Lake Elsinore and Canyon Lake Nutrient Source Assessment

FINAL REPORT

Submitted to:
Santa Ana Watershed Project Authority
11615 Sterling Avenue
Riverside, CA 92503

Submitted by:
Tetra Tech, Inc.
10306 Eaton Place
Suite 340
Fairfax, Virginia 22030

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TETRA TECH, INC.

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Executive Summary

The objective of this project was to assess nutrient loadings contributed to Lake Elsinore and Canyon Lake by the San Jacinto River Basin, which encompasses a 770-square-mile area extending from the San Jacinto Mountains to Elsinore Valley. Both Lake Elsinore and Canyon Lake were included by the Santa Ana Regional Water Quality Control Board (RWQCB) on the 1998 Clean Water Act Section 303(d) list as impaired waterbodies for nutrients, unknown toxicity, low dissolved oxygen, turbidity, and pathogens. To support the assessment effort and the RWQCB's Total Maximum Daily Load (TMDL) development effort, a comprehensive modeling system of the San Jacinto River watershed was developed. The model provides a framework for nutrient source assessment through representation of contributing landuses in a subwatershed network and subsequent determination of required nutrient load reductions and allocations to meet TMDL objectives. In addition, the modeling system will provide guidance on and facilitate testing of alternative management scenarios for design of a watershed management plan to achieve water quality objectives and goals.

The San Jacinto River Basin is composed primarily of shrublands in the headwaters, while downstream portions consist of an urban and agricultural mix. Land around both Canyon Lake and Lake Elsinore is highly urbanized. Key nutrient sources throughout the watershed include dairy farm runoff, runoff from cropland and pasture, urban area runoff, contributions from septic systems, and background/non-anthropogenic loads. Due to the ephemeral nature of the San Jacinto River system, the location of key sources plays a critical role in ultimate nutrient contributions to the lakes. Urban development and agricultural land practices in the lower portion of the San Jacinto River watershed below Mystic Lake (including Perris Valley and Salt Creek) have the greatest impact on water quality in Canyon Lake, especially under average rainfall conditions. However, during periods of torrential rains and extended periods of rainfall, the storage capacity of Mystic Lake is exceeded and surface flow from the headwaters, including shrubland, urban runoff from the City of Hemet, and agricultural runoff upstream of Mystic Lake, reaches Canyon Lake and sometimes overflows into Lake Elsinore. Other than overflows of the Canyon Lake dam during extreme rain events, pollutant loads to Lake Elsinore are dominated by nonpoint sources downstream of Canyon Lake.

The modeling system was designed to represent all known sources in the watershed and to provide a quantitative tool for predicting nutrient load contributions to Canyon Lake and Lake Elsinore. It is composed of two linked models developed in parallel: a watershed model of the entire basin and a receiving waterbody model of Canyon Lake. U.S. EPA's Loading Simulation Program C++ (LSPC) was selected as the watershed model platform, and it simulates all nonpoint sources in the watershed and routes flow and water quality through stream networks to Canyon Lake and Lake Elsinore. U.S. EPA's Environmental Fluid Dynamics Code (EFDC) was selected as the basis for the Canyon Lake model. EFDC simulates hydrodynamics and simplified nutrient processes in the lake to predict overflows to Lake Elsinore and corresponding nutrient contributions.

The modeling system was tested (full calibration and validation) for flow and water quality representation using monitoring data collected since the 1990's. The watershed model then run for a 10-year period (1991 through 2000) to predict contributions to Canyon Lake for an array of hydrologic conditions and to characterize the distribution of pollutant loading throughout the San Jacinto River Basin. Since the upper San Jacinto River and many of the river's tributaries are typically dry, it was necessary to simulate multiple years dynamically to capture episodes when extreme rainfall results in significant streamflow and transport of pollutants from far reaches of the river basin. The model predicted daily flows and concentrations of total nitrogen and total phosphorus delivered to both Canyon Lake and Lake Elsinore. For select years, output from the watershed model was used as input to the Canyon Lake model for prediction of nutrient loads to Lake Elsinore.

The resulting nutrient loads were summarized and reported both monthly and annually to provide an analysis of the temporal variability of loadings to the lakes. Annual nutrient loads delivered to Canyon Lake and Lake Elsinore varied by nearly two orders of magnitude from one year to the next, depending on rainfall conditions. Annual total nitrogen loads to Canyon Lake ranged from 10,264 lbs to 498,175 lbs, while those for total phosphorus ranged from 3,186 lbs to 152,318 lbs. Loads to Lake Elsinore also varied greatly from one year to the next. Annual total nitrogen loads to Lake Elsinore ranged from 1,722 lbs to 952,632 lbs, while those for total phosphorus ranged from 1,022 lbs to 223,896 lbs.

Three water years were selected as representative of varying hydrologic/hydraulic conditions in the watershed: (1) year that both Mystic Lake and Canyon Lake overflow (WY 1998), (2) year that only Canyon Lake overflows (WY 1994), and (3) year that neither Mystic Lake nor Canyon Lake overflow (2000). Each of these years was modeled and results were assessed to determine nutrient loading characteristics and distribution of sources under the varying conditions. Results showed that nutrient loading to the lakes and source distribution varied greatly between each of the three model scenarios. The magnitude and sources of nutrients were highly dependent on the overflow of both Mystic Lake and Lake Elsinore.

Urbanization of the San Jacinto River watershed is predicted to have substantial impact to the nutrient loads to Canyon Lake and Lake Elsinore. As a result of analyses of pre-development, existing, and future (built-out) conditions, two competing factors are determined to cause varying results in impacts to nitrogen and phosphorus loads to the lakes: (1) hydrology changes resulting from increase in impervious area, and (2) redistribution of landuse and resulting changes to nutrient loading rates.

1.0 Introduction and Objectives

The Santa Ana Watershed Protection Authority (SAWPA) has coordinated a watershed assessment and modeling study to support management initiatives and development of Total Maximum Daily Loads (TMDLs) for the San Jacinto River watershed, specifically, Lake Elsinore and Canyon Lake. Tetra Tech, Inc., has supported the Santa Ana Regional Water Quality Control Board, SAWPA, and the Lake Elsinore/San Jacinto River Watershed Stakeholder TMDL Workgroup in this endeavor. Funding for this watershed modeling effort was provided by the Lake Elsinore and San Jacinto Watershed Authority and a 205(j) grant through the State Water Resources Control Boards Water Quality Planning Program. The objectives of the project included:

- Compilation of available geographic, monitoring, regulatory, and land practice/activity data for the San Jacinto Watershed, Lake Elsinore, and Canyon Lake
- Analysis of nutrient loading by source and location
- Estimation of nutrient contributions to Lake Elsinore and Canyon Lake using computer models developed specifically for this project
- Preliminary assessment of the cause-effect relationship between the watershed loadings and lake water quality
- Development of a modeling framework that will support TMDL development and future watershed/reservoir management needs
- Public meeting support for the project and TMDL development

Tetra Tech, Inc., has supported aspects of each of the above objectives, with a primary focus on data compilation, analysis of nutrient sources and loadings in the San Jacinto River watershed, and development of a modeling framework for the watershed and linkage to lake models developed for Lake Elsinore and Canyon Lake. This report represents the final of a series of deliverables for the Lake Elsinore and Canyon Lake Nutrient Source Assessment project. It includes a review and assessment of the data collected, description of the development and parameterization of the modeling system, overview of the model calibration and validation process, and summary of model results for nutrient source assessment.

2.0 Watershed Background

This section provides an inventory, description, and review of information and data compiled to support the completion of the project tasks. Review of the data includes a preliminary assessment of watershed characteristics, river and lake characteristics, and nutrient sources specific to land use and management practices. This assessment was used as guidance in selection of the modeling strategy.

2.1 General Information

Lake Elsinore and Canyon Lake are located in the southwestern portion of the San Jacinto River watershed (HUC 18070202), approximately 60 miles southeast of Los Angeles (Figure 2-1). Most of the San Jacinto River watershed falls within Riverside County; however, a small western section is located in Orange County. Land use in the watershed is predominantly shrubland at the headwaters area and mostly agricultural and urban in the middle and downstream areas.

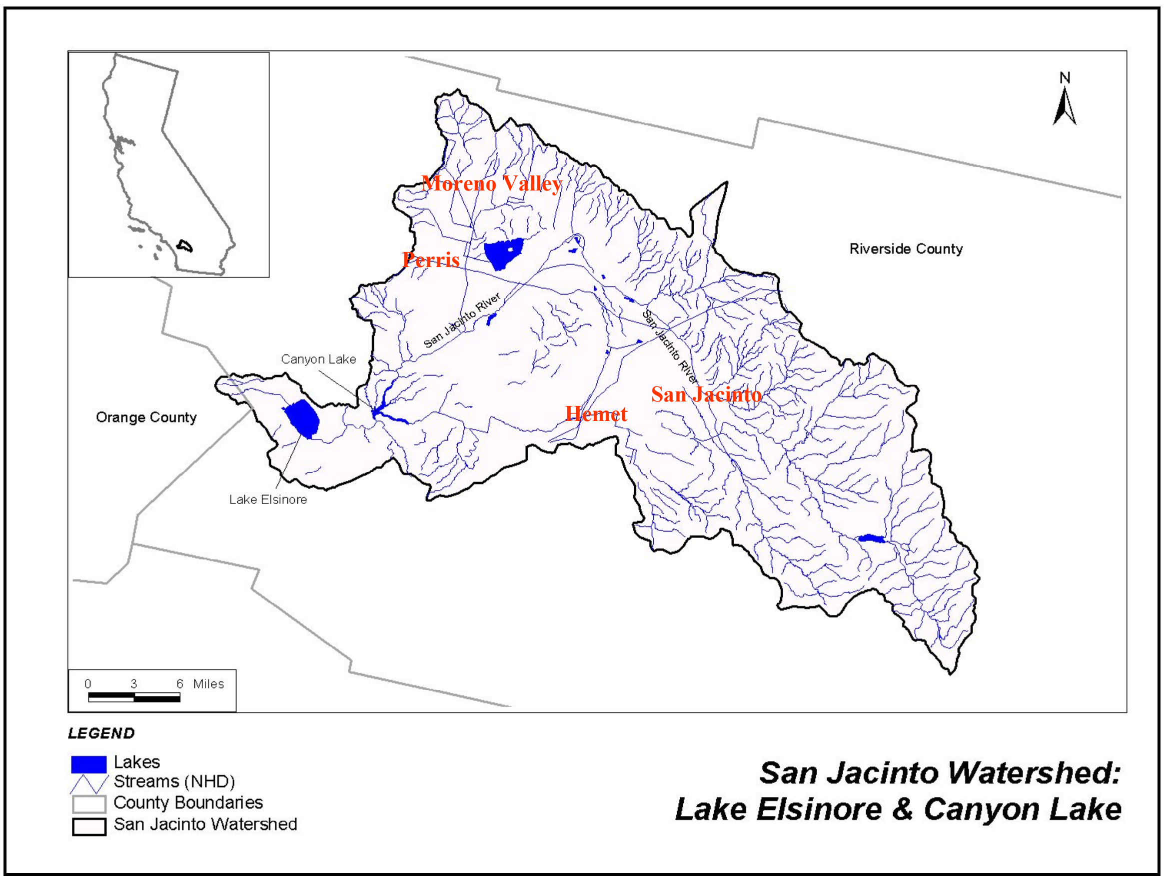

Figure 2-1 Locations of the San Jacinto River, Canyon Lake, and Lake Elsinore

Point source discharges are prohibited in the San Jacinto watershed, with the exception of discharges from urban stormwater outfalls and the overflow of processed wastewater from dairy and animal feeding operations during acceptable conditions (rainfall event defined in Title 27, Chapter 7, Subchapter 2, Article 1, Section 22562(a), California Code of Regulations and 40 CFR Part 412). Major nonpoint source contributors in the watershed include agricultural lands, dairies, feedlots, grazing, land development, and urban runoff.

Canyon Lake is located near the watershed outlet and was formed by the damming of the San Jacinto River (Figures 2-2, 2-3, and 2-4). Lake Elsinore is located approximately 3 miles downstream of Canyon Lake, at the bottom of the San Jacinto watershed (Figures 2-2 and 2-5). Runoff from as far as Moreno Valley, San Jacinto, Hemet, and Perris contribute to surface flows that reach Canyon Lake during rainfall events. Over 90 percent of the San Jacinto watershed drains to Canyon Lake. During normal dry periods, the San Jacinto River is essentially dry, contributing little or no flow to Canyon Lake. Surface flow from the San Jacinto watershed reaches Lake Elsinore through release, overflow, or seepage from the Canyon Lake dam. Lake Elsinore acts much like a sink, with almost nonexistent outflow. In rare situations, including torrential rains and extended rain periods, the lake overflows into Temescal Creek, and ultimately to the Santa Ana River (RWQCB, 1995).

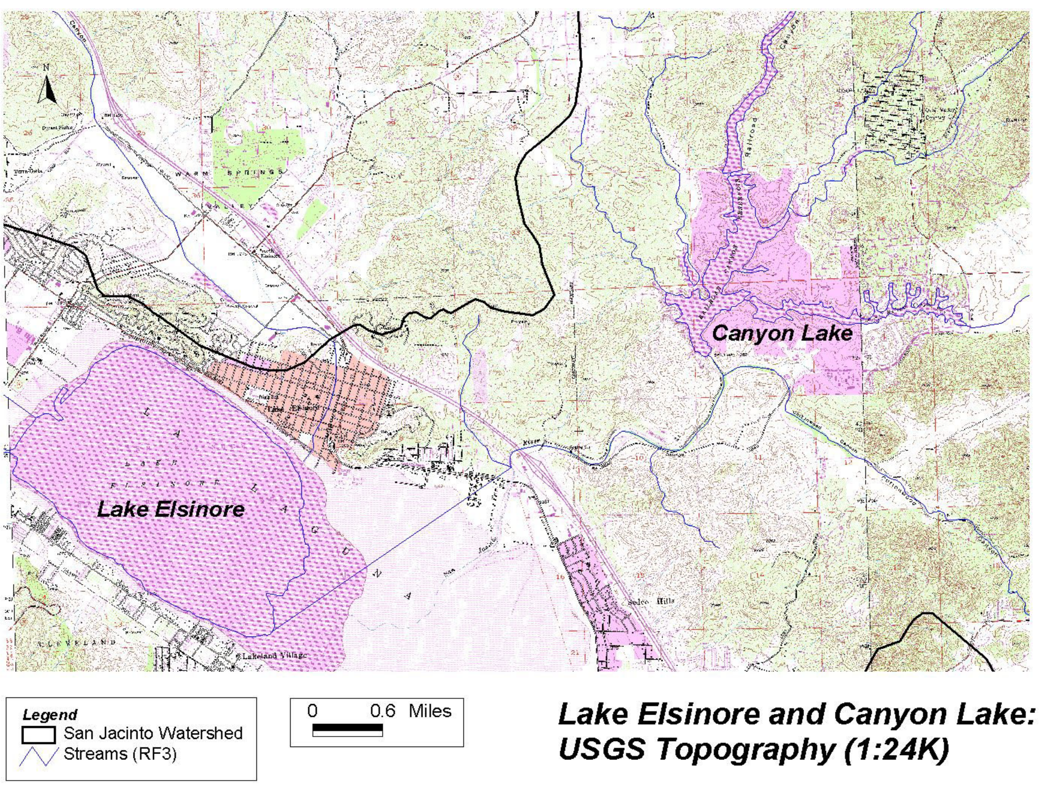

Figure 2-2 Lake Elsinore and Canyon Lake

Figure 2-3 Canyon Lake – facing northeast

Figure 2-4 Canyon Lake dam – facing southeast

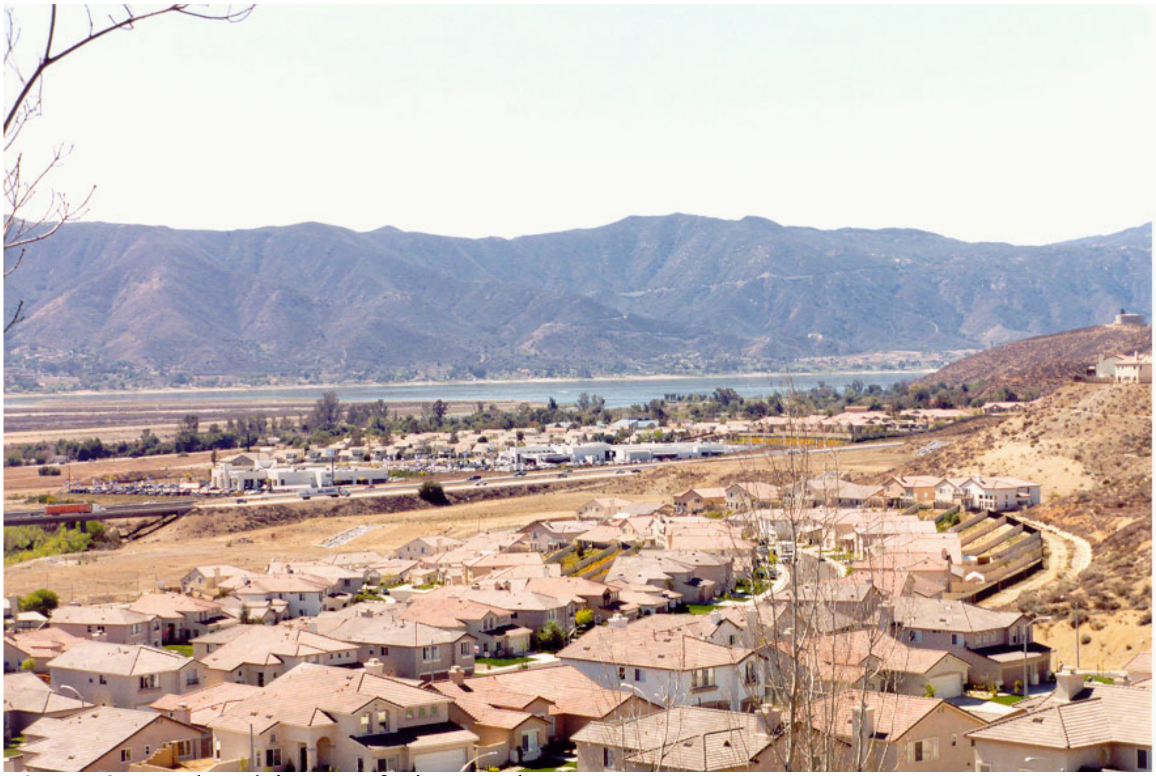

Figure 2-5 Lake Elsinore - facing southwest

Both Lake Elsinore and Canyon Lake have been included by the Santa Ana Regional Water Quality Control Board (RWQCB) on the 1998 Clean Water Act Section 303(d) list as impaired waterbodies for nutrients, unknown toxicity, low dissolved oxygen, turbidity, and pathogens. Table 2-1 presents the 1998 303(d) list information for Lake Elsinore and Canyon Lake. TMDLs are required for these two waterbodies.

Table 2-1 Listed waterbody characteristics – 1998 303(d) list

Waterbody Name	Waterbody Size (acres)	Designated Uses	Pollutant of Concern	Primary Source of Impairment
Canyon Lake	600	AGR, MUN, GWR, REC1, REC2, WARM, WILD	Nutrients, Pathogens	Nonpoint Source
Lake Elsinore	3300	REC1, REC2, WARM, WILD	Nutrients, Low Dissolved Oxygen, sedimentation and unknown toxicity	Urban Nonpoint Source

AGR: Agricultural Supply; MUN: Municipal and Domestic Supply; GWR: Groundwater Recharge; REC1: Water Contact Recreation; REC2: Non-Contact Water Recreation; WARM: Warm Freshwater Habitat; WILD: Wildlife Habitat

2.2 Data Inventory

Tables 2-2 through 2-5 identify available data that were used to support the nutrient assessment and modeling effort for the San Jacinto River watershed, Canyon Lake, and

Lake Elsinore. These data include water quality observations, nutrient source information, land use and land characteristics, and meteorological data. They were compiled and reviewed to determine the existence of possible data gaps. The following data inventory list is divided into four main categories: geographic or locational information, monitoring data, regulatory or policy information, and land practice activities.

Table 2-2 Available geographic or locational information

Type of Information	Data Source(s)
Stream Network	USEPA BASINS (Reach File, Versions 1 and 3); USGS NHD reach file
Land Use	USGS MRLC (1993); Eastern Municipal Water District (1999 & 2025) (Does not include eastern & western portions of the watershed)
Counties	BASINS
Cities/Populated Places	BASINS, U.S. Census
Soils	BASINS (USDA-NRCS STATSGO); USGS – Southern California Aerial Mapping Project (provided by County of Riverside); Santa Ana RWQCB; Hydrology Manual - Riverside County Flood Control and Water Conservation District
Watershed Boundaries	BASINS (8-digit hydrologic cataloguing unit - verified and edited by Tetra Tech, Inc. using USGS topographical maps)
Topographic and Digital Elevation Models (DEMs)	BASINS (DEM); USGS Digital Raster Graphs
Dam Locations	BASINS, USACE and FEMA
Roads	BASINS; Riverside County
Ecoregions	BASINS (USDA Level 3 ecoregions)
Water Quality and Biological Monitoring Station Locations	BASINS; USEPA's STORET; Santa Ana RWQCB; Riverside County Flood Control and Water Conservation District
Meteorological Station Locations	BASINS; NOAA-NCDC, Earth Info; Riverside County Flood Control and Water Conservation District
Permitted Facility Locations	USEPA's Permit Compliance System (PCS) database

Type of Information	Data Source(s)
Concentrated Animal Feeding Operation Locations	County of Riverside, EMWD
Impaired Waterbodies (303(d)-listed segments)	Santa Ana RWQCB: Lake Elsinore and Canyon Lake (Railroad Canyon Reservoir)
Vegetation	WRCOG data (provided by Riverside County)

Table 2-3 Available monitoring data

Type of Information	Data Source(s)
Waterbody Characteristics	
Physical Data	BASINS (Reach File, Versions 1 and 3); USGS NHD reach data
HEC-1 and HEC-RAS Models of San Jacinto River	Riverside County Flood Control and Water Conservation District
Lake Bathymetry	Elsinore Valley Municipal Water District; Riverside County Flood Control and Water Conservation District
Flow	
Historical Flow Record (daily, hourly, 15 minute interval)	USGS; Riverside County Flood Control and Water Conservation District
Peak Flows, Average Daily Flows	USGS
Historical Record of Purchased Water Stored in Canyon Lake	Elsinore Valley Municipal Water District
Meteorological Data	
Rainfall	NOAA-NCDC, Earth Info; Riverside County Flood Control and Water Conservation District
Temperature	NOAA-NCDC, Earth Info
Wind Speed	NOAA-NCDC, Earth Info
Dew Point	NOAA-NCDC, Earth Info
Humidity	NOAA-NCDC, Earth Info
Cloud Cover	NOAA-NCDC, Earth Info

Type of Information	Data Source(s)
Water Quality Data (surface water, groundwater)	
Water Quality Monitoring Data	STORET; Santa Ana RWQCB; Riverside County Flood Control and Water Conservation District

Table 2-4 Available regulatory or policy information

Type of Information	Data Source(s)
Applicable State Water Quality Standards	Santa Ana RWQCB
Problem Statements for TMDL for Nutrients in Lake Elsinore and Canyon Lake; Draft Lake Elsinore Nutrient TMDL Numeric Targets and Linkage Analysis	Santa Ana RWQCB
303 (d) List of Impaired Waterbodies	Santa Ana RWQCB
Water Quality Management Plans (WQMPs)	Santa Ana River Basin - Water Quality Control Plan (1995); Lake Elsinore WQMP (1994)

Table 2-5 Available information on land practice and activities

Type of Information	Data Source(s)
On-site Waste Disposal	
Septic Systems	EVMWD; EMWD
Major Crops/Rotation	EMWD land use data; Riverside County
Livestock Estimates (cattle, poultry, swine, sheep, other)	Santa Ana RWQCB

2.3 Watershed Characteristics

The following sections provide an overview of the characteristics of the San Jacinto River watershed and summarize watershed attributes that influence both hydrologic and water quality processes in the basin.

2.3.1 Land Use

USGS Multi-Resolution Land Characteristics (MRLC) 1993 data were used to assess the land use characteristics of the San Jacinto River watershed (Figure 2-6). Land use in the watershed is primarily deciduous shrubland in the headwaters. In the central and lower portions of the basin, agricultural and urban lands dominate. Table 2-6 provides a summary of the overall land use distribution in the watershed.

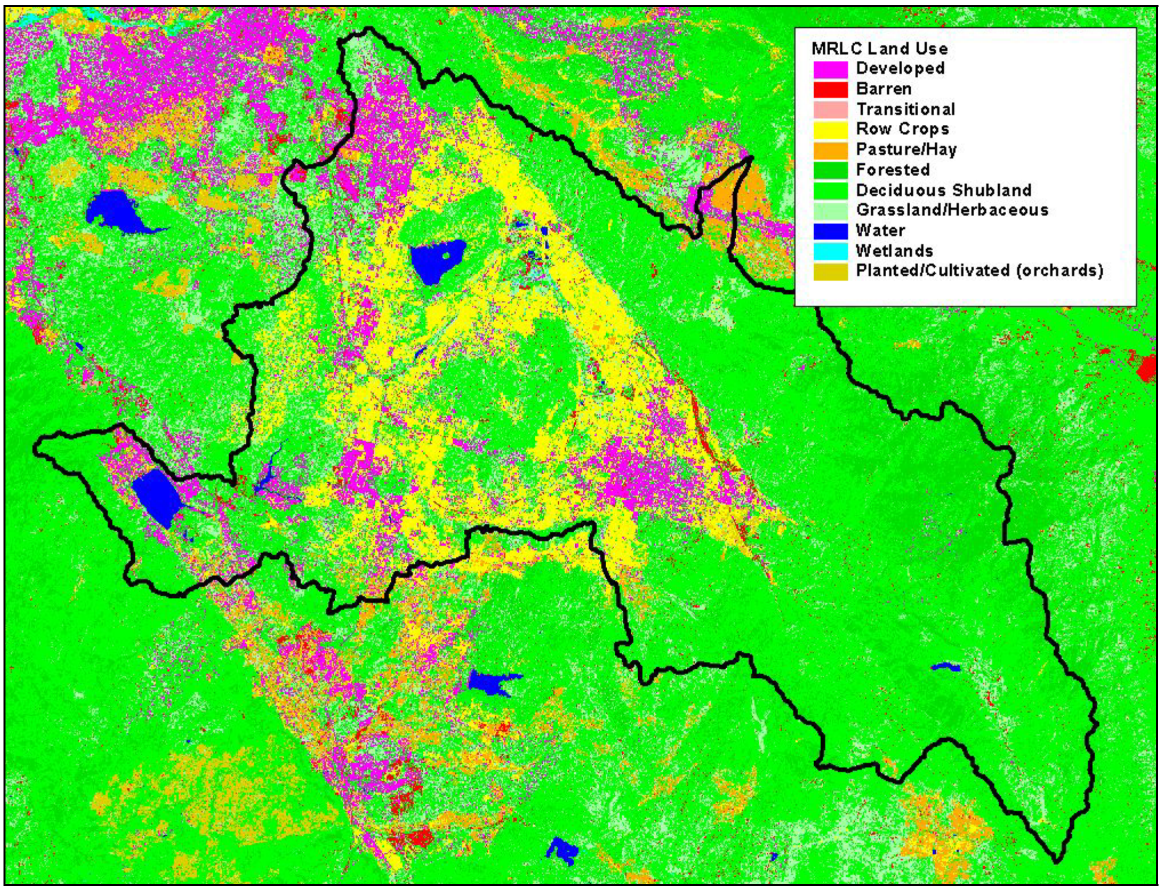

Figure 2-6 Multi-Resolution Land Characteristics (MRLC) land use data (1993) for the San Jacinto River watershed

Table 2-6 Land use distribution in the San Jacinto River watershed

Land Use Type	Area (acres)	Percent of Watershed
Water	5,650	1.1%
Developed	39,202	8%
Barren	7,752	1.6%
Forested	60,614	12.3%
Deciduous Shrubland	236,052	47.9%
Planted/Cultivated (orchards, vineyards, groves)	1,893	0.4%
Grassland/Herbaceous	53,465	10.8%
Pasture/Hay	6,302	1.3%
Row Crops	65,546	13.3%
Small Grains/Fallow/Urban-Rec Grasses	16,228	3.3%
Wetlands	284	0.1%

Land use data collected by the Eastern Municipal Water District (EMWD) were used to supplement the MRLC data for the San Jacinto watershed. EMWD data provide a more detailed characterization of land uses within the district. In 1999, EMWD modified the 1993 Southern California Association of Governments (SCAG) land use data to represent conditions for 1998 within the District's boundaries (Figure 2-7). This land use coverage provides the most recent representation of the area, as well as additional detail (with field verification) regarding urban categories, irrigated and non-irrigated cropland, and the location of concentrated animal feeding operations (CAFOs). The approach for using both the MRLC and EMWD land use data is described later in this document.

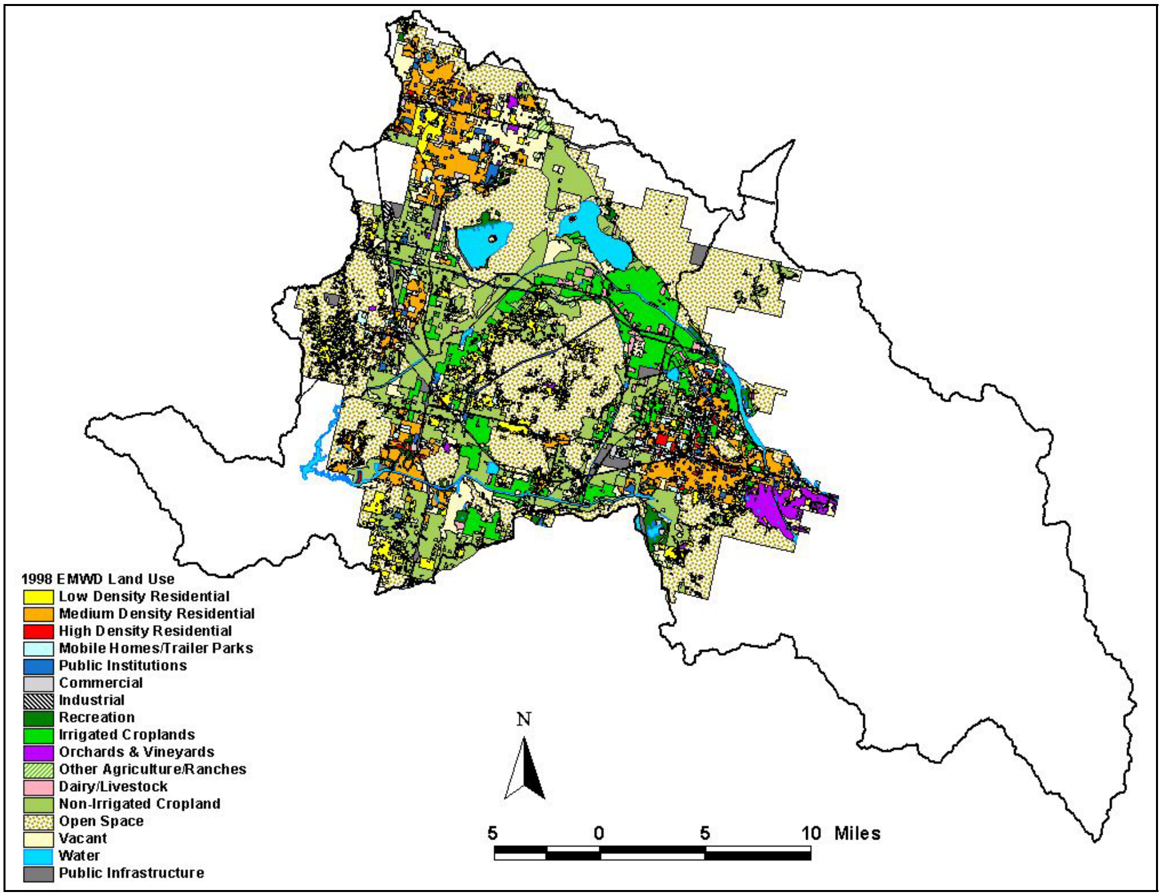

Figure 2-7 The Eastern Municipal Water District (EMWD) land use data (1998) for the San Jacinto River watershed

2.3.2 Soils

Soil composition varies widely throughout the watershed and plays an important role in hydrology. Hydrologic soil groups categorize soils based on infiltration characteristics and are used for watershed runoff estimation. Soils in the San Jacinto River watershed fall into each of the four major hydrologic soil groups (or a combination of the soil groups) as defined by the Soil Conservation Service (1974). Characteristics of the four soil groups in the basin are presented in Table 2-7. Figure 2-8 presents the soil distributions for the San Jacinto River Watershed. The predominant hydrologic soil group is type C, with type B soils also present in large areas of the basin. Table 2-8 presents the percentages of each soil group in the watershed (based on dominant soil type in each STATSGO region).

Table 2-7 Characteristics of the SCS soil groups

Soil Type	Runoff Potential	Infiltration Rates (when thoroughly wetted)	Soil Texture and Drainage
A	Low	High	Typically deep, well-drained sands or gravels
B	Moderately Low	Moderate	Typically deep, moderately well to well-drained moderately fine to coarse-textured soils
C	Moderately High	Slow	Typically poorly-drained, moderately fine to fine-textured soils containing a soil layer that impedes water movement or exhibiting a moderately high water table
D	High	Extremely Slow	Typically clay soils with a higher water table and high swelling potential that may be underlain by impervious material, has very slow infiltration rates

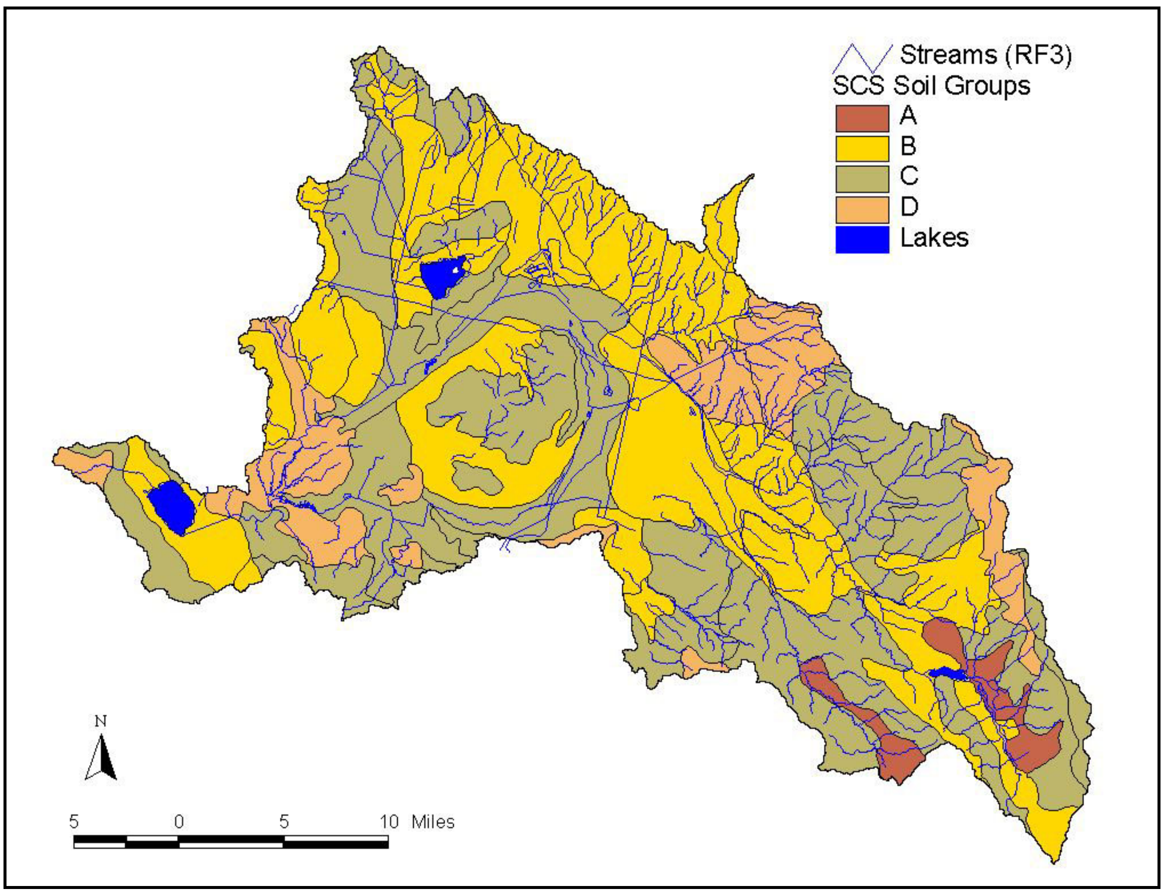

Figure 2-8 Soil groups data for the San Jacinto River watershed

Table 2-8 Area percentages of SCS soil groups in the San Jacinto River watershed

Soil Type	Area (acres)	% of total watershed area
A	12,752	3%
B	193,222	40%
C	219,830	46%
D	56,736	12%
Sum	482,540	100%

2.3.3 Climate

The Santa Ana region is essentially a desert area and is considered to have a Mediterranean climate. The region is generally dry in the summer with mild winters. With a wet period extending from November through March, the average annual rainfall in the region is approximately 15 inches (California RWQCB – Santa Ana Region, 1995). Three types of storms generally occur in the region: general winter storms, general summer storms, and high intensity thunderstorms. Precipitation in the area primarily results from winter storms that normally occur in late fall and winter and generally have durations of several days. Thunderstorms can occur at any time of the year, but are most common from July through September. These storms are characterized by short periods of very high intensity rainfall. General summer storms are rare and normally occur from July through September. These storm events can result in heavy rainfalls over the course of several days (Riverside County Flood Control and Water Conservation District – Hydrology Manual).

2.4 Waterbody Characteristics

The San Jacinto River begins in the San Jacinto Mountains and then turns northwest and follows the San Jacinto Valley. At the base of the San Jacinto Valley lies the San Jacinto fault zone, which is responsible for the relatively high subsidence rates that have resulted in the formation of a closed depression that periodically fills with water to form Mystic Lake. Downstream of Mystic Lake, the San Jacinto River turns west and forms a wide fluvial plain. The river then flows through the narrow Railroad Canyon and into Canyon Lake. Overflow from Canyon Lake flows into Lake Elsinore (California RWQCB – Santa Ana Region, 2001). The following sections provide an overview of data that characterize the San Jacinto River, Mystic and Canyon Lakes, and Lake Elsinore.

2.4.1 San Jacinto River Flow

The San Jacinto River is generally characterized as an ephemeral system, with flow from the river only reaching Canyon Lake and Lake Elsinore during wet periods. Average daily flow measurements have been collected at various locations throughout the San Jacinto River watershed. Figures 2-9 and 2-10 show data for the last ten years for two representative gages in the basin. The flow at the San Jacinto River gage near Elsinore and downstream of Canyon Lake is controlled by the Canyon Lake dam (Figure 2-9). Also shown is the flow at the Perris Valley storm drain that drains an urbanized area and is dry under normal conditions (Figure 2-10). Streamflows at these locations are characterized by dry periods with relatively sharp peaks and abrupt recession of flows that are likely the result of storm runoff and little contribution from groundwater or interflow.

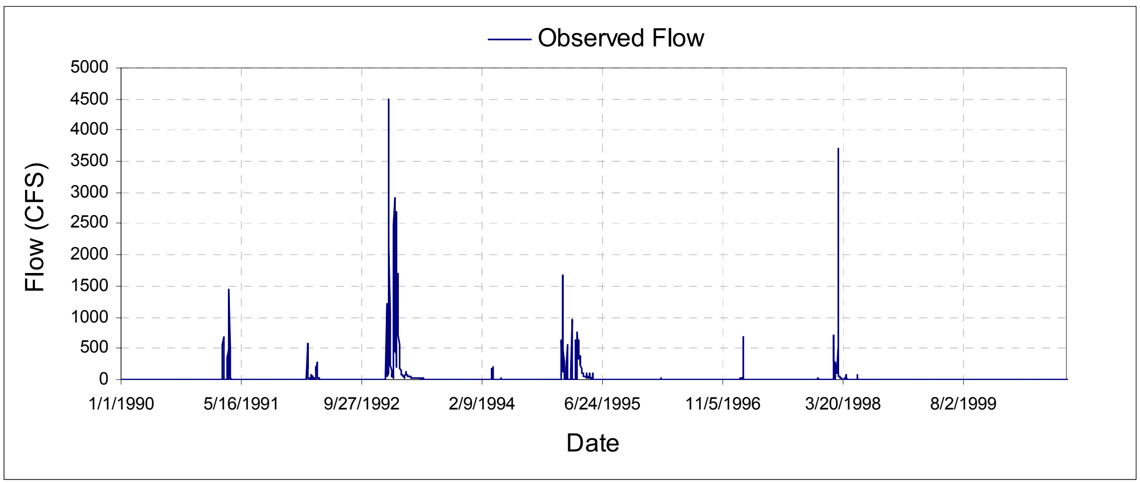

Figure 2-9 Average daily flow data for San Jacinto River near Elsinore (USGS 11070500)

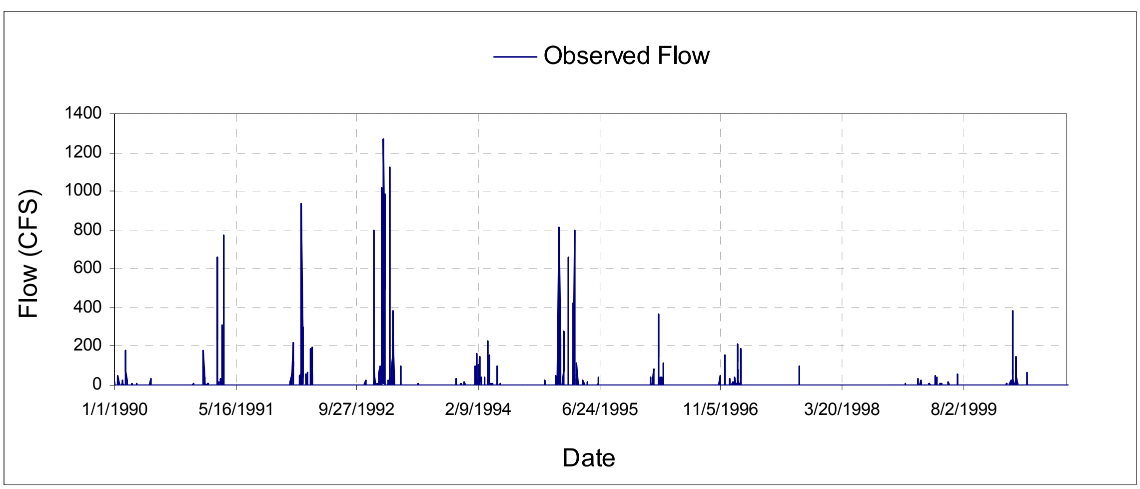

Figure 2-10 Average daily flow data for Perris Valley Storm Drain–Nuevo Rd (USGS 11070270)

Streamflows in the headwater portions of the watershed, however, appear to have more influence from interflow and/or groundwater contributions. Figure 2-11 depicts streamflows observed for the San Jacinto River near San Jacinto from 1996 through 2001. Compared to Figures 2-9 and 2-10, the hydrographs at this location show a much more attenuated and gradual increase and decline of flow.

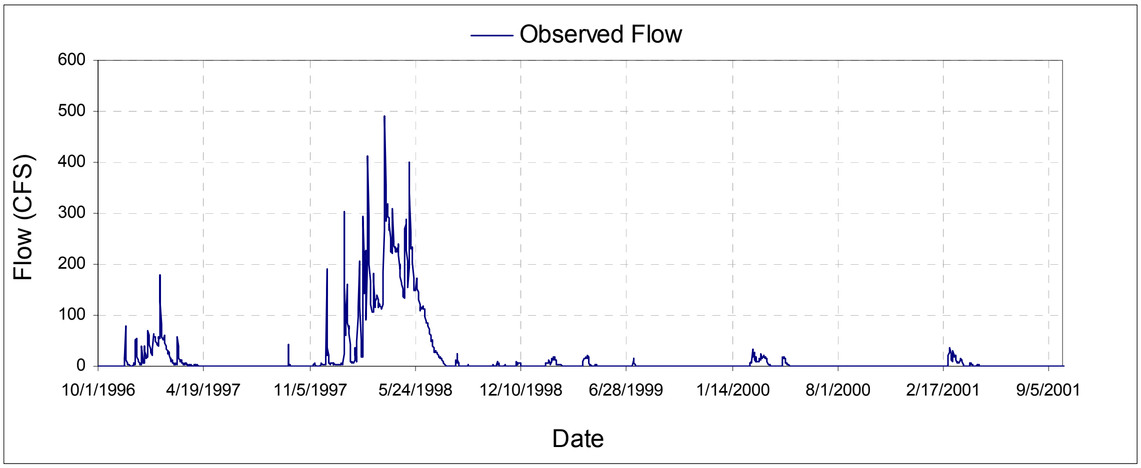

Figure 2-11 Average daily flow data for San Jacinto River near San Jacinto (USGS 11069500)

2.4.2 Mystic Lake - Physical Characteristics

Very little information is available for Mystic Lake regarding the storage capacity, losses due to groundwater infiltration, and overflow characteristics and resulting return of flow to the San Jacinto River. Moreover, very little streamflow is available downstream of Mystic Lake during large storm events when the lake is believed to overflow. However, a rough stage versus storage curve of Mystic Lake (Figure 2-12) was available from a 1975 study of the San Jacinto River hydrology (Riverside County Flood Control and Water Conservation District, 1975). Assuming a surface area of approximately 1000 acres when overflow occurs and a resulting maximum water surface elevation of 1422 feet (estimated from USGS topographical data and USEPA BASINS data, Reach File, version 3), the storage volume of Mystic Lake was estimated to be 5200 acre-feet. When the water surface is above the 1422-foot elevation, Mystic Lake is assumed to spill into the downstream portion of the San Jacinto River. Although the stage versus storage curve in Figure 2-12 estimates much higher storage capabilities, this curve was developed to simulate 100-year storm flows that far exceed normal conditions modeled in this project.

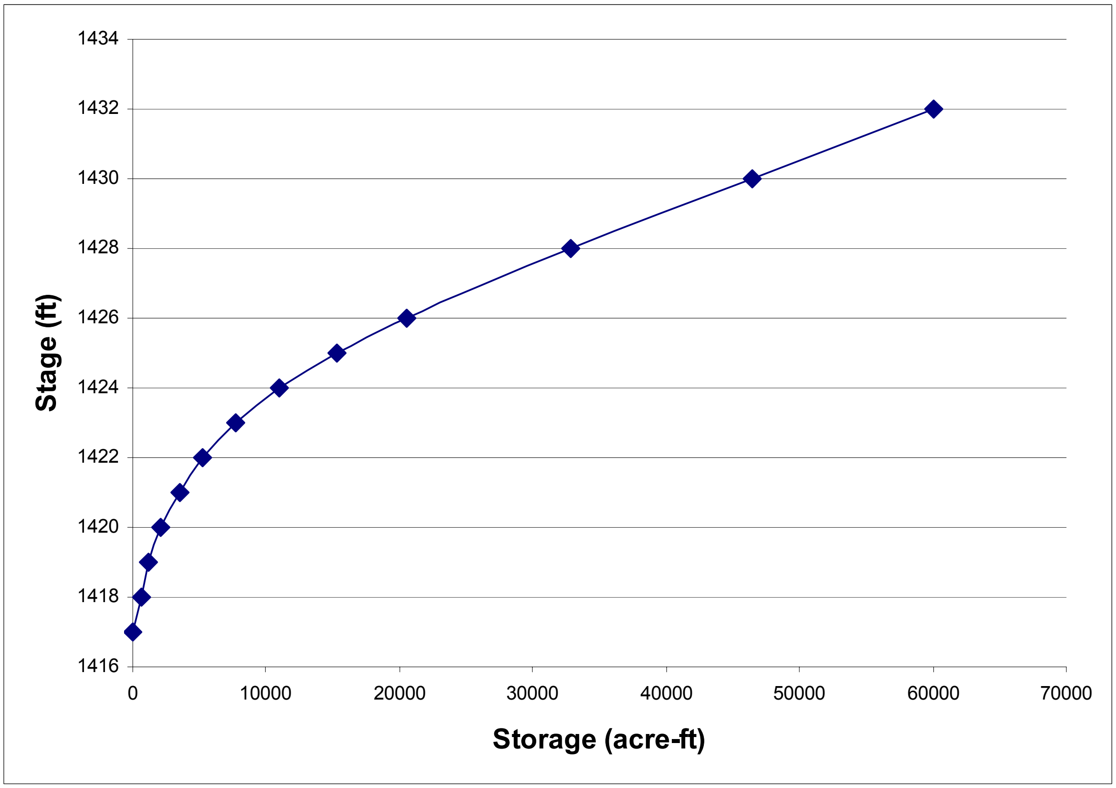

Figure 2-12 Mystic Lake stage versus storage curve

2.4.3 Canyon Lake - Physical Characteristics

To provide accurate predictions of the water quality within Canyon Lake and overflow into Lake Elsinore, data describing the physical characteristics of the lake were required. Specifically, volume and dam overflow data were necessary to effectively simulate the water budget of the lake. Figures 2-13 and 2-14 depict the stage versus storage curve and dam overflow rating curve, respectively, used to develop water volume and outflow estimates for the lake (data provided by Elsinore Valley Municipal Water District).

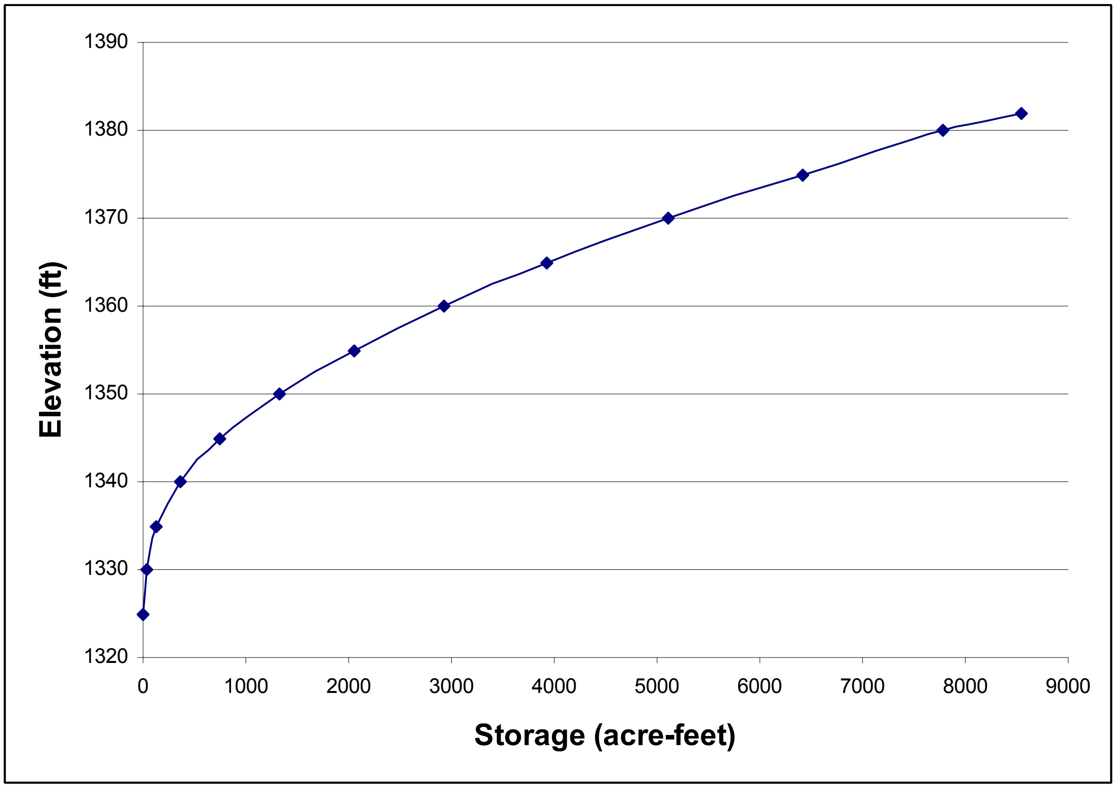

Figure 2-13 Canyon Lake stage versus storage curve

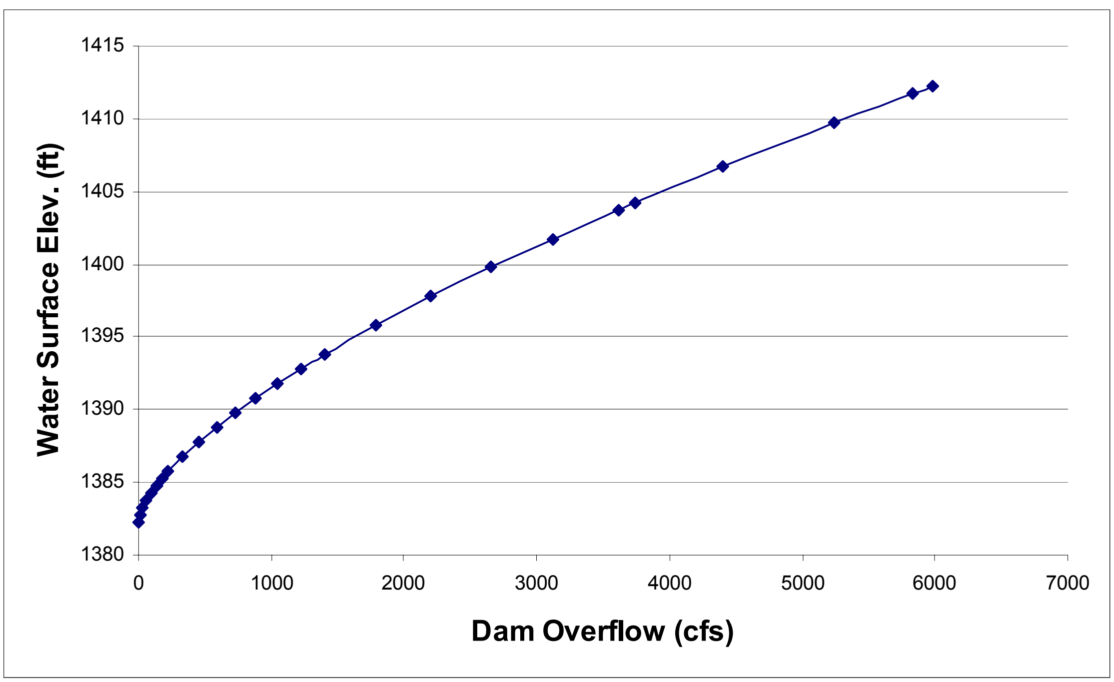

Figure 2-14 Rating Curve – Canyon Lake dam

To support quantification of flow and nutrient loads transported from Canyon Lake to Lake Elsinore, historic water surface elevations were obtained for a 5-year period. Since outflow from Canyon Lake is predicted from water surface elevations using the rating curve in Figure 2-14, it is crucial that water surface elevations are predicted as accurately as possible. As can be seen in Figure 2-15, Canyon Lake experiences significant seasonal fluctuations in volume.

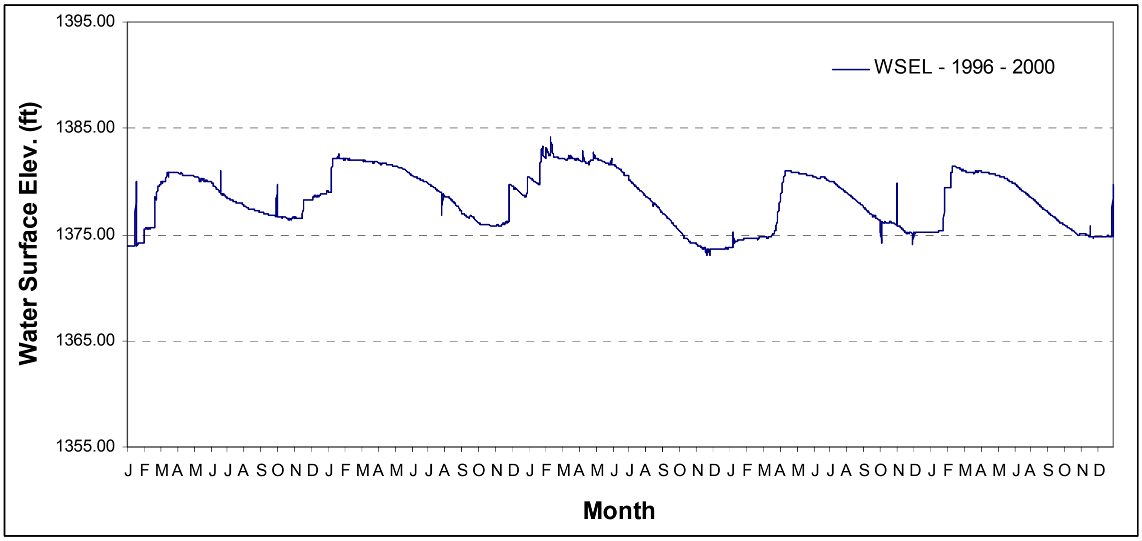

Figure 2-15 Historic Canyon Lake water surface elevations

2.5 Water Quality

The RWQCB and Riverside County Flood Control and Water Conservation District have collected water quality data for Canyon Lake, Lake Elsinore, and in-stream locations throughout the San Jacinto watershed in support of TMDL development for the lakes. The following sections discuss these data.

2.5.1 Lake TMDL Data

Water quality data have been collected at 3-foot depth intervals for both Canyon Lake and Lake Elsinore at the stations listed in Table 2-9.

Table 2-9 Lake TMDL stations

Station #	Lake	Site Description	Period of Record
7	Canyon Lake	At Dam	6/13/00 - 6/4/01
8	Canyon Lake	North Channel	6/13/00 - 6/4/01
9	Canyon Lake	Road Runner Park (East Bay)	6/15/00 - 6/4/01
10	Canyon Lake	Snug Cove	5/31/00 - 6/4/01
14	Lake Elsinore	San Jacinto River Inlet	5/24/00 - 6/5/01
15	Lake Elsinore	West Marina	5/24/00 - 6/5/01
16	Lake Elsinore	Center of Lake	5/24/00 - 6/5/01

At each station and depth, the following parameters were measured.

- Temperature
- Dissolved Oxygen
- pH
- Ortho Phosphate - P
- Total Phosphate - P
- Turbidity
- Conductivity
- Percent DO Saturation
- Total Nitrogen
- Total Dissolved Solids
- Nitrate
- Nitrite
- BOD
- COD
- Chlorophyll a
- Total Suspended Solids
- Ammonia
- Total Inorganic Nitrogen
- Organic Nitrogen
- Total Kjeldahl Nitrogen

2.5.2 In-stream TMDL Data

In-stream water quality data have been collected at various stations throughout the San Jacinto River basin (Figure 2-16). Descriptions of each TMDL station are listed in Table 2-10. The number of parameters measured is specific to the TMDL station and sampling date. A summary of the water quality data collected at each station is provided in Appendix A.

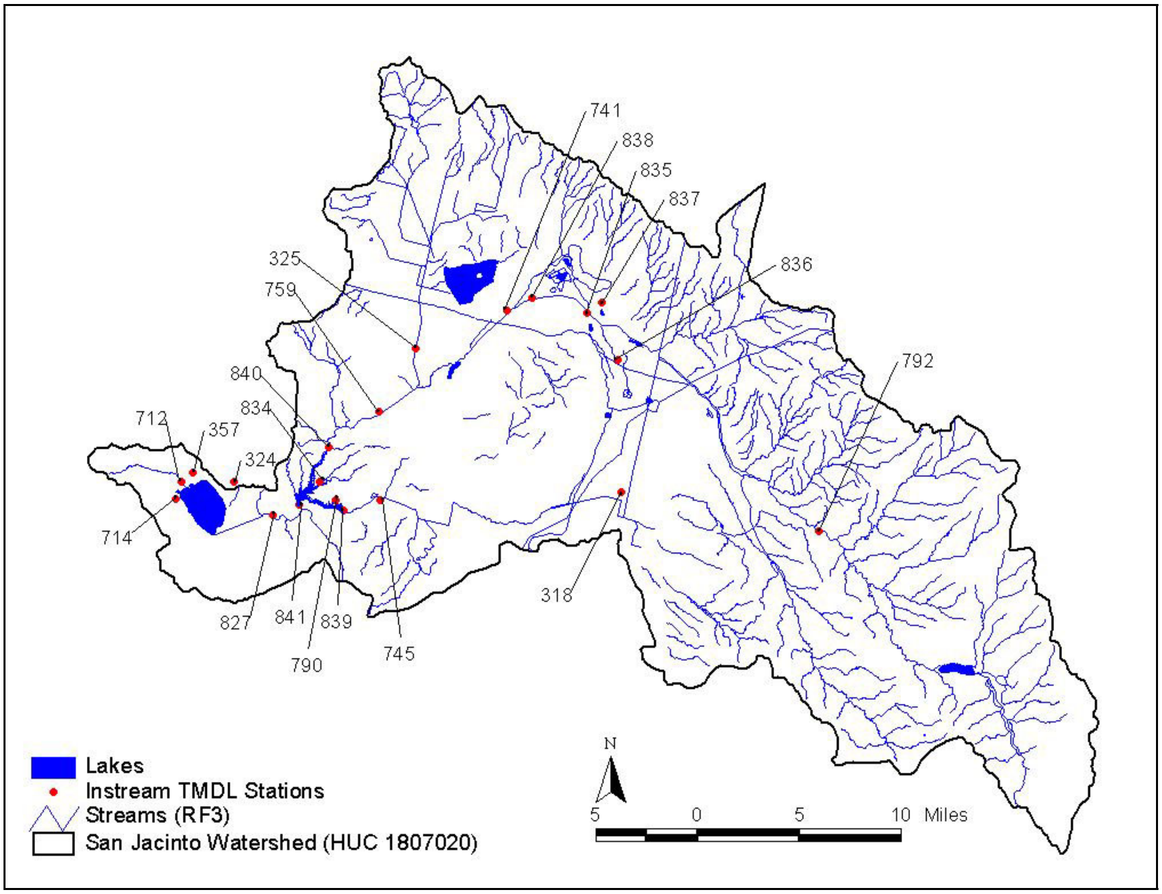

Figure 2-16 Locations of in-stream TMDL stations

Table 2-10 In-stream TMDL station descriptions

Station #	Station Name	Period of Record
318	Hemet Channel NPDES -Sanderson Av to Cawston Av	6/25/93 - 2/28/01
324	Elsinore Outlet Channel	No Data
325	Perris Valley Channel @ Nuevo Rd	2/12/00 - 6/19/01
357	Four Corners NPDES -Storm Drain Outlet @ Lehr Dr	1/3/92 - 2/25/01
712	Leach Canyon Channel Outlet @Lake Elsinore	1/3/92 - 2/13/01
714	Ortega Canyon Channel -L.Elsinore	1/3/92 - 2/13/01
741	San Jacinto River at Romona Expressway	1/12/01 - 1/26/01
745	Salt Creek at Murrieta Road	1/11/01 - 3/3/01
759	San Jacinto Riv @ Goetz Rd	2/21/96 - 3/2/01
790	Canyon Lake TMDL SD at Fair Weather Dr.	1/11/01 - 3/2/01
792	S.Jacinto River @ Cranston	8/17/95 - 4/17/01
827	San Jacinto River at Elsinore -USGS Station	9/8/94 - 3/3/01
834	Canyon Lake TMDL at Sierra Park	1/11/01 - 3/2/01
835	San Jacinto River at Bridge St TMDL	No Data
836	Stream at Ramona Expressway and Warren Rd. TMDL	1/11/2001
837	Mystic Lake Inflow TMDL	No Data
838	Mystic Lake Outflow TMDL	No Data
839	Salt Creek at Canyon Lake TMDL	1/11/01 - 2/27/01
840	San Jacinto River at Canyon Lake TMDL	No Data
841	San Jacinto River at Canyon Lake Spillway	2/28/01 - 3/2/01

3.0 Nutrient Source Overview

Nutrient contributions to the San Jacinto River system are dominated by non-point sources. These are extremely variable in location and contribution processes, and require detailed analyses for quantification. Non-point sources that contribute loads through surface runoff during rainfall events can be predicted using rainfall/runoff models. These contributions are highly influenced by management practices, such as best management practices (BMPs), and land use practices that may contribute, influence, or inhibit the transport of nutrients from the land surface (e.g., fertilizer application).

In addition to surface transport mechanisms, other potential mechanisms for nutrient loading include discharges from failing septic systems, unimpeded access of cattle to streams, and unsolicited discharges. While the latter two have not been identified as issues in the San Jacinto River watershed, septic systems are potential sources and will be discussed further in this document.

3.1 Agricultural Areas

The following sections discuss the identified sources of nutrients in the San Jacinto River watershed, including agricultural, urban, and background sources. Section 4.3.1 discusses the representation of these sources in the modeling analysis and the estimation of their nutrient contributions in the watershed. Potential nutrient sources identified in agricultural areas of the San Jacinto River watershed include cropland, pastureland, and dairies. These sources are typically influenced by management practices specific to each land use.

3.1.1 Cropland

Stormwater runoff from croplands and resulting nutrient loads due to fertilization are highly influenced by crop type (Figure 3-1). The location and area of croplands (including orchards and vineyards) are available in the MRLC and EMWD land use datasets. However, comprehensive information is currently unavailable regarding the spatial variability of individual crop types. Common crops in the watershed include grapes, orange trees, turf, and alfalfa. Much of the cropland identified in the watershed may remain idle and unused for extended time periods.

Fertilizer application in the San Jacinto River watershed can have direct effects on nutrient loading from these areas. Fertilizer applied to cropland accumulates on the land surface where it is available for runoff and delivery to watershed streams during storm events. The amount of nutrient loading from fertilizer application depends on the quantity and frequency of land application, as well as the nutrient content of the fertilizer. Also affecting nutrient loading in the watershed is runoff from areas that practice land application of animal manure (Figure 3-2). Manure spreading can potentially contribute large quantities of nutrients to watershed lands and subsequently to receiving waterbodies.

Figure 3-1 Cropland in the San Jacinto River watershed

Figure 3-2 Land application of manure in the San Jacinto River watershed

3.1.2 Dairies

A large number of dairy facilities (operated as CAFOs) are located in the mid-portion of the San Jacinto River watershed, in close proximity to the river (Figure 3-3). From the 1998 EMWD land use data, approximately 1,585 acres are designated as dairy/livestock. Based on data from January 2001, there are 34,327 milking cows; 6,254 dry cows; 16,070 heifers; and 6,121 calves in the San Jacinto River basin (Cindy Li, personal communication, RWQCB – Santa Ana Region).

Storage facilities that process wastewater from dairy and animal feeding operations must be designed to contain all process-generated wastewater plus the runoff from a 25-year, 24-hour rainfall event (Figure 3-4) (Title 27, Chapter 7, Subchapter 2, Article 1, Section 22562(a), California Code of Regulations and 40 CFR Part 412). It is unknown if current and historic operation and design of these facilities meet this criterion. During large and/or frequent storm events, these facilities have the potential to overflow and contribute untreated animal waste to the San Jacinto River. Such spillages would be characteristically high in nutrient concentrations, resulting in significant nutrient loading.

CAFO wastewater storage facilities can also impact nearby streams through contamination of groundwater resulting from infiltration of wastewater. Although no data is currently available to quantify such influences, estimates can be made for infiltration and wastewater concentrations using literature values and model calibration to provide a reasonable estimate of such contributions.

Figure 3-3 Dairy feedlot in the San Jacinto River watershed

Figure 3-4 Agricultural BMP in the San Jacinto River watershed

3.2 Urban Areas

Urban areas are characterized by unique management practices and surface attributes that must be understood before inferences can be made regarding their respective contributions of nutrients to the San Jacinto River, Canyon Lake, and Lake Elsinore. The following sections discuss several factors that can influence the nutrient loadings from urban areas.

3.2.1 Population

The population density of an urban area is a good indicator of potential nutrient loading. For different densities, the relative contribution of various nutrient sources differs (e.g., fertilization of urban lawns; pets). Population densities can be estimated from the MRLC and EMWD land use data; for each specific land use, information regarding the population is often used as criteria for classification. For example, Figure 2-11 depicts a typical urban area in Hemet with land use described by the EMWD dataset. The EMWD land use designated as Low Density Residential (LDR) assumes that 0 to 4 dwelling units (e.g., large lot single-family homes) reside in each acre of area. Likewise, Medium Density Residential (MDR) is defined as an area with a density of greater than 4 but less than 12 units per acre (e.g., small lot single-family homes, apartments). In terms of nutrient loading, relative differences in loadings can often be attributed to the population, with higher loads from more densely populated areas. However, in High Density Residential (HDR) areas, less lawn space and associated fertilizer application could result in less nutrient load than a less populated MDR area.

3.2.2 Percent Impervious

Urban areas are associated with higher percentages of impervious area resulting from pavement and concrete cover of the land surface. Higher percentages of impervious area result in higher runoff potential due to the reduced ability of water to infiltrate into the ground during rainfall events. As an example, for each urban land use designated in the EMWD land use datasets (Figure 3-5), a percent of impervious area can be assumed (e.g., 90% for Commercial, 85% for Industrial). The amount of nutrient loading (export from the land surface) is directly dependent on the volume of runoff available that does not infiltrate.

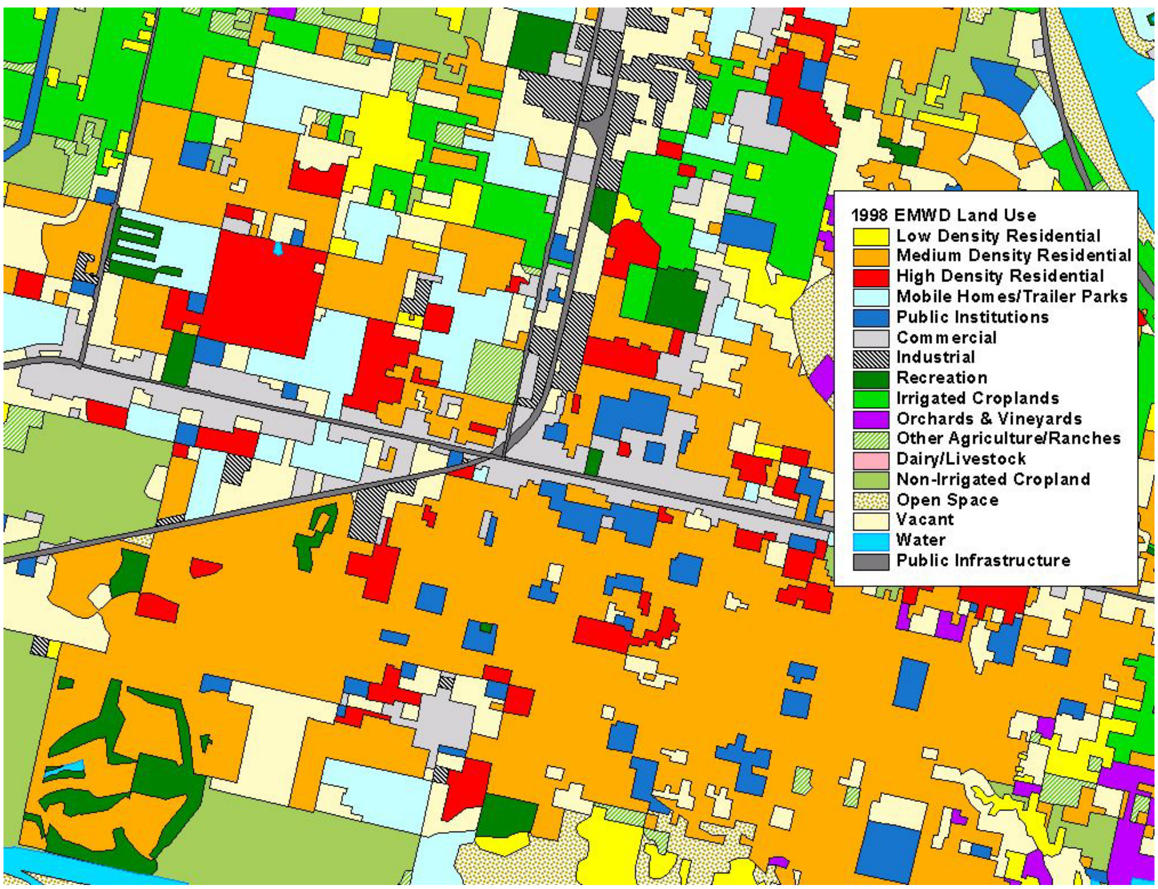

Figure 3-5 EMWD land use of downtown Hemet

3.2.3 Wastewater Disposal

Although a good portion of the watershed's population is sewered, there are many potential opportunities for contribution of nutrients from human waste to waters of the San Jacinto River watershed. These mechanisms of transport include:

- Direct permitted discharges of treated wastewater to a waterbody
- Unsolicited discharges of untreated wastewater to a waterbody
- Leaking of sewage mains and resulting discharge either directly into a waterbody, or indirectly through groundwater transport
- Groundwater transport of leachate to a waterbody from failed septic systems adjacent to the waterbody

Currently, there are no known direct discharges of wastewater treatment plant effluent to the San Jacinto River, Canyon Lake, or Lake Elsinore. Also, the impact of unsolicited discharges and leaking sewage mains are not considered an issue in the basin and are not substantiated by any identified datasets. However, septic systems are expected to impact the San Jacinto River watershed, Canyon Lake, and Lake Elsinore. Figure 3-6 shows land parcels in the vicinity of Lake Elsinore and Canyon Lake that use septic systems for wastewater disposal. Several parcels are observed to be relatively close to the shoreline where direct loading of nutrients is possible. Parcel and sewer main GIS data have also been provided by EMWD so that a similar analysis of septic system locations can be provided for the remainder of the watershed upstream of Canyon Lake.

The Clean Lakes Program study of Lake Elsinore estimates an average of 3.5 persons per parcel and corresponding wastewater flow of 50 gallons per person per day. The study also assumes that the phosphorus concentration of the untreated domestic sewage was 10 mg/L, assuming no phosphorous removal. Based on these assumptions and an estimate of 350 parcels operating septic systems near the Lake Elsinore shoreline, the total phosphorus loading to Lake Elsinore in 1993 was estimated at 1,900 pounds per year (Black & Veatch, 1994).

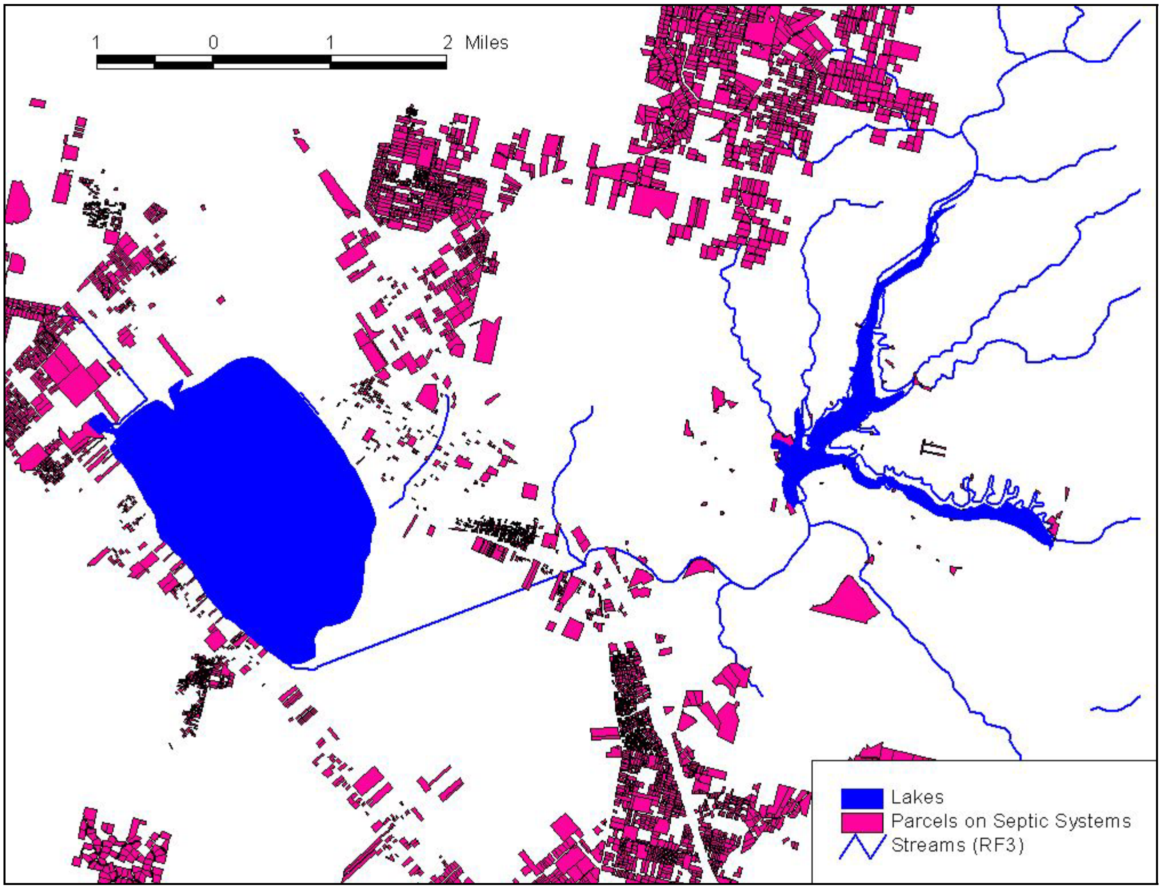

Figure 3-6 Parcels on septic systems in the Lake Elsinore/Canyon Lake vicinity (Source: EVMWD)

<u>3.2.4 Fertilizer Application</u>

Urban lawns and golf courses are often fertilized to produce prosperous growth. However, they can result in a considerable buildup of nutrients on the land surface for subsequent washoff during rainfall events.

3.3 Background Loads

Background nutrient loads to the San Jacinto River basin are from non-human, natural sources, and can usually be estimated from water quality data collected at headwater stations where the land use of the contributing watershed consists almost entirely of natural landscape with little or no human influence. Sources of nutrients in the background include not only vegetative inputs, but also account for atmospheric deposition.

4.0 Technical Approach

This section provides an overview of the approach used to assess the sources and transport of nutrients throughout the San Jacinto River watershed, including the rationale for selecting the models applied, background of these models, and details regarding model configuration, calibration, and validation.

4.1 Model Selection

To meet the objectives defined for the Lake Elsinore and Canyon Lake Nutrient Assessment Project, development of a comprehensive watershed model was necessary to represent the San Jacinto River watershed (including a receiving water model to represent Canyon Lake). 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. Many watershed models are also capable of simulating in-stream processes using the land-based calculations as input.

Receiving water models are composed of a series of algorithms applied to characteristics data to simulate flow and water quality of a waterbody. The characteristics data, in this case, represent physical and chemical aspects of a lake, river, or estuary. These models vary from simple 1-dimensional box models to complex 3-dimensional models capable of simulating water movement, salinity, temperature, sediment transport, and water quality.

4.1.1 Selection Criteria

In selecting an appropriate modeling platform to support management initiatives and development of Total Maximum Daily Loads (TMDLs) for Lake Elsinore and Canyon Lake, the following criteria were considered and addressed (expanding on classification of Mao, 1992):

- Technical Criteria
- Regulatory Criteria
- User Criteria

Technical criteria refer to the model's simulation of the physical system in question, including watershed and/or stream characteristics/processes and constituents of interest. Regulatory criteria make up the constraints imposed by regulations, such as water quality standards or procedural protocol. User criteria comprise the operational or economical constraints imposed by the end-user and include factors such as hardware/software compatibility and financial resources. The following discussion details considerations within each of these categories specific to the San Jacinto River, Lake Elsinore, and Canyon Lake.

4.1.2 Technical Criteria

The watershed and lakes of the San Jacinto River present a challenging system for modeling hydrology, pollutant loading and transport, and internal lake processes. This section outlines key functions and processes that were necessary for consideration in the selection of an appropriate modeling strategy.

4.1.2.a Hydrology

Several influencing hydrologic factors in the San Jacinto watershed required proper attention to ensure that the system be modeled accurately. These factors were considered for selection and development of the modeling system.

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 or the lakes is expected to be 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 streamflow (personal communication with Steven Clark, Riverside County Flood Control and Water Conservation District).

Mystic Lake

Mystic Lake (Figure 4-1) is located roughly in the middle of the San Jacinto River watershed and impounds all San Jacinto River flow. In the Model Analysis Workplan (Tetra Tech, Inc., 2002), it was assumed that river flow is diverted around Mystic Lake via a low-flow channel constructed by local farmers. Recent communication with local experts, however, has clarified that 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.

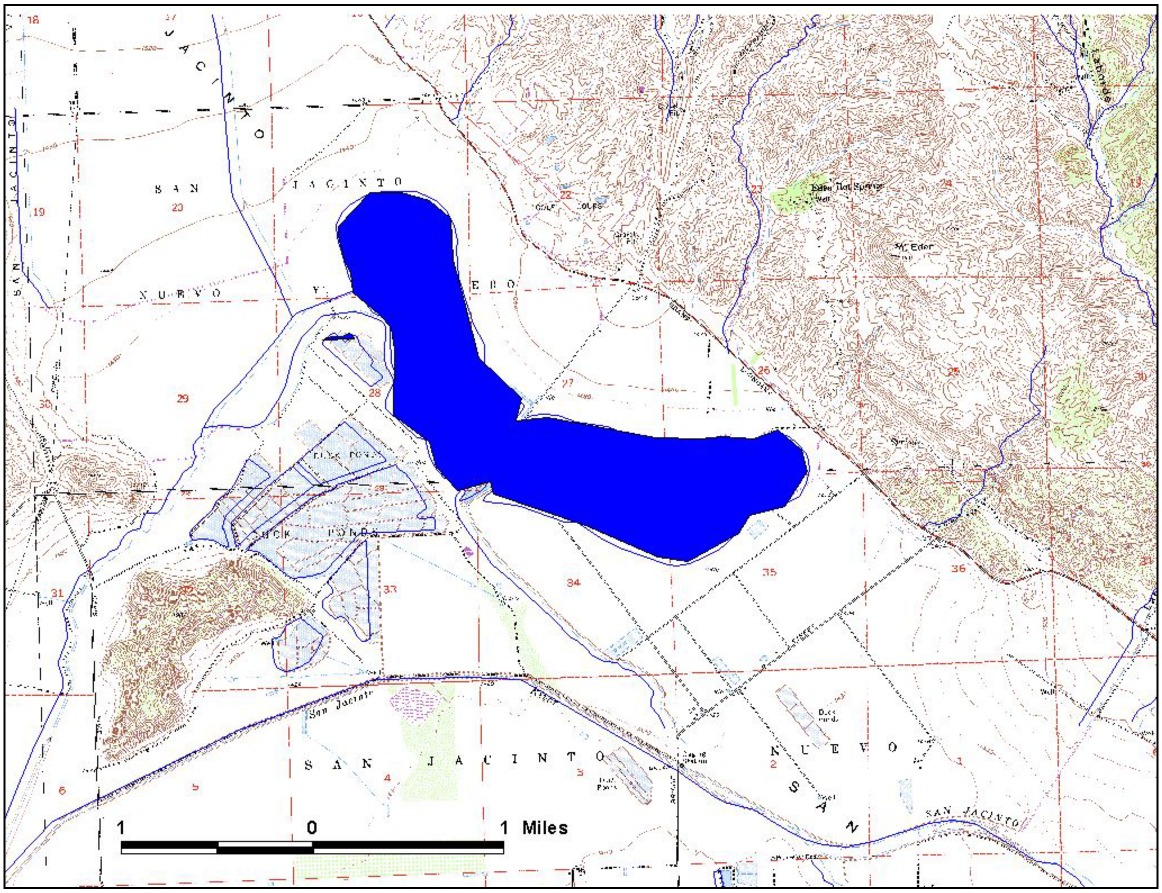

Figure 4-1 Mystic Lake

Perris Reservoir

Another major impoundment in the San Jacinto watershed, the Perris Reservoir (Figure 4-2), 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).

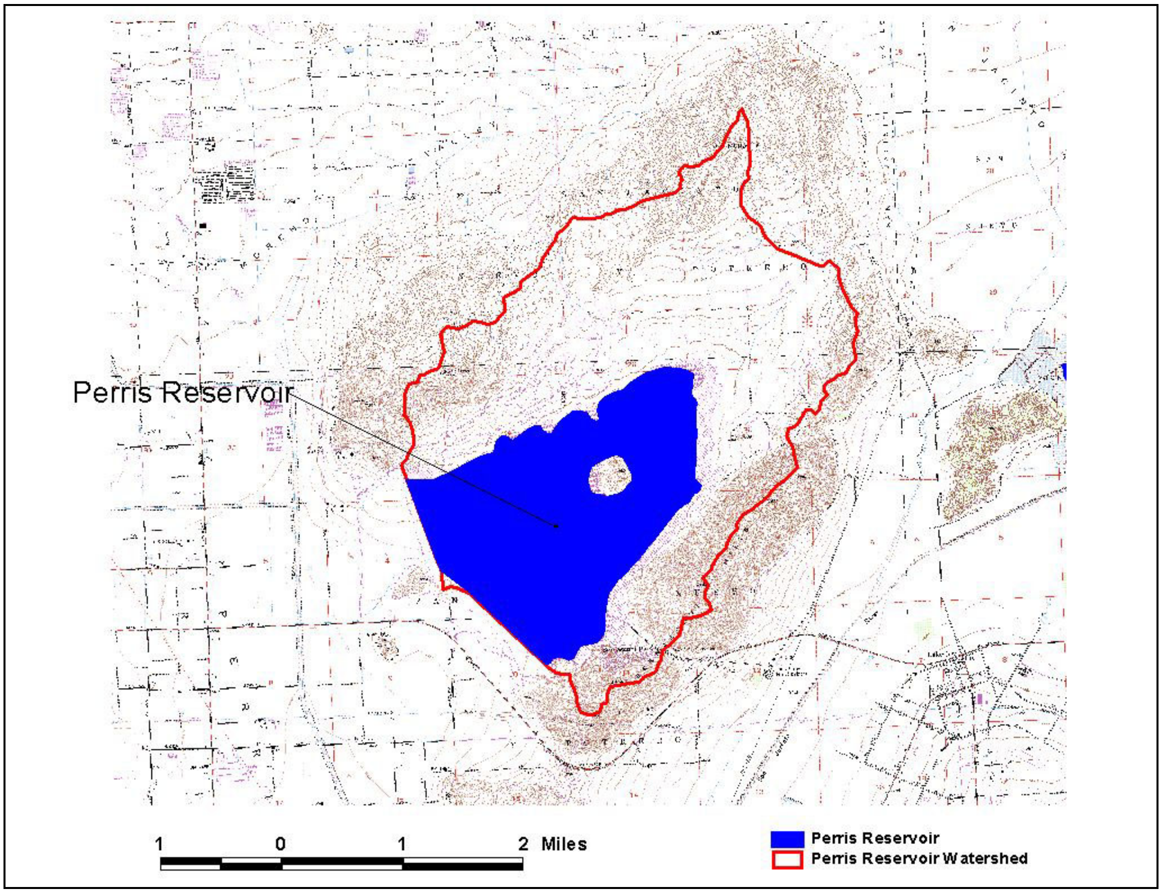

Figure 4-2 Perris Reservoir watershed

Management Practices

During periods of rainfall, storage of runoff or streamflow 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.

Canyon Lake

Accurate prediction of Canyon Lake outflow is an important step in the modeling of the San Jacinto River watershed. Since the inflows to Lake Elsinore are dominated by Canyon Lake outflows, and the water quality of Lake Elsinore is observed to be greatly influenced by these inflows, correct quantification of the Canyon Lake outflow, in the form of either overflow or dam seepage, is crucial to ensuring the accurate predictive capability of the modeling system.

4.1.2.b Water Quality

Many factors were expected to have a significant impact on the water quality of Canyon Lake, Lake Elsinore, and the runoff of the San Jacinto watershed. These issues needed to be defined and addressed in the selected modeling system to ensure its accuracy and predictive capability. Key nutrient/water quality factors were discussed in the Nutrient Source Overview (Section 3) of this report. Additional critical factors impacting model selection were identified and are discussed in the following sections.

Source Representation

The sources of nutrients (identified in Section 3 of this 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 waterbodies 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.
- BMPs provide nutrient removal through several processes intrinsic of the type (detention facilities, buffer zones, etc.) and size of the BMP. The model should include the ability to include the potential impacts of BMPs to assess the relative benefits of alternative management scenarios.
- Existing and future conditions are dependent on land use data; the model should use the most accurate land use data for nonpoint source estimation.

Receiving Water Representation

In-stream and in-lake nutrient interactions in the San Jacinto River, Canyon Lake, and Lake Elsinore had to be examined to ensure that the selected model properly simulated the system. The water quality processes included in the model of Canyon Lake needed to consider critical influences on nutrient concentrations in the lake, including settling, biological uptake, and sediment interaction processes. With the focus of the study being an overall nutrient source quantification, a general representation of these processes is sufficient (e.g., first-order decay to represent losses and transformations). Future, more detailed lake modeling studies may consider simulation of algal biomass and dissolved oxygen dynamics.

4.1.3 Regulatory Criteria

A properly designed and applied model provides the source-response linkage component of the TMDL and enables accurate assimilative capacity assessment and allocation proposition. A lake's assimilative capacity is determined through adherence to predefined water quality criteria. Table 4-1 presents the RWQCB's surface water quality standards for the designated uses of Canyon Lake and Lake Elsinore. In addition to these water quality standards, the RWQCB has proposed more specific numeric targets to ensure that the designated uses of the lakes are supported by the TMDLs (Table 4-2). These targets are based on water quality data collected from each lake and are subject to revision as more data become available.

In selecting the modeling system, consideration was given to the regulatory targets designated by the RWQCB for TMDL development. The selected models must be capable of simulating these water quality parameters using time-series simulation so that applicable averaging periods and peak levels (or minimum levels, in the case of DO) can be determined and compared to numeric targets.

Table 4-1 Applicable water quality standards

Selected Water Quality Objectives - Surface Waters

Reference: Santa Ana River Basin - Water Quality Control Plan (1985)

Parameter	Water Quality Objective	
	Canyon Lake	Lake Elsinore
Algae	Waste discharges shall not contribute to excessive algal growth	
Ammonia, Un-ionized	Criteria calculated based on pH and temperature data. WARM and COLD criteria	
Bacteria, Coliform	(MUN): Total coliform: less than 100 count/100 mL	(REC-1): Fecal coliform: log mean less than 200 count/100mL with 5 or more samples within a 30-day period, and not more than 10% of the samples exceed 400 count/100 mL for any 30-day period.
Chloride	90 mg/L	not given
Dissolved Solids, Total	700 mg/L	2000 mg/L
Hardness (as $CaCO_3$)	325 mg/L	not given
Nitrate	10 mg/L (as N)	45 mg/L (as NO3)
Nitrogen, Total Inorganic	8 mg/L	1.5 mg/L
Oxygen, Dissolved	WARM: Not be depressed below 5 mg/L	
pH	Not above 8.5 or below 6.5	
Sodium	100 mg/L	not given
Sulfate	290 mg/L	not given
Temperature	Not above 90^{o}F June through October or above 78^{o}F in other months. Lake temperature shall not be raised more than 4^{o}F above established normal values.	
Turbidity	Dependent on natural turbidity levels (maximum increase allowed in parentheses): 0-50 NTU (20%), 50-100 (10 NTU), >100 NTU (10%)	

Table 4-2 Proposed numeric TMDL targets

California Regional Water Quality Control Board - Santa Ana Region

Reference: Problem Statement for TMDL for Nutrients in Lake Elsinore (2001); Canyon Lake Nutrient TMDL Problem Statement (2001); Lake Elsinore Nutrient TMDL Numeric Targets and Linkage Analysis - DRAFT (2002)

Parameter	Proposed TMDL Target	
	Canyon Lake	Lake Elsinore
Chlorophyll a	10 ug/L annual mean, 20 ug/L daily peak	40 ug/L seasonal mean (July through October)
Secchi Depth	not given	Seasonal mean secchi depth shall be no less than 2 feet during July through October
Nitrogen, Total	0.5 mg/L annual mean	not given
Nitrogen, Total Inorganic	not given	1.5 mg/L
Oxygen, Dissolved	Daily average DO greater than 5 mg/L at hypolimnetic zone, when lake stratifies; and average DO over depth no less than 5 mg/L when lake is well mixed from top to bottom	Daily average DO (measured daily during summer-fall, and monthly during winter-spring) be greater than 5 mg/L with greater than 50% of the lake volume.
Phosphorus, Total	not given	Seasonal mean TP concentration (January through April) shall be no greater than 100 ug/L.
Phosphate, Total as P	0.05 mg/L annual mean	not given

4.1.4 User Criteria

User criteria are determined by the needs, expectations, and resources of SAWPA, RWQCB, and the Lake Elsinore/San Jacinto River Watershed Stakeholder TMDL Workgroup. Modeling software must be compatible with existing personal-computer-based hardware platforms, and due to future use for planning and permitting decisions, should be well-documented, tested, and accepted. From a resource perspective, the level of effort required to develop, calibrate, and apply the model must be commensurate with available funding, without compromising the ability to meet technical criteria. In addition to these primary criteria, the required time frame for model development, application, and completion is important, as well as the level of concern or priority of the impaired lakes.

4.2 Model Background

Modeling the San Jacinto River watershed, Lake Elsinore, and Canyon Lake presented a challenge using currently available modeling tools. The system involves various unique features including: hydraulic issues in the San Jacinto River (e.g., storage in Mystic Lake, flow impediments), 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. In addition to TMDL development, the model will be utilized to support future development of a watershed management plan by testing alternative scenarios and modifications produced by various management and environmental factors. Such scenarios may result from the augmentation of input data to be collected in ensuing monitoring efforts, future implementation of various management strategies or BMPs, or adaptation and linkage to additional models developed in subsequent projects. Therefore, model flexibility was a key attribute for model selection.

The modeling system can be divided into two components representative of the processes essential for accurately modeling nutrient loading and internal mass balances of the lakes. The first component of the modeling system consists of a watershed model that predicts stormwater runoff and transport of nutrients as a result of rainfall events (and direct, non-storm loadings to waterbodies). It was beneficial for the selected watershed model to also include predictive capability for pathogens (which are targeted for future TMDL development). The second component includes a series of lake models that predict the response and mass balance of nutrients within the water column for Lake Elsinore and Canyon Lake. A dynamic model of Canyon Lake was utilized to provide time-series output for the existing Lake Elsinore BATHTUB model. This output is converted to the appropriate format to operate with this seasonal model. If more detailed, mechanistic modeling of Lake Elsinore is implemented in future projects, the modeling system must be relatively easy to link and provide the necessary time-series input required. A flow chart of the models for each component of the modeling system is illustrated in Figure 3-4. Details of each component and selected model follow.

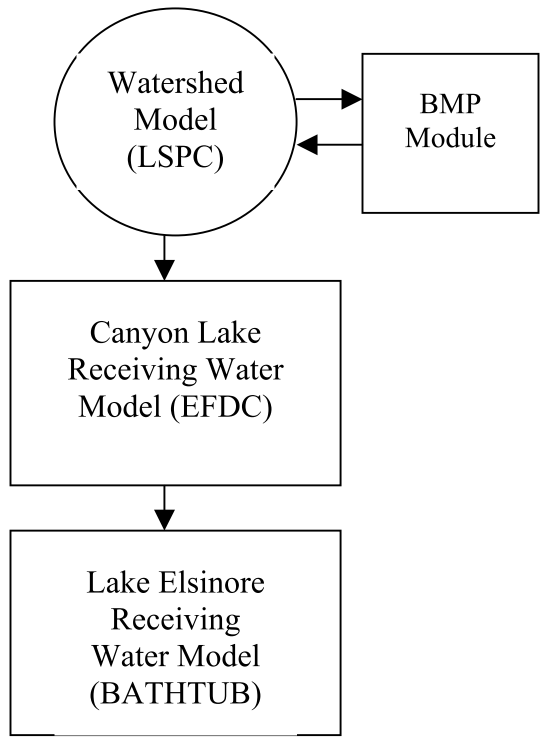

Figure 4-3 Flow Chart of San Jacinto Modeling System

4.2.1 Watershed Model (LSPC)

The Loading Simulation Program C++ (LSPC) was used for simulation of watershed processes, including hydrology and pollutant accumulation and washoff. 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 that dictates no software requirements.

The Toolbox (Figure 4-4) 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. A website for distribution of Toolbox modules is currently under construction and will ultimately be supported by EPA Region 4 (sample at http://tmdl.tetratech-ffx.com/). It will include all models and tools, as well as documentation and installation instructions.

Figure 4-4 TMDL Toolbox

LSPC has been used successfully for development of pathogen TMDLs in Alabama; nutrient and/or dissolved oxygen TMDLs in Georgia, Tennessee, Kentucky, and Alabama; and metals TMDLs (using a derivative system, MDAS) in Alabama, West Virginia, Virginia, and Arizona.

4.2.1.a Model Advantages

While LSPC and HSPF are similar models fundamentally, LSPC offers a number of advantages over HSPF and currently available platforms for running HSPF (such as NPSM in BASINS 2.0 or WinHSPF in BASINS 3.0). These advantages include:

- LSPC provides storage of all geographic, modeling, and point source permit data in a Microsoft Access database and text file formats – thus data manipulation is efficient and straightforward.
- LSPC presents no inherent limitations regarding the size and number of watersheds and streams that can be modeled.
- LSPC can be easily linked to other models (advanced hydrodynamic and water quality models such as EFDC and WASP) in a modular fashion.
- LSPC can be easily modified to include additional features that are specific to the San Jacinto watershed - such features include the BMP module or other management strategies that can influence the potential runoff and water quality loading characteristics of the watershed.
- LSPC provides the user the ability to specify and develop queries to generate unique reports of model results.
- LSPC provides post-processing and analytical tools designed specifically to support TMDL development and reporting requirements (including a TMDL calculator).
- LSPC contains an archival mechanism for saving each and every model run (critical to support the administrative record for TMDL development and for model transfer between users).
- LSPC includes a customized GIS interface that does not require user-purchased software (critical for the public participation process/stakeholder input)

4.2.1.b BMP Module

A BMP module has been developed for LSPC that models the storage and pollutant reduction processes incurred by numerous types of BMPs. The BMP module was modified to function within the LSPC model framework, providing a single platform for modeling of both watershed hydrology/hydraulic processes and management practices that affect the final quantity and water quality of the runoff from a given watershed.

The BMP module uses time series runoff output produced by the LSPC model and routes the flow through selected BMP types, including stormwater detention ponds, bio-retention basins, buffer zones, grassed swales, and many others. The BMP module uses simplified process-based algorithms to simulate BMP control of modeled flow and water quality using weir and orifice control structures, storm swale characteristics, flow and pollutant transport, flow routing and networking, infiltration and saturation, evapotranspiration, and a general loss/decay representation for a pollutant. It offers the user the flexibility to design retention style or open-channel BMPs, and define flow routing through a BMP or BMP network. Since the underlying algorithms are based on physical processes, BMP effectiveness can be evaluated and estimated over a wide range of storm conditions, BMP designs, and flow routing configurations.

The use of the BMP module to explicitly simulate existing BMPs was not justified for nutrient estimation under historic and existing conditions due to the expected minor impact during critical in-lake conditions. However, the BMP module will be used extensively during testing and simulation of multiple scenarios for development of the watershed management plan for the San Jacinto River basin and potentially for TMDL allocation.

4.2.2 Canyon Lake Model (2-D EFDC)

A hydrodynamic and nutrient transport model was developed to simulate the water budget and fate and transport of nutrients in Canyon Lake. The computational framework of the Canyon Lake model is based on the Environmental Fluid Dynamics Code (EFDC), a comprehensive three-dimensional model capable of simulating hydrodynamics, salinity, temperature, suspended sediment, water quality, and the fate of toxic materials. EFDC is a widely accepted model (particularly by EPA) and is also a component of the Toolbox. EFDC is capable of simulating 21 water quality parameters including dissolved oxygen, suspended algae (3 groups), various components of carbon, nitrogen, phosphorus and silica cycles, and fecal coliform bacteria. The kinetic processes included use the Chesapeake Bay three-dimensional water quality model, CE-QUAL.ICM (Cerco & Cole, 1994).

Since the primary purpose of the Canyon Lake model was to provide an estimate of nutrient loads to Lake Elsinore, it was not necessary to develop a fully configured 3-D hydrodynamic and eutrophication simulation model in the present stage of the modeling study. Instead, a simplified, two-dimensional hydrodynamic and nutrient transport model was developed. This model includes a hydrodynamic sub-model and a coupled nutrient fate and transport sub-model. The hydrodynamic sub-model is capable of simulating Canyon Lake water circulation in a depth-integrated fashion based on water budget and momentum balance. The nutrient fate and transport sub-model was developed based on a simplification of kinetics for total phosphorus and total nitrogen. The major sources of the two constituents are the non-point source load from the watershed model and the benthic flux from the sediment. Important sinks for the two constituents are characterized in the model by a first order decay process, as well as the overflow and seepage through the dam. The EFDC computer code was modified to enable use of total phosphorus and total nitrogen as surrogates for ortho-phosphate and ammonia during operation.

In the event that other models of Lake Elsinore are later developed that are more data-intensive than the current BATHTUB model, the EFDC time-series output from Canyon Lake will be accommodating. Two- or three-dimensional upgrading of lake models is often a useful option if additional data collection or analysis proves that higher model resolution is necessary when simulating critical processes. Additionally, if future studies of Canyon Lake require more detailed analysis of water quality processes within the lake, modifications to the model can be made to provide three-dimensional circulation analysis and a fully configured eutrophication model capable of simulating algae dynamics, dissolved oxygen balance and the fate and transport of pollutant. Simulation of a sediment process model with 27 state variables is also possible with the EFDC model (using a slightly modified version of the Chesapeake Bay three-dimensional model [DiToro & Fitzpatrick, 1993]).

4.2.3 Lake Elsinore Receiving Water Model (BATHTUB)

A BATHTUB model of Lake Elsinore was previously developed by University of California - Riverside with noted success (Anderson, 2001). BATHTUB is a steady-state eutrophication model specifically designed for lakes and uses empirical relationships for prediction of water quality conditions including total phosphorus, total nitrogen, chlorophyll *a*, transparency, organic nitrogen, nonortho-phosphorus, and hypolimnetic oxygen deletion rate (Walker, 1996). Anderson also performed a study to quantify the internal loading of nutrients to the lake from sediments and re-suspension; results were used for input parameterization of the BATHTUB model. The study found that sediment release and re-suspension are the dominant sources of nutrients to Lake Elsinore during periods of little precipitation.

Anderson presented a comparison of the BATHTUB model results with lake monitoring data for total nitrogen that showed a relatively large discrepancy, possibly the result of atmospheric nitrogen fixation by blue-green algae. Nitrogen fixation can be an important factor, but if the lake is phosphorus limited, nitrogen budgeting is only useful for descriptive purposes and less useful in chlorophyll *a* prediction (Walker, 1996). Results of the Clean Lakes Study performed on Lake Elsinore have indicated that phosphorus is only limiting under dry conditions when there is no overflow from Canyon Lake. During wet conditions, when Canyon Lake overflows, nitrogen is the limiting nutrient to algal growth (CA RWQCB – Santa Ana Region, 2001).

With the most critical periods (when DO is at a minimum and chlorophyll values are high) being under dry conditions, the BATHTUB model may be appropriate for TMDL development. However, depending on the selected TMDL target(s), there may be a need to assess conditions on a shorter time step than the seasonal or annual basis provided by BATHTUB. A more detailed, mechanistic model may be needed to analyze these conditions in the lake. If such a model is developed, output from the San Jacinto watershed and Canyon Lake modeling system will be compatible.

4.3 Model Configuration

This section outlines the configuration of the watershed model (LSPC) and Canyon Lake model (EFDC), and provides details regarding issues and assumptions necessary for successful development of the modeling system.

4.3.1 Watershed Model (LSPC)

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

4.3.1.a Watershed Segmentation

Watershed segmentation refers to the subdivision of the entire San Jacinto watershed into smaller, discrete subwatersheds for modeling and analysis. This subdivision was primarily based on the stream networks and topographic variability, and secondarily on the locations of flow and water quality monitoring stations, consistency of hydrologic factors, landuse consistency, and existing watershed boundaries (from previous studies, including the recent USGS study, or for management considerations). Figure 4-5 depicts the subwatershed delineation for the San Jacinto River basin. The watershed was divided into 35 subwatersheds for model configuration.

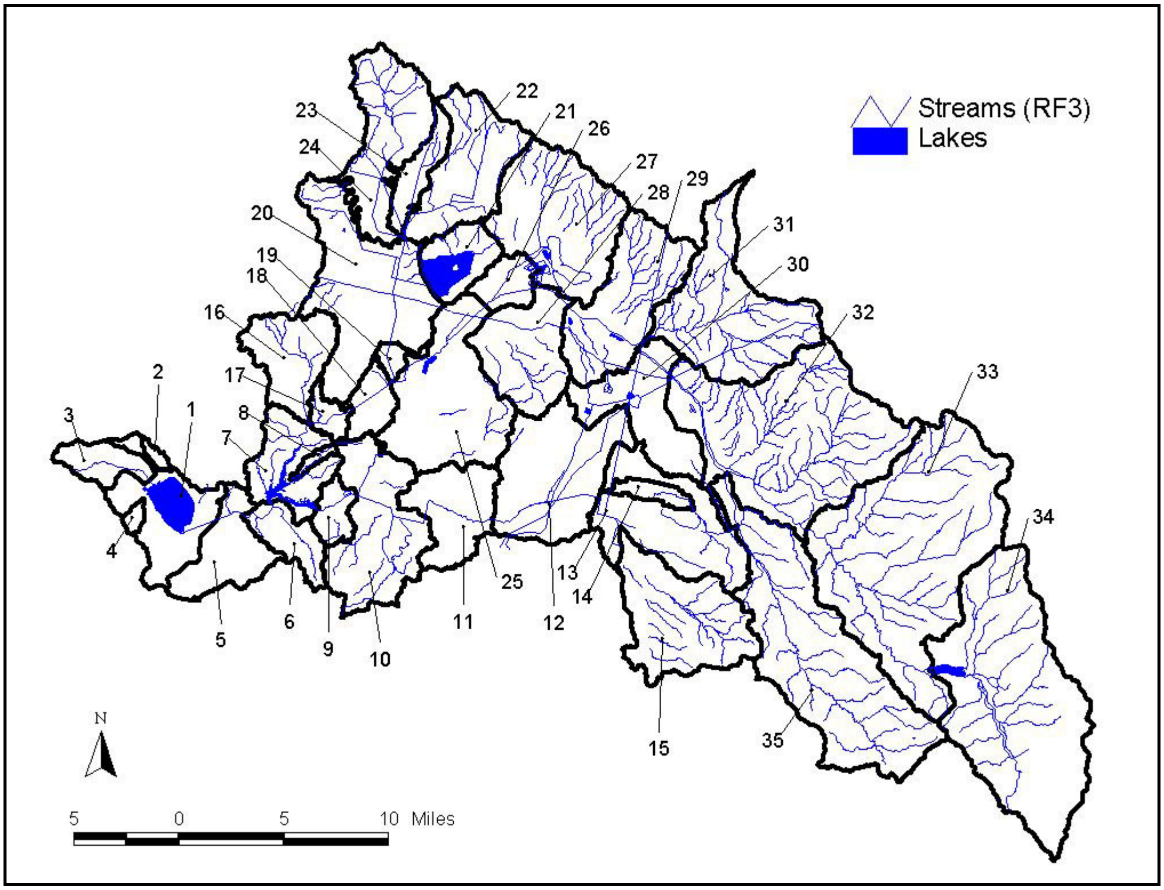

Figure 4-5 Model subwatersheds for the San Jacinto River basin

4.3.1.b Watershed Model Configuration

Configuration of the watershed model involved consideration of four major components: meteorological data, land use representation, hydrologic and pollutant representation, and waterbody 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). Waterbody representation refers to LSPC modules or algorithms used to simulate flow and pollutant transport through streams and rivers.

Meteorology

Meteorological data are a critical component of the watershed model. Appropriate representation of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dew point are required to develop a valid model. These data provide necessary input to LSPC algorithms for hydrologic and water quality representation. Meteorological data have been accessed from a number of sources in an effort to develop the most representative dataset for the San Jacinto watershed.

Because non-point sources are typically driven by rainfall and runoff, precipitation data are an important input in NPS models 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. Long-term hourly precipitation data from three National Climatic Data Center (NCDC) rain gages and six Riverside County Flood Control and Water Conservation District (RCFC) rain gages located within or near the San Jacinto watershed were used in the watershed model (Figure 4-6 and Table 4-3). Figure 4-6 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 Elsinore station will be driven by this station's data).

A number of specific modifications to the rainfall representation were made during the modeling process. Although the NCDC gage in Beaumont is located close to the northern side of the watershed, its data were found to be unrepresentative of the modeled watersheds in close proximity (through the model calibration process). To extend the period of record for the NCDC gage at the Idyllwild Fire Department (Station No. CA4211), RCFC rain data from Hurkey Creek Park were used.

Long-term hourly wind speed, cloud cover, temperature, and dew point data are available for a number of weather stations in close proximity, but outside the watershed (Figure 4-7). After analyzing the data from these stations, the Camp Pendleton surface airways station (Station No. 03154) was selected as the most appropriate station to represent conditions throughout the San Jacinto watershed. However, data for the Camp Pendleton station was incomplete for 1993, so data from the El Toro airways station (Station No. 93101) was used for this period. These stations are summarized in Table 4-3. The METCMP utility, available from USGS, was used to calculate hourly potential evapotranspiration data using available meteorological data.

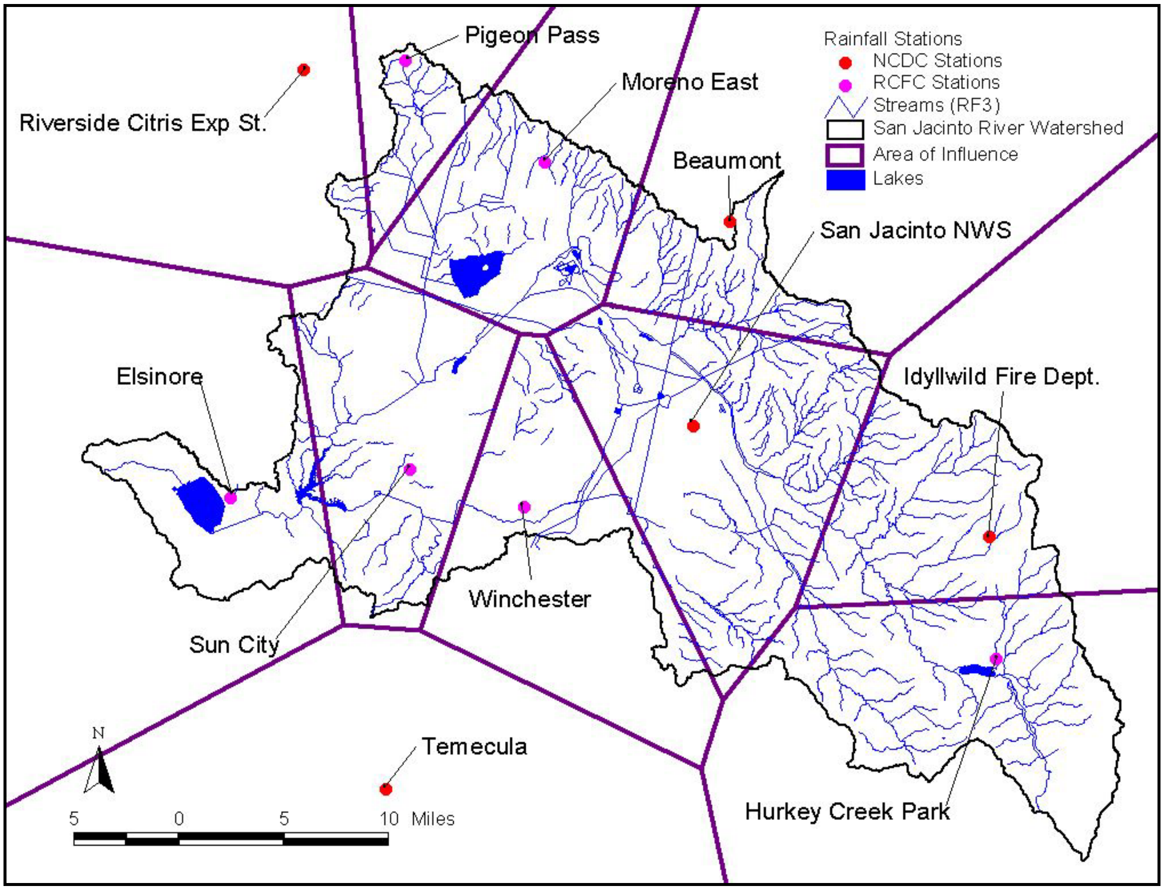

Figure 4-6 Rainfall gages in the San Jacinto River basin

Table 4-3 Meteorological monitoring stations

Station Code	Agency	Station Name	Parameter	Period of Record Collected	Located within watershed?
CA7813	NCDC	San Jacinto NWS	Precipitation	7/1/1948 - 12/29/2001	Yes
CA0606	NCDC	Beaumont	Precipitation	10/1/1957 - 12/29/2001	Yes
CA4211	NCDC	Idyllwild Fire Dept.	Precipitation	6/1/1952 – 2/16/2001	Yes
67	RCFC	Elsinore	Precipitation	7/1/1990 – 6/29/2001	Yes
212	RCFC	Sun City	Precipitation	7/1/1990 – 6/29/01	Yes

Station Code	Agency	Station Name	Parameter	Period of Record Collected	Located within watershed?
155	RCFC	Pigeon Pass	Precipitation	7/1/1990 – 6/29/2001	Yes
124	RCFC	Moreno East	Precipitation	7/1/1990 – 6/29/2001	Yes
248	RCFC	Winchester	Precipitation	7/1/1990 – 6/29/2001	Yes
89	RCFC	Hurkey Creek Park	Precipitation	7/1/1990 – 6/29/2001	Yes
93101	NOAA	El Toro MCAS	Surface airways data (air temperature, dewpoint temperature, windspeed & direction, cloud cover)	3/10/1945 - 5/14/1999	No
03154	NOAA	Camp Pendelton MCAS	Surface airways data (air temperature, dewpoint temperature, windspeed & direction, cloud cover)	7/1/1966 – 3/31/2002	No

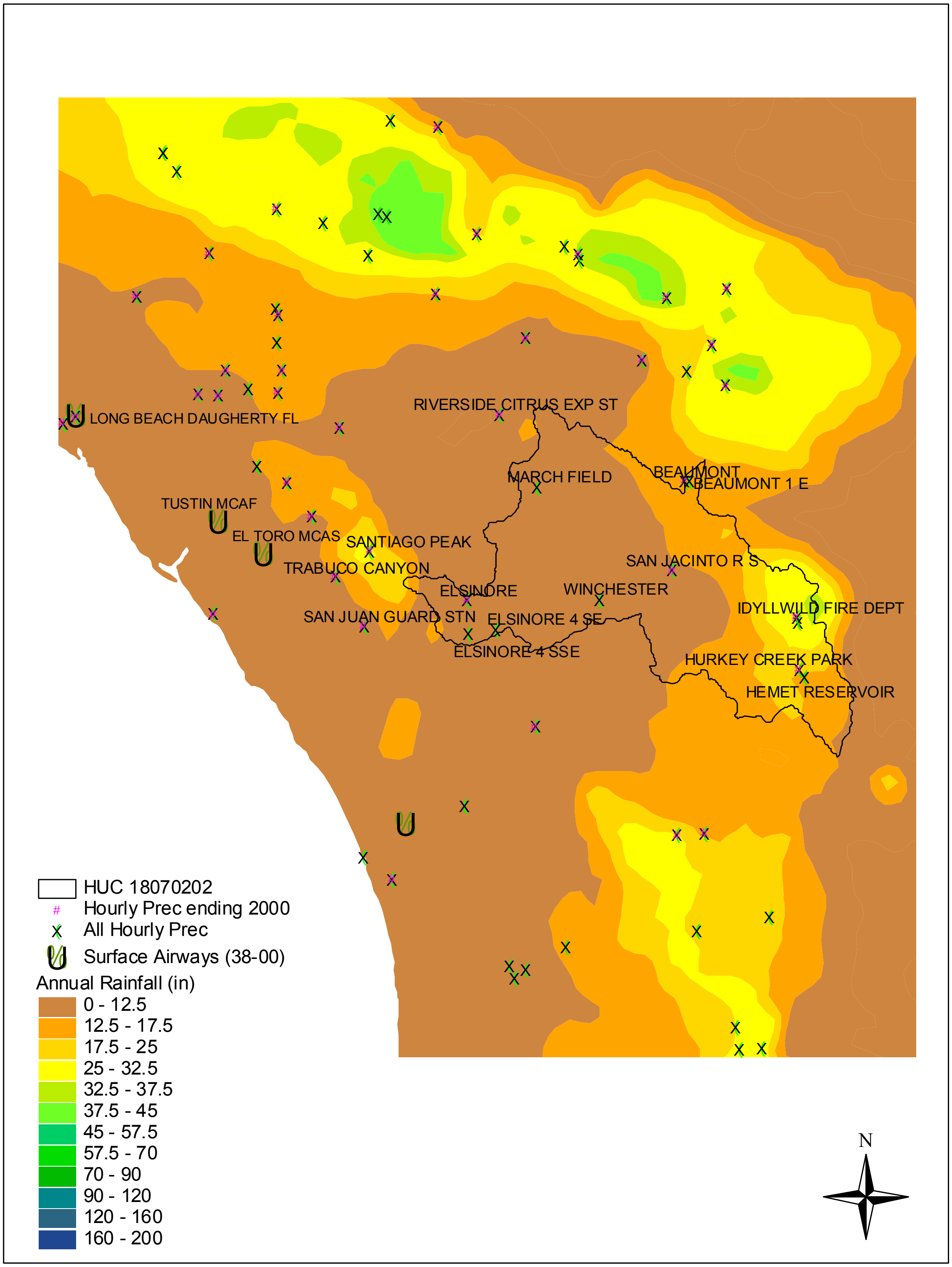

Figure 4-7 NCDC weather monitoring stations

Landuse

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 will be provided by landuse coverage of the entire watershed.

As discussed in Section 2.3.1, land use GIS data were collected from two sources: (1) USEPA/USGS MultiResolution Land Characteristics (MRLC) Consortium data and (2) Eastern Municipal Water District (EMWD) data. To utilize the most recent EMWD land use data and account for those areas in the San Jacinto River watershed not included in this dataset, a combination of the EMWD and MRLC data was necessary. Since the MRLC and EMWD each utilize a different numeric land use classification system, land use categories for both datasets were reclassified to common land use codes using the Anderson Classification System as a foundation. Table 4-4 lists the land use codes used by MRLC and EMWD, as well as the reclassified codes created as the basis for this study. 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. The resulting composite landuse coverage is shown in Figure 4-8.

Although the multiple categories in the landuse 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 landuse categories were grouped into similar classifications, resulting in a subset of 14 categories for modeling. Selection of these landuse categories was based on the availability of monitoring data and literature values that could be used to characterize individual landuse contributions and critical nutrient-contributing practices associated with different landuses. 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 landuse categories used in the watershed model is shown in Figure 4-9.

Table 4-4 Land use reclassification

Land Use Description	MRLC Code	EMWD Code	Model Codes	Model LU Descriptions	Model % Impervious
Unclassified	0	0	0	Unclassified	0
High-Density Residential	22	3	1110	High-Density Residential	65
Mobile Home/Trailor Parks		4	1111	Mobile Home/Trailor Parks	65
Medium-Density Residential		2	1120	Medium-Density Residential	27
Low-Density Residential	21	1	1130	Low-Density Residential	15
Commercial	23	6	1000	Urban	15
Public Institutions		5	1000	Urban	15
Industrial	23	7	1000	Urban	15
Public Infrastructure		17	1000	Urban	15
Vacant		15	1130	Low-Density Residential	15
Recreation/urban lawns	85	8	1130	Low-Density Residential	15
Row Crops	82		2100	Cropland	0
Irrigated Cropland		9	2101	Irrigated Cropland	0
Non-Irrigated Cropland		13	2102	Non-Irrigated Cropland	0
Pasture/Hay	81, 83		2120	Pasture/Hay/Ranches	0
Fallow	84		7000	Open Space/Bare Rock	0
Orchards and Vineyards	61	10	2200	Orchards and Vineyards	0
Dairy/Livestock		12	2300	Dairy/Livestock	0
Other Agriculture/Ranches		11	2120	Pasture/Hay/Ranches	0
Deciduous Forest	41		4000	Forest/Shrubland/Orchard	0
Coniferous Forest	42		4000	Forest/Shrubland/Orchard	0
Mixed Forest	43		4000	Forest/Shrubland/Orchard	0
Grassland/Herbaceous	71		4000	Forest/Shrubland/Orchard	0
Deciduous Shrubland	51		4000	Forest/Shrubland/Orchard	0
Water	11	16	5000	Water	0
Herbaceous Wetland	92		4000	Forest/Shrubland/Orchard	0
Wooded Wetland	91		4000	Forest/Shrubland/Orchard	0
Open Space	12	14	7000	Open Space/Bare Rock	0
Bare Rock/Sand	31		7000	Open Space/Bare Rock	0
Quarries/Strip Mines/Gravel Pits	32		7000	Open Space/Bare Rock	0
Transitional	33		7000	Open Space/Bare Rock	0

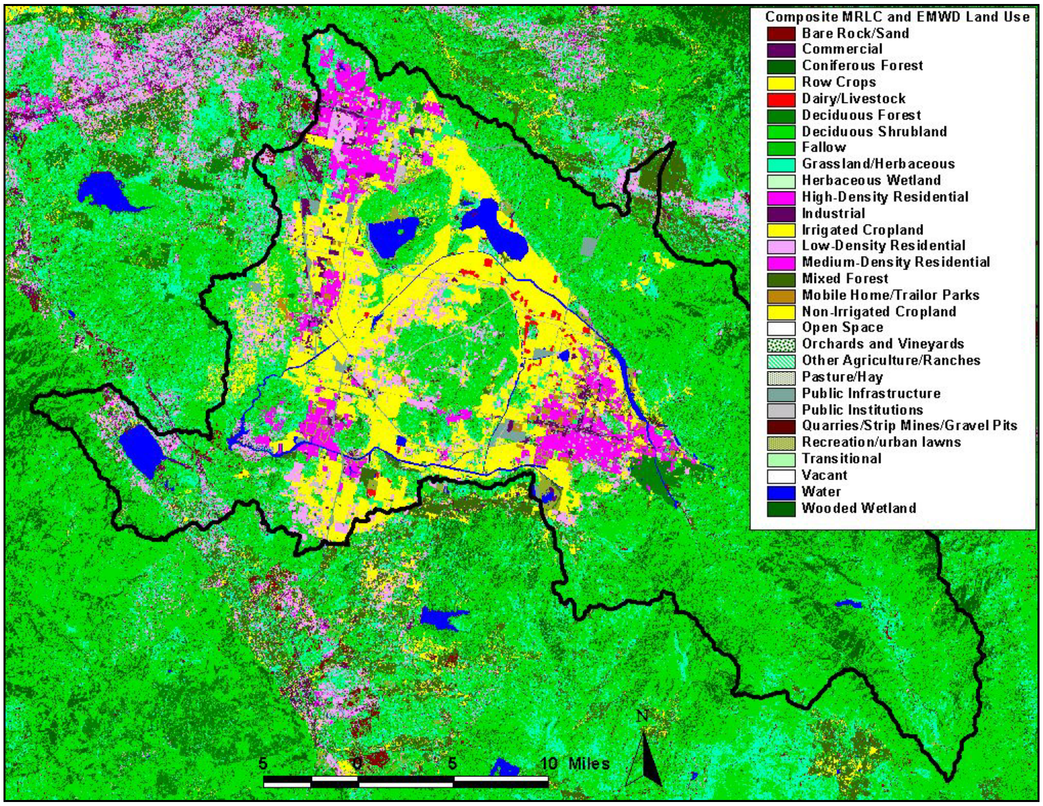

Figure 4-8 Composite MRLC and EMWD land use

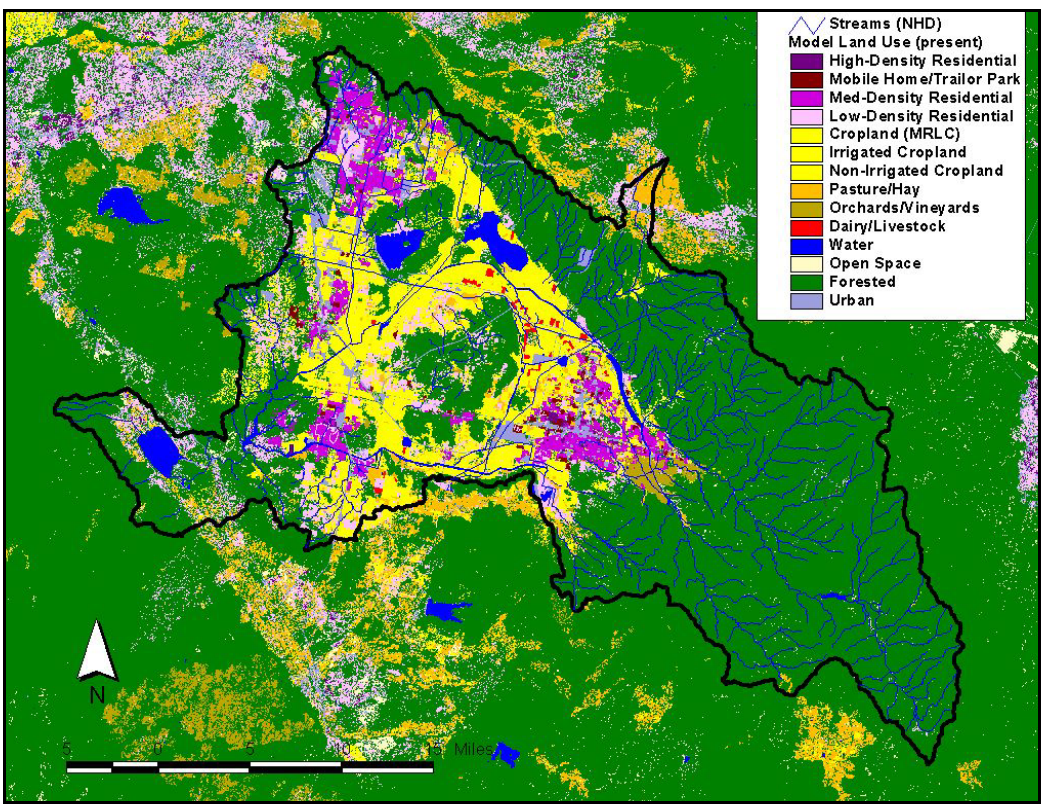

Figure 4-9 Landuse categories used in watershed model

LSPC algorithms require that land use categories be divided into separate pervious and impervious land units for modeling. This division was made for the appropriate landuses (primarily urban) to represent impervious and pervious areas separately (Table 4-4). The division was based on typical impervious percentages associated with different land use types from the Soil Conservation Service's TR-55 Manual (Soil Conservation Service, 1986).

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). Designation of key hydrologic parameters in the PWATER and IWATER modules of LSPC were required. These parameters are associated with infiltration, groundwater flow, and overland flow. The STATSGO Soils Database and the Riverside County Hydrology Manual served as a starting point for designation of infiltration and groundwater flow parameters. For parameter values not easily derived from these sources, documentation on past HSPF applications were accessed, particularly the recent USGS modeling study for the headwaters of the watershed (USGS, 2002). 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, three groups of hydrology parameters were configured in the model. Assignment of appropriate group parameters were dependent upon location and predominant SCS hydrologic soil groups of each subwatershed (soil groups outlined in Section 2.3.2). Soil groups were defined as follows:

1. Areas located at the bottom portion of the San Jacinto watershed (downstream of Hemet), with soils classified predominately as SCS soil type B.
2. Areas located at the bottom portion of the San Jacinto watershed (downstream of Hemet), with soils classified predominately as SCS soil type C/D.
3. Headwater areas of the San Jacinto watershed (upstream of Hemet).

Pollutant Representation

The primary pollutants represented in the watershed model include total nitrogen and total phosphorus. 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. 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) except for cropland areas where assumptions were made from regional data for land application of manure (described later in this section). These starting values served as baseline conditions for water quality calibration; the appropriateness of these values to 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 landuse- and pollutant-specific accumulation rates.

As mentioned, local information was required to assist in 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 (personal communication with Cindy Li, RWQCB). From data collected by RWQCB, the content of the manure loads were estimated as 0.00437 pounds total nitrogen per pound of manure and 0.000892 pounds total phosphate per pound of manure. The resulting annual loads attributed to land application of manure are estimated as 0.0587 lbs/acre of total phosphate and 0.2873 lbs/acre of total nitrogen. Assuming 3.07 pounds of total phosphorus for every 1 pound of total phosphate (ratio determined from dairy manure content data reported in American Society of Agricultural Engineers Standards, 2001), the annual load of total phosphorus is estimated as 0.18 lbs/acre. Build-up limits for these agricultural loads were determined through the calibration process described in the next section.

As discussed in Section 3.2.3, failed septic systems are believed to be major contributors to nutrient loads in the San Jacinto River basin. To quantify these impacts, several assumptions were made so that loadings could be simulated dynamically in the watershed model. A crucial step in the quantification of septic loads was the identification of all septic systems in the San Jacinto River watershed that pose potential risks to failure and are in close proximity to waterbodies where associated loads can be transported. Using a similar method to that used by EVMWD for identification of land parcels on septic systems in the vicinity of Lake Elsinore (Figure 3-6), 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. 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 4-10).

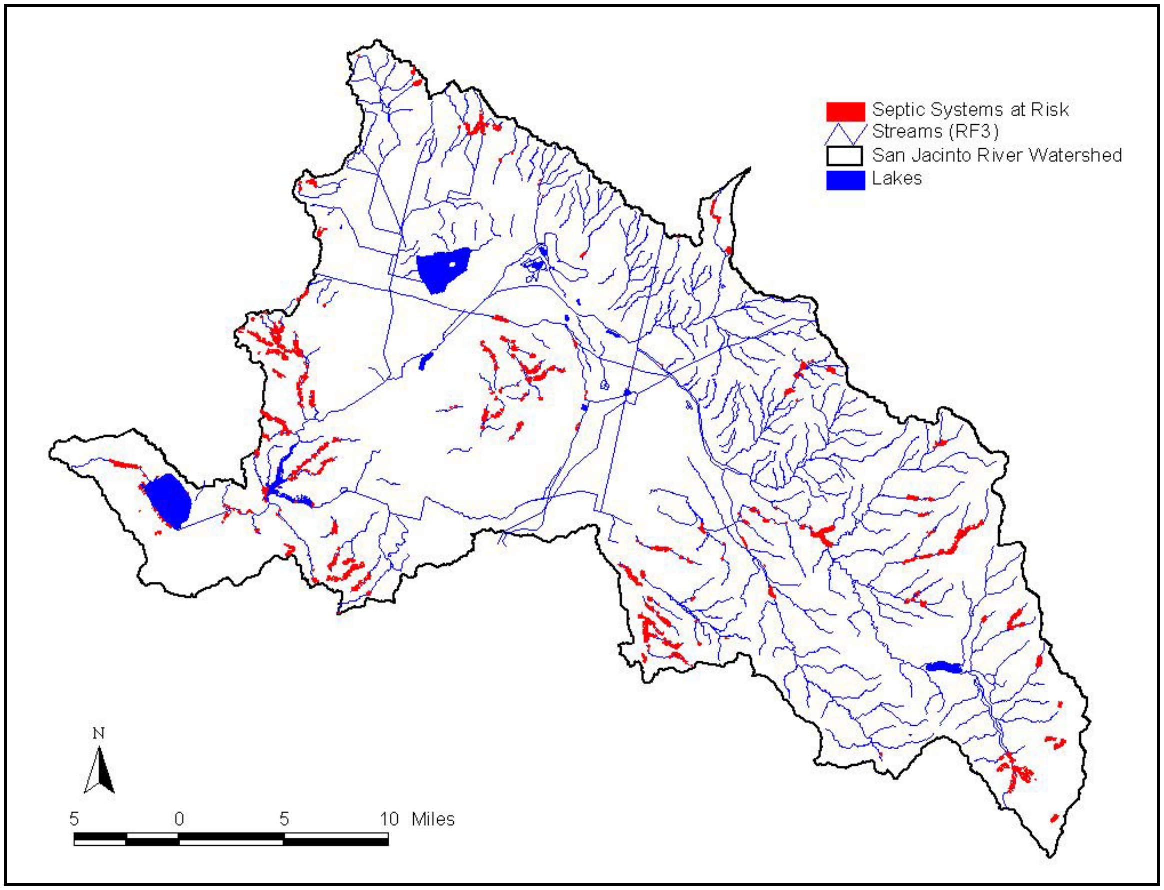

Figure 4-10 Septic systems at risk of failure and contamination of surface waters

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

- 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 4-5, 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 streamflow 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 landuse, with all flow routed through the interflow routines of the PWATER functions of the modeling system. These source contributions were calibrated by adjusting the artificial landuse area and pollutant concentrations so that annual average loads over a 10-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.

Typically, HSPF and LSPC have problems associated with prediction of water quality concentrations when streamflows approach zero. Because of the significant dry periods of the San Jacinto River basin, this issue initially presented a problem with modeling of the watershed. To remedy the problem, the LSPC model was modified to limit the minimum streamflow to 10^{-8} cfs for calculation of nutrient concentrations. Loads at such low flows were determined insignificant and did not influence the overall loads from the watershed. Adjustments to flows were only performed for calculation of nutrient concentrations; model output reported original (unmodified) flows.

Waterbody 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 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.

To represent Lake Hemet and Mystic Lake in the watershed model, 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, with dam overflow calculated using simple weir equations. The lake functions were assigned to the model reaches of subwatersheds 27 and 33 for Mystic Lake and Lake Hemet, respectively. Lake volumes and weir overflow functions were calibrated for Lake Hemet during calibrations of flows for subwatershed 33 at USGS streamflow gage 11069500 (see Section 4.3.1.c).

Limited calibration was possible for Mystic Lake due to lack of sufficient stormflow data downstream.

4.3.1.c Model Calibration and Validation

After initially configuring the San Jacinto River watershed model, model calibration and validation were performed. Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. The calibration was performed for different LSPC modules at multiple locations throughout the watershed. This approach ensured that heterogeneities were accurately represented. The 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 hourly/daily average flow and hourly/daily average concentrations for the modeled nutrients for each of the subwatersheds. Flow monitoring data are available at USGS flow gauging stations located throughout the watershed, while water quality monitoring data are available at these locations and additional locations where flow was not monitored.

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 and an adjustment of key hydrologic parameters to result in most closely representing the system and reproducing observed flow patterns and magnitudes. USGS gage stations are shown in Figure 4-11 and were considered for use in model calibration. 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 less than one year of data in 2001 (Table 4-5). 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.

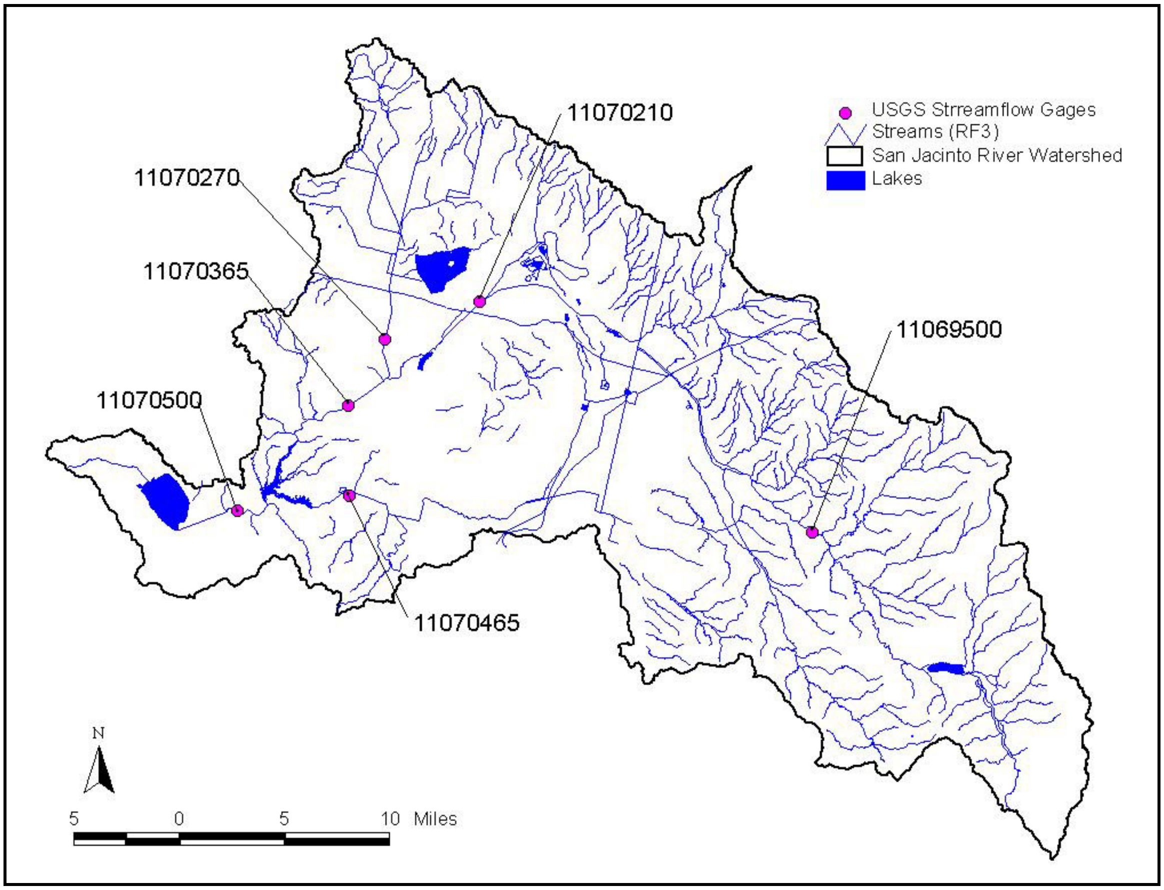

Figure 4-11 USGS streamflow gages

The calibration years were selected based on an examination of annual precipitation variability and the availability of observation data. The periods selected were determined to represent a range of hydrologic conditions, including low, mean, and high flow conditions. Calibration for these conditions was necessary to ensure that the model accurately predicted a range of conditions for a longer period of time. Details regarding location, period of historical record, and selected periods for calibration and validation are listed for each gage in Table 4-5.

Table 4-5 USGS station descriptions

Station Number	Station Name	Historical Record	Selected Calibration Period	Selected Validation Period
11069500	San Jacinto River near San Jacinto	10/1/1920 - 9/30/1991; 10/1/1996 - 9/30/2001	10/1/1996 - 9/30/2001	10/1/1990 - 9/30/1991
11070270	Perris Valley Storm Drain at Nuevo Rd. near Perris	10/1/1969 - 9/30/1997; 10/1/1998 - 2/14/2001	1/1/1991 - 9/30/1997	10/1/1998 - 2/14/2001
11070500	San Jacinto River near Elsinore	1/1/1916 - present	none (influenced by Canyon Lake overflow)	none (influenced by Canyon Lake overflow)
11070475	Salt Creek at Murrieta Rd.	10/1/1969 - 9/30/1978; 8/25/2000 - 9/30/2001	none (insufficient period of record)	10/1/2000 - 6/29/2001
11070375	San Jacinto River at Goetz Rd.	10/1/2000 - 9/30/2001	none (insufficient period of record)	10/1/2000 - 6/29/2001
11070210	San Jacinto River at Romona Exp.	10/1/2000 - 9/30/2001	none (insufficient period of record)	10/1/2000 - 6/29/2001

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.

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 11070475, 11070375, 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.

Figure 4-12 shows the location of USGS gage 11069500 in the headwaters of the San Jacinto River. The predominant landuse for this portion of the watershed is forested. This area represented the headwaters region (Group 3 hydrologic parameters) and was also descriptive of the hydrologic characteristics associated with a predominantly forested area.

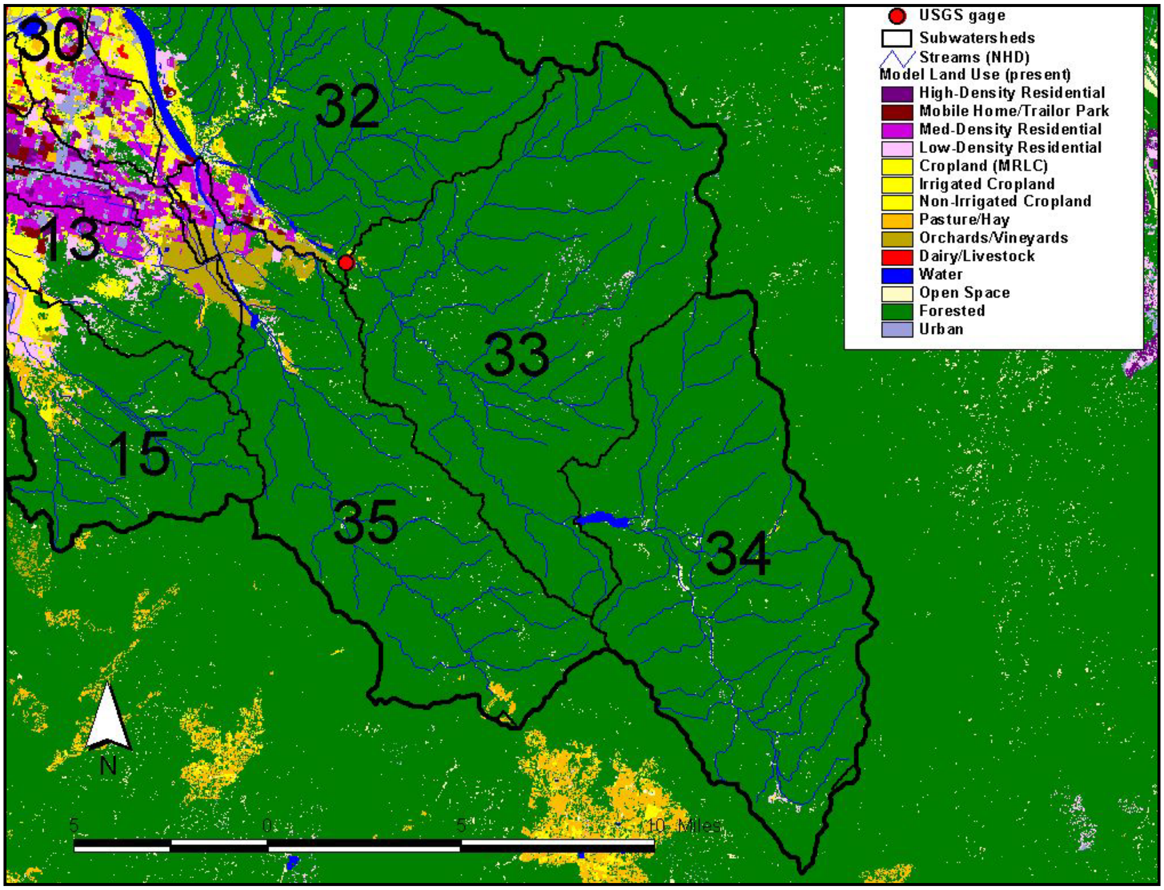

Figure 4-12 USGS gage 11069500 calibration area

Figure 4-13 depicts the time-variable plot used for model calibration at this gage (output from subwatershed 33). As can be seen from the plot, two relatively large storms occurred in the period from 1997 to 1998 that required accurate prediction. However, calibration to these larger storms also affected the accuracy of the model for the average smaller stormflows that are likely to occur in a given dry year (e.g., 1999 and 2000). The overall calibration process accounted for both hydrologic regimes without substantially causing a gross misrepresentation of either. The relative error of the model is reported in Table 4-6 for several periods 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 2.0 percent, with the model under-predicting the top 10 percent highest flows by only 0.4 percent. Additional summary statistics and graphical analyses used for calibration are provided in Appendix C.

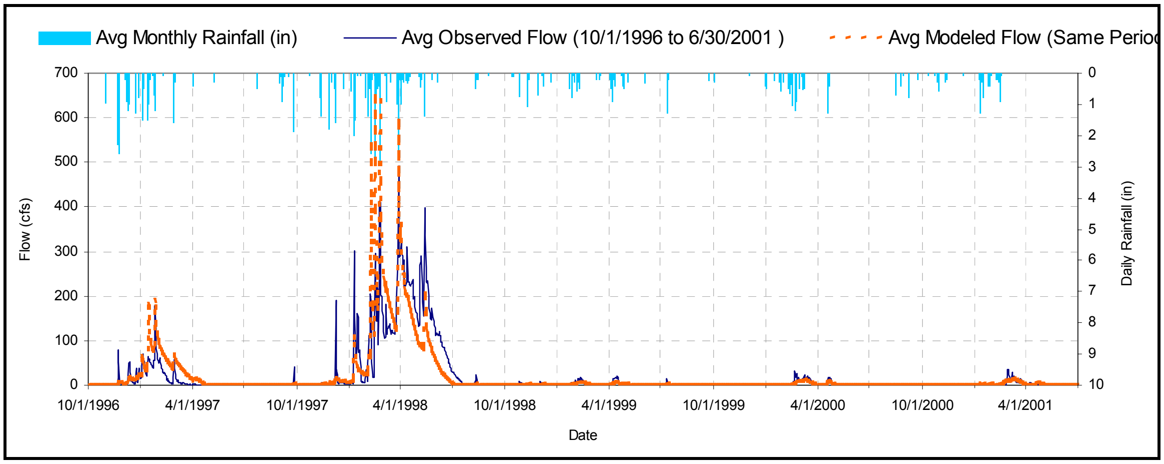

Figure 4-13 Graphical analysis of USGS 11069500 calibration period

Table 4-6 Relative error analysis of USGS 11069500 calibration period

LSPC Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM SUBBASIN 33 4.75-Year Analysis Period: 10/1/1996 - 6/30/2001 Flow volumes are (inches/year) for upstream drainage area		**USGS 11069500 San Jacinto River Near San Jacinto** Riverside County, California		
Total Simulated In-stream Flow:	**11.39**	Total Observed In-stream Flow:		**11.16**
Total of simulated highest 10% flows:	**9.52**	Total of Observed highest 10% flows:		**9.56**
Total of Simulated lowest 50% flows:	**0.00**	Total of Observed Lowest 50% flows:		**0.01**
Simulated Summer Flow Volume (months 7-9):	**0.03**	Observed Summer Flow Volume (7-9):		**0.16**
Simulated Fall Flow Volume (months 10-12):	**0.35**	Observed Fall Flow Volume (10-12):		**0.41**
Simulated Winter Flow Volume (months 1-3):	**7.58**	Observed Winter Flow Volume (1-3):		**5.10**
Simulated Spring Flow Volume (months 4-6):	**3.44**	Observed Spring Flow Volume (4-6):		**5.49**
Errors (Simulated-Observed)	*Current Run (n)*	*Recommended Criteria*		
Error in total volume:	2.04	10		
Error in 10% highest flows:	-0.40	15		

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 4-14 shows the results of the model validation for the period of October 1990 to September 1991. 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 discrepancy between the observed and modeled hydrograph peaks for the first storm 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 on the watershed during that storm period.

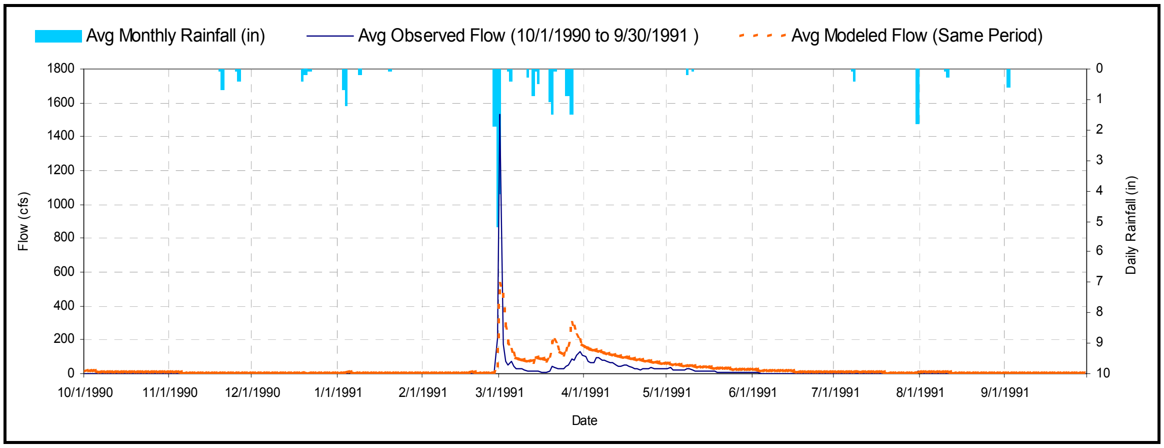

Figure 4-14 Graphical analysis of USGS 11069500 validation period

Figure 4-15 depicts the location of USGS gage 11070270 on Perris Valley storm drain in the northwest portion of the San Jacinto River watershed. As seen in the figure, the watershed (including subwatersheds 20, 22, 23 and 24) 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 1 (Class B soils) and Group 2 (Class C/D soils) hydrologic parameters.

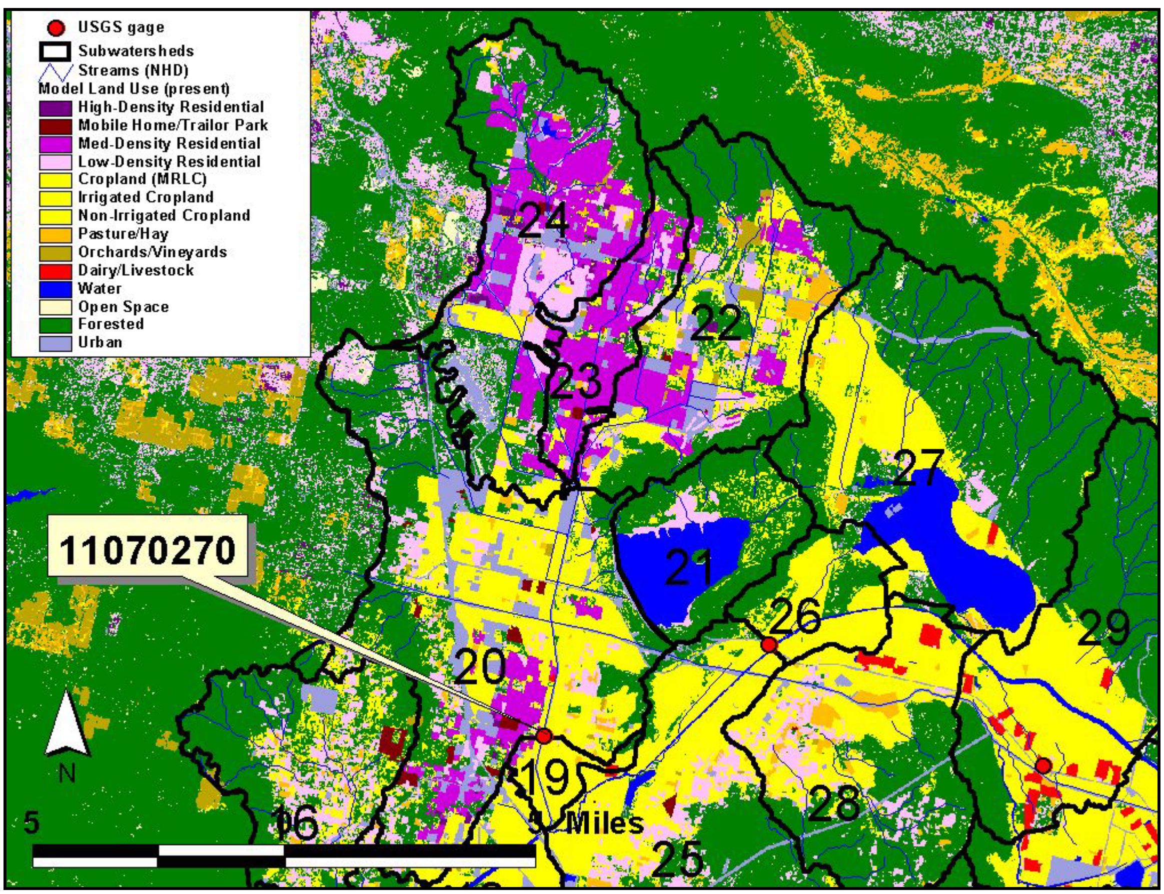

Figure 4-15 USGS gage 11070270 calibration area

Figure 4-16 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 a typical urban response. Flow is relatively 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 4-7, and showed only a 3.8 percent error between predicted and observed total volumes, and only a 0.6 percent error in the highest 10 percent of predicted and observed streamflows. Additional summary statistics and graphical analyses used for calibration are provided in Appendix C.

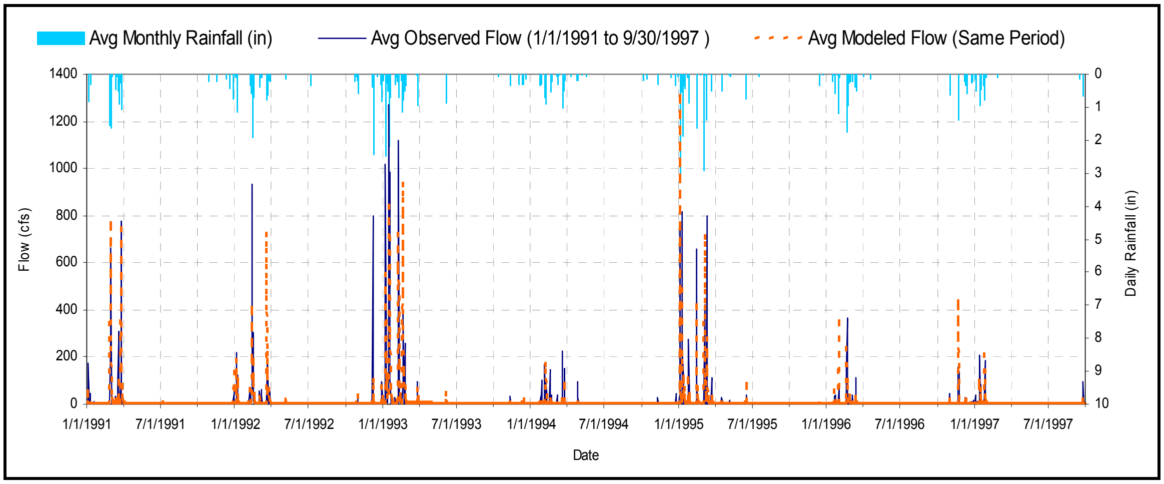

Figure 4-16 Graphical analysis of USGS 11070270 calibration period

Table 4-7 Relative error analysis of USGS 11070270 calibration period

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 20 6.75-Year Analysis Period: 1/1/1991 - 9/30/1997 Flow volumes are (inches/year) for upstream drainage area		**USGS 11070270 PERRIS VALLEY STORM DR A NUEVO RD** Riverside County, California Hydrologic Unit Code 18070202 Latitude 33°48'04", Longitude 117°12'19" NAD27 Drainage area 93.30 square miles	
Total Simulated In-stream Flow:	**1.50**	Total Observed In-stream Flow:	**1.45**
Total of simulated highest 10% flows:	**1.45**	Total of Observed highest 10% flows:	**1.44**
Total of Simulated lowest 50% flows:	**0.00**	Total of Observed Lowest 50% flows:	**0.00**
Simulated Summer Flow Volume (months 7-9):	**0.01**	Observed Summer Flow Volume (7-9):	**0.01**
Simulated Fall Flow Volume (months 10-12):	**0.07**	Observed Fall Flow Volume (10-12):	**0.11**
Simulated Winter Flow Volume (months 1-3):	**1.39**	Observed Winter Flow Volume (1-3):	**1.31**
Simulated Spring Flow Volume (months 4-6):	**0.04**	Observed Spring Flow Volume (4-6):	**0.02**
Errors (Simulated-Observed)	*Current Run (n)*	*Recommended Criteria*	
Error in total volume:	3.84	10	
Error in 10% highest flows:	0.57	15	

The validation period from October of 1998 through February of 2001 at station 11070270 also showed a good fit to the observed flow data. Figure 4-17 shows the comparison of modeled and observed streamflows for this period.

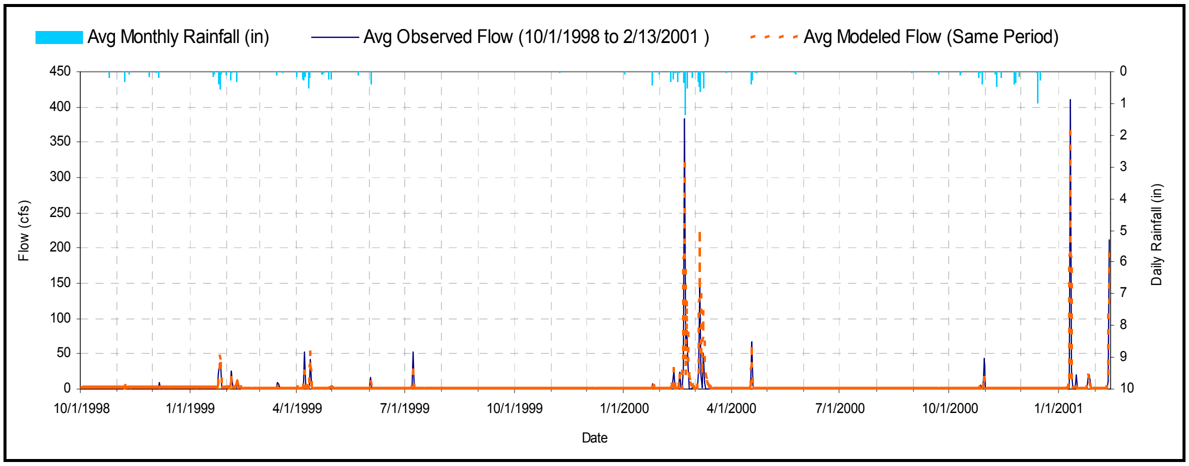

Figure 4-17 Graphical analysis of USGS 11070270 validation period

Three other gages (11070465, 11070365, 11070210) located upstream of Canyon Lake were also selected for model validation (see Figure 4-11). Calibration to these gages was not performed due to the lack of sufficient data that include periods of varying hydrologic conditions (data were only available for 2001). Figures 4-18 through 4-20 show graphical analysis of the validation periods for these gages in the same scale to provide an overview of the effectiveness of the model's flow predictions.

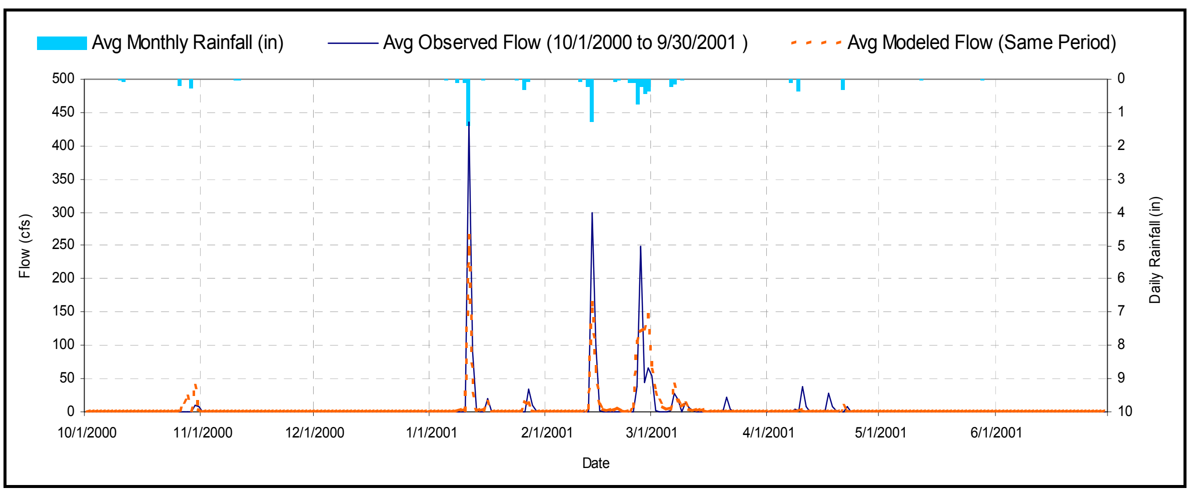

Figure 4-18 Graphical analysis of USGS 11070465 validation period

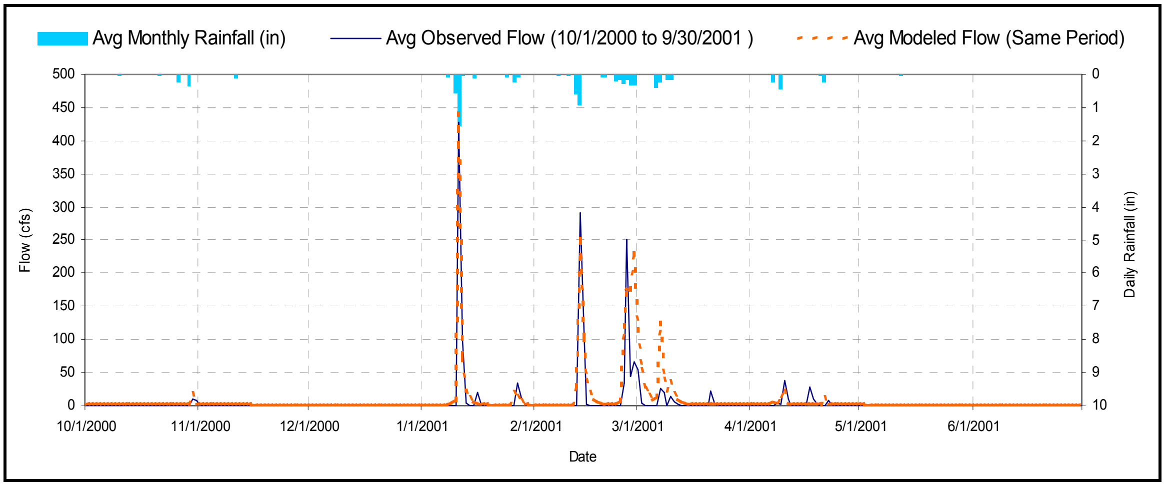

Figure 4-19 Graphical analysis of USGS 11070365 validation period

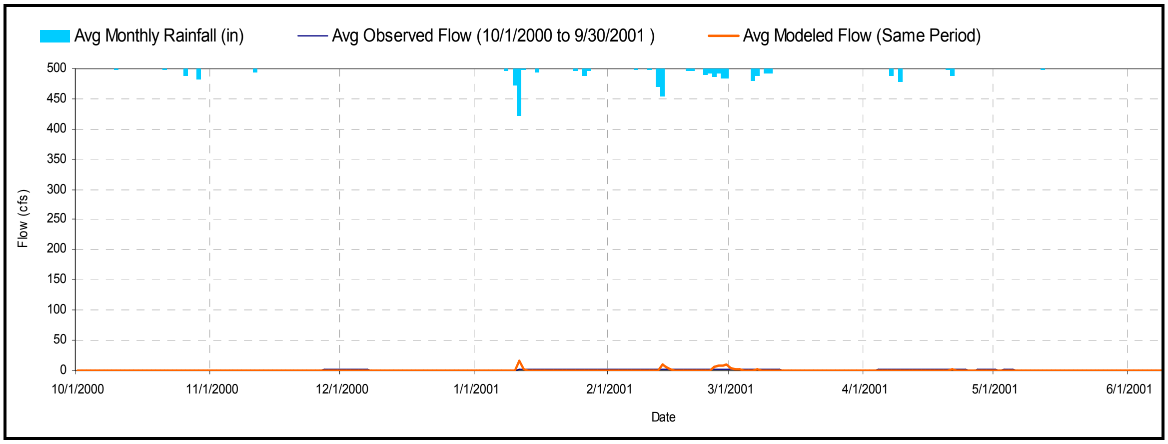

Figure 4-20 Graphical analysis of USGS 11070210 validation period

The model results at station 11070210 (Figure 4-20) are depicted out of scale of the observed flow for comparison purposes with stations 11070365 and 11070465. The relatively low flows for station 11070210 are the result of the storage of San Jacinto River flow in Mystic Lake. Without additional data to either substantiate Mystic Lake assumptions or provide further guidance in the lake's representation in the model, existing assumptions are regarded as sufficient based on local expertise and available data. Moreover, the variation depicted in Figure 4-20 is only relevant for relatively small flows. For larger stormflows the overflow of Mystic Lake has not been quantified and conclusions cannot be drawn regarding the overall performance of the model at this location without more comprehensive flow data that include rainfall periods when Mystic Lake overflow is a factor.

Water Quality

After hydrology was sufficiently calibrated, water quality calibration was performed. Modeled versus observed in-stream concentrations were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing 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 landuses, in particular). The TMDL monitoring stations were particularly important in calibrating landuse-specific pollutant loading parameters.

Adjusted water quality parameters included pollutant buildup, washoff, and subsurface concentrations (primarily interflow for the San Jacinto watershed). Water quality calibration adequacy was primarily assessed through review of time-series plots. Looking at a time-series plots of modeled versus observed data provided more insight into the nature of the system and was more useful in water quality calibration than a statistical comparison. Flow (or rainfall) and water quality was compared simultaneously, providing insight into conditions during the monitoring period (dry period versus storm event). Due to the relative lack of water quality monitoring data, statistical comparisons were not made. If additional data are collected in the future, it may be beneficial to perform error analyses such as correlation (R-squared), Root Mean Square Error, and Mean Absolute Error.

Table 4-8 lists the TMDL 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. Model calibration and validation was performed for hourly model predictions of total nitrogen and total phosphorus.

Water quality parameters for the watershed model were then validated through a comparison of observed water quality data to modeled in-stream values. The validation was performed, to the extent possible, at locations with sufficient water quality observation data located in areas draining large, mixed-landuse portions of the watershed.

Table 4-8 TMDL station calibration/validation periods

Station Number	Station Name	Period of Record	Selected Calibration Period	Selected Validation Period
318	Hemet NPDES	12/15/1992 -2/28/2001	1/11/2001 - 2/28/2001	6/1/1993 - 2/15/1998
325	Perris Ch @ Nuevo Rd	2/12/2000 - 6/19/2001	1/11/2001 - 6/19/2001	2/12/2000 - 8/22/2000
357	Four Corners NPDES	1/3/1992 - 2/25/2001	2/3/1998 - 2/25/2001	1/3/1992 - 12/16/1997
712	Leach Cyn ChanOutlet	1/3/1992 - 2/13/2001	1/11/2001 - 2/13/2001	none
714	Ortega Cyn Chan	1/3/1992 - 2/13/2001	1/11/2001 - 2/13/2001	none
745	Salt Creek @ Mur Rd	1/11/2001 - 3/3/2001	1/11/2001 - 3/3/2001	none
759	S.JacintoRiv@GoetzRd	2/21/1996 - 3/2/2001	1/11/2001 - 3/2/2001	none
792	S.Jac.Riv @ Cranston	8/17/1995 - 4/17/2001	1/14/1998 - 4/17/2001	8/17/1995 - 9/24/1997
834	Cyn Lk@ Sierra Park	1/11/2001 - 3/2/2001	1/11/2001 - 3/2/2001	none

Figure 4-21 shows the landuse of subwatershed 14 and the location of TMDL 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 20 is predominately urban. Such homogeneity for a watershed provides justification for parameterization of other landuses in more heterogeneous areas where contributions from individual landuse types are difficult to isolate.

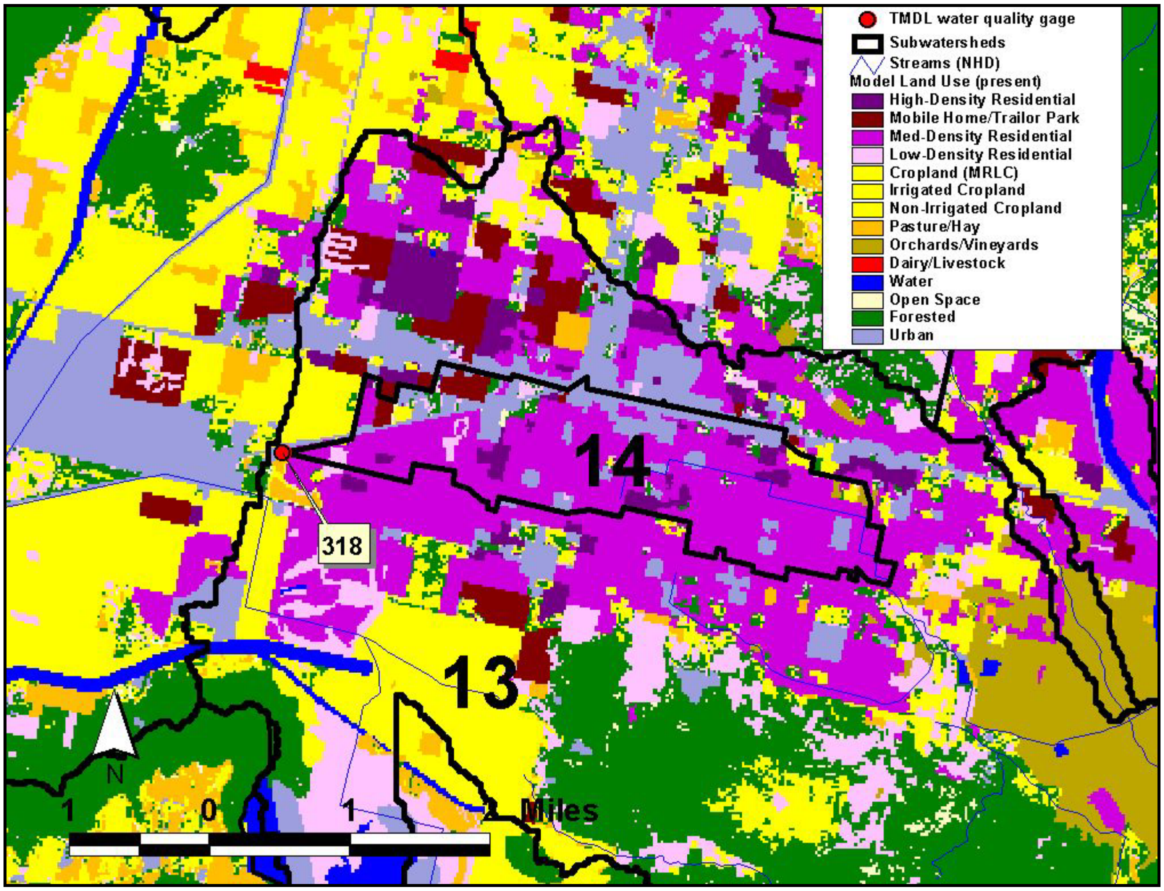

Figure 4-21 Location of TMDL station 318

Calibration to TMDL gage 318 was performed for total nitrogen and total phosphorus using hourly LSPC output as depicted in Figures 4-22 through 4-25. Model predictions of nutrients are plotted with observed data in Figures 4-22 and 4-24 to show the temporal and storm calibration. To analyze the variability between model and observed water quality as a function of the magnitude of concentrations, Figures 4-23 and 4-25 are provided. This second analysis provides a comprehensive comparison of overall variability and ranges of nutrient concentrations.

Model predictions of total phosphorus appeared consistently higher than observed concentrations. After closer examination of the landuse in subwatershed 14, it became apparent that approximately 30 acres of agricultural land in the area had a pronounced influence on model predictions. For this subwatershed, the operation of the small agricultural area can be quite different than overall assumptions for agricultural areas throughout the entire San Jacinto Basin. Therefore, the slight over-prediction of total phosphorus was considered acceptable because calibration was appropriate in other areas where agriculture is a dominant landuse.

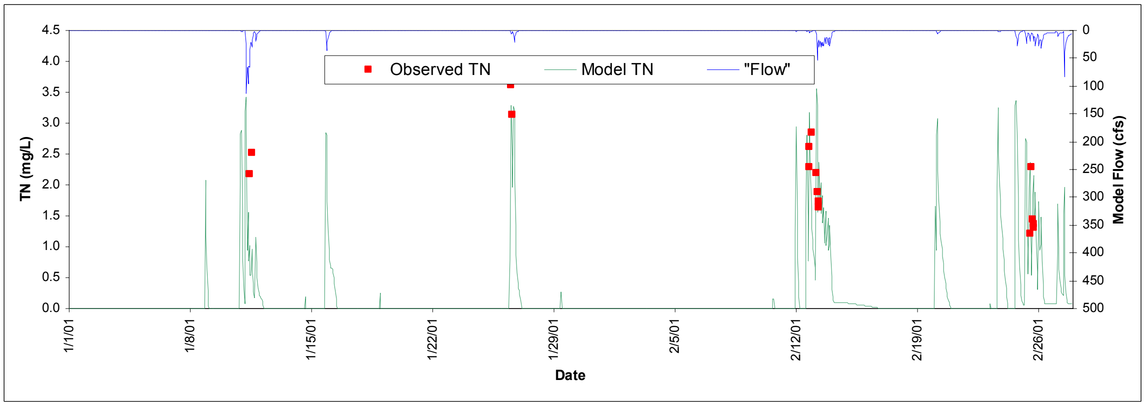

Figure 4-22 Model calibration of total nitrogen concentrations at TMDL station 318

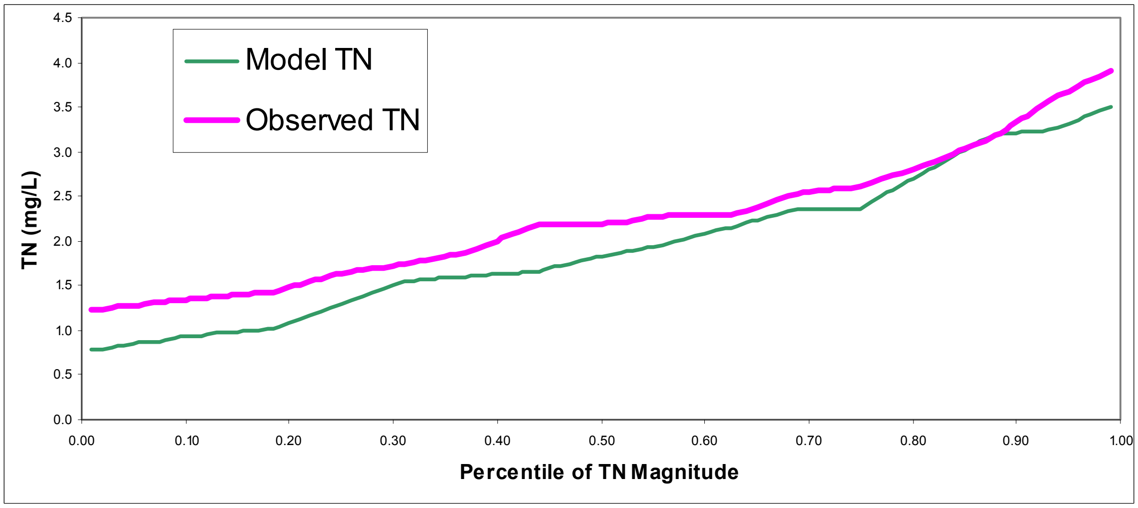

Figure 4-23 Graphical comparison of modeled versus observed total nitrogen concentrations at TMDL station 318

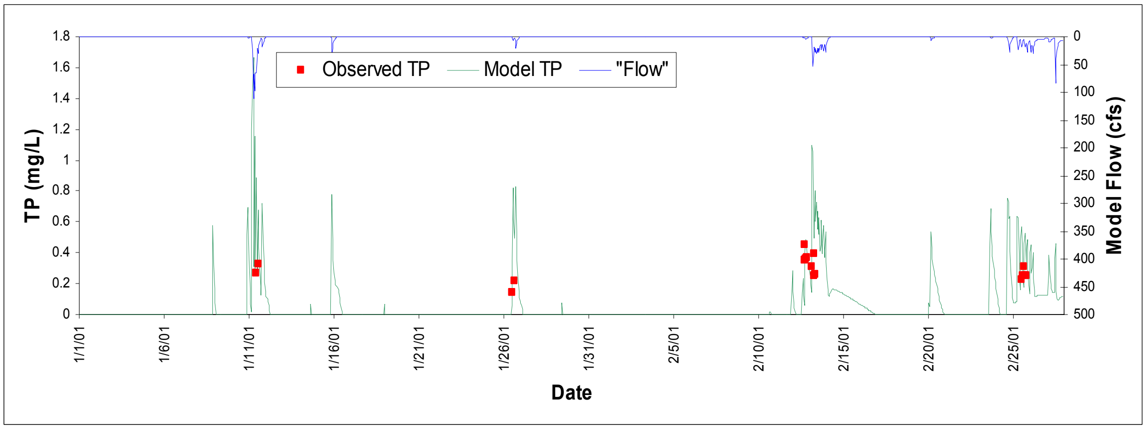

Figure 4-24 Model calibration of total phosphorus concentrations at TMDL station 318

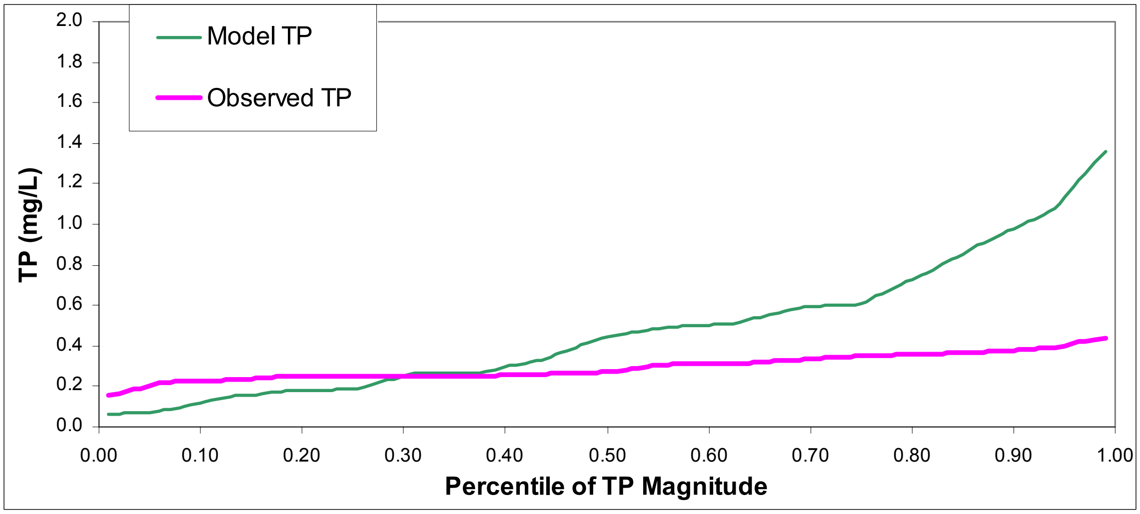

Figure 4-25 Graphical comparison of modeled versus observed total phosphorus concentrations at TMDL station 318

Model results for TMDL station 318 were validated over a period from June 1993 through February 1998. Results of this validation period are shown in Figures 4-26 through 4-29. As with the calibration, model results for this period compared well with observed data. However, the initial validation results for total nitrogen (Figure 4-26) showed consistent under-prediction of observed data. The reason for the lower predicted range is unclear, but since the observed data were collected on days when the model predicted little or no streamflow and no flow data are available to determine if flow is calculated efficiently during this period, the under-predicted total nitrogen concentrations are considered acceptable and possibly due to unknown influences or problems with data. The second period of the validation (Figure 4-27) showed a good fit to observed data, justifying the assumption that unforeseen circumstances caused the discrepancy in the first validation period.

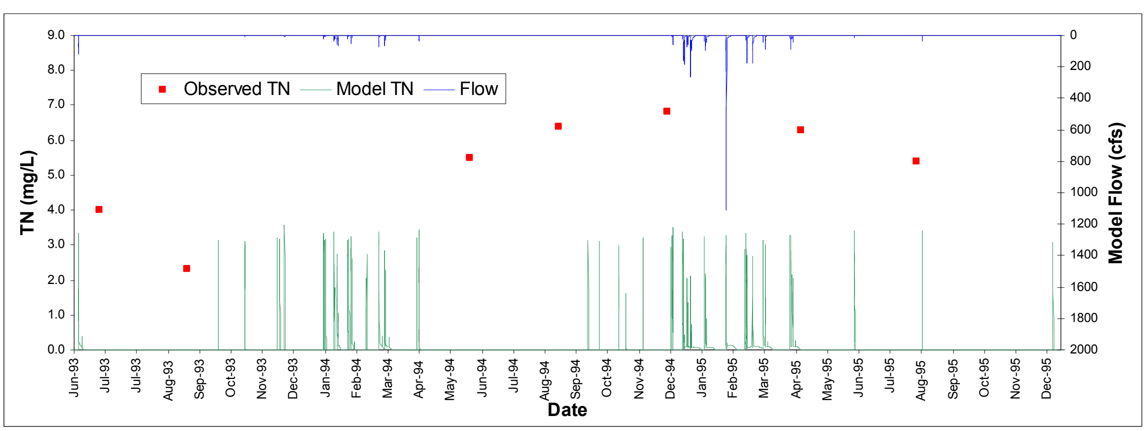

Figure 4-26 Model validation of total nitrogen concentrations at TMDL station 318 (June 1993 – December 1995)

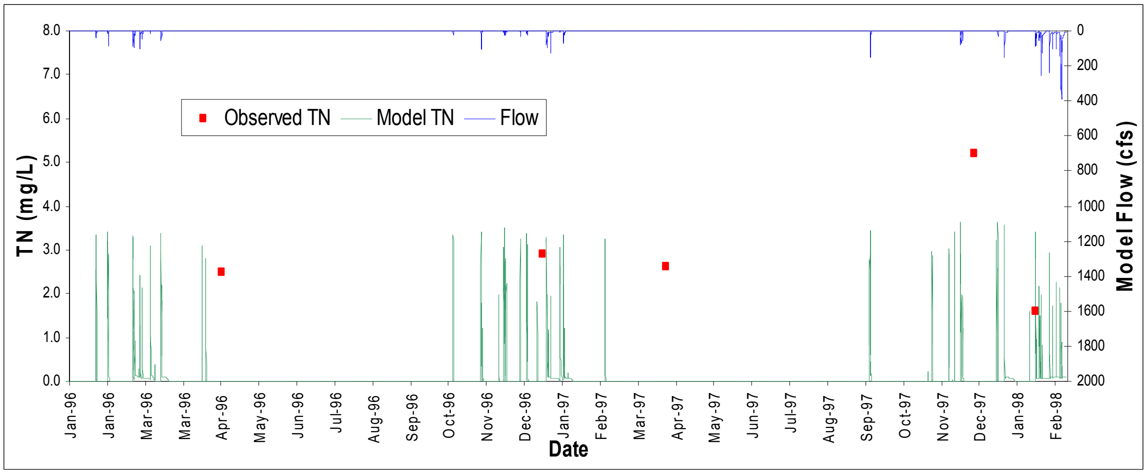

Figure 4-27 Model validation of total nitrogen concentrations at TMDL station 318 (January 1996 – February 1998)

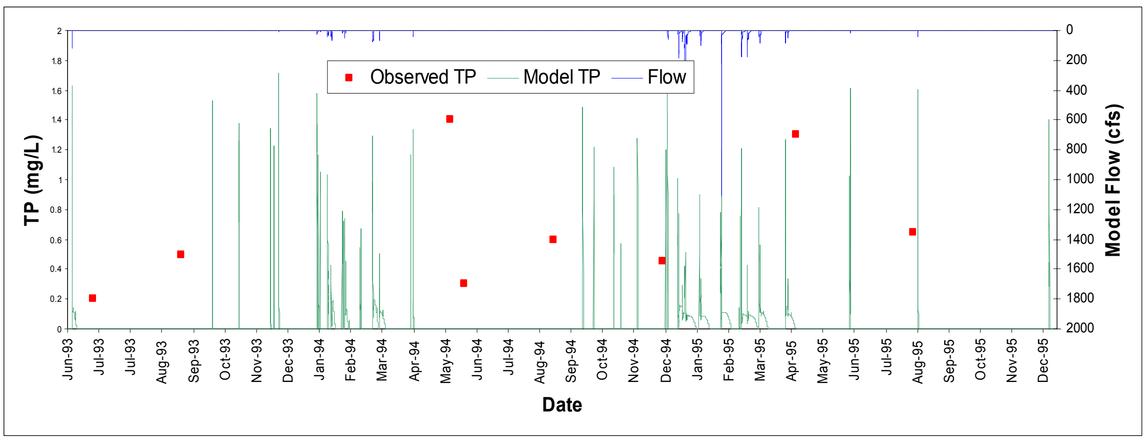

Figure 4-28 Model validation of total phosphorus concentrations at TMDL station 318 (June 1993 – December 1995)

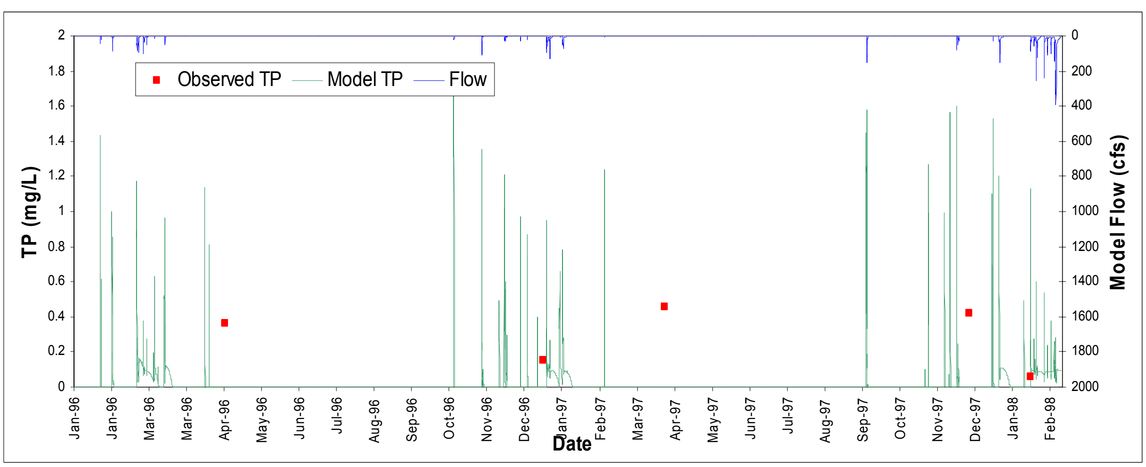

Figure 4-29 Model validation of total phosphorus concentrations at TMDL station 318 (January 1996 – February 1998)

TMDL stations 357, 712, and 714, in the vicinity of Lake Elsinore, provided additional guidance for modeling nutrient runoff from urban areas, but also include substantial forested and pasture areas. Figure 4-30 shows the gage locations, landuse, and the boundaries of subwatersheds 2, 3, and 4, which provide drainage to TMDL stations 357, 712, and 714, respectively.

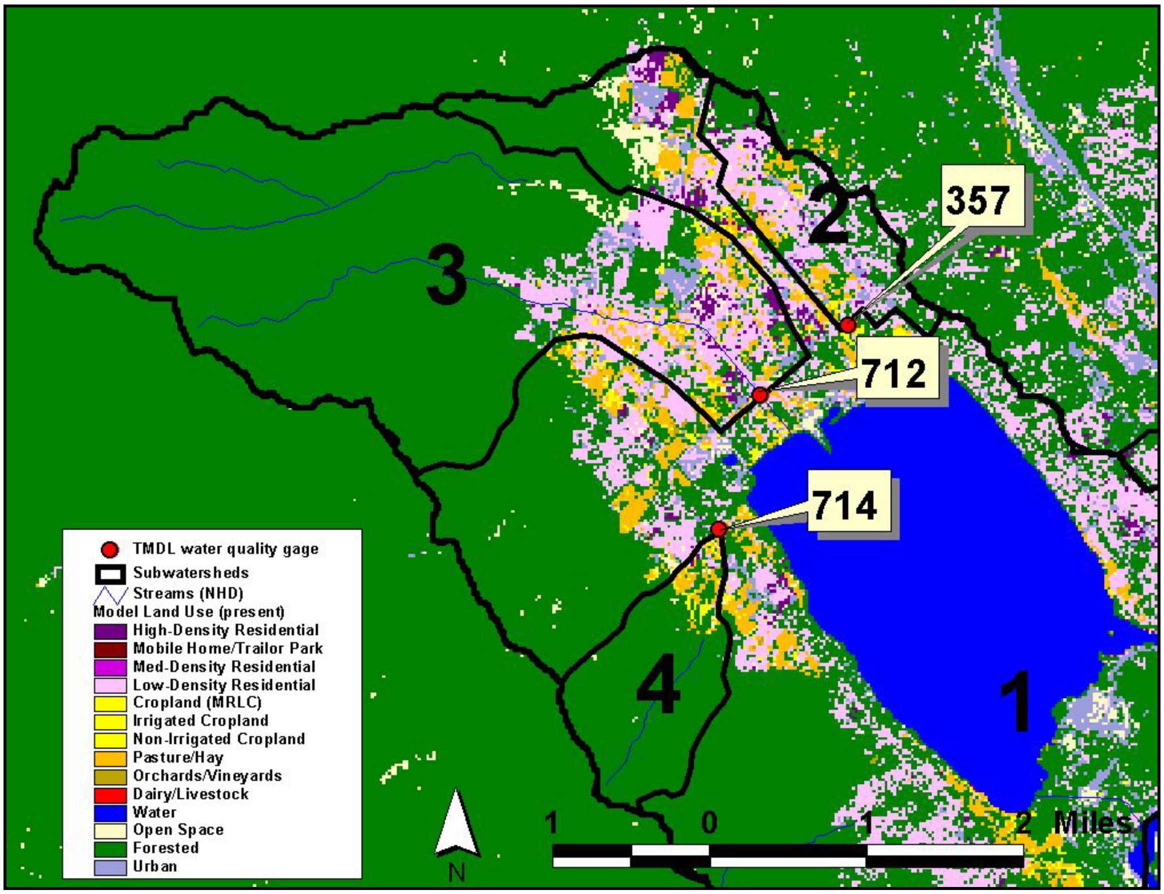

Figure 4-30 Locations of TMDL stations 357, 712, and 714

Water quality calibration was performed for TMDL station 357 over a 3-year period. As seen in Figures 4-31 and 4-32, model predictions of total nitrogen and total phosphorus compared well with observed data. Because of the long period of record and observance of several water quality observations when the rainfall data showed no occurrence of rainfall (resulting in no model flow or nutrient concentrations), the ability to provide a graphical analysis of percentiles of flow magnitude (e.g., Figure 4-25) was difficult for this gage. Therefore, to provide additional confidence in model predictions, validation was performed over a 6-year period (Figures 4-33 through 4-36). Validation results were consistent with the calibration.

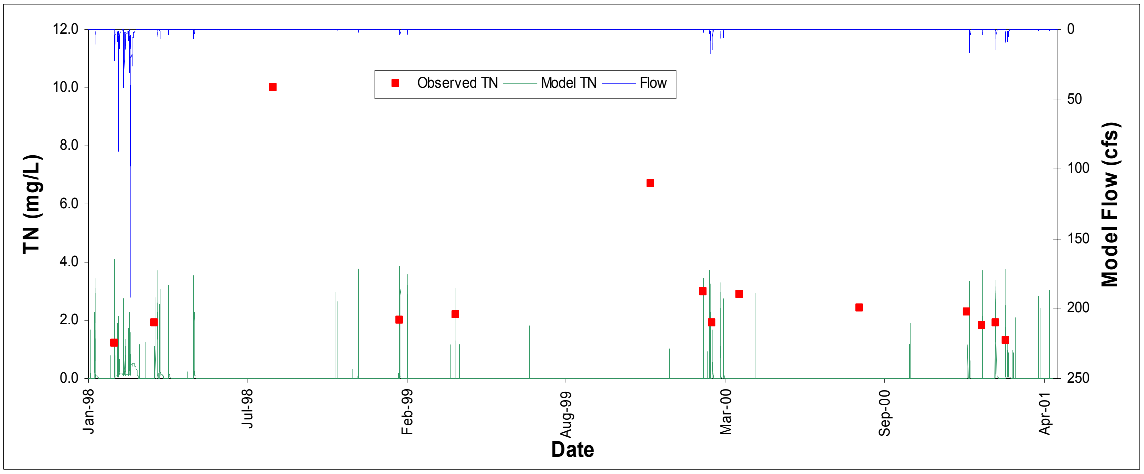

Figure 4-31 Model calibration of total nitrogen concentrations at TMDL station 357

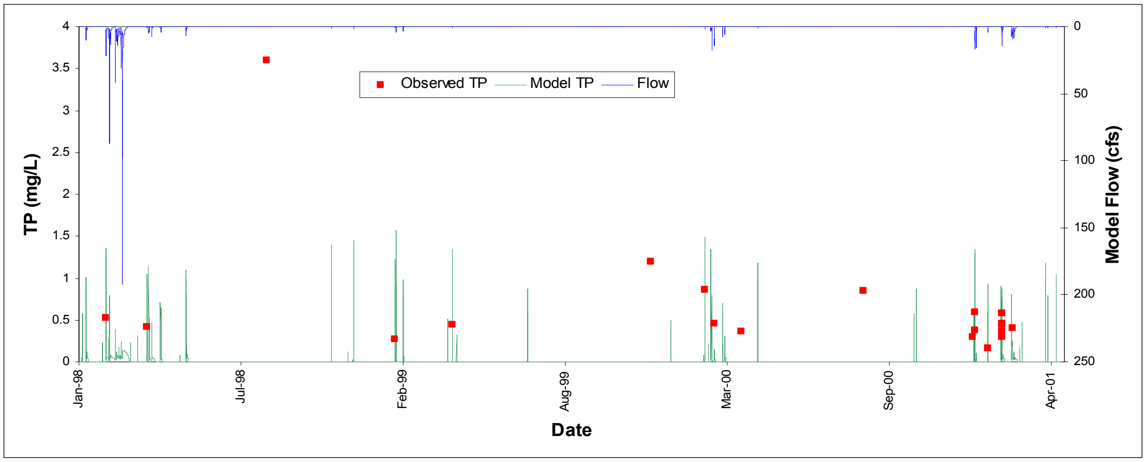

Figure 4-32 Model calibration of total phosphorus concentrations at TMDL station 357

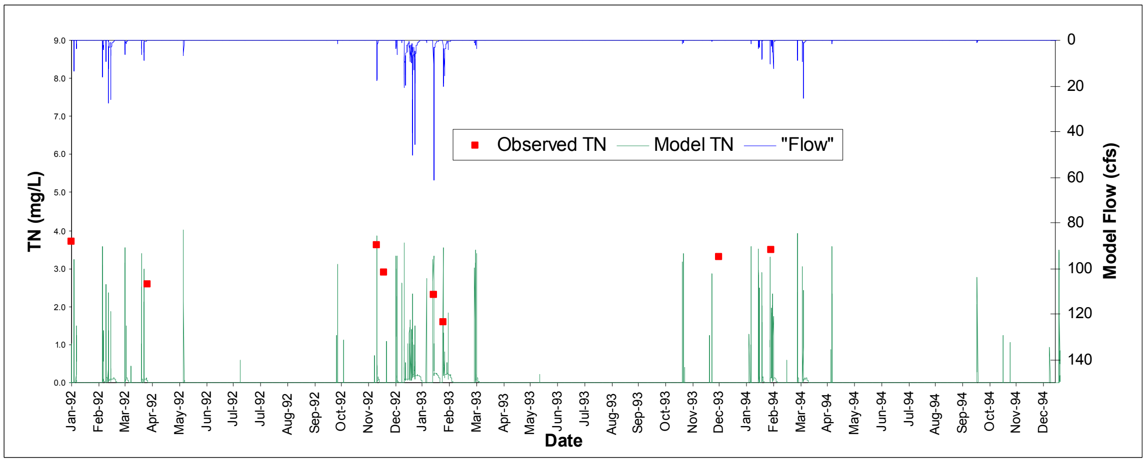

Figure 4-33 Model validation of total nitrogen concentrations at TMDL station 357 (January 1992 – December 1994)

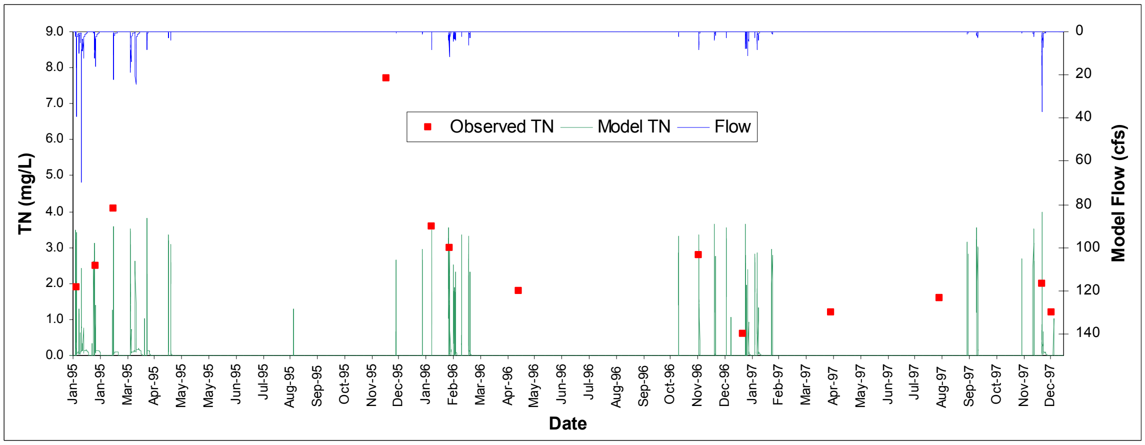

Figure 4-34 Model validation of total nitrogen concentrations at TMDL station 357 (January 1995 – December 1997)

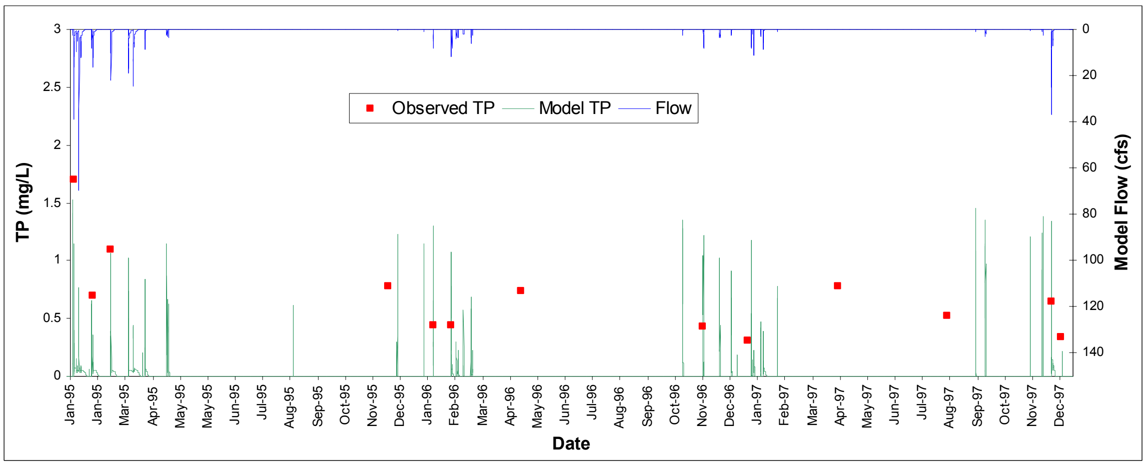

Figure 4-35 Model validation of total phosphorus concentrations at TMDL station 357 (January 1995 – December 1997)

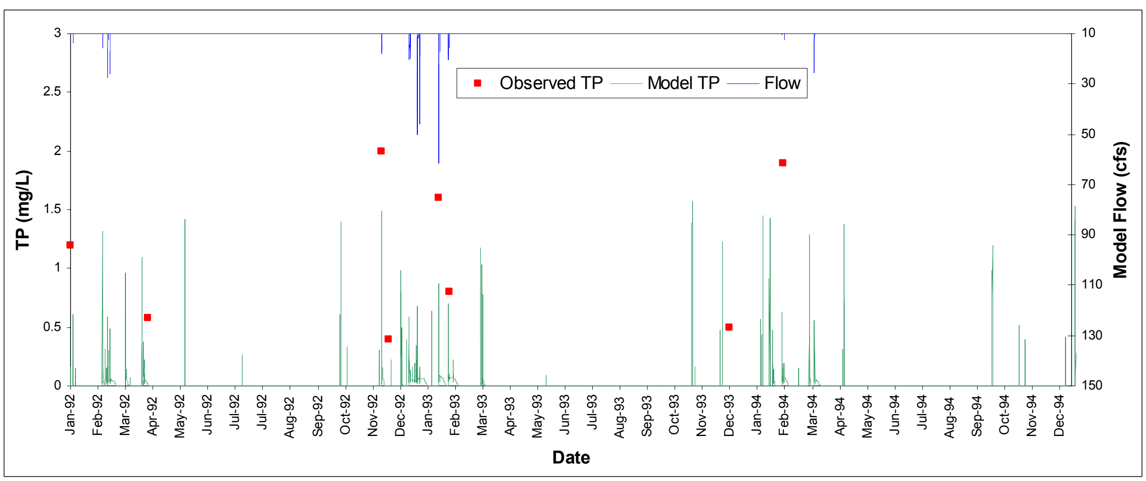

Figure 4-36 Model validation of total phosphorus concentrations at TMDL station 357 (January 1992 – December 1994)

For TMDL station 712 (subwatershed 3), calibration was performed for a period from January to February of 2001. Results were compared both temporally (Figures 4-37 and 4-39) and as relative magnitudes of predicted concentrations versus observed water quality data (Figures 4-38 and 4-40). The model showed good calibration to observed data.

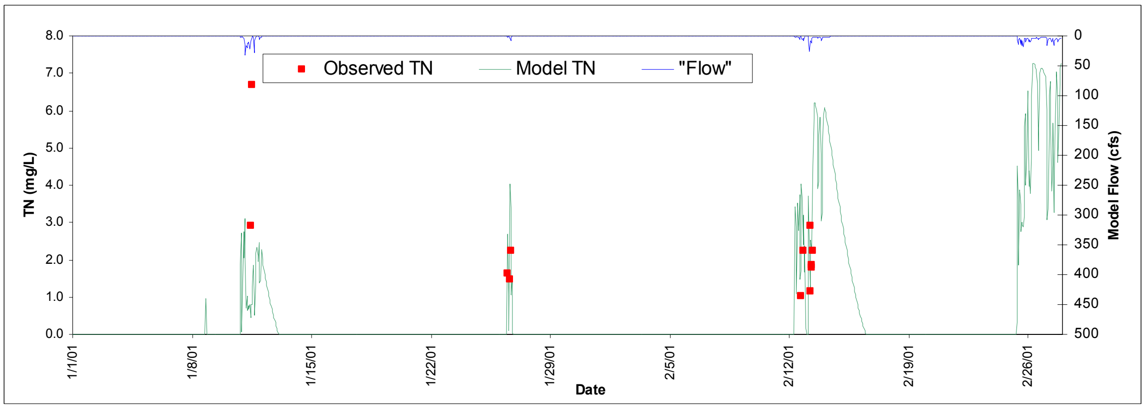

Figure 4-37 Model calibration of total nitrogen concentrations at TMDL station 712

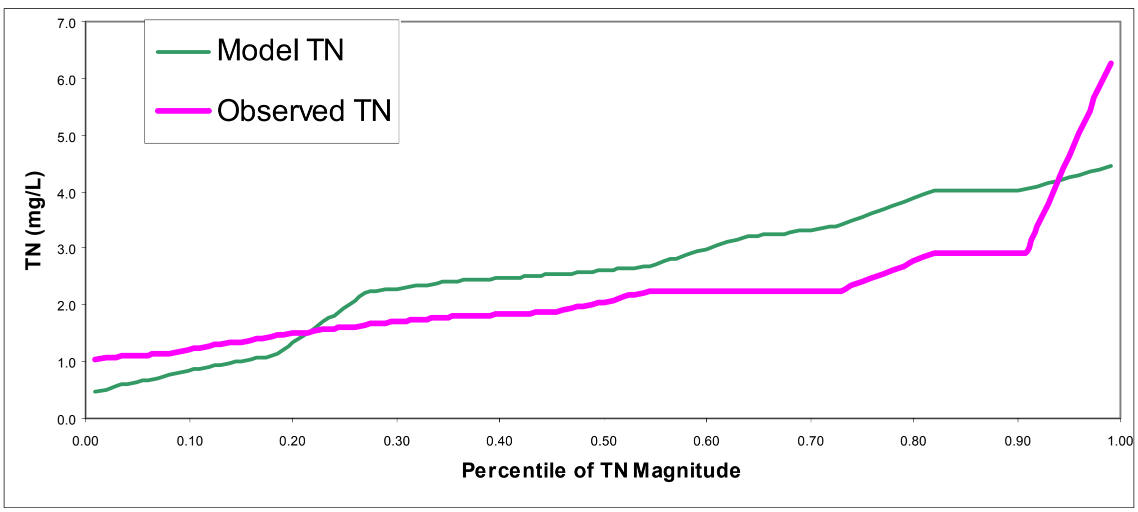

Figure 4-38 Graphical comparison of model versus observed total nitrogen concentrations at TMDL station 712

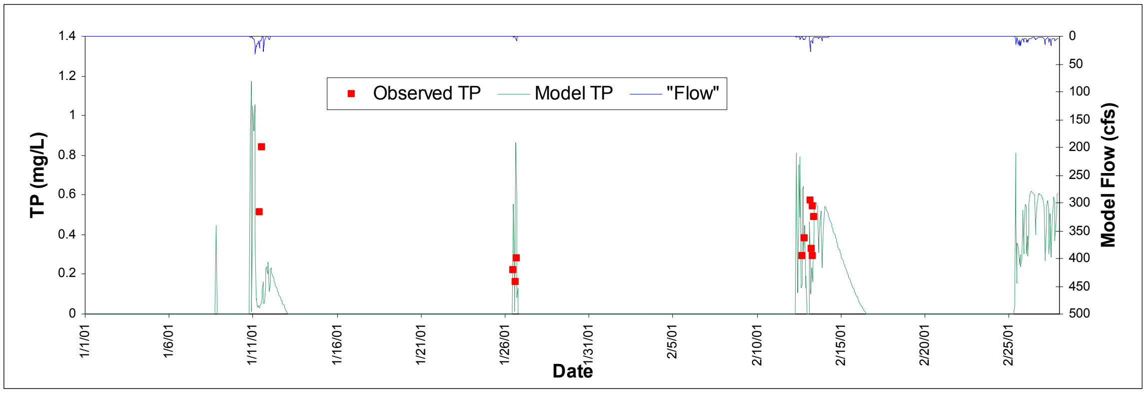

Figure 4-39 Model calibration of total phosphorus concentrations at TMDL station 712

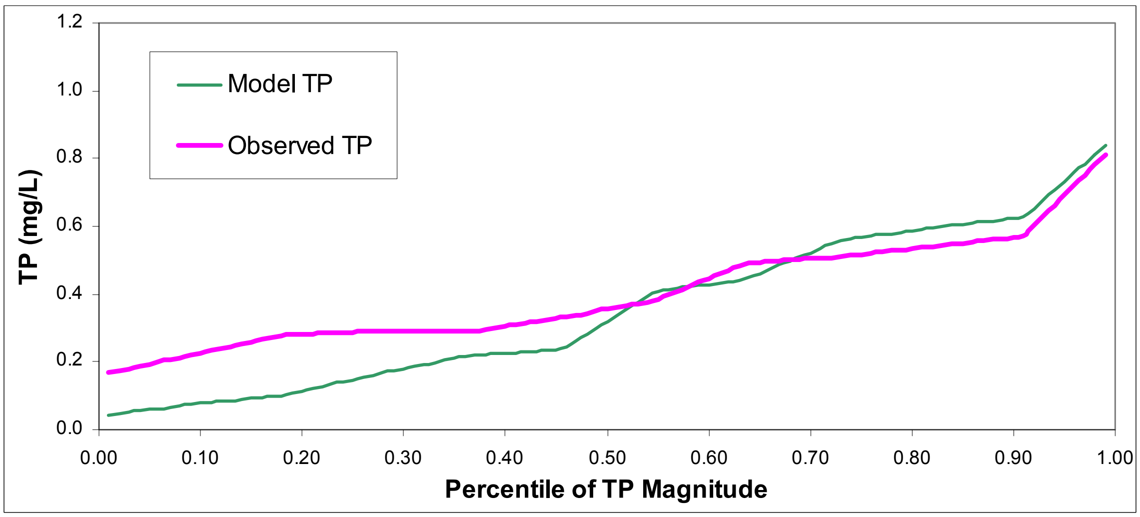

Figure 4-40 Graphical comparison of model versus observed total phosphorus concentrations at TMDL station 712

For TMDL station 714 (subwatershed 4), data was also limited and calibration was confined to January and February of 2001 (Figures 4-41 and 4-42). Model predictions for subwatershed 4 consistently under-predicted both total nitrogen and total phosphorus when compared to observed data. The reason for this inconsistency is believed to be the result of either a misrepresentation of landuse for the watershed or possible influence of an unknown source of nutrients upstream of the TMDL station that cannot be accounted for through landuse representation. Although the 1993 MRLC data was updated with 1999 EMWD landuse data, the EMWD data did not include the Lake Elsinore area. Additional development likely occurred in the period from 1993 to 2001 (when TMDL water quality data was collected at station 714), making misrepresentation of the landuse in the area a likely explanation. Since correlations were good for subwatersheds 2 and 3 in the same vicinity, results of calibration to TMDL station 714 were considered acceptable until better landuse data for the area become available.

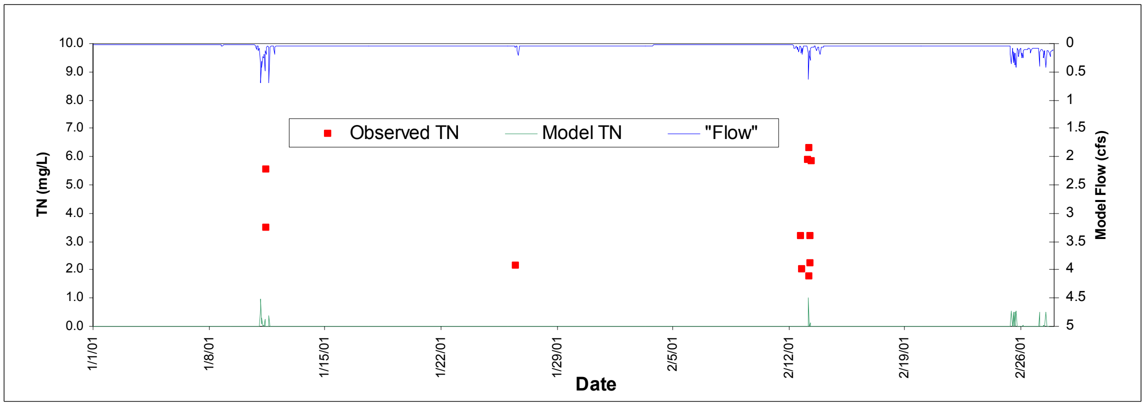

Figure 4-41 Model calibration of total nitrogen concentrations at TMDL station 714

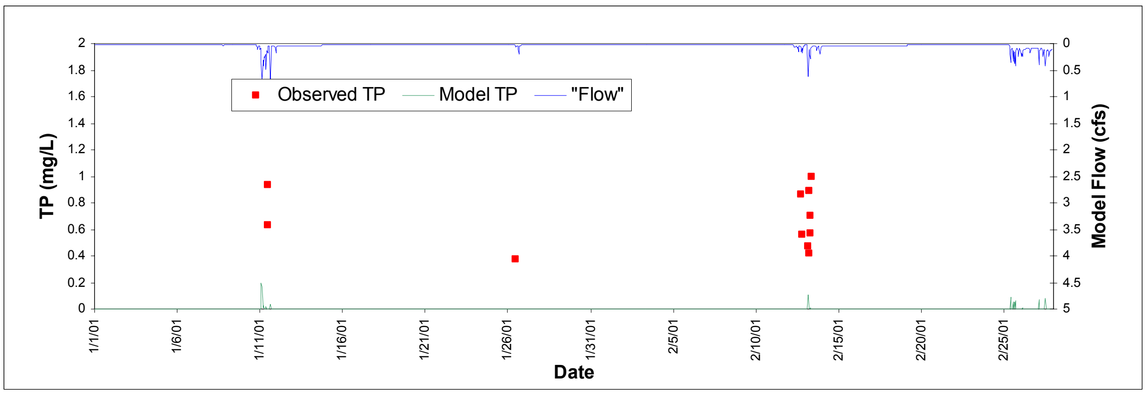

Figure 4-42 Model calibration of total phosphorus concentrations at TMDL station 714

Residential

TMDL station 834, located on the northwest side of Canyon Lake, provides water quality data for a watershed (subwatershed 8) that is dominated by residential landuse (Figure 4-43). Initial comparison of model-predicted and observed water quality data showed much higher model predictions than expected (Figures 4-44 and 4-45). This is the result of the numerous septic systems identified in the area and the associated loads resulting from assumptions outlined in section 4.3.1.b. Due to the subwatershed's proximity to Canyon Lake, it is possible that the loading associated with failed septic systems directly impacts the lake (through shallow subsurface transport or other mechanisms) and not the water quality of stormflows in the subwatershed's stream. Although the model over-predicts nutrient concentrations for stormflows in the streams of subwatershed 8, they are still expected to be contributed to the lake. Therefore, the model captures their inputs as part of the overall nutrient balance, while their specific representation may not be entirely representative of conditions.

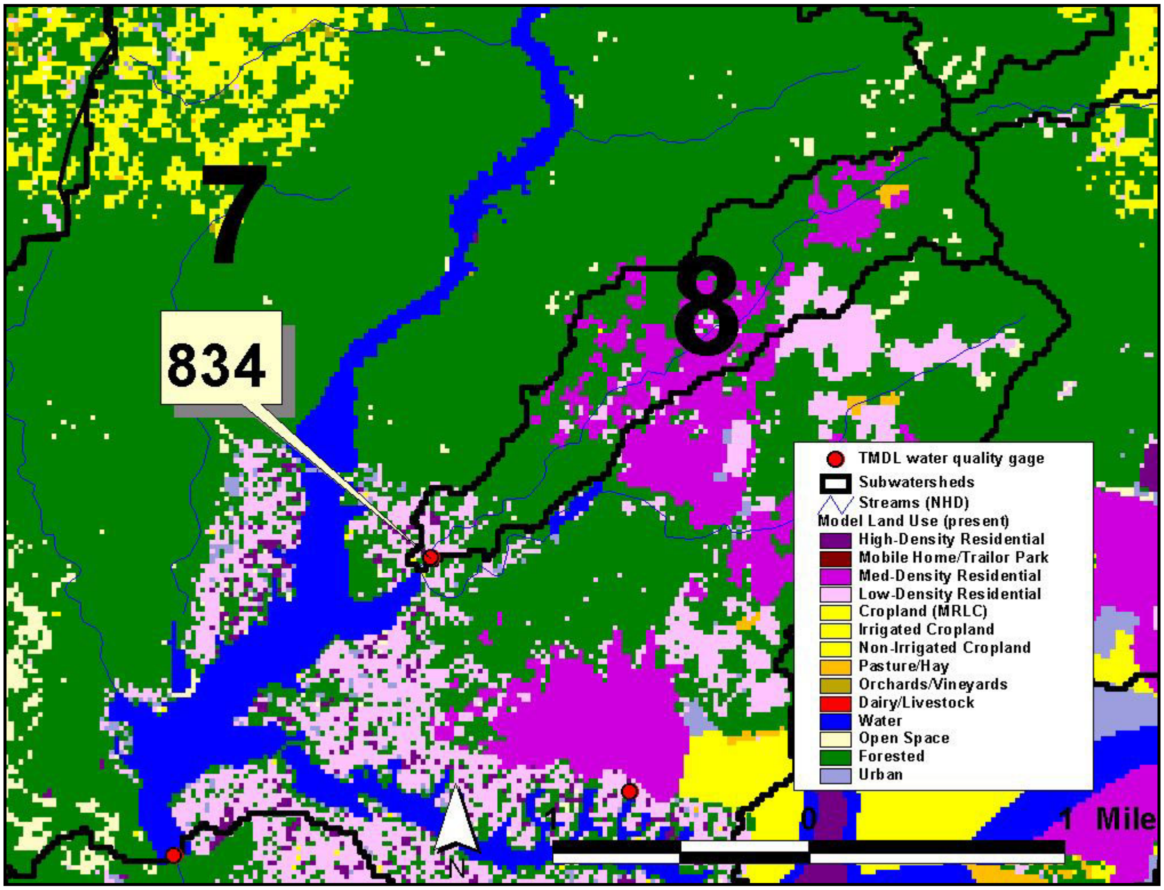

Figure 4-43 Location of TMDL station 834

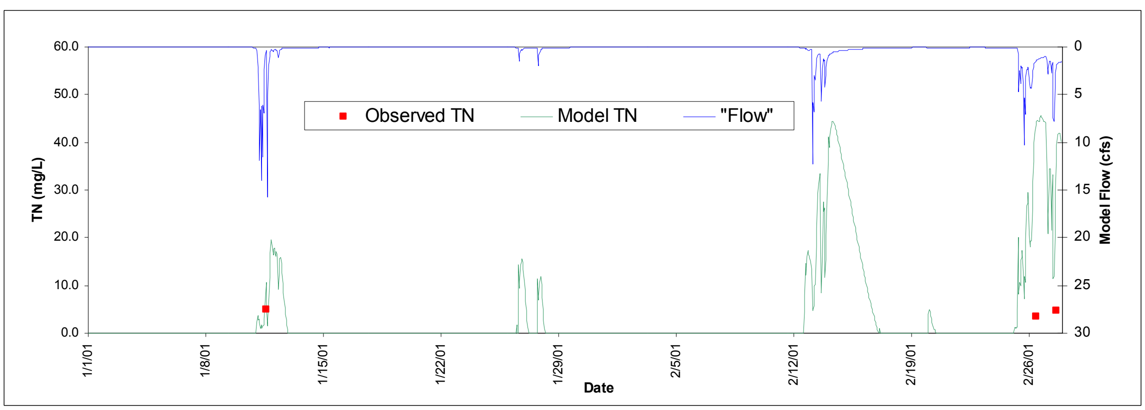

Figure 4-44 Model calibration of total nitrogen concentrations at TMDL station 834

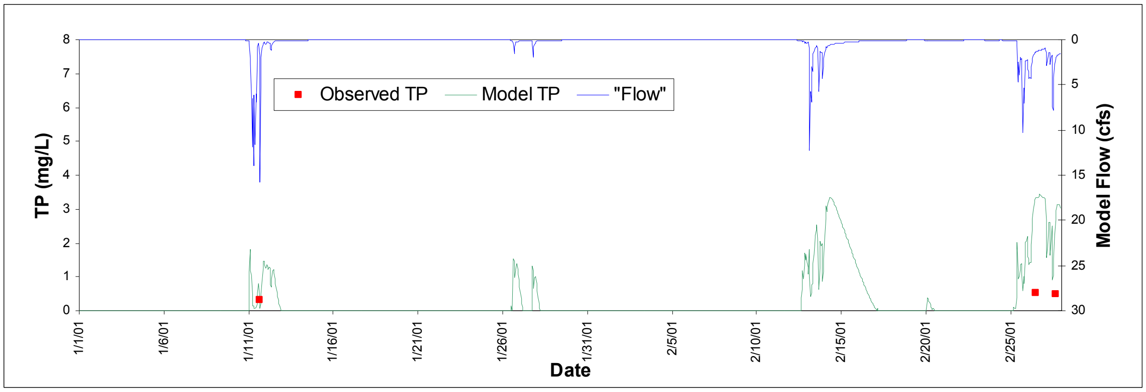

Figure 4-45 Model calibration of total phosphorus concentrations at TMDL station 834

Cropland

TMDL station 325, located at the same location as USGS streamflow gage 11070270 (Figure 4-15), included many of the landuses previously calibrated, but also included a substantial amount of cropland area for calibration of agricultural loading parameters in the model. Figures 4-46 through 4-49 depict results of calibration to this TMDL station for a period from January to June of 2001. Good correlation at this station provided confidence in model results, since hydrology was also calibrated at this location. To verify the appropriateness of model calibration, validation of model performance was performed for February to August of 2000 (Figures 4-50 and 4-51).

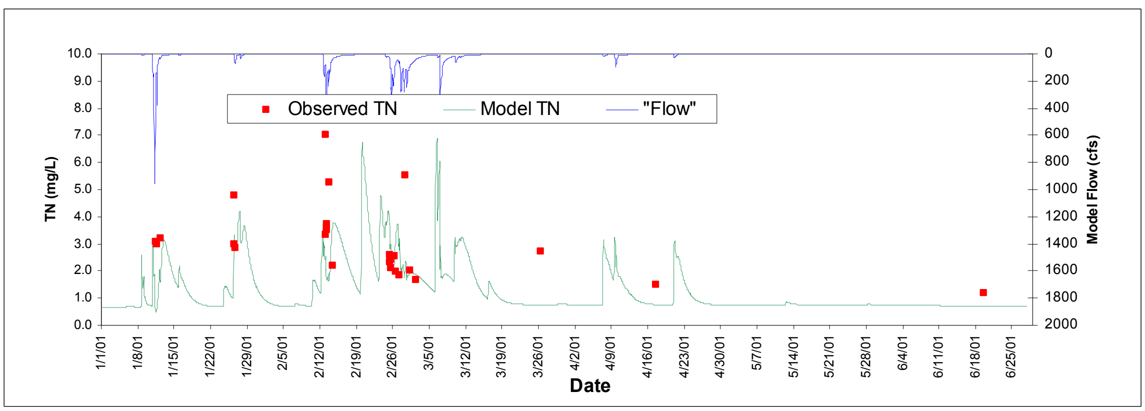

Figure 4-46 Model calibration of total nitrogen concentrations at TMDL station 325

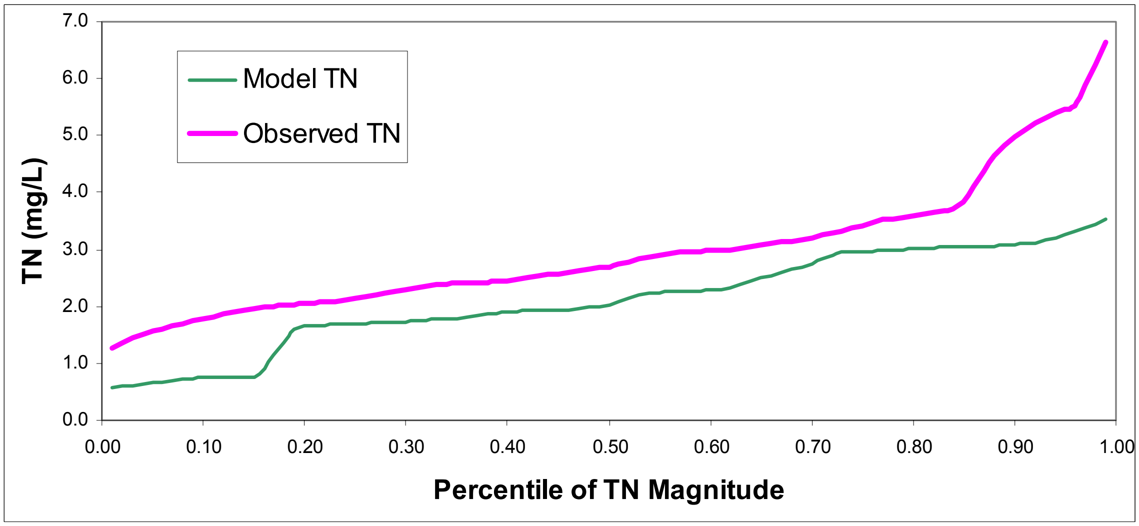

Figure 4-47 Graphical comparison of model versus observed total nitrogen concentrations at TMDL station 325

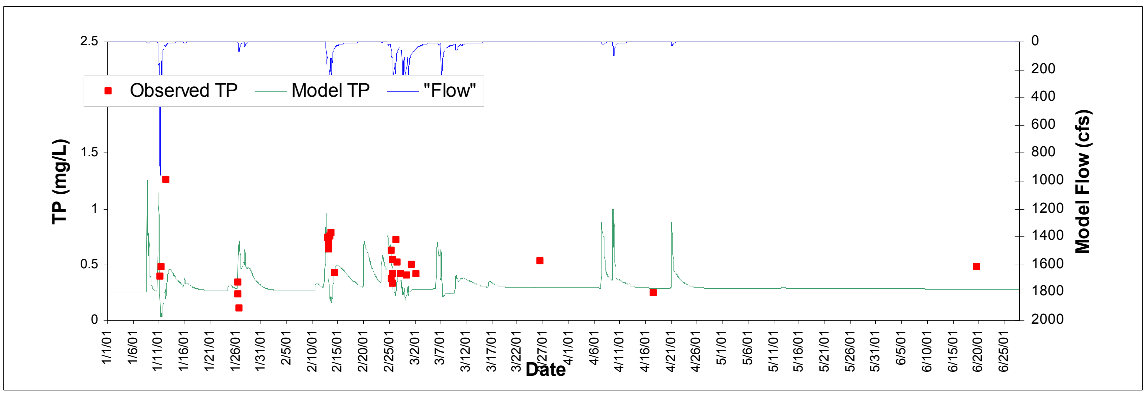

Figure 4-48 Model calibration of total phosphorus concentrations at TMDL station 325

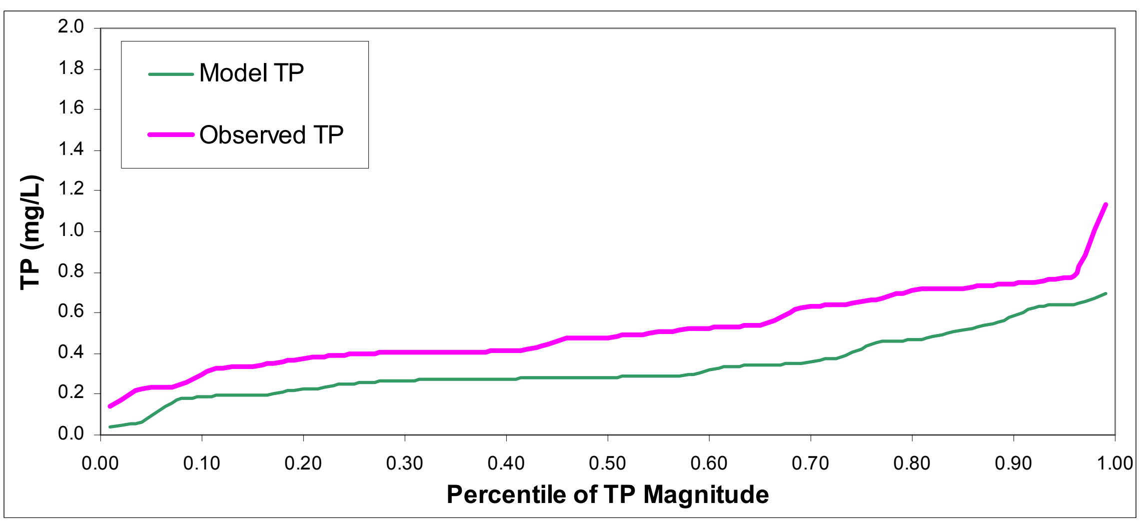

Figure 4-49 Graphical comparison of model versus observed total phosphorus concentrations at TMDL station 325

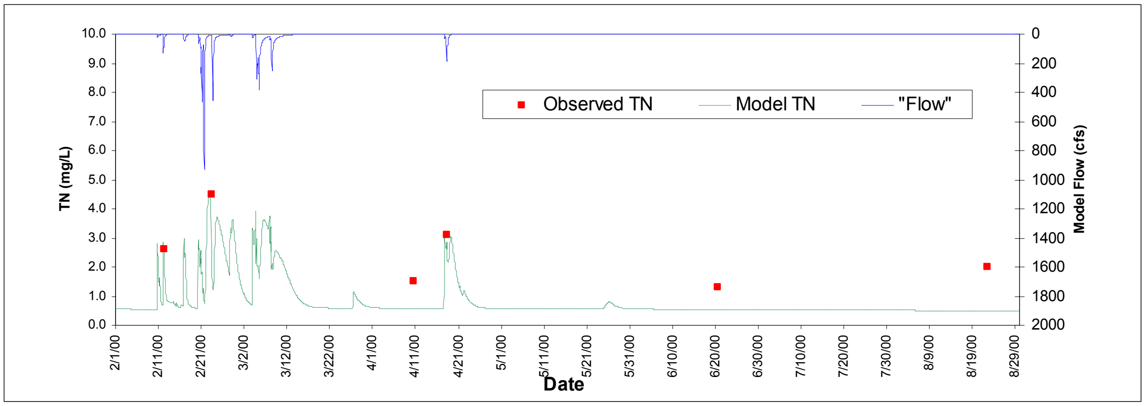

Figure 4-50 Model validation of total nitrogen concentrations at TMDL station 325 (February 2000 – August 2000)

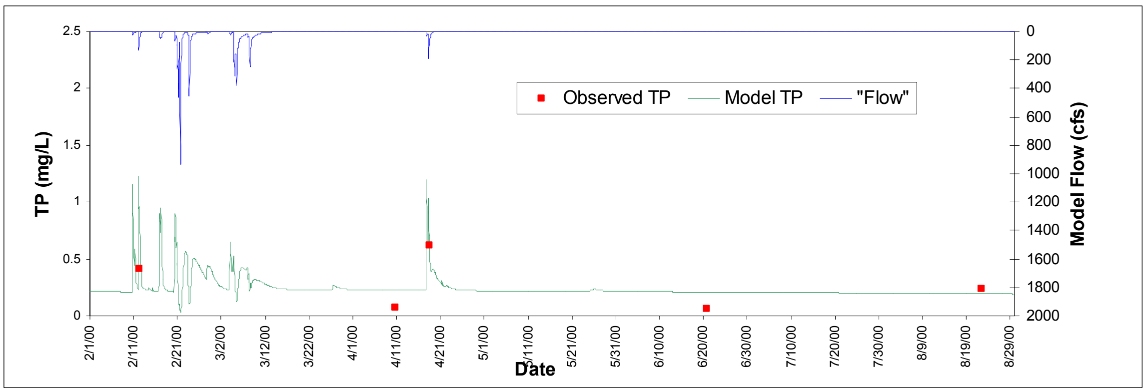

Figure 4-51 Model validation of total phosphorus concentrations at TMDL station 325 (February 2000 – August 2000)

Forested

Calibration of the model to TMDL station 792 located at the headwaters of the San Jacinto River watershed (same location as USGS gage 11069500 of Figure 4-12) was important to ensure that the forested headwaters were represented effectively. Since much of the flow at this gage was associated with interflow and groundwater, calibration to this gage provided a check of the assigned background groundwater concentrations. Figures 4-52 through 4-55 show results of the water quality calibration to this station for the period from January 1998 to April 2001. To validate the model parameters, a second period was analyzed from August 1995 through September 1997 (Figures 4-56 and 4-57).

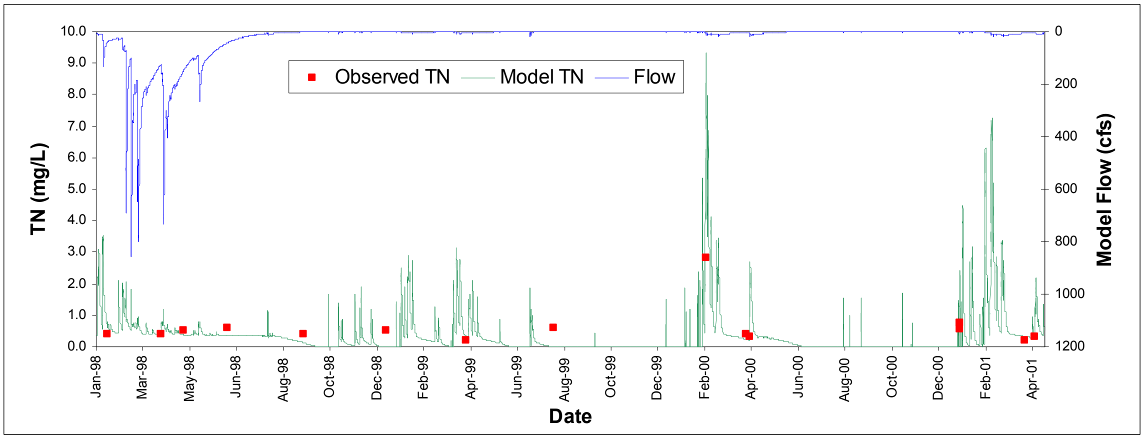

Figure 4-52 Model calibration of total nitrogen concentrations at TMDL station 792

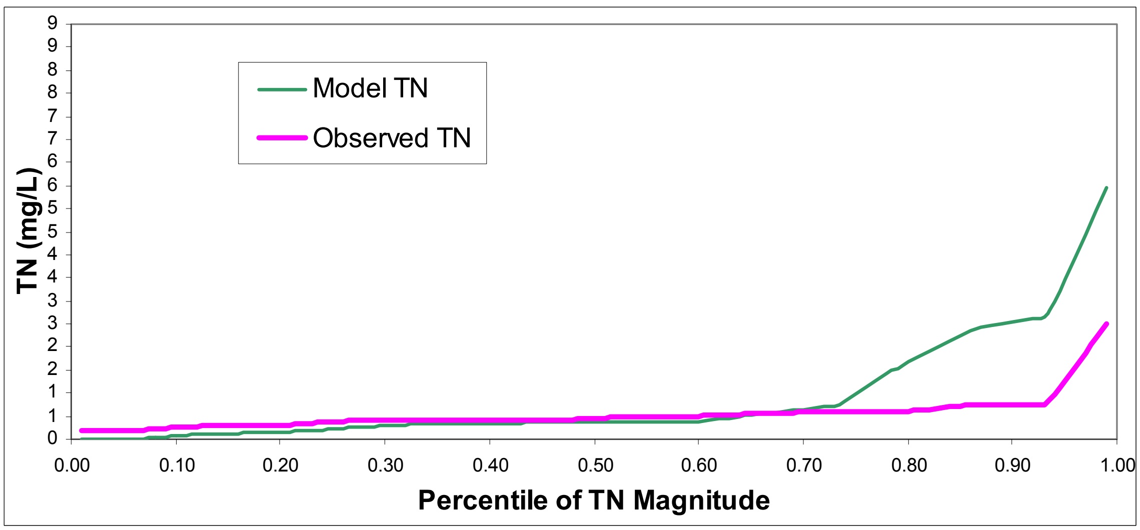

Figure 4-53 Graphical comparison of model versus observed total nitrogen concentrations at TMDL station 792

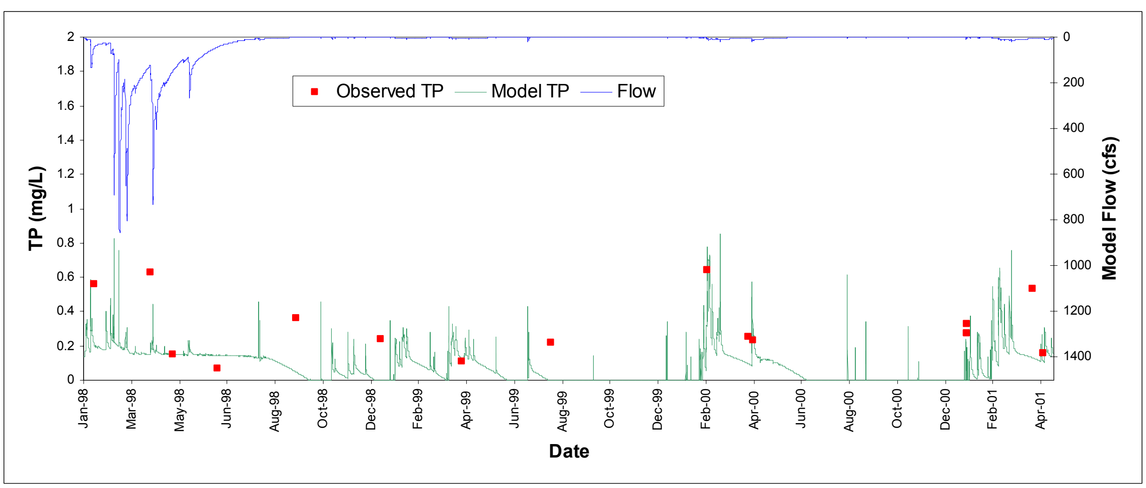

Figure 4-54 Model calibration of total phosphorus concentrations at TMDL station 792

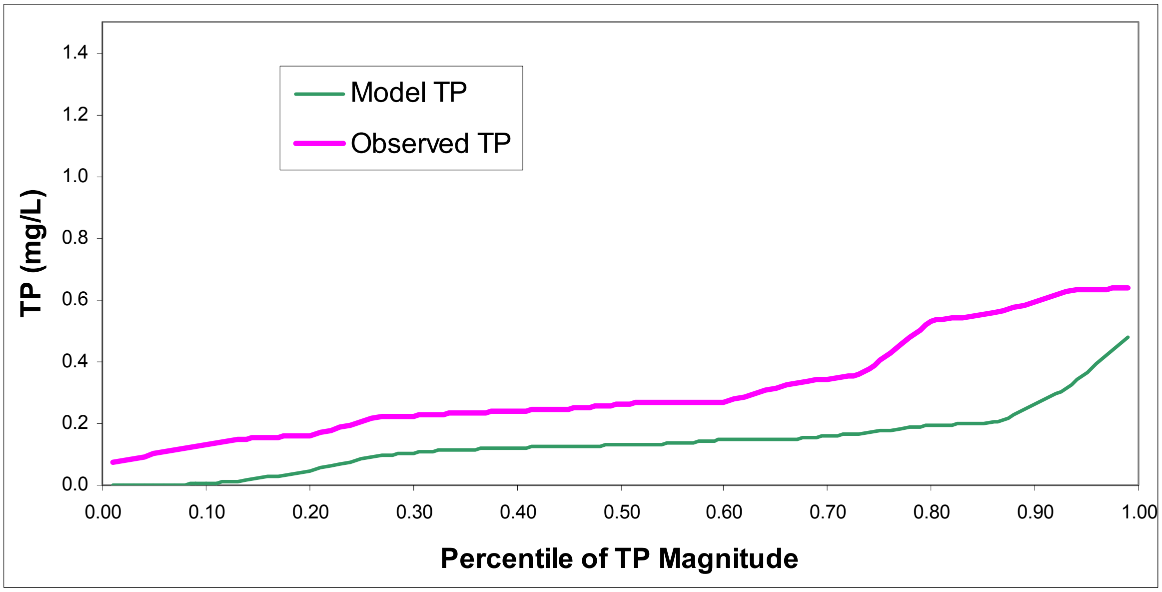

Figure 4-55 Graphical comparison of model versus observed total phosphorus concentrations at TMDL station 792

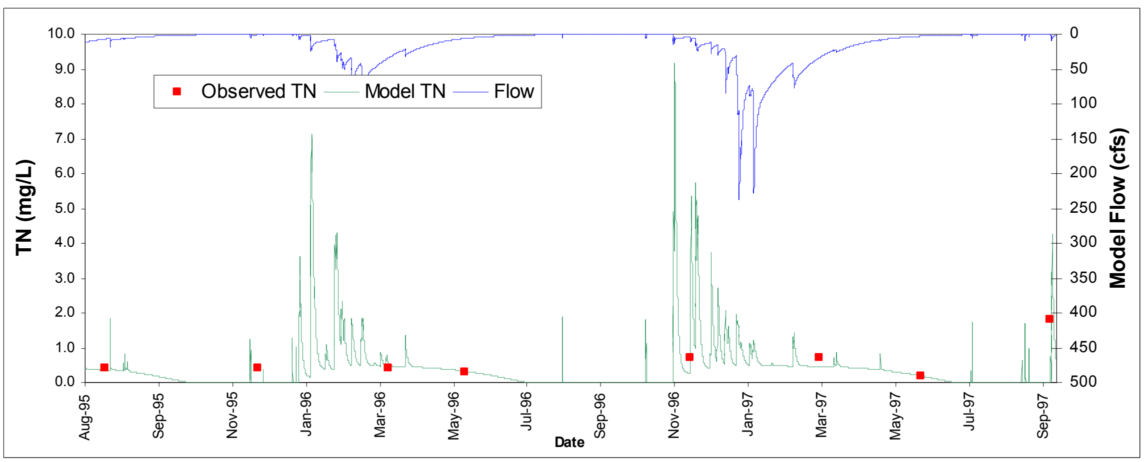

Figure 4-56 Model validation of total nitrogen concentrations at TMDL station 792 (August 1995 – September 1997)

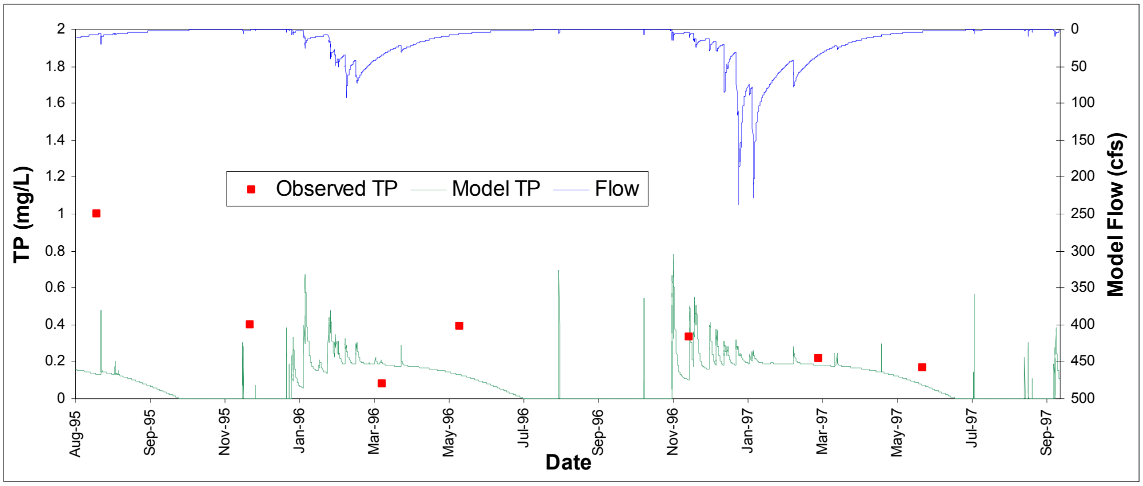

Figure 4-57 Model validation of total phosphorus concentrations at TMDL station 792 (August 1995 – September 1997)

Two TMDL stations, 745 and 759, are located on the two major tributaries to Canyon Lake: the San Jacinto River and Salt Creek (Figure 4-58). Although the water quality data collected at these stations was limited to January through March of 2001, 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 each of these stations, so validation of the agricultural model parameters is possible through comparison of model results with observed data at these locations. Calibration results are depicted for stations 745 and 759 in Figures 4-59 through 4-66.

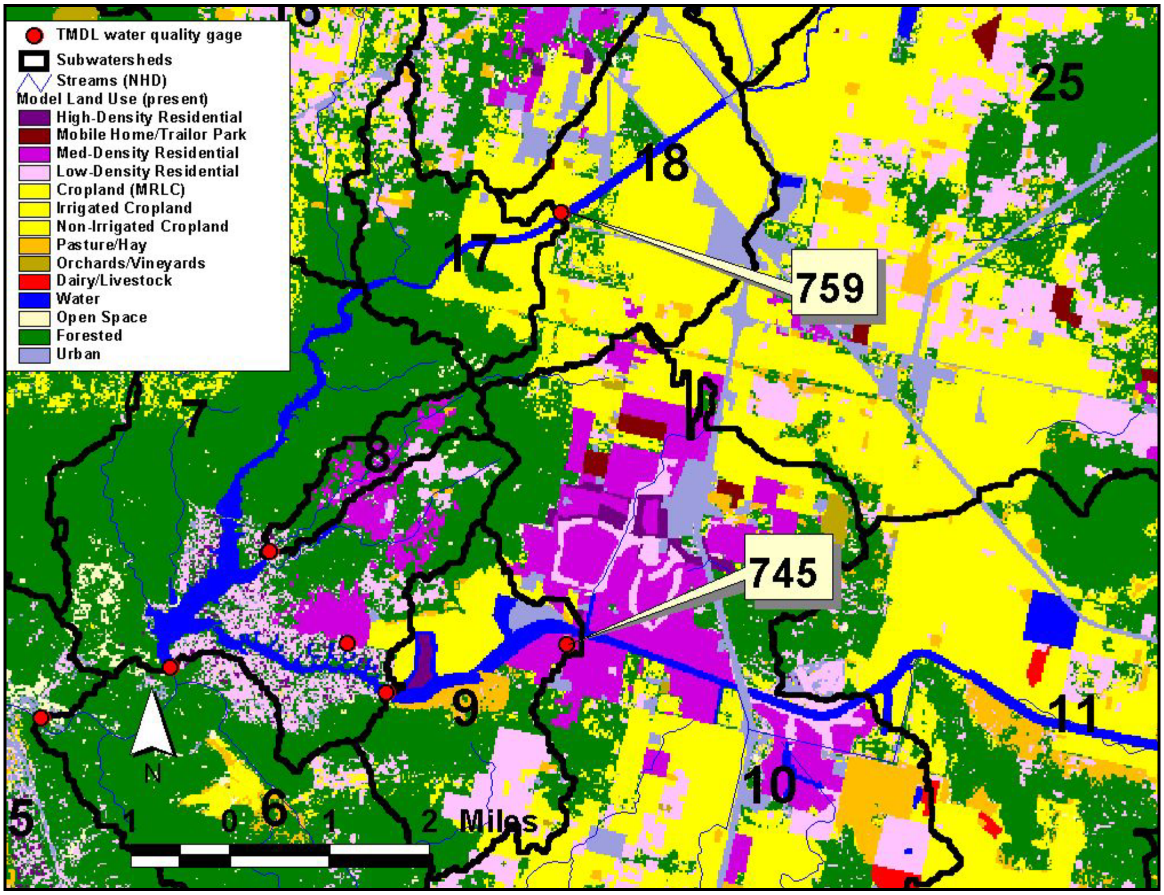

Figure 4-58 Locations of TMDL stations 759 and 745

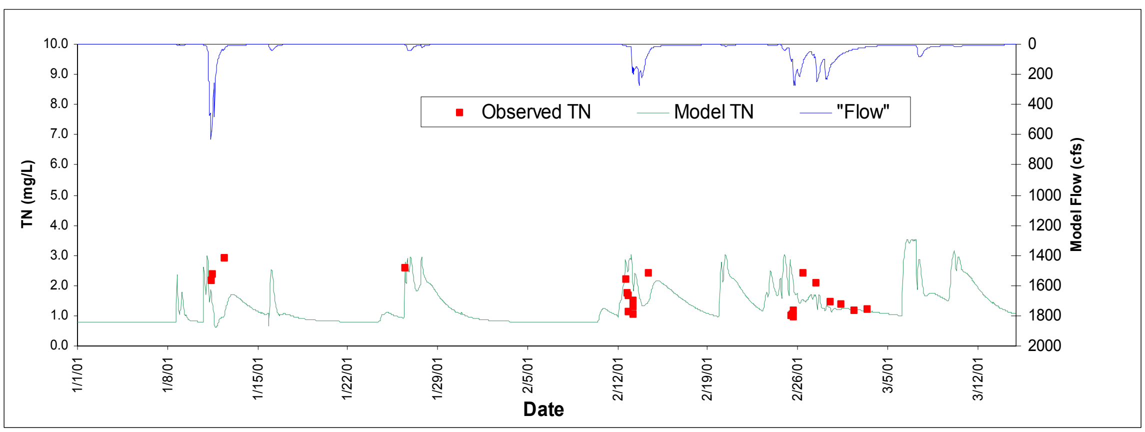

Figure 4-59 Model calibration of total nitrogen concentrations at TMDL station 745

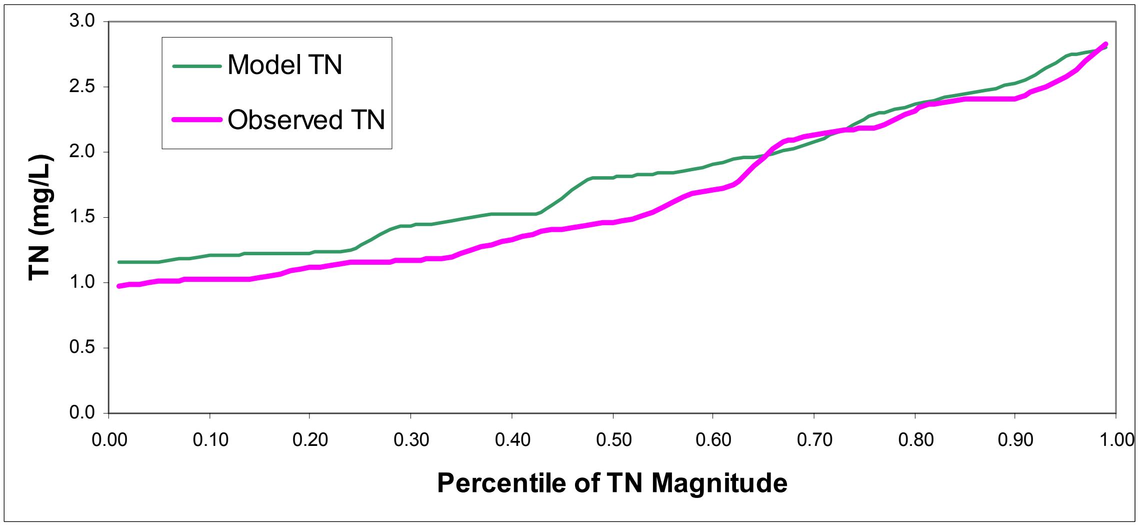

Figure 4-60 Graphical comparison of model versus observed total nitrogen concentrations at TMDL station 745

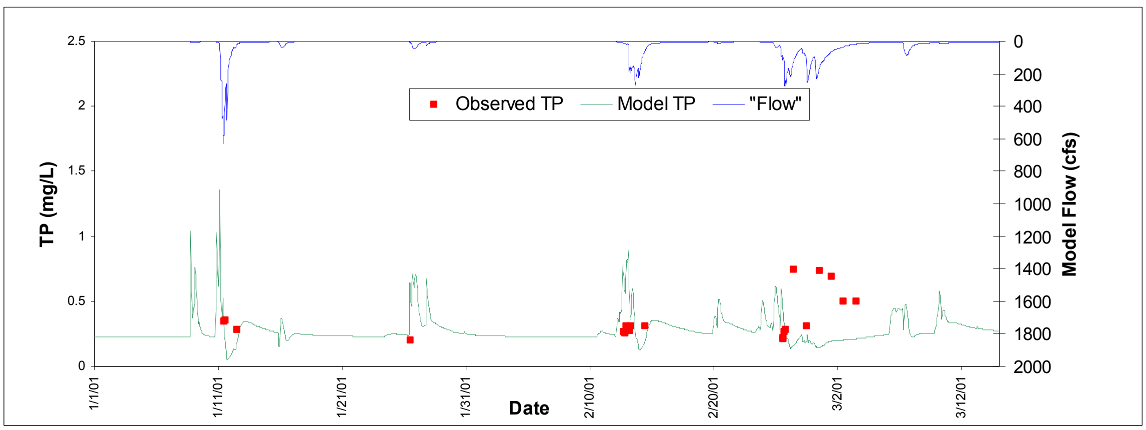

Figure 4-61 Model calibration of total phosphorus concentrations at TMDL station 745

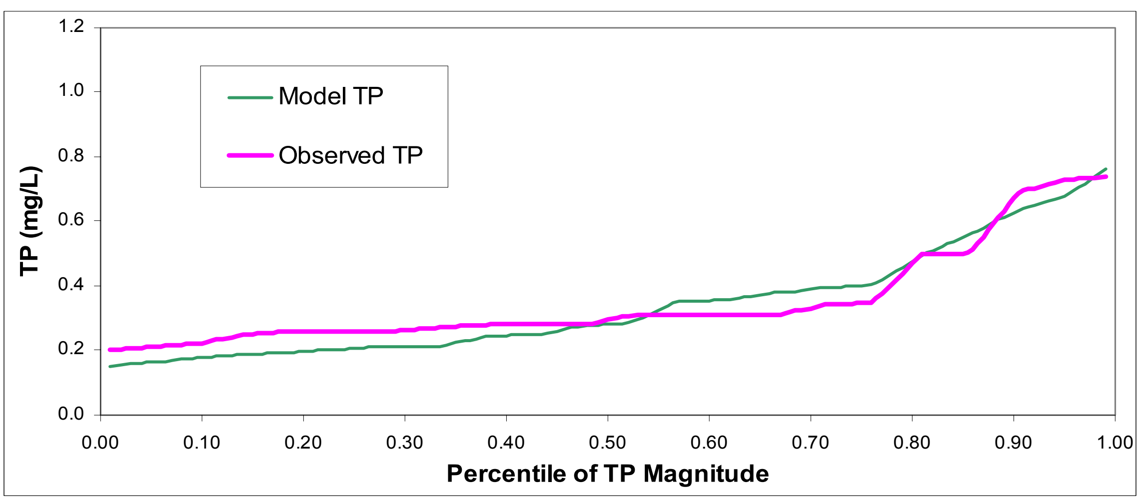

Figure 4-62 Graphical comparison of model versus observed total phosphorus concentrations at TMDL station 745

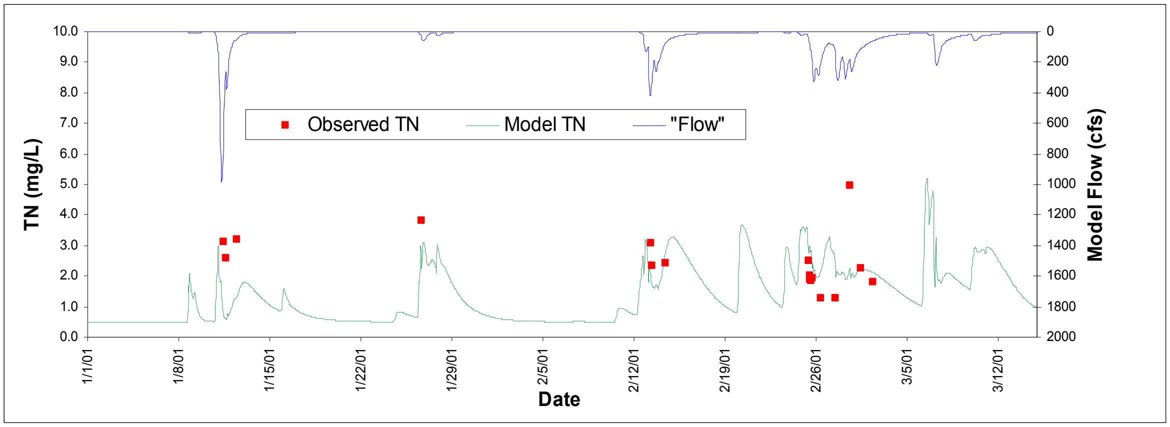

Figure 4-63 Model calibration of total nitrogen concentrations at TMDL station 759

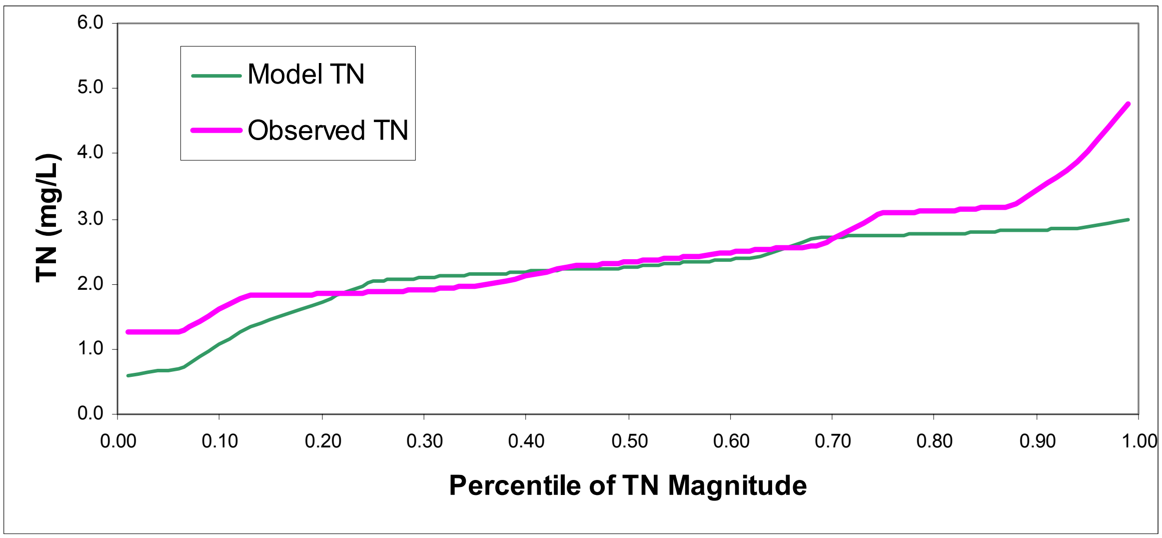

Figure 4-64 Graphical comparison of model versus observed total nitrogen concentrations at TMDL station 759

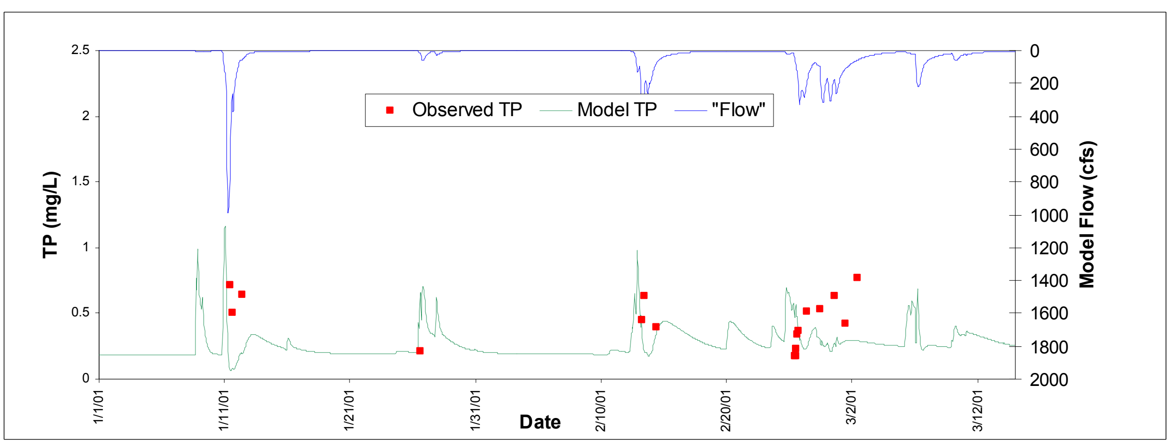

Figure 4-65 Model calibration of total phosphorus concentrations at TMDL station 759

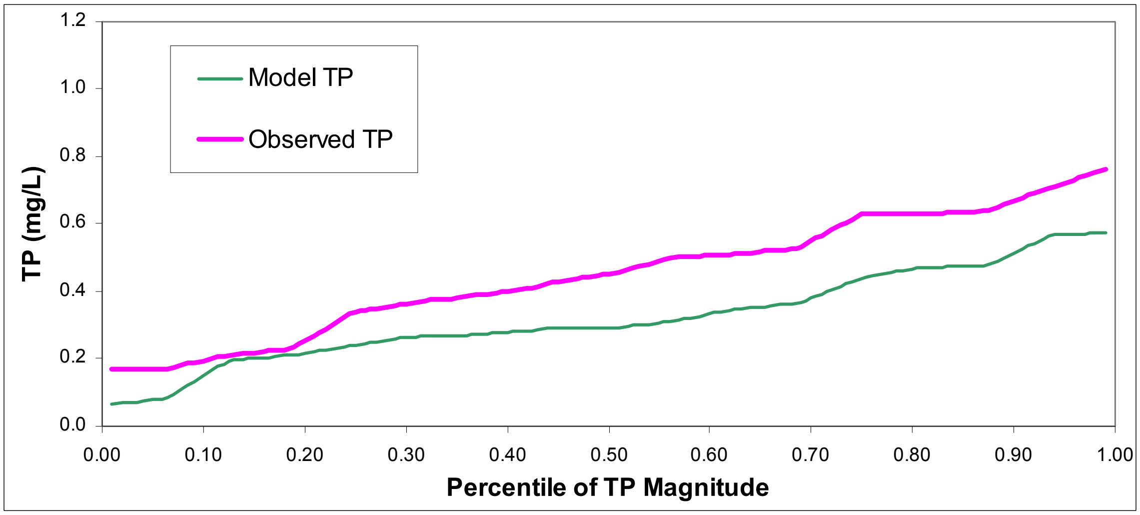

Figure 4-66 Graphical comparison of model versus observed total phosphorus concentrations at TMDL station 759

Model Simulation for Existing Conditions and Scenarios

The fully calibrated model was run from September 1990 to October 2000 to generate flow and nutrient loadings under a variety of conditions for 10 full hydrologic years. Model output was summarized to provide insight into monthly and annual loads for the simulation period, and output from selected years were applied to the Canyon Lake model for prediction of nutrient loads to Lake Elsinore. The existing conditions represent the starting point for TMDL analyses. As part of the ensuing effort and development of a watershed management plan, 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 model configuration will permit future applications and upgrades, such as explicit representation of BMPs using the BMP Module in LSPC. To simulate endpoint-based scenarios, watershed-based load reduction goals expected to meet in-lake water quality criteria will be identified by RWQCB. Then, the watershed model will be run with landuse conversions or load reductions (representative of management strategies) in different regions to reach these goals.

4.3.2 Canyon Lake Model (2-D EFDC)

Development of the Canyon Lake model to address the project objectives involved a number of important steps:

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

4.3.2.a Model Segmentation

Based on the analysis of the bathymetric data of the lake, a finite difference segmentation system with 245 horizontal computational cells was developed (Figure 4-67). The size of each cell was determined by considering required model resolution and objectives, as well as user criteria (primarily computational time).

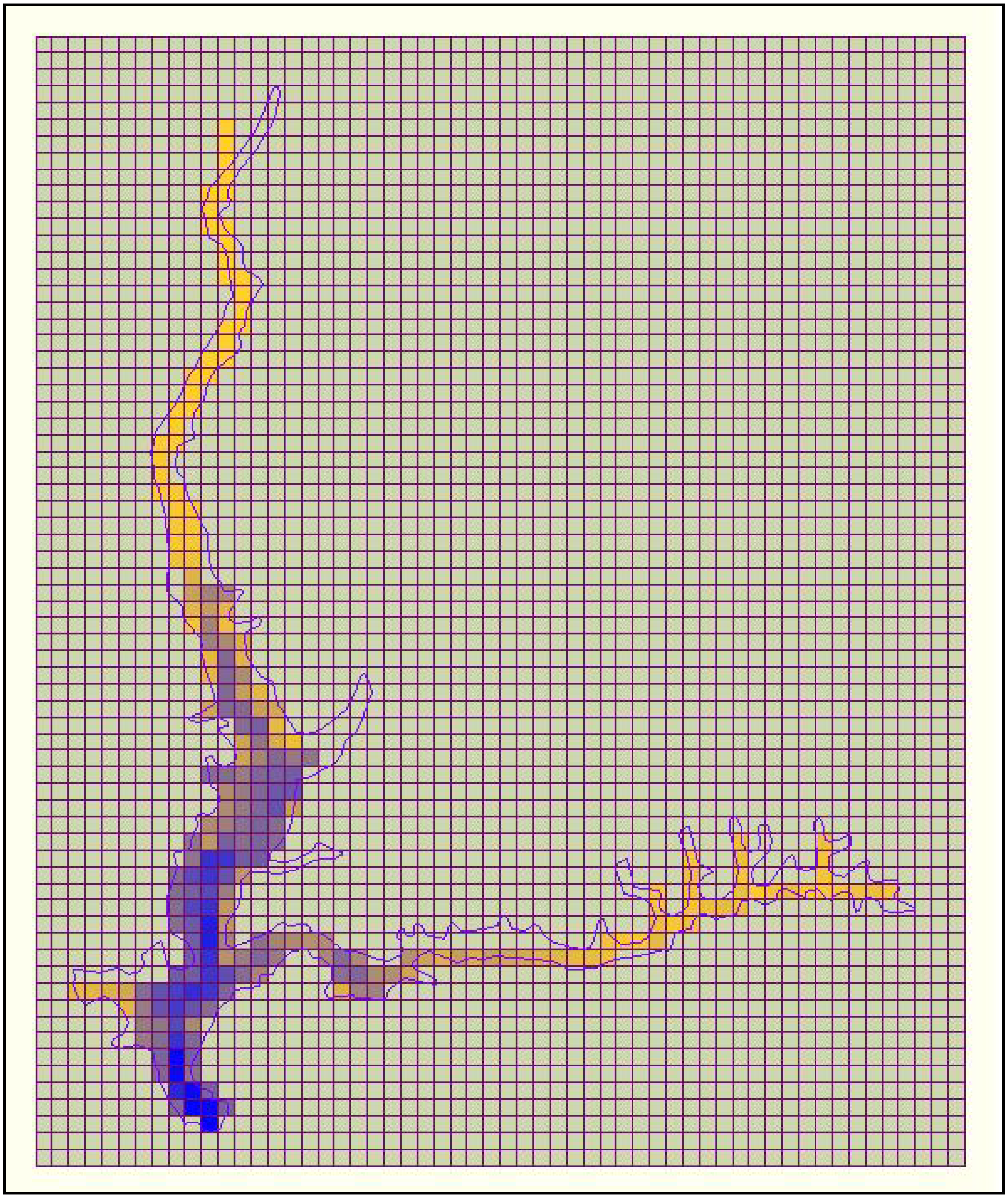

Figure 4-67 EFDC model segmentation

4.3.2.b Configuration of Key Model Components

Boundary Conditions

Four major inflow tributaries were identified for Canyon Lake. The flows and nutrient loading rates were determined based on the simulation results of the calibrated LSPC watershed model. The outflows of the lake were accounted for by two components: dam spillway overflow and through-dam seepage. When the water surface elevation was higher than 1381.76 ft, both spillway and seepage occur. Otherwise, seepage would account for all the outflow of water and nutrients.

The spillway was represented through use of a weir equation in the model. Based on the elevation-discharge relationship data, a non-linear weir equation was obtained as:

$$Qo = 147.64 * H^{1.7023} \qquad (4.1)$$

where Qo is the flow rate of the spillway and H is the water surface elevation in reference to the weir crest.

The seepage of water through the dam was represented as:

$$Qs = a + b(H_1 - H_r) \qquad (4.2)$$

Where Qs is the seepage flow through the dam, a is the background seepage, b is the coefficient accounting for the elevation-dependent portion of seepage flow, $H1$ is the water surface elevation, and Hr is a reference elevation below which the elevation-dependent seepage is not considered. The coefficients in Equation (4.2) were determined through the model calibration process.

The water surface boundary condition was set using the meteorological data obtained from the NOAA Long Beach, CA weather station (WBAN 23129). This station was used because all required recent surface airways parameters were available, including atmospheric pressure, dry atmospheric temperature, wet bulb atmospheric temperature, and cloud cover fraction. The data used to set up the water surface boundary condition were wind velocity, wind direction, air temperature and solar radiation.

Initial Conditions

The initial conditions for water surface elevation were set based on observed data. The model was initiated for a full year prior to the target model year to simulate initial water quality conditions.

4.3.2.c Model Calibration and Validation

After configuration, the reservoir model calibration involved realistic representation of limnological processes and fluxes specifically for Canyon Lake. A calibration was provided to ensure that predicted Canyon Lake water balance and water quality match available TMDL monitoring data. This calibration included a check of the lake's water balance and outflow/in-lake water quality.

Water Balance

Water balance is typically calibrated through comparison of predicted water surface elevations to measured reservoir elevations. Reservoir model calibration is generally performed for a shorter period of time than that for the watershed model; however it should still cover a variety of conditions including dry (normal) and wet. Calibration was performed for 1997 through 2000 (Figures 4-68 through 4-71), which included both wet and normal conditions. Good calibration of water surface elevation was crucial to ensure that the calculated flow over the dam spillway was accurate (and this was necessary for appropriate nutrient load transport to Lake Elsinore).

Good correlation was achieved for most years, with the exception of a model over-prediction in 1999. This period marked a relatively wet year, when Mystic Lake was known to overflow and influence the inflows to Canyon Lake. Unfortunately, no data regarding flow from Mystic Lake were available for this time period. Additionally, the impoundments resulting from undersized culverts on road crossings on the San Jacinto River also likely affect the inflows due to flow attenuation caused by the storage. Without additional flow data on the San Jacinto River mainstem between Mystic Lake and Canyon Lake during characteristically wet periods, model assumption cannot be tested and validated.

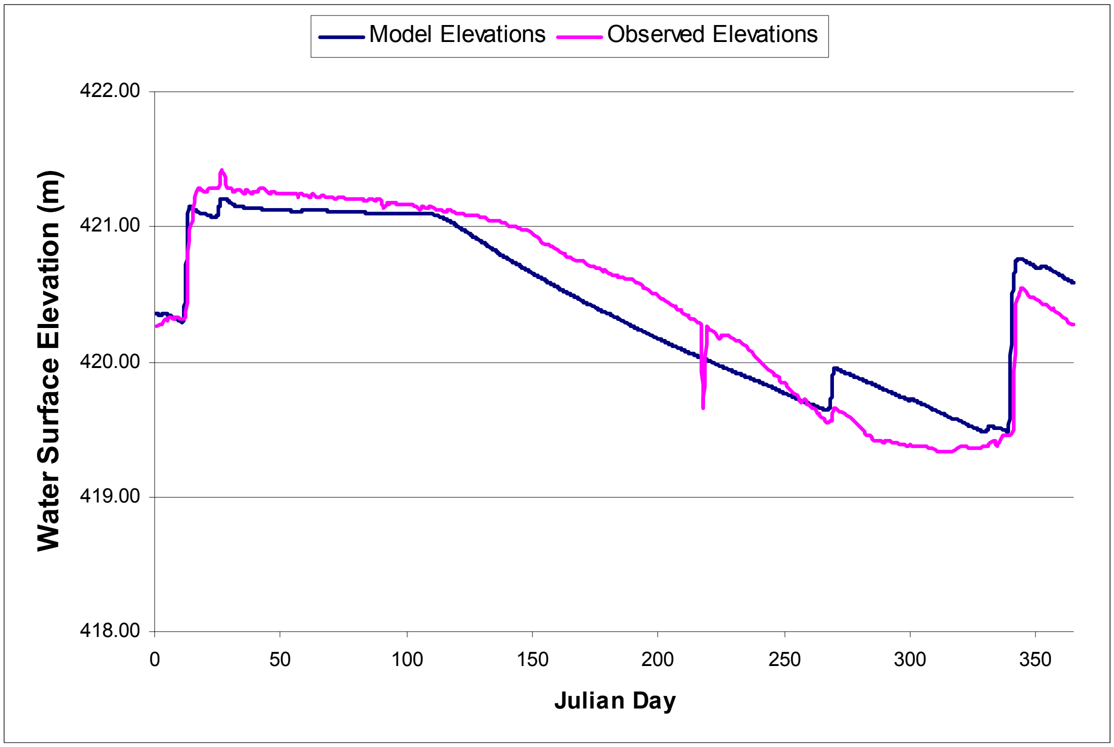

Figure 4-68 Calibration of Canyon Lake water surface elevations – 1997

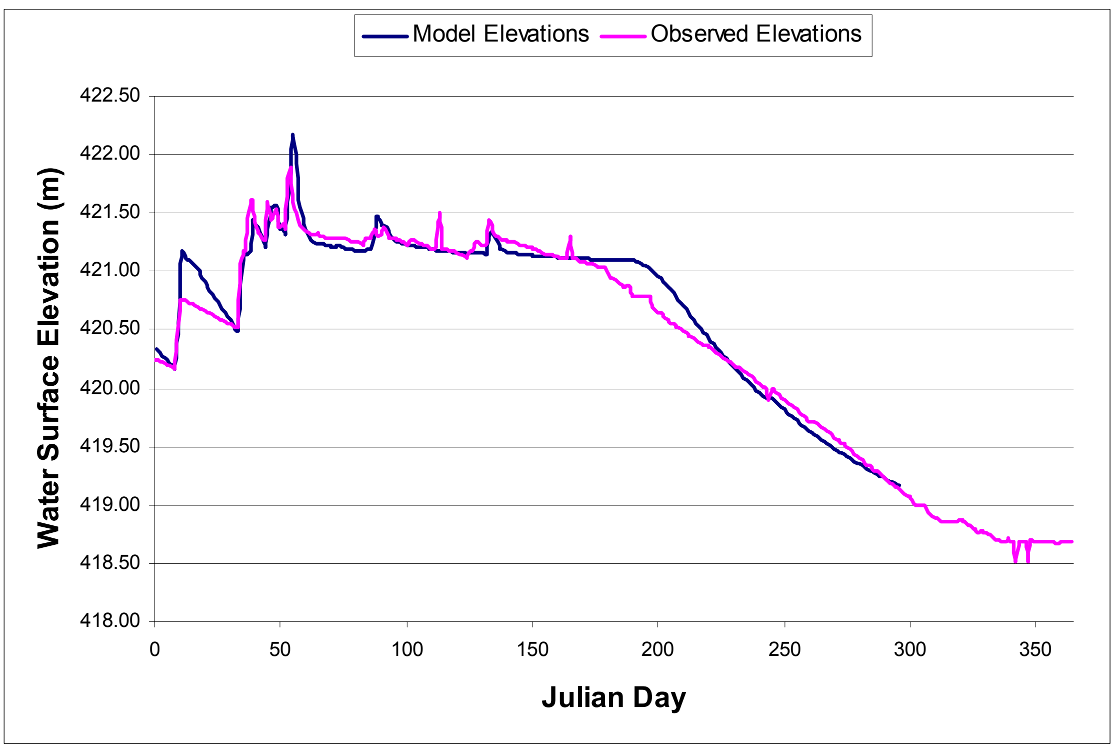

Figure 4-69 Calibration of Canyon Lake water surface elevations – 1998

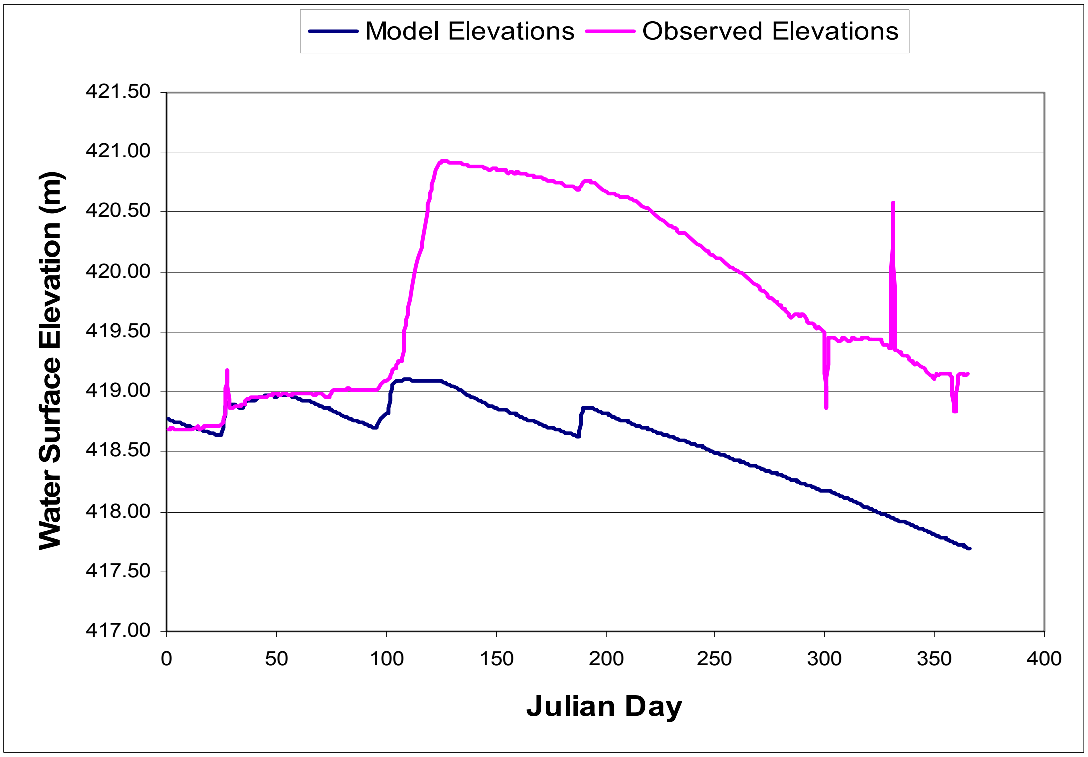

Figure 4-70 Calibration of Canyon Lake water surface elevations – 1999

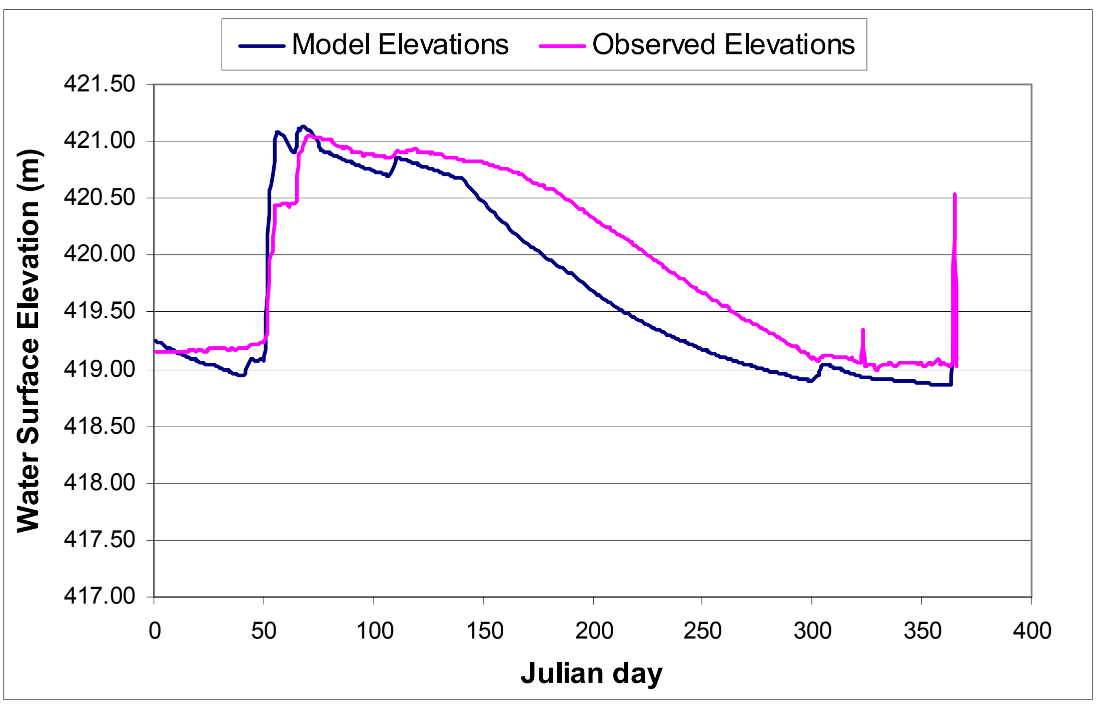

Figure 4-71 Calibration of Canyon Lake water surface elevations – 2000

Validation of the Canyon Lake water budget was performed through comparison of 1997 and 1998 model-predicted lake outflow to observed data at USGS gage 11070500 located about 2 miles downstream. Figure 4-72 shows results of the model validation period. Although the model consistently over-predicts flow, lack of sufficient data upstream of Canyon Lake and downstream of Mystic Lake prevent more robust investigation of high storm events at this time. Most importantly, the model is shown to appropriately simulate the times of Canyon Lake overflow and capture the resulting affects on downstream flow.

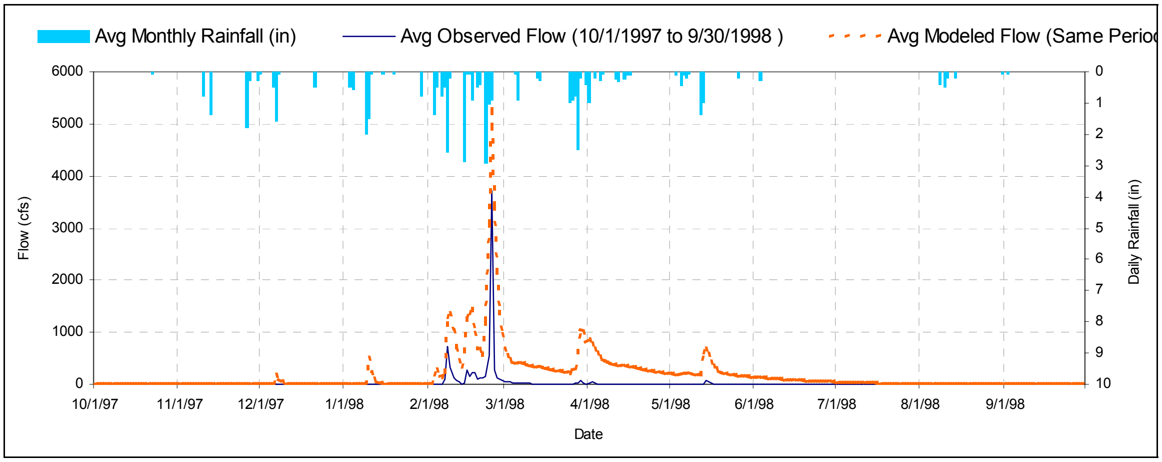

Figure 4-72 Validation of Canyon Lake overflow (1997-1998)

Water Quality

With the focus of the modeling effort being on nutrient source contribution quantification, the calibration of model outflow and in-lake water quality was performed using a simplified procedure. In-lake water quality calibration was performed using lake data collected at the Canyon Lake dam (TMDL site #7). This assured that the quality of water that passes the dam either through seepage or weir overflow is characteristic of observed conditions. If a more detailed model is desired in the future for Canyon Lake, a more robust calibration of water quality at specific locations in the lake can be performed using the current model configuration.

Figures 4-73 and 4-74 show results of the water quality calibration of Canyon Lake to data collected in 2000. Because no total phosphorus data were collected in Canyon Lake, model total phosphorus concentrations were compared to observed total phosphate data to evaluate relative trends in water quality throughout the year.

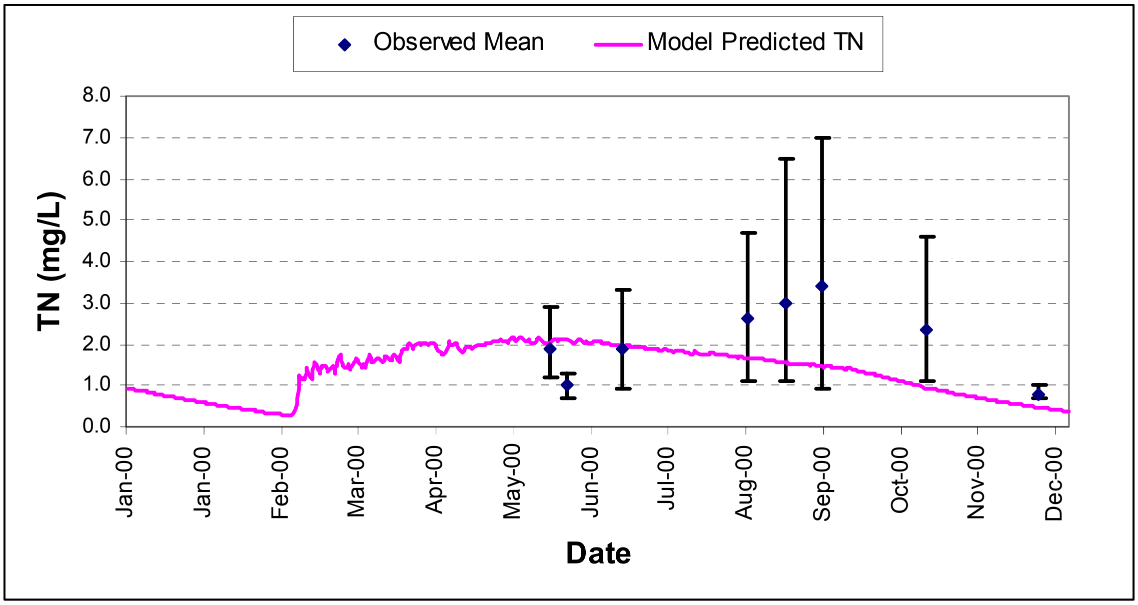

Figure 4-73 Calibration of Canyon Lake total nitrogen concentrations – 2000

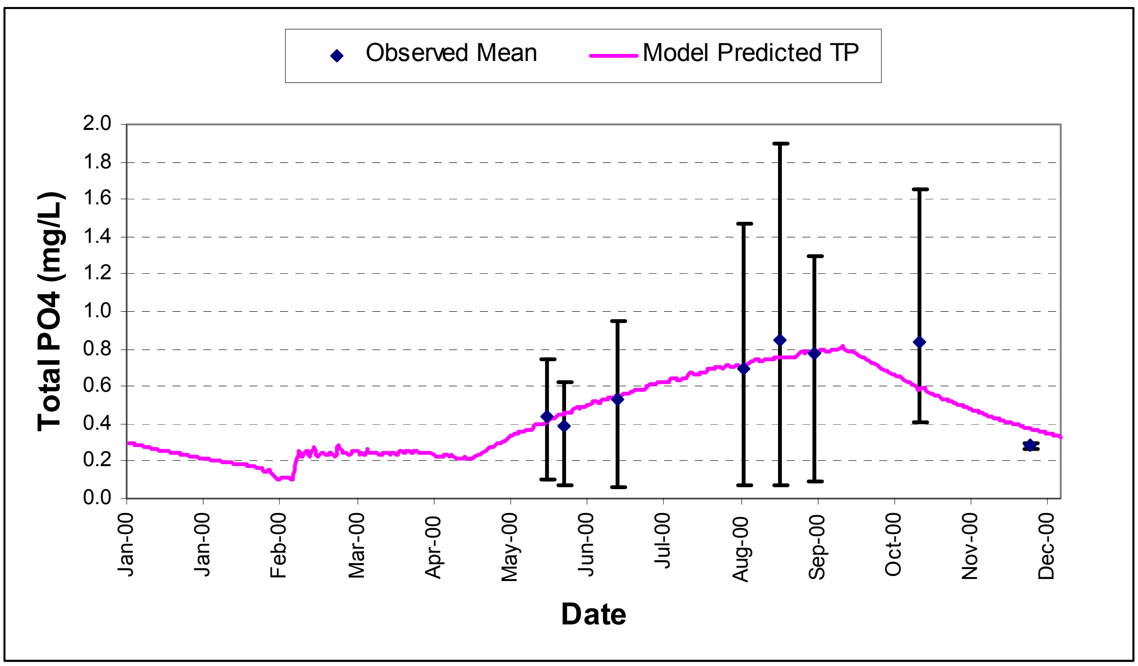

Figure 4-74 Calibration of Canyon Lake total phosphorus concentrations – 2000

Model Simulation for Existing Conditions and Scenarios

Flow and loadings from the watershed model served as the initial basis for driving the water budget and water quality in the Canyon Lake model. Some adjustments to the watershed hydrologic representation in the watershed model were required to resolve instabilities observed in the lake model. Following the water balance and water quality calibration, necessary adjustments to model parameters were made. Output from the lake model was summarized with additional watershed model output simulating the section of the watershed downstream of Canyon Lake dam. Final results were summarized in monthly and annual loads to Lake Elsinore.

Although the watershed model was run for a 10-year period to assess the spatial, temporal, and source-based contributions of flow and nutrients in the watershed, shorter time periods were selected for summarizing Canyon Lake model outputs (and thus contributions to Lake Elsinore). This was necessary because the lake model is very sensitive to incoming flows and nutrient loadings, particularly due to large storm events. Minor differences between model simulation results and observed surface elevations during early years in a long-term simulation can propagate into significant discrepancies in later years. With long-term simulation, these discrepancies can lead to major misrepresentation of Canyon Lake overflows and thus nutrient contributions to Lake Elsinore. Detailed simulation and calibration of a more complex Canyon Lake model would likely mitigate these observed discrepancies during long-term simulation.

For the current study, three model years were selected with conditions representative of variable hydrologic, hydraulic, and nutrient loading characteristics of the watershed. 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 water years (WY) 1998, 1994, and 2000, respectively (water years extend from October 1 through September 30). The selected model years provide sufficient insight into the nutrient load distribution under the range of conditions (extreme wet and dry periods) and are useful for TMDL development.

5.0 Model Results

Assessing the total load of pollutants contributed to Canyon Lake and Lake Elsinore and characterizing the distribution of sources and loads within the basin was addressed through two major techniques. The primary assessment method involved analyzing output from the watershed model and Canyon Lake model and summarizing model output on a monthly and annual basis. The second technique involved assessment of the nutrient load distribution spatially and by landuse. This analysis provides insight into the relative load contribution from different locations and will help guide future nutrient management efforts.

In addition to an analysis of existing conditions, the modeling system was used to predict relative nutrient loads to the lakes for both predevelopment and future landuse conditions. For the predevelopment condition, the entire watershed was represented by the "forested" landuse category in the model. For future conditions, landuse provided by EMWD representing build-out conditions, were used. Comparison of scenario results to the existing conditions provides insight into the watershed and lakes' sensitivity to landuse-based load contributions.

5.1 Nutrient Loads to Canyon Lake and Lake Elsinore

Nutrient loads from the watershed model were summarized to provide monthly and annual predictions to Canyon Lake over a 10-year period. Monthly and annual nutrient loads from the Canyon Lake model were predicted for 3 separate model years, which represent a range of hydrologic conditions, for analysis of total loads to Lake Elsinore.

5.1.1 Canyon Lake

Monthly nutrient loads to Canyon Lake from 1991 through 2000 are presented graphically in Figures 5-1 through 5-4. Monthly values are additionally tabulated in Appendix B. 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. Table 5-1 lists the annual loads to Canyon Lake for the 10-year period (water years).

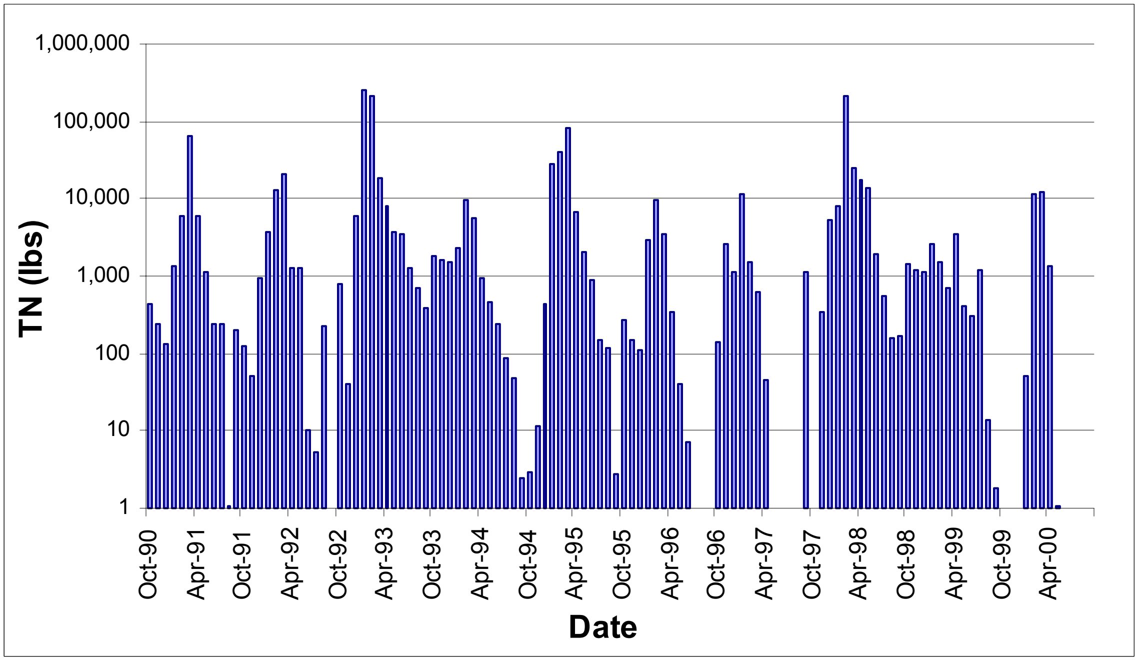

Figure 5-1 Monthly predicted total nitrogen loads to Canyon Lake

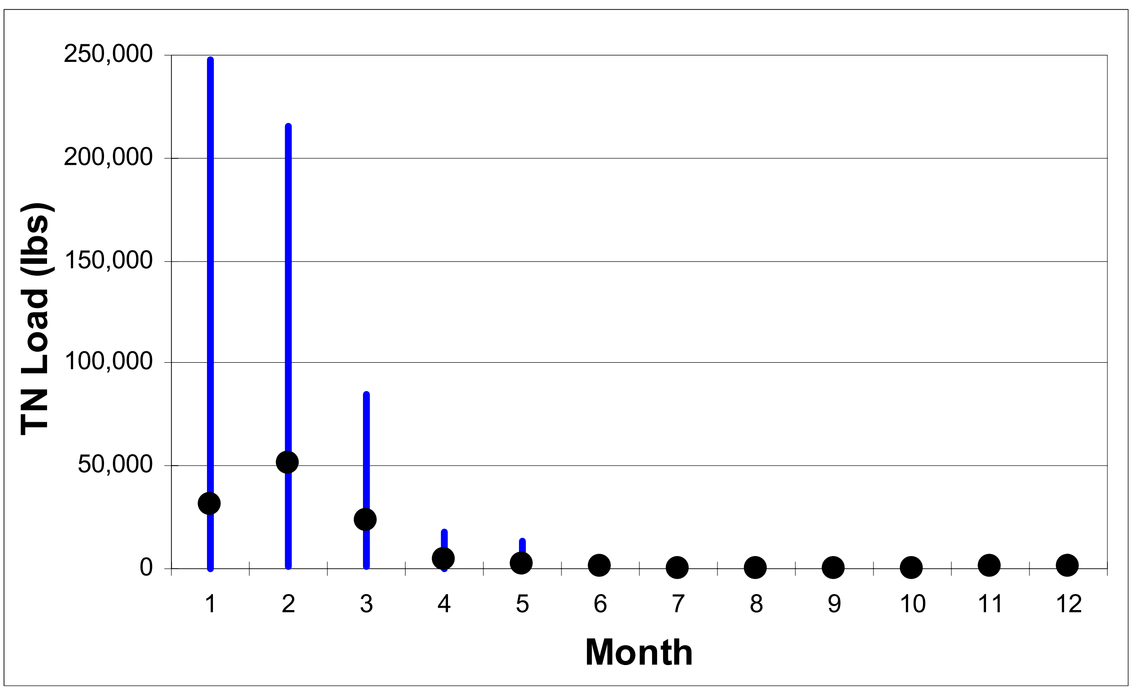

Figure 5-2 Monthly predicted ranges (minimum and maximum) and means of total nitrogen loads to Canyon Lake (month 1 corresponds to January)

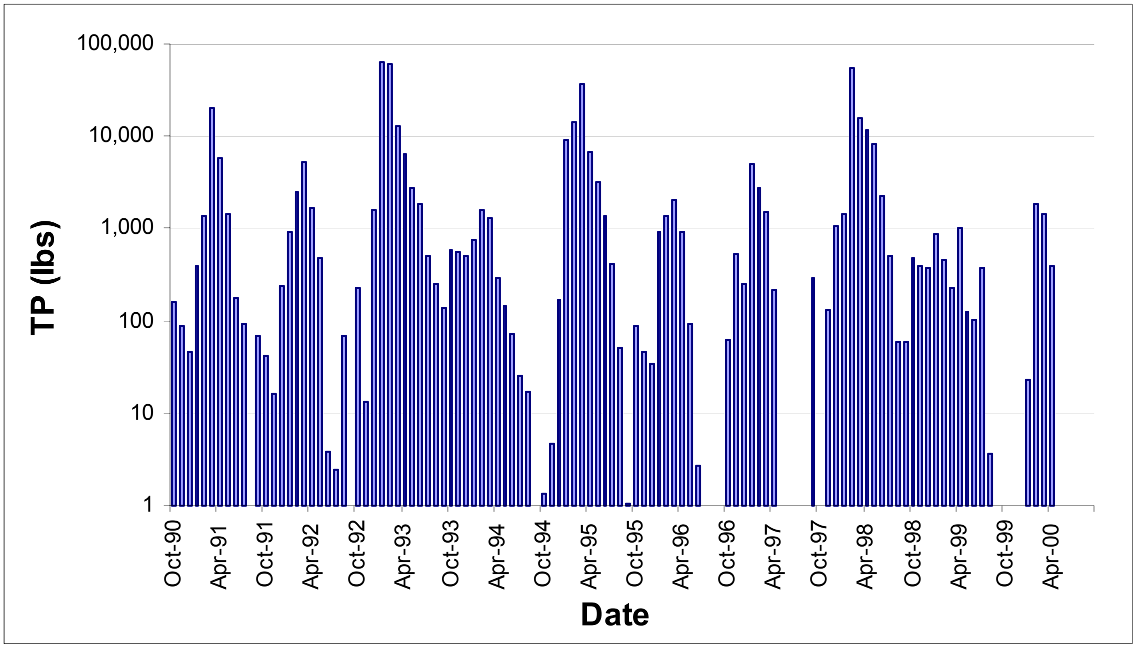

Figure 5-3 Monthly predicted total phosphorus loads to Canyon Lake

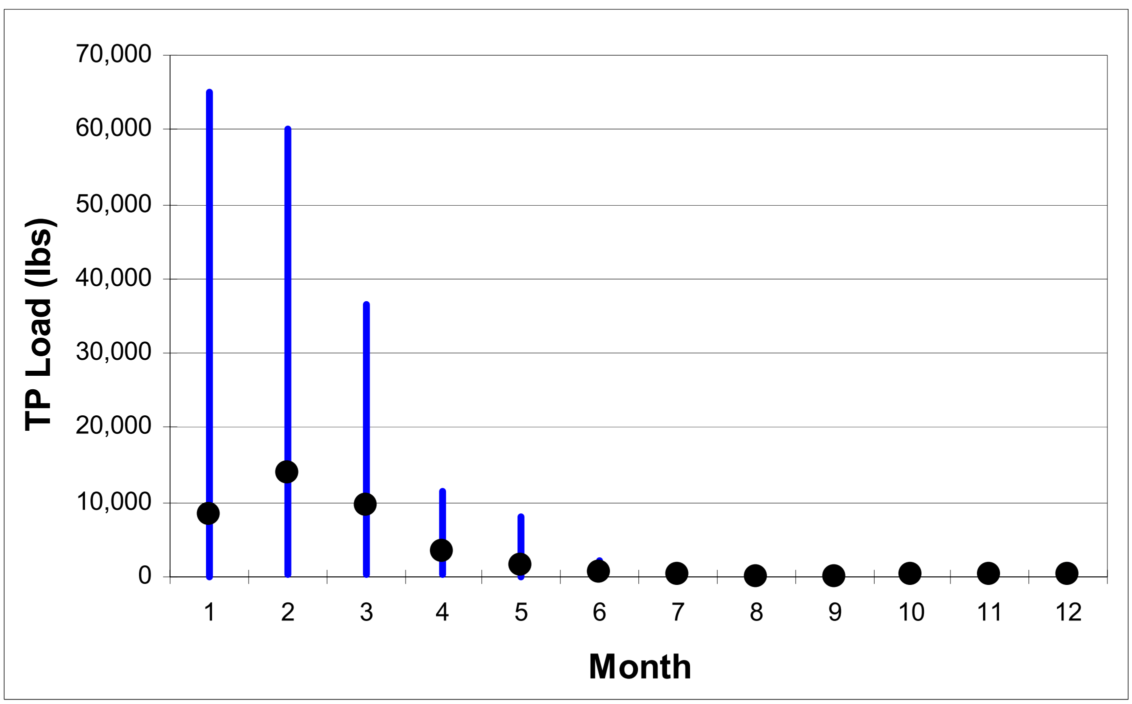

Figure 5-4 Monthly predicted ranges (minimum and maximum) and means of total phosphorus loads to Canyon Lake (month 1 corresponds to January)

Table 5-1 Annual nutrient loads to Canyon Lake (water years)

WY	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
1991	13,422.3	29,590.7	36,688.4	80,883.1
1992	5,169.2	11,396.0	19,093.9	42,094.4
1993	69,157.7	152,465.0	226,807.8	500,020.4
1994	2,699.5	5,951.3	10,904.0	24,039.1
1995	32,619.3	71,912.5	73,949.5	163,029.1
1996	2,519.2	5,553.7	7,617.1	16,792.6
1997	4,799.2	10,580.4	8,480.4	18,696.0
1998	43,030.6	94,865.2	130,508.9	287,719.8
1999	2,020.2	4,453.7	6,380.6	14,066.7
2000	1,674.0	3,690.5	11,484.6	25,319.0

5.1.2 Lake Elsinore

To evaluate the variability in nutrient loading and dependence on hydrologic conditions, three separate water years were analyzed separately (see Section 4.3.2.c). 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 water years (WY) 1998, 1994, and 2000, respectively (water years extend from October 1 through September 30).

Monthly loads of total nitrogen and total phosphorus to Lake Elsinore are summarized for each WY modeled in Tables 5-2 through 5-4. For WY 2000, when the Canyon Lake dam does not overflow, average monthly loads to Lake Elsinore are notably less than those predicted for Canyon Lake due to the in-lake storage of Canyon Lake. However, for the years that the Canyon Lake dam was predicted to overflow (WY 1994 and 1998), predicted nutrient loads contributing to Lake Elsinore were much greater. As a result, nutrients stored in Canyon Lake during dry periods are determined to have a major impact on Lake Elsinore during wet periods when Canyon Lake dam overflows.

Table 5-2 Monthly nutrient loads to Lake Elsinore (WY 1994)

Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Oct-93	1.7	3.8	6.9	15.3
Nov-93	3.7	8.2	10.8	23.7
Dec-93	1.3	2.9	4.9	10.7
Jan-94	21.1	46.5	452.6	997.8
Feb-94	549.4	1,211.2	13,173.6	29,042.5
Mar-94	195.3	430.6	4,850.0	10,692.2
Apr-94	8.0	17.6	29.9	66.0
May-94	4.5	9.9	16.6	36.5
Jun-94	2.7	6.0	10.1	22.4
Jul-94	1.3	2.8	5.1	11.1
Aug-94	0.3	0.7	1.4	3.1
Sep-94	0.0	0.0	0.1	0.1
Total	789.4	1,740.3	18,561.9	40,921.5

Table 5-3 Monthly nutrient loads to Lake Elsinore (WY 1998)

Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Oct-97	0.0	0.0	0.0	0.0
Nov-97	2.6	5.6	6.5	14.4
Dec-97	423.1	932.7	785.9	1,732.6
Jan-98	640.4	1,411.9	912.0	2,010.6
Feb-98	42,050.7	92,704.9	223,194.5	492,054.7
Mar-98	27,550.4	60,737.7	106,052.3	233,802.8
Apr-98	10,272.8	22,647.4	35,143.3	77,477.0
May-98	14,043.6	30,960.6	45,029.3	99,271.7
Jun-98	5,327.2	11,744.4	16,685.0	36,783.7
Jul-98	1,243.9	2,742.4	4,287.7	9,452.7
Aug-98	2.7	5.8	9.7	21.3
Sep-98	1.2	2.7	4.6	10.1
Total	101,558.7	223,896.3	432,110.8	952,631.5

Table 5-4 Monthly nutrient loads to Lake Elsinore (WY 2000)

Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Oct-99	0.0	0.0	0.0	0.0
Nov-99	0.0	0.0	0.0	0.0
Dec-99	0.0	0.0	0.0	0.1
Jan-00	0.0	0.0	0.0	0.0
Feb-00	246.0	542.2	324.1	714.5
Mar-00	217.2	478.8	454.8	1,002.7
Apr-00	0.6	1.4	2.0	4.3
May-00	0.0	0.0	0.0	0.0
Jun-00	0.0	0.0	0.0	0.0
Jul-00	0.0	0.0	0.0	0.0
Aug-00	0.0	0.0	0.0	0.0
Sep-00	0.0	0.0	0.0	0.0
Total	463.8	1,022.5	780.9	1,721.6

5.2 Assessment of Spatial and Landuse Loading Effects

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. To evaluate the variability in nutrient loading and dependence on hydrologic conditions, three separate water years were analyzed separately. These scenarios were consistent with periods selected for Canyon Lake model runs where (1) Mystic Lake and Canyon Lake overflowed (WY 1998), (2) Canyon Lake overflowed but Mystic Lake did not (WY 1994), and (3) neither Mystic Lake nor Canyon Lake overflowed (WY 2000).

Nutrient loads predicted by the watershed model were summarized both spatially and by landuse to provide a useful assessment of the variability of nutrient loads throughout the watershed and guidance for TMDL load reduction scenarios. To analyze the spatial variability of nutrient loads, the San Jacinto River watershed was divided into 9 zones of impact. Figure 5-5 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. Zones 1 and 2 are summarized as the load *to* Lake Elsinore and Canyon Lake, respectively. Summary of loads *to* the lakes instead of *from* the lakes (as with Mystic Lake and Zone 7) was provided so that assessments can be made regarding impacts to the lakes for TMDL development. 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. Likewise, Zone 1 includes the load exported from Canyon Lake and the local load from the area within the Zone 1 boundary.

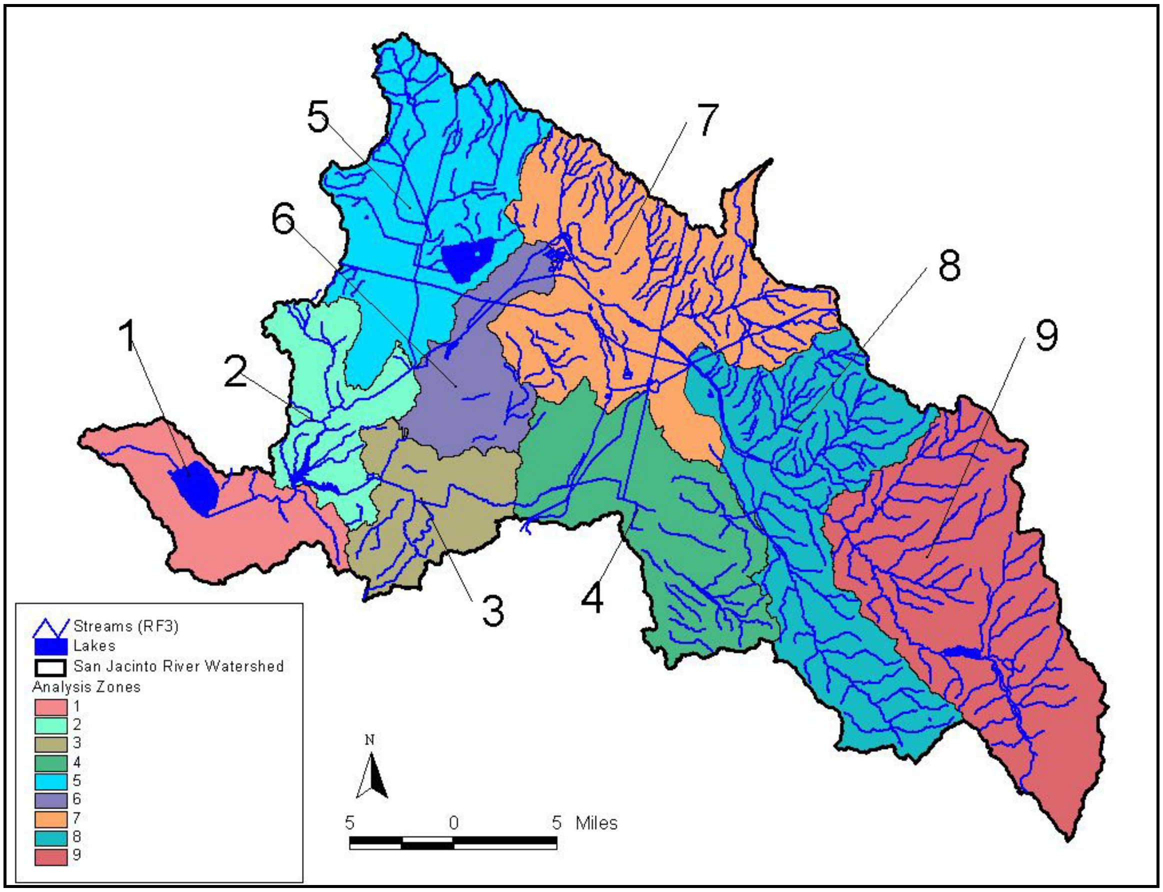

Figure 5-5 Watershed analysis zones

Summaries of model-predicted total nitrogen and total phosphorus loads for all 9 Zones are provided in Tables 5-5 through 5-10 for each hydrologic scenario (WY 1994, 1998, and 2000) and landuse represented in the modeling system. The reported loads are the net loads exported from the zones, including loads transported from upstream zones. For example, the total nitrogen load exported from Zone 8 for WY 1994 is 16,020 lbs, which includes 8,708 lbs from Zone 9 subject to instream losses through Zone 8. Hence, distribution of loads by landuse 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 landuse percentages corresponding to Zone 9). For local runoff in each Zone, loading rates (lbs/acre/year) were predicted for each landuse category and are reported in Tables D-1 through D-6 of Appendix D.

For Zone 1 (Lake Elsinore), an additional category was included to account for in-lake nutrient sources in Canyon Lake attributed to sediment release or other sources accounted for implicitly through model calibration. Further studies are recommended to provide a more in-depth understanding of in-lake nutrient sources. Also, it is recommended that the Canyon Lake model be updated for simulation of 3 dimensions and more explicit representation of sediment nutrient flux and additional internal lake sources identified and quantified.

Table 5-5 Total nitrogen loads (lbs) for Scenario 1 – both Mystic Lake and Canyon Lake overflowed (WY 1998)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	95,178	94,192	20,029	11,161	25,463	38,688	21,674	10,458	56
Dairy/Livestock	31,613	31,613	7,705	1,407	1,530	25,948	33,068	10,269	0
Forest	41,766	37,065	4,198	4,558	5,035	26,157	31,839	122,166	67,613
Urban	11,254	9,931	2,025	1,996	5,564	2,185	1,596	715	88
High-Density Residential	2,783	1,859	875	955	658	193	225	265	46
Medium-Density Residential	14,043	14,043	4,719	4,692	8,875	1,128	1,299	2,736	0
Low-Density Residential	15,698	12,366	2,776	1,963	4,380	2,702	1,196	759	108
Mobile Home/Trailor Park	2,227	2,227	837	1,065	565	630	474	969	0
Open	2,199	1,717	196	232	554	828	937	3,301	1,087
Orchard/Vineyards	1,535	1,512	552	772	324	651	802	3,629	5
Pasture	11,344	8,907	3,371	2,150	1,624	3,538	3,477	3,986	223
Septics	84,492	72,288	8,209	4,758	18,475	9,524	10,630	18,895	16,851
Internal Canyon Lake Load	638,500								
Total	952,632	287,720	55,493	35,710	73,047	112,173	107,217	178,149	86,076

Table 5-6 Total phosphorus loads (lbs) for Scenario 1 – both Mystic Lake and Canyon Lake overflowed (WY 1998)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	46,350	45,977	7,403	4,300	8,046	27,443	21,807	4,540	23
Dairy/Livestock	6,337	6,337	689	126	113	6,317	7,744	1,034	0
Forest	28,131	26,426	1,415	1,638	1,488	24,430	29,328	47,917	25,386
Urban	4,214	3,674	701	680	1,377	1,565	1,375	448	53
High-Density Residential	462	304	127	144	82	72	84	36	6
Medium-Density Residential	2,198	2,198	708	717	1,172	420	487	415	0
Low-Density Residential	2,492	1,982	425	278	487	707	437	108	14
Mobile Home/Trailor Park	406	406	121	164	72	188	170	130	0
Open	214	179	12	15	31	132	153	228	71
Orchard/Vineyards	438	433	92	140	49	314	379	734	1
Pasture	1,420	1,187	301	197	124	765	827	407	21
Septics	6,578	5,761	536	320	1,022	1,595	1,840	1,366	1,186
Internal Canyon Lake Load	124,658								
Total	223,896	94,865	12,528	8,721	14,063	63,948	64,631	57,364	26,760

Table 5-7 Total nitrogen loads (lbs) for Scenario 2 –Canyon Lake overflowed (WY 1994)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	8,191	8,086	3,677	2,034	2,913	1,025	0	377	1
Dairy/Livestock	1,370	1,370	1,513	278	206	57	0	1,295	0
Forest	2,737	2,043	1,071	1,018	581	122	0	11,290	7,317
Urban	2,231	2,013	818	839	1,414	66	0	102	12
High-Density Residential	795	640	483	467	223	3	0	48	9
Medium-Density Residential	3,229	3,229	2,079	1,891	1,844	15	0	492	0
Low-Density Residential	2,799	2,294	941	728	888	137	0	126	16
Mobile Home/Trailor Park	624	624	447	479	172	36	0	213	0
Open	203	128	46	47	63	7	0	356	120
Orchard/Vineyards	155	152	137	159	34	3	0	467	1
Pasture	1,300	915	736	454	183	54	0	476	23
Septics	3,335	2,546	800	678	594	24	0	778	1,210
Internal Canyon Lake Load	13,953								
Total	40,922	24,039	12,747	9,070	9,114	1,547	0	16,020	8,708

Table 5-8 Total phosphorus loads (lbs) for Scenario 2 – Canyon Lake overflowed (WY 1994)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	640	2,901	1,453	806	957	371	0	133	0
Dairy/Livestock	24	117	142	25	16	5	0	105	0
Forest	359	685	382	373	177	41	0	3,402	1,881
Urban	202	649	274	302	480	18	0	21	2
High-Density Residential	49	118	100	105	39	0	0	7	1
Medium-Density Residential	132	633	456	453	367	3	0	74	0
Low-Density Residential	170	452	184	156	172	21	0	15	2
Mobile Home/Trailor Park	25	119	95	111	30	6	0	30	0
Open	5	7	3	3	3	0	0	19	5
Orchard/Vineyards	6	25	24	29	5	0	0	76	0
Pasture	46	78	68	42	14	5	0	39	1
Septics	81	166	54	47	34	1	0	39	58
Internal Canyon Lake Load	0								
Total	1,740	5,951	3,233	2,452	2,294	472	0	3,960	1,950

Table 5-9 Total nitrogen loads (lbs) for Scenario 3 – neither Mystic Lake nor Canyon Lake overflowed (WY 2000)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	352	8,161	2,568	1,261	4,077	621	0	138	0
Dairy/Livestock	47	1,197	1,411	229	240	30	0	672	0
Forest	292	1,764	469	463	731	64	0	6,199	3,708
Urban	107	1,499	291	311	1,377	35	0	66	6
High-Density Residential	47	335	157	148	168	1	0	37	4
Medium-Density Residential	86	2,177	724	698	2,056	6	0	353	0
Low-Density Residential	189	1,914	377	279	990	55	0	77	9
Mobile Home/Trailor Park	14	347	138	178	155	16	0	137	0
Open	29	121	19	22	78	4	0	202	64
Orchard/Vineyards	5	97	46	73	55	1	0	309	0
Pasture	150	779	499	253	265	28	0	286	12
Septics	405	6,929	705	238	2,266	32	0	450	619
Internal Canyon Lake Load	0								
Total	1,722	25,319	7,404	4,154	12,457	894	0	8,925	4,423

Table 5-10 Total phosphorus loads (lbs) for Scenario 3 – neither Mystic Lake nor Canyon Lake overflowed (WY 2000)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	503	1,998	760	363	889	123	0	41	0
Dairy/Livestock	16	65	102	15	12	1	0	46	0
Forest	161	426	119	124	148	12	0	1,601	796
Urban	85	296	72	87	289	6	0	10	1
High-Density Residential	13	36	20	21	16	0	0	5	0
Medium-Density Residential	48	195	90	102	210	1	0	43	0
Low-Density Residential	70	226	43	39	102	4	0	8	1
Mobile Home/Trailor Park	9	38	16	24	15	1	0	17	0
Open	2	5	1	1	3	0	0	9	2
Orchard/Vineyards	3	10	5	10	6	0	0	42	0
Pasture	19	45	35	17	14	1	0	20	1
Septics	93	351	37	12	86	1	0	20	25
Internal Canyon Lake Load	0								
Total	1,022	3,690	1,300	815	1,789	151	0	1,862	826

Although Tables 5-5 through 5-10 present nutrient loads by source throughout the watershed, more detailed information regarding loadings in the vicinity of Canyon Lake (Zone 2) and Lake Elsinore (Zone 1) are useful to assess the relationship between the lakes and gain a better understanding of the system. Tables 5-11 through 5-13 report loads from the San Jacinto River watershed that are transported to Canyon Lake (columns A and E), loads transported from Canyon Lake to Lake Elsinore (columns B and F), loads from the local watershed of Lake Elsinore downstream of Canyon Lake dam (columns C and G), and the total load to Lake Elsinore (columns D and H). Tables D-7 through D-9 of Appendix D list the percentages of the total loads by source to the lakes.

Table 5-11 Nutrient loads to Canyon Lake and Lake Elsinore for Scenario 1 (WY 1998)

Land Use	Total Nitrogen A Into Canyon Lake (lbs)	Total Nitrogen B From Canyon Lake (lbs)	Total Nitrogen C Local Lake Elsinore (lbs)	Total Nitrogen D Total to Lake Elsinore (B+C)	Total Phosphorus E Into Canyon Lake (lbs)	Total Phosphorus F From Canyon Lake (lbs)	Total Phosphorus G Local Lake Elsinore (lbs)	Total Phosphorus H Total to Lake Elsinore (F+G)
Cropland	94,192	94,192	986	95,178	45,977	45,977	373	46,350
Dairy/Livestock	31,613	31,613	0	31,613	6,337	6,337	0	6,337
Forest	37,065	37,065	4,701	41,766	26,426	26,426	1,704	28,131
Urban	9,931	9,931	1,323	11,254	3,674	3,674	539	4,214
High-Density Residential	1,859	1,859	924	2,783	304	304	157	462
Medium-Density Residential	14,043	14,043	0	14,043	2,198	2,198	0	2,198
Low-Density Residential	12,366	12,366	3,332	15,698	1,982	1,982	510	2,492
Mobile Home/Trailor Park	2,227	2,227	0	2,227	406	406	0	406
Open	1,717	1,717	482	2,199	179	179	35	214
Orchard/Vineyards	1,512	1,512	23	1,535	433	433	4	438
Pasture	8,907	8,907	2,436	11,344	1,187	1,187	233	1,420
Septics	72,288	72,288	12,204	84,492	5,761	5,761	816	6,578
Internal Canyon Lake Source	na	638,500	na	638,500	na	124,658	na	124,658
Total	287,720	926,220	26,412	952,632	94,865	219,524	4,373	223,896

Table 5-12 Nutrient loads to Canyon Lake and Lake Elsinore for Scenario 2 (WY 1994)

Land Use	Total Nitrogen A Into Canyon Lake (lbs)	Total Nitrogen B From Canyon Lake (lbs)	Total Nitrogen C Local Lake Elsinore (lbs)	Total Nitrogen D Total to Lake Elsinore (B+C)	Total Phosphorus E Into Canyon Lake (lbs)	Total Phosphorus F From Canyon Lake (lbs)	Total Phosphorus G Local Lake Elsinore (lbs)	Total Phosphorus H Total to Lake Elsinore (F+G)
Cropland	8,086	8,086	105	8,191	2,901	605	35	640
Dairy/Livestock	1,370	1,370	0	1,370	117	24	0	24
Forest	2,043	2,043	694	2,737	685	143	216	359
Urban	2,013	2,013	219	2,231	649	135	67	202
High-Density Residential	640	640	154	795	118	25	25	49
Medium-Density Residential	3,229	3,229	0	3,229	633	132	0	132
Low-Density Residential	2,294	2,294	505	2,799	452	94	76	170
Mobile Home/Trailor Park	624	624	0	624	119	25	0	25
Open	128	128	75	203	7	1	4	5
Orchard/Vineyards	152	152	3	155	25	5	1	6
Pasture	915	915	384	1,300	78	16	30	46
Septics	2,546	2,546	789	3,335	166	35	46	81
Internal Canyon Lake Source	na	13,953	na	13,953	na	0	na	0
Total	24,039	37,992	2,929	40,922	5,951	1,240	500	1,740

Table 5-13 Nutrient loads to Canyon Lake and Lake Elsinore for Scenario 3 (WY 2000)

	Total Nitrogen				Total Phosphorus			
Land Use	A Into Canyon Lake (lbs)	B From Canyon Lake (lbs)	C Local Lake Elsinore (lbs)	D Total to Lake Elsinore (B+C)	E Into Canyon Lake (lbs)	F From Canyon Lake (lbs)	G Local Lake Elsinore (lbs)	H Total to Lake Elsinore (F+G)
Cropland	8,161	323	29	352	1,998	495	8	503
Dairy/Livestock	1,197	47	0	47	65	16	0	16
Forest	1,764	70	222	292	426	106	56	161
Urban	1,499	59	48	107	296	73	12	85
High-Density Residential	335	13	34	47	36	9	4	13
Medium-Density Residential	2,177	86	0	86	195	48	0	48
Low-Density Residential	1,914	76	113	189	226	56	14	70
Mobile Home/Trailor Park	347	14	0	14	38	9	0	9
Open	121	5	24	29	5	1	1	2
Orchard/Vineyards	97	4	1	5	10	2	0	3
Pasture	779	31	119	150	45	11	8	19
Septics	6,929	274	131	405	351	87	6	93
Internal Canyon Lake Source	na	0	na	0	na	0	na	0
Total	25,319	1,001	721	1,722	3,690	914	108	1,022

5.3 Assessment of Pre-development, Existing, and Future Conditions

Comparison of model results for varying urban developmental stages in the San Jacinto River watershed provides insight into the impact that urbanization has on both Canyon Lake and Lake Elsinore. Three stages of urbanization were compared: (1) a pre-development stage where the entire San Jacinto River watershed was assumed to have nutrient loading and hydrology characteristics respective of forested conditions, (2) existing/calibrated conditions reported in Sections 5.1 and 5.2, and (3) future conditions with landuse distributions based on a built-out representation assumed by EMWD. For the future landuse, the EMWD data was combined with 1993 MRLC landuse data using the same methodology utilized in compilation of the existing landuse coverage described in Section 4.3.1.b. Figure 5-6 depicts the composite future landuse coverage used for model predictions and analysis.

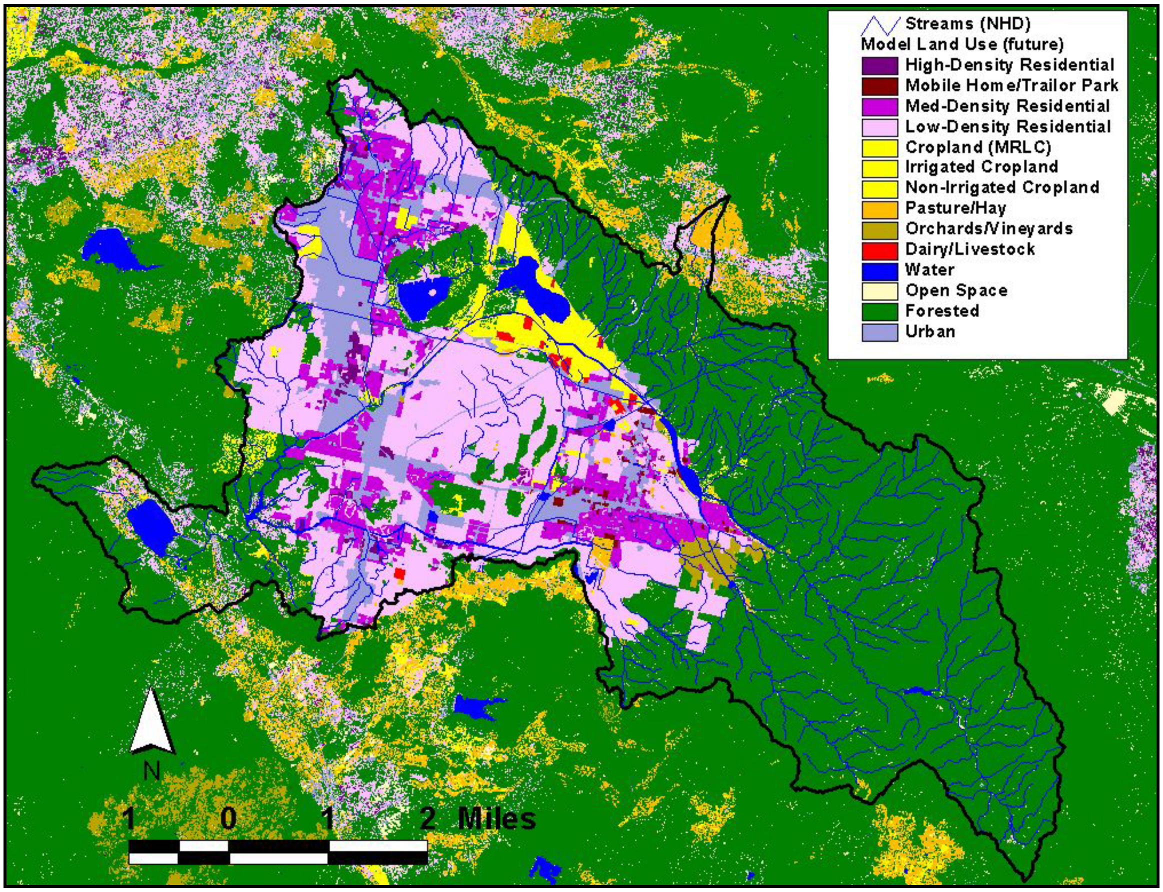

Figure 5-6 Composite MRLC and assumed future/built-out EMWD land use

For the pre-development and future model scenarios, hydrology and nutrient loading characteristics were assigned using landuse-specific parameters determined through the calibration process outlined in Section 4.2.1.c. Therefore, the only change to model input was the landuse distribution. Model runs for each scenario were based on rainfall data for the three hydrologic/hydraulic scenarios outlined in Section 4.3.2.c (WY 1994, 1998, and 2000). This allowed comparison of model results for each stage of urban development for varying hydrology conditions.

Figures 5-7 through 5-10 present the relative loads for each of the WYs modeled. Nutrient loads from the pre-development and future scenarios are listed in Tables 5-14 and 5-15 (loads for the existing conditions scenario are reported in Tables 5-1 through 5-4). For WYs 1994 and 2000 hydrologic conditions, nutrient loads to both lakes for the pre-development scenario were negligible. 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 Lake Elsinore under WY 1998 hydrologic conditions, with nitrogen loads increasing almost an order of magnitude between pre-development and existing conditions.

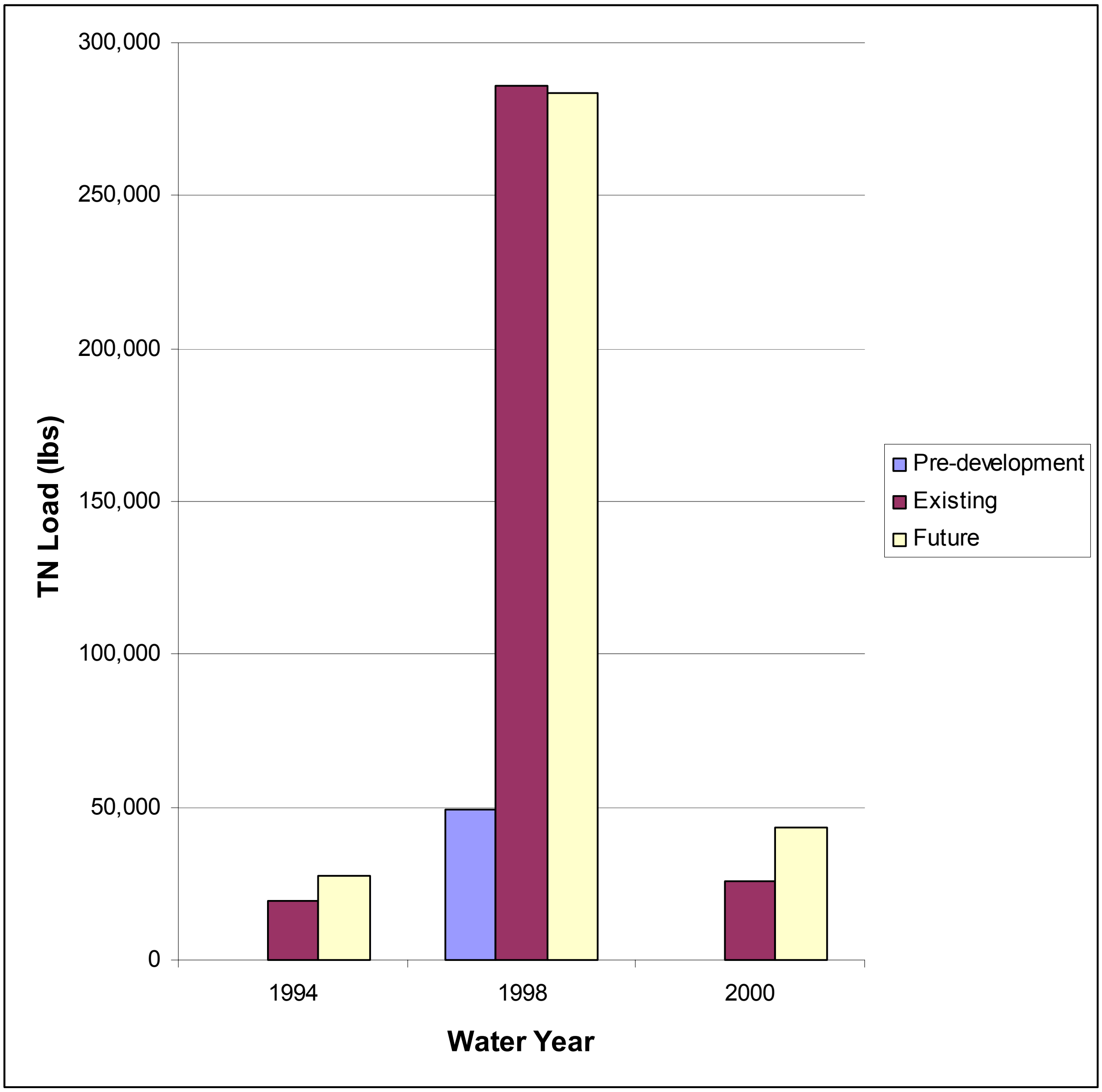

Figure 5-7 Comparison of nitrogen loads to Canyon Lake for varying developmental conditions

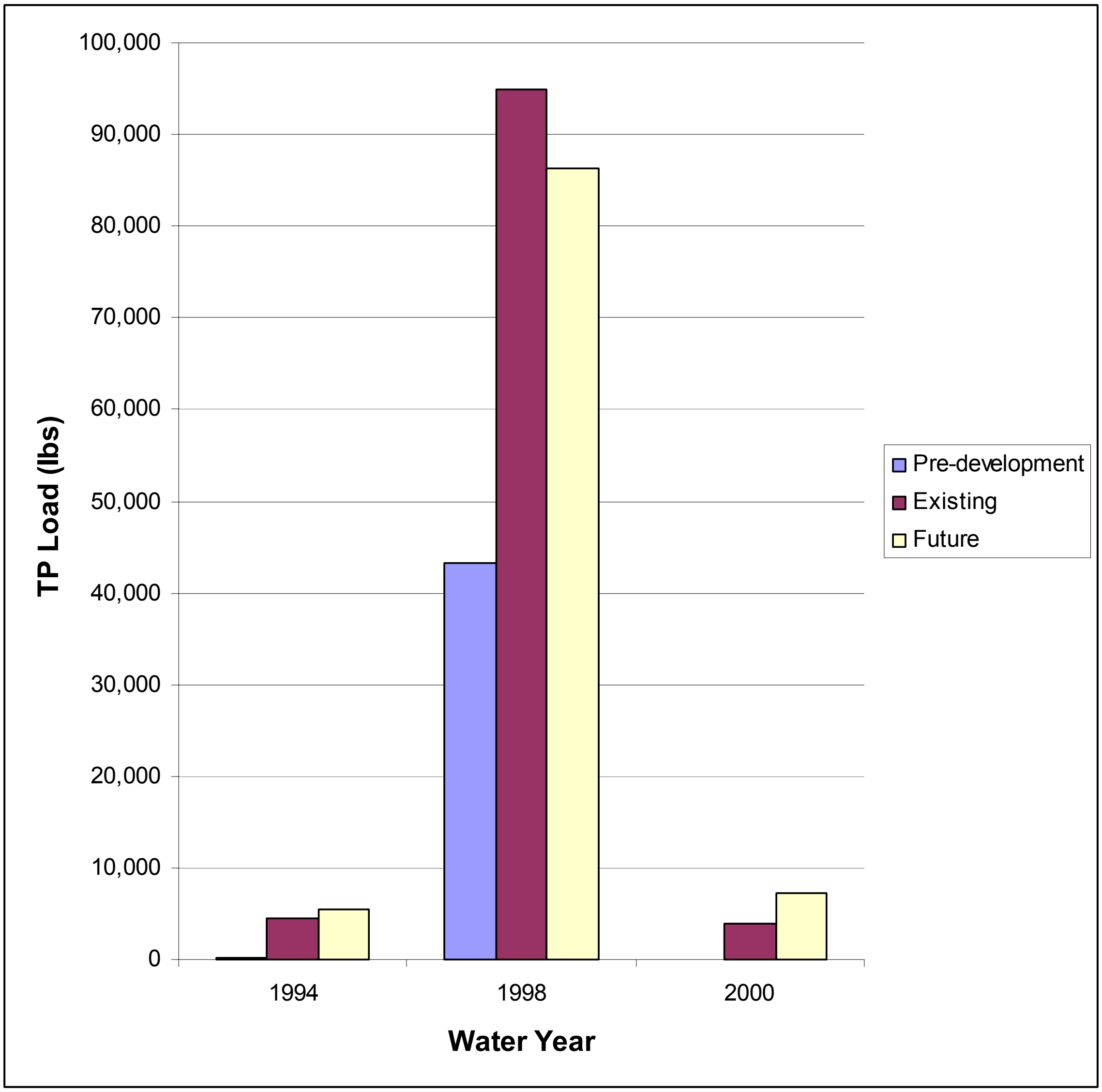

Figure 5-8 Comparison of phosphorus loads to Canyon Lake for varying developmental conditions

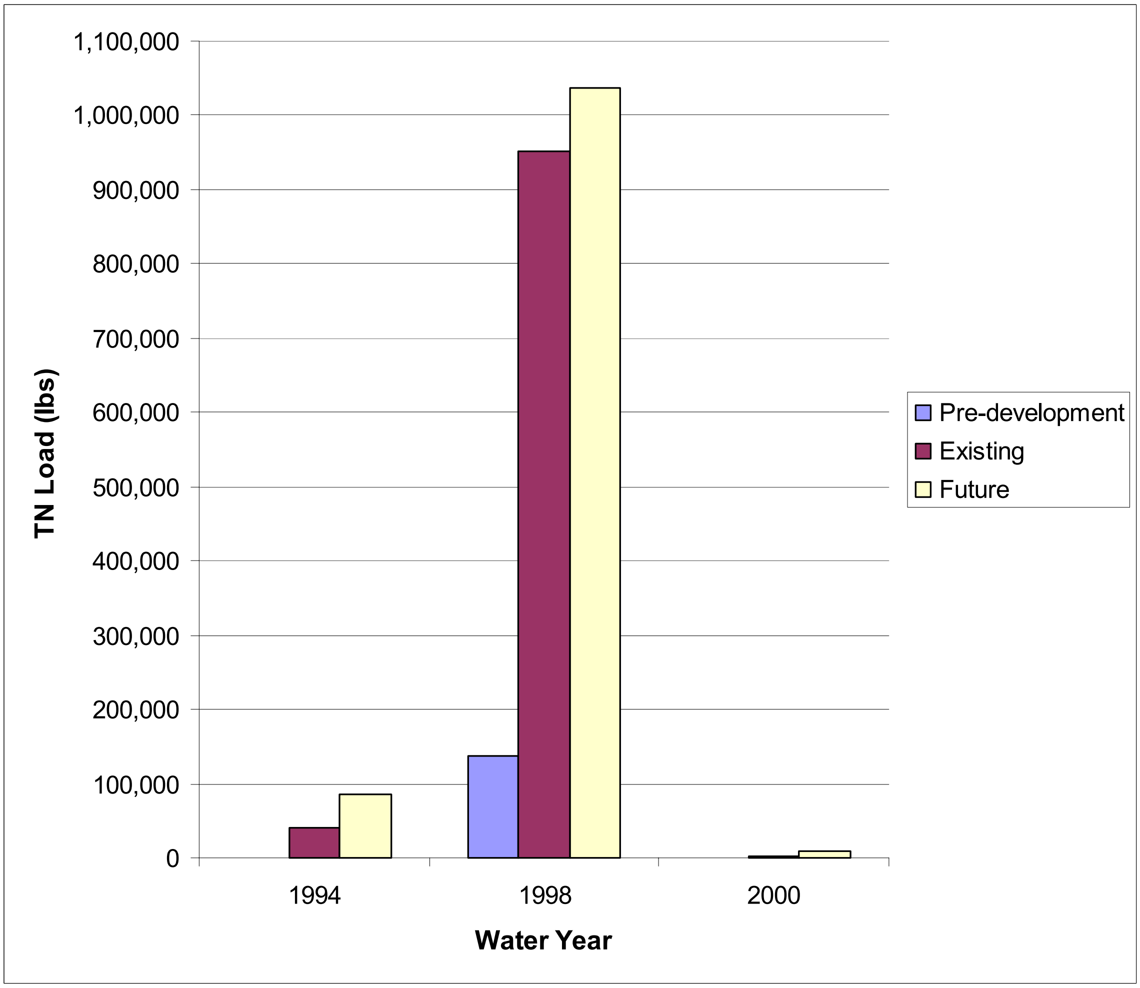

Figure 5-9 Comparison of nitrogen loads to Lake Elsinore for varying developmental conditions

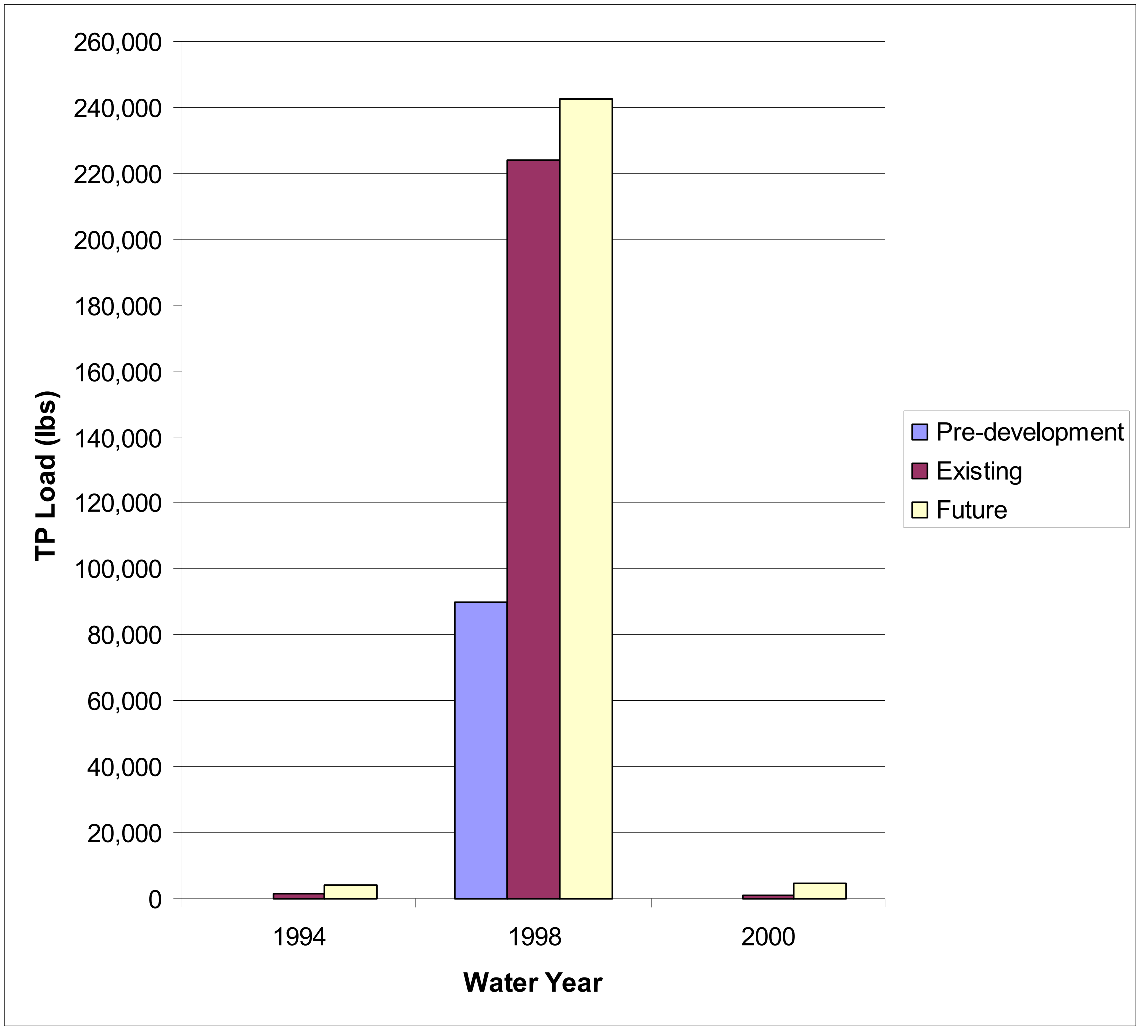

Figure 5-10 Comparison of phosphorus loads to Lake Elsinore for varying developmental conditions

Table 5-14 Annual nutrient loads to Canyon Lake at pre-development conditions

Year	Annual TP (kg)	Annual TP (lbs)	Annual TN (kg)	Annual TN (lbs)
1994	96	212	111	245
1998	19,580	43,166	22,196	48,934
2000	0	0	0	0

Table 5-15 Annual nutrient loads to Lake Elsinore at pre-development conditions

Year	Annual TP (kg)	Annual TP (lbs)	Annual TN (kg)	Annual TN (lbs)
1994	5	10	12	26
1998	40,759	89,858	62,528	137,848
2000	0	0	0	0

Table 5-16 Annual nutrient loads to Canyon Lake at future/built-out conditions

Year	Annual TP (kg)	Annual TP (lbs)	Annual TN (kg)	Annual TN (lbs)
1994	2,462	5,427	12,504	27,565
1998	39,158	86,327	128,720	283,777
2000	3,328	7,336	19,671	43,366

Table 5-17 Annual nutrient loads to Lake Elsinore at future/built-out conditions

Year	Annual TP (kg)	Annual TP (lbs)	Annual TN (kg)	Annual TN (lbs)
1994	1,779	3,921	39,167	86,347
1998	109,998	242,501	470,380	1,037,000
2000	2,150	4,740	4,270	9,414

6.0 Summary and Conclusions

6.1 Overview

To support SAWPA and the RWQCB in assessing the nutrient load distribution throughout the San Jacinto Watershed and estimating the temporal contribution of nutrients to Canyon Lake and Lake Elsinore, a comprehensive watershed modeling system was developed. The system uses EPA's LSPC and EFDC models to simulate flow and nutrient loading in the watershed and hydrodynamics and water quality response in Canyon Lake. It was designed to represent all known sources in the watershed and to provide a quantitative tool for predicting nutrient load contributions to Canyon Lake and Lake Elsinore.

The modeling process involved extensive data collection, in-depth assessment of nutrient sources in the watershed, configuration of both a watershed and a lake model, calibration and validation of both models using monitoring data for short and extended time periods, long-term simulation of watershed conditions (1991 through 2000), and simulation of lake response to selected water years with specific hydrologic/hydraulic conditions (WY 1994, 1998, and 2000). Annual nutrient loads delivered to Canyon Lake varied greatly from one year to the next, depending on rainfall conditions. Annual total nitrogen loads to Canyon Lake ranged from 10,264 lbs to 498,175 lbs, while those for total phosphorus ranged from 3,186 lbs to 152,318 lbs. Loads to Lake Elsinore also varied greatly from one year to the next. Annual total nitrogen loads to Lake Elsinore ranged from 1,722 lbs to 952,632 lbs, while those for total phosphorus ranged from 1,022 lbs to 223,896 lbs. A seasonal trend in loading was also apparent, with the largest load delivery generally occurring in January through March and the smallest occurring mid-summer.

In addition to long-term assessment, the relationship between loadings into and out of Canyon Lake were further explored. Three water years were selected as representative of varying hydrologic/hydraulic conditions in the watershed: (1) year that both Mystic Lake and Canyon Lake overflow (WY 1998), (2) year that only Canyon Lake overflows (WY 1994), and (3) year that neither Mystic Lake nor Canyon Lake overflow (2000). Each of these years was modeled and results were assessed to determine nutrient loading characteristics and distribution of sources under the varying conditions. Results showed that nutrient loading to the lakes and source distribution varied greatly between each of the three model scenarios. The magnitude and sources of nutrients were highly dependent on the overflow of both Mystic Lake and Canyon Lake.

When Mystic Lake overflowed (WY 1998), a significant nutrient load was delivered to the lakes from the upper portion of the watershed. Although the sources in the upper portion of the watershed are mostly forested, the volume of water transported resulted in a relatively large load contribution. This effect resulted in not only a substantial increase in nutrient loads to Canyon Lake and Lake Elsinore, but greatly influenced the distribution of source contributions. For WY 1994 and 2000, although the upper basin showed high loadings at the source level, most of its contributions were not ultimately delivered to Canyon Lake and Lake Elsinore (because Mystic Lake was not predicted to overflow).

As Canyon Lake overflows, nutrients from throughout the watershed (extent controlled by Mystic Lake overflow) are delivered to Lake Elsinore as well as sources from within Canyon Lake (e.g., sediment release). Transport of nutrients through Canyon Lake and from in-lake sources is highly variable and often depends upon the period preceding a wet year or even a large storm event. For WY 1998, sources within Canyon Lake accounted for 69% of the total nitrogen load and 57% total phosphorus load exported from Canyon Lake to Lake Elsinore. For WY 1994, 14% of the total nitrogen load from Canyon Lake is from in-lake sources, although no in-lake sources are responsible for the phosphorus load. This dynamic variability results from a combination of functions related to external loading to Canyon Lake (stored from previous runoff events) and assimilation of such loads in conjunction with assumptions for in-lake losses (e.g., biological processes) and gains (e.g., sediment release) developed through model calibration.

The landuse analysis identified the dairy/livestock landuse as contributing the largest load on a unit area basis, while forest and open space were expected to contribute the least. The actual impact of these landuse categories on lake conditions was highly dependent on location in the watershed and landuse area. Due to the ephemeral nature of the San Jacinto River system, the location of key sources played a critical role in ultimate nutrient contributions to the lakes. Urban development and agricultural land practices in the lower portion of the San Jacinto River watershed below Mystic Lake (including Perris Valley and Salt Creek) had the greatest impact on water quality in Canyon Lake, especially in years that Mystic Lake did not overflow (WY 1994 and 2000). However, during periods of torrential rains and extended periods of rainfall (WY 1998), the storage capacity of Mystic Lake is exceeded and surface flow from the headwaters, including shrubland, urban runoff from the City of Hemet, and agricultural runoff upstream of Mystic Lake, reaches Canyon Lake and sometimes overflows into Lake Elsinore.

Urbanization of the San Jacinto River watershed is predicted to have substantial impact to the nutrient loads to Canyon Lake and Lake Elsinore. As a result of analyses of pre-development, existing, and future (built-out) conditions, two competing factors are determined to cause varying results in impacts to nitrogen and phosphorus loads to the lakes: (1) hydrology changes resulting from increase in impervious area, and (2) redistribution of landuse and resulting changes to nutrient loading rates. Increases in urban/residential areas results in increases in impervious area, and this results in changes to storm runoff characteristics (higher peak stormflows and sharper increases and declines in storm hydrographs). Such changes in hydrology are expected to increase overflow from Canyon Lake and Mystic Lake and dramatically impact nutrient loading dynamics. In conjunction with changes to landuse distribution and associated nutrient loading characteristics, the loading to Lake Elsinore and Canyon Lake can also vary significantly. For WY 1998 hydrologic conditions, nutrient loads to both lakes increased from pre-development to existing conditions, as was expected. However, for future (build-out) conditions, loads to Canyon Lake slightly decreased but loads to Lake Elsinore increased.

6.2 Data Limitations and Recommendations

Through the data collection and modeling process, a number of data limitations and gaps were identified. While these limitations and gaps did not prevent the assessment from being conducted, addressing them would greatly benefit future studies in the basin and help to further validate the model.

Collection of additional water quality data is the greatest data need. While existing data were adequate to calibrate the modeling system for the nutrient assessment, it would be beneficial to continue collection efforts to further validate or refine modeling parameters and to support watershed management plan development. The lack of rainfall in the watershed over the past few years has limited the amount of data collected at several TMDL monitoring locations, particularly for large stormflows. Because the San Jacinto River Watershed carries nutrients throughout the watershed (from headwaters to Canyon Lake and Lake Elsinore) in heavy stormflow years, data collected during such storm events would be useful in validation of model assumptions. Additionally, some of the monitoring stations are relatively young (since 2000) and have had little data collected through today. Continued collection of data from both stream and lake stations is critical. The spatial variability of the current TMDL monitoring program is useful for assessing loading contributions from different regions and landuses and should be continued.

Very little data are available regarding flow and nutrient transport through Mystic Lake under high flow conditions. There is a significant need to collect streamflow and in-stream water quality data downstream of the lake during large storm flows when overflows from the lake occur. Water quality data have been collected downstream of the lake since January of 2000; however a longer period of record covering more variable hydrologic conditions is necessary. In addition, survey data of Mystic Lake would be useful to quantify the relationship between storage volume and outflow so that model assumptions can be verified. Also, understanding of the relationship between Mystic Lake and the low-flow channel circumventing the lake could be validated with more intensive field surveys. Presently, all stormflows are assumed to flow through the lake.

Loading rates for agricultural areas were estimated from literature values and refined through model calibration, but additional data would be useful to validate these rates. Specifically, local estimates of total nitrogen and total phosphorus resulting from each of three agricultural management practices would be useful: fertilizer application, manure application, and irrigation of wastewater from dairy waste detention facilities. Additionally, if fertilizers are used in urban areas, such as on lawns or turf farms, quantifiable information would further support the assessment and management effort. Comprehensive information would also be useful regarding the spatial variability of individual crop types in agricultural areas, as well as management practices that result in either crop rotation or idle land for extended periods.

6.3 Future Efforts

The current model provides a framework for nutrient source assessment in the San Jacinto River Basin and for evaluation of nutrient reduction scenarios. It is intended to support TMDL development efforts for Lake Elsinore and Canyon Lake as well as development of a nutrient management strategy for the entire basin.

In the event that a more robust representation of hydrodynamics and water quality response are necessary for Canyon Lake or Lake Elsinore, the current model can be readily modified. The Canyon Lake model was developed to simulate the lake in two dimensions; however, a three-dimensional version could be developed to provide more insight into the variability of water quality concentrations throughout the lake allowing for a more detailed assessment of conditions in different areas of the lake. Additionally, full representation of nutrient kinetics and transformation processes, as well as sediment diagenesis, would provide the model with additional predictive capabilities, such as the impact of decreased nutrient loading on reduced sediment flux rates. An EFDC model of Lake Elsinore could additionally be developed to support similar analyses and link directly to the current San Jacinto River Basin and Canyon Lake models.

In addition to TMDL analysis and evaluation of lake water quality response, the modeling system will provide guidance and facilitate testing of alternative management scenarios for design of a watershed management plan. The model will be used to identify "hot-spots" and/or "management zones" to guide selection of potential control measures. After potential BMPs have been identified for different sources, the model will be reconfigured to represent and evaluate multiple BMP implementation scenarios. Results of this analysis will shed light on the feasibility and benefits of various strategies.

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Appendix A

Appendix A: Instream water quality data collected in the San Jacinto River basin

	Organic N (mg/L)	TKN (mg/L)	Ortho P (mg/L)	TP (mg/L)	TDS (mg/L)	Turbidity (NTU)	Hardness (mg/L)	BOD (mg/L)	COD (mg/L)
Hemet NPDES (318)									
12/15/92 - 2/28/01									
Count	9	31	5	31	1	27	31	31	31
Mean	2.31	2.69	0.61	0.39	1280.00	37.07	145.06	14.06	70.26
Median	1.80	2.00	0.50	0.33	1280.00	32.80	38.00	10.00	55.00
Max	5.70	17.00	0.95	1.40	1280.00	85.00	447.00	51.00	200.00
Min	0.70	0.50	0.20	0.06	1280.00	3.80	5.00	4.00	26.00
Perris Ch @ Nuevo Rd (325)									
2/12/00 - 6/19/01									
Count	10	35	1	35	-	35	35	35	35
Mean	1.39	1.78	0.88	0.70	-	197.57	130.74	7.40	46.49
Median	1.25	1.50	0.88	0.42	-	147.50	71.00	7.00	40.00
Max	2.40	4.20	0.88	8.50	-	588.00	590.00	17.00	140.00
Min	0.80	0.50	0.88	0.06	-	2.90	15.00	3.00	17.00
Four Corners NPDES (357)									
1/3/92 - 2/25/01									
Count	28	49	4	49	1	41	49	49	49
Mean	2.81	2.76	0.81	0.85	158.00	141.12	111.59	20.88	111.53
Median	1.20	1.30	0.35	0.50	158.00	71.00	59.00	8.00	54.00
Max	34.00	48.00	2.40	7.60	158.00	800.00	504.00	540.00	2020.00
Min	0.10	0.50	0.15	0.16	158.00	0.11	18.00	4.00	19.00
Leach Cyn ChanOutlet (712)									
1/3/92 - 2/13/01									
Count	-	26	-	26	-	24	26	26	26
Mean	-	1.15	-	0.36	-	55.51	43.81	4.77	34.00
Median	-	1.00	-	0.29	-	42.25	36.50	4.50	27.00
Max	-	3.30	-	0.84	-	185.00	165.00	11.00	90.00
Min	-	0.50	-	0.11	-	20.00	15.00	2.00	12.00
Ortega Cyn Chan (714)									
1/3/92 - 2/13/01									
Count	-	15	-	15	-	13	15	15	15
Mean	-	2.37	-	0.63	-	524.92	51.20	5.07	70.07
Median	-	1.90	-	0.57	-	410.00	43.00	5.00	37.00
Max	-	5.70	-	1.00	-	2025.00	153.00	10.00	260.00
Min	-	0.50	-	0.37	-	41.00	23.00	1.00	21.00
Salt Creek @ Mur Rd (745)									
1/11/01 - 3/3/01									
Count	-	22	1	22	-	22	22	22	22
Mean	-	1.09	1.32	0.36	-	113.16	66.45	4.27	23.95
Median	-	1.00	1.32	0.30	-	97.25	31.50	4.00	23.50
Max	-	2.20	1.32	0.74	-	314.00	239.00	7.00	35.00
Min	-	0.50	1.32	0.20	-	35.00	20.00	3.00	9.00
San Jacinto River @ Goetz Rd (759)									
2/21/96 - 3/2/01									
Count	-	19	1	19	-	19	17	17	17
Mean	-	1.38	0.89	0.53	-	297.29	71.35	5.82	29.00
Median	-	1.40	0.89	0.50	-	235.50	75.00	6.00	27.00
Max	-	2.60	0.89	1.40	-	890.00	86.00	10.00	44.00
Min	-	0.50	0.89	0.17	-	42.00	47.00	4.00	22.00
CynLk SD@Fairweather (790)									
1/11/01 - 3/2/01									
Count	-	3	1	3	-	3	3	3	3
Mean	-	0.93	0.97	0.58	-	119.17	138.33	4.33	32.33
Median	-	0.90	0.97	0.59	-	146.00	146.00	3.00	23.00
Max	-	1.40	0.97	0.80	-	190.00	183.00	7.00	52.00
Min	-	0.50	0.97	0.36	-	21.50	86.00	3.00	22.00
S.Jac.Riv @ Cranston (827)									
9/8/94 - 3/3/01									
Count	27	33	8	33	-	32	31	31	31
Mean	0.90	1.16	0.65	0.50	-	41.10	463.03	7.45	30.58
Median	0.70	0.70	0.48	0.35	-	10.68	500.00	5.00	23.00
Max	3.30	8.20	2.20	2.70	-	590.00	700.00	19.00	85.00
Min	0.10	0.20	0.05	0.05	-	0.40	123.00	3.00	10.00
Cyn Lk@ Sierra Park (834)									
1/11/01 - 3/2/01									
Count	-	4	1	4	-	4	4	4	4
Mean	-	1.38	0.57	0.44	-	109.81	557.00	4.75	56.75
Median	-	1.25	0.57	0.45	-	94.50	606.50	4.00	56.00
Max	-	2.00	0.57	0.53	-	241.00	975.00	8.00	77.00
Min	-	1.00	0.57	0.33	-	9.25	40.00	3.00	38.00
Stream R Exy/W TMDL (836)									
1/11/2001									
Count	-	1	-	1	-	1	1	1	1
Mean	-	5.40	-	9.75	-	1040.00	98.00	13.00	75.00
Median	-	5.40	-	9.75	-	1040.00	98.00	13.00	75.00
Max	-	5.40	-	9.75	-	1040.00	98.00	13.00	75.00
Min	-	5.40	-	9.75	-	1040.00	98.00	13.00	75.00
Salt Creek @CnL TMDL (839)									
1/11/01 - 2/27/01									
Count	-	4	1	4	-	4	4	4	4
Mean	-	2.03	0.61	0.38	-	186.75	87.25	5.00	35.00
Median	-	1.35	1.00	0.48	-	202.50	101.00	4.00	28.50
Max	-	4.90	0.61	0.54	-	242.00	118.00	8.00	50.00
Min	-	0.50	0.61	0.23	-	100.00	29.00	4.00	27.00
Canyon Lake Spillway (841)									
2/28/01 - 3/2/01									
Count	-	3	1	3	-	3	3	3	3
Mean	-	1.70	0.06	0.17	-	6.82	333.67	9.67	40.00
Median	-	1.40	0.06	0.18	-	6.60	303.00	7.00	35.00
Max	-	2.70	0.06	0.21	-	8.10	428.00	15.00	53.00
Min	-	1.00	0.06	0.12	-	5.75	270.00	7.00	32.00

	Temp. (oF)	DO (mg/L)	pH (std. units)	TN (mg/L)	NO3 (mg/L)	NO2 (mg/L)	NH3-N (mg/L)	TIN (mg/L)
Hemet NPDES (318)								
12/15/92 - 2/28/01								
Count	-	9	29	13	17	18	14	20
Mean	-	7.97	8.35	5.08	2.72	0.50	1.06	1.22
Median	-	8.48	8.30	4.60	2.70	0.50	0.30	1.00
Max	-	12.45	9.56	17.00	4.90	0.50	5.30	5.00
Min	-	0.27	7.40	1.50	0.40	0.50	0.10	0.40
Perris Ch @ Nuevo Rd (325)								
2/12/00 - 6/19/01								
Count	11	4	31	10	24	25	11	25
Mean	68.65	7.31	8.23	2.14	4.48	0.50	0.94	1.49
Median	72.50	7.63	8.30	2.10	3.90	0.50	0.40	1.30
Max	96.00	8.92	10.28	4.40	11.90	0.50	4.60	3.70
Min	48.00	5.04	5.50	0.90	1.20	0.50	0.20	0.80
Four Corners NPDES (357)								
1/3/92 - 2/25/01								
Count	11	13	26	36	13	13	36	17
Mean	60.18	13.42	7.92	4.58	4.54	0.50	1.24	3.12
Median	54.00	6.52	7.90	2.35	4.50	0.50	0.65	1.30
Max	94.00	103.00	9.26	66.00	7.80	0.50	18.00	32.00
Min	45.00	1.55	6.20	0.60	1.40	0.50	0.10	0.70
Leach Cyn ChanOutlet (712)								
1/3/92 - 2/13/01								
Count	-	2	21	2	24	24	2	24
Mean	-	7.41	7.85	2.20	3.65	0.50	0.45	1.12
Median	-	7.41	8.00	2.20	3.05	0.50	0.45	0.95
Max	-	7.80	8.97	2.30	14.30	0.50	0.60	3.70
Min	-	7.01	3.00	2.10	0.50	0.50	0.30	0.60
Ortega Cyn Chan (714)								
1/3/92 - 2/13/01								
Count	-	2	13	2	13	13	2	13
Mean	-	7.51	7.94	2.25	3.73	0.50	0.50	1.13
Median	-	7.51	7.90	2.25	2.50	0.50	0.50	0.80
Max	-	7.58	8.68	2.70	12.00	0.50	0.70	3.30
Min	-	7.44	7.30	1.80	1.50	0.50	0.30	0.60
Salt Creek @ Mur Rd (745)								
1/11/01 - 3/3/01								
Count	-	3	22	-	21	22	1	22
Mean	-	7.63	8.16	-	2.03	0.50	2.70	0.81
Median	-	7.45	8.10	-	2.20	0.50	2.70	0.80
Max	-	8.20	8.80	-	3.70	0.50	2.70	1.30
Min	-	7.24	7.90	-	0.30	0.50	2.70	0.30
San Jacinto River @ Goetz Rd (759)								
2/21/96 - 3/2/01								
Count	-	1	15	2	16	17	3	17
Mean	-	7.13	8.22	2.80	4.01	0.51	1.53	1.19
Median	-	7.13	8.15	2.80	3.55	0.50	0.90	1.10
Max	-	7.13	8.60	3.10	8.30	0.60	3.20	2.10
Min	-	7.13	7.90	2.50	2.70	0.50	0.50	0.90
CynLk SD@Fairweather (790)								
1/11/01 - 3/2/01								
Count	-	-	-	-	2	3	1	3
Mean	-	-	-	-	6.50	0.50	2.90	1.50
Median	-	-	-	-	6.50	0.50	2.90	1.00
Max	-	-	-	-	10.70	0.50	2.90	2.60
Min	-	-	-	-	2.30	0.50	2.90	0.90
S.Jac.Riv @ Cranston (827)								
9/8/94 - 3/3/01								
Count	6	22	27	29	3	4	30	10
Mean	73.00	7.22	8.11	2.22	0.53	0.50	1.32	1.72
Median	73.50	7.61	7.99	1.90	0.50	0.50	0.90	0.65
Max	88.00	10.85	9.30	8.30	0.60	0.50	10.70	6.90
Min	53.00	0.35	6.90	0.20	0.50	0.50	0.10	0.20
Cyn Lk@ Sierra Park (834)								
1/11/01 - 3/2/01								
Count	-	1	1	-	3	4	1	4
Mean	-	8.40	8.30	-	15.63	0.50	2.80	2.98
Median	-	8.40	8.30	-	14.20	0.50	2.80	2.95
Max	-	8.40	8.30	-	22.40	0.50	2.80	5.10
Min	-	8.40	8.30	-	10.30	0.50	2.80	0.90
Stream R Exy/W TMDL (836)								
1/11/2001								
Count	-	1	1	-	1	1	-	1
Mean	-	8.20	8.98	-	17.80	0.50	-	5.20
Median	-	8.20	8.98	-	17.80	0.50	-	5.20
Max	-	8.20	8.98	-	17.80	0.50	-	5.20
Min	-	8.20	8.98	-	17.80	0.50	-	5.20
Salt Creek @CnL TMDL (839)								
1/11/01 - 2/27/01								
Count	-	-	1	-	3	4	1	4
Mean	-	-	5.30	-	2.33	0.50	9.20	1.10
Median	-	-	3.15	-	2.40	0.50	1.00	0.75
Max	-	-	5.30	-	2.50	0.50	9.20	2.20
Min	-	-	5.30	-	2.20	0.50	9.20	0.70
Canyon Lake Spillway (841)								
2/28/01 - 3/2/01								
Count	-	-	3	-	2	3	1	3
Mean	-	-	8.83	-	0.50	0.50	0.50	0.17
Median	-	-	8.70	-	0.50	0.50	0.50	0.10
Max	-	-	9.50	-	0.50	0.50	0.50	0.30
Min	-	-	8.30	-	0.50	0.50	0.50	0.10

Appendix B

Appendix B: Monthly nutrient loads to Canyon Lake

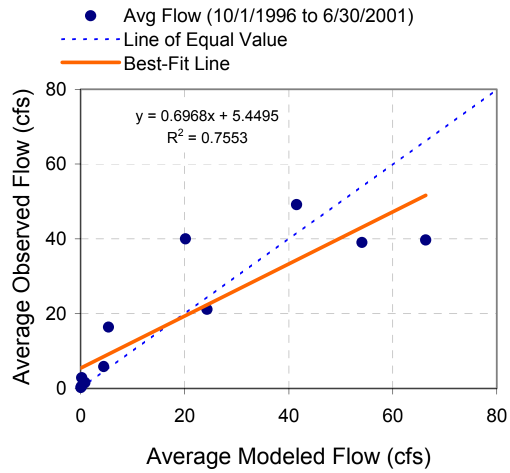
Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Oct-90	74.2	163.6	194.2	428.1
Nov-90	40.5	89.2	109.1	240.6
Dec-90	21.2	46.7	58.1	128.2
Jan-91	178.1	392.6	607.8	1339.9
Feb-91	625.2	1378.4	2636.8	5813.1
Mar-91	9011.2	19866.1	29556.6	65160.5
Apr-91	2648.1	5838.0	2718.0	5992.1
May-91	669.4	1475.8	500.3	1103.0
Jun-91	80.2	176.8	108.0	238.0
Jul-91	42.8	94.5	109.4	241.1
Aug-91	0.2	0.4	0.5	1.1
Sep-91	31.1	68.7	89.6	197.6
Oct-91	19.0	41.9	57.6	127.0
Nov-91	7.4	16.4	23.0	50.7
Dec-91	109.1	240.6	429.3	946.4
Jan-92	417.7	920.8	1731.1	3816.4
Feb-92	1163.0	2563.9	5998.4	13224.0
Mar-92	2440.8	5381.0	9593.9	21150.8
Apr-92	759.1	1673.4	566.6	1249.2
May-92	218.4	481.5	581.8	1282.6
Jun-92	1.7	3.8	4.6	10.2
Jul-92	1.1	2.4	2.4	5.4
Aug-92	31.8	70.2	105.1	231.7
Sep-92	0.0	0.0	0.0	0.0
Oct-92	102.1	225.2	352.2	776.4
Nov-92	5.9	13.1	18.3	40.4
Dec-92	719.8	1586.9	2693.9	5939.0
Jan-93	29507.7	65052.7	112191.9	247338.2
Feb-93	27304.8	60196.2	95132.9	209730.1
Mar-93	6024.6	13281.9	8516.0	18774.4
Apr-93	2979.0	6567.4	3585.5	7904.7
May-93	1260.3	2778.5	1689.3	3724.2
Jun-93	853.4	1881.5	1566.8	3454.1
Jul-93	225.2	496.6	576.5	1271.0
Aug-93	113.0	249.2	313.8	691.8
Sep-93	61.7	135.9	170.5	376.0
Oct-93	272.5	600.8	807.0	1779.0
Nov-93	258.2	569.3	747.1	1647.0
Dec-93	230.3	507.8	673.2	1484.1
Jan-94	347.1	765.2	1018.3	2244.9
Feb-94	736.3	1623.2	4243.4	9355.1
Mar-94	598.6	1319.7	2605.7	5744.6
Apr-94	135.9	299.5	428.6	944.8
May-94	67.7	149.2	212.0	467.4

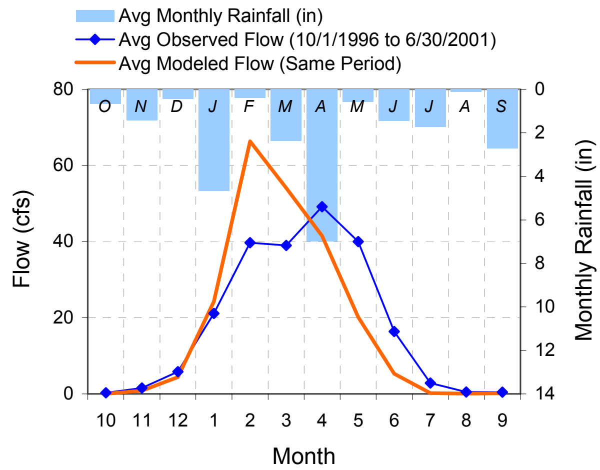
Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Jun-94	33.3	73.3	106.7	235.3
Jul-94	11.5	25.3	39.0	86.0
Aug-94	7.8	17.2	22.0	48.4
Sep-94	0.4	0.8	1.1	2.4
Oct-94	0.6	1.3	1.3	2.8
Nov-94	2.1	4.7	5.1	11.2
Dec-94	77.4	170.7	199.7	440.3
Jan-95	4209.7	9280.7	12832.3	28290.1
Feb-95	6481.2	14288.3	18152.8	40019.7
Mar-95	16535.0	36453.2	38287.9	84409.6
Apr-95	3053.2	6731.2	3024.0	6666.8
May-95	1425.3	3142.1	910.2	2006.5
Jun-95	625.5	1379.0	413.5	911.6
Jul-95	185.6	409.2	67.7	149.4
Aug-95	23.1	50.9	53.6	118.3
Sep-95	0.5	1.0	1.2	2.8
Oct-95	39.5	87.1	123.3	271.9
Nov-95	21.4	47.1	68.4	150.9
Dec-95	16.0	35.3	48.7	107.4
Jan-96	425.5	938.1	1302.8	2872.1
Feb-96	626.1	1380.2	4287.6	9452.4
Mar-96	925.5	2040.3	1612.8	3555.6
Apr-96	420.6	927.2	151.1	333.2
May-96	43.3	95.5	18.6	41.0
Jun-96	1.2	2.6	3.3	7.3
Jul-96	0.1	0.3	0.4	0.9
Aug-96	0.0	0.0	0.0	0.0
Sep-96	0.0	0.0	0.0	0.0
Oct-96	27.8	61.2	62.5	137.8
Nov-96	240.9	531.0	1175.2	2590.8
Dec-96	116.3	256.3	504.7	1112.6
Jan-97	2239.6	4937.5	5250.1	11574.4
Feb-97	1259.9	2777.5	686.5	1513.5
Mar-97	684.0	1507.9	283.4	624.7
Apr-97	99.4	219.2	20.4	44.9
May-97	0.0	0.0	0.0	0.0
Jun-97	0.0	0.0	0.0	0.0
Jul-97	0.0	0.0	0.0	0.0
Aug-97	0.0	0.0	0.0	0.0
Sep-97	131.4	289.6	497.7	1097.2
Oct-97	0.1	0.2	0.2	0.4
Nov-97	60.1	132.5	151.5	334.1
Dec-97	495.4	1092.3	2426.3	5349.0
Jan-98	659.0	1452.9	3748.0	8262.9
Feb-98	24465.1	53935.8	97505.2	214960.0
Mar-98	7116.3	15688.6	11381.2	25091.0

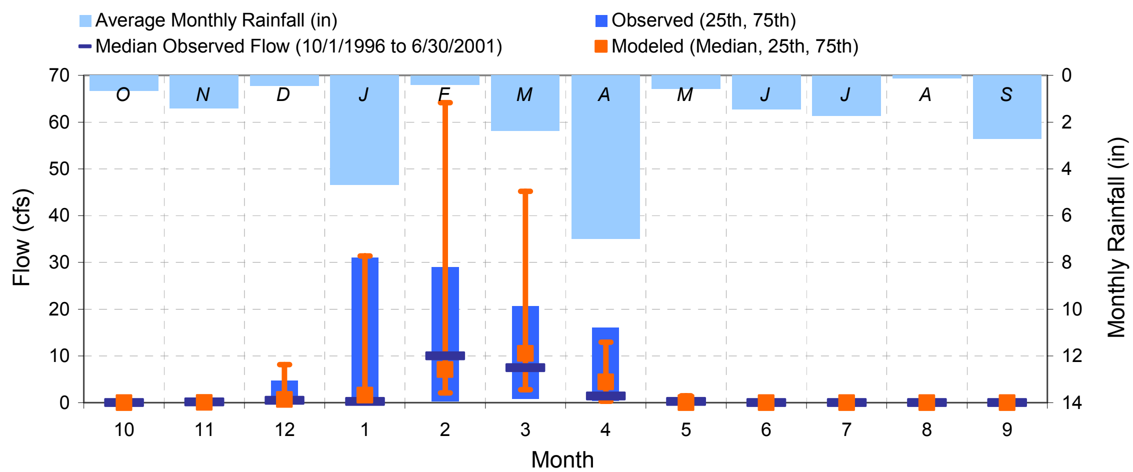
Month	Monthly TP (kg)	Monthly TP (lbs)	Monthly TN (kg)	Monthly TN (lbs)
Apr-98	5204.0	11472.8	7911.6	17442.0
May-98	3694.1	8144.0	6106.6	13462.7
Jun-98	1051.8	2318.7	882.5	1945.6
Jul-98	230.0	507.1	251.5	554.6
Aug-98	27.7	61.0	69.6	153.5
Sep-98	26.9	59.3	74.4	164.1
Oct-98	219.5	483.8	656.1	1446.5
Nov-98	183.2	403.9	551.9	1216.8
Dec-98	172.1	379.5	516.6	1138.9
Jan-99	403.0	888.5	1192.5	2628.9
Feb-99	206.3	454.7	701.9	1547.4
Mar-99	102.8	226.5	320.2	706.0
Apr-99	459.7	1013.6	1575.4	3473.2
May-99	57.8	127.4	186.9	412.0
Jun-99	46.7	102.9	138.6	305.5
Jul-99	167.1	368.4	533.4	1175.9
Aug-99	1.7	3.7	6.2	13.7
Sep-99	0.3	0.7	0.8	1.9
Oct-99	0.0	0.0	0.0	0.0
Nov-99	0.0	0.0	0.0	0.0
Dec-99	0.0	0.0	0.0	0.0
Jan-00	10.6	23.3	23.7	52.3
Feb-00	845.2	1863.3	5188.0	11437.5
Mar-00	641.2	1413.5	5676.6	12514.6
Apr-00	176.8	389.8	595.5	1312.9
May-00	0.1	0.3	0.5	1.1
Jun-00	0.0	0.0	0.0	0.0
Jul-00	0.0	0.0	0.0	0.0
Aug-00	0.0	0.0	0.0	0.0
Sep-00	0.2	0.4	0.3	0.7
Oct-00	95.1	209.8	303.1	668.1
Nov-00	0.0	0.0	0.0	0.0
Dec-00	0.0	0.0	0.0	0.0

Appendix C

Summary statistics of model hydrology calibration to USGS gage 11069500 (1 of 2)

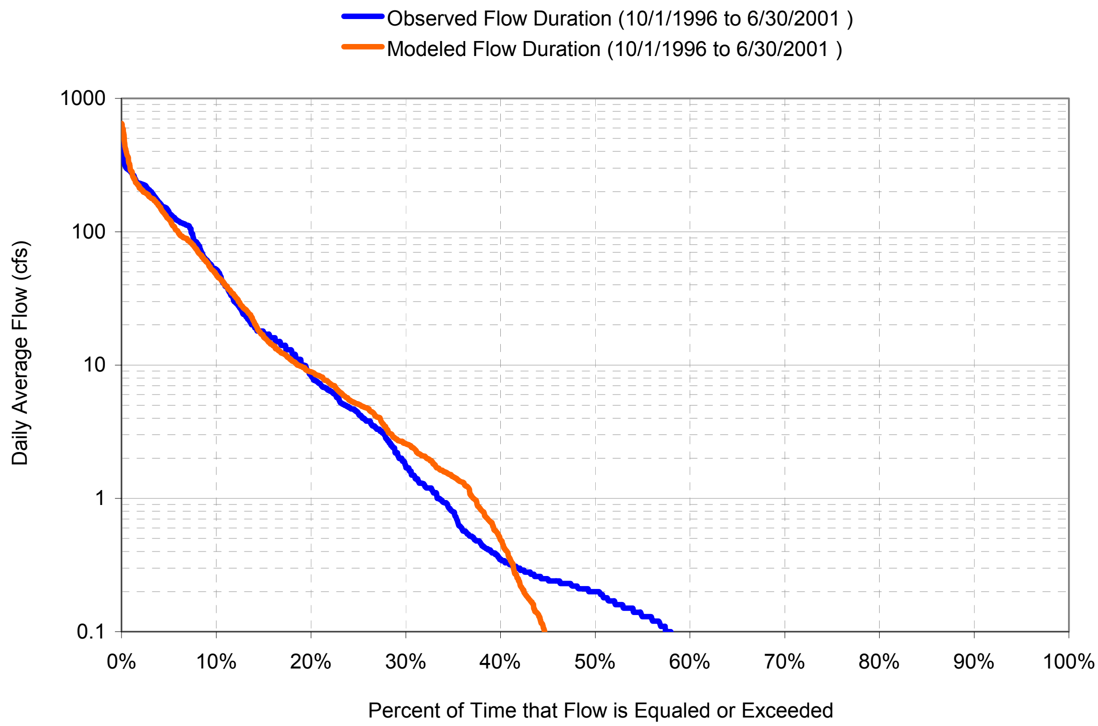


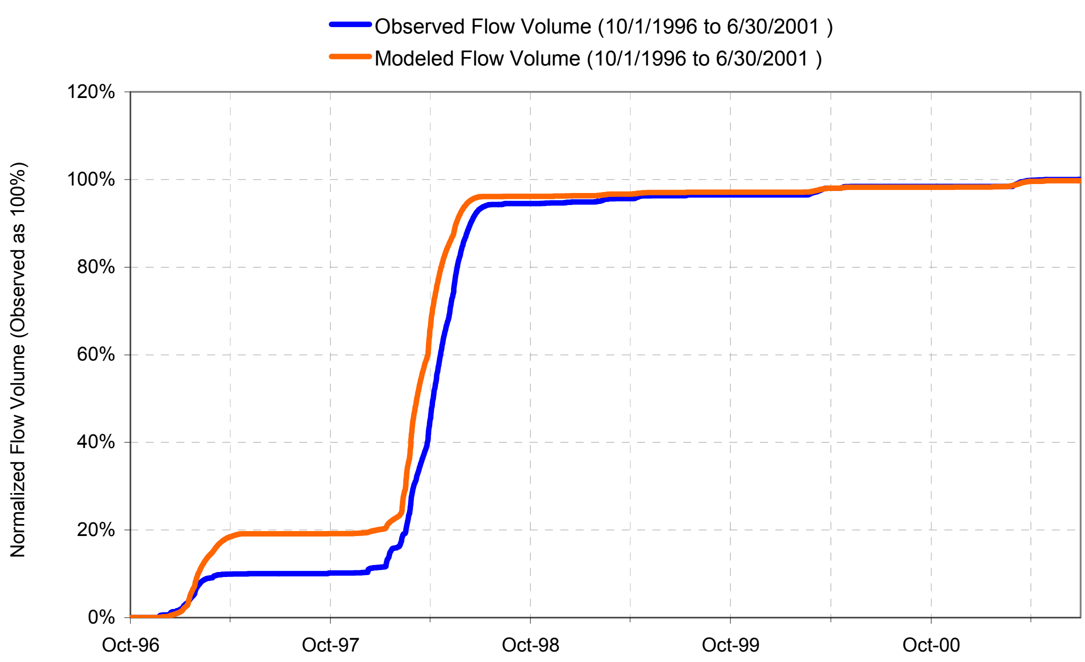




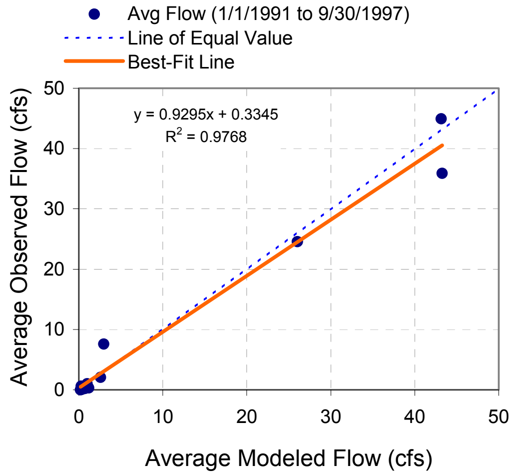
MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	0.27	0.02	0.00	0.14	0.06	0.00	0.00	0.00
Nov	1.58	0.16	0.00	0.48	0.84	0.03	0.00	0.96
Dec	5.85	0.48	0.00	4.75	4.46	0.67	0.00	8.15
Jan	21.15	0.25	0.04	31.00	24.31	1.63	0.06	31.37
Feb	39.67	10.00	0.29	29.00	66.32	7.08	2.09	64.14
Mar	39.00	7.45	0.79	20.58	54.09	10.52	2.80	45.22
Apr	49.18	1.40	0.41	16.00	41.50	4.44	0.28	12.93
May	40.01	0.23	0.08	0.81	20.17	0.00	0.00	1.48
Jun	16.41	0.00	0.00	0.35	5.34	0.00	0.00	0.00
Jul	2.87	0.00	0.00	0.27	0.23	0.00	0.00	0.00
Aug	0.56	0.00	0.00	0.02	0.14	0.00	0.00	0.00
Sep	0.47	0.00	0.00	0.09	0.17	0.00	0.00	0.00

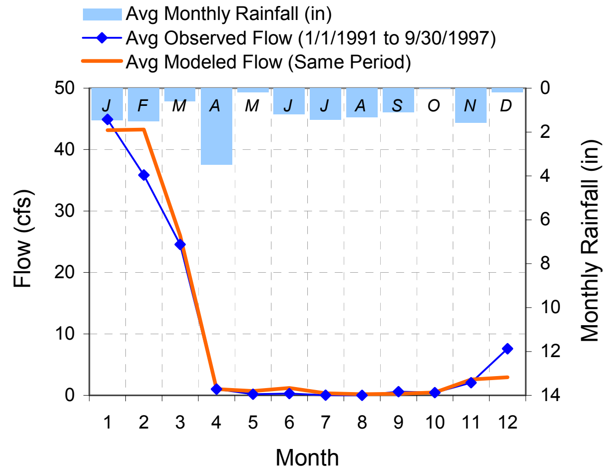
Summary statistics of model hydrology calibration to USGS gage 11069500 (2 of 2)

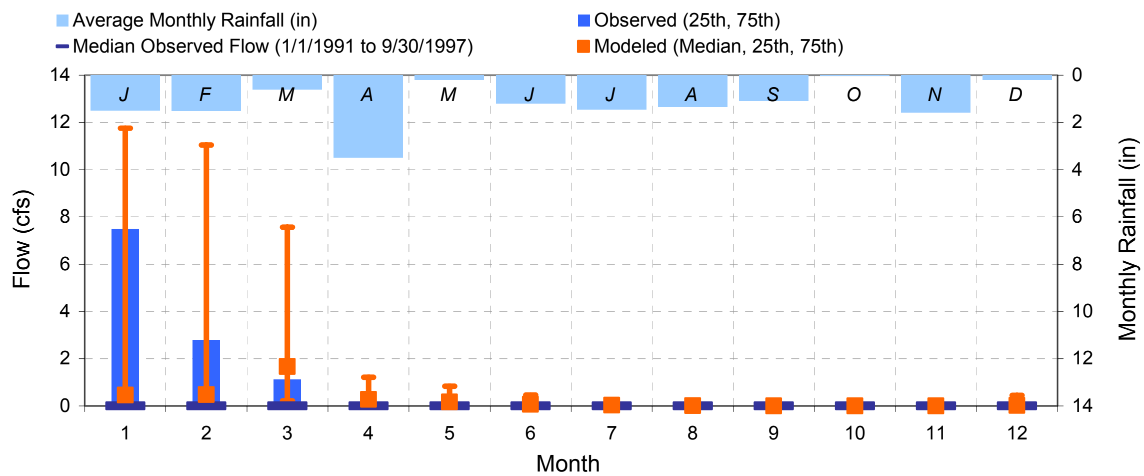




Summary statistics of model hydrology calibration to USGS gage 11070270 (1 of 2)

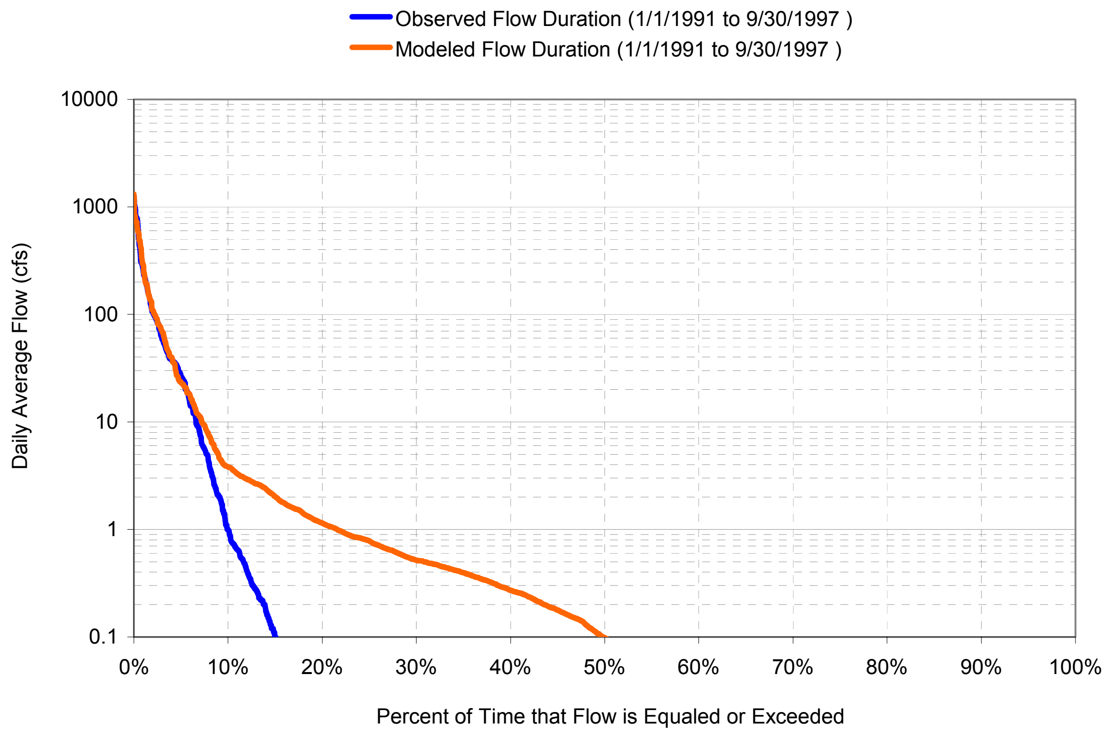


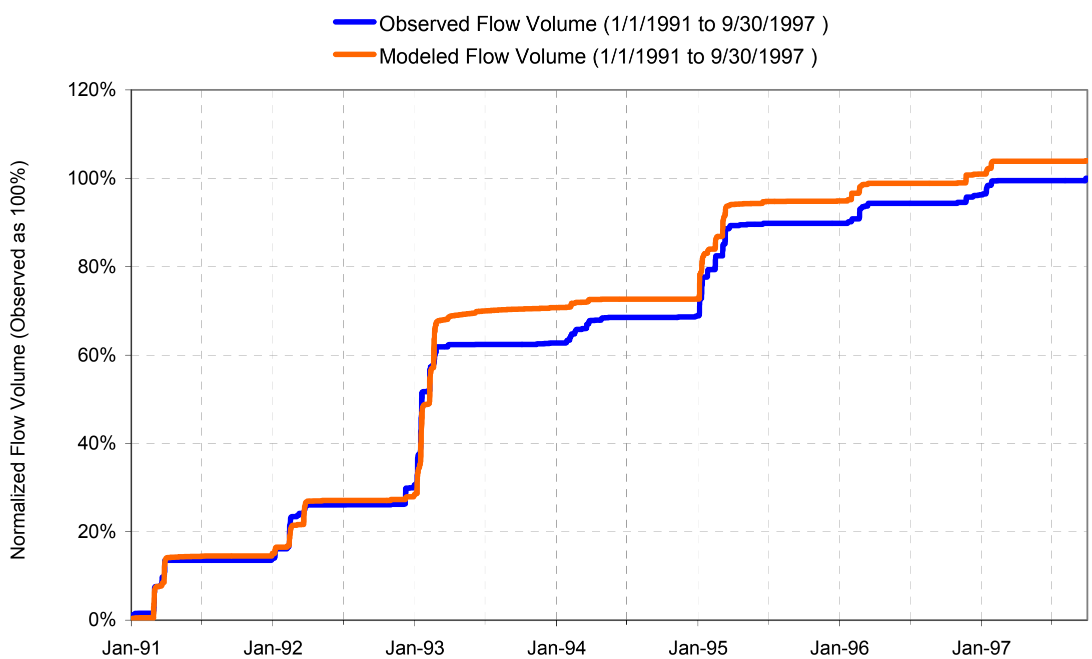




MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	44.91	0.00	0.00	7.50	43.16	0.46	0.09	11.75
Feb	35.88	0.00	0.00	2.78	43.27	0.48	0.24	11.05
Mar	24.56	0.00	0.00	1.10	26.03	1.66	0.21	7.56
Apr	0.99	0.00	0.00	0.00	0.99	0.27	0.04	1.21
May	0.18	0.00	0.00	0.00	0.73	0.17	0.01	0.83
Jun	0.31	0.00	0.00	0.00	1.19	0.07	0.00	0.46
Jul	0.02	0.00	0.00	0.00	0.34	0.03	0.00	0.26
Aug	0.01	0.00	0.00	0.00	0.19	0.01	0.00	0.15
Sep	0.61	0.00	0.00	0.00	0.27	0.00	0.00	0.09
Oct	0.45	0.00	0.00	0.00	0.48	0.00	0.00	0.07
Nov	2.07	0.00	0.00	0.00	2.59	0.00	0.00	0.03
Dec	7.60	0.00	0.00	0.07	2.95	0.02	0.00	0.45

Summary statistics of model hydrology calibration to USGS gage 11070270 (2 of 2)





Appendix D

Table D-1 Total nitrogen loading rates (lbs/acre/year) for Scenario 1 (WY 1998)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	2.315	3.047	2.094	2.577	3.693	2.517	4.390	6.831	2.508
Dairy/Livestock	na	na	63.997	52.495	87.011	78.348	116.999	320.359	na
Forest	0.320	0.406	0.295	0.422	0.457	0.359	0.524	1.375	1.403
Urban	2.207	1.389	1.179	1.695	1.775	1.209	2.136	1.847	1.982
High-Density Residential	4.431	2.415	2.409	3.800	3.136	2.410	3.831	5.008	5.867
Medium-Density Residential	na	1.153	1.153	2.378	1.867	1.153	2.610	2.087	na
Low-Density Residential	1.373	1.128	0.761	1.313	1.327	0.780	1.327	1.123	1.050
Mobile Home/Trailor Park	na	2.619	2.417	3.308	2.738	2.417	3.827	5.602	na
Open	1.162	1.322	1.101	1.708	1.663	1.258	1.677	4.236	3.815
Orchard/Vineyards	0.824	1.116	0.894	1.473	1.104	0.914	1.164	2.298	3.627
Pasture	2.496	2.956	2.214	2.669	3.327	2.678	3.925	8.399	8.608

na: not applicable; zone does not contain area assigned to landuse

Table D-2 Total phosphorus loading rates (lbs/acre/year) for Scenario 1 (WY 1998)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	0.981	1.291	0.883	1.106	1.582	1.056	1.885	2.947	1.085
Dairy/Livestock	na	na	6.405	5.252	8.708	7.842	11.703	32.045	na
Forest	0.130	0.163	0.118	0.169	0.183	0.144	0.210	0.550	0.561
Urban	1.009	0.527	0.529	0.644	0.595	0.536	0.727	1.155	1.272
High-Density Residential	0.847	0.431	0.430	0.640	0.530	0.430	0.644	0.691	0.775
Medium-Density Residential	na	0.215	0.215	0.405	0.334	0.215	0.437	0.314	na
Low-Density Residential	0.236	0.175	0.145	0.207	0.200	0.146	0.210	0.161	0.149
Mobile Home/Trailor Park	na	0.447	0.430	0.568	0.471	0.430	0.643	0.750	na
Open	0.095	0.100	0.083	0.120	0.127	0.097	0.119	0.296	0.266
Orchard/Vineyards	0.175	0.226	0.183	0.297	0.225	0.188	0.235	0.462	0.731
Pasture	0.267	0.306	0.229	0.273	0.346	0.280	0.398	0.854	0.875

na: not applicable; zone does not contain area assigned to landuse

Table D-3 Total nitrogen loading rates (lbs/acre/year) for Scenario 2 (WY 1994)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	0.499	0.424	0.270	0.344	0.475	0.309	0.641	0.596	0.086
Dairy/Livestock	na	na	9.764	7.600	13.196	12.388	17.505	97.474	na
Forest	0.096	0.061	0.049	0.069	0.059	0.056	0.072	0.423	0.431
Urban	0.738	0.340	0.206	0.522	0.508	0.217	0.753	0.679	0.750
High-Density Residential	1.498	0.849	0.844	1.362	1.200	0.847	1.378	2.360	3.290
Medium-Density Residential	na	0.317	0.317	0.703	0.436	0.317	0.795	0.905	na
Low-Density Residential	0.421	0.291	0.149	0.357	0.303	0.159	0.347	0.484	0.441
Mobile Home/Trailor Park	na	0.902	0.848	1.092	0.939	0.847	1.375	2.967	na
Open	0.365	0.200	0.167	0.252	0.213	0.185	0.212	1.319	1.191
Orchard/Vineyards	0.251	0.169	0.138	0.222	0.130	0.142	0.168	0.713	1.090
Pasture	0.797	0.459	0.337	0.413	0.421	0.420	0.580	2.492	2.547

na: not applicable; zone does not contain area assigned to landuse

Table D-4 Total phosphorus loading rates (lbs/acre/year) for Scenario 2 (WY 1994)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	0.216	0.066	0.000	0.025	0.069	0.000	0.027	0.091	0.037
Dairy/Livestock	na	na	0.977	0.760	1.320	1.239	1.751	9.748	na
Forest	0.038	0.024	0.020	0.028	0.024	0.022	0.029	0.169	0.172
Urban	0.291	0.139	0.067	0.205	0.227	0.072	0.313	0.176	0.196
High-Density Residential	0.308	0.168	0.167	0.333	0.276	0.166	0.337	0.432	0.568
Medium-Density Residential	na	0.067	0.067	0.184	0.114	0.067	0.207	0.168	na
Low-Density Residential	0.081	0.072	0.029	0.084	0.077	0.029	0.087	0.071	0.066
Mobile Home/Trailor Park	na	0.201	0.167	0.275	0.215	0.167	0.335	0.521	na
Open	0.025	0.014	0.011	0.017	0.015	0.013	0.014	0.089	0.080
Orchard/Vineyards	0.050	0.034	0.028	0.045	0.026	0.029	0.034	0.143	0.217
Pasture	0.080	0.046	0.034	0.042	0.042	0.043	0.058	0.250	0.255

na: not applicable; zone does not contain area assigned to landuse

Table D-5 Total nitrogen loading rates (lbs/acre/year) for Scenario 3 (WY 2000)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	0.379	0.619	0.427	0.541	0.848	0.493	0.856	0.320	0.109
Dairy/Livestock	na	na	16.470	15.919	19.588	17.247	22.109	74.101	na
Forest	0.084	0.084	0.074	0.080	0.095	0.077	0.099	0.373	0.376
Urban	0.444	0.437	0.298	0.491	0.630	0.304	0.670	0.649	0.653
High-Density Residential	0.893	1.015	1.013	1.096	1.147	1.014	1.100	2.755	2.829
Medium-Density Residential	na	0.344	0.344	0.658	0.620	0.344	0.721	0.951	na
Low-Density Residential	0.259	0.366	0.163	0.347	0.430	0.166	0.397	0.440	0.431
Mobile Home/Trailor Park	na	1.050	1.015	1.028	1.077	1.015	1.102	2.803	na
Open	0.318	0.273	0.256	0.307	0.334	0.268	0.358	1.142	1.098
Orchard/Vineyards	0.211	0.245	0.194	0.259	0.270	0.195	0.240	0.692	0.832
Pasture	0.675	0.646	0.559	0.585	0.778	0.582	0.751	2.203	2.223

na: not applicable; zone does not contain area assigned to landuse

Table D-6 Total phosphorus loading rates (lbs/acre/year) for Scenario 3 (WY 2000)

Landuse	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9
Cropland	0.164	0.267	0.183	0.233	0.366	0.212	0.370	0.139	0.047
Dairy/Livestock	na	na	1.647	1.592	1.959	1.725	2.211	7.410	na
Forest	0.033	0.034	0.030	0.032	0.038	0.031	0.039	0.149	0.150
Urban	0.176	0.176	0.115	0.204	0.262	0.118	0.284	0.149	0.155
High-Density Residential	0.175	0.197	0.196	0.228	0.222	0.197	0.229	0.499	0.508
Medium-Density Residential	na	0.063	0.063	0.143	0.125	0.063	0.158	0.170	na
Low-Density Residential	0.050	0.074	0.026	0.072	0.088	0.026	0.083	0.064	0.063
Mobile Home/Trailor Park	na	0.206	0.196	0.211	0.211	0.197	0.228	0.505	na
Open	0.022	0.019	0.018	0.021	0.023	0.019	0.025	0.077	0.074
Orchard/Vineyards	0.042	0.049	0.039	0.052	0.054	0.039	0.048	0.139	0.165
Pasture	0.068	0.065	0.057	0.059	0.079	0.059	0.076	0.221	0.223

na: not applicable; zone does not contain area assigned to landuse

Table D-7 Distribution of loads to Canyon Lake and Lake Elsinore by source (WY 1998)

Land Use	Total Nitrogen				Total Phosphorus			
	A Into Canyon Lake (lbs)	B From Canyon Lake (lbs)	C Local Lake Elsinore (lbs)	D Total to Lake Elsinore (B+C)	E Into Canyon Lake (lbs)	F From Canyon Lake (lbs)	G Local Lake Elsinore (lbs)	H Total to Lake Elsinore (F+G)
Cropland	32.7	10.2	3.7	10.0	48.5	20.9	8.5	20.7
Dairy/Livestock	11.0	3.4	0.0	3.3	6.7	2.9	0.0	2.8
Forest	12.9	4.0	17.8	4.4	27.9	12.0	39.0	12.6
Urban	3.5	1.1	5.0	1.2	3.9	1.7	12.3	1.9
High-Density Residential	0.6	0.2	3.5	0.3	0.3	0.1	3.6	0.2
Medium-Density Residential	4.9	1.5	0.0	1.5	2.3	1.0	0.0	1.0
Low-Density Residential	4.3	1.3	12.6	1.6	2.1	0.9	11.7	1.1
Mobile Home/Trailor Park	0.8	0.2	0.0	0.2	0.4	0.2	0.0	0.2
Open	0.6	0.2	1.8	0.2	0.2	0.1	0.8	0.1
Orchard/Vineyards	0.5	0.2	0.1	0.2	0.5	0.2	0.1	0.2
Pasture	3.1	1.0	9.2	1.2	1.3	0.5	5.3	0.6
Septics	25.1	7.8	46.2	8.9	6.1	2.6	18.7	2.9
Internal Canyon Lake Source	na	68.9	na	67.0	na	56.8	na	55.7
Total Load	287,720	926,220	26,412	952,632	94,865	219,524	4,373	223,896

Table D-8 Distribution of loads to Canyon Lake and Lake Elsinore by source (WY 1994)

Land Use	Total Nitrogen				Total Phosphorus			
	A Into Canyon Lake (lbs)	B From Canyon Lake (lbs)	C Local Lake Elsinore (lbs)	D Total to Lake Elsinore (B+C)	E Into Canyon Lake (lbs)	F From Canyon Lake (lbs)	G Local Lake Elsinore (lbs)	H Total to Lake Elsinore (F+G)
Cropland	33.6	21.3	3.6	20.0	48.8	48.8	7.1	36.8
Dairy/Livestock	5.7	3.6	0.0	3.3	2.0	2.0	0.0	1.4
Forest	8.5	5.4	23.7	6.7	11.5	11.5	43.3	20.6
Urban	8.4	5.3	7.5	5.5	10.9	10.9	13.4	11.6
High-Density Residential	2.7	1.7	5.3	1.9	2.0	2.0	4.9	2.8
Medium-Density Residential	13.4	8.5	0.0	7.9	10.6	10.6	0.0	7.6
Low-Density Residential	9.5	6.0	17.2	6.8	7.6	7.6	15.1	9.8
Mobile Home/Trailor Park	2.6	1.6	0.0	1.5	2.0	2.0	0.0	1.4
Open	0.5	0.3	2.6	0.5	0.1	0.1	0.8	0.3
Orchard/Vineyards	0.6	0.4	0.1	0.4	0.4	0.4	0.1	0.3
Pasture	3.8	2.4	13.1	3.2	1.3	1.3	6.0	2.7
Septics	10.6	6.7	26.9	8.1	2.8	2.8	9.2	4.6
Internal Canyon Lake Source	na	36.7	na	34.1	na	0.0	na	0.0
Total Load	24,039	37,992	2,929	40,922	5,951	1,240	500	1,740

Table D-8 Distribution of loads to Canyon Lake and Lake Elsinore by source (WY 2000)

Land Use	Total Nitrogen				Total Phosphorus			
	A Into Canyon Lake (lbs)	B From Canyon Lake (lbs)	C Local Lake Elsinore (lbs)	D Total to Lake Elsinore (B+C)	E Into Canyon Lake (lbs)	F From Canyon Lake (lbs)	G Local Lake Elsinore (lbs)	H Total to Lake Elsinore (F+G)
Cropland	32.2	32.2	4.0	20.4	54.1	54.1	7.3	49.2
Dairy/Livestock	4.7	4.7	0.0	2.7	1.8	1.8	0.0	1.6
Forest	7.0	7.0	30.8	16.9	11.6	11.6	51.5	15.8
Urban	5.9	5.9	6.7	6.2	8.0	8.0	11.1	8.3
High-Density Residential	1.3	1.3	4.7	2.7	1.0	1.0	3.8	1.3
Medium-Density Residential	8.6	8.6	0.0	5.0	5.3	5.3	0.0	4.7
Low-Density Residential	7.6	7.6	15.7	11.0	6.1	6.1	12.6	6.8
Mobile Home/Trailor Park	1.4	1.4	0.0	0.8	1.0	1.0	0.0	0.9
Open	0.5	0.5	3.3	1.7	0.1	0.1	1.0	0.2
Orchard/Vineyards	0.4	0.4	0.1	0.3	0.3	0.3	0.1	0.3
Pasture	3.1	3.1	16.5	8.7	1.2	1.2	7.0	1.8
Septics	27.4	27.4	18.1	23.5	9.5	9.5	5.7	9.1
Internal Canyon Lake Source	na	0.0	na	0.0	na	0.0	na	0.0
Total Load	25,319	1,001	721	1,722	3,690	914	108	1,022

Appendix E

Santa Ana Watershed Project Authority

SAWPA

COMMISSION FOR THE PROJECT AUTHORITY

EASTERN MUNICIPAL WATER DISTRICT
INLAND EMPIRE UTILITIES AGENCY
ORANGE COUNTY WATER DISTRICT
SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT
WESTERN MUNICIPAL WATER DISTRICT

GENERAL MANAGER

P. JOSEPH GRINDSTAFF

November 12, 2002

Andrew Parker, Project Manager
Tetra Tech Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 22030.

Re: Comments: Lake Elsinore and Canyon Lake Nutrient Source Assessment

Mr. Parker,

We have reviewed the Lake Elsinore and Canyon Lake Nutrient Source Assessment. Our initial comments on the report are as follows:

1. Please show a regression analysis (R^2 value) and summary statistics (annual flows, outfalls) for the hydrology calibration for both the in-stream and lake models.
2. Please show a table, which breaks out the loading by source into Canyon Lake (including percentages).
3. Please show comments on the appropriateness to the San Jacinto Watershed of the land use build up rates taken from literature for total nitrogen and total phosphorus.
4. How were the "zero flow" occurrences from the long dry periods in the watershed dealt with in the water quality modeling? Generally, the model reports unrealistic values when flows drop to zero. This is important for this model, due to the long dry periods and infrequency of storm events.
5. Looking at the hydrology plots with multiple curves it is difficult to distinguish between the two curves. Could we make the curve in the forefront dashed?
6. Figures 4-25, 4-35, and 4-36 located on pages 4-38, 4-42 and 4-42 respectively have incorrect figure headings.

If you have any questions or comments, please call Rick Whetsel at (909) 354-4222.

Sincerely,

Mark Norton

Mark Norton
Planning Dept. Manager

11615 Sterling Avenue, Riverside, CA 92503-4979 • (909) 354-4220
Administration FAX (909) 785-7076 • Planning FAX (909) 352-3422

California Regional Water Quality Control Board
Santa Ana Region

Winston H. Hickox
Secretary for Environmental Protection

3737 Main Street, Suite 500, Riverside, California 92501-3348
Phone (909) 782-4130 - FAX (909) 781-6288

Gray Davis
Governor

TO: Andrew Parker
Tetra Tech, Inc.

FROM: Cindy Li
SANTA ANA REGIONAL WATER QUALITY CONTROL BOARD

DATE: November 15, 2002

SUBJECT: LAKE ELSINORE AND CANYON LAKE NUTRIENT SOURCE ASSESSMENT – FINAL REPORT

I downloaded the above-mentioned document from your *ftp* site on October 23, 2002. After reviewing the report by Adam Fisher and myself, we are providing the following comments.

1. On page 35, it was stated that it is unknown if the current dairy operations meet the 24-hour 25-year storm storage requirement. Most meet the requirement now and all of them could be expected to meet the requirements within two years if not a year. It should be kept in mind that during the model run periods, almost none of the dairies met the requirement and a number of dairies discharged manured runoff directly into tributaries to the San Jacinto River. Nearly all of those conditions have been corrected since to some degree. This could be a factor in the result errors.

2. On page 62, the report referred to the assumed 12 dry tons/acre/yr. Adam Fisher wrote a report trying to estimate the rate that it was over applied. See the attached file.

3. The report provided the monthly total phosphorus and total nitrogen loads to Canyon Lake and Lake Elsinore. But the main objective of the project is to simulate the flow and nutrient loads from different sources as specified by land use types. The report should provide the contribution of nutrients to Canyon Lake and Lake Elsinore by source under various hydrologic conditions. For example, the contribution of nutrients to Lake Elsinore should be summarized into San Jacinto River, and local watershed (which should be further summarized by land use types). For Canyon Lake, the nutrient contribution can be summarized into San Jacinto River, Salt Creek, Perris Channel storm drain, and land use types in each sub-watershed.