependent upon the amount of rainfall in a given year. Most notable impacts due to urbanization are observed for Canyon Lake during dryer years, when nutrient loads simulated for the pre-development scenario are negligible, but the existing condition shows significant loading. During wet years both scenarios show significant loads, with the existing scenario showing an increase of an order of magnitude between pre-development and existing conditions for some years (WY's 1998 and 2005).

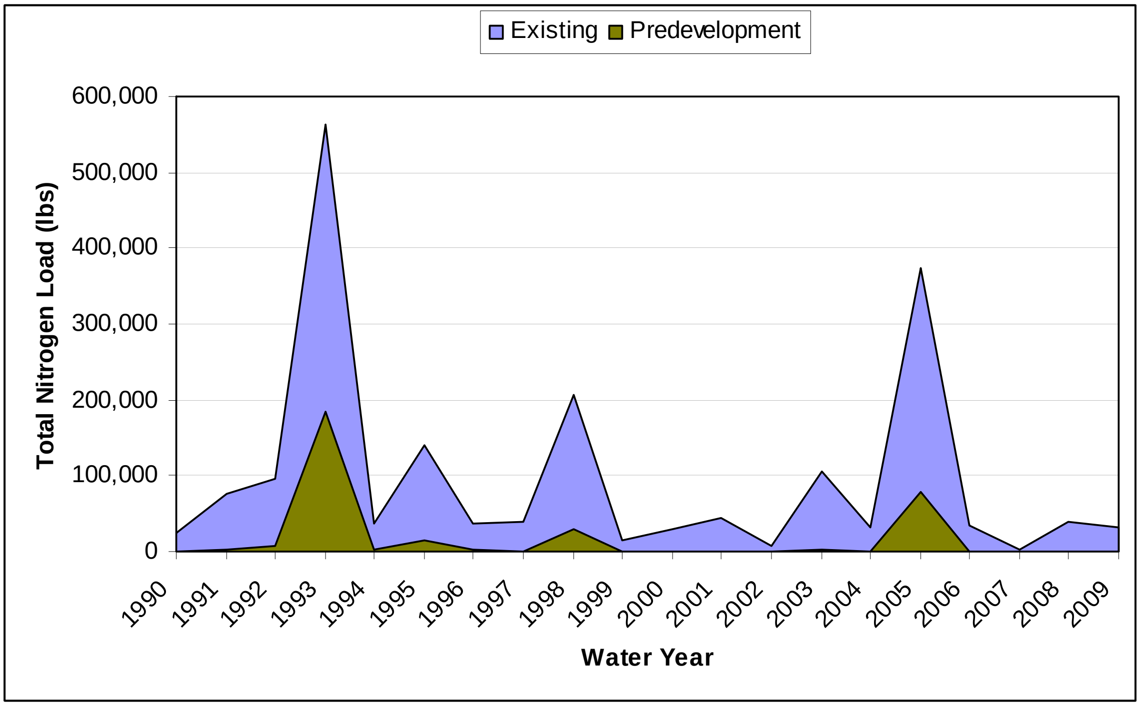

Figure 3-12. Comparison of nitrogen loads to Canyon Lake for varying developmental conditions

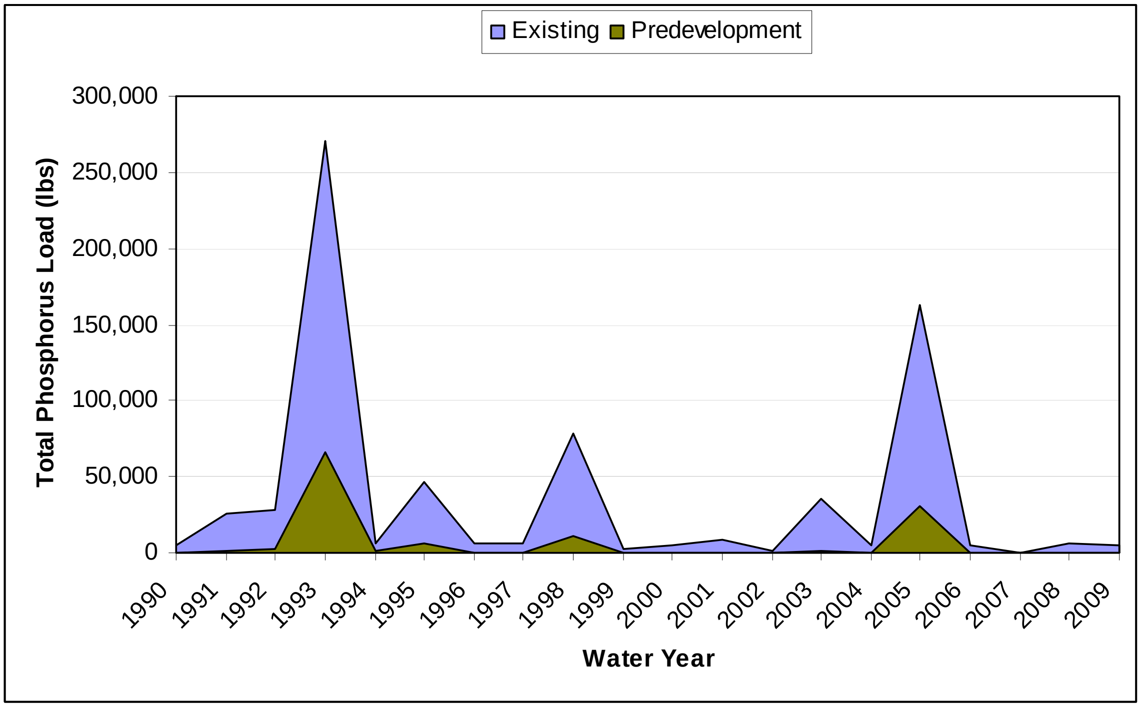

Figure 3-13. Comparison of phosphorus loads to Canyon Lake for varying developmental conditions

Table 3-12. Annual nutrient loads to Canyon Lake at pre-development conditions

Water Year	Pre-development		Existing	
	Total nitrogen load (lbs)	Total phosphorus load (lbs)	Total nitrogen load (lbs)	Total phosphorus load (lbs)
1990	150	60	25,710	4,308
1991	3,204	1,239	77,123	25,199
1992	6,512	2,533	96,739	28,444
1993	183,843	66,251	562,151	270,697
1994	1,590	630	36,255	6,416
1995	15,106	5,852	141,061	47,074
1996	1,528	606	36,305	6,502
1997	503	200	38,271	6,101
1998	29,649	10,533	206,755	78,723
1999	38	15	14,624	2,340
2000	412	164	29,304	5,061
2001	934	372	43,666	8,162
2002	3	1	7,415	1,213
2003	3,409	1,320	106,562	35,062
2004	336	133	32,573	5,150
2005	78,855	30,234	374,163	163,129
2006	652	258	34,023	5,306
2007	0	0	3,507	605
2008	286	114	39,520	6,094
2009	493	196	32,247	5,270
Average	**16,375**	**6,036**	**96,899**	**35,543**

Appendix A – Modeling Data Needs and Final Recommendations

Date:	January 4, 2010
Recipient:	Rick Whetsel, Watershed Planner
Address:	11615 Sterling Avenue, Riverside, CA 95203
Subject:	Modeling Tasks for Lake Elsinore & Canyon Lake TMDLs
Subject:	Modeling Data Needs and Final Recommendations

Introduction

The purpose of this memo is to outline the data needs required to update the San Jacinto River watershed model that was previously developed by Tetra Tech (Tt) and to provide a final accounting of the data obtained to date (through 12/31/09). Model updates follow the Scope of Work (SOW) that was developed to support stakeholders of the Lake Elsinore and Canyon Lake nutrient Total Maximum Daily Loads (TMDLs) in the reassessment and TMDL calculation effort. Modeling tasks will include:

- Representation of Mystic Lake based on available bathymetry and discharge information
- Representation of large, regional BMPs
- Land use data updates based on current information
- Revise nutrient loading rates for forest lands (U.S. Forest Service) and agricultural lands; updated septic information
- Obtain recent water quality data collected within the watershed for comparison to model output
- Update subwatershed delineation to account for municipal boundaries and the location of stormwater conveyance
- Extend weather data file to provide for 20-year estimation of nutrient loads

The majority of these tasks required the collection of additional data from watershed stakeholders. An overview of each task and the data requirements are specified in the following sections. An accounting of the data received to date is included below (status updates). This memo represents the final of four (9/17, 10/20, 11/20, 12/31) status updates to the original Data Needs memo. Additional data requests beyond those outlined in the following sections are not anticipated. Surrogate data or assumptions will be used to supplement the specified data needs where the requested data are unavailable. A brief overview of how the data received to date will be incorporated into the model updates is provided at the end of each modeling task section.

1 Representation of Mystic Lake

Mystic Lake rarely overflows and transports loads from the upper portion of the watershed. As documented in the Lake Elsinore and Canyon Lake Nutrient Source Assessment Final Report (January 2003), very little information was available at the time regarding storage capacity, losses due to groundwater infiltration, and overflow characteristics and return of flow to the San Jacinto River. Previous model development was based on a gross stage-storage curve from a 1975 study of the San Jacinto River hydrology and assumptions regarding storage volume, surface area, and overflow elevation. The model will be updated to more accurately represent the unique outflow and pollutant trapping characteristics of the lake based on recent survey data, as available. The relationship between storage volume and outflow will be used to quantify the relationship between storage volume and outflow so the model assumptions can be verified or updated, as needed. A field survey of the low flow channel that circumvents the lake is also needed to determine if the lake receives all stormflows, as previously modeled.

Data Needs:

- Received map and stage-storage data table for the "dead storage" area of Mystic Lake (data provided by Riverside County Flood Control and Water Conservation District [RCFCWCD], 8/19/09). Notes: "Mystic Lake will retain approximately 17,000 acre-feet at a water surface elevation of 1425 before there will be outflow to the southwest between the two hills. An additional volume will be detained above this elevation, but our mapping does not cover sufficient area to perform a stage-storage-discharge analysis above 1425".
- The existing stage-storage-discharge relationship will be updated based on these data. Assumptions will be made regarding the additional storage volume provided by the lake above 1425 and the resulting outflow.
- Recent water quality and flow data upstream/downstream of Mystic Lake for updating water quality parameters (collected during overflow events). Flow data will be used to verify model output matches observed flow levels.
- Field survey of the low flow channel to verify function

Status update 9/17/09:

- Awaiting recent water quality and flow data upstream/downstream of Mystic Lake. FY 2008-2009 water quality data will be provided by the end of September (9/3/09 email from Rick Whetsel). Please include a GIS coverage that shows the monitoring station locations along with the data.
- Awaiting verification of low-flow channel function
- Awaiting sump data for Mystic Lake (9/2/09 email from Jason Uhley). Additional information/clarification is needed regarding the sump data (definition; how will this information be used to refine the Mystic Lake discharge relationship?).
- Tt will verify if the model used the stage/storage/discharge curve from the existing SJR Master Plan (per 9/3/09 email from Jason Uhley). Please send the SJR Master Plan, including the referenced stage/storage/discharge curve.
- A preliminary rating curve for the Canyon Lake spillway was developed by the RCFCD and USGS (9/3/09 email from Steve Clark). Noted that the updated rating curve differs significantly from the curve used in the original model. Please send this information for review.

Status update 10/20/09:

- Received updated Canyon Lake spillway rating curve (10/5/09)

1) Awaiting Mystic Lake stage-storage-discharge curve and the associated SJR Master Plan source document.
2) Awaiting low-flow channel function / field survey
3) Awaiting Mystic Lake sump data and clarification of how it will be used to refine the Mystic Lake discharge relationship. Tt assumes that these are the data describing the smaller storage basin below the 1,426 ft. reservoir outfall.
4) Awaiting water quality and flow data upstream/downstream of Mystic Lake.

Status update 11/20/09:

All data requests related to the representation of Mystic Lake have been received.

- Received Mystic Lake stage-storage-discharge curve
- Confirmed that the Mystic Lake low-flow channel is no longer in operation (10/28/09 conversation with Alberto Martinez)
- Confirmed that Mystic Lake outflow water quality data are not available due to the reservoir not having overflowed since monitoring efforts began

Status update 12/31/09:

All available data related to the representation of Mystic Lake have been received. See above.

Proposed model updates:

The mystic lake stage-storage-discharge data will be used to develop a rating curve for the model representation of the reservoir. Per conversations with Alberto Martinez, there will be no representation of the low-flow channel, which is no longer in operation and water quality simulation will have to be evaluated upstream and downstream of the lake due to the lack of monitoring data for the lake itself.

2 Representation of large regional BMPs

The effects of BMPs within the watershed were implicitly considered during calibration of the current watershed model. The model will be updated to incorporate larger BMPs that may impact lake water quality conditions, especially during critical periods. LSPC's BMP module will be used to explicitly model existing BMPs to estimate pollutant reduction benefits that BMPs may be currently providing within the watershed. The incorporation of BMPs and approval of the methodology used will help support future watershed planning activities by identifying critical areas and resource management needs. This capability will enhance the utility of the San Jacinto modeling framework.

Data Needs:

- GIS shapefile of BMP locations and drainage areas
- BMP treatment efficiencies either as a % reduction or outflow concentration
- Data required to represent BMP hydrology in LSPC is dependent on BMP Type. BMPs can be grouped as either storage or infiltration BMPs. Data requirements for each include:
    - Storage BMP data needs:
        - Pond/basin cross-section geometry and dimensions
        - Pond/basin length and slope
        - Outflow control structure type (e.g. weir, underdrain)
        - Outflow control structure dimensions including invert depth
    - Infiltration BMP data needs:
        - Structure cross-section geometry and dimensions
        - Structure length and slope
        - Depth and porosity of backfill if applicable
        - Infiltration rate
        - Infiltration depth
        - Drain time

Please use the data table at the end of this text to provide the BMP data needs.

Status update 9/17/09:

- Tt provided additional information regarding the identification of BMPs to include in the watershed model (9/4/09 email from Clint Boschen). The main criteria is that these facilities should be providing treatment to a large area, not "onsite" facilities that serve a subdivision or other small area. These should also be "in-line" facilities (located within the river/stream channel).
- BMP facilities have been identified for model updates including:
    - Major flood control facilities built in the 70's and 80's (Jason Uhley 9/2/09)
    - Four dams and/or regional detention basins (Jason Uhley 9/3/09)
    - The I-215 freeway dam for which stage-storage-discharge data are available (Jason Uhley 9/3/09)
    - Awaiting submittal of BMP data requested for these facilities
- Awaiting submittal of BMP data requested including for the newly identified facilities

Status update 10/20/09:

- Received shapefile of RCFCWCD Facilities (Penny Nanney 10/15/09). Tt assumes these are stormwater retention ponds. Also received a shapefile of RCFCWCD Lines. Tt assumed these are stormwater conveyance channels and are addressed under that data request.
- Received shapefiles of four drainage areas associated with the RCFCWCD facilities: Nasson, Poorman, Lasalle, and Lakeview. Tt assumes that these are the four dams/regional ponds referenced in the 9/3/09 email (Jason Uhley).

- Please clarify whether the county anticipates sending BMP data in addition to those identified in Status Update 9/17/09 (Major flood control facilities built in the 70's and 80's; Four dams/regional ponds; I-215 Freeway Dam) and those received as part of the RCFCWCD facilities shapefile. LESJWA was originally tasked with compiling BMP data [email from Rick Whetsel (9/2/09)]. Tt is currently assuming that these data are forthcoming.

1) Awaiting BMP design data for RCFCWCD facilities (includes the four dams/regional ponds). BMP design data needs are those for storage BMPs, which are listed above.
    - Where available stage-storage-discharge data are preferred (most likely available for dams).
2) Awaiting drainage areas (except for the four dams/regional ponds) and treatment efficiencies for RCFCWCD facilities if available.
3) Awaiting BMP data for I-215 freeway dam.
    - If available stage-storage-discharge data is preferred to design data.
4) Awaiting BMP data for the "Major flood control facilities built in the 70's and 80's."
5) Awaiting BMP data for any other BMP facilities the county intends to provide (LESJWA).

Status update 11/20/09:

- Received stage-storage-discharge data for the four dams/regional ponds (subset of RCFCWCD facilities)
- Established that the I-215 freeway dam is a proposed facility and will not be included in the model updates (10/28/09 conversation with Alberto Martinez)
    - Railroad Canyon Mouth Gorge, a facility downstream of the proposed site, will be included in the model updates. Received stage-storage-discharge data for this facility

1) Awaiting BMP design data for the remainder of the RCFCWCD facilities (other than the four dams/regional ponds)
2) Awaiting drainage areas (except for four dams/regional ponds) and treatment efficiencies for all RCFCWCD facilities if available
3) Awaiting BMP data for the "Major flood control facilities built in the 70's and 80's"
4) Awaiting BMP data for any other BMP facilities the county intends to provide (LESJWA)
5) The U.S. Forest Service provided forestry-related information on 10/28/09 (Robert Taylor). Asked whether trail decommissions and road maintenance activities could be included as part of BMP representation. Tt replied on 10/30/09 – stated that this information can be incorporated in the report, at a minimum. If GIS data are available regarding trail and road locations it may be possible to represent reduced loading from these areas, although significant decrease in loads at the watershed scale would not be expected. Awaiting further guidance.

Status update 12/31/09:

- Confirmed that the stage-storage-discharge data for the four dams/regional ponds that were provided by the RCFCWCD represent the "Major flood control facilities built in the 70's and 80's" (Alberto Martinez).
- Tt sent a list of 28 RCFCWCD facilities located in the San Jacinto watershed for which design data and BMP drainage areas have not been obtained (11/25/09). RCFCWCD did a search of as-built plans/rating curves for these facilities and found that some were readily available.
- Confirmed that the RCFCWCD facilities provide only flood control (100-yr storm design) and do not have a nutrient reduction component. It was noted that the flow-through design of the RCFCWCD facilities also impacts hydrology for smaller rainfall events (Jason Uhley).
- Confirmed that of the remaining RCFCWCD facilities for which design data and drainage areas have not been obtained, only those that influence watershed hydrology should be represented in the model. Tt requested that RCFCWCD review the list of 28 RCFCWCD facilities to assist in identifying those that meet this criteria (12/29/09).

1) Awaiting drainage area for Railroad Canyon Mouth Gorge
2) Awaiting BMP design data and drainage areas that were obtained by RCFCWCD in an initial search of the 28 facilities provided by Tt
3) Awaiting BMP design data and drainage areas for the remaining RCFCWCD facilities that meet the criteria of affecting watershed hydrology as determined by RCFCWCD
4) The U.S. Forest Service provided forestry-related information on 10/28/09 (Robert Taylor). Asked whether trail decommissions and road maintenance activities could be included as part of BMP representation. Tt

replied on 10/30/09 – stated that this information can be incorporated in the report, at a minimum. If GIS data are available regarding trail and road locations it may be possible to represent reduced loading from these areas, although significant decrease in loads at the watershed scale would not be expected. No additional information was provided.

Proposed model updates:
Currently the only BMP information received by Tt are the locations of RCFCWCD facilities, stage-storage-discharge data and drainage areas for the “four major flood control facilities” (subset of RCFCWCD facilities), and the location and stage-storage-discharge data for Railroad Canyon Mouth Gorge. GIS analysis identified 28 additional RCFCWCD facilities located in the watershed. This list was provided to RCFCWCD to determine if the data required for model representation are available. Per communication with Alberto Martinez, as-built plans/rating curves for a few additional facilities may be available. Tt requested that RCFCWCD assess the remaining facilities to determine their potential for affecting watershed hydrology. Jason Uhley indicated that all facilities in the watershed serve only a water detention function (100-yr storms), but flow may be affected. Tt will incorporate additional BMP facilities into the watershed model, depending on the availability of required data from RCFCWCD. Similar to the model representation of Mystic Lake discussed above, model rating curves will be developed for BMPs to simulate the hydrologic changes caused by the impoundments.

Land use data updates

Land use data used for the previous Nutrient Source Assessment study were based on two data sources: 1993 USGS Multi-Resolution Land Characteristics (MRLC) data and 1998 land use data provided by the Eastern Municipal Water District (EMWD). These data were combined to create a customized land use coverage to take advantage of the relative strengths of each dataset. These data were merged so that the MRLC data were used where no EMWD data existed, or where EMWD classified the land use as “open space” or “vacant”. Note that the EMWD dataset did not cover the eastern and western portions of the watershed. Similar land use categories were grouped together for modeling efficiency, resulting in the 14 unique categories listed in the table below.

Model Land Use	
High-Density Residential	Pasture/Hay
Mobile Home/Trailer Park	Orchards/Vineyards
Med-Density Residential	Dairy/Livestock
Low-Density Residential	Water
Cropland (MRLC)	Open Space
Irrigated Cropland	Forested
Non-Irrigated Cropland	Urban

The model will be updated based on more recent land use data available for the watershed. If data gaps exist, Tt will consult with project stakeholders to determine the best approach for updating the modeled land uses. Land-use specific pollutant accumulation rates, build-up limits, and assigned interflow and groundwater concentrations should also be provided if available.

Data Needs:

- Updated EMWD land use GIS shapefile
- Percent impervious of the EMWD land use types
- 2001 MRLC data (Tt to download)
- For pre-development condition model run, what land use type(s) will be used to define the pre-development condition? Assume Forested category only.

Status update 9/17/09:

- Tt downloaded the most recent MRLC land use data (2001) for the study area
- Three local land use datasets have been referenced as possibly being provided in place of EWMD data
    - The latest available TLMA or SCAG land use dataset (Jason Uhley 9/2/09)
    - Riverside County IT department recommended land use dataset (Jason Uhley 9/3/09)

  - County APN land use dataset (Jason Uhley 9/3/09)
- Updated land use data will be grouped into the land use classes used for the original modeling study by the provider
- Local land use dataset will be supplemented with detailed agricultural land use data
  - WRCAC is converting land use data from original modeling project into a GIS shapefile. Shapefile should be ready by mid-late October (Pat Boldt 9/8/09; 9/16/09)
- Awaiting submittal of requested land use data

Status update 10/20/09:

- Received local APN land use dataset.
- Received preliminary WRCAC “baseline” Agricultural Land Use dataset.

1) APN land use class percent imperviousness.
2) Literature discussing the background and development of the APN land use dataset.
3) Final WRCAC Agricultural Land Use dataset.

* Note that the WRCAC and APN land use coverages together do not cover the entire San Jacinto watershed. MRLC land use data or another dataset will need to be incorporated in order to develop a composite land use coverage for the entire watershed.

Status update 11/20/09:

- Received 2005 SCAG land use dataset
- Obtained SCAG land use class percent imperviousness

1) Awaiting final WRCAC Agricultural Land Use dataset
2) APN land use class percent imperviousness
3) APN land use “REALUSE” field code descriptions
4) Literature discussing the background and development of the APN land use dataset
5) The U.S. Forest Service provided forestry-related information on 10/28/09 (Robert Taylor). Offered to provide detailed GIS data for forested areas if this information would be useful for modeling. Tt replied on 10/30/09 – stated that all forest types were grouped for modeling efficiency in 2003. The same was done for other land use types, where loading rates were fairly similar. The same land use grouping will be used for consistency. Proposed including this information in the report for watershed characterization purposes. Awaiting further guidance.

Status update 12/31/09:

- Received WRCAC Agricultural Land Use dataset with final spatial information excluding exemption adjustments (Jennifer Ferrando 12/29/09). Tetra Tech assumes that the polygon land use classifications have been finalized (SJWA area updates) and only exemption statuses require updating.
- Received statistics regarding actual exemption areas as a percentage of agricultural land use (12/19/09)
- Confirmed that the model land use will be based on a composite of the WRCAC land use dataset and the 2005 SCAG land use dataset. A separate land use memo describes the methodology that will be used to develop the composite watershed coverage.

1) Awaiting guidance on how to update the WRCAC dataset with the exemption statistics

Proposed model updates:

The model land use coverage will be a composite of the WRCAC Agricultural land use dataset and the 2005 SCAG land use dataset. The WRCAC dataset covers all agricultural lands in the watershed and is considered to be an important part of model land use development since agricultural lands are considered to be a significant source of nutrient loadings in the watershed. The SCAG dataset will be used to characterize the non-agricultural areas of the watershed. A separate memo that describes the methodology that will be used to develop the composite watershed coverage was developed by Tt.

Revise nutrient loading rates

Nutrient loading rates for forested areas were provided by the U.S. Forest Service via the RWQCB on 8/12/09. The U.S. Forest Service loading rates were previously used to revise the TMDL allocation for forest land within the watershed. The current model will be compared to these loading rates to determine if updates are necessary. In addition, updated nutrient loading rates for agricultural land uses and septic information would be beneficial

Data Needs:

- U.S. Forest Service data were provided to Tt on 8/12/09
- Updated cropland manure application rates (by crop type) if available (mass/area/timescale)

Status update 9/17/09:

- Awaiting confirmation of availability of updated cropland manure application rates
- Crop nutrient runoff loading rates for the San Jacinto watershed are available from UCR (Rick Whetsel 9/8/09). Please send these data in the format and detail requested by Tetra Tech if possible.
    - A list of the types of associated data that would be useful for developing the model was submitted by Tetra Tech (9/16/09)
    - Basic crop nutrient loading data was provided (Rick Whetsel 9/16/09)
- Updated septic data are available in a septic management plan study and in a Quail Valley septic study done by EMWD (Pat Boldt 9/3/09). Please send these data.

Status update 10/20/09:

1) Awaiting crop nutrient runoff loading rates in the format and detail requested by Tt [email from Clint Boschen (9/16/09)].
2) Awaiting confirmation of availability of updated cropland manure application rates.
3) Awaiting updated septic data.

Status update 11/20/09:

- Seasonal runoff loads by crop type in pounds per acre provided by Laosheng (10/30/09)
    - Crop runoff loads per storm/irrigation event and runoff volumes for all scenarios (seasonal, storm/irrigation event) also to be provided (Laosheng 10/30/09)
- Manure application rates are available for different areas, but maximum rates are based on a rate established by "persons taking tipping fees applying in open areas with no crops and claiming to be agricultural operators" (Pat Boldt 10/28/09)
- Septic data are available in a grant report and Jason Uhley may be aware of additional septic data, including the one study on septics in the watershed done by SJWRC (Pat Boldt 10/28/09)
    - Tt will use septic data from previous modeling effort b/c updates will not be appreciably more accurate (Clint Boschen 11/4/09)
- Received the Dairy Waste Water (DWW) Land Application BMP study from Jennifer Ferrando (11/1609). Tetra Tech is reviewing the document to determine if and how these data can be incorporated into the modeling framework.

1) Awaiting crop nutrient runoff loading rates per storm/irrigation event and runoff volumes for all scenarios (seasonal, storm/irrigation event) mentioned above
2) Tt would like to request the manure application data mentioned above and if possible differentiation between "typical" application rates and those associated with "persons taking tipping fees applying in open areas with no crops and claiming to be agricultural operators"

Status update 12/31/09:

- Received spreadsheets of 2008 dairy farm animal counts and manure hauling manifests
    - Requires some clarification
- Received assumptions about manure application to non-dairy farmland
- Requires some clarification
- Confirmed that data from Dairy Waste Water (DWW) Land Application BMP study will not be used in the model
- Received the San Jacinto Watershed Integrated Regional Dairy Management Plan (IRDMP). Tetra Tech is reviewing the document to determine if and how these data can be incorporated into the modeling framework.

- Received Assessment of BMPs to Reduce Nutrient Loads document. Document includes crop runoff loads.

Proposed model updates:
Crop nutrient runoff loading rates will be used to develop nutrient loading rates for the model agricultural land uses. They can also be used to calibrate model simulated stormwater pollutant concentrations. Manure application data, if available, can be used to characterize the build up of nutrients on model agricultural land uses.

Obtain recent water quality data

Water quality monitoring data provided by the RWQCB and RCFCWCD were used for watershed characterization and model development for the Nutrient Source Assessment Study. Data were collected at 4 stations in Canyon Lake, 3 stations in Lake Elsinore, and at 15 in-stream stations within the watershed. Model updates require recent water quality data to validate or refine modeling parameters and to support future watershed planning activities.

Data Needs:
- Spreadsheet or database that includes station name, ID number, waterbody name, location, data collection period, field and laboratory analysis method used, sample depth, value, and units
- GIS shapefile showing sampling locations and attributes

Status update 9/17/09:
- Awaiting recent water quality and flow data upstream/downstream of Mystic Lake. FY 2008-2009 water quality data will be provided by the end of September (9/3/09 email from Rick Whetsel). Please include a GIS coverage that shows the monitoring station locations along with the data.

Status update 10/20/09:
1) Anticipate receipt of available water quality and flow data from SAWPA (Rick Whetsel) by October end

Status update 11/20/09:
- Received water quality and flow data
    - Cranston Guard Station dry-weather data to be provided when they become available (Rick Whetsel 10/28/09)

Status update 12/31/09:
All data requests related to water quality and flow data have been received. See above.

Proposed model updates:
Water quality data will be used to characterize ambient conditions in the watershed and to calibrate the water quality model.

Update subwatershed delineation

The current watershed model represents 35 subwatersheds, which were delineated based on the location of monitoring stations, lake boundaries, and regional differences in land use and other watershed characteristics. Refinement to the subwatershed delineation is needed to represent municipal boundaries and the location of stormwater conveyance. These updates will provide greater resolution in order to estimate pollutant loads that are contributed by various municipalities within the watershed.

Data Needs:
- GIS shapefile of stormwater conveyance channels (pipes) and drainage areas
- Stormwater conveyance channel data needs are the same as those for diversion conveyance channels

Status update 9/17/09:
- A GIS shapefile of the original subwatershed delineation has been received
- A shapefile of city boundaries is available (Jason Uhley (9/2/09). Please send these data.

- To clarify, stormwater conveyance channel data needs are the same as those for storage BMPs (x-section geometry and dimensions, length and slope, outflow structure type, and outflow control structure dimensions).
- Awaiting requested data for subwatershed delineation, including a shapefile coverage of municipal boundaries if it differs from the shapefile of city boundaries mentioned in the second bullet

Status update 10/20/09:

- Received a shapefile of city boundaries [Penny Nanney (10/15/09)].
- Received a shapefile of RCFCWCD Lines. These data area assumed to be stormwater conveyance channels.

1) Awaiting stormwater conveyance channel data needs if available. These are the same as those for storage BMPs (x-section geometry and dimensions, length and slope, outflow structure type, and outflow control structure dimensions).

Status update 11/20/09:

- Confirmed that BMP data for stormwater conveyance channels are not available (Alberto Martinez 10/28/09)

Status update 12/31/09:

- Tetra Tech provided a list of the stormwater conveyance channel IDs associated with the 28 additional RCFCWCD facilities in the San Jacinto watershed (see BMP section). Requested general design assumptions (construction material, representative x-sectional area, etc.) in lieu of specific design data.

1) Awaiting stormwater conveyance channel general design assumptions from RCFCWCD

Proposed model updates:

Municipal boundaries will be incorporated into the model subwatershed network to allow for characterization of pollutant loads for these areas. If no information is available to characterize the stormwater conveyance channels, these will be assumed to be trapezoidal with surface roughness attributes similar to natural channels and cross sectional area determined by the contributing drainage area.

Extend weather data file

The previous modeling time period was from 1991-2000. This time period included dry and wet periods that included overflow from Mystic Lake and Canyon Lake. The weather data file used for modeling would need to be extended to represent a 20-year time period.

Data Needs:

- Identification of the specific 20-year time period to be modeled
- Hourly precipitation time-series for the 20-yr model time period for the local weather gages (RCFCWCD)
- GIS shapefile of weather data stations (if new stations exist, need from RCFCWCD)

Status update 9/17/09:

- Awaiting requested weather extension data

Status update 10/20/09:

- Received weather extension data [Steve Clark (10/5/09)]

Status update 11/20/09:

- All data requests related to extending weather files have been received

1) The U.S. Forest Service provided forestry-related information on 10/28/09 (Robert Taylor). Indicated that a 20-year modeling time period is not of sufficient length to represent the fire return interval (and the natural increase in sediment loading that follows a fire). GIS coverages are available for the fire history in the area. Tt replied on 10/30/09 – stated that this information can be incorporated in the report, at a minimum. A 10-20 year period is typically selected for modeling, which encompasses typical hydrologic and pollutant loading conditions. Additional weather data would be need to be downloaded and included in the weather data file if

a longer modeling period is needed. Another option is to assume a percent increase in sediment/nutrient loading based on literature values/BPJ, which would not require additional modeling resources. Awaiting further guidance

Status update 12/31/09:

- All data requests related to extending weather files have been received

1) Awaiting guidance on the model representation of fire history (see status update 11/20/09)

Proposed model updates:

The extended weather data will be used to develop the watershed model water quality simulation for the 20-yr model time period.

Item			Content (description, value, etc)
BMP Information	BMP type		
	Date of installation		
	Water treatment structure cross-section geometry and measurements		
	Water treatment volume		
	Water treatment surface area		
	Bottom area (if different from surface area)		
	Bottom slope (if available)		
	Bottom length		
	Drawdown time (if available)		
	Soil Type and/or hydraulic conductivity (designed soil media and/or underlying soil)		
	Depth to seasonal high water table		
	Description of vegetation cover		
	Designed outlet flow rate		
	Outlet Structure	Outlet type (weir, orifice, or other)	
		Height of outlet from the bottom (ft)	
		Rectangular weir width if applicable (ft)	
		Triangular weir angle if applicable (degree)	
		Orifice diameter if applicable (inch)	
		Dimensions of other outlet if needed	
		(If more than one outlet exists or if this is a system of BMPs – e.g., treatment train, please list all of them with dimensions)	

Appendix B – Model Land Use Updates

Date: January 4, 2010

Recipient: Rick Whetsel, Watershed Planner

Address: 11615 Sterling Avenue, Riverside, CA 95203

Project: Modeling Tasks for Lake Elsinore & Canyon Lake TMDLs

Subject: Model Land Use Updates

Introduction

The purpose of this memo is to review the properties of the land use data updates for the San Jacinto watershed and to describe the method for including them into the 2010 watershed model setup. The proposed method should be consistent with the methods used in the previous 2003 watershed modeling study done by Tetra Tech (Tt). Land use updates include an agricultural land use dataset for select portions of the watershed developed by Aerial Information Systems Inc. for the Western Riverside County Agriculture Coalition (WRCAC) and a watershed-wide land use dataset. The 2005 Southern California Association of Governments (SCAG) land use data set will be used as the watershed-wide dataset and will be supplemented by the WRCAC data. Other watershed-wide land use datasets that were considered for the model updates included, a local land use dataset based on county parcel data provided by Jason Uhley (as described in emails sent 9/2/09 and 9/3/09) and the 2001 National Land Cover Dataset (NLCD) available through the Multi-Resolution Land Characteristics Consortium (MRLC).

The WRCAC agricultural land use dataset made available to Tt is currently under review to refine data included by agriculture stakeholders that includes parcels flagged as agricultural exemptions, which define areas zoned for agriculture, but are not being used as such. The land use areas presented in this memo may be updated, as appropriate, after receipt of the final WRCAC land use dataset.

1 Modeling study (2003) land use data

Land use characteristics of the San Jacinto River watershed were collected from two data sources for the 2003 Nutrient Source Assessment modeling study: (1) MRLC 1993 NLCD and (2) Eastern Municipal Water District (EMWD) agricultural data. NLCD data are produced by a cooperative of federal agencies collectively known as the MRLC. Land cover classifications are interpreted from satellite imagery based on the reflective properties of land surfaces. EMWD data is a modified version of the 1993 Southern California Association of Governments (SCAG) land use data that provides additional detail (with field verification) regarding urban categories, irrigated and non-irrigated cropland, and the location of concentrated animal feeding operations (CAFOs). Land use categories for the MRLC and EMWD datasets are presented in Table 1.

Table 1. 2003 modeling study land use data sets and land use categories

Land use description	MRLC code
Unclassified	0
Water	11
Low-Density Residential	21
High-Density Residential	22
Commercial	23

Land use description	EMWD code
Unclassified	0
Low-Density Residential	1
Medium-Density Residential	2
High-Density Residential	3
Mobile Home/Trailor Parks	4

Land use description	MRLC code
Industrial	23
Bare Rock/Sand	31
Quarries/Strip Mines/Gravel Pits	32
Transitional	33
Deciduous Forest	41
Coniferous Forest	42
Mixed Forest	43
Deciduous Shrubland	51
Orchards and Vineyards	61
Grassland/Herbaceous	71
Pasture/Hay	81, 83
Row Crops	82
Fallow	84
Recreation/urban lawns	85
Wooded Wetland	91
Herbaceous Wetland	92

Land use description	EMWD code
Public Institutions	5
Commercial	6
Industrial	7
Recreation/urban lawns	8
Irrigated Cropland	9
Orchards and Vineyards	10
Other Agriculture/Ranches	11
Dairy/Livestock	12
Non-Irrigated Cropland	13
Open Space	14
Vacant	15
Water	16
Public Infrastructure	17

To utilize the more detailed EMWD land use data while still accounting for those areas in the San Jacinto River watershed not included in this dataset, a custom composite land use layer was created from the EMWD and MRLC datasets. Since the MRLC and EMWD datasets utilize a different numeric land use classification system, land use categories for both datasets were reclassified to common land use codes. Once reclassified, the EMWD and MRLC land use datasets were merged so that the MRLC data were used where no EMWD data are available, or where EMWD classified the land use as “open space” or “vacant” and the MRLC data are considered more detailed. Similar land use categories were grouped together for modeling efficiency, resulting in the 14 unique categories. Table 2 lists the land use codes used by MRLC and EMWD, as well as the reclassified codes and the final subset of land use categories used in the watershed model.

Table 2. 2003 modeling study land use reclassifications

Land use description	MRLC code	EMWD code	Model code	Model land use description
Unclassified	0	0	0	Unclassified
High-Density Residential	22	3	1110	High-Density Residential
Mobile Home/Trailor Parks		4	1111	Mobile Home/Trailor Parks
Medium-Density Residential		2	1120	Medium-Density Residential
Low-Density Residential	21	1	1130	Low-Density Residential
Commercial	23	6	1000	Urban
Public Institutions		5	1000	Urban
Industrial	23	7	1000	Urban
Public Infrastructure		17	1000	Urban
Vacant		15	1130	Low-Density Residential
Recreation/urban lawns	85	8	1130	Low-Density Residential
Row Crops	82		2100	Cropland
Irrigated Cropland		9	2101	Irrigated Cropland
Non-Irrigated Cropland		13	2102	Non-Irrigated Cropland
Pasture/Hay	81, 83		2120	Pasture/Hay/Ranches
Fallow	84		7000	Open Space/Bare Rock
Orchards and Vineyards	61	10	2200	Orchards and Vineyards
Dairy/Livestock		12	2300	Dairy/Livestock

Land use description	MRLC code	EMWD code	Model code	Model land use description
Other Agriculture/Ranches		11	2120	Pasture/Hay/Ranches
Deciduous Forest	41		4000	Forest/Shrubland/Orchard
Coniferous Forest	42		4000	Forest/Shrubland/Orchard
Mixed Forest	43		4000	Forest/Shrubland/Orchard
Grassland/Herbaceous	71		4000	Forest/Shrubland/Orchard
Deciduous Shrubland	51		4000	Forest/Shrubland/Orchard
Water	11	16	5000	Water
Herbaceous Wetland	92		4000	Forest/Shrubland/Orchard
Wooded Wetland	91		4000	Forest/Shrubland/Orchard
Open Space		14	7000	Open Space/Bare Rock
Bare Rock/Sand	31		7000	Open Space/Bare Rock
Quarries/Strip Mines/Gravel Pits	32		7000	Open Space/Bare Rock
Transitional	33		7000	Open Space/Bare Rock

2 Land use data updates (2010)

Land use data updates for the 2010 San Jacinto watershed model will utilize datasets similar to those used for the previous Nutrient Source Assessment study including: the 2005 SCAG land use dataset and the 2009 WRCAC agriculture land use data.

The Southern California Aerial Land Use Consortium, an organization consisting of public and quasi-public agencies, headed by the Southern California Association of Governments (SCAG), originally contracted with AIS to develop a region-wide land use data layer in 1990, which came to be known as the SGAG land use dataset. Land used data updates were completed in 1993, 2000, and 2005. Beginning in 2000, the updates were performed using computer interactive photo interpretation techniques and digital natural color imagery. Polygon attributes and boundaries were revised by the photo interpreters to reflect current conditions. Hard to identify photo signatures were flagged for on-site visits to ensure the accuracy of the interpretations.

2009 WRCAC agricultural data were derived using methodologies presented in *A Land Use and Land Cover Classification System for use with Remote Sensor Data* (Anderson et al. 1976). Agricultural land use classifications derived from satellite imagery were refined based on stakeholder information regarding agricultural production and manual review of the satellite imagery. Using this information, a spatial coverage for portions of Riverside County was developed which includes large areas in the western and central portions of the San Jacinto watershed. Land use categories and percent distributions available in the 2009 WRCAC agriculture data are presented in Table 3 and Figure 1. WRCAC agricultural land uses that are similar to categories included in the EMWD dataset are highlighted and listed with the associated EMWD land use category in Table 3 to show the similarities and differences between these two agricultural datasets.

Table 3. WRCAC land classifications and area distribution

WRCAC land use description	WRCAC code	Associated EMWD land use description	Area (acres)	% Area
Irrigated Agriculture	2110	Irrigated Cropland	20,962	23.1%
Wildlife Reserve	1850		19,756	21.8%
Non Irrigated Agriculture	2120	Non-Irrigated Cropland	15,969	17.6%
Vacant Zoned Agriculture	2121		12,171	13.4%
Citrus	2210		3,178	3.5%
Horses	2700	Dairy/Livestock	2,875	3.2%
Water	4000	Water	2,806	3.1%
Flood Control	1437		2,419	2.7%
Unknown Agriculture	9999		2,202	2.4%

WRCAC land use description	WRCAC code	Associated EMWD land use description	Area (acres)	% Area
Placeholder				
Backyard Livestock	2620	Dairy/Livestock	1,562	1.7%
Turf Farms	2310		1,130	1.2%
Dairies Non Intensive	2142	Dairy/Livestock	1,080	1.2%
Dairies Intensive	2411	Dairy/Livestock	1,022	1.1%
Water Storage	1434		1,010	1.1%
Nurseries Undifferentiated	2300		957	1.1%
Other Ag Undifferentiated	2600		352	0.4%
Water Transfer	1436		337	0.4%
Poultry	2500	Dairy/Livestock	329	0.4%
Other Livestock	2420	Dairy/Livestock	201	0.2%
Orchards Vineyards Undifferentiated	2200	Orchards and Vineyards	180	0.2%
Manure Piles	2610	Dairy/Livestock	148	0.2%
Abandoned Orchards Vineyards	3200		15	0.0%
Christmas Tree Farms	2320		13	0.0%
		Total	90,677	100.0%

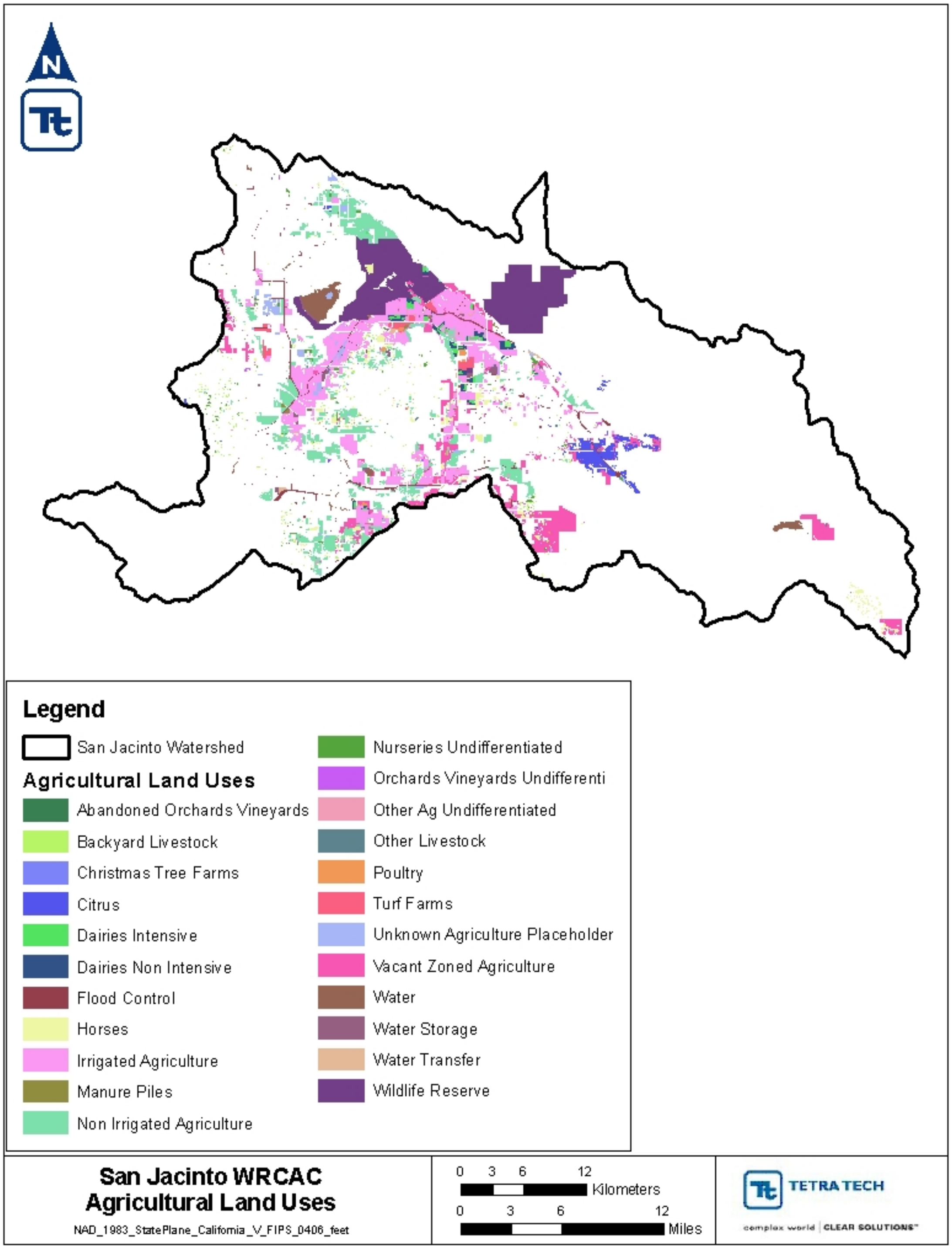

Figure 1. WRCAC agricultural land use data in the San Jacinto watershed

Similar to the 2003 study, two datasets will be combined to create a custom composite land use coverage to take advantage of the more detailed WRCAC agricultural data, where available. Areas for which WRCAC data are not available will be characterized using the 2005 SCAG land use dataset. Table 4 lists the land use codes used in the 2005 SCAG and 2009 WRCAC datasets, as well as two possible land use subsets that will be considered for the watershed model update. Similar land use categories were grouped for modeling efficiency in both subsets.

The WRCAC agricultural land use categories were grouped in the same way for both subsets. These grouped categories are consistent with the 2003 study. The two subsets differ in the grouping of residential and urban land uses from the 2005 SCAG dataset. The second subset groups the SCAG urban land uses into classifications that are identical to the 2003 modeling study. SCAG land use descriptions were compared to the 2003 model land use categories to determine how to best group the SCAG residential and urban land uses. GIS was also used to compare parcels between the 2003 model land use coverage and the 2005 SCAG data for land uses that were more difficult to categorize (High-Density Single Family Residential; Trailer Parks and Mobile Home Courts, High-Density; Mixed Residential; and Rural Residential, High-Density). The first subset includes simplified groupings for residential land uses and a more detailed characterization of urban areas. These categories were further grouped in the second subset to be consistent with the 2003 model land use categories. Tt will review available land use loading values to determine if the additional land use detail provided in the first subset will provide meaningful information for the current modeling update. The final determination of which land use subset will be used will be made during the model parameterization process.

Table 4. 2009 modeling study land use reclassifications

Land use description	SCAG code	WRCAC code	Model land use subset 1	Model land use subset 2
Abandoned Orchards/Vineyards		3200	Forested	Forested
Backyard Livestock		2620	Dairy/Livestock	Dairy/Livestock
Christmas Tree Farms		2320	Orchards/Vineyards	Orchards/Vineyards
Citrus		2210	Orchards/Vineyards	Orchards/Vineyards
Dairies - Intensive		2411	Dairy/Livestock	Dairy/Livestock
Dairies - Non-Intensive		2412	Dairy/Livestock	Dairy/Livestock
Flood Control		1437	Water	Water
Horses		2700	Dairy/Livestock	Dairy/Livestock
Irrigated Agriculture		2110	Irrigated Cropland	Irrigated Cropland
Manure Piles		2610	Dairy/Livestock	Dairy/Livestock
Non-Irrigated Agriculture		2120	Non-Irrigated Cropland	Non-Irrigated Cropland
Nurseries Undifferentiated		2300	Orchards/Vineyards	Orchards/Vineyards
Orchards/Vineyards Undifferentiated		2200	Orchards/Vineyards	Orchards/Vineyards
Other Agriculture Undifferentiated		2600	Cropland	Cropland
Other Livestock		2420	Dairy/Livestock	Dairy/Livestock
Poultry		2500	Dairy/Livestock	Dairy/Livestock
Turf Farms		2310	Pasture/Hay	Pasture/Hay
Unimproved Floodway		1438	Water	Water
Unknown Agriculture/Placeholder		9999	Open Space	Open Space
Vacant Zoned Agriculture		2121	Forested	Forested
Water Bodies		4000	Water	Water
Water Storage		1434	Water	Water
Water Transfer		1436	Water	Water
Wildlife Preserve		1850	Forested	Forested
High-Density Single Family Residential	1111		High-Density Single Family Residential	Med-Density Residential
Low-Density Single Family Residential	1112		Low-Density Single Family Residential	Low-Density Residential
Mixed Multi-Family Residential	1121		Multi-Family Residential	High-Density Residential
Duplexes, Triplexes and 2- or 3-Unit Condominiums and	1122		Multi-Family Residential	High-Density Residential
Low-Rise Apartments, Condominiums, and Townhouses	1123		Multi-Family Residential	High-Density Residential
Medium-Rise Apartments and Condominiums	1124		Multi-Family Residential	High-Density Residential
High-Rise Apartments and Condominiums	1125		Multi-Family Residential	High-Density Residential
Trailer Parks and Mobile Home Courts, High-	1131		Multi-Family Residential	Med-Density Residential

Land use description	SCAG code	WRCAC code	Model land use subset 1	Model land use subset 2
Density				
Mobile Home Courts and Subdivisions, Low-Density	1132		Multi-Family Residential	Low-Density Residential
Mixed Residential	1140		Multi-Family Residential	High-Density Residential
Rural Residential, High-Density	1151		High-Density Single Family Residential	Med-Density Residential
Rural Residential, Low-Density	1152		Low-Density Single Family Residential	Low-Density Residential
Low- and Medium-Rise Major Office Use	1211		Commercial	Urban
High-Rise Major Office Use	1212		Commercial	Urban
Skyscrapers	1213		Commercial	Urban
Regional Shopping Center	1221		Commercial	Urban
Retail Centers (Non-Strip With Contiguous Interconnect	1222		Commercial	Urban
Modern Strip Development	1223		Commercial	Urban
Older Strip Development	1224		Commercial	Urban
Commercial Storage	1231		Commercial	Urban
Commercial Recreation	1232		Commercial	Urban
Hotels and Motels	1233		Commercial	Urban
Attended Pay Public Parking Facilities	1234		Commercial	Urban
Government Offices	1241		Institutional	Urban
Police and Sheriff Stations	1242		Institutional	Urban
Fire Stations	1243		Institutional	Urban
Major Medical Health Care Facilities	1244		Institutional	Urban
Religious Facilities	1245		Institutional	Urban
Other Public Facilities	1246		Institutional	Urban
Non-Attended Public Parking Facilities	1247		Institutional	Urban
Correctional Facilities	1251		Institutional	Urban
Special Care Facilities	1252		Institutional	Urban
Other Special Use Facilities	1253		Institutional	Urban
Pre-Schools/Day Care Centers	1261		Institutional	Urban
Elementary Schools	1262		Institutional	Urban
Junior or Intermediate High Schools	1263		Institutional	Urban
Senior High Schools	1264		Institutional	Urban
Colleges and Universities	1265		Institutional	Urban
Trade Schools and Professional Training Facilities	1266		Institutional	Urban
Base (Built-up Area)	1271		Institutional	Urban
Vacant Area	1272		Open Space	Open Space
Air Field	1273		Commercial	Urban
Manufacturing, Assembly, and Industrial Services	1311		Industrial	Urban
Motion Picture and Television Studio Lots	1312		Industrial	Urban
Packing Houses and Grain Elevators	1313		Industrial	Urban
Research and Development	1314		Industrial	Urban
Manufacturing	1321		Industrial	Urban
Petroleum Refining and Processing	1322		Industrial	Urban
Open Storage	1323		Industrial	Urban
Major Metal Processing	1324		Industrial	Urban
Chemical Processing	1325		Industrial	Urban
Mineral Extraction - Other Than Oil and Gas	1331		Industrial	Urban
Mineral Extraction - Oil and Gas	1332		Industrial	Urban
Wholesaling and Warehousing	1340		Commercial	Urban

Land use description	SCAG code	WRCAC code	Model land use subset 1	Model land use subset 2
Airports	1411		Transportation	Urban
Railroads	1412		Transportation	Urban
Freeways and Major Roads	1413		Transportation	Urban
Park-and-Ride Lots	1414		Transportation	Urban
Bus Terminals and Yards	1415		Transportation	Urban
Truck Terminals	1416		Transportation	Urban
Harbor Facilities	1417		Industrial	Urban
Navigation Aids	1418		Industrial	Urban
Communication Facilities	1420		Industrial	Urban
Electrical Power Facilities	1431		Industrial	Urban
Solid Waste Disposal Facilities	1432		Industrial	Urban
Liquid Waste Disposal Facilities	1433		Industrial	Urban
Water Storage Facilities	1434		Industrial	Urban
Natural Gas and Petroleum Facilities	1435		Industrial	Urban
Water Transfer Facilities	1436		Industrial	Urban
Improved Flood Waterways and Structures	1437		Industrial	Urban
Maintenance Yards	1440		Industrial	Urban
Mixed Transportation	1450		Transportation	Urban
Mixed Transportation and Utility	1460		Transportation	Urban
Mixed Commercial and Industrial	1500		Industrial	Urban
Mixed Urban	1600		Commercial	Urban
Under Construction	1700		Commercial	Urban
Golf Courses	1810		Open Space	Open Space
Developed Local Parks and Recreation	1821		Open Space	Open Space
Undeveloped Local Parks and Recreation	1822		Open Space	Open Space
Developed Regional Parks and Recreation	1831		Open Space	Open Space
Undeveloped Regional Parks and Recreation	1832		Open Space	Open Space
Cemeteries	1840		Open Space	Open Space
Wildlife Preserves and Sanctuaries	1850		Forested	Forested
Specimen Gardens and Arboreta	1860		Open Space	Open Space
Beach Parks	1870		Open Space	Open Space
Other Open Space and Recreation	1880		Open Space	Open Space
Irrigated Cropland and Improved Pasture Land	2110		Irrigated Cropland	Irrigated Cropland
Non-Irrigated Cropland and Improved Pasture Land	2120		Non-Irrigated Cropland	Non-Irrigated Cropland
Orchards and Vineyards	2200		Orchards/Vineyards	Orchards/Vineyards
Nurseries	2300		Orchards/Vineyards	Orchards/Vineyards
Dairy, Intensive Livestock, and Associated Facilities	2400		Dairy/Livestock	Dairy/Livestock
Poultry Operations	2500		Dairy/Livestock	Dairy/Livestock
Other Agriculture	2600		Cropland	Cropland
Horse Ranches	2700		Dairy/Livestock	Dairy/Livestock
Vacant Undifferentiated	3100		Forested	Forested
Abandoned Orchards and Vineyards	3200		Forested	Forested
Vacant With Limited Improvements	3300		Open Space	Open Space
Beaches (Vacant)	3400		Open Space	Open Space
Water, Undifferentiated	4100		Water	Water
Harbor Water Facilities	4200		Water	Water
Marina Water Facilities	4300		Water	Water
Water Within a Military Installation	4400		Water	Water