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Appendices

Appendix A Supporting Biological Data

Appendix B Tabular Summary of Model Subarea Characteristics Used to Parameterize the Watershed Runoff Model

Acronyms

AFY	Acre-feet/year
AF	Acre-feet
af/d	Acre-feet/day
AgNMP	Agricultural Nutrient Management Plan
Alum	Aluminum sulfate
BASINS	Better Assessment Science Integrating Point and Non-Point Sources
Basin Plan	Water Quality Control Plan for the Santa Ana River Basin
BMP	best management practice
BOD	Biological Oxygen Demand
°C	degrees Celsius
C	Concentration
CAEDYM	Computational Aquatic Ecosystem Dynamics Model
CAFO	Concentrated Animal Feeding Operation
CCC	Criterion Continuous Concentration (chronic)
CDF	Cumulative Distribution Frequency
CDFG	California Department of Fish and Game
CEDEN	California Environment Data Exchange Network
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
cm	centimeter
CMC	Criterion Maximum Concentration (acute)
CNRP	Comprehensive Nutrient Reduction Plan
COD	Chemical Oxygen Demand
CSTR	Continuous Stirred Tank Reactor
CWAD	Conditional Waiver for Agricultural Discharges
DCIA	Directly Connected Impervious Area
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DYRESM	Dynamic Reservoir Simulation Model
EA	Environmental Assessment
EC	Electrical Conductivity
EFDC	Environmental Fluids Dynamic Code
ELCOM	Estuary, Lake and Coastal Ocean Model

CDM Smith

EPA	United States Environmental Protection Agency
EMWD	Eastern Municipal Water District
EVWMD	Elsinore Valley Water Management District
ft	feet
$g/m^2/d$	grams/square meter/day
HBI	Hilsenhoff Biotic Index
IMP	Imperviousness
in/yr	inch/year
IR	Infrared
kg	kilogram
kg/yr	kilograms/year
LA	Load allocation
lb	pound
LC_{50}	Lethal Concentration with 50% mortality
LEAMS	Lake Elsinore Aeration and Mixing System
LECL Task Force	Lake Elsinore and Canyon Lake Task Force
LEMA	Lake Elsinore Management Authority
LEMP	Lake Elsinore Management Plan
LID	Low Impact Development
LSPC	Loading Simulation Program in C+
m	meter
mL	milliliters
mg/L	Milligrams/liter
mg/mL	milligrams/milliliter
$mg/m^2/d$	milligrams/square meter/day
mi^2	Square miles
MRLC	Multi-Resolution Land Characteristics Consortium
MSL	Mean Sea Level
µg/L	Micrograms/liter
µS/cm	microSiemens/centimeter
MS4	Municipal Separate Storm Sewer System
MUN	Municipal and Domestic Water Supply
nm	nanometer
NAWQA	National Water Quality Assessment
NH_3	Un-ionized Fraction of Total Ammonia
NNE	Numeric Nutrient Endpoint

NPDES	National Pollutant Discharge Elimination System
NSQD	National Stormwater Quality Database
Org/L	Organisms/Liter
Ortho-P	Orthophosphate
OSTDS	Onsite Sanitary Treatment and Disposal Systems
PAR	Photosynthetically Active Radiation
PLOAD	Pollutant Loading Estimator
POA	Property Owners Association
ppt	Parts per thousand
Q	Discharge
RC	Runoff Coefficient
RCFCWCD	Riverside County Flood Control and Water Conservation District
REC1	Water Contact Recreation
REC2	Non-Contact Water Recreation
RWRF	Regional Water Reclamation Facility
%RE	Percent Relative Error
Santa Ana Water Board	Santa Ana Regional Water Quality Control Board
SAWPA	Santa Ana Watershed Protection Authority
SMAV	Species Mean Acute Value
SOD	Sediment Oxygen Demand
SRP	Soluble Reactive Phosphorus
SSD	Species Sensitivity Distribution
SSURGO	Soil Survey Geographic Database
$t_{1/2}$	half life
Task Force	Lake Elsinore/Canyon Lake Task Force
TIN	Total Inorganic Nitrogen
TKN	Total Kjeldahl Nitrogen
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
State Water Board	State Water Resources Control Board
UCR	University of California, Riverside
USGS	U.S. Geological Survey
UV	Ultraviolet

V	Volume
W/m	Watts/square meter
WARM	Warm Freshwater Habitat
WLA	Wasteload Allocation
WQO	Water Quality Objective
WRCAC	Western Riverside County Agricultural Coalition

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Chapter 1

Introduction

Lake Elsinore first appeared on California's 303(d) list of impaired waterbodies in 1994. Canyon Lake was added to that list in 1998. The lakes were deemed to be impaired by low dissolved oxygen (DO) levels and excess algae growth. Elevated nutrient concentrations (e.g., phosphorus and nitrogen) were cited as the primary cause of poor water quality in both lakes.

The Santa Ana Regional Water Quality Control Board (Santa Ana Water Board) adopted a Total Maximum Daily Load (TMDL) for nutrient discharges to Canyon Lake and Lake Elsinore in 2004 (Santa Ana Water Board 2004a). The TMDL became effective when the United States Environmental Protection Agency (EPA) gave it final approval on September 30, 2005. The scientific data and analysis used to justify the TMDL is summarized in a detailed technical support document prepared by the Santa Water Board staff (Santa Ana Water Board 2004b).

The TMDL specified numeric targets for DO, Chlorophyll-*a*, Ammonia, Total Phosphorus (TP) and Total Nitrogen (TN) concentrations in both lakes (see Table 2-3). It also established Load Allocations (LA) and Waste Load Allocations (WLA) to govern the discharge of excess nutrients from non-point sources and point sources, respectively. The TMDL includes a detailed Implementation Plan which describes a variety of activities that must be undertaken to meet water quality standards in Canyon Lake and Lake Elsinore. In the decade following EPA's approval, stakeholders throughout the watershed initiated a large number of programs and projects to comply with the requirements set forth in the TMDL Implementation Plan.

- From 2002-2008, fisheries management was implemented as a means of enhancing water quality in the lake. Carp were periodically removed to reduce the impact of their feeding behavior of rooting through the sediments which increases turbidity and enhances the release of nutrients from the lake sediments. An assessment of the program in 2008 showed significant reductions in carp (City of Lake Elsinore 2008).
- In 2005, the stakeholders formed the Lake Elsinore and Canyon Lake Task Force ("LECL Task Force") to coordinate and share the cost of all implementation efforts. The LECL Task Force is comprised of all the dischargers identified in the TDML, including: Municipal Separate Storm Sewer System (MS4) permittees, wastewater treatment plants, agricultural operators, concentrated animal feeding operations (dairies), and a number of other state, federal, or tribal agencies that own land or operate facilities that discharge in the watershed.
- In 2006, the LECL Task Force developed and submitted a water quality monitoring program for both lakes and the major tributary streams (LESJWA 2006). This plan was approved by the Santa Ana Water Board on March 3, 2006 (Santa Ana Water Board 2006).
- In 2007, the LECL Task Force developed and submitted a Sediment Nutrient Reduction Plan for Lake Elsinore (LECL Task Force 2007), which was subsequently approved by the Santa Ana Water Board (Santa Ana Water Board 2007b).

- In 2008, the Lake Elsinore Aeration and Mixing System (LEAMS) project, designed to improve water quality in Lake Elsinore, began full-time operation.
- In 2010, the Santa Ana Water Board reauthorized the National Pollutant Discharge Elimination System (NPDES) permit governing stormwater discharges in Riverside County (Santa Ana Water Board 2010). That permit obligated the MS4 permittees to comply with the nutrient TMDL and required them to develop a Comprehensive Nutrient Reduction Plan (CNRP) for Canyon Lake and Lake Elsinore. The CNRP was prepared and submitted in 2012 and the Santa Ana Water Board approved it 2013 (CDM Smith 2013a, Santa Ana Water Board 2013a). Since then, the permittees have been actively implementing the CNRP.
- In 2013, the Western Riverside County Agricultural Coalition (WRCAC) submitted a final Agricultural Nutrient Management Plan (AgNMP) for agricultural operators in the watershed (WRCAC 2013).
- In recent years the LECL Task Force has initiated a large-scale alum application program in Canyon Lake. Aluminum sulfate ("alum") binds with phosphorus thereby preventing excess algae growth in the lake. As of March 2017, 880 metric tons of alum have been applied and an estimated 4,000 kilograms (kg) (8,800 pounds [lb]) of phosphorus have been neutralized in Canyon Lake. Water quality has improved dramatically since the program began.

The LECL Task Force has supported a large number of supplemental scientific studies in the ten years since the TMDL was first approved. These studies were designed to aid the stakeholders in selecting the most effective and efficient management strategies to control nutrient loads in both lakes. The special studies were also intended support any necessary revisions to the TMDL as better information became available.

In 2010, the LECL Task Force contracted with Tetra Tech, Inc. to update the runoff models used to estimate nutrient loads to both lakes (Tetra Tech 2010). This same firm also developed the original watershed model that the Santa Ana Water Board relied on to support and justify the nutrient TMDL. Among the key improvements was a more accurate characterization of storage capacity in the Mystic Lake area and a more precise description of how rainfall and runoff vary in the region. At the Task Force's direction, Tetra Tech also developed a spreadsheet tool that could be used to estimate changes in nutrient loading based on changes in land use throughout the watershed.

Beginning in 2011, the LECL Task Force contracted with Dr. Michael Anderson at University of California, Riverside (UCR) to develop more sophisticated dynamic models to predict water quality in both lakes. The Canyon Lake model was completed in 2012 and was instrumental in selecting alum applications as the most cost-effective nutrient control strategy for that lake (Anderson 2012a). The new water quality model for Lake Elsinore was just recently completed (Anderson 2016a). These models are designed to estimate the concentration of key water quality parameters under natural, pre-development conditions (Anderson 2012b). The models are also used to predict how various nutrient management strategies will affect water quality and the time required to meet the response targets specified in the TMDL. Among Dr. Anderson's many key findings are the following:

(1) Nutrients cycle in the lakes far longer and decay much slower than previously thought. This finding suggests that the previous water quality models may have underestimated the level of effort and length of time required to attain the water column targets for nitrogen and phosphorus specified in the current TMDL.

(2) Canyon Lake is unlikely to achieve the current response targets for DO or Chlorophyll-*a* even after the stakeholders achieve compliance with the LA and WLA specified in the TMDL. This is principally due to nutrient loads contributed by the lake-bottom sediments.

(3) Naturally-elevated salinity concentrations inhibit the zooplankton populations needed to constrain algae growth in Lake Elsinore. The interactions between salinity, biology and water quality were not considered when the current TMDL targets were originally developed.

(4) The strong asymmetric pattern of precipitation and drought in the watershed indicate that the lakes would not be able to consistently comply with the current TMDL response targets under natural, pre-development conditions.

(5) The natural hydrology of Lake Elsinore has been significantly altered by the construction of a large levee designed to reduce its size by 50% and by the addition of more than 50,000 acre-feet of recycled water to the lake. Both projects are intended to protect aquatic habitat and recreational uses by ensuring that the lake no longer dries up as it did during periodic droughts of the past. But, keeping the lake wet also alters some of the natural "reset" mechanisms that once governed water quality conditions in Lake Elsinore.

Dr. Anderson's findings indicate that important elements of the original TMDL, including the water quality targets and the LA/WLA, must be revisited to ensure that they are appropriate and achievable. It is also necessary to update the technical analysis to reflect current land use conditions which have changed significantly since the original TMDL was developed. And, finally, the TMDL should be revised to account for the large nutrient load reductions that have resulted from Best Management Practice (BMP) implementation, low-impact development (LID) requirements, restrictions on dairy discharges, changes in certain water quality standards (e.g., ammonia), and the in-lake remediation projects that have occurred over the last 10 years.

None of this is intended to imply that the original TMDL was deficient or defective. It was not; it was based on the best data available at the time. Today, however, we know a great deal more about how the lakes actually work than we did just a decade ago. We also know considerably more about which nutrient control strategies are most effective at improving water quality. And, we know that many critical factors (especially source loads from changing land use) are now quite different from what was assumed when the TMDL was first approved.

According to EPA, updating the TMDL to reflect all of this new information will "facilitate better watershed planning and adaptive implementation" (EPA 2012). In fact, the Santa Ana Water Board believed that regular review and revision is so critical to ultimate success that it adopted an Implementation Plan specifying that the TMDL be "re-evaluated at least once every three years to determine the need for modifying the load allocations, numeric targets or implementation schedule" (Santa Ana Water Board 2004a; see Task #14 on page 21 of 22). Doing so provides reasonable assurance of continued progress toward attainment of water quality standards and protection of beneficial uses in Lake Elsinore and Canyon Lake.

Section 2

Problem Statement

The purpose of the Problem Statement is to provide the foundation or basis for the development of a TMDL. The statement typically includes an assessment of current water quality conditions and the basis for the identified impairments of the waterbodies of concern for which a TMDL is deemed necessary. This Problem Statement provides not only the information used to adopt the original nutrient TMDL for Lake Elsinore and Canyon Lake (**Figure 2-1** and **2-2**) but also provides an overview of the substantial body of data and information that has been generated since adoption of the 2004 TMDL. This collective body of information provides the basis for revising the existing TMDL.

Figure 2-1. Sunrise on Lake Elsinore, 2016 (Source: Amec Foster Wheeler)

2.1 Regulatory Background

This section summarizes the basis for the adoption of the 2004 TMDL for Lake Elsinore and Canyon Lake and planned revision of this TMDL.

2.1.1 Beneficial Uses and Water Quality Objectives

Chapters 2 and 3 of the Water Quality Control Plan for the Santa Ana River Basin ("Basin Plan", Santa Ana Water Board 2016, as amended) establish the beneficial uses and water quality objectives, respectively, applicable to Lake Elsinore and Canyon Lake. **Figure 2-3** provides an illustration of the geographic location of these waterbodies within the San Jacinto River watershed. **Table 2-1** summarizes each waterbody's beneficial uses and the numeric and narrative water quality objectives relevant to nutrients and related constituents. These objectives provide the basis for assessing the impairment status of each lake.

Figure 2-2. Canyon Lake Reservoir, 2016 (Source: Amec Foster Wheeler)

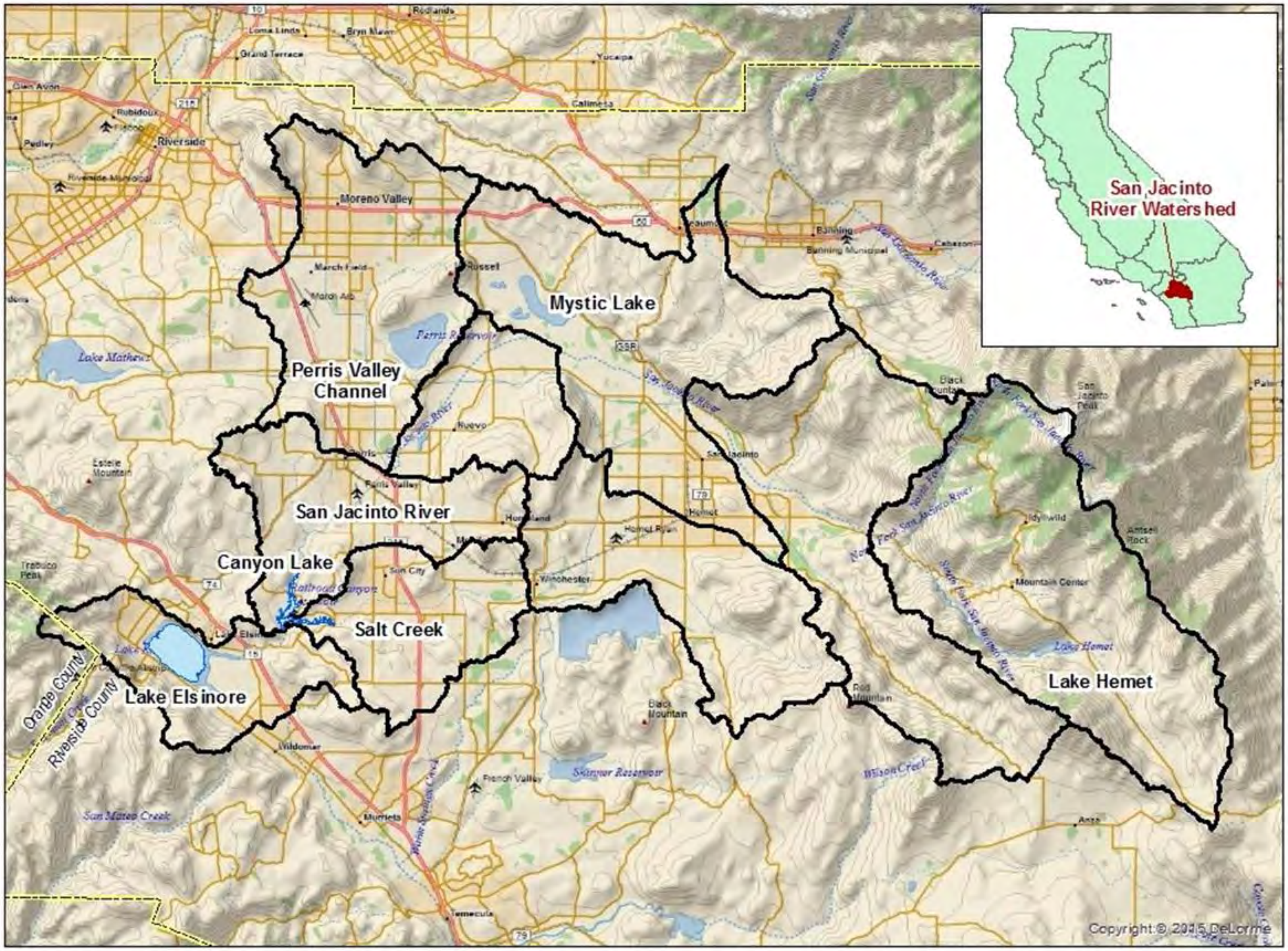

Figure 2-3. San Jacinto River Watershed with Key Subwatersheds Highlighted

Table 2-1. Lake Elsinore and Canyon Lake Beneficial Uses and Water Quality Objectives (Basin Plan, Santa Ana Water Board 2016)

Lake	Constituent	Relevant Water Quality Objectives
Lake Elsinore • Warm Freshwater Aquatic Habitat – (WARM) • Water Contact Recreation (REC1) • Non-Contact Recreation (REC2) • Wildlife Habitat (WILD)	Total Inorganic Nitrogen (TIN)[1]	1.5 mg/L
	Algae	Waste discharges shall not contribute to excessive algal growth in receiving waters
	Un-ionized Ammonia[2]	• Acute (1-hour) Objective = 0.822 [0.87/FT/FPH/2] • Chronic (4-day) UIA-N Objective = 0.822 [0.87/FT/FPH/RATIO]
	Dissolved Oxygen	Dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated WARM
	Total Dissolved Solids (TDS)	2,000 mg/L TDS
Canyon Lake • Municipal and Domestic Water Supply (MUN) • Agriculture Water Supply (AGR) • Groundwater Recharge (GWR) • Water Contact Recreation (REC1) • Non-Contact Recreation (REC2) • Warm Freshwater Aquatic Habitat (WARM) • Wildlife Habitat (WILD)	Total Inorganic Nitrogen (TIN)[1]	8 mg/L
	Algae	Waste discharges shall not contribute to excessive algal growth in receiving waters
	Un-ionized Ammonia[2]	• Acute (1-hour) Objective = 0.822 [0.87/FT/FPH/2] • Chronic (4-day) UIA-N Objective = 0.822 [0.87/FT/FPH/RATIO]
	Dissolved Oxygen	Dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated WARM

[1] TIN is the sum of nitrate, nitrite and ammonia forms of nitrogen. The TIN water quality objective was established based on the TIN historical average in the lake prior to 1975.
[2] See page 4-8 of the Basin Plan for formulas for "FT", "FPH", and "RATIO" relevant to pH and water temperature

2.1.2 Basis for Adoption of 2004 Nutrient TMDL

2.1.2.1 Lake Elsinore

The Santa Ana Water Board first listed Lake Elsinore as impaired in 1994, based on a historical record of periodic fish kills and excessive algae blooms in the lake since the early 20th century. This listing remains in place on the most recently approved impaired waters or 303(d) list for the region (State Water Board 2010) and includes unknown toxicity, nutrients, organic enrichment/low DO and sedimentation/siltation. Uses impaired include warm freshwater habitat (WARM), water contact recreation (REC1) and non-water contact recreation (REC2). Based on these impairments the Santa Ana Water Board developed a nutrient-based TMDL. During TMDL development, the first Problem Statement developed in 2000 identified hypereutrophication as the most significant water quality problem affecting Lake Elsinore (Santa Ana Water Board 2000). In 2004, a final Problem Statement was developed that included information from the 2000 Problem Statement and findings from a number of newly completed studies as referenced in the document (Santa Ana Water Board 2004b). These findings provided additional information with regards to the basis for impairment. Specifically, hypereutrophic conditions arise due to nutrient enrichment (phosphorus and nitrogen) resulting in high algal productivity (mostly planktonic algae). Algae respiration and decay depletes available water column oxygen, resulting in adverse effects on aquatic biota, including fish. In 2004, the Problem Statement documented what was known with regards to reported algal blooms and fish kills, which have been documented since early last century (Section 2.2.2.4 below provides additional information regarding the fish kill data record). The decay of dead algae and fish also produces offensive odors and an unsightly lakeshore, adversely affecting use of the lake for recreational purposes. In addition, massive populations of algal cells in the water column cause high turbidity in the lake, making the water an uninviting murky green color at times.

2.1.2.2 Canyon Lake

Canyon Lake is located approximately five miles upstream of Lake Elsinore. The lake was created as a result of the construction of Railroad Canyon dam in 1928. Only during wet years does Canyon Lake overflow and send water downstream to Lake Elsinore. Concerns regarding water quality were identified in the latter part of the 1990s, in particular concerns regarding periodic algal blooms and fish kills, but neither as significant as occur in Lake Elsinore. However, the water quality concerns were sufficient for the Santa Ana Water Board to place Canyon Lake on the impaired waters list in 1998, where it remains listed for nutrients in the most recent 2010 impairment assessment.

Development of the 2004 nutrient TMDL for Canyon Lake was done in coordination with the Lake Elsinore nutrient TMDL. An initial Problem Statement specific to Canyon Lake was drafted in 2001 (Santa Ana Water Board 2001). This Problem Statement documented that the beneficial uses of the lake were impaired because of excess phosphorus and nitrogen. Subsequently, a revised Problem Statement was prepared in 2004 based on completion of a number of studies that provided additional understanding regarding water quality concerns in Canyon Lake (Santa Ana Water Board 2004b).

2.1.2.3 2004 TMDL Adoption

In June of 2004 the Santa Ana Water Board released for public comment the *Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Loads* (see footnote 5) which established numeric targets for both lakes (**Table 2-2**). Based on the outcomes of public workshops held in June and September 2004, a formal resolution to adopt the TMDL was put forward for Board approval. The TMDL was adopted on December 20, 2004 (Santa Ana Water Board 2004a). The State Water Resources Control Board (State Water Board) approved the TMDL on May 19, 2005 (State Water Board 2005); Office of Administrative Law approved on July 26, 2005, and the EPA approved the TMDL on September 30, 2005.

Table 2-2. 2004 TMDL Numeric Compliance Targets

Indicator	Lake Elsinore	Canyon Lake
Total Phosphorus Concentration (Final)	Annual average no greater than 0.1 mg/L to be attained no later than 2020	Annual average no greater than 0.1 mg/L to be attained no later than 2020
Total Nitrogen Concentration (Final)	Annual average no greater than 0.75 mg/L to be attained no later than 2020	Annual average no greater than 0.75 mg/L to be attained no later than 2020
Ammonia Nitrogen Concentration (Final)	Calculated concentrations to be attained no later than 2020 *Acute*: 1-hour average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Maximum Concentration (CMC) (acute criteria), where CMC = $0.411/(1+10^{7.204-pH}) + 58.4/(1+10^{pH-7.204})$ *Chronic*: 30-day average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the Criterion Continuous Concentration (CCC) (chronic criteria), where CCC = $(0.0577/(1+10^{7.688-pH}) + 2.487/(1+10^{pH-7.688})) * \min(2.85, 1.45*10^{0.028(25-T)})$	Calculated concentrations to be attained no later than 2020 *Acute*: 1-hour average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the CMC (acute criteria), where CMC = $0.411/(1+10^{7.204-pH}) + 58.4/(1+10^{pH-7.204})$ *Chronic*: 30-day average concentration of total ammonia nitrogen (mg/L) not to exceed, more than once every three years on the average, the CCC (chronic criteria), where CCC = $(0.0577/(1+10^{7.688-pH}) + 2.487/(1+10^{pH-7.688})) * \min(2.85, 1.45*10^{0.028(25-T)})$
Chlorophyll-*a* concentration (Interim)	Summer average no greater than 40 µg/L; to be attained no later than 2015	Annual average no greater than 40 µg/L; to be attained no later than 2015
Chlorophyll-*a* Concentration (Final)	Summer average no greater than 25 µg/L; to be attained no later than 2020	Annual average no greater than 25 µg/L; to be attained no later than 2020
Dissolved Oxygen Concentration (Interim)	Depth average no less than 5 mg/L; to be attained no later than 2015	Minimum of 5 mg/L above thermocline; to be attained no later than 2015
Dissolved Oxygen Concentration (Final)	No less than 5 mg/L 1 meter (m) above lake bottom to be attained no later than 2015	Daily average in hypolimnion no less than 5 mg/L; to be attained no later than 2015

2.1.3 Basis for TMDL Revision

The post-TMDL implementation period from 2004 to 2016 has been a period of planning, monitoring, and scientific research. Findings from these efforts have been used to support the implementation of watershed-wide and in-lake projects (see summary in Section 1), evaluate the effectiveness of the projects and, where appropriate, refine or reassess implementation activities. Using this adaptive management approach, substantive new information regarding typical hydrologic and water quality conditions and cycles that exist in each lake has been developed. In total, the body of work completed to date provides a firm foundation regarding what is potentially attainable with regards to water quality given the highly managed conditions that exist. Accordingly, these prior work products will serve as the primary resources for updating and revising the current TMDL.

In June 2015, the Task Force petitioned the Santa Ana Water Board to reopen and revise the TMDL based on new information developed since TMDL adoption (LESJWA 2015). The Santa Ana Water Board agreed to make this effort a high priority for Regional Board staff (Santa Ana Water Board

2015a). As part of this agreement, the Task Force accepted responsibility to develop the documentation needed to update and amend the nutrient TMDL for Lake Elsinore and Canyon Lake.

This Problem Statement updates the previously developed 2000, 2001 and 2004 Problem Statements. The sections below provide relevant information regarding our current understanding of water quality conditions, lake biology and unique characteristics of the lakes and surrounding watershed after many years of study. This new information will be critical in updating all elements of the TMDL, including, but not limited to, numeric targets, linkage analysis, and source assessment.

2.2 Waterbody Characteristics

2.2.1 San Jacinto River Watershed

Lake Elsinore and Canyon Lake lie within the San Jacinto River Watershed (see Figure 2-1), an area encompassing approximately 780 square miles in the San Jacinto River Basin. Located approximately 60 miles southeast of Los Angeles and 22 miles south of the City of Riverside, the San Jacinto River Watershed lies primarily in Riverside County with a small portion located within Orange County. Area climate is characterized as semi-arid with dry warm to hot summers and mild winters. Average annual precipitation in the entire Lake Elsinore/Canyon Lake watershed area is approximately 11 inches occurring primarily as rain during winter and spring seasons. Within just the upper portion of the watershed that drains to these lakes, the precipitation averages 18.7 inches annually. Historically, land use development in the San Jacinto watershed has been associated with agricultural activities. However, a continual shift from agricultural to urban land use has been occurring for many years.

There are several impoundments upstream in the San Jacinto River watershed that are upstream of Canyon Lake and Lake Elsinore that retain most runoff from their respective drainage areas; including (see Figure 2-1):

- *Lake Perris* – Lake Perris is a drinking water reservoir for the State Water Project which is used to meet demands in the region. An undeveloped drainage area of approximately 10 square miles surrounds Lake Perris and contributes runoff to the lake. Lake Perris does not overflow to the San Jacinto River and therefore this drainage area.

- *Mystic Lake* – Mystic Lake is a large depression area in the San Jacinto River watershed that captures all runoff from the upper watershed. U.S. Geological Survey (USGS) topographic surveys by Morton (2015) in 2004 and 2014 have shown that the depression that forms Mystic Lake is subsiding at an average rate of ~1 inch/year (in/yr). Interpretation of these topographic surveys suggests a storage capacity increased by approximately 200 acre-feet per year (AFY) from 2004 to 2014 (RCFCWCD 2015). Depending upon antecedent moisture conditions, in very wet consecutive hydrologic years, Mystic Lake overflows back to the San Jacinto River. In setting WLAs, the 2004 TMDL assumed overflows of Mystic Lake would occur in 16 percent of hydrologic years. The most recent overflow occurred 18 years ago in 1998, despite the fact that 2005 runoff volume was double that of 1998 as recorded in the San Jacinto River between Canyon Lake and Lake Elsinore The TMDL revision includes a revised estimate of overflow frequency and volume for use in developing allocations for external loads that considers the rate of subsidence and relevant hydrological conditions (see Section 4.1.3.4).

- *Lake Hemet* – Lake Hemet is a reservoir within the San Jacinto National Forest that is used by the Lake Hemet Municipal Water District to provide water to a service area in and around Garner Valley. Lake Hemet was formed by construction of Hemet Dam in 1887. Runoff from an approximately 65 mi^2 watershed, comprising the headwaters of the South Fork of the San Jacinto River, is captured in Lake Hemet for recreational and municipal uses.

- *Concentrated Animal Feeding Operations (CAFOs)* – CAFOs must retain runoff from up to a 25-year return period storm event on-site. Retention ponds within CAFO properties are used to comply with this permit requirement, which also serves to limit any discharge to the San Jacinto River or Salt Creek during most hydrologic years. In addition to compliance with these runoff retention requirements, more than 40 percent of manure generated in the San Jacinto River watershed is hauled out of the watershed.[1] This percentage of manure hauled out of the watershed is expected to continue to increase. The TMDL revision proposes to account for successful compliance with CAFO Permits.

2.2.2 Lake Elsinore

Lake Elsinore is the largest natural lake in Southern California. Originally, at a lake elevation of 1260 feet (ft) the surface area of the lake was approximately 5,950 acres with an average depth of 21.5 ft) (Engineering-Science 1984). This section provides a detailed history of the lake, which demonstrates that (a) under historical natural conditions, Lake Elsinore periodically became a dry lakebed, eliminating aquatic life as well as opportunities for recreation; and (b) even under current conditions, the lake continues to experience significant fluctuations in lake levels that have a significant impact on the attainability of beneficial uses in the lake.

2.2.2.1 Historical Background of the Lake Elsinore Area

The history of anthropogenic activity in Lake Elsinore area has been well-documented by a number of sources for various reasons. Following is a summary of this activity from the pre-historical period to today generally compiled by Engineering-Science (1984) or City of Lake Elsinore (2011), which relied primarily on James (1964), County of Riverside Historical Committee (1968), Beck and Haase (1974), Hudson (1978), O'Neill and Evans (1980) and Hoover (1966):

About 2,000 years ago the inhabitants in the Lake Elsinore area were the ancestors of other known inhabitants of southern California, in particular the Luiseño and a related group, the Juaneño. It is unknown which people group the Lake Elsinore area belonged to but there is evidence that the Juaneño had ties to the area based on a known trail that linked the Elsinore area with San Juan Capistrano on the coast of California. Per Engineering-Science (1984), there is a "reference to a Juaneño creation myth, in which 'man was created out of the mud of the lake (Elsinore)' (Harrington, cited in O'Neil and Evans 1980)." In addition, the Elsinore Hot Springs in the local area had religious significance to the Juaneños and Luiseños.

The Spanish missions began to be established in southern California in 1769. The San Luis Rey Mission, which had an influence in the Lake Elsinore area, was established in 1798 near what is

[1] Based on findings in annual reporting by CAFOs to the Santa Ana Water Board, 2014.

now Oceanside California. In 1810, the water level of the *Laguna Grande* was first described by a traveler as being little more than a swamp about a mile long (USGS 1917).

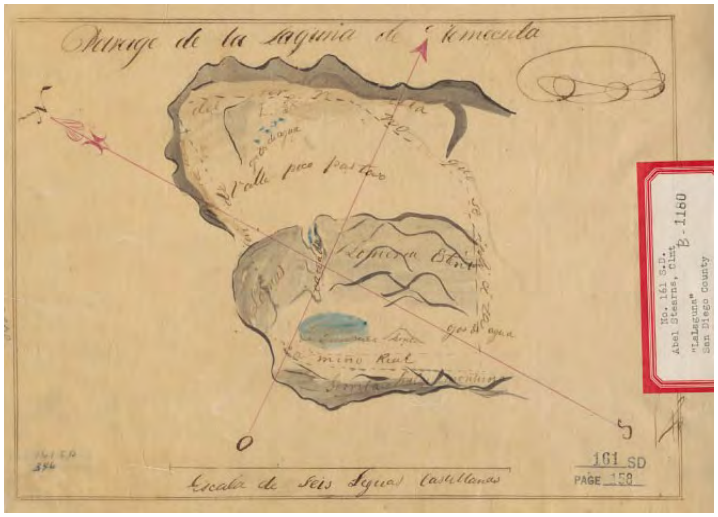

Figure 2-4. Historic Drawing of Laguna Grande

Leandro Serrano settled in the Lake Elsinore area that the Spanish referred to as Laguna Grande in 1818. He is the first known non-Indian to have settled in the area. The settlement he established, Glen Ivy Hot Springs, is today located in the Temescal Valley approximately nine miles northwest of Lake Elsinore. Laguna Grande is the name that the Spanish gave to Lake Elsinore (**Figure 2-4**) and La Laguna is the historic name for what is today the City of Lake Elsinore.

In 1844 Julian Manriquez, after receiving a 13,339-acre land grant from the Governor of Mexico, established La Laguna Rancho. This adobe was described by Benjamin Hayes, who stayed there overnight January 27, 1850 (Wolcott 1929):

> *"In about 15 miles reach some timber where the hills approach near, apparently the termination of the valley of Temecula, a sort of low divide over which we enter into another valley. In both these is much good soil, although in the latter more of the wiry grass and more marshy, some little evergreen oak among the hills.*
>
> *"Come to the Laguna, two miles from the divide. Some good young grass, great deal of elder on its banks; as we rode along frequent flocks of geese rose from the shore; many shots at them; none brought down. The water of the Laguna is saltish, the animals cannot drink it; if they could, such a sheet of fresh water here would be invaluable to the owner of this land….*
>
> *"At sunset, the moon rises behind the snowy peaks to the eastward and is reflected on the lake. Wild sage; the lake has evidently once, near the house, been with a much broader basin. How is it supplied with water? Clover around it. The house is a substantial adobe. A small stream seems to enter it on the east. A low range of hills nearly surrounds the lake, higher where we are encamped on the southern side. The lake valley seems to be higher than that of Temecula."*

Abel Stearns took possession of this land in 1851 as a result of foreclosure proceedings and then sold the land to Augustin Machado in 1858. Augustin Machado further developed La Laguna Rancho and between 1858 and 1861 the Butterfield Overland Mail Route (between Temecula to the south and Temescal Station to the north, a distance of about 30 miles) regularly stopped at Machado's ranch house.

Figure 2-5. Streets of Elsinore in the 1880s (Source: INSERT)

Charles Sumner acquired most of Augustin Machado's Laguna Rancho in 1873. Sumner is credited with being the first person to note the potential benefits of hot springs in the area. When lake levels were low, Sumner noted that presence of more than 300 hot springs in the area. Three investors, including Franklin Heald, who is the founder of the City of Lake Elsinore, purchased Laguna Rancho in 1883 and developed a health resort called "Elsinore Colony". The Crescent Bath House, which is today a registered national historic site in the City Lake Elsinore, was established in 1887 (**Figure 2-5**). During the latter part of the 19th century a yacht, the Marguerita, ferried passengers across the lake. A steamship, the Lady Elsinore provided lake cruises.

The California Southern Railroad began building a rail line from San Diego to Barstow in 1881 and completed it in 1885. In the Lake Elsinore area, the railroad was built through what was then the San Jacinto River Canyon, but later renamed Railroad Canyon. The La Laguna rail station was established just east of Lake Elsinore near what is now the intersection of Mission Trail Road and Diamond Drive.

Figure 2-6. Boating on Lake Elsinore, ca. 1940 (Source: Lake Elsinore Naval School)

Elsinore became known as a small town in 1883, incorporated in 1888, and was designated as a city in 1893. The establishment of the railroad and later a highway connection increased the number of residents and visitors. The completion of the lakefront resort, Laguna Vista Club House, and the Mount Elsinore County Club in the 1920s made Lake Elsinore a destination for visitors. Around the same time efforts continued to support a tourist industry centered on the lake (**Figure 2-6**). In 1926 a double-decked pier was built on the lake; in 1927 the National Speed Boat Race was held on the lake. In the 1930s a "ship pier" was constructed on the south side of the lake. During World War II, the lake was used to test seaplanes. The City of Lake Elsinore has grown significantly in the last few decades. **Table 2-3** summarizes population growth in the area since 1900 (City of Lake Elsinore [2011] for 1900-2011; State of California for 2017 [2017]).

Table 2-3. Population Changes in the City of Lake Elsinore, 1900 – 2017

Census Date	Population
1900	279
1910	488
1920	633
1930	1,350
1950	2,068
1960	2,432
1970	3,530
1980	5,982
1990	18,285
2000	28,928
2011	52,503
2017	62,092

2.2.2.2 Lake Level Dynamics

The USGS published a summary of anecdotal records that illustrate the variation in wet and dry periods that have occurred in southern California from 1770 to 1913 (USGS 1918). Wet and dry records were compiled from a San Diego County resident who had lived in the county since 1869 and the records of Mission Fathers. **Table 2-4** summarizes the published findings. In addition, the USGS published a summary of anecdotal descriptions of Lake Elsinore lake levels for generally the same time period (USGS 1917) (**Figure 2-7**):

"Apparently the earliest specific reference to the amount of water in Elsinore Lake is contained in the notes of a traveler through southern California about 1810, who mentions 'Laguna Grande,' the original Mexican name for the lake, as being little more than a swamp about a mile long. For the period between that time and 1862 data as to its rise and fall are not available, but in 1862 it was very high and probably overflowed. During the succeeding dry period, especially during the years 1866 and 1867, when practically no rain fell on the drainage area tributary to the lake, it receded very rapidly but was full again in 1872 and overflowed down its outlet through Temescal Canyon. After this it again evaporated to a level probably as low as it has ever been since, but the great rains of the winter of 1883-84 filled it to overflowing in three weeks.

"Americans had settled around it [The Lake] by this time and their descriptions of conditions say that large willow trees surrounding the low-water shoreline were of such size that they must have been thirty or more years old. The rainfall in the next ten years was excessive, and the lake stayed high and overflowed naturally during three or four years of the decade. It [The Lake] was purchased by the Temescal Water Co. for the irrigation of lands at Corona, California, and its outlet channel was deepened, permitting gravity flow to Corona for a year or more after the lake level had sunk below the elevation of its outlet. As the surface still receded a pumping plant was installed and the water was raised a maximum of about 10 feet and then flowed down the natural channel of Temescal Canyon. Pumping was continued a couple of seasons, but the concentration of salts in the lake, due to the evaporation and low rainfall, soon made the water unfit for irrigation.

Table 2-4. Recorded Wet and Dry Year Conditions in Southern California (USGS 1918)

Year(s)	Conditions	Year(s)	Conditions
1770	Drought	1853	Big floods and snow
1786	Copious rainfall	1850-1856	Flood and good years
1787	Rainfall insufficient; crops short	1856-1857	Driest in 20 years
1791	Extremely dry; no rain for whole year	1857-1862	Medium rainfalls
1794	Rainfall insufficient; crops short	1862-1863	Dry years
1795	Very dry	1863-1869	All good wet years
1811	Flood year	1869	Very exceptional year; rainfall in December estimated at 12 inches in 24 hours
1815	Flood year	1869-1870	Dry season
1819	Short in rain and crops	1870-1871	Dry season
1825	Great flood changed course of Santa Ana River	1872-1874	Fairly wet seasons
1826-1828	Dry years	1875-1876	Good rainfall
1832	Short in rain and crops	1876-1877	Dry season
1840-1841	Driest years every known	1877-1882	Good seasons
1841-1842	Wettest year ever known	1882-1883	Dry years
1842-1843	Very open and dry	1883-1884	Wettest winter known
1843-1844	Very dry; no grain grown in Sacramento Valley	1885-1893	Series of good years
1845	Drought	1893-1894	Short rainfall
1845-1846	Wet in north; dry in southern California; cattle starved	1895-1897	Three good wet years
1846-1847	Considerable rain; crops good	1897-1900	Three dry years
1848-1849	Most snowy winter known; rainfall moderate	1901-1910	Fairly good wet years
1849-1850	One of the wettest and most floody winters	1910-1913	Dry years at end of season
1850-1851	Open; rainfall moderate	1912-1913	Dry year

"After 1893 the water level sank almost continuously for nearly ten years, with, of course, a slight rise every winter. The heavier precipitation, beginning in 1903, gradually filled the lake to about half the depth between its minimum level since 1883 and its high level or overflow point. The flood of January 1916, rapidly raised the level, to overflowing, although the run-off from its drainage area into the lake appears to have been considerably less than that of the wet years of 1883-84 and 1888-89. The fact that large trees were growing 20 feet or more below the high-water level when the lake filled in 1883-84 indicates that the high water of the sixties and seventies must have been of very short duration. The stumps of the trees were still visible in 1888 and 1889 many hundred feet from shore, but by the tune the lake receded in the middle nineties these had disappeared."

A comparison between the noted high lake levels in the above USGS descriptions and Table 2-4 shows some correspondence between anecdotal wet/dry condition records and known Lake Elsinore water levels. For example, the reference to rapid filling of the lake in 1883-1884 is consistent with the notation that the 1883-1884 winter was the "wettest winter known". Differentiations are no doubt caused by the wet/dry condition records are not specifically from the San Jacinto River watershed. Regardless, there is a wide range of wet and dry conditions and varying lake levels documented in early written reports for the region.

Figure 2-7. Period of Drying in Lake Elsinore in the Early 1900s.

Hudson (1978) provides a 200-year historical perspective of the Lake Elsinore area from 1776 to 1977. This compilation of historical records provides a number of anecdotal descriptions of Lake Elsinore, especially during the 19th century. **Table 2-5** summarizes this information.

In 1931, the Metropolitan Water District of Southern California commissioned the preparation of a report that compiled and studied available information "for the purpose of determining and reconstructing the record of rainfall and run-off fluctuations in Southern California since the arrival of the Spanish Mission Fathers in 1769" (Lynch 1931). Based on this research, Lynch (1931) reconstructed lake elevations for Lake Elsinore from the 1770s through 1930 using reported elevations, reported wet/dry conditions and interpolation **(Figure 2-8**). Lynch (1931) stated the following as the basis for his reconstruction:

> *"Lake Elsinore forms by far the best link which we have in Southern California for directly comparing present and past run-off conditions. Its level has fluctuated widely from overflow to practical dryness. Since 1859 these fluctuations have been recorded in testimony in lawsuits, in maps made at the time, and since 1915 in measurements by the United States Geological Survey. In addition are memories as to previous water levels and conditions by men still living. Prior to 1859 are a few references to its level. As in all of this work, periods of rainfall shortage show more clearly than periods of excess."*

Based on this reconstruction, the periods of time with the lowest lake elevations was 1810 and 1860. Times of lowest rainfall and lake elevation occurred prior to 1810, around 1830, prior to 1860, the early 1880's and around 1905. Per Hudson (1978), the lake was completely dry in 1810, 1859 and 1882, consistent with several of the records documented by Lynch (1931).

Table 2-5. Anecdotal Descriptions of Lake Elsinore from 1797-1932 from Hudson (1978)

Date	Anecdotal Description
1797	Francisco Padre Juan Santiago described Lake Elsinore as a full lake, with trees around the edges and lots of animals
1858-1872	“In those days, as now, the lake had its full years and its low years. While the wet seasons were blessed with more grass for livestock, perhaps a high level of the lake itself was not so much desired by the Machado’s, for a very good reason: when the lake was low there was a great meadow at the east end where cattle and sheep would graze. And, high or low lake, there was always water for thirsty animals.”
1875	“The lake did not go completely dry, but before the rains came it was only a pool of stagnant water in a vast sea of mud. It was this period that Sumner later wrote that there were more than three hundred springs in and around the lake. These springs, he said, where of many varieties, including black Sulphur, soda and salt, hot sulphur [sic] water and clear cold water. “
~1883	“with scant rainfall, the San Jacinto River became only a dry streambed. Willows along the shore of the lake died. Fish in the lake died and their stench fouled the clean air. Immense swarms of lake-bred gnats, with no fish to eat their larvae, took flight to pester man and livestock. As if in protest against the drought there was an upheaval in the lake that caused water to sprout up, geyser like, and to turn blood red. The Mexicans and Indians thought it was the blood of an evil spirit. Perhaps it was.”
1884	“The rains which Ida spoke started in January 1884 and continued as late as June. Rainfall records vary, but some say that sixty-two inches of rain fell during that time. The railroad through Railroad Canyon was washed out and months passed before it was again ready for use. The lake rose so high that it overflowed into Water Springs Creek.” (same as Temescal Creek).
1926	Hudson: “By the end of February 1926 the San Jacinto River was flowing and the level of Lake Elsinore was rising. The rains that caused the river to flow were timely, for four years had passed since the lake had been replenished.” Winter of 1926-27, the tracks are washed out again (also washed out in 1891).
1931-1932	Hudson: “19 inches of rain had fallen in the valley in 1931. Lake Elsinore rose ten inches during the winter and on March 3, 1932 flood gates at Railroad Canyon Dam were opened, pouring almost ten thousand-acre feet of water into the Lake and bringing the lake level to 1244.32.”

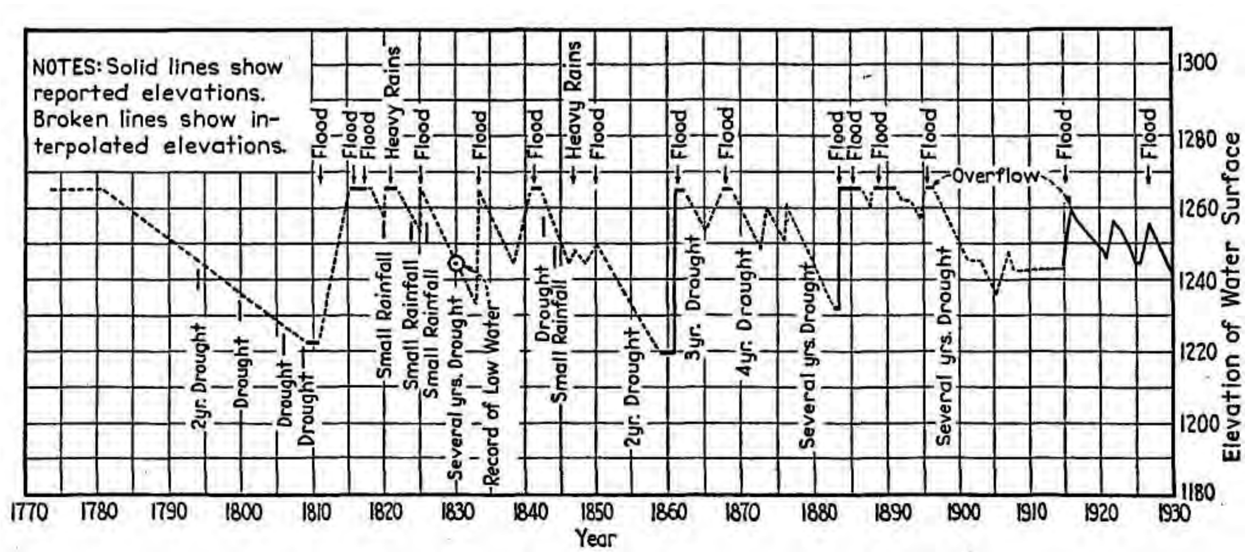

Figure 2-8. Estimated Lake Elsinore Lake Levels Based on Historical Records (from Figure 8, Lynch 1931)

Figure 2-2 also shows periods when Lake Elsinore was likely full (surface water elevation of approximately 1,265 ft.), especially in 1815 and following, early 1840s, several years in the 1860s, and in the mid to late 1880s. Lynch (1931) illustrates the extreme variability in lake level through the following findings:

- If no water flowed into the lake, a full lake would evaporate and become completely dry in about 11 years.
- When the lake overflows, it may be an indicator of what the previous year's inflow was like, but it is not an indicator of conditions over any period of years. Lynch (1931) notes as an example that the single wet season of 1861-1862 filled the lake from it being almost completely dry to where there was a significant overflow.
- The lowest elevation was estimated at 1,220 ft. above mean sea level (msl). The shallow nature of the lake as a whole is demonstrated by the fact that at elevation 1,224 ft. the water surface would covers more than two square miles and at elevation 1,234 ft. the lake covers more than four square miles.
- The evaporation rate of the lake is not only significant but as the lake fills and its water surface expands laterally, the rate of evaporation increases rapidly. This characteristic prevents the lake from overflowing, except as a result of an extended period of heavy rainfall.
- Based on reports, Lake Elsinore overflowed in 1841, 1862, 1868, several years between 1884 and 1895 and in 1916. The 1916 overflow was significant as reports indicate the flow was as much as 10 ft. above the outlet elevation.
- The latter part of the 1800s illustrates the dynamic nature of the wetting and drying cycles in Lake Elsinore. The lake overflowed in 1841, but during the generally long dry period from 1841 to 1883 the lake's level dropped 40 feet; it refilled and overflowed 1862 and 1868. After 1868, the lake again lowered over thirty feet.

The work of Lynch (1931) was updated and extended in ACOE (1987) through the addition of information provided by the RCFCWCD based on information found in 1842, 1859, 1875, and 1884 diaries (no specific references provided) and State Park Ranger Data (no specific reference provided). **Figure 2-9** illustrates the updated Lynch (1931) figure (i.e., Figure 2-2). The figure again shows the dry lakebed that occurred in 1810, 1859 and 1882, but expands the record to show the dry lake bed that occurred off and on in the 1950s and 1960s. The figure also illustrates the dramatic change that occurred in as a result of a very wet period that occurred in beginning in 1978 (ACOE 1987):

> *"...1978 marked the beginning of consecutive wet years when heavy rains raised the lake elevation approximately 15 ft. to about 1,245 ft. Although there is no available flood damage data from the 1800s, the recent floods of 1980 and 1983 are well documented. Of these two years, 1980 was the most significant. The rainfall of 1980 had, by February, equaled the total annual average for the Elsinore area. Beginning on February 13, and continuing for the next six days, the area again received an amount of precipitation in excess of the total annual average. The lake level reached 1265.72 ft. and over 250 homes were flooded leaving one-third of the Lake Elsinore residents temporarily homeless...the 1980 flood is estimated to closely represent the conditions of a 100-year lake level."*

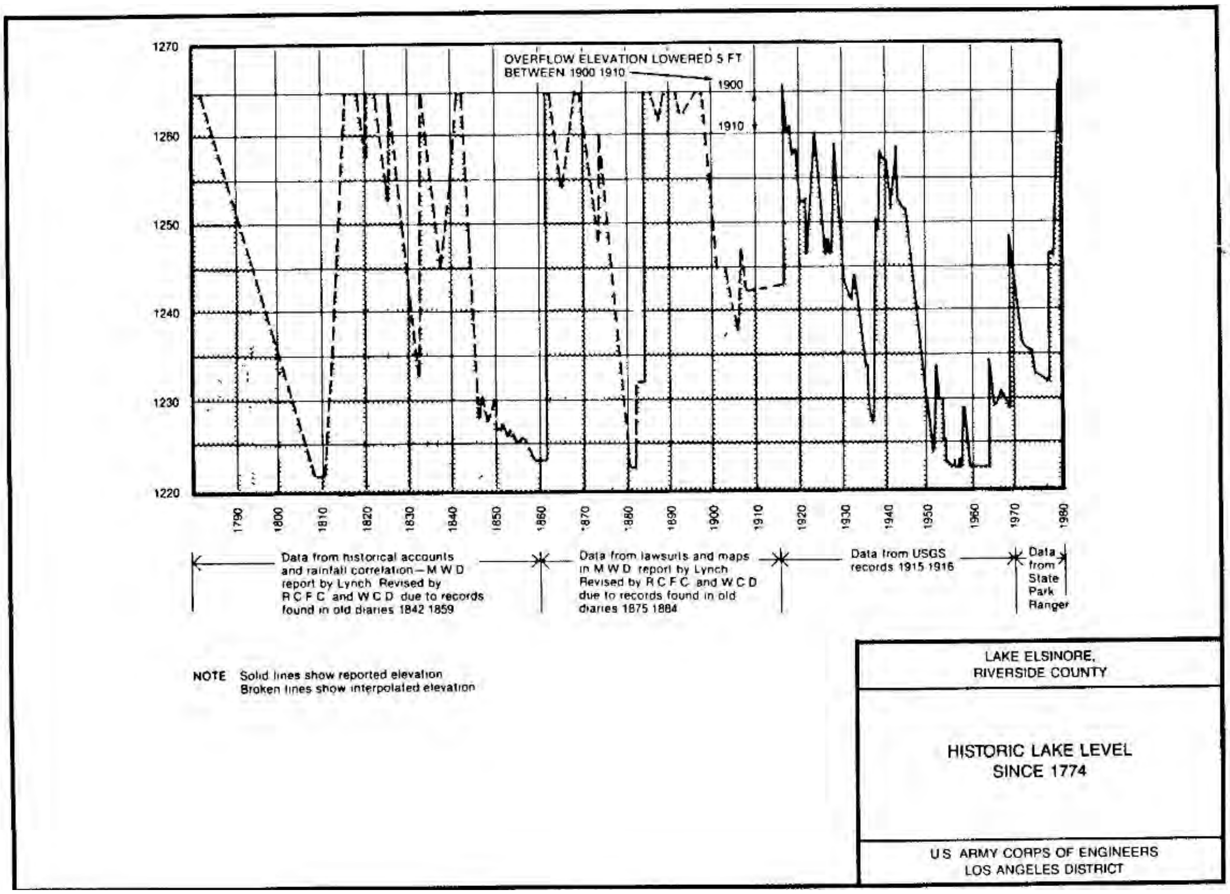

Figure 2-9. Historic Lake Levels in Lake Elsinore Based on Revision of Lynch (1931) and Additional Information (Figure 6 in ACOE 1988)

When Lake Elsinore goes through periods of drying the descriptions of the lake illustrate how poor conditions can become (**Figure 2-10**). For example, in an April 1936 letter from the Chief State Bureau of Sanitary Engineering to the Mayor of Elsinore, the following description was provided (EDAW 1974):

> *"…(the Lake) depth is now about 10 feet…concentration of the Lake water is at a dizzy speed…rapid change of chemical characteristics of the water is almost certain to affect the variations of life that will be encountered from now on…we calculated 135,000 tons of algae crop….comparison with the algae figure for April, 3 years ago, when the fish died, indicates there are now over 200 times the quantity of algae…there are probably 20 to 30 acres of mud flats covered with a pastey, black sludge – it is intensely foul smelling…we sincerely hope that a proper balance of nature will prevail through the summer…"*

The longest dry period that has occurred in Lake Elsinore was in the mid-1950s and again in the early 1960s. The complete dry up of the lake in 1954 was the subject of an extensive article on the lake (Fortnight: The Magazine of California 1954) (**Figure 2-11**):

Figure 2-10. Illustration of Algal Bloom Along Shoreline of Lake Elsinore in 2016 During Period of Low Water Levels

"Lake Elsinore's reputation stems from its annoying habit of drying up at inconvenient intervals, and also from an irrational tendency to spew forth dead fish along its lovely shoreline. One year it may be the garden spot of Southern California…the next year its resorts may be deserted…its once invigorating atmosphere palsied o'er with the unmistakable order of dead fish, and maverick hordes of gnats singing their siren song over all…Why? Because Lake Elsinore has done one of its periodic disappearing acts, its cool blue waters transformed into a barren sea of pitted, pock-marked earth.

"This year the Lake is choosing to be particularly perverse. It is dry enough to make the Oklahoma Dust Bowl seem like a summer sunning of the French Riviera. There is not even a mud puddle to remind observers of the glories that used to be. Its surface is lined with cracks, its center a dangerous quicksand area. Boiling pots bubble continuously."

Figure 2-11. Comparison of Lake Level Extremes in Lake Elsinore (Source: Fortnight: The Magazine of California 1954)

2.2.2.3 Modifications to the Watershed and Lake Elsinore

Since the 1920s, changes have occurred in the San Jacinto River watershed and the natural characteristics of Lake Elsinore. These changes are described in the subsections below.

Construction of Canyon Lake

The construction of Railroad Canyon Reservoir, which was completed in 1929, had the potential to significantly impact the downstream Lake Elsinore, especially given that the reservoir is only about five river miles upstream of Lake Elsinore (**Figure 2-12**). Because of a lawsuit filed by George Tilley, the Tilley Agreement was established to ensure that a minimum amount of water reached Lake Elsinore. The terms of the October 29, 1927 settlement stipulated that Canyon Lake was entitled to a maximum of 2,000-acre feet (AF) of watershed runoff. Lake Elsinore would receive any water over that amount (California Public Utilities Commission 2009). Within the Agreement, which was between Temescal Water, owners of Railroad Canyon Reservoir and the people below the Reservoir, the following justification for ensuring sufficient water reaches Lake Elsinore was included (EDAW 1974):

> *"…unless the water level of Lake Elsinore be maintained at a level of 1245 feet above sea level or higher, that the water line recedes so far into the bed of the Lake as to make the shores unsightly; algae form in abundance in the Lake, and die and rot and cause a green slime to accumulate upon the surface of the Lake along the shore and over a large area of the Lake, which at such times, gives off noxious odors…"*

Figure 2-12. Proximity of Canyon Lake Reservoir to Lake Elsinore

Overflows from Canyon Lake to Lake Elsinore occur only periodically (**Figure 2-13**), and, as noted above, even with the Agreement, Lake Elsinore continued to experience significant fluctuations in water levels, with the lake completely drying out periodically in the 1950s and 1960s (see discussion above).

Modification of Lake Elsinore

In the early 1980's new efforts were initiated to resolve concerns with the lakes dynamic behavior which resulted in significant fluctuations in lake elevation and associated shoreline variability, flooding and water quality problems (Engineering-Science 1984). While this was the latest effort to address these lake concerns, Engineering-Science (1984) notes that the search for solutions had been the subject of evaluation for some time:

Figure 2-13. Overflow of Canyon Lake Dam, approximately 1936-1937 (Source: Lake Elsinore Naval School)

> *"The development and evaluation of options for the long-term solution to the problems associated with Lake Elsinore has been nearly a constant activity during the past two decades. In the 1960s, deep wells were installed to provided replenishment water to Lake Elsinore during periods of drought. In the early 1970s, plans for establishing a permanent lake were formulated. In the early 1980s, programs for minimizing flood damage were investigated following the disastrous floods in 1979 and 1980. "*

The outcome of the latest effort was the proposed Lake Elsinore Management Project (LEMP). Per the Environmental Assessment (EA), the key purposes of the proposed project included (Engineering-Science 1984):

- Provide a reliable source of agricultural water;
- Prevent localized flooding;
- Provide recreation opportunities;
- Improve water quality;
- Reduce fluctuation in lake water levels;
- Maintain a minimum pool in the lake basin, and
- Manage the lake to meet the above objectives.

With regards to water quality concerns, the Need and Purpose of the EA included the following description (Engineering-Science 1984):

> *"The character of Lake Elsinore has varied from a 'dust bowl' to a 6,000-acre flooded lake covering most of the floor of the Elsinore Valley. The dynamic behavior of this water resource has caused several major problems.*

> *Shoreline Fluctuation Problems. Changes in the water levels of Lake Elsinore can be dramatic, ranging from several feet to nearly 20 feet in a single year…Within a period of one to two years, shoreline facilities can be faced with flood water conditions or 'high and dry' as the water's edge recedes several hundred to several thousand feet. The wide migration of the shoreline precludes the full recreational use and long-term development of recreational facilities…*
>
> *Water Quality Problem. Traditionally, Lake Elsinore receives the outflow of the San Jacinto River Watershed and functions as a large evaporation lake, because the natural lake outlet is about 30 to 40 feet higher than the floor of the lake basin. As the lake level drops due to evaporative water losses, the dissolved materials content of the residual lake pool increases and eventually severe water quality problems result. In the past, several fish kills have occurred and odor problems have preceded the 'drying up' of the lake."*

Table 2-6 provides a comparison of the expected outcomes from construction of the proposed alternative (construction of a levee) and the no project alternative. The proposed alternative or LEMP included three major projects. These projects and their construction dates include:

- Construction of a levee to separate the main lake from the back basin to reduce the lake surface area from about 6,000 to 3,000 acres, and thereby prevent significant evaporative losses (June 1989 – March 1990);
- Realignment of the lake inlet channel to bring natural runoff from the San Jacinto River when Canyon Lake overflows (February 1990 – March 1991); and,
- Lowering of the lake outlet channel to increase outflow to downstream Temescal Creek when the lake level exceeds an elevation of 1,255 ft. (October 1993 – April 1995).

With a reduction of lake level fluctuations and improved water quality, it was expected that there would be significant improvement in the biotic resources in the lake (Engineering-Science 1984):

> *"The establishment of a permanent lake…is a significant long-term benefit to the biotic resources that are associated with this lake. The development of a stable fishery resource in Lake Elsinore will be realized for two key reasons. Adverse natural factors, such as poor water quality and drying up of the lake, will not continue to depress or to interrupt fish growth rates. Second the establishment of a permanent lake with good water quality will provide a sufficient resource basis for additional game fish stocking…the stabilization of the shoreline within elevations of 1235 and 1252 feet will encourage fuller development of a perennial plant community and associated bird populations.*

As a result of LEMP, Lake Elsinore today now has current approximate surface area of 3,000 acres (approximately 50 percent of original surface area), average depth of approximately 13 feet., and a maximum depth of approximately 27 feet. Monitoring data indicate that with the exception of brief periods of stratification Lake Elsinore is typically well-mixed with a limited thermocline.

Table 2-6. Comparison of the Expected Outcomes of Implementation of the Proposed Project or No Project Alternatives (adapted in part from Table 2.5 in Engineering-Sciences 1984)

Proposed Alternative – Construct Levee	No Project Alternative
• Lake Characteristics - Lake Status – Permanent Lake; levee to separate Lake Elsinore from its southeasterly floodplain - Outlet Elevation – 1,252 ft. - Water Level – 1,235 to 1,252 ft. - Surface Area – 2,700 to 3,060 acres - Average Depth – 9 to 27 ft. • Water Resources - Groundwater – Pump for agricultural use and to replenish lake to 1,235 ft. - Surface Water – Improved water quality (TDS) due to lower evaporation loses and increased flow-through and replenishment sources - Imported water and local groundwater used to supplement natural flows to maintain a minimum pool (elevation 1,235 ft.) • Recreation - Establishment of recreational beaches, boat launches and other features to support public fishing • Lake inlet relocated and improved to provide flood protection	• Lake Characteristics - Lake Status – Intermittent Lake; periods of low water will probably predominate; occasional periods of very high water will occur - Outlet Elevation – 1,260 ft. - Water Level – 1,223 (dry) to 1,260 ft. - Surface Area – 0 to 5,950 acres - Average Depth – 0 to 21 ft. • Water Resources - Groundwater – pump during drought periods to replenish water; inconsistent quality of the water in the lake; precludes use of lake as a non-potable water source - Surface Water – ▪ Continued wide fluctuation in water quality; ▪ Gradual deterioration of water quality as lake level drops below 1,260 ft. and especially in the range of 1,226 and 1,230 ft.); creates unsuitable habitat for fishes continues to function as a large evaporation lake • Recreation – - Shoreline fluctuation will continue preventing establishment of permanent recreational areas - Additional acreage for park but no new boat launching or beach areas; no new fishing access • During times of extreme floods when water levels approach 1,270 ft. (1,265 ft = 100-yr floodplain), extensive flood damage will occur

Addition of Recycled Water

While one of the key outcomes of LEMP was to stabilize lake water levels, variations in the lake level and water quality can still be substantial in Lake Elsinore due to seasonal fluctuations and alternating periods of drought and heavy rains during El Niño conditions. To mitigate this concern, Elsinore Valley Municipal Water District (EVMWD) has provided an average of 4,700-AFY of supplemental makeup water since 2007 to maintain lake levels at an adopted operation range of 1,240 to 1,249 feet. Sources of supplemental water since 2007 include EVMWD reclaimed water (~ 95 percent of total input) and production from non-potable wells on islands in the lake (~ 5 percent of total input).

During the most recent dry period prior to the winter of 2016-2017, modeling analyses indicate that Lake Elsinore would have been completely dry. LEMP coupled with inputs of supplemental water have been successful in avoiding lakebed desiccation or extremely low lake levels, despite the recent period of severe drought.

2.2.2.4 Historical Water Quality and Biological Community Characteristics

As noted above, water quality in Lake Elsinore varies with variation lake elevation. This section provides first an overview of water quality data was used to support development of the original TMDL and the LEMP project. Following this overview, additional water quality information is provided that focuses on (a) salinity characteristics of the lake; (b) fish kills as they may relate to water quality changes; and (c) the most recent water quality observed in the lake as the result of the monitoring program implemented to support TMDL implementation.

Water Quality to Support LEMP and the TMDL

Preparation of the LEMP Environmental Assessment included a compilation of relatively recent water quality data available at the time (**Table 2-7**). Data were summarized from two-time periods, one with a relatively low lake elevation (1975); the other period was a time of relatively high lake elevation (1981). The differences in water quality between the two reporting periods are notably different, especially for salinity.

Table 2-7. Water Quality Data for Lake Elsinore Under Low Water Level (1975) and High Water Level (1981) Conditions (adapted from Engineering-Science 1984)

Measurement		High Water Level (1,255 ft.) – 1981[1]		Low Water Level (1,233 ft.) – 1975[2]	
		Range	Average	Range	Average
Conductivity (µS/cm)		1,070 – 1,210	1,118	1,026-6,407[3]	5,572
pH (Standard Units)		8.0 – 8.5	8.2	8.5 – 9.4	9.1
Alkalinity ($CaCO_3$) mg/L		178 – 180	179	122 – 1,780	956
Sulfate (SO_4) mg/L		110 – 120	111	Not determined	
Nitrogen (mg/L)	Ammonia	0.2 – 0.4	0.23	0.04 – 0.09	0.058
	Nitrate and Nitrite	< 0.101 – 0.521	0.233	0.03 – 0.31	0.089
	Organic	1.1 – 2.8	1.62	0.5 – 4.9	3.2
	Total Nitrogen	1.513 – 2.521	2.06	0.58 – 5.00	3.25
Phosphorus (mg/L)	Orthophosphate	0.033 – 0.065	0.045	0.03 – 0.27	0.128
	Total Phosphate	0.065 – 0.196	0.087	0.05 – 0.65	0.450

[1] Data collected from 14 lake locations in January 1981 (Engineering-Science 1981)

[2] Data collected from 6 lake locations in March, June and November 1975 (EPA 1976)

[3] Conductivity results from extremely low water levels were in the range of 28,000 to 30,000 µS/cm (see Figure 2-4 below)

When the 2004 TMDL was developed, the following sources provided key water quality data for the TMDL development effort:

- In 1975, EPA conducted a eutrophic survey among 24 lakes and reservoirs in the western United States, including Lake Elsinore (EPA 1978). The study categorized Lake Elsinore as hypereutrophic due to high levels of chlorophyll-*a*, TP, TN, and low Secchi depth readings. As part of the EPA study, an effort was made to determine whether the limiting nutrient was nitrogen or phosphorus. The study consisted of an algal growth test (assay) using the algae Selenastrum capricomutum. Results indicated that at that time, nitrogen was the limiting nutrient (EPA 1978). A survey of phytoplankton indicated a dominance of flagellate-green, blue-green algae and diatoms. The abundance of the algal cells increased the turbidity of the water column. The presence of the blue-green algae suggested that nitrogen fixation was a process for the blue-green algae to utilize nitrogen directly from the atmosphere.

- The Santa Ana Watershed Project Authority (SAWPA) was awarded a Clean Water Act Section 314 grant (Clean Lakes Study) in 1993 to conduct a water quality study of Lake Elsinore. Black & Veatch was retained by SAWPA to conduct a water quality monitoring program under the contract with the then Lake Elsinore Management Authority (LEMA) from 1994 through 1997. The results and findings of the studies were reported in two technical documents prepared by Black & Veatch in 1994 and1996 and are summarized in the original TMDL Problem Statement for Lake Elsinore (Santa Ana Water Board 2000).

Salinity

Water quality varies in Lake Elsinore in large part due to the changing lake elevation. Of particular significance is the variability in salt content that increases with decreasing lake level. This periodic change in salinity has significance to the biology of the lake (see discussion below). Variability in salinity has been well documented through a number of sources dating back to at least 1850 when Benjamin Hayes noted the following description of Lake Elsinore in his diary (Wolcott 1929): "*The water of the Laguna is saltish, the animals cannot drink it; if they could, such a sheet of fresh water here would be invaluable to the owner of this land….*"

The USGS provides an indication of salinity concerns in the lake from information developed from the latter part of the 19^{th} century (USGS 1917):

> *"[The Lake water] was purchased by the Temescal Water Co. for the irrigation of lands at Corona, California, and its outlet channel was deepened, permitting gravity flow to Corona for a year or more after the lake level had sunk below the elevation of its outlet. As the surface still receded a pumping plant was installed and the water was raised a maximum of about 10 feet and then flowed down the natural channel of Temescal Canyon. Pumping was continued a couple of seasons,* ***but the concentration of salts in the lake, due to the evaporation and low rainfall, soon made the water unfit for irrigation****." (emphasis added)*

Harbeck and others (1951) reported on the results of a water quality sample collected in 1949 as part of a general survey of western lakes and reservoirs. The elevation of the lake surface was 1,232.7 feet. on the sample collection date of June 7, 1949; maximum depth of the lake was approximately 9 feet and the majority of the lake was less than 5 feet. deep. A water sample was collected in the afternoon from near the pier at the Aloha Beach Club at Elsinore. The TDS concentration was 8,890 parts per million (ppm); the water temperature was 90° F. Sample results also indicated the presence of hydrogen sulfide.

The State Water Board (1953) conducted an investigation to identify solutions to water quality concerns in the lake and develop a cost estimate for importing Colorado River water from the aqueduct to supplement local supplies for domestic and agricultural use in the basin. The investigation also evaluated the possibility and cost of stabilizing lake levels for recreational purposes. Report findings include:

"Since there is ordinarily no outlet from Lake Elsinore, the mineral quality of water in the lake varies inversely with the amount of water it contains. This results from processes of concentration of solubles by evaporation and dilution by inflow. ***With the lake full in 1916, the water contained about 1,300 ppm of dissolved solids, while with the lake nearly dry, in 1951, it contained about 214,000 ppm of dissolved solids.****" (emphasis added)*

Increased salinity can have a significant impact on the biological community of Lake Elsinore. This relationship is described in the following summary of water quality issues associated with increased salinity (Engineering-Science 1984):

"Lake Elsinore basically functions as a large evaporation lake. The lake has no outlet until the water level reaches 1,260 feet, then water flows into Temescal Wash…As a result of the evaporation process, the dissolved materials content of the remaining lake water increases. Inflows from the watershed and other sources can slow down this concentration process; however, the net effect is dependent upon the volume and quality of inflow. Using conductivity as a general index of overall water quality, it is clear that as the lake elevation drops below 1,235 feet the quality of water begins to rapidly deteriorate…As the lake level continues to drop, the dissolved salts increase, plankton begin to die and their decomposition consumes the available dissolved oxygen, and fish begin to die. Fish-kills (i.e., 150 tons) have occurred in the past as Lake Elsinore approached the final stages of drying up. These die-offs resulted in serious health hazards and odor problems."

Figure 2-14 from Engineering-Science (1984) illustrates the relationship between lake levels and salinity as known at the time when the LEMP project was under development. This information was further developed in EIP Associates (2005) from water quality work completed by Black & Veatch (1996) (**Figure 2-15**). EIP Associates (2005) notes that at lake elevations of about 1,253 feet. or less, the typical state of Lake Elsinore is brackish with TDS concentrations above 1,000 mg/L (typical of freshwaters that are potable) but less than seawater where TDS is > 35,000 mg/L. TDS levels fluctuate in the lake due to varying processes and conditions (EIP Associates 2005):

"As a general observation, it has been historically true that when the lake water surface elevations are low (i.e., lake volumes are low) due to a prolonged periods of inadequate inflows from the San Jacinto River, TDS steadily increases due primarily to evapoconcentration of dissolved constituents. Conversely, when the lake receives substantial inflows during wet water-years, the inflows serve to bring low salinity water to the lake, thereby reducing TDS concentrations…In reality, historical TDS concentrations in Lake Elsinore are a function of: 1) the influent salinity levels; 2) the frequency, duration and magnitude of inflows to the lake; 3) the evaporation rates; 4) the frequency of lake flushing; and 5) the aqueous geochemistry of the system."

More recent monitoring data shows how much TDS can fluctuate from year to year (see discussion of current water quality below in Section 2.2.2.5).

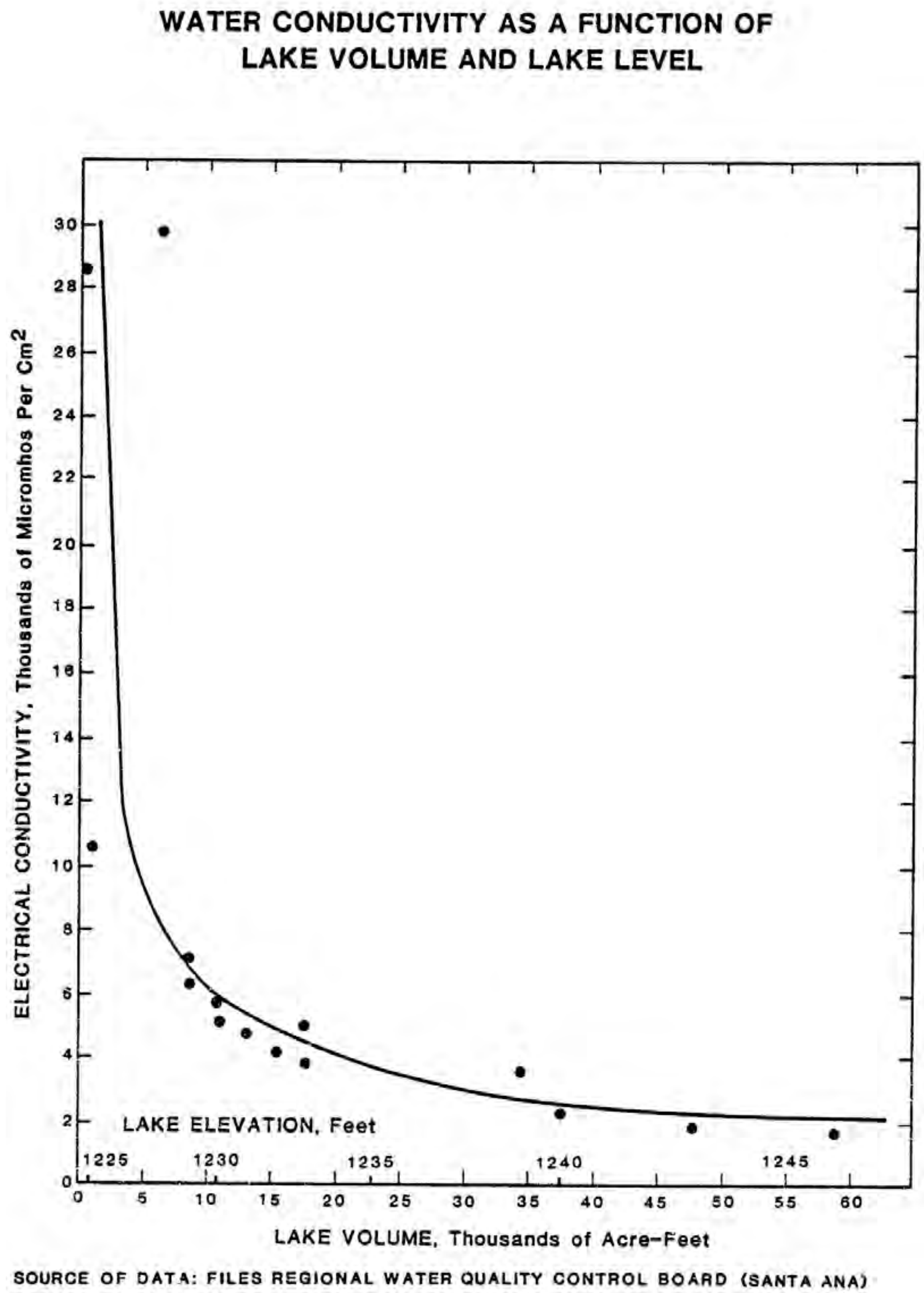

Figure 2-14. Relationship Between Electrical Conductivity (EC) and Lake Elevation (from Figure 2-4 in Engineering-Science [1984]) (Note: Total Dissolved Solids equals approximately 0.64 * EC)

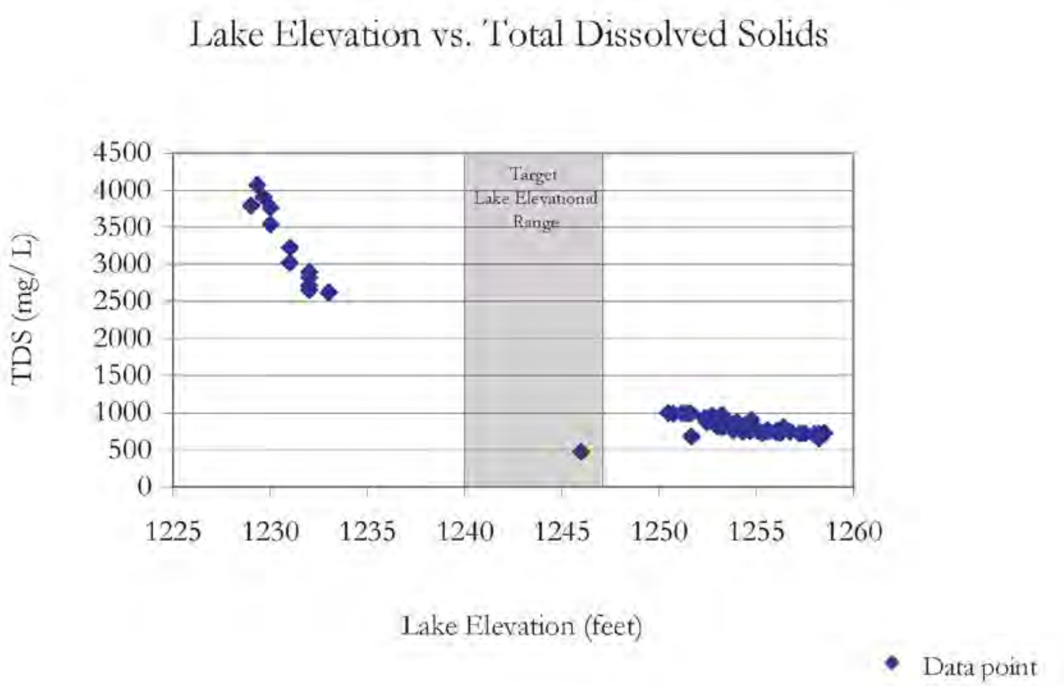

Figure 2-15. Relationship Between TDS (mg/L) and Lake Elevation (feet.) (Adapted from EIP Associates [2005] based on data from Black and Veatch [1996]) (Note: "Target Lake Elevational Range" based on analysis in EIP Associates [2005] for implementation of a fish recovery program)

Fish Community

Engineering-Science (1984) documented what was known of the fish community at that time, including reference to a Department of Fish and Game survey (California Department of Fish and Game 1973) that identified seven fish species: largemouth bass, bluegill, channel catfish, white catfish, carp, mosquito-fish and threadfin shad as well as other species reported from U.S Fish and Wildlife survey (U.S. Fish and Wildlife Service 1982): tilapia, crappie, redear sunfish, green sunfish and golden shiner.

Engineering Science (1984) describes the fishery resource within the context of known water quality as follows (see **Figure 2-16**):

> "*Although not documented, the fisheries resources in LE have probably exhibited wide variability due to fluctuating water levels and attendant changes inn habitat features, esp. water quality. At higher waters levels (1240 to 1265 feet), the resident fish population probably thrived due to the presence of good quality water, inundation of floodplain to the south creating shallow water habitat, and increased growth of plankton populations. As the water level drops to 1240 feet and below, the fisheries resources of the lake begin to experience decline. Loss of habitat occurs and the concentrations of dissolved salts increases. The latter creates conditions for algal blooms. The metabolic breakdown of the biomass generated by the algal blooms soon lowers the dissolved oxygen content of the water, and in some instances, to a concentration that results in fish suffocation. Following the die-off of*

> *resident stock in the lake, a new fisheries resource would have to be reestablished beginning with fish planting."*

The "die-off" of resident stock in the lake is a well-known phenomenon with the history of such fish kills well-documented as they have been occurring for a long time even prior to development (EIP Associates 2005):

Figure 2-16. Algal Bloom in Lake Elsinore, 2016 (Source: Amec Foster Wheeler)

> *"Fish kills have occurred periodically in Lake Elsinore for millennia due to adverse environmental conditions. Even under pristine conditions the lake would shrink and occasionally dry up completely. During these periods the fish fauna would be lost, only to recolonize the lake during more favorable hydrological conditions. Historically, fish kills have been reported at the lake even prior to any significant upstream diversions of water (principally the completion of Railroad Canyon Dam in 1928)."*

Table 2-8 summarizes the documented history of fish kills in Lake Elsinore. This information was largely developed by EIP Associates (2005) and supplemented from other sources where information was available. EIP Associates (2005) has noted that fish kills may occur under a variety of conditions, including when the lake elevation is high. For example, in those instances where lake elevation was known, of 21 fish kills eight or 38 percent of them occurred when the lake was equal to or greater than 1,240 feet. The remainder occurred when the lake level was low or nearly dry. Anecdotal information from the time of a fish kill illustrate how significant the event can be. For example, in an October 1948 letter from the State Department of Fish and Game to U.S. Department of Interior (as documented in EDAW (1974) (**Figure 2-17**):

> *"…fish losses in Lake Elsinore have occurred to a varying degree almost annually for the past ten to fifteen years…once a good fishing lake containing bass, bluegill and catfish, the Lake now only contains a large population of carp…in 1933, 1940, 1941 and again this year, heavy fish losses occurred…the recent kill August 31-September 2 consisted of the loss of approximately 300-500 tons of carp…losses nothing unusual…causes might be summarized as follows: 1) increased alkalinity and mineral concentration…2) over abundance of plankton algae coupled with high water temperature results in oxygen deficiency…"*

Table 2-8. Summary of Historic Fish Kills in Lake Elsinore.

Date	Dissolved Oxygen (mg/L)		Duration of Fish Kill (days)	Lake Water Surface Elevation (ft)	Lake Volume (acre-ft)	Fish Species	Estimated Weight of Fish (tons)	Probable Cause	Reference
	Initial	Final							
1883**								"fish died in the lake and their stench filled the air"	Hudson (1978)
Circa 1886[1]						Arroyo chub			Couch (1952)
Circa 1898								Attributed to a sulfurous gas released from the lake bottom	Couch (1952)
January 1906									Couch (1952)
1915				~1,243	48,200	Black Bass		Low lake level and "salty" water	Couch (1952)
1917[2]				~1,258	116,000			High water temperature	Couch (1952)
September 13, 1927			10	~1,253	90,000				Elsinore Valley News (September 22, 1927)
April 7, 1933*			6	~1,242	45,000	Mostly carp and a few "minnows," i.e., arroyo chub		Lake turnover[3]: chlorides = 1,540 mg/L, TDS = 4,386 mg/L, dissolved oxygen at the surface at the shoreline at 25% saturation on April 13. High algal density. *Oscillatoria* about 30% of phytoplankton sample.	Elsinore Leader Press (May 4, 1933)
1936				1,227	5,400			Tons of algae reported	Bovee (1989)
August 15, 1940*				1,252	85,500	Arroyo chub; Small/young fish	Heavy Kill[3]	Sudden change in the mineral content of the lake	Bovee (1989), Couch (1952)
1941							Heavy Kill		See table note 4
August 27, 1948*[5]			6	1,232	16,200	Carp	300-500[6]	(1) Increased alkalinity and mineral concentrations; (2) Over-abundance of algae coupled with high water temperature resulting in oxygen reduction[7]	Couch (1952); Hudson (1978); Bovee (1989)

Table 2-8. Summary of Historic Fish Kills in Lake Elsinore.

Date	Dissolved Oxygen (mg/L)		Duration of Fish Kill (days)	Lake Water Surface Elevation (ft)	Lake Volume (acre-ft)	Fish Species	Estimated Weight of Fish (tons)	Probable Cause	Reference
	Initial	Final							
1950*				1,230	12,000			No fish in the lake[8]	Bovee (1989)
1954				1,223	0			Lake dried up[9]	Bovee (1989)
1966*				1,229	9,600		Heavy kill[3]	Dissolved oxygen reduction	Bovee (1989)
August 31, 1972*			8	1,235	24,000	Primarily threadfin shad	800	Water temperatures ranged from 27.2 to 29.5ºC	Bovee (1989)
August 6, 1975			~2	1,230	12,000		Dump Truck Loads		Bovee (1989)
Fall 1976				1,229	9,600		41		Bovee (1989)
August 1987				1,240	39,000	Threadfin shad	Minor kill[3]		Bovee (1989)
October 1988				1,233	18,700		Minor; 300 lbs		Bovee (1989)
July/August 1990	6	0	60[10]	1,237	28,400		1500		MWH (2002)
1991								"120 thousand tons of fish killed by algae"	Press Enterprise
July/August 1992	6.5	2	60[11]	1,231	14,000				MWH (2002)
1993								More than 100,000 tons of fish died	Black and Veatch
June/July 1995	9	3	60[12]	1,254	95,000	Various species	200	Low dissolved oxygen	North County Times (August 22, 2002); MWH (2002)
1996								"in August, smaller fish die off"	Press Enterprise
1997								On April, 7 tons of shad died of oxygen depletion	Press Enterprise

Table 2-8. Summary of Historic Fish Kills in Lake Elsinore.

Date	Dissolved Oxygen (mg/L)		Duration of Fish Kill (days)	Lake Water Surface Elevation (ft)	Lake Volume (acre-ft)	Fish Species	Estimated Weight of Fish (tons)	Probable Cause	Reference
	Initial	Final							
November 11, 1998*				~1,250	76,000	Threadfin shad	240	Migratory birds stressing high density shad population during period of low dissolved oxygen	Kilroy (1998)
August 2001				1,239	35,000	Carp			LESWA (2002)
August 22, 2002			2	1,236		Primarily Carp	50	Low dissolved oxygen	North County Times (August 24, 2002)

[1] Based on the memory of Jessie Stephens. Unreliable record.

[2] Letter from James Gyger, Fish and Game warden, written in 1919 and published in the Lake Elsinore Valley Press on June 13, 1919. States: "About every 15 or 20 years it [Lake Elsinore] gets so low that everything in it dies."

[3] Definition or description of what constitutes a minor or heavy kill is not provided in EIP Associates (2005)

[4] Fish kill observed to have begun over the deep part of the lake.

[5] Letter from the California Department of Fish and Game to the U.S. Department of the Interior states "… fish losses in Lake Elsinore have occurred to a varying degree almost annually for the past 10-15 years." Quoted by Bovee (1989).

[6] Estimated at 1,000 tons in Hudson (1978).

[7] Letter from the California Department of Fish and Game to the U.S. Department of the Interior quoted by Bovee (1989).

[8] The lake dried up in 1951. Probably few to no fish in the lake since the fish kill in August/September 1948.

[9] Lake partially refilled in 1952 to about 11 feet deep.

[10] Fish mortality occurred over this period of time.

[11] Fish mortality occurred over this period of time.

[12] Fish mortality occurred over this period of time.

* In both EIP Associates (2005) and Santa Ana Water Board Staff Report (Santa Ana Water Board 2004).

** In Hudson (1978)

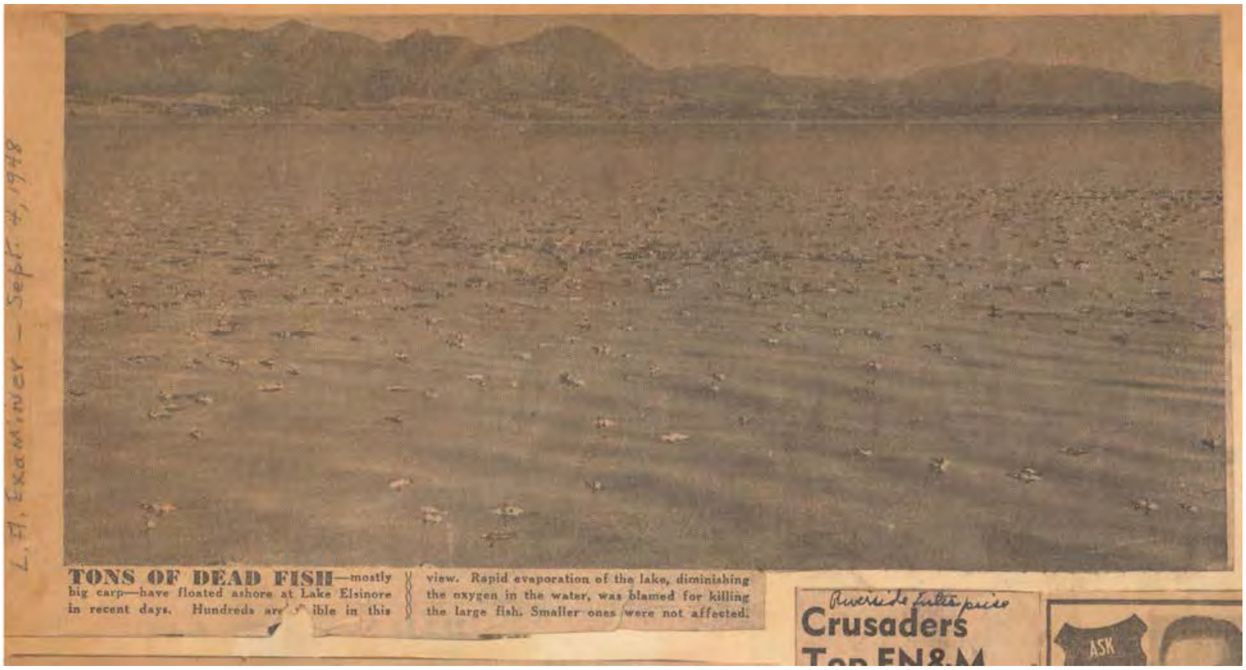

Figure 2-17. Illustration of 1948 Fish Kill in Lake Elsinore (Source: Lake Elsinore Naval School).

Finally, when the lake dried up in 1951, Fortnight: The Magazine of California (1954) provided additional biological descriptions of lake conditions in association with the lake drying up in 1951:

> *"In 1951, there was another mass death of fish, followed by another horrible stench and another back-breaking hauling away. Then the Lake performed what was in some ways its most diabolical act of all. With the fish dead, clouds of gnats began to descend upon the town…A light trap set up by one of the researches (sic) caught an announced 56,000 gnats in an hour and tests of the lake bottom showed scads of larvae, representing still more generations of the winged pests. (In normal years the larvae would have been eaten by the fish)."*

2.2.2.5 Recent Water Quality Findings

A significant body of monitoring data has been collected for Lake Elsinore since the start of the development of the original TMDL in May 2000. These data are reviewed here with the goal of developing statistical relationships to understand the dominant drivers of water quality (especially chlorophyll-*a* concentrations). Importantly, this time period includes periods of pronounced drought, resulting in increased salinities and lower lake levels, as well as El Nino events with large freshwater inputs that are generally elevated in dissolved nutrients. Water samples were routinely collected for nutrient analysis, chlorophyll-*a*, and a number of other associated measures including biological and chemical oxygen demand (BOD and COD), total and dissolved organic carbon (TOC and DOC), and TDS at one to three sampling stations, LEE1, LEE2, and LEE3 located along a central axis in the center of the lake (**Figure 2-18**). The highest frequency of monitoring occurred at the most central location, LEE2.

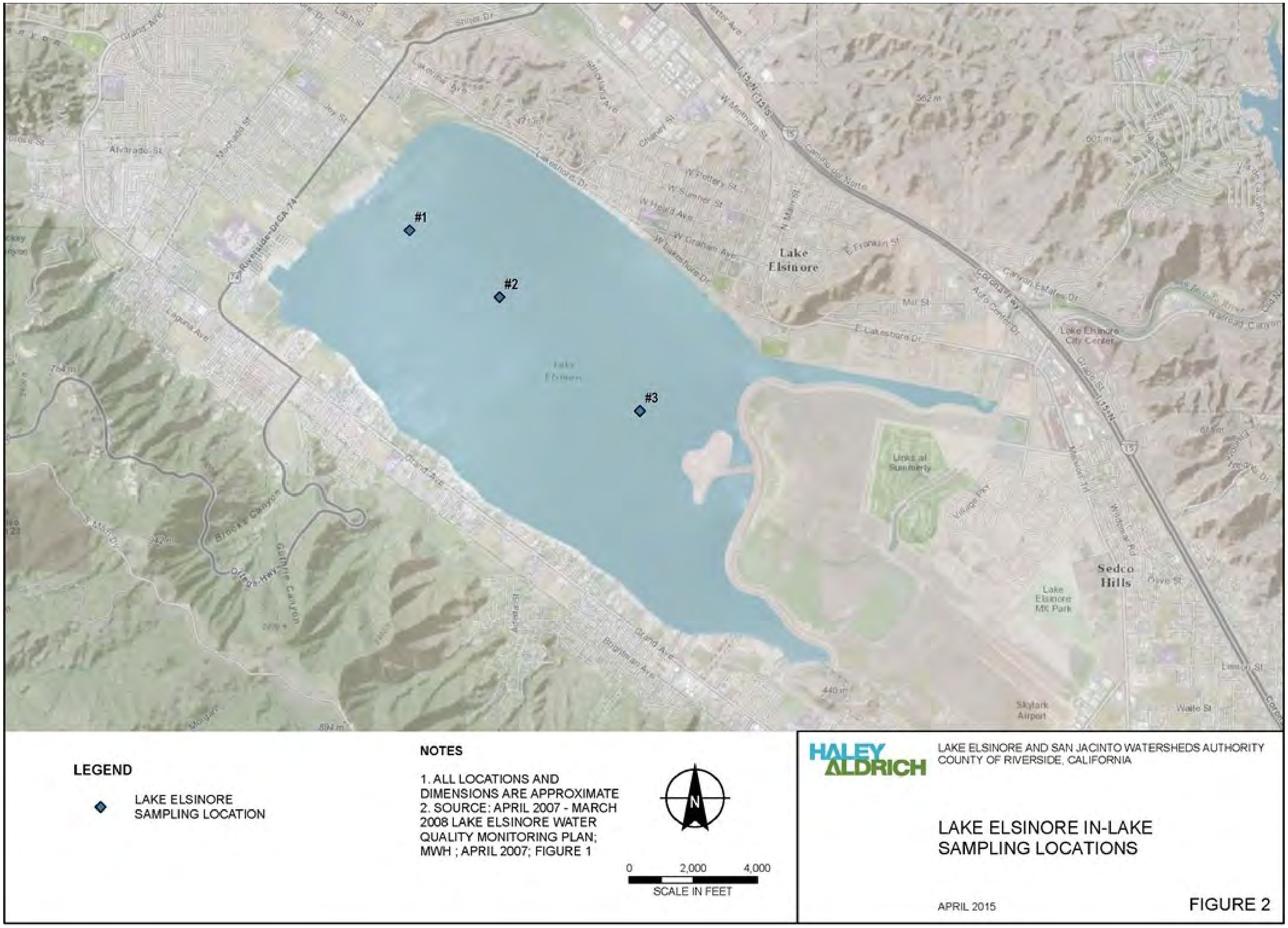

Figure 2-18. Location of Lake Elsinore Sample Locations (LEE1, #1; LEE2, #2; and LEE3, #3). Figure 2 from Lake Elsinore & Canyon Lake Nutrient TMDL Compliance Monitoring Work Plan (Haley & Aldrich 2015)

Between 2001 and 2012 monitoring was typically performed at a weekly or bi-weekly frequency during the summer months (June, July, August, and September), and bi-weekly or monthly from October through May. Water samples for nutrients and other associated measures generally were collected as an integrated composite of the water column. Chlorophyll-a has frequently been measured as an integrated surface sample representative of the top 2-m of the water column. Physical parameters such as temperature, DO, pH, conductivity, and water clarity were also measured at three-foot intervals at the time of sample collection.

Between 2000 and 2012 a number of other special studies were performed to gather nutrient-related water quality data at a number of other locations to enhance understanding of spatial variability throughout the lake, assess any changes in water quality related to amending the lake with reclaimed water and groundwater, and to assess the effectiveness of the aeration/ mixing system (Anderson and Lawson 2005; Veiga Nascimento and Anderson 2004; Anderson 2006; Anderson 2008a; Anderson 2010; Santa Ana Water Board 2007a; and Horne 2009). A break in monitoring occurred between 2012 and 2015 to reallocate resources for the implementation of water quality BMPs in both Lake Elsinore and Canyon Lake, but monitoring was reinitiated in 2015 (**Figure 2-19**).

Figure 2-19. Lake Elsinore, September 2016 (Source: Amec Foster Wheeler)

Currently, monitoring and analysis of nutrients and chlorophyll-a occurs monthly during the summer months of July, August, and September, and bi-monthly between September and July. Beginning in July 2016, the monitoring frequency of Lake Elsinore was increased to bi-weekly during the summer months of July, August, and September. The increased monitoring in Lake Elsinore during the summer months was performed to provide more data points during this time-frame due to the current TMDL compliance target for chlorophyll-*a*, which is based on a summer average for this lake, as opposed to an annual average in Canyon Lake. Nutrients and TDS are analyzed in a single surface to bottom integrated sample as described in the Work Plan for the current TMDL monitoring program (Haley and Aldrich 2015). Chlorophyll-*a* is measured in both an integrated sample of the entire water column, as well as a surface sample representative of the top 2-m of the water column. Depth profiles of temperature, DO, pH, conductivity, and water clarity are also measured at 1-m intervals on the day of sampling for nutrients. For the first time, these measures are now being performed twice during the day (am and pm) to assess diel variability associated with photosynthesis and respiration cycles of algae which can substantially alter DO concentrations over short periods of time.

In the following subsections data are presented for Site LEE2 given its central location and the greatest history of data at this site. In addition, spatial differences on any given day for nutrients are generally limited based on a review of past monitoring data. Note that supporting water quality analyses presented in tables and graphs within this section for Lake Elsinore focus on the most recent available data collected in a consistent manner over the past 14-16 years. These data are now available in a single California Environmental Data Exchange Network (CEDEN)-compatible database and has been collated and validated through a third party prior to analysis. Older data are referenced where applicable, but are not presented graphically. All values presented in the associated figures represent water column averages derived from depth-integrated water column samples, with the exception of DO which is plotted as both a depth-integrated value and discreet values measured at 1-m from the bottom. The presentation of data is also presented in relation to the current 2004 TMDL compliance metrics for comparison purposes.

Nutrients (Phosphorus and Nitrogen)

The current TMDL includes a numeric target for TP in Lake Elsinore of 0.1 mg/L to be achieved by 2020 as an annual average concentration (see Table 2-2). The TMDL numeric target for TN in Lake Elsinore is 0.75 mg/L, also to be achieved by 2020 as an annual average concentration (see Table 2-2).

Phosphorus exists in the water in either a dissolved phase or a particulate phase. Dissolved inorganic phosphate (orthophosphate, Ortho-P) is the soluble reactive form of phosphorous that is readily available to algae (bioavailable) and under certain conditions it can stimulate excess algae growth. Both TP and Ortho-P are routinely analyzed in water quality data collected from Lake Elsinore.

TP and Ortho-P concentration data from 1992 through 1997 are shown graphically in the 2000 Nutrient TMDL Problem Statement for Lake Elsinore. Prior to January 1993, orthophosphate concentrations in Lake Elsinore were below the detection limit (0.05 mg/L). In January 1993, Canyon Lake overflowed which altered the phosphorus concentrations in Lake Elsinore. After the Canyon Lake overflow, both Ortho-P and TP increased dramatically: Ortho-P increased from non-detect to 0.5 mg/L, and TP increased from 0.5 mg/L to 1.2 mg/L. The increase in phosphorus more than likely came from the Canyon Lake overflows to Lake Elsinore, which comprised a higher ortho-P fraction than in Lake Elsinore prior to the overflow.

Phosphorus concentrations from 2002 to present have also exhibited strong seasonal and inter-annual variations as well. **Figure 2-20** shows a graphical summary of available TP data from 2002 to 2016, representing depth-integrated water column average concentrations. **Table 2-9** provides the associated range, average, and median values of TP from 2002 to present. For the summaries that follow, only TP is presented for direct comparability to Basin Plan objectives and the existing TMDL targets. In general, a majority of the TP is in the organic form and trends between the two are tightly coupled. Note that available water quality data between 1997 and 2002 is limited and inconsistent, and thus not included as a part of the evaluations in this document.

Overall, TP has averaged between 0.1 and 0.4 mg/L in Lake Elsinore between 2002 and 2016 with majority below 0.6 mg/L and no visually discernable long-term trend. Low values of < 0.1 mg/L have been reported on a few dates (October 2002, April 2008, and May 2012). Values increased to > 0.5 mg/L in 2003-2004. Concentrations decreased beginning in 2005 and have more recently ranged from about 0.2 to 0.3 mg/L with the exception of one large spike to 0.9 mg/L in April 2011 and a spike to 0.5 mg/L in June of the same year. Current values over monitoring periods in July 2015 to August 2016 have ranged from 0.3 to 0.6 mg/L (Figure 2-20).

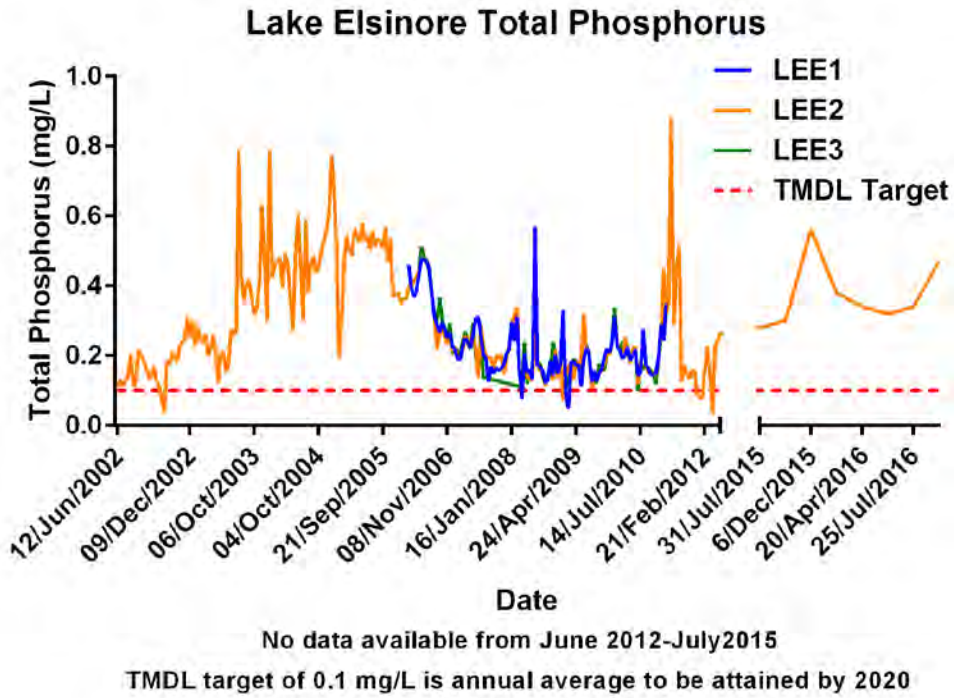

Figure 2-20. Depth-Integrated Average Total Phosphorus Concentrations in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

Table 2-9. Historical Dissolved Oxygen, Nutrient, Chlorophyll-*a*, and TDS Summary for Lake Elsinore between 2002 and 2016 (TMDL Compliance Monitoring)

Parameter	Date Type	No of Samples (2002-2012)	2002-2012				2015-2016 (N = 7 to 8)			
			Min	Max	Mean	Median	Min	Max	Mean	Median
Dissolved Oxygen (mg/L)	Depth-Integrated	113	2.0	11.7	6.3	6.1	3.0	11.1	5.0	4.1
	Bottom 1-m	113	0.02	10.5	4.2	4.2	0.65	11.0	3.3	2.4
Chlorophyll-*a* (µg/L)	Depth-Integrated	178	6.2	440	137	116	172	326	236	250
Total N (mg/L)	Depth-Integrated	226	0	9.9	4.1	3.8	5.0	9.8	6.4	7.1
Total P (mg/L)	Depth-Integrated	235	0.03	0.89	0.29	0.23	0.28	0.56	0.37	0.34
Total Ammonia (mg/L)	Depth-Integrated	187	< 0.05	1.52	0.18	0.11	0.05	0.71	0.21	0.05
Un-ionized Ammonia (mg/L)	Depth-Integrated	187	0	0.28	0.04	0.02	0.01	0.26	0.05	0.02

TDS (mg/L)	Depth-Integrated	188	427	2240	1376	1433	2600	3500	3000	3000

All of the forms of nitrogen were analyzed in the Clean Lakes Study and the subsequent TMDL compliance monitoring efforts; nitrate, nitrite, ammonium, and total kjeldahl nitrogen (TKN). TN is calculated as the sum of TKN, nitrate, and nitrite. Like phosphorus, nitrogen concentrations also exhibit strong seasonal and inter-annual variations as well.

In Lake Elsinore, the major form of nitrogen exists as organic nitrogen. During the Clean Lakes Study, nitrogen forms were reported separately, but a majority of the TN was captured by TKN with generally very low concentrations of nitrate and nitrite in Lake Elsinore. The concentration of TKN was as high as 13 mg/L prior to the Canyon Lake overflow in January 1993. After the overflow, nitrogen concentrations dropped dramatically to 2 mg/L. There was an increase in TKN concentration (mostly the organic nitrogen) in October 1993, up to 6 mg/L, possibly due to an algal bloom. There are no data for TKN concentrations in 1994; analyses resumed in 1995 and the TKN concentrations remained stable from 1995 through 1997 at approximately 3 mg/L. **Figure 2-21** shows graphical summary of available TN data from 2002 to 2016. Table 2-9 provides the associated range, average, and median values of TN from 2002 to present. Between 2002 and 2012, TN concentrations were generally between 2 and 6 mg/L with an average of approximately 4.0 mg/L. As with phosphorus, there appears to be no visually discernable long-term trend in nitrogen concentrations. There have been several spikes of TN greater than 8.0 mg/L in November 2003, January 2004, and August and October of 2004, and most recently in February 2016. The near record runoff in the winter of 2005 dramatically reduced TN concentrations in the lake. Within a period of a couple months TN concentrations declined from 8 mg/L to almost 2 mg/L. The lowest concentration of TN recorded in Lake Elsinore since 2002 was 0.8 mg/L in May 2008.

An evaluation of the ratio of TN to TP can be used to determine whether the limiting nutrient is nitrogen or phosphorus with regard to algal productivity. In general, a TN:TP ratio of < 10 indicates a lake with productivity limited by nitrogen, while a TN:TP ratio > 20 indicates a lake with productivity limited due to phosphorus (EPA 1999a). Once the limiting nutrient is identified, specific control measures targeted at that nutrient can be identified and implemented. A plot of the ratio of TN to TP from 1992 to 1997 in Lake Elsinore is provided in the 2000 TMDL Problem Statement. Phosphorus was the limiting nutrient from 1992 to the 1993 before the overflow of Canyon Lake. After Canyon Lake overflowed, nitrogen became the limiting nutrient in Lake Elsinore. From 1995 to 1997, phosphorus became the limiting nutrient once again.

The TN:TP ratio has accordingly varied strongly over the past decade (**Figure 2-22**). Ratios suggesting phosphorus-limitation are typical, as well as intervals in 2005-2006 and short periods in 2008 and 2011 where nitrogen-limitations might be inferred based on a TN:TP ratio of < 10, Despite varying TN:TP ratios, the overall availability of nutrients, based on concentration, has generally been sufficiently high that light or other limitations are thought to be more important in regulating algal productivity in the lake. For example, periods of low dissolved Silicon are traditionally seen during the spring, likely serving as a limitation to diatom production.

It is apparent from evaluation of the data during both wet and dry conditions, that both nitrogen and phosphorus can be critical nutrients with regards to algal growth in Lake Elsinore. Because the limiting nutrient can vary depending on the hydrologic conditions, the current TMDL address both nutrients.

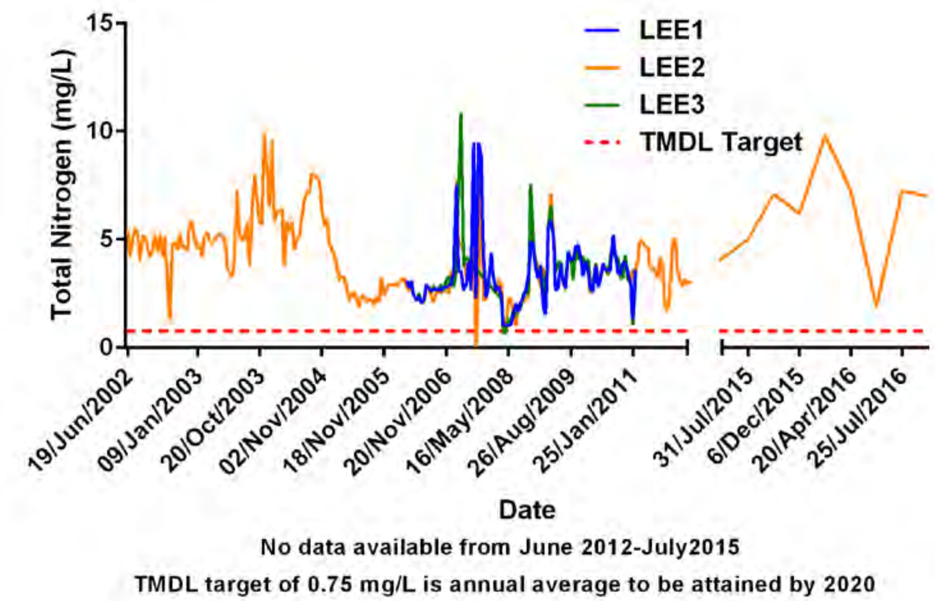

Figure 2-21. Depth Integrated Average Total Nitrogen Concentrations in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

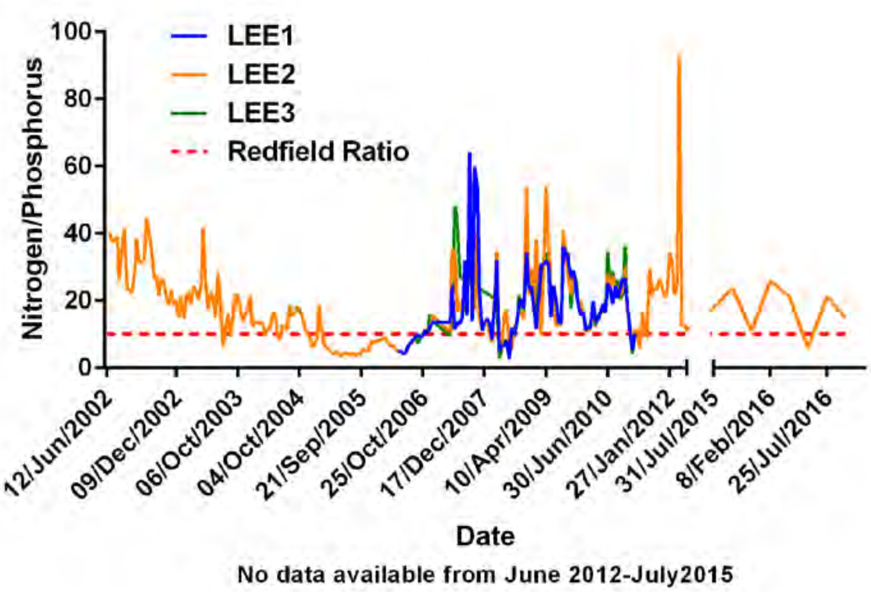

Figure 2-22. Nitrogen to Phosphorus Ratios in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

Ammonia

Ammonia is a toxic component of the nitrogen cycle, formed and released from the breakdown of organic material under anoxic conditions. Acute and chronic objectives for total ammonia are derived based on the pH and temperature of the lake at the time of sampling (see Table 2-1). These parameters, particularly pH, drive the fraction of un-ionized ammonia, which is the most toxic form of this compound. As pH increases, the fraction of un-ionized ammonia increases.

Concentrations of ammonia were not reported in the studies summarized in the 2000 TMDL Problem Statement that included results from the 1975 EPA study and monitoring by Black and Veatch between 1992 and 1997. However, results are available and have been summarized for studies from 2002 to 2016 (**Figures 2-23** and **2-24**) representing depth-integrated water column average concentrations. Table 2-9 provides the associated range, average, and median values of total and un-ionized ammonia from 2002 to 2016.

Levels of total ammonia are generally very low in Lake Elsinore with a range from less than 0.05 mg/L to 1.5 mg/L and a mean value of 0.18 mg/L between 2002 and 2012. The mean value for total ammonia in 2015 was 0.08 mg/L, ranging from 0.05 to 0.13 mg/L. Associated measures of un-ionized ammonia throughout the 2002 to 2016 period are also generally very low despite the elevated pH observed in Lake Elsinore. Values range from less than detection to 0.28 mg/L, with an average of 0.02 to 0.04 mg/L which is well below that expected to cause toxic effects to species found in Lake Elsinore as described further in Section 2.3.3 below. These results indicate consistent compliance with the current TMDL target for ammonia based on the EPA 1999 criterion (EPA 1999b), as well as updated more stringent values developed by EPA in 2013 (EPA 2013). Due to its acute toxicity when present, and the potential for rapid spikes in ammonia following plankton blooms under certain conditions, continued monitoring of ammonia is still recommended in Lake Elsinore.

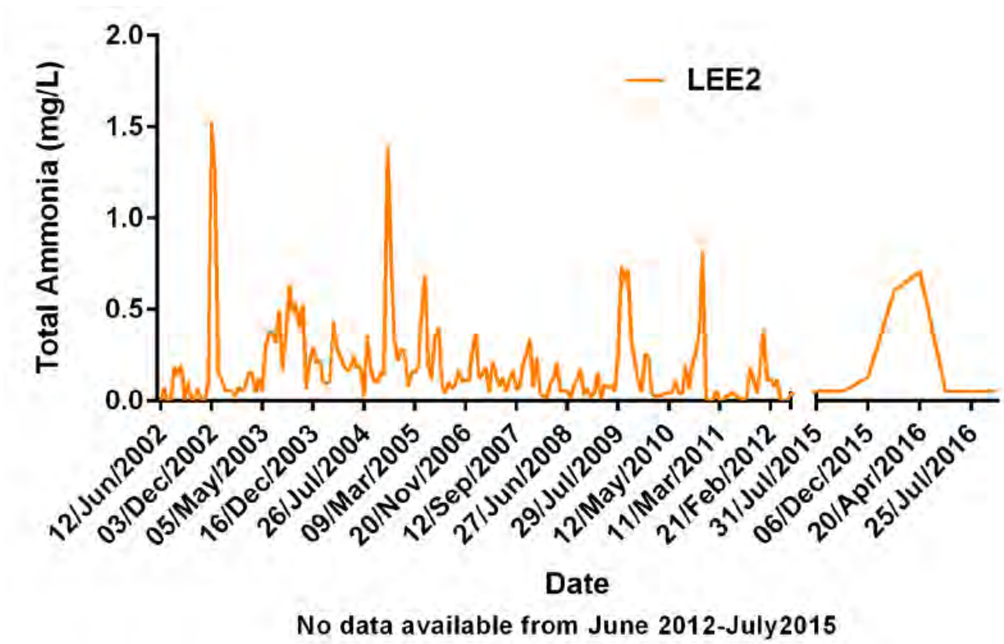

Figure 2-23. Depth-Integrated Average Total Ammonia Concentrations in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

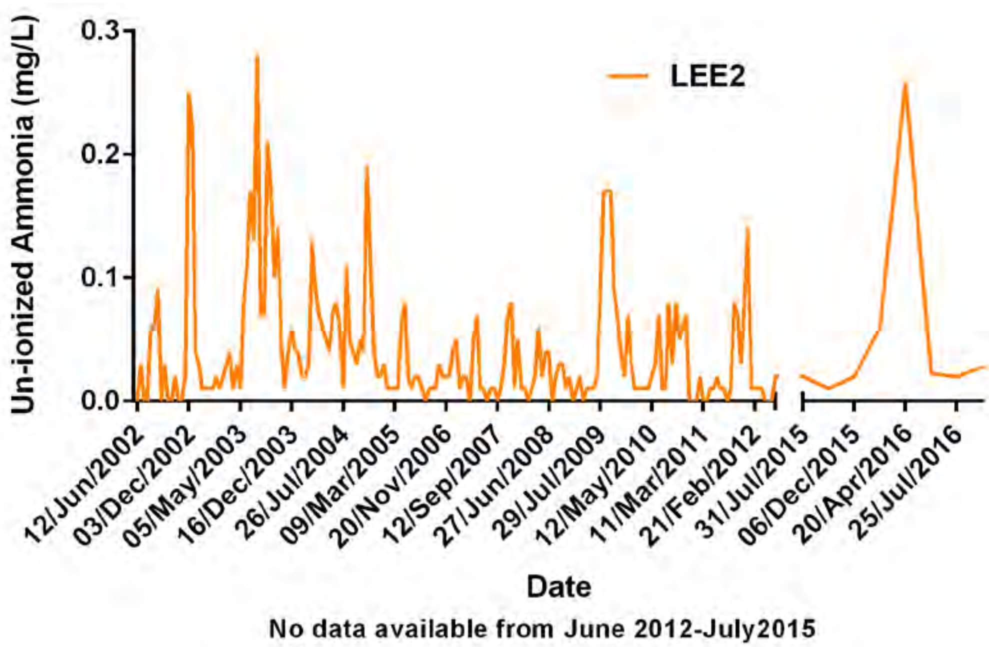

Figure 2-24. Depth-Integrated Average Un-ionized Ammonia Concentrations in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

Chlorophyll-a

Chlorophyll-*a* is an indicator for algal biomass and eutrophication status. In general, a lake with an average chlorophyll-*a* concentration of over 10 µg/L is considered eutrophic (EPA 1974). The current TMDL compliance threshold target for chlorophyll-*a* in Lake Elsinore is a summer average value of ≤ 40 µg/L in 2015 and ≤ 25 µg/L in 2020 (see Table 2-2).

In the EPA study performed in 1975, chlorophyll-*a* in Lake Elsinore ranged from 42 to 118 µg/L (**Table 2-10**). During the Clean Lakes Study and Lake Elsinore Water Quality Monitoring Program chlorophyll-*a* reached a maximum concentration of 950 µg/L in October 1993. A seasonal pattern was observed between 1995 and 1997, with values ranging from 100 to 624 µg/L between July and November, and concentrations ranging from < 10 to 65 µg/L during December to May.

Table 2-10. EPA 1975 Eutrophic Survey Results of Lake Elsinore*

Sampling Date	Chlorophyll-*a* (µg/L)	Total-P (mg/L)	Ortho-P (mg/L)	Inorganic-N (mg/L)	Secchi Depth (m)
3/10/75	52.1	0.52	0.25	0.08	0.3
6/23/75	41.9	0.47	0.09	0.12	0.2
11/13/75	118	0.37	0.05	0.24	0.3
Mean	**70.6**	**0.45**	**0.13**	**0.15**	**0.3**

* As reported in the Santa Ana Water Board 2000 TMDL Problem Statement for Lake Elsinore (Santa Ana Water Board 2000).

Figure 2-25 shows available chlorophyll-*a* data for TMDL compliance monitoring studies performed from 2002 to 2016. Table 2-9 provides the associated range, average, and median values of chlorophyll-*a* during this same period of time. Values presented in Figure 2-25 and Table 2-9 represent average depth-integrated concentrations. Between 2002 and 2012 chlorophyll-*a* concentrations have ranged from < 10 µg/L in a few samples (June 2006 and January 2007), to values in excess of 300 µg/L in late summer-fall of 2002-2004. Concentrations on average were less than 100 µg/L between 2004 and 2008, with a few spikes greater than 200 µg/L. Concentrations of chlorophyll-*a* have generally been increasing since 2008, corresponding with drier conditions overall. During the three most recent monitoring dates between July and August 2016, chlorophyll-*a* concentrations have ranged from 91 to 326 µg/L, with the greatest concentration measured in July 2015. On average, concentrations of chlorophyll-*a* between 2002 and 2012 were greatest in the fall and winter (172 and 150 µg/L, respectively), compared to 100 µg/L in spring and 117 µg/L in summer. These concentrations are frequently well above the current 2004 TMDL summer average target of 40 mg/L by 2015 and 25 mg/L by 2020.

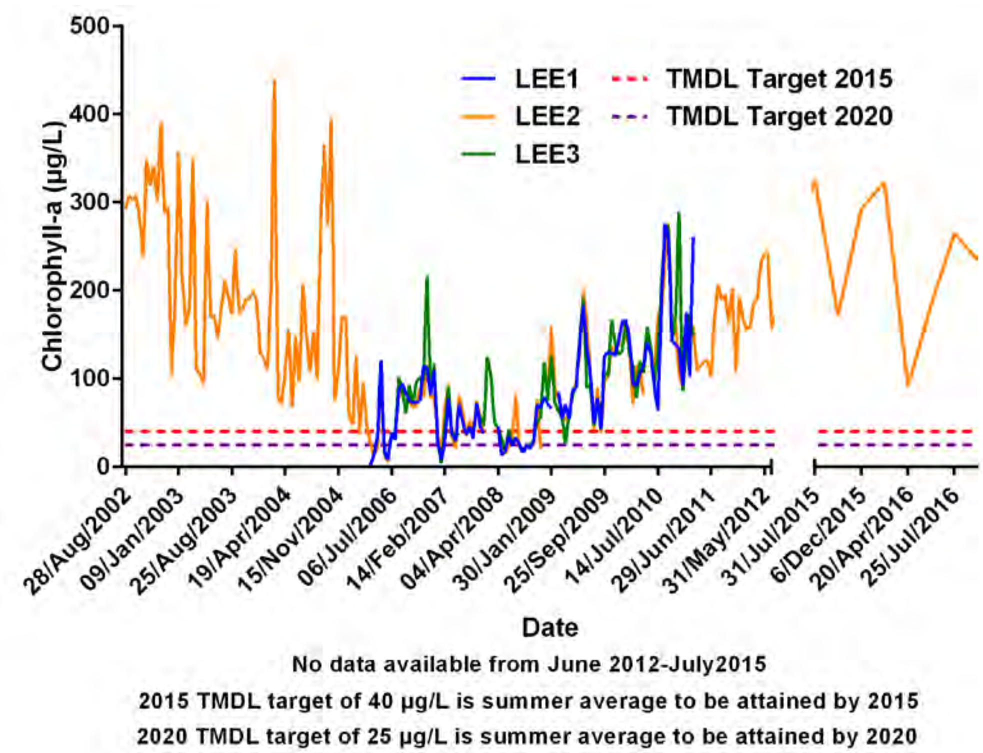

Figure 2-25. Depth-Integrated Average Chlorophyll-*a* Concentrations in Lake Elsinore - 2002-2016 (Note discontinuous data record on x-axis)

Dr. Michael Anderson (UCR) conducted a simple correlation analysis in 2010 to explore statistical relationships between summer-average chlorophyll-*a* concentrations and TP, TN, TN:TP ratio, and TDS (Anderson 2010). A summer average was evaluated to reduce the "noise" associated with seasonal variability in water quality. This simple statistical analysis indicates that total P alone is a poor predictor of summer average chlorophyll-*a* concentrations in the lake, while lake level, salinity and TN each individually account for 49-62 percent of the variance in observed chlorophyll-*a* levels. Adding a second variable predictably improved regressions, with TDS in combination with TP or TN accounting for 69-72 percent of the variance in chlorophyll-*a* concentrations. This analysis provides some insight into the potential causes of algae blooms, but also highlights some of the complicated factors at play.

Dissolved Oxygen

The 2000 TMDL Problem Statement for Lake Elsinore shows the average DO concentrations for the Lake Elsinore stations (measured at the top, middle and bottom of the water column) from March 1994 to June 1996. DO values were not reported in the 1975 EPA study summarized in the 2000 TMDL Problem Statement. DO concentrations between 2002 and present and shown graphically in **Figure 2-26** as a top to bottom depth-integrated measure, and in **Figure 2-27** for the portion of the water column approximately 1-m from the bottom of the lake. Table 2-9 provides the associated range, average, and median values from 2002 to present.

Depth-integrated (average) concentrations of DO in Lake Elsinore range from approximately 6.0 to 7.0 mg/L. As with nutrients there is substantial seasonal and inter-annual variability with no discernable visual long-term trend over time for this parameter. Unlike temperature, there often is vertical stratification for this parameter, with typically much lower concentrations near the sediment surface, averaging approximately 4.0 mg/L. This stratification of DO is a natural condition for most lakes. The low DO near the bottom, particularly during the summer months (occasionally at or near zero mg/L), indicates that there is a high oxygen demand from the sediment. Many of the documented historic fish kills have been associated with periods of high temperature and low DO. The elevated DO often recorded at the surface indicates that algae photosynthesis is frequently supersaturating the water with DO.

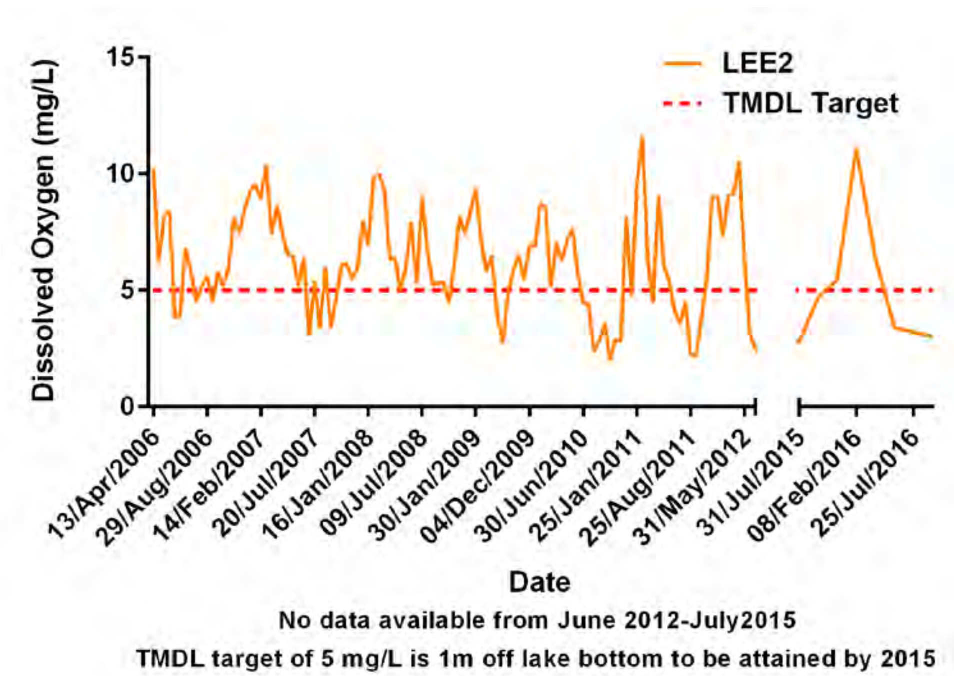

Figure 2-26. Depth-Integrated Average Dissolved Oxygen Concentrations in Lake Elsinore - 2006-2016 (Note discontinuous data record on x-axis)

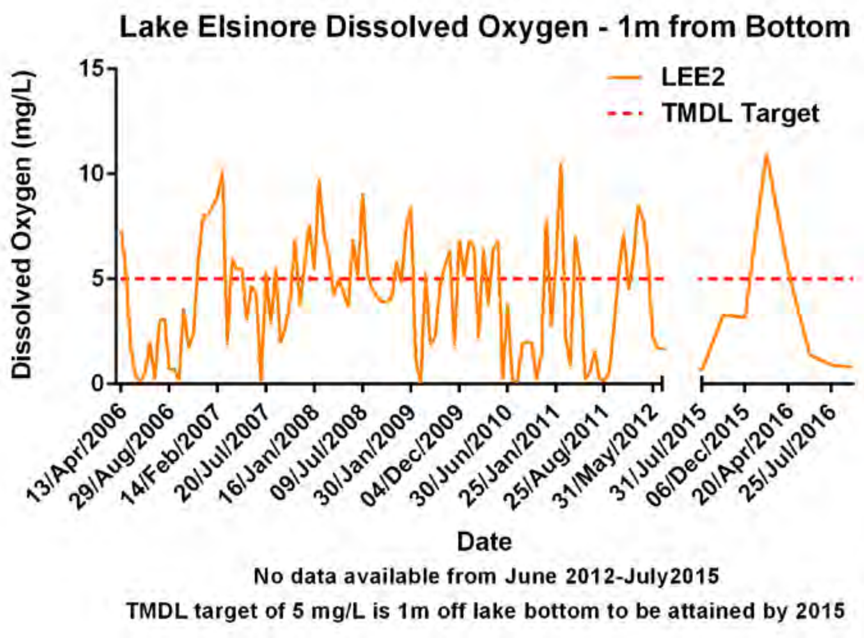

Figure 2-27. Dissolved Oxygen Concentrations (1-m from Bottom) in Lake Elsinore - 2006-2016 (Note discontinuous data record on x-axis)

Total Dissolved Solids

With large evaporative losses from the lake each summer, combined with winters of limited rainfall and periodic El Nino events, TDS concentrations have varied substantially in Lake Elsinore. TDS values were not reported in the studies summarized in the 2000 TMDL Problem Statement that included results from the EPA 1975 study and monitoring by Black and Veatch between 1992 and 1997. However, results are available and have been summarized for studies from 2003 to 2016 (**Figure 2-28**). Table 2-9 provides the associated range, average, and median values of TDS from 2003 to present.

TDS concentrations increased approximately exponentially during the drought of 2000-2002 to values over 2,200 mg/L, before decreasing following rainfall and runoff in 2003 to about 1,400 mg/L, and declining further in 2005 to about 800 mg/L as reported by Anderson (2010). TDS concentrations increased from 2006-2007 and remained around 1,600 mg/L into the summer of 2009 (Figure 2-28). In the midst of a severe drought, the most recent concentrations of TDS in the lake have ranged from 2,600 to 3,500 mg/L between July 2015 and August 2016.

Thresholds for TDS and conductivity related to aquatic life are discussed further in Section 2.3.1. Concentrations are below that expected to be problematic for fish species that use the lake, but exceed concentrations at times that will affect invertebrate species, particularly large cladocerans that are more effective at grazing and reducing algae concentrations.

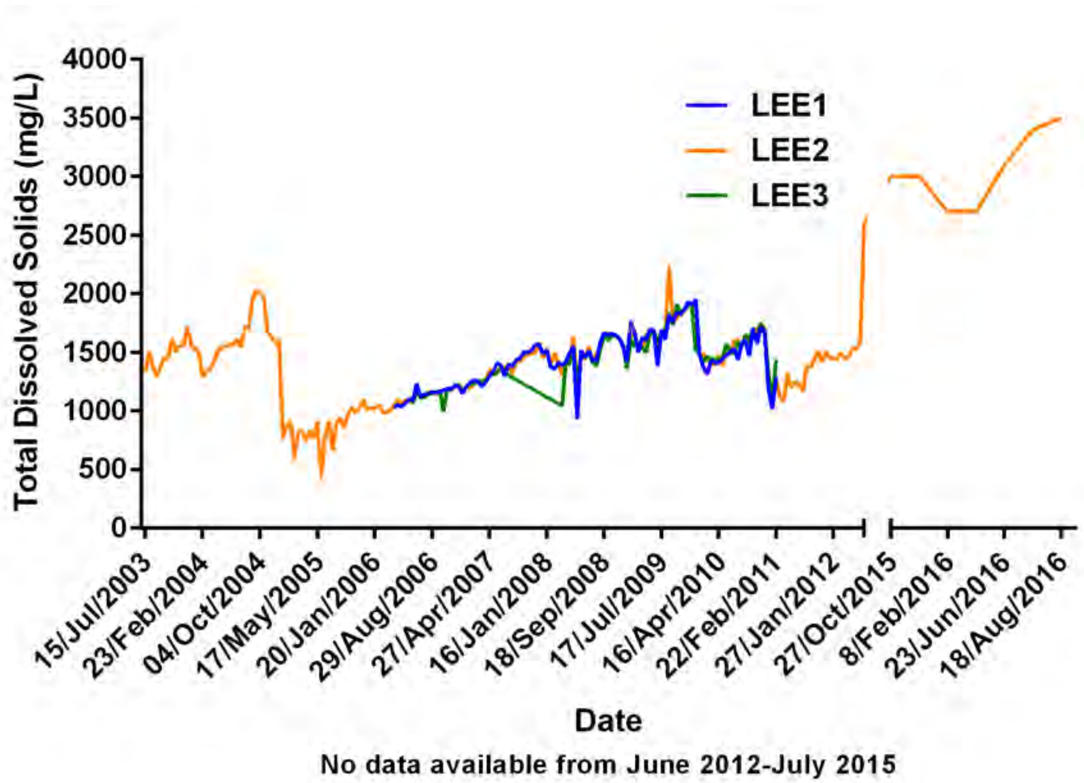

Figure 2-28. Depth-Integrated Average TDS Concentrations in Lake Elsinore - 2003-2016 (Note discontinuous data record on x-axis)

2.2.2.6 Existing Biological Characteristics

The beneficial uses of Lake Elsinore and Canyon Lake include the protection of warm water biological communities in addition to human use activities. The following subsections summarize our current knowledge of existing fish, invertebrate, and plankton communities with regards to their tolerance to chemical and physical factors of primary concern in the lakes as identified in the TMDL. Identifying biological thresholds of potential concern for desired species found in and relevant to these two lakes can help guide the development of revised numeric targets, validate the appropriateness of current objectives, and where determined appropriate new water quality objectives. A better understanding of these biological relationships under varying environmental conditions (e.g., elevated TDS) is also important to understand the close connection between these communities and water quality. Furthermore, enhancement of water quality through biological control is possible and has already been applied in Lake Elsinore: removal of carp to reduce nutrient release from their sediment disturbance, and stocking of bass to prey on shiner perch which feeds heavily on large zooplankton, an important grazer of algae. Understanding the preferred and tolerable water quality conditions for species of interest for biological control is important for future success using such approaches. The subsections below provide a summary of the biological characteristics as known in Lake Elsinore; Section 2.2.3.4 provides similar information for Canyon Lake. Supporting figures and tables are provided in Appendix A.

Fish community

Lake Elsinore has a highly variable fishery, with periodic fish kills and intervals of low diversity. The lake has experienced periods of high densities of Common Carp (*Cyprinus carpio*) and a low abundance of sport fish (EIP Associates 2005) as well as periods of increased fish diversity associated with higher densities of sport fish (Anderson 2008b). Historically, the native Arroyo Chub (*Gila orcuttii*) existed in the lake (Couch 1952); however, Lake Elsinore is now a managed fishery with regular stockings of a variety of fish primarily for the purpose of recreational fishing. Stock fish species have included, but are not limited to, Largemouth Bass (*Micropterus salmoides*), Channel Catfish (*Ictalurus punctatus*), Black Crappie (*Pomoxis nigromaculatus*), Bluegill (*Lepomis macrochirus*), and Hybrid Striped Bass (*Morone saxatilis* x *chrysops*).

Other fish known to reside in the lake and considered nuisance species are the Common Carp and Threadfin Shad (*Dorosoma petenense*). The presence of these two nuisance species aggravate the nutrient problem in Lake Elsinore. Carp are benthic feeders that forage for food in the sediment, which stirs it up. This action, called "bioturbation," resuspends organic silt and thereby increases the amount of nutrients released to the water column. Shad are zooplanktivores, consuming planktonic cladoceran and copepod species that in turn feed on planktonic algae. This predation by shad reduces the zooplankton population, particularly the large-bodied taxa which are the most efficient feeders, thus reducing the ability of the zooplankton to keep algal blooms in check. Efforts have been made to reduce the populations of these two nuisance species through netting (carp) beginning in 2002 and the stocking of hybrid striped bass which feed on both carp juveniles and shad. The carp removal program in Lake Elsinore has been successful in that it has reduced the percentage of large fish composed of carp from 88.5 percent in 2003 to 15-43 percent in 2008, and reduced the pounds of carp per acre from 533 in 2003 to 62 in 2008. At the same time, large gamefish density increased from 9.5 percent of fish captured in 2003 to 57-85 percent in 2008.

Due to the natural cycle of periodic lake drying events (see Section 2.2.2.2), mass extinction events of the fish populations have occurred. The in-lake fishery has recovered from these drying events primarily as a result of stocking and secondarily by repopulation from upstream sources (i.e., Canyon Lake) during high flow events.

The most recent hydroacoustic survey of the fish population was performed by Dr. Michael Anderson in April 2015 (Anderson 2016b). This survey found the density of fish within the lake to be approximately 56,600 fish per acre (fish/acre), more than double the highest density observed among previous surveys by Dr. Anderson of 27,720 fish/acre in December 2010. The vast majority of the fish observed in April 2015 (95.6 percent) were < 3.5 centimeters (cm) in length, consistent with threadfin shad, known to be a dominant fish in the lake. Previous surveys of the fish population in Lake Elsinore by Dr. Anderson in April 2008 and March/December 2010 have yielded fairly consistent mean fish length ranging from 4.0 – 4.7 cm. However, the April 2015 survey indicated a dramatic decrease in mean size to 1.8 cm. The number of large fish per acre (> 20 cm) has fluctuated somewhat decreasing from a high of 1,050 in April 2008, to a low of 6 in March 2010, rebounding in December of 2010 to 273, and the most recent survey exhibiting a density of 12 large fish/acre. However, the large fish population have never comprised more than 5.8 percent of the fish community in Lake Elsinore.

There is a long history of fish kills in Lake Elsinore dating back to 1883 (see Table 2-8 above). These fish kills have been minor consisting of 300 pounds of fish, to major consisting of 100,000 tons of fish. Potential historical causes of the kills have been linked to “sulfurous gases”, lake level, “salty water”, temperature, DO, over-abundance of algae, “sudden change in mineral content”, and the lake drying up.

Invertebrate Communities

There are two distinct types of invertebrate populations in Lake Elsinore: a benthic community which resides in or on the lake-bottom sediment, and a pelagic zooplankton community residing in the water column. The primary source of planktonic community studies in Lake Elsinore is Dr. Michael Anderson’s laboratory at the UCR (Veiga Nascimento 2004 and Tobin 2011). These two zooplankton studies demonstrate that while there were some similarities, some large differences were exhibited between both seasons and years. An additional extensive benthic invertebrate study of multiple sites was performed by the Santa Ana Water Board in 2003 (Santa Ana Water Board 2007a).

- *Benthic Invertebrates* - The 2003 Santa Ana Water Board study sampled both the wet (April) and dry (June & October) seasons. Low overall taxa richness was observed across all sample locations and during both sample seasons. None of the stations contained sensitive, pollutant-intolerant taxa. The taxa present were those typically found at disturbed or stressed sites and included: snail, *Physa* sp., benthic daphnids (water fleas), amphipod, *Hyalella* sp., chironomid spp. (midges), tubificid spp. (worms), corixid species (water boatmen), and ostracod spp. (seed shrimp).

- *Zooplankton* - The zooplankton community in Lake Elsinore is composed of three primary types of invertebrates: cladocerans (water fleas), copepods, and rotifers. Of these three groups, the algal grazing rates of large bodied cladocerans such as *Daphnia* spp. are considered to be quite high compared to the other zooplankton (Moss 1998).

  The zooplankton populations in Lake Elsinore exhibit large seasonal variations in composition and density (Appendix A, Figures A-1 to A-3). Veiga Nascimento (2004) found that with the exception of two rotifer species, the winter of 2003 appeared to be a period of overall reduction in the Lake Elsinore zooplankton community, as all three of the major zooplankton groups were noticeably reduced at this time. During the period of this study (February 2002 to May 2005) the zooplankton populations generally exhibited their peak populations during the late spring and summer. Copepod and rotifer communities were typically on the order of hundreds to thousands of organisms per liter (organisms/L, org/L) at their peaks, while the cladocerans reached approximately 60 org/L during this same time period. Overall, the cladoceran density was substantially lower in comparison to the copepod and rotifer densities. Additionally, those cladocerans that were observed in the lake were small-bodied and did not have efficient filtering capacities. In particular, the important filter feeder *Daphnia exilis* was rarely present.

  Tobin (2011) observed a slightly different pattern in 2009 and 2010. The zooplankton community was composed primarily of smaller zooplankters, dominated by rotifers during summer through fall and cyclopoid copepods, which were more prominent during cooler seasons (Appendix A, Figure A-4). Again, the cladoceran community in the lake was very small to nonexistent (Appendix A, Figure A-5) and only found early in 2010 after heavy rainfall caused Canyon Lake to spill over into Lake Elsinore. Estimated zooplankton species richness was greatest in February 2010 with a second, slightly lower peak in October 2010 and the lowest values in June 2010.

Anderson (2016b) sampled Lake Elsinore zooplankton at two locations (San Jacinto River inlet and Site LEE2) in March 2015. Adult copepods dominated the zooplankton community, comprising 83.8 percent of the total individuals counted. Juvenile copepods (nauplii) were the second most abundant group of zooplankton at 14.7 percent of the community. Few rotifers were observed and only comprised 0.8 percent of the entire sample. A single *Daphnia* individual was present in the samples, corresponding to a relative abundance of 0.2 percent within the zooplankton community.

These zooplankton studies demonstrate that while there were some similarities between seasons and years, some large differences were exhibited as well. Anderson (2016b) and Tobin (2011) observed copepod dominance during early spring, while Veiga Nascimento (2004) observed a noticeable reduction in all three groups at this time. The low proportion of *Daphnia* within the zooplankton community in 2015 was consistent with findings from 2003-04 and 2009-10 when cladocerans comprised approximately < 0.6 percent of the community.

Phytoplankton community

As with zooplankton, the primary sources of phytoplankton community data have been studies conducted by Dr. Michael Anderson's UCR laboratory (Veiga Nascimento 2004 and Tobin 2011). Tobin (2011) described the phytoplankton community of Lake Elsinore as a complex assemblage of genera and species that followed a seasonal succession dominated by diatoms in the winter and cyanobacteria during summer months (Appendix A, Figure A-6) – a finding that may be expected for a shallow eutrophic lake.

Veiga Nascimento (2004) noted a similar pattern in 2002 through 2004, the cyanobacteria *Pseudanabaena limnetica* (formerly *Oscillatoria*) was the dominant phytoplankton. Evidence suggests that *Daphnia* growth and reproduction is reduced as concentrations of *P. limnetica* approach 400 cells/mL, even in the presence of adequate food supplies (Infante and Abella 1985).

Similarly, Anderson (2016b) found the cyanobacteria *P. limnetica* to dominate (> 95 percent) the algal community during the spring and summer of 2015. This same species dominated the community during the very poor transparencies and very high chlorophyll-*a* concentrations observed in 2002-2004 (Veiga-Nascimento 2004), and was also the dominant phytoplankton during the summer of 2010 (75-90 percent of the biomass in June-August 2010) (Tobin 2011). While the cyanobacteria *P. limnetica* is not known to form cyanotoxins (Dr. Michael Anderson, pers. comm.), three potentially toxic cyanobacteria were present during the 2010 sampling season: *Planktothrix agardhii, Pseudanabaena catenata, Cylindrospermopsis raciborskii* (Tobin 2011).

This seasonal successional pattern of shifting to a population to high levels of cyanobacteria over the summer likely reflect the high nutrient levels and conditions that are characteristic of a terminal basin with long residence times and increasing eutrophication. Similar phytoplankton assemblages (*P. agardhii*, *P. limnetica*, *C. raciborskii*, and *Aphanizomenon* species) and successions (cyanobacteria dominant in summer through fall) to those observed in Lake Elsinore have been observed in three eutrophic lakes (shallow and deep) in Eastern Germany (Nixdorf et al. 2003). A shallow, hypereutrophic lake, Albufera in Spain, also showed a similar composition of genera to Lake Elsinore and some similar seasonal trends (Romo and Miracle 1994). Cyanobacteria tend to develop more in summer when water residence times are longer, while diatoms and green algae are often dominant in winter during periods when water residence times are short (Wetzel 2001).

2.2.3 Canyon Lake

2.2.3.1 Establishment of Canyon Lake

Canyon Lake, also known as Railroad Canyon Reservoir was constructed to store water from the San Jacinto River for agricultural irrigation in the area (**Figure 2-29**). The Railroad Canyon Reservoir Dam is located approximately five river miles upstream from Lake Elsinore. Approximately 735 square miles of the San Jacinto River Watershed drains into Canyon Lake before reaching Lake Elsinore. In many years, drainage from the San Jacinto River Watershed terminates at Canyon Lake without reaching Lake Elsinore.

Figure 2-29. Canyon Lake Reservoir

The City of Canyon Lake has documented the establishment of the Railroad Canyon Reservoir, which is now known as Canyon Lake. Following are excerpts of this early history (**Figure 2-30**):[2]

> *"The California Southern Railroad built a line in 1882 from Perris to Elsinore along the east side of the [San Jacinto] river. Later the Santa Fe Railroad bought the line and joined it with their line from San Bernardino. However, the floods of 1884, 1916, and 1927 washed out the tracks, and Santa Fe decided to abandon the line…"*

> *"The Temescal Water Company of Corona spent $500,000 for the development of a water supply in Ethanac (now called Romoland) and its transportation through Railroad Canyon to Corona…Around 1920, the water levels dropped in the Ethanac wells, and the water became saline and unusable. Plans were made to build a dam across the San Jacinto River for water storage. There were already open ditches and pipelines to continue the water flow to Corona, and Temescal Water [Company] obtained the land for the future reservoir by purchase or condemnation. Henry Evans, the largest landowner at that time, sold 1,150 acres to the company. Construction of the dam started in 1927 and was completed in 1929. "Joy Jamison, then president of the Temescal Water Company, became the brunt of "Jamison's folly" jokes made by board members in Corona when, after the completion of the dam, sparse rains*

[2] http://www.cityofcanyonlake.org/history

Figure 2-30. Undated Photograph of the Evans Camp that Supported Fisherman at Railroad Canyon Lake

prevented the river from bringing water. Eventually winter rains returned, and the lake slowly began to fill with water."

The area around Canyon Lake was sparsely populated during this time period but it was a popular destination for fishermen. A temporary disruption occurred beginning in 1949 when the lake was drained for to repair the dam's floodgates. The area began to change in 1968 when the Corona Land Company began the development of 5,000 lots around the reservoir (**Figure 2-31**). The lake and the fringe of land around it were owned by the Temescal Water Company and leased to the Canyon Lake Property Owners Association (POA) for recreational purposes. Subsequently, the EVMWD bought the Temescal Water Company, and in 1989, EVMWD entered into a contract to acquire the lake and these leases. The agreement between EVMWD and the Canyon Lake POA requires that the minimum lake elevation be kept at 1,372 feet above sea level. The City of Canyon

Figure 2-31. Development of Property around Canyon Lake Today (Source: Google Earth, July 26, 2017)

Table 2-11. City of Canyon Lake Population Since Incorporation in 1990

Census Date	Population
1991	10,292
2000	9,978
2010	10,561
2017	10,891

Lake was incorporated on December 1, 1990 and population records show that the local population has remained relatively stable since then (State of California 2017) (**Table 2-11**).

The surface area of Canyon Lake is approximately 500 acres, with an estimated current storage capacity of 8,760 acre-feet. The lake has three key areas: (1) Main Lake, which is the deepest part of the lake upstream of the dam; (2) East Bay, the relatively shallow arm of the lake upstream of the causeway crossing the lake; and (3) north portion of the lake above the causeway crossing upstream of the Main Lake. Canyon Lake receives inflows from two sources: (1) San Jacinto River drains to the Main Lake; and (2) Salt Creek drains to the East Bay. Canyon Lake has a small surface area (500 acres) and steep topography. Water depth varies greatly depending on the location in the Lake. The Main Lake is deepest (over 50 feet near the Dam); the East Bay is shallow (approximately 8 feet near the Salt Creek inflow). A detailed bathymetric survey was conducted by UCR in the summer of 2015 to map the lake bottom elevation and to study the nutrient cycles in Canyon Lake (**Figure 2-32**).

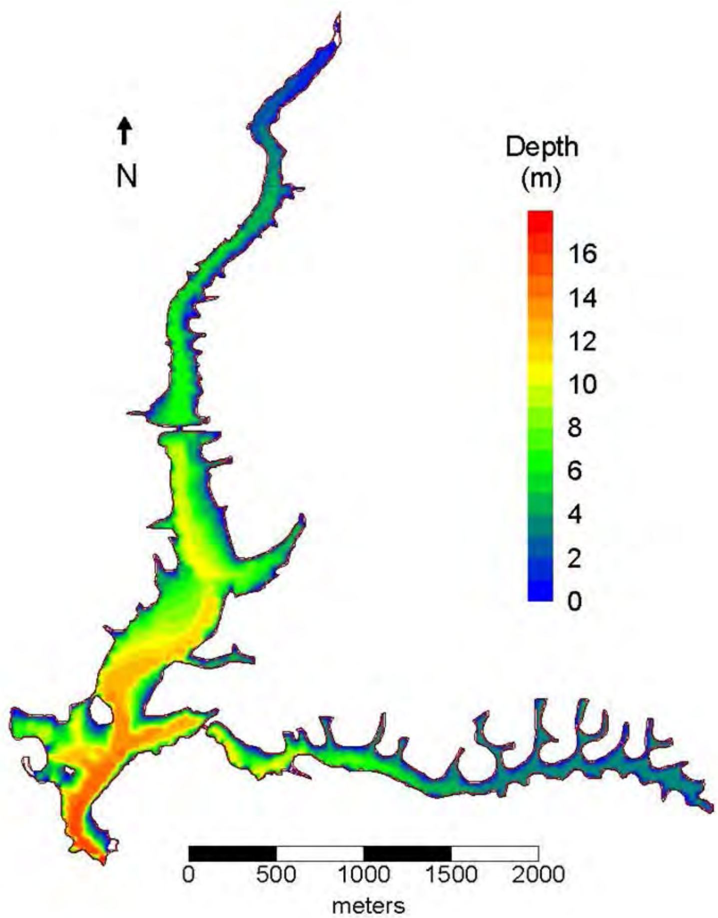

Figure 2-32. Bathymetric map of Canyon Lake (Anderson 2015a).

The temperature profile of the Canyon Lake water column routinely demonstrates that the Lake is thermally stratified in the summer. The most pronounced stratification occurs at the Dam where the water is deepest. Thermal stratification within Canyon Lake disappears in the fall and winter when the lake turns over resulting in more uniform water temperatures and DO profiles throughout the water column. The water column at the East Bay sampling locations is generally well-mixed year-round in areas less than 3-m deep. **Table 2-12** summarizes the total depth and mean Secchi depths observed at four sampling locations within Canyon Lake.

Table 2-12. Canyon Lake Water Depth and Secchi Depth (July 15 – August 2015)

Sample Site	Location Description	Total Depth (ft)	Secchi Depth (in)
CL-07	At Dam	48	74
CL-08	North Channel	28	73
CL-09	Canyon Bay	23	54
CL-10	East Bay	11	44

Canyon Lake is a local source of drinking water. EVMWD draws water from Canyon Lake (near the Dam) and treats it at the Canyon Lake Water Treatment Plant, before delivery to the District's customers. The eutrophic conditions in Canyon Lake may impact the MUN beneficial use. Low oxygen levels result in high concentrations of manganese and iron in the hypolimnion. When manganese levels in the water column exceed 0.45 mg/L, EVMWD shuts down the water treatment plant. The high algal productivity also necessitates periodic shutdown of the Canyon Lake Water Treatment Plant because algal cells can clog the water treatment filters.

2.2.3.2 Historical Water Quality

Prior to the 1980s few water quality data, in particular nutrient data, are available from Canyon Lake. Since then water quality data became available from various sources (Santa Ana Water Board 2001):

- Regional Board staff collected water samples from Canyon Lake from 1983-1986 for various constituents as part of the Region's monitoring and assessment program.
- Earth Sciences Consultants measured temperature, DO and electrical conductivity at three stations in Canyon Lake and five stations in Lake Elsinore on August 19, 1994. The three stations in Canyon Lake, "Boom", Buoy", and "Intake", were all in close proximity to the dam.
- SAWPA measured DO, water temperature, specific conductance, and pH near the Canyon Lake dam on July 10, 1996 in order to compare Canyon Lake water quality with Lake Elsinore. The results were similar to those obtained by the Earth Sciences Consultants in 1994.
- Black & Veatch collected water samples (one composite from the upper level and one composite sample from the lower level) from one station in Canyon Lake for conventional chemical constituent analysis in July and October 1995 and January, April and July 1996.

- EVMWD began monitoring the water quality of Canyon Lake in March 1996. A Hydrolab multi-probe has been used to measure the water temperature, DO and other parameters. These data are used by EVMWD to develop the water column depth profile to determine the appropriate depth for water withdrawal and also to determine when lake "turn-over" occurs. EVMWD also collected surface water samples from near shore locations for analysis of various constituents. EVMWD continues to monitor the physical and chemical characteristics of Canyon Lake at their treatment plant uptake points; however, EVMWD discontinued the surface water quality monitoring program since the Santa Ana Water board and stakeholders initiated the TMDL monitoring program in the summer of 2000 (see below).

- The USGS began the National Water Quality Assessment (NAWQA) Study in the Santa Ana Watershed in 1998. One sediment core was taken in Canyon Lake to determine the sedimentation rate and to analyze for metals, organochlorine pesticides, and polyaromatic hydrocarbons.

- RCFCWCD collected water quality data in the San Jacinto River watershed (1992-1999) as required by their MS4 stormwater permit. The data provided some understanding of the dynamics of Canyon Lake in relation to its watershed.

2.2.3.3 Recent Water Quality Findings

The Santa Ana Water Board and stakeholders began monitoring the water quality of Lake Elsinore and Canyon in May 2000, specifically for nutrients and chlorophyll-*a*, as part of the TMDL development. Water samples were collected for nutrient analysis at four sampling stations, CL07, CL08, CL09 and CL10 (**Figure 2-33**). From 2001 to 2012, monitoring was typically performed at a weekly or bi-weekly frequency during the summer months (June, July, August, and September), and bi-weekly or monthly from October through May. Water samples generally have been collected at two to three depths to characterize the vertical variation. Physical parameters such as temperature, DO, pH, conductivity, and turbidity are also measured at three-foot intervals at the time of sample collection. This nutrient TMDL monitoring program continued through 2012 (**Figure 2-34**).

A break in monitoring occurred between 2012 and 2015 to reallocate resources for the implementation of water quality BMPs in both lakes, but was reinitiated in 2015. Currently field monitoring and analysis of nutrients and chlorophyll-*a* occurs monthly during the summer months of July, August, and September, and bi-monthly between September and July. Vertical depth profiles of pH, temperature, DO, and conductivity are performed twice during each monitoring event (am and pm), with these values averaged at each depth for a given day.

The subsections below discuss water quality conditions in Canyon Lake based on the monitoring studies completed to date. As with data presented for Lake Elsinore, supporting water quality analyses graphically presented in tables and graphs within this section for Canyon Lake focus on the most recent available data collected in a consistent manner over the past 14-16 years. These data are now available in a single CEDEN-compatible database and has been collated and validated through a third party prior to analyses. Older data are referenced where applicable, but are not presented graphically. All values presented in the associated figures represent water column averages derived from depth-integrated water column samples, with the exception of DO which is plotted as depth-integrated (average) values both above and below the thermocline defined as the epilimnion (above the thermocline) and hypolimnion (below the thermocline), respectively.

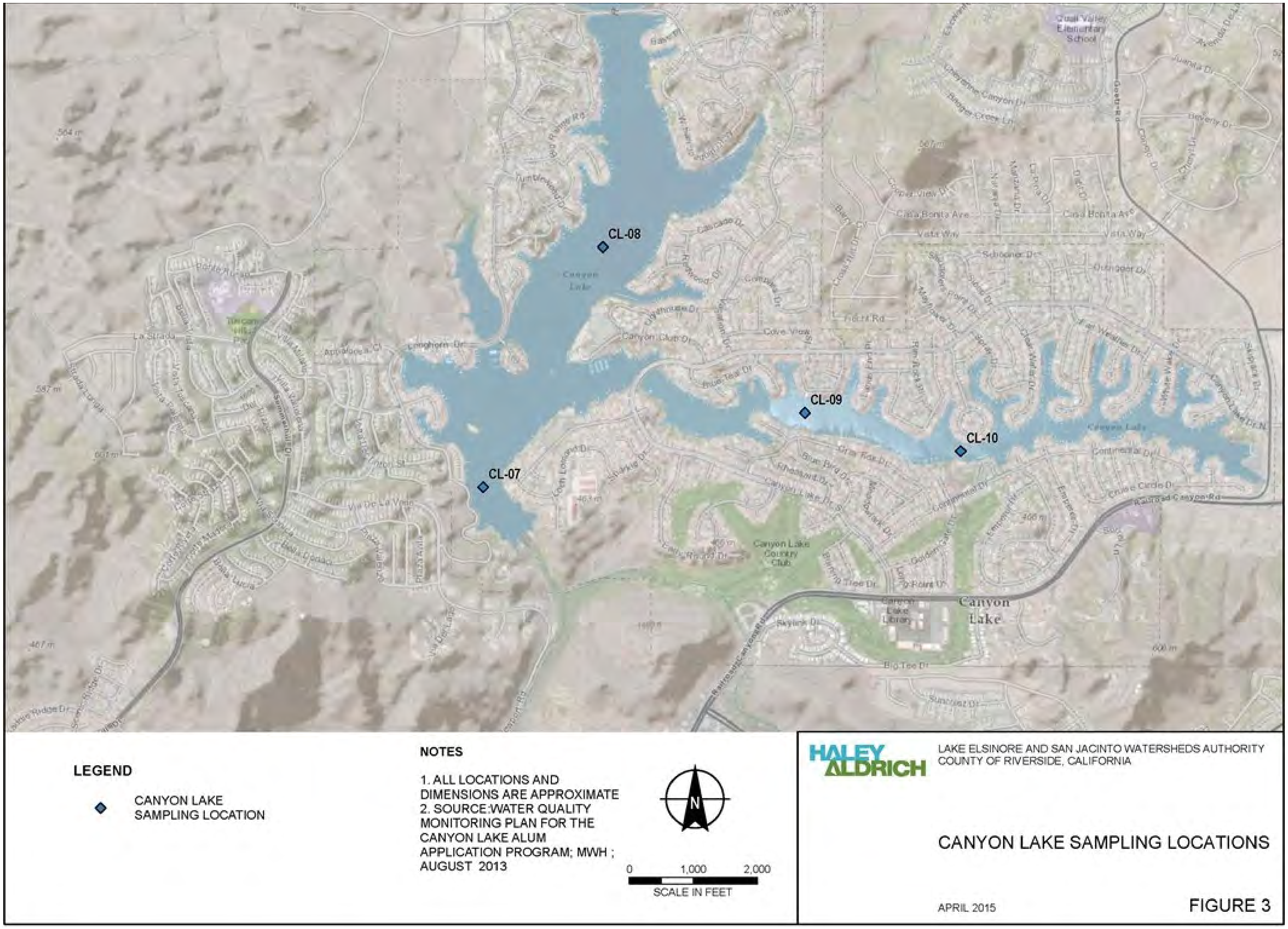

Figure 2-33. Location of Canyon Lake Sample Locations (CL-07, CL-08, CL-09, and CL-10). Figure 3 from Lake Elsinore & Canyon Lake Nutrient TMDL Compliance Monitoring Work Plan (Haley & Aldrich 2015)

Nutrients (Phosphorus and Nitrogen)

Figure 2-34. Water Quality Monitoring on Canyon Lake (Source: Amec Foster Wheeler)

There are several forms of phosphorus and nitrogen in the water column; both phosphorus and nitrogen are essential nutrients for algal growth. As in Lake Elsinore, phosphorus concentrations in Canyon Lake exhibited strong seasonal and inter-annual variations. **Table 2-13** provides a tabular summary of nutrient measurements conducted by the Santa Ana Water Board in 2000-2001. **Figure 2-35** shows a graphical summary of available depth-integrated TP data collected during TMDL compliance monitoring efforts from 2001 to 2016. **Tables 2-14 and 2-15** provide the associated range, average, and median values of TP from 2001 to 2016 for the Main Basin (Sites CL-07 and CL-08), and East Basin (Sites CL-09 and CL-10) sites, respectively.

Table 2-13. Nutrient and Chlorophyll-*a* Concentrations in Canyon Lake between 2000 and 2001*

Statistic	Ortho-P (mg/L)	Total P (mg/L)	Chlorophyll-*a* (µg/L)	TKN (mg/L)	Nitrate as N (mg/L)	Nitrite as N (mg/L)	Ammonium-N (mg/L)	TKN/P Ratio
Detection Limit	0.02	0.02	1	0.5	0.1	0.1	0.1	NA
Min	ND	0.06	ND	ND	ND	ND	ND	2
Max	1.61	1.9	180	7	0.38	ND	5.4	15.7
Median	0.18	0.25	17.6	1.1	ND	ND	0.14	7.8
Mean	NA	0.46	NA	NA	NA	NA	NA	7.97
N	116	129	64	139	139	130	143	46

* As reported in the Santa Ana Water Board, Canyon Lake Problem Statement (Santa Ana Water Board 2001)

During TMDL compliance monitoring efforts in Canyon Lake between 2001 and 2016, the concentrations of TP have ranged from 0.09 to 2.3 mg/L, with a mean of 0.47 mg/L in the Main Basin and 0.45 in the East Basin (Tables 2-14 and 2-15). These values encompass the range observed by the Santa Ana Water Board in 2000-2001. As in Lake Elsinore, a majority of the phosphorus in the water column in Canyon Lake exists in soluble reactive form (Ortho-P). Spikes in TP of greater than 1.0 mg/L were recorded in August 2007, and several dates between October 2010 and June 2011. The elevated concentrations in the spring and early summer of 2011 appear to follow a few large storm events and some flooding that was documented in December 2010 - January 2011. Notably, the mean concentrations of TP during the four monitoring events from

Table 2-14. Historical Dissolved Oxygen, Nutrient, Chlorophyll-*a*, and TDS Summary for Canyon Lake between 2002 and 2016 - Sites CL-07 and CL-08 (Main Basin) (TMDL Compliance Monitoring)

Parameter	Sample Type	No. of Samples (2002-2012)	2002-2012				2015-2016 (N = 7 to 8)			
			Min	Max	Mean	Median	Min	Max	Mean	Median
Dissolved Oxygen (mg/L)	Above the Thermocline	74	1.2	19	8.7	8.4	4.6	12	8.8	9.1
	Hypolimnion	74	0.0	6.3	0.59	0.21	0.10	5.3	1.3	0.3
Chlorophyll-*a* (µg/L)	Depth-Integrated	53	5.2	459	45	40	24	79	50	43
Total N (mg/L)	Depth-Integrated	61	0.20	5.81	2.0	1.7	1.2	1.8	1.5	1.4
Total P (mg/L)	Depth-Integrated	77	0.10	1.74	0.57	0.57	0.03	0.28	0.10	0.10
Total Ammonia (mg/L)	Depth-Integrated	75	0.03	2.88	0.84	0.83	0.05	1.5	0.57	0.35
Un-ionized Ammonia (mg/L)	Depth-Integrated	75	0.0	0.18	0.03	0.02	< 0.01	0.03	< 0.01	< 0.01
TDS (mg/L)	Depth-Integrated	101	152	985	593	593	665	825	746	735

Table 2-15. Historical Dissolved Oxygen, Nutrient, Chlorophyll-*a*, and TDS Summary for Canyon Lake between 2002 and 2016 - Sites CL-09 and CL-10 (East Basin) (TMDL Compliance Monitoring)

Parameter	Sample Type	No. of Samples (2002-2012)	2002-2012				2015-2016 (N = 4)			
			Min	Max	Mean	Median	Min	Max	Mean	Median
Dissolved Oxygen (mg/L)	Above the Thermocline	44	5.6	16	10	10	7.1	14	10.5	10.3
	Hypolimnion	44	0.0	4.0	0.59	0.24	0.25	10.3	3.1	1.8
Chlorophyll-*a* (µg/L)	Depth-Integrated	61	1.0	220	60	53	14	102	42	25
Total N (mg/L)	Depth-Integrated	73	0.11	8.0	2.0	1.7	1.1	2.1	1.4	1.3
Total P (mg/L)	Depth-Integrated	83	0.09	2.3	0.52	0.47	0.03	0.36	0.13	0.12
Total Ammonia (mg/L)	Depth-Integrated	67	0.03	1.54	0.51	0.35	0.05	0.14	0.07	0.05
Un-ionized Ammonia (mg/L)	Depth-Integrated	67	0	0.5	0.04	0.02	< 0.01	< 0.01	< 0.01	< 0.01
TDS (mg/L)	Depth-Integrated	97	336	1206	701	671	640	930	820	870

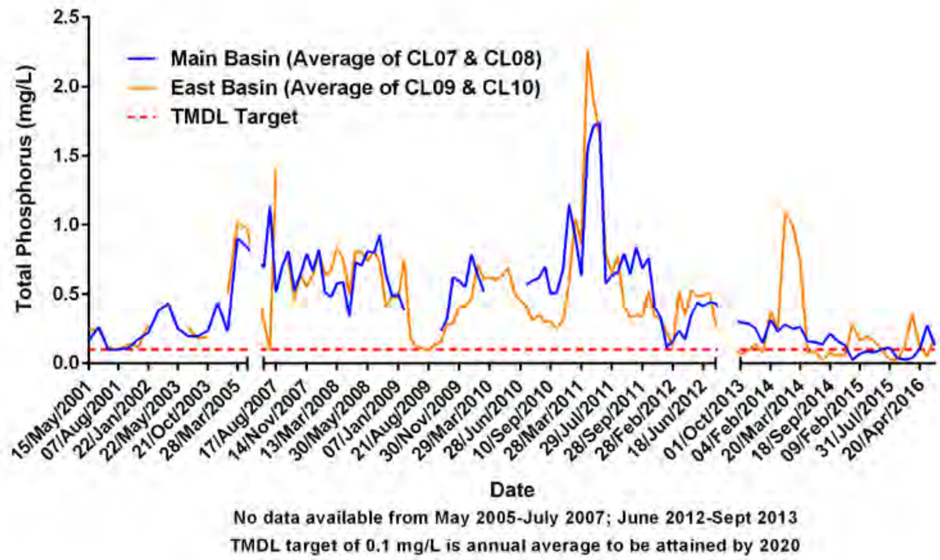

Figure 2-35. Depth-Integrated Average Total Phosphorus Concentrations in Canyon Lake - 2001-2016 (Note discontinuous data record on x-axis)

July 2015 through August 2016 are substantially lower than that historically observed, with an average concentration of 0.05 and 0.13 mg/L in the Main and East Basins of the lake, respectively. The reduced concentrations of phosphorus during this time frame correspond with the application of alum treatments designed to reduce mobility of phosphorus from the sediments in the lake, indicating that these efforts appear to be successful. A discussion of the ongoing alum treatment program and its relevance to implementation of existing TMDL requirements and its potential role as an implementation element in revised TMDLs may be found in Section 7.

Like phosphorus, nitrogen concentrations also exhibit strong seasonal and inter-annual variations as well. **Figure 2-36** shows a graphical summary of depth-integrated TN data collected during TMDL compliance monitoring efforts from 2001 to 2016. Tables 2-14 and 2-15 provide the associated range, average, and median values of TN from 2001 to 2016 for the Main Basin (Sites CL-07 and CL-08) and the East Basin (Sites CL-09 and CL-10), respectively.

As in Lake Elsinore, nitrate and nitrite are typically below analytical detection limits (0.1 mg/L) in Canyon Lake. Since nitrate and nitrite are mostly below detection limits, TKN represents TN. Ammonium is the main form of inorganic nitrogen in Canyon Lake; often 100 percent based on the few detections of nitrate and nitrite.

During TMDL compliance monitoring efforts in Canyon Lake between 2001 and 2016, the concentrations of TN have ranged from 0.01 to 8.0 mg/L, with a mean of 1.8 mg/L and 1.9 mg/L in the Main Basin and East Basin, respectively (Tables 2-14 and 2-15). These values encompass the range observed by the Santa Ana Water Board in 2000-2001. A few spikes in TN above 4.0 mg/L were recorded from August to November 2007 and again in February 2012. Mean concentrations of TN during the seven monitoring events from July 2015 through August 2016 are similar to that historically observed, with an average concentration of 1.4 and 1.3 mg/L in the Main and East Basins of the lake, respectively.

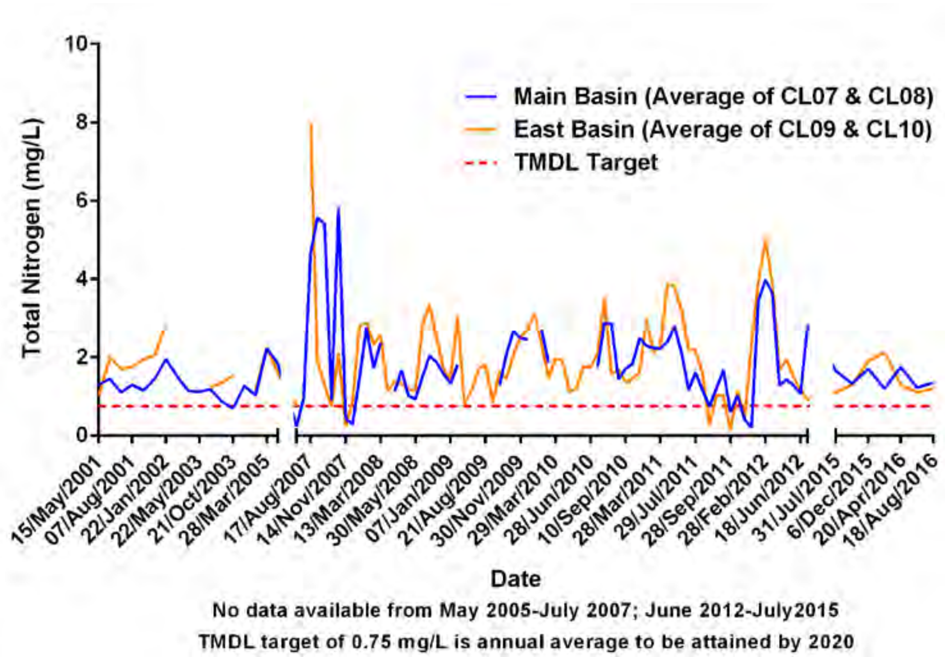

Figure 2-36. Depth-Integrated Average Total Nitrogen Concentrations in Canyon Lake - 2001-2016 (Note discontinuous data record on x-axis)

The TN:TP ratio for Canyon Lake is variable, ranging from 0.3 to 96, with an average of 6.5 in the Main Basin and 7.7 in the East Basin (**Figure 2-37**). The ratio varies spatially and temporally in Canyon Lake. On average, conditions throughout Canyon Lake are nitrogen-limited, which is the opposite of that for Lake Elsinore. However, since 2015 and application of the alum treatments, Canyon Lake appears to have shifted to a more phosphorus-limited condition which was a goal for this water quality management approach. As noted above and discussed in Section 7, alum treats are currently being applied Canyon Lake. Shifting the lake to a more phosphorus-limited state is considered desirable due to the proven effectiveness of alum in its ability to reduce phosphorus in other lake systems, and literature that suggests limitation of phosphorus is more important than limiting nitrogen with regard to resulting algal blooms (Wang and Wang 2009). In addition, actively limiting nitrogen availability *in situ* is a more difficult task in comparison based on existing available technologies.

A review of seasonal trends indicates that phosphorus is occasionally the limiting nutrient for brief periods in the summer; in the fall and winter, nitrogen becomes the limiting nutrient. At various times and locations, both phosphorus and nitrogen can be the limiting nutrient in Canyon Lake; therefore, both nutrients could be controlled to control excessive algal growth. In recent years (2015-2016) following implementation of the alum treatments, Canyon Lake has exhibited greater phosphorus limitation overall which is the goal of this program (See Figure 2-35).

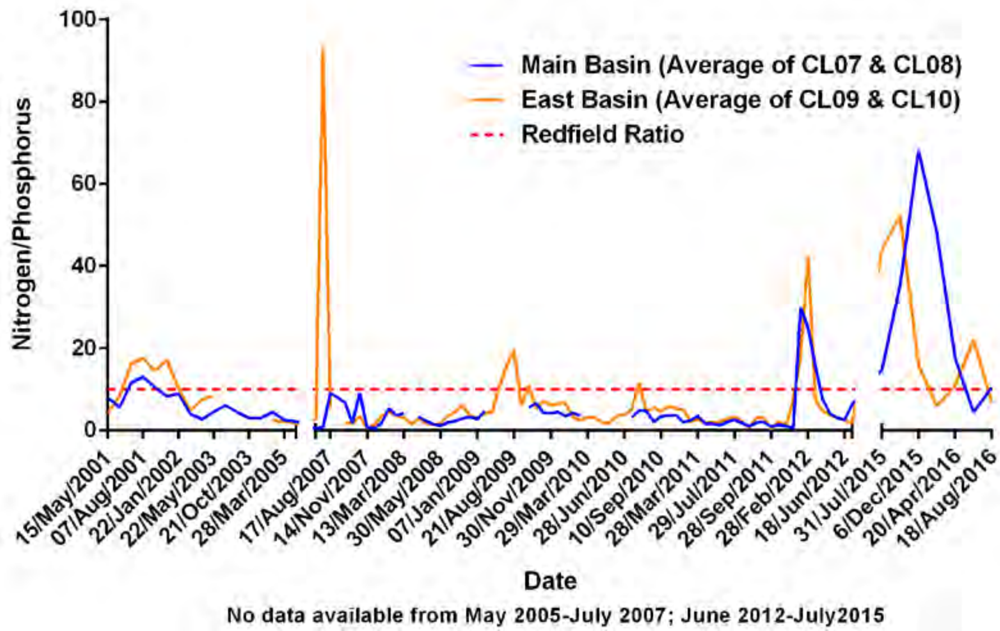

Figure 2-37. Nitrogen to Phosphorus Ratios in Canyon Lake - 2001-2016 (Note discontinuous data record on x-axis)

Ammonia

Consistent with Lake Elsinore, levels of total ammonia are generally low in Canyon Lake, though slightly greater overall in this waterbody. Total ammonia in Canyon Lake during TMDL compliance monitoring efforts between 2007 and 2012 ranged from less than 0.05 mg/L to 2.9 mg/L, with corresponding mean values of 0.82 mg/L in the Main Basin and 0.47 mg/L in the East Basin (**Figure 2-38** and Tables 2-14 and 2-15). These values encompass the range observed by the Santa Ana Water Board in 2000-2001 with the exception of a greater maximum value of 5.4 mg/L reported during that timeframe.

Associated measures of un-ionized ammonia throughout the 2001 to 2016 period are also generally low, but can vary substantially with depth on any given day given a gradient of pH that is often lower near the bottom and greater near the surface in Canyon Lake. Integrated depth-averaged total ammonia and pH values were used to derive the un-ionized values presented herein. Concentrations of un-ionized ammonia ranged from less than detection to 0.5 mg/L, with an average of 0.03 in the Main Basin and 0.04 in the East Basin (**Figure 2-39**; Tables 2-14 and 2-15). These average values are well below that expected to cause toxic effects to species found in Canyon Lake as described further in Section 2.3.3 below. A single transient spike of greater than 0.5 mg/L was recorded in 2008 which might approach a chronic toxicological threshold of potential concern for fish species in the lake.

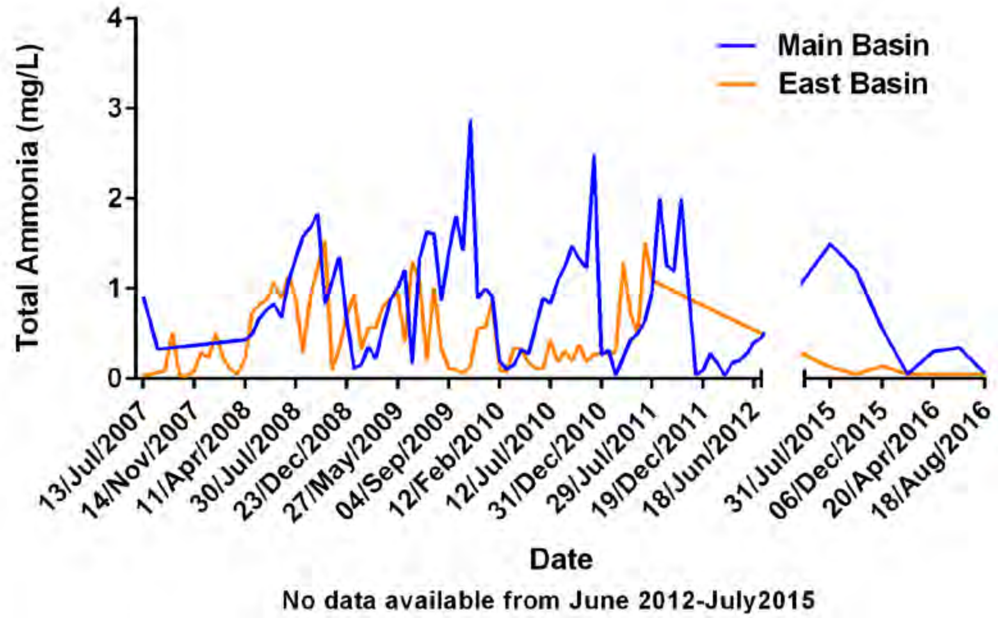

Figure 2-38. Depth-Integrated Average Total Ammonia Concentrations in Canyon Lake - 2007-2016 (Note discontinuous data record on x-axis)

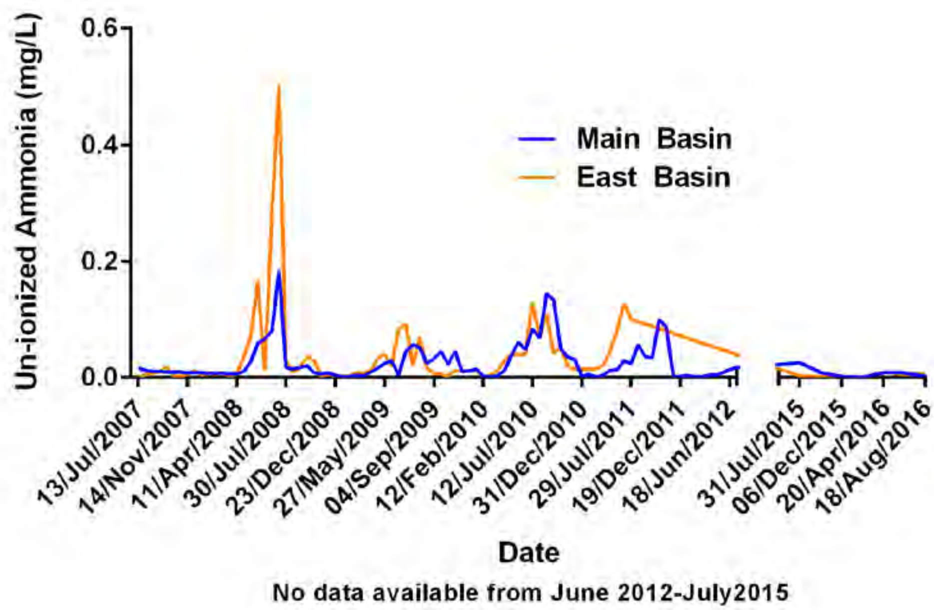

Figure 2-39. Depth-Integrated Average Un-ionized Ammonia Concentrations in Canyon Lake - 2007-2016 (Note discontinuous data record on x-axis)

Chlorophyll-a

The current TMDL compliance threshold target for chlorophyll-*a* in Canyon Lake is a summer average value of $\leq$ 40 µg/L in 2015 and $\leq$ 25 µg/L in 2020. During TMDL compliance monitoring efforts in Canyon Lake between 2001 and 2016, the concentrations of chlorophyll-*a* have varied widely from 1 µg/L to a maximum of 220 µg/L in the East Basin. Unlike nutrient concentrations which are relatively similar in all portions of the lake on a given day, average concentrations of chlorophyll-*a* are typically lower in the deeper East Basin relative to that in the shallower West Basin with integrated-depth average concentrations of 37 and 62 µg/L, respectively between 2001 and 2016 (**Figure 2-40**; Tables 2-14 and 2-15). These values encompass the range observed by the Santa Ana Water Board in 2000-2001. Chlorophyll-*a* concentrations are routinely less in Canyon Lake relative to that in Lake Elsinore.

A few spikes in chlorophyll-*a* above 100 µg/L were recorded in Canyon Lake in November 2008, August 2010, July through February 2011, and most recently in December 2015. All of these values were reported within the East Basin with the exception of the December 2015 result which was reported in the Main Basin.

Chlorophyll-*a* concentrations at all sites in Canyon Lake generally remain low in the summertime and then increase in the fall/winter season when the lake turns over, though this trend is not consistent all the time (Figure 2-37). During summertime, the lake is stratified so that the nutrients in the hypolimnion are not available for algae uptake; meanwhile the nutrients in the epilimnion can be used for algal productivity, but are in limited supply. When the lake turns over, the hypolimnion provides a new source of nutrients that can cause an increase in algal productivity. Since turnover usually occurs in the fall/winter period when temperatures are lower and days are shorter, algal responses and growth are not as likely to result in severe algal blooms. Such a phenomenon is quite different from Lake Elsinore, which usually has algal blooms in the summertime when the lake bottom water becomes more anoxic. Because Lake Elsinore is much shallower and does not stratify during the summer, nutrients released from the sediments are readily available for algal growth at all times. Although Canyon Lake receives more nutrients from the San Jacinto River and Salt Creek Watersheds than Lake Elsinore, algal blooms and fish kills are not as severe as those that occur in Lake Elsinore. The greater water depth in Canyon Lake prevents the nutrients from the sediment from becoming available for algal growth in the photic zone.

Because of the algal biomass increase during the Canyon Lake turnover period, EVMWD typically stops operation of the water treatment plant for about two weeks because algal cells can clog the filters in the treatment plant. Occasionally, copper sulfate is applied by the Canyon Lake POA and EVMWD staff as an algaecide during algal blooms to improve water clarity.

Dissolved Oxygen

Figures 2-41 and **2-42** show DO concentrations between 2002 and 2016 for the Main Basin (average for Sites CL07 and CL08), and East Basin (average for Sites CL07 and CL08) areas, respectively. Depth-integrated average values are shown for the epilimnion and the hypolimnion. When a thermocline was not present depth-integrated average values are presented for measures taken throughout the entire water column. Tables 2-14 and 2-15 provide the associated range, average, and median values from 2002 to 2016 in the epilimnion and hypolimnion, respectively.

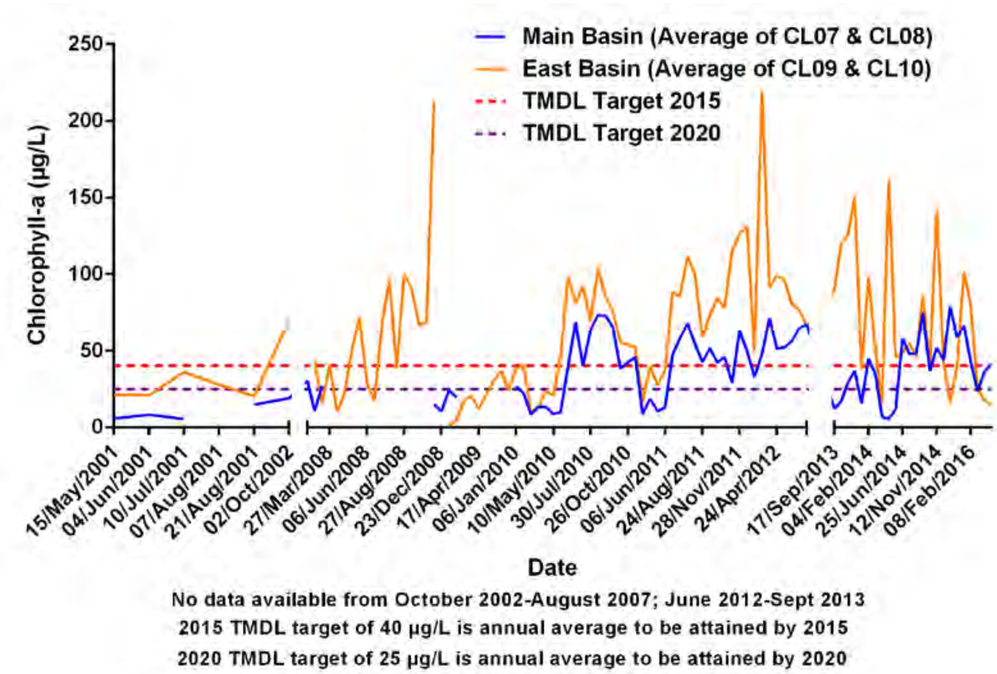

Figure 2-40. Depth-Integrated Average Chlorophyll-*a* Concentrations in Canyon Lake - 2001-2016 (Note discontinuous data record on x-axis)

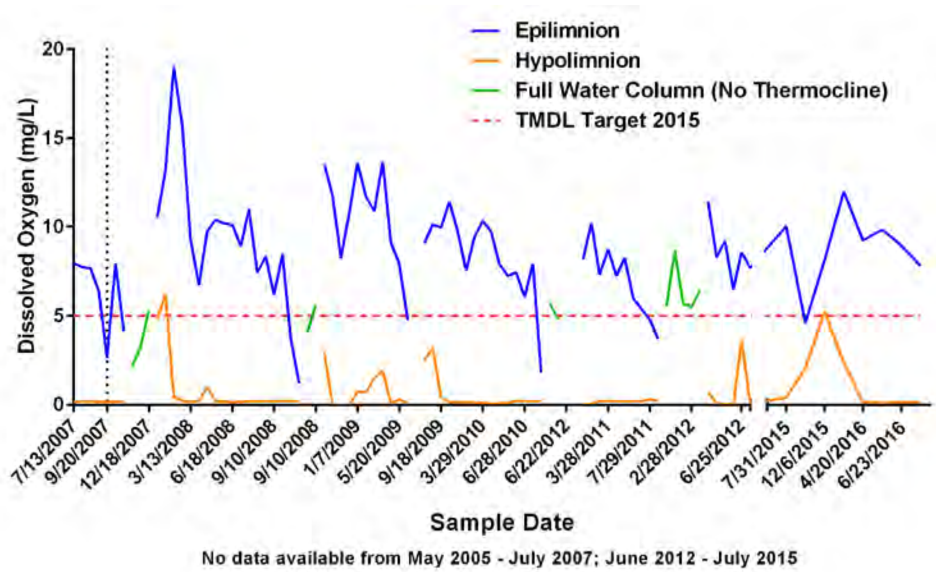

Figure 2-41. Depth-Integrated Average Dissolved Oxygen Concentrations in Canyon Lake (Main Basin) - 2007-2016 (Note discontinuous data record on x-axis)

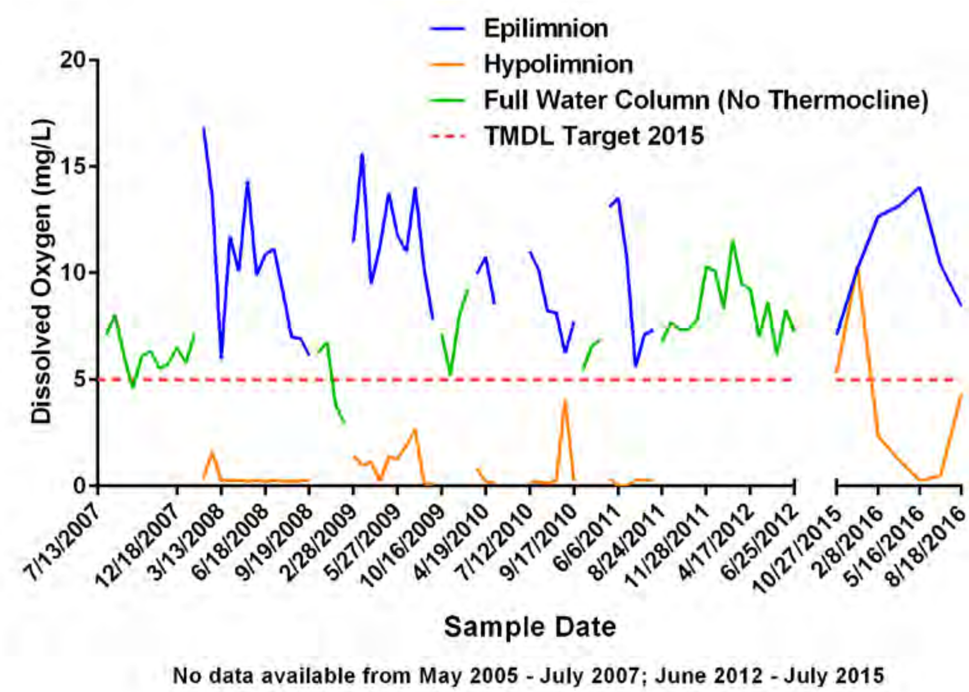

Figure 2-42. Depth-Integrated Average Dissolved Oxygen Concentrations in Canyon Lake (East Basin) - 2007-2016 (Note discontinuous data record on x-axis)

DO levels in Canyon Lake range from over-saturation at the surface to near zero below at the thermocline. During the TMDL compliance monitoring efforts from 2007 through 2016 average concentrations of DO in Canyon Lake in the epilimnion when the lake is stratified ranged from approximately 1.2 to 19 mg/L with average values of 8.7 mg/L in the Main Basin and 10 mg/L in the East Basin. Average concentrations of DO in the hypolimnion ranged from approximately 0.0 to 10 mg/L with average values of 0.67 mg/L in the Main Basin and 1.01 mg/L in the East Basin. The low DO below the hypolimnion, particularly during the summer months (occasionally at or near zero mg/L), is likely attributable to the decomposition of algae, high oxygen demand from the sediment surface, and the lack of mixing. This stratification of DO is a natural condition for most lakes. Low DO levels below approximately 5.0 mg/L for extended periods of time may cause effects to aquatic life including occasional fish kills. When the lake is not stratified depth-integrated DO concentrations ranged from 2.2 to 8.7 mg/L with an average value of 5.4 mg/L in the Main Basin while concentrations in the East Basin ranged from 2.9 to 11.6 mg/L, with an average of 7.3 mg/L over the same time period.

The low DO levels have also resulted in the release of high levels of soluble manganese and iron from the sediment. EVMWD shuts down the water treatment plant when the manganese concentration is above 0.45 mg/L. The anoxic condition in the hypolimnion may also facilitate the release of phosphorus and ammonia from the sediment, both of which then become available for algal growth when the lake turns over.

Total Dissolved Solids

During TMDL compliance monitoring efforts in Canyon Lake between 2001 and 2016, the concentrations of TDS have varied from 152 to 1,206 mg/L with average concentrations of 602 in the deeper Main Basin, and 709 mg/L in the shallower East Basin (**Figure 2-43**; Tables 2-14 and 2-15). These concentrations are comparable with the range of TDS observed in watershed runoff to Canyon Lake from Salt Creek. Concentrations of TDS from the San Jacinto River entering the north arm and Main Basin of the lake are generally less than 200 mg/L. TDS concentrations are consistently much lower in Canyon Lake relative to that in Lake Elsinore. Thresholds for TDS and conductivity related to aquatic life are discussed further in Section 2.3.1. Concentrations are below that expected to be problematic for fish species that reside in the lake, but do at times approach concentrations which could affect survival and reproduction of sensitive invertebrate species.

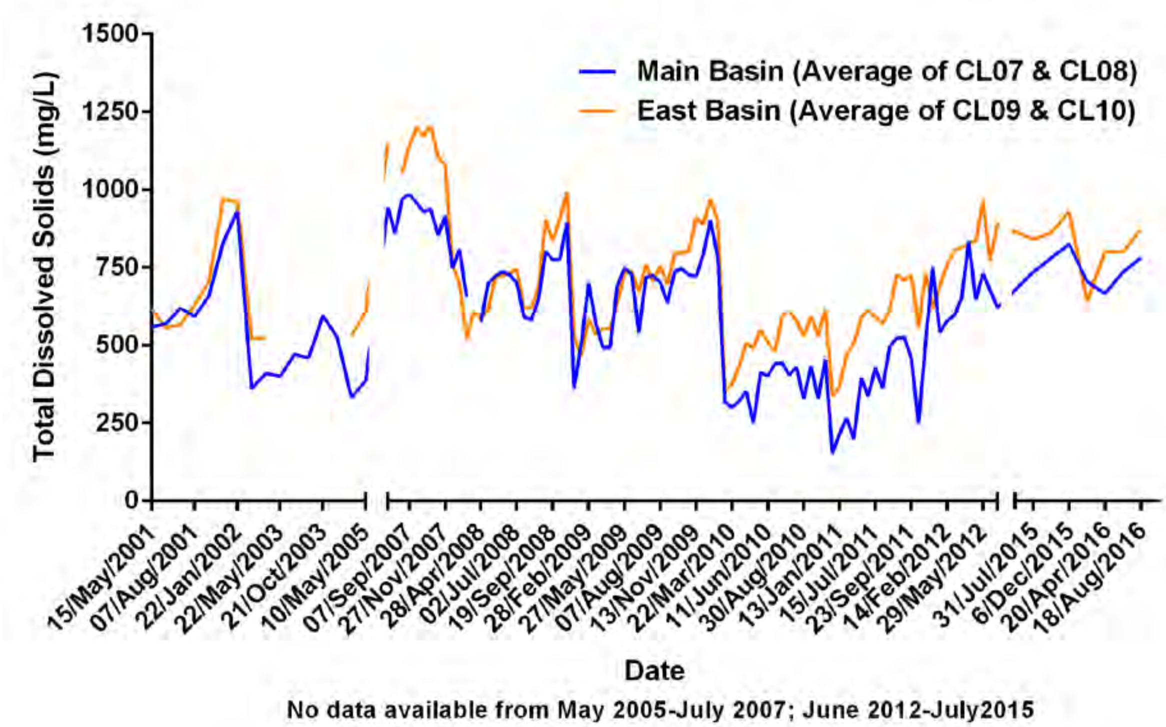

Figure 2-43. Depth-Integrated Average TDS Concentrations in Canyon Lake - 2001-2016 (Note discontinuous data record on x-axis)

Chemical Stratification

As discussed above, Canyon Lake is thermally stratified in the summer, mixes in the fall and stays mixed through the winter (**Figure 2-44**). During late spring, the lake stratifies again. This thermal stratification can also result in the chemical stratification of constituents such as orthophosphate-P, total phosphate-P and TKN during the summertime. When the lake turns over, the chemical concentrations throughout the water column become uniform until stratification occurs again in the spring or summer. A review of historic data indicates that stratification of nutrients is generally limited overall in Canyon Lake, though trends are apparent occasionally. Due to limited differentiation between the top and bottom of the water column, current TMDL compliance monitoring methods include the collection of a single depth-integrated sample for analysis of nutrients and TDS. Stratification of chlorophyll-*a*, however has been more prominent, with values typically greater near the surface where sunlight penetrates and algae accumulates. Given this trend, chlorophyll-*a* is currently measured in both a top to bottom depth-integrated sample, as well as a 0-2 m depth integrated sample representing just the surface.

Figure 2-44 Canyon Lake Reservoir (Source: Amec Foster Wheeler)

2.2.3.4 Existing Biological Characteristics

This section provides a summary of the biological characteristics as known in Canyon Lake. Supporting figures and tables are provided in Appendix A.

Fish Community

The fish community characteristics of Canyon Lake are less known than the fish community in Lake Elsinore. The lake was originally populated with fish that had migrated (or been washed down) from the San Jacinto River watershed as the lake filled after completion of the dam. The lake was owned by the Evans family who started a fishing business on the lake in 1937. During this time Canyon Lake was marketed as a fishing "hot spot". The lake was drained in 1949 to perform repairs to the floodgates, and the lake slowly refilled over the next two years. In 1951, the California Department of Fish and Game (CDFG) restocked the lake with largemouth bass, crappie, and bluegill, and the heavy rains of 1952 brought the water level high enough that the resort could reopen in 1953. The fishing camp was in operation until 1968. It is likely that the lake contains catfish and other sunfish (*Lepomis* spp., as well as small baitfish such a threadfin shad given its prevalence in Lake Elsinore. The draft Lake Management Plan for Canyon Lake notes that the lake, which has crappie and bluegill, is stocked with catfish and bass by the Canyon Lake POA (Canyon Lake POA 2016).

CDM Smith

Unlike Lake Elsinore, very little information is available on fish kills in Canyon Lake. In the original TMDL staff report (Santa Ana Water Board 2004b), the Regional Board staff stated it could find no written record of fish kills for Canyon Lake, but anecdotal information indicated that there have been fish kills. However, the document also states that Canyon Lake experiences periods of oxygen depletion due to algae respiration and decomposition that can result in fish kills, adversely affecting the warmwater aquatic habitat beneficial use. More recently, a fish kill was documented on October 29, 2010 when about 50 to 100 shad were observed on Sunset Beach (Canyon Lake POA 2016).

Invertebrate community

Very little is known of the aquatic invertebrate populations in Canyon Lake. At this time, the only known effort to evaluate the invertebrate community in Canyon Lake was a July 2004 benthic invertebrate study (Weston Solutions 2004). This study sampled eight East Basin open water locations as well as four East Basin shoreline locations. Depth at the eight open water locations ranged from 7.6 to 20 feet, with DO concentrations ranging from 6.0 to 8.4 mg/L. The study observed a total of 24 taxa and found a significant difference between the offshore benthic community and those along the shoreline. The open water sites exhibited very low taxa diversity and were composed almost exclusively of one dipteran taxa, the phantom midge *Chaoborus* spp., and a relatively small number of annelid oligochaetes (aquatic worms). The shoreline sites contained from 8 to 18 taxa. The midge, *Chironomus* spp. and the amphipod, *Hyalella* spp. were the most abundant taxa in shoreline samples, comprising 28 and 36 percent of the entire community, respectively. Other shoreline taxa included the damselfly, *Enallagma* sp., the aquatic beetle, *Tropisternus* sp., the mayfly, *Caenis* sp., the caddisfly, *Oxyethira* sp. and the water mite, *Koenikea* sp. Three snail genera were also collected. The study did not observe the presence of any sensitive taxa. Of the entire benthic invertebrate community, 79 percent was considered tolerant of generalized pollutants with a Hilsenhoff Biotic Index (HBI) value of ≥7 (Hilsenhoff 1987, 1998) (on a scale of 1 to 10 with higher values indicating a more pollutant-tolerant community.

The findings for Canyon Lake are not atypical for similar moderately deep lakes in other urbanized settings. A benthic community study performed by Amec Foster Wheeler in Lake Merced, near downtown San Francisco, CA (Amec Foster Wheeler 2014) found that in sediments ranging in depth from 11.6 to 20.3 feet, and DO concentrations ranging from 4.1 to 6.7 mg/L, the benthic community primarily consisted of dipterans and oligochaetes (combined, they represented 80 to 100 percent of the benthic community). The benthic community at these sites was considered highly tolerant with all HBI values > 8.9. Another recent study looking at the functional composition of lake benthic invertebrate communities in urbanized settings (Twardochleb and Olden 2016) also found results very similar to those observed in Canyon Lake. This study found that lakes with high levels of watershed and shoreline development were characterized by relatively dense macrophyte cover in eulittoral zones - a pattern that was associated with lower functional diversity of benthic invertebrate communities. Additionally, among regional characteristics, watershed development was an important predictor that interacted with TP and woody debris habitat, resulting in lower functional diversity in developed lakes.

Phytoplankton community

Information on the phytoplankton community is also limited. The Canyon Lake Nutrient TMDL Problem Statement indicated that the dominant types of algal species in Canyon Lake are flagellate-green and green algae (Santa Ana Water Board 2001). It is likely that diatoms also comprise some proportion of the community during times of the year, given the brownish-green tint of the water during recent 2015-2016 monitoring events.

2.3 Sensitivity of Biological Communities to Proximate Stressors

Proximate stressors are those that are in contact with the organism(s) in question, e.g., chemical constituents that can cause a direct effect on the organisms, such as low DO, elevated ammonia, or conductivity. This is opposed to indirect stressors such as nutrients or chlorophyll-*a*, which are related, but are not the causative agent of deleterious effects. The following sections describe the sensitivity of the organisms found in Lake Elsinore and Canyon Lake (or closely related organisms) to four probable proximate stressors within these lakes.

2.3.1 Conductivity

Conductivity in Lake Elsinore is elevated and has been measured as high as 8,650 µS/cm (4.8 parts per thousand [ppt] salinity) during routine water quality monitoring events dating back to 2002. It has been identified as a likely stressor particularly to the zooplankton populations with the lake. The conductivity in Canyon Lake is considerably lower, measured as high as 1,719 µS/cm in the East Basin in October 2007. While this conductivity level approaches the threshold effect level (1,820 µS/cm 10-day LC_{50}) (Veiga-Nascimento and Anderson 2004), for the most sensitive daphnid zooplankter observed in either lake, the long term 15-year mean (May 2001 – February 2016) for Canyon Lake is 900 µS/cm in the Main Basin and 1,060 µS/cm in the East Basin, well below the LC_{50} threshold effect level. Therefore, conductivity is not likely a significant stressor to the biological community in Canyon Lake.

Elevated conductivity acts as an osmotic stressor by interfering with the proper balance of salts and water within the body of an organism, which is necessary to maintain various physiological and biochemical processes. The fish and zooplankton that reside in Lake Elsinore are exposed to rising levels of conductivity during summers and particularly during extended drought periods when rainfall totals do not keep up with evaporation rates. The addition of recycled supplemental water to Lake Elsinore has helped to decrease spikes in conductivity during drought periods, but also elevates the long term mean conductivity.

Conductivity levels currently observed in Lake Elsinore do not appear to be high enough to cause significant acute stress to the fish found there, as these taxa exhibit a relatively high tolerance to elevated conductivity (Appendix A, Table A-2). However, the conductivity threshold of cladocerans (water fleas) is within the range in which a toxicological effect would be expected at typical conductivities observed in Lake Elsinore (Appendix A, Table A-3). Rotifers and copepods exhibit a higher tolerance to conductivity than cladocerans, with LC_{50} values (the concentration at which one would expect 50 percent mortality) above the highest conductivity measured during routine water quality monitoring events dating back to 2001.

2.3.2 Dissolved Oxygen

Both Canyon Lake and Lake Elsinore experience low DO concentrations for at least some portion of the lake and for some portion of the year. During summer months Canyon Lake stratifies with rapidly decreasing DO concentrations below the thermocline, and often times super-saturated waters near the surface. During summer months DO concentrations are near zero at the bottom. As the lakes turnover in late fall and winter, in addition to the increased winds causing mixing of the water column in late fall and early winter (e.g., Santa Ana winds) and low DO water near the bottom mixes with surface water potentially causing impacts to fish and other organisms which can no longer escape to higher oxygenated surface areas of the lake. Lake Elsinore does not stratify or turnover in the classic sense. Some limited temperature and DO stratification may occur when winds are calm for some period, but when winds occur, lake generally mixes.

Fish are more sensitive to low DO levels in general (relative to some invertebrates), and particularly sensitive to DO levels that drop sharply. Fish are able to adapt to short term exposures to low DO (assuming the concentration is not zero) and are more likely to adapt if the DO concentration exhibits a gradual decline. Additionally, fish have the ability to move to areas of higher DO when localized depressed concentrations are experienced. Sharp drops in DO, such as during lake turnover or caused by algal respiration at night during algal blooms, can cause acute mortality in short periods of time.

Given that fish kills were cited as a major factor in the original 303(d) impairment listing, data are presented here for both acute and chronic DO sensitivity thresholds of the various fish species found in both lakes (Appendix A, Table A-4). Of the fish observed in Lake Elsinore and Canyon Lake, largemouth bass appears to be the most sensitive to decreased DO levels. Petit (1973) reported that largemouth bass begin to experience distress (e.g., increased respiration and reduced metabolic rate) when DO concentrations fall below 5.0 mg/L. Moore (1942) reported that black crappie begin to experience decreased survival rates when held at a DO concentration of 4.3 mg/L for more than 24 hours at 26 °C. Carp begin to experience stress related to low DO concentrations at 4.2 mg/L (Beamish 1964) and increased mortality at concentrations < 1.0 mg/L (Opuszyfiski 1967). Krouse (1968) reported that striped bass (*Morone saxatilis*) begin to experience reduction in survival at 3.0 mg/L DO and Bailey et al. (2014) reported an LC_{50} of 1.6 mg/L DO. Gizzard shad (*Dorosoma cepedianum*), a close relative of the threadfin shad, begins to experience increased mortality at 2.0 mg/L (Gephart, and Summerfelt 1978).

DO available to fish is also influenced by temperature, with increases in temperature causing a reduction in the ability of water to hold oxygen (i.e., lower saturation). Studies have also shown that as the DO saturation level declines to less than 50 percent saturation, significant reductions in the survival times of some fish species occur when exposed to lethal solutions of un-ionized ammonia concentrations [reference to be incorporated]. Therefore, there are interactions between chemical constituents that may cause accelerated responses or synergistic effects at concentrations that would normally be benign for either constituent.

2.3.3 Ammonia

Ammonia, in particular the un-ionized fraction, is acutely toxic to aquatic life. While the ratio of total ammonia to un-ionized ammonia is driven by pH, salinity, and temperature, it is primarily driven by pH, with a sharp increase in un-ionized ammonia as pH rises above 8.3.

Fish are much more sensitive to elevated levels of un-ionized ammonia than are invertebrates, as can be seen in the two species sensitivity distributions (SSD) presented in (Appendix A, Figures A-7 and A-8). According to these SSDs, at 1.0 mg/L unionized ammonia, approximately 44 percent of the invertebrate species surveyed would exhibit a lethal response. At the same concentration of un-ionized ammonia, this lethal response increases to 70 percent of fish species surveyed.

Of the fish species found in the lakes, the hybrid striped bass with a species mean acute value (SMAV) of 0.43 mg/L un-ionized ammonia appears to be the most sensitive, followed by bluegill (0.99 mg/L), largemouth bass (1.09 mg/L), channel catfish (1.43 mg/L), and carp (1.44 mg/L) (Appendix A, Table A-5). The invertebrate population in the lakes consisting primarily of planktonic rotifers, copepods, cladocerans, and benthic midges is less sensitive to un-ionized ammonia. The water flea, *Ceriodaphnia acanthine* (a close relative of *Ceriodaphnia quadrangula* found in Lake Elsinore) was the most sensitive of the invertebrates surveyed, with an SMAV of 0.62 mg/L un-ionized ammonia (Appendix A, Table A-6).

Historical concentrations of un-ionized ammonia in Lake Elsinore calculated using historical depth integrated total ammonia values, along with depth integrated mean pH, temperature, and salinity show that these concentrations are generally below the levels expected to cause acute toxicity to fish and invertebrates in Lake Elsinore (Appendix A, Figure A-9). However, the sensitivity of one fish species, the white perch, *Morone americana*, not found in the lake, but within the same genus as the hybrid striped bass, does have an estimated SMAV of 0.27 mg/L un-ionized ammonia, which is within the upper range of historical un-ionized ammonia concentrations observed in Lake Elsinore (maximum un-ionized ammonia concentration observed March 2002 to June 2012 is 0.28 mg/L). As such, there is the potential for un-ionized ammonia to be at concentrations that are potentially toxic to fish in Lake Elsinore, but to date it has not been related to any fish kills. Lake Elsinore is dynamic and toxic conditions can be fleeting as it relates to the presence of un-ionized ammonia. Under the right conditions (high pH and high temperature) acutely toxic concentrations of un-ionized ammonia can have a quick effect on fish populations, which may not be detected during routine monitoring activities which are "point-in-time" measures. The effects of elevated un-ionized ammonia concentrations can be exacerbated by low DO and elevated temperature, which add additional stresses to the fish.

2.3.4 Zooplankton Food Sources

Zooplankton, particularly the types found in Lake Elsinore, feed largely on phytoplankton, with a relatively minor portion of their diet consisting of protozoans, bacteria, and detritus. The zooplankton community at Lake Elsinore is heavily dominated by copepods and rotifers, which are not as efficient at grazing dense phytoplankton populations as cladocerans. The small population of cladocerans observed in the lake were small-bodied and did not have efficient filtering capacities. However, even a robust *Daphnia* population may not be able to adequately graze the majority phytoplankton in the lake due to the strong dominance of *Pseudanabaena limnetica* (formerly *Oscillatoria*). This species of blue-green algae is a poor food resource for filter-feeding *Daphnia* and other large-bodied cladocerans, since the algal filaments are too large to enter the mouth and further interfere with filtration of smaller phytoplankton. This species is also thought to potentially produce neurotoxins (Jakubowska et al. 2013) which could induce acute or chronic effects in both fish and invertebrates. Therefore, while phytoplankton (a major proportion of diet of zooplankton) densities are high, the carrying capacity of the lakes for populations of large bodied cladocerans may be suppressed by the type of algae that typically dominates the phytoplankton community.

2.4 Unique Characteristics of Lake Elsinore and Canyon Lake

More than ten years of studies completed on Lake Elsinore and Canyon Lake have provided new insight regarding water quality characteristics of each lake. These studies have identified a number of unique factors that must be considered in developing revised TMDL for the lakes. These factors include:

- Under natural conditions in Lake Elsinore, extended droughts may cause severe evapo-concentration of salts and nutrients to levels that cannot support expected biological communities as well as periodic lakebed desiccation that completely eliminates the aquatic ecosystem (also see Section 2.2.2.4)
- Highly efficient retention of runoff and associated sediment and nutrients in both Canyon Lake and Lake Elsinore, which severely limits or reduces the delivery of runoff volume to the lakes.
- Natural land cover in the San Jacinto River watershed is characterized by highly erodible soils that are rich in nutrients that generate significant sediment and associated nutrient loads to the lakes during extreme wet weather events.

These factors lead to evapo-concentration of salts in Lake Elsinore during periods of extended drought and, if recycled water were not discharged to the lake, eventual lakebed desiccation. In Canyon Lake, sedimentation rates far in excess of typical ranges for reservoirs facilitate the buildup of nutrient rich lake bottom sediments that continually depletes DO and sustains hypereutrophic conditions through repeated internal cycling.

In addition to these unique factors, which are discussed in more detail below, the Task Force has been conducting studies that have provided better understanding of lake dynamics. These findings will also need to be considered when revising the TMDL, as discussed below.

2.4.1 Extended Drought

Section 2.2.2.4 provides a summary of the historical nature of lake elevations in Lake Elsinore. This section builds on that information particularly as it relates to revision of the TMDLs. Measured inflows to Canyon Lake and inflows from Canyon Lake to Lake Elsinore show that extended drought, upstream runoff retention, and the very large drainage area exasperate long-term fluctuations in water delivered to the lakes. While the watershed to Canyon Lake is large relative to the lake surface area, it is also very efficient at retaining runoff in upstream impoundments such as Lake Hemet and Mystic Lake and through natural channel bottom recharge. In addition, Canyon Lake is used as a water supply source for EVMWD. Complete retention of runoff inflows to Canyon Lake has occurred in approximately half of hydrologic years since 1916. Conversely, in very wet years, runoff volumes commonly greater than the total Canyon Lake storage capacity are flushed through to Lake Elsinore.

USGS gauge data for inflows to Lake Elsinore show significant variability exists even when considering decadal averages (**Figure 2-45**). Review of cumulative runoff volume delivered to Lake Elsinore from the San Jacinto River shows that as much as two thirds of total inflow volume since the lake was dry in 1964 has been delivered during just five of 52 years. (**Figure 2-46**).

Long-term periods of low (1950-1966) and high (1980-1990) inflow volumes can alter the hydrology of Lake Elsinore from complete lakebed desiccation at a water elevation of approximately 1,225 feet. to wet weather overflow to Temescal Creek at water elevation 1255 ft., as shown in historical water level records (**Figure 2-47**).

Management of the lakes water level by addition of supplemental water began after 1964 and has successfully avoided extremely low water levels from occurring in Lake Elsinore. The DRYESM-CAEDYM model for Lake Elsinore includes a water budget, which suggests that without any supplemental water additions, the current extended drought would have yielded a lake level of 1225 feet. (Anderson 2016a). This level would be comparable to the modeled level around 1960, when multiple references document the presence of a completely dry lakebed (see Figure 2-9). Further, without the implementation of the LEMP project to reduce the surface area of Lake Elsinore, it is plausible that even sharper water level declines would have occurred in response to the current drought.

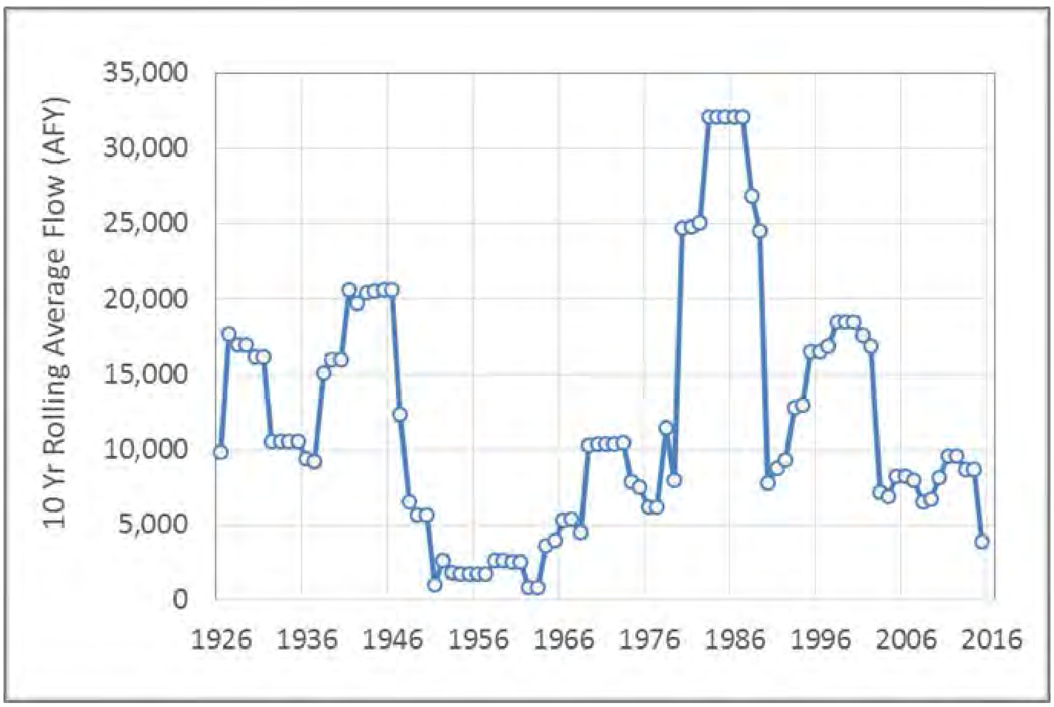

Figure 2-45. 10-Year Rolling Average Annual Runoff Inflow to Lake Elsinore from San Jacinto River Watershed

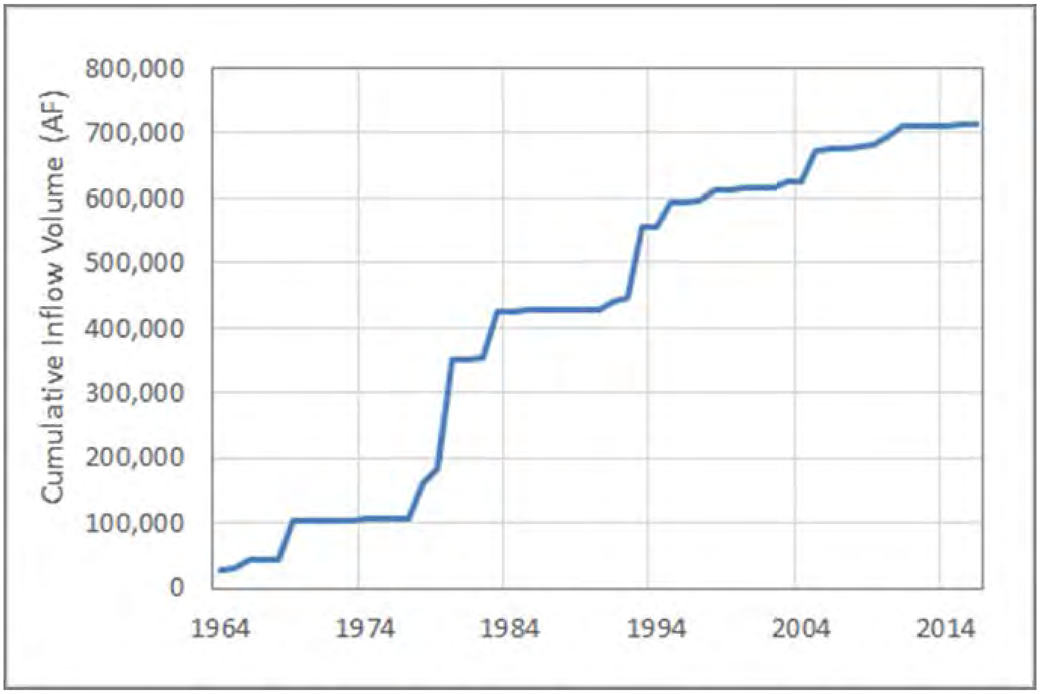

Figure 2-46. Cumulative Delivery of Runoff Volume to Lake Elsinore from the San Jacinto River (1964-2016)

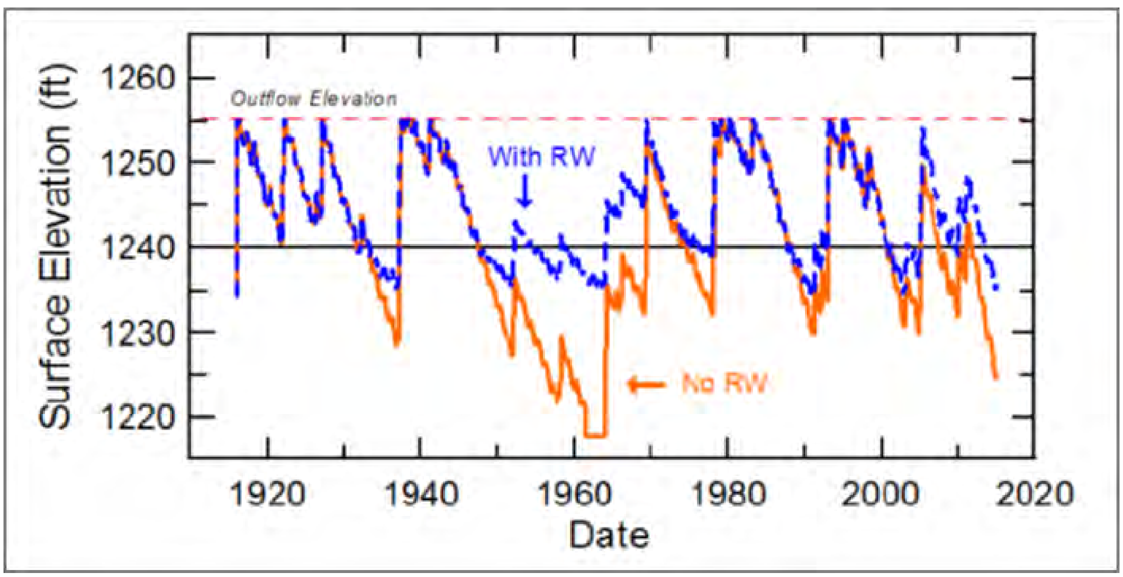

Figure 2-47. Modeled water level in Lake Elsinore for Scenarios with and without Supplemental Water Additions (from Anderson 2015b)

The impact of extended droughts that historically lead to lakebed desiccation is a complete reset of the aquatic ecosystem. Prior to desiccation, water quality is degraded by evapo-concentration of nutrients and other salts in the water column. As the lake volume slowly declines to zero, the concentrations of ammonia and TDS reach extremely high values that far exceed acute toxicity thresholds for aquatic organisms (see Section 2.3). In addition, nutrient concentrations reach levels that may sustain blooms of algae in the remaining volume to harmful levels. Thus, not only does the drying out of the lake pose a significant threat to the aquatic ecosystem, but also the evapo-concentration during extended droughts prior to complete desiccation causes water quality conditions that may substantially impact most organisms.

Prevention of such use impairment requires interventions involving supplemental water additions. Supplemental water available to stabilize the water level in Lake Elsinore has a typically higher concentration of TDS than runoff in overflows from Canyon Lake or stormwater from the City of Lake Elsinore. DYRESM-CAEDYM model results estimated a higher long-term average TDS concentration in the lake with supplemental water addition, but successful avoidance of lakebed desiccation or evapo-concentration to levels that exceed toxicity thresholds in most years (Anderson 2016a).

2.4.2 Sediment and Nutrient Retention

Flushing is a hydrologic process involving the conveyance of detained water through a waterbody to downstream waters. The water quality benefits of hydrologic flushing are to remove nutrients and algae contained in stored water and reduce the residence time of bioavailable nutrients to support new algal growth. Generally, lakes with low storage capacity relative to their drainage area size, like Canyon Lake and Lake Elsinore, overflow during moderately sized storms. However, highly variable hydrology and upstream retention limit the amount of flushing that these lakes experience. The opposite of flushing is retention. Runoff retention equates to complete retention of external loads of sediment and nutrients, which enhances eutrophic conditions of increased productivity and cycling of nutrients within the waterbody. Even without retaining all runoff, sediment and nutrients may still be retained by settling to the lake bottom before overflowing to the downstream waterbody.

Both Canyon Lake and Lake Elsinore have a low rate of hydrologic flushing; moreover, these waterbodies are configured in a way that facilitates retention of most external loads of sediment and nutrients. These characteristics can impact lake water quality and biological conditions. Sediment and nutrient retention characteristics of each lake are discussed below.

2.4.2.1 Lake Elsinore

In the period with concurrent gauge data (2001-2015), almost 90 percent of overflow volume from Canyon Lake to Lake Elsinore occurred during two wet seasons: 2004-2005 and 2010-2011. The volumes delivered in these wet seasons amounted to 4-5 times the total storage capacity of Canyon Lake. No overflows from Lake Elsinore to Temescal Creek have occurred since 1993, and therefore all runoff and associated sediment and nutrients that have passed through Canyon Lake have been retained in Lake Elsinore.

When overflows to Temescal Creek do occur, significant water quality benefits are expected, in particular salt, nutrient, and algae export via flushing. Historically, overflows to Temescal Creek occurred in roughly 10 percent of hydrologic years, but more efficient upstream retention appears to be reducing the frequency of overflows with the last event occurring in 1995.

2.4.2.2 Canyon Lake

Canyon Lake retains a significant portion of sediment and nutrients. Horne (2002) compared bathymetry mapping for East Bay conducted in 1986 and 1997 to estimate the accumulation of sediment over the 11-year period between surveys and found unusually high sedimentation rates of 2-3 in/yr, which are roughly 60 times greater than a typical lake (**Table 2-16**).

Table 2-16. Sediment Accumulation in Canyon Lake East Bay from 1986 to 1997

Site	Approximate Sediment Depth (ft)		Average Annual Sediment Deposition (in/yr)
	1986	1997	
Site 1	6.5	9.1	2.8
Site 2	2.2	4.3	2.3
Site 3	2.7	4.5	2.0
Site 4	1.4	3.2	2.0
Site 5	1.2	3.5	2.5

An earlier USGS survey of 56 U.S. lakes, including Canyon Lake, involved different age-dating techniques to estimate sediment accumulation rates (US Geological Survey, 2004). The radionuclide ^{137}Cs was used as the primary age-dating technique for 42 of 56 lakes and is based on the apparent peak in ^{137}Cs that occurred after fallout from a short period of extensive testing of nuclear weapons in 1964. For Canyon Lake, the peak ^{137}Cs activity was identified at 118 cm depth from a single core collected from the downstream end of the Main Lake in November 1998, equating to an average annual sediment accumulation of 3.5 cm/yr (1.4 in/yr). This rate is based on a Main Lake sediment core and is lower than estimates for East Bay (see Table 2-16).

In the most recent bathymetric survey, Anderson (2015a) collected hydroacoustic echograms at three frequencies which allowed for mapping of the lake bottom, as well as an estimate of the thickness of sediment. Sediment samples collected from five sites across the lake at the same time as the hydroacoustic surveys showed that mobile-P was correlated to the low frequency echograms, which facilitated mapping of areas with greater organic content and mobile-P across the lake bottom (**Figure 2-48**). These areas, generally in the more downstream region of each lake segment pose the greatest potential for oxygen depletion and for releasing bioavailable nutrients to the water column.

Historically, the sediment and nutrients retained in Canyon Lake would naturally (without Railroad Canyon Dam) have been delivered to Lake Elsinore, since 94 percent of the Lake Elsinore watershed area is upstream of Canyon Lake. Of the sediment and nutrient loads that are not retained in Canyon Lake, referred to as pass-through, most are ultimately retained within Lake Elsinore.

The nutrient load to Canyon Lake and from Canyon Lake to Lake Elsinore can be determined from historical flow and water quality data from the two inputs to Canyon Lake (Salt Creek and San

Jacinto River[3]) and overflow to Lake Elsinore. Continuous flow data was obtained from USGS gauges at these sites for the period of 2001 through 2014. **Figure 2-49** compares the total inflow runoff volume to Canyon Lake from Salt Creek and the San Jacinto River with overflow volume to Lake Elsinore. The estimate of Canyon Lake overflow is from USGS Gauge 11070500 (San Jacinto River near Lake Elsinore), which is approximately 2 miles downstream of the Canyon Lake spillway and therefore includes some runoff from a small subarea (~7,000 acres) between the two lakes in addition to Canyon Lake overflows. Annual runoff volumes from this gauge were summed for years when Canyon Lake exceeded its spill water elevation of 1,381.76 ft (2003-2005, 2008, and 2010-2011). In dry years when the lake did not reach its spill elevation, outflow was assumed to be zero (2002, 2006, 2007, and 2009). Results from wet weather monitoring during 25 storm events since 2007 for inflows to and outflow from Canyon Lake show that nutrient concentrations are reduced by approximately 50 percent when overflows are occurring (see Section 4, "Source Assessment"). Combining nutrient and sediment loads that are retained when volume is retained and the estimated settling prior to overflows in wet years, an estimated 62 and 41 percent of long-term average external loads of TP and TN, respectively, is retained in Canyon Lake.

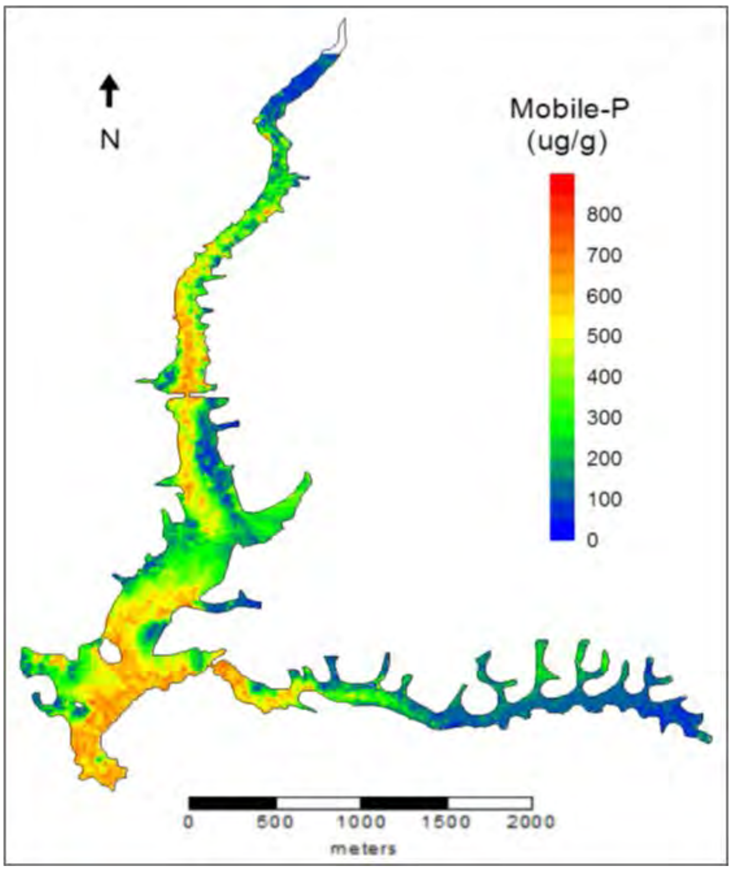

Figure 2-48. Estimated Concentration of Mobile-P in Canyon Lake Bottom Sediments Based on 2014 Hydroacoustic Survey (from Anderson 2015a)

[3] However, as noted in Section 2.2.1, flows from the San Jacinto River Watershed need to be revised per new understanding regarding upstream retention, e.g., in the Mystic Lake subwatershed.

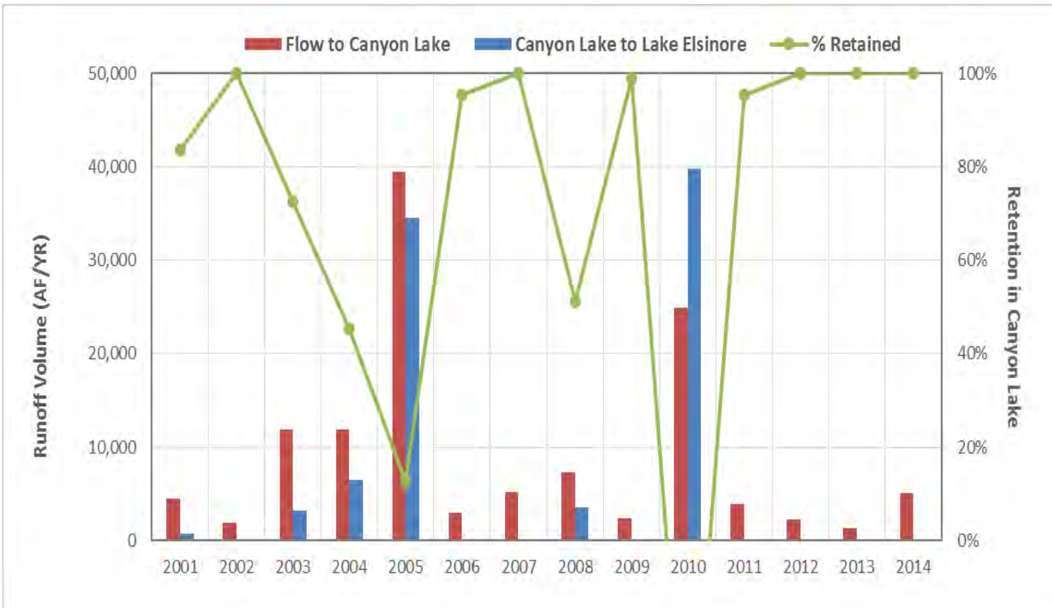

Figure 2-49. Annual Runoff Volume into Canyon Lake and Overflow to Lake Elsinore

2.4.3 Watershed Soil Erosion

Monitoring data show very high concentrations of suspended solids and nutrients during high intensity storm events (most recently in January 2011) that generate significant soil erosion, even from undeveloped hillsides. Sediment loads from these types of events may exceed typical winter storms by 100 times (Horne 2002). While these events may be infrequent and episodic, the impact to water quality in the downstream lakes persists for multiple years in the form of enrichment of bottom sediments and subsequent nutrient flux rates to the water column.[4] Anderson (2012d) estimated the half-life of nutrients delivered to the lake bottoms of Canyon Lake ($t_{1/2}$ of 6.7 years for organic-P and 16.7 years for TN) and Lake Elsinore ($t_{1/2}$ of 60.4 years for organic-P and 30.1 years for TN). The TMDL revision must consider that these episodic nutrient loads are partially attributable to natural background lands areas and would be likely to occur in a pre-developed or "reference" watershed. Moreover, returning loads to a reference level will not provide immediate water quality improvements.

2.4.4 Canyon Lake Dynamics

The existing nutrient TMDL for Canyon Lake employed a linkage analysis that assumed a single fully mixed lake basin and thereby developed a single set of allocations for external loading. However, as described above and as demonstrated by studies Canyon Lake has three distinct segments, namely the Main Lake, North Ski Area, and East Bay. The North Ski Area and Main Lake receive runoff from the San Jacinto River. Runoff from the San Jacinto River flows into the North Ski Area and then through culverts under Greenwald Avenue to the Main Lake. Hydraulically,

[4] Section 4, "Source Assessment" characterizes existing information of nutrient washoff from watershed lands during such events and the conditions that may explain their occurrence.

these two lake segments are completely connected, and the North Ski Area is an extension of the Main Lake to its transition to the San Jacinto River inflow. For this reason, these two lake segments are not treated as separate receiving waters in the TMDL revision.

Conversely, the East Bay of Canyon Lake is very different in many ways from the Main Lake (**Table 2-17**). The East Bay has an entirely different drainage area than the Main Lake, with most runoff coming from Salt Creek. During wet weather events water from East Bay outflows to the lower part of the Main Lake via a single 12-foot culvert under Canyon Lake Drive. Exchanges between the Main Lake and East Bay are minor during dry weather conditions. Thus, it is important for East Bay, and its Salt Creek source area, to be treated separately in the revised TMDL.

2.5 Summary

This Problem Statement has identified a number of key findings from more than 10 years of research that need to be considered as part of the TMDL revision to provide a more appropriate basis for the establishment of numeric targets in Lake Elsinore and Canyon Lake. These findings include:

Table 2-17. Key Differences between Canyon Lake Main Lake and East Bay

Characteristic	Main Lake	East Bay
Watershed	San Jacinto River	Salt Creek
Lake Depth	30-60 feet	5-15 feet
Thermal Stratification	Hypolimnion ~1,500 AF (30% of full pool) April – November	Hypolimnion ~200 AF (5% of full pool) April – September
Water Quality Drivers	Low DO, high NH_3, SRP in hypolimnion mixes over water column at turnover and causes fish kills, algal blooms	Nutrient rich sediments from large watershed loadings, flux to water column sustains algal blooms throughout the year
Primary Conveyance	Overflow to Lake Elsinore	To Main Lake through culvert

- Better understanding of the San Jacinto River Watershed and retention of flows in the upper watershed, e.g., as retained by Mystic Lake.
- The highly managed nature of Lake Elsinore and Canyon Lake and its influence on expected water quality and biological conditions.
- Water quality conditions related to naturally occurring hydrologic cycles that influence water quality and aquatic biological expectations, especially for Lake Elsinore.
- Dynamics of sediment and nutrient retention and their influence on conditions in each lake.
- Role that natural background levels of nutrients in the watershed have on downstream water quality.

- Better understanding of the differences in the dynamics in the East Bay and North Ski Area versus the Main Lake in Canyon Lake and how this may influence water quality expectations. This page intentionally left blank.

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Section 3
Numeric Targets

Lake Elsinore and Canyon Lake are impaired for the warm freshwater aquatic habitat (WARM) and water contact and non-water contact recreation (REC1 and REC2) beneficial uses. Canyon Lake is considered impaired for the Municipal and Domestic Water Supply (MUN) use. A TMDL establishes numeric targets to provide a basis for demonstrating attainment of water quality objectives (WQOs) and protection of impaired beneficial uses. That is, achievement of the numeric target(s) is expected to result in the waterbody of concern no longer being impaired. Where the water quality objective(s) are narrative, the TMDL translate narrative water quality objective into appropriate response targets to assure attainment of the objective. This section establishes the numeric targets for the revised TMDLs and provides the technical basis for the selection of these targets.

Table 2-3 in the 2004 TMDL presents the numeric targets for Lake Elsinore and Canyon Lake for interim (2015) and final (2020) compliance timelines. The Staff Report for the TMDL describes the scientific basis used to determine these targets (Santa Ana Water Board 2004). This TMDL revision uses additional scientific understanding from research performed after the existing TMDL was adopted to revise these numeric targets for Lake Elsinore and Canyon Lake (Main Lake and East Bay). The primary objective in the development of revised numeric targets is to establish water quality conditions that are equal to or better than what would occur in the lakes if the watershed was returned to a reference condition (i.e., pre-development). This section is organized into the following sections to describe how this objective has been achieved with the revised TMDL numeric targets described below:

- *Section 3.1 - Water Quality Standards Interpretation*: Water quality standards include beneficial use classifications, WQOs, and antidegradation criteria for named waters in the Basin Plan. For Lake Elsinore and Canyon Lake, a TMDL was developed to address impairment of water quality standards in these lakes. The WQOs applicable to the beneficial uses of these lakes serve as the building blocks for developing the TMDL numeric targets described in this section.

- *Section 3.2 – Establishment of a Reference Watershed*: No watersheds comparable to Canyon Lake or Lake Elsinore exist in southern California or other areas with similar climatic regimes. As such it is not possible to establish allowable pollutant loads using another watershed/downstream waterbody combination as a means to describe an expected reference condition. Instead, using data from reference subwatersheds within the San Jacinto River watershed upstream of Lake Elsinore and Canyon Lake, a lake water quality modeling scenario representative of a hypothetical reference watershed condition for drainage areas to Lake Elsinore and Canyon Lake was developed to provide the basis for establishing numeric targets. This approach will be described in this section. In addition, this section will briefly describe the characteristics of the reference watershed condition for Lake Elsinore and Canyon Lake.

- *Section 3.3 - Numeric Targets*: – Numeric targets are presented as cumulative distribution frequencies (CDFs) to characterize spatial and temporal variability in water quality that may be expected in Lake Elsinore and Canyon Lake (Main Lake and East Bay) under a reference watershed condition. This section contains CDFs of model results for a reference watershed scenario for indicators of beneficial use impairments, including nitrogen, phosphorus, chlorophyll-*a*, DO, and ammonia.

3.1 Water Quality Standards Interpretation

Water quality standards set forth in the Basin Plan include beneficial use designations, WQOs required to protect those uses, and an antidegradation policy. Where water quality standards are not being attained and a finding has been made that one or more beneficial uses is not protected, a TMDL is developed to establish the maximum allowable pollutant loads that the waterbody may receive from all sources and meet water quality standards. The Canyon Lake and Lake Elsinore Nutrient TMDLs were developed as a result of impairment of the WARM, REC1, and REC2 uses. The TMDL for Canyon Lake also considered impairment of the MUN beneficial use.

3.1.1 Warm Freshwater Habitat (WARM) Beneficial Use

The Basin Plan defines the WARM beneficial use as follows (Santa Ana Water Board 2016):

> *"WARM waters support ecosystems that may include, but are not limited to, preservation and enhancement of aquatic habitats, vegetation, fish and wildlife, including invertebrates."*

Protection of this beneficial use requires consideration of a number of water quality characteristics. These characteristics as well as the Basin Plan water quality objectives established to protect his use are discussed in the following sections.

3.1.1.1 WARM Use Protection

Table 3-1 identifies specific metrics that may support an impairment finding for the WARM use. These metrics are listed in a hierarchy of causality ranging from direct[1] measures of impairment of the WARM use (Levels 1 and 2) to indirect measures. Use of indirect measures often require an understanding of complex inter-relationships among several factors prior to determining that the WARM use is impaired (Levels 3, 4, 5). Level 5 nutrients are causal variables because all other use impairment indicators at higher levels in the hierarchy are ultimately caused by excess nutrients. Accordingly, factors such as algae concentrations (Level 4) and water quality stressors (Level 3) may be referred to as response variables. However, in the impairment hierarchy, Level 3 and 4 indicators may also cause direct use impairments themselves. For example, low levels of dissolved oxygen can directly impair the WARM use.

Direct impairment of the WARM use can be assessed with indices of biological integrity and frequency of fish kills. Since fish kills do not routinely occur and biological integrity indices require focused snapshot surveys, using these indicators to measure progress towards

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[1] Levels 1 and 2 are direct indicators of use impairment or 'measures of effect'; Levels 3, 4 and 5 are indirect indicators of use impairments, with levels 3 and 4 comparable to 'intermediate measures' and level 5 comparable to 'measures of exposure' as defined in the California's numeric nutrient endpoint (NNE) framework for freshwater (Tetra Tech, Inc. 2006).

attainment is challenging. The State Water Board is in the process of developing a Biological Integrity Assessment Implementation Plan (for Perennial Streams and Rivers),[2] which may evolve to include lakes and provide a new methodology for use of this impairment indictor in future assessments. Instead, other indicators can be measured directly using field and laboratory techniques including Level 3 water quality stressors.

Table 3-1. Hierarchal Assessment of WARM Use Attainment in Lake Elsinore and Canyon Lake

Priority	Beneficial Use Integrity Indicator	Direct or Indirect Measure[1]
Level 1	Fish kills	Direct
Level 2	Biological health indices: Species richness & abundance	Direct
Level 3	Water quality stressors: Dissolved oxygen, unionized ammonia, hydrogen sulfide, cyanotoxins	Indirect
Level 4	Algae bloom concentration and persistence	Indirect
Level 5	Nutrients: Nitrogen and phosphorus	Indirect

[1] See text.

Level 3 water quality stressors include a series of indicators that may contribute, in varying degrees, to impacts on biological community health and occurrence of fish kills. The degree to which each contributes individually is unknown, i.e., to date, little to no data exist to point to which of these stressors are the primary cause of impairment of the WARM use in Lake Elsinore or Canyon Lake. Each Level 3 stressor is described below:

- *Dissolved Oxygen*: When algae decay and settle, the lake bottom sediments become enriched with nutrients and oxygen demanding organic matter. Sediment oxygen demand creates anoxic conditions in lake bottom waters. For stratified lake segments, there is not enough reaeration from the lake surface to offset sediment oxygen demand and oxygen can be depleted throughout most of the hypolimnion. Turnover is the mixing of bottom waters with top waters after the lake mixes (de-stratifies) around October-November when the top waters cool. Immediately following turnover, low dissolved oxygen conditions throughout the water column may occur and cause stress for fish.

- *Unionized Ammonia*: Anoxic conditions in the lake bottom, an indirect result of algae decay and enrichment of bottom sediments as described above, facilitates the process of ammonification. Ammonification is the conversion of organic nitrogen to ammonia by anaerobic decomposition. In its unionized form (NH_3), ammonia is toxic to aquatic species. The unionized fraction of ammonia increases exponentially with changes in temperature and pH (EPA 2013). Photosynthesis by algae in lakes increases pH, which in turn increases the NH_3 fraction of total ammonia nitrogen.

[2] http://www.swrcb.ca.gov/plans_policies/biological_objective.shtml

- *Total Dissolved Solids (TDS)*: Lakes with limited flushing and significant evaporative losses relative to average runoff inflows experience increased TDS by evapoconcentration, most severely in periods of extended drought. TDS is a stressor for freshwater aquatic life, including many fish species. Zooplankton communities that graze upon algae, which can mitigate the duration and magnitude of algal blooms, are often highly vulnerable to rises in TDS.

- *Hydrogen Sulfide*: Anoxic conditions in the lake bottom, an indirect result of algae decay and enrichment of bottom sediments as described above, also facilitates sulfate reduction to hydrogen sulfide by anaerobic bacteria respiration. Hydrogen sulfide is toxic to aquatic species.

The revised TMDL includes a numeric target for chlorophyll-*a*, which is a measure of a pigment found within algae, and a commonly used measure of algae concentration in surface waters. Algae require sunlight for photosynthesis and therefore are generally found within the photic zone of a surface water. The TMDL numeric target for algae is for the average chlorophyll-a concentration within the top one meter of the water column. Below one meter, light penetration is often inhibited and by algal and inorganic turbidity.

At the bottom of the hierarchy as shown in Table 3-1 are the nutrients nitrogen and phosphorus, which influence algae growth and persistence of algal blooms. Nutrients are the only indicator that can be accounted for in external inputs to the lakes, and therefore provide the basis for the existing TMDL, expressed as the total allowable load of nutrients to each lake segment. The relationship between Level 5 indicator nutrients and Level 1 and 2 direct measures of WARM use attainment involves many complex physical, chemical, and biological processes, as illustrated in **Figure 3-1**. The TMDL linkage analysis will identify the relationships between nutrients and higher-level use attainment indicators, such as algae (as measured as chlorophyll-*a*), dissolved oxygen, and ammonia toxicity. These are better measures of impairment and will be used as the basis for establishing revised numeric targets in the TMDLs.

Not included in the WARM use attainment hierarchy (Table 3-1) is the potential effects of extended drought. For example, extended drought can impact algae as depicted in Figure 3-1, and the influence of extended droughts in the watersheds that drain to Canyon Lake and Lake Elsinore can contribute to the severity of WARM use impairments. For example, Figure 3-1 shows how increased salinity by evapoconcentration constrains zooplankton communities, which in turn limits the effectiveness of this aquatic community to graze and mitigate algal levels. Also, as salinity rises, the types of algae (e.g., cyanobacteria that may contain toxins) that thrive in higher TDS conditions are more prevalent, and tend to be less edible for zooplankton. This process of increasing salinity is most applicable to Lake Elsinore because of its greater susceptibility to extended droughts because of its almost complete lack of flushing, significant evaporative loss from its large surface area, and reduced inflow of freshwater from retention of runoff upstream in Hemet Lake, Mystic Lake and other recharge basins, as well as within Canyon Lake (e.g., see Section 2.2.3 of the Problem Statement).

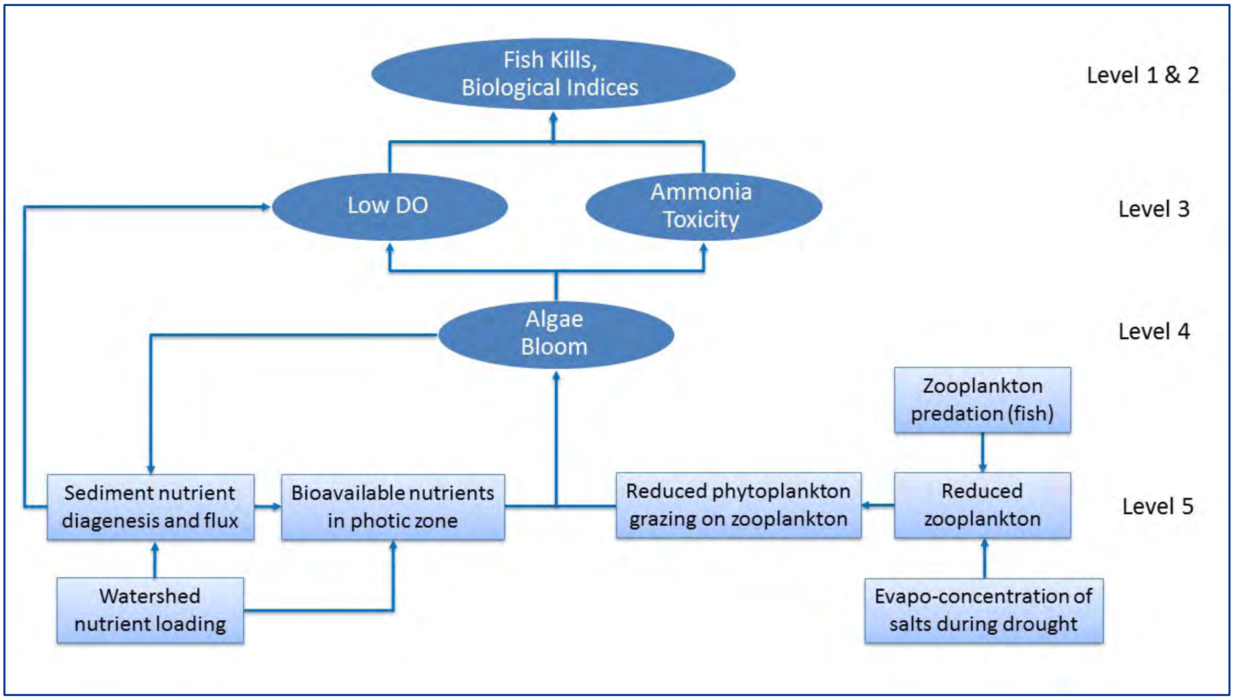

Figure 3-1. Processes that Cause Impairment of the WARM Beneficial Use Organized According to the WARM Use Hierarchy (see Table 3-1)

3.1.1.2 Water Quality Objectives

The Basin Plan includes WQOs for several of the water quality indicators presented above. Table 2-1 in Section 2 (Problem Statement) summarizes these objectives. The following sections summarize how these objectives have been considered in the development of numeric targets for the revised TMDLs:

Algae

The water quality objective for algae is narrative and therefore does not include a numeric threshold value for use in developing TMDL numeric targets (Santa Ana Water Board 2016). Specifically:

> *"Waste discharges shall not contribute to excessive algal growth in inland surface receiving waters"*

Development of a TMDL numeric target requires interpretation of the above narrative language, most notable being the need to interpret the term "excessive" used to describe the level of algae growth that is to be controlled. The approach used to set TMDL numeric targets for Canyon Lake (Main Lake and East Bay) and Lake Elsinore is based on the premise that "excessive" is equivalent to any amount of algae above that which would occur if the upstream watershed were to be returned to a reference condition (see Section 3.2 below). Chlorophyll-*a*, a pigment found within algae, is a commonly used measure of algae concentration in surface waters and therefore numeric targets in nutrient TMDLs are based on concentrations of chlorophyll-*a*.

Dissolved Oxygen

The Basin Plan water quality objective for dissolved oxygen is as follows (Santa Ana Water Board 2016):

> *"The dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated WARM, or 6 mg/L for waters designated COLD, as a result of controllable water quality factors"*

The water quality objective is used to develop TMDL numeric targets based on the threshold concentration of 5 mg/L for WARM use. The Basin Plan dissolved oxygen water quality objective specifically limits the responsibility to dischargers to "controllable water quality factors." This qualifier supports the use of a reference watershed approach, where impacts to dissolved oxygen in the downstream waterbodies can be related to controllable factors in a developed watershed. The corollary case is that dissolved oxygen impairments that occur naturally, as a result of reference watershed loads, i.e., under pre-development conditions, could be reasonably categorized as resulting from uncontrollable water quality factors.

The dissolved oxygen water quality objective does not include any guidance on how compliance should be evaluated, particularly with regards to spatial or temporal averaging. With regards to the former, dissolved oxygen concentrations may vary significantly from the surface to the bottom of a lake simply because of natural processes associated with stratification. The applicability of DO objectives to the entire water column for Lake Elsinore and Canyon Lake was uncertain per the 2004 TMDL Staff Report, which stated (Santa Ana Water Board 2004):

> "*The Basin Plan does not identify the depth over which compliance with this objective is to be achieved, nor does it reflect seasonal differences that may result in DO variations associated with stratification in the lakes… As the relationship between nutrient input and dissolved oxygen levels in the lakes is better understood, the TMDL targets for dissolved oxygen can be revised appropriately to ensure protection of aquatic life beneficial uses."*

From a biological standpoint, it is important that fish and aquatic life have sufficient access to waters with greater than 5 mg/L in enough portion of key habitat areas of the lake volume to find refuge during periods of depressed oxygen levels. This especially important given that fish kills resulting from low DO conditions generally occur over small windows of time. The development of numeric targets for the revised Lake Elsinore and Canyon Lake Nutrient TMDLs will define the spatial and temporal extent of water with greater than 5 mg/L DO based on conditions that would be expected for a reference watershed (see Section 3.2 below).

Ammonia Toxicity

In 2013, EPA completed final ammonia criteria (EPA 2013) based on new scientific studies. These criteria updated the previously published 1999 criteria (EPA 1999). The 2013 EPA criteria are not WQOs unless included in the Basin Plan. To date, there have been no amendments to the Basin Plan to update WQOs for ammonia; however, the Santa Ana Water Board's Fiscal Year 2015-2018 Triennial Review Priority List and Work Plan includes a task to review the Basin Plan ammonia objectives based on the 2013 EPA criteria (Santa Ana Water Board 2015b). While this review has not yet occurred, the Basin Plan does include a narrative objective for general toxic substances as follows (Santa Ana Water Board 2016):

> *"The concentrations of toxic pollutants in the water column, sediments or biota shall not adversely affect beneficial uses."*

Currently, Lake Elsinore is listed as impaired for "unknown toxicity" (State Water Board 2010). Given this listing, and the toxics narrative objective above, for this TMDL revision numeric targets for ammonia will be developed for Lake Elsinore using the EPA 2013 ammonia criteria.

The 2013 EPA ammonia criteria involves a calculated acute and chronic concentration for total ammonia-N that is dependent upon temperature and pH, which impact the portion of total ammonia that is in the toxic unionized form. The 2013 criteria address the frequency for which acute and chronic concentrations must be protected, as follows:

- Acute - One-hour average concentration does not exceed, more than once every three years on the average.
- Chronic - Thirty-day average concentration does not exceed, more than once every three years on the average.
- Highest four-day average within the 30-day period should not exceed 2.5 times the chronic criteria, more than once every three years on the average.

Two sets of criteria have been published depending upon whether the waterbody contains highly sensitive freshwater mussels in the unionid family. This family of mussels was not present in any surveyed southern California lakes in recent surveys (Howard et. al. 2015 and Howard 2010), nor from historical surveys by Coney (1993). Despite these surveys not directly involving Lake Elsinore and Canyon Lake, the findings are sufficient to develop TMDL numeric targets based on the absence of unionid mussels. If surveys within Canyon Lake or Lake Elsinore show the presences of unionid mussels in the future, then the TMDL numeric target should be revised to the more stringent criteria.

3.1.2 Recreational Beneficial Uses

The Basin Plan defines the REC1 and REC2 beneficial uses as follows (Santa Ana Water Board 2016):

- *REC1* - Waters used for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses may include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, whitewater activities, fishing and use of natural hot springs.
- *REC2* - Waters used for recreational activities involving proximity to water, but not normally involving body contact with water where ingestion of water would be reasonably possible. These uses may include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing and aesthetic enjoyment in conjunction with the above activities.

The REC uses were determined to be impaired based on nutrient levels and presence of excessive algae, which "produces offensive odors and an unsightly lakeshore, adversely affecting use of the lake for water-contact and non-contact recreational purposes" (Santa Ana Water Board 2004). In addition, certain species of algae, when lysed, release cyanotoxins that can be stressors to other aquatic species. The toxicity of cyanotoxins to humans and pets is an important consideration when ensuring protection of the recreation beneficial uses.

As noted above, the water quality objective for algae is narrative. Specifically: "Waste discharges shall not contribute to excessive algal growth in inland surface receiving waters" (Santa Ana Water Board 2016). To implement this narrative, it is necessary to interpret the term "excessive," which can provide the basis for determining the level of algae growth that is to be controlled.

3.2 Establishment of a Reference Watershed

Development of numeric targets for this TMDL revision relies on the use of a lake water quality modeling scenario that is representative of a hypothetical reference watershed condition for the areas that drain to Lake Elsinore and Canyon Lake. This approach as well the characteristics of this this reference watershed are described below.

3.2.1 Overall Approach

The revision of the Lake Elsinore and Canyon Lake Nutrient TMDLs relies on the use of a reference watershed approach for setting numeric targets and determining allowable loading capacity for developing allocations (**Figure 3-2**). The process shown in Figure 3-2 characterizes the reference watershed approach involving first estimate of nutrient loads for a reference watershed, followed by linkage analysis and numeric target determination. The primary objective of developing a TMDL using a reference watershed approach is to establish targets that when met result in water quality conditions in each lake segment that are to equal or better than would be expected for a natural, or reference, waterbody.

The reference watershed approach embodies the State Water Board's basis for making an impairment finding:

> *"A water segment shall be placed on the section 303(d) list if the water segment exhibits significant degradation in biological populations and/or communities as compared to reference site(s) and is associated with water or sediment concentrations of pollutants including but not limited to chemical concentrations, temperature, dissolved oxygen, and trash."*

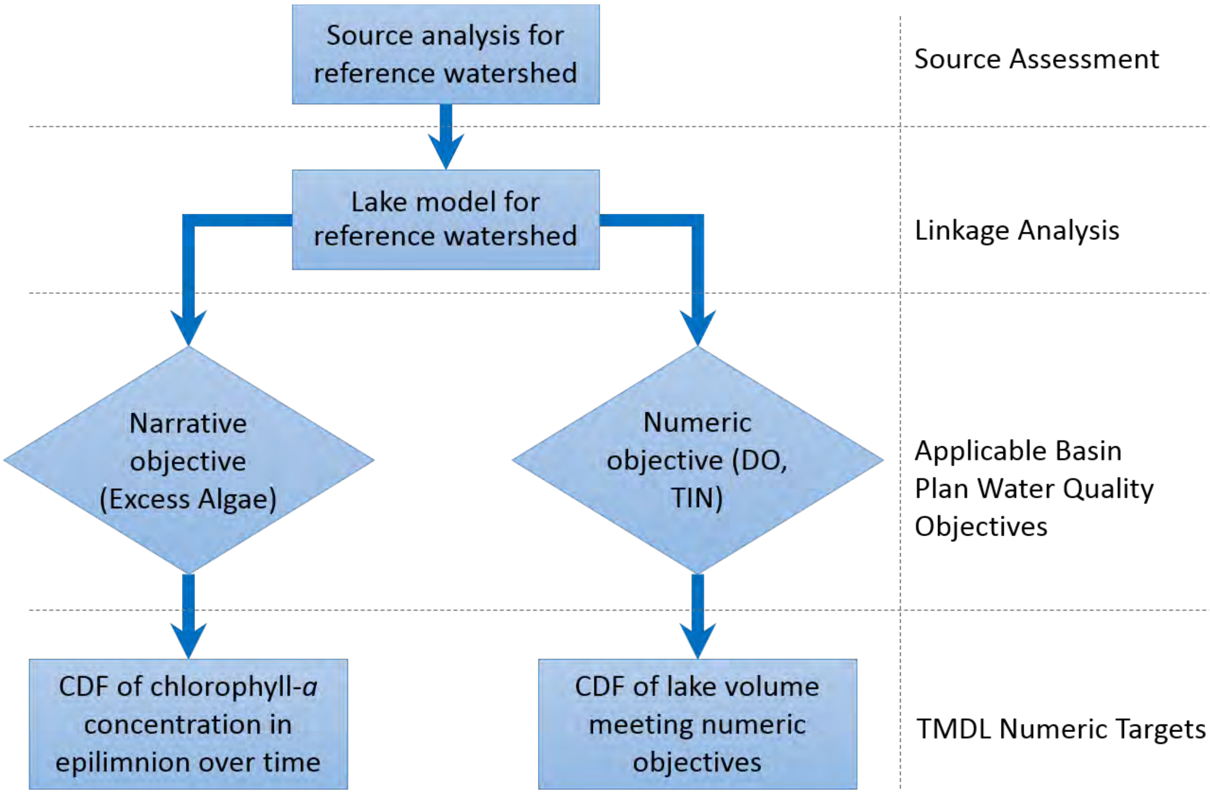

Figure 3-2. Process for Developing TMDL Numeric Targets Using a Reference Watershed Approach (Note: For a narrative objective, it may be necessary to define what is an exceedance of the objective)

3.2.1.1 Use of the Watershed to Define Reference Condition

There are no comparable inland lakes to Lake Elsinore or Canyon Lake that could be considered reference sites. These lakes have unique conditions that would be very unlikely to be replicated downstream of a natural watershed in the same geographic region where urban development is widespread. These unique conditions were described in the Problem Statement (see Section 2.4). Therefore, for the Lake Elsinore and Canyon Lake Nutrient TMDL revisions, a hypothetical scenario was employed to define the reference site, whereby runoff and nutrient loads representative of a completely natural, or reference, watershed was assumed to comprise the entire drainage area to the existing lake basins. This approach is consistent with EPA Region 9 in Guidance for Developing TMDLs in California (EPA 2000). This guidance recognizes the utility of hillslope targets, such as a reference watershed nutrient load, for setting numeric targets in a TMDL for impaired receiving waters:

> *"…It is sometimes possible to supplement instream indicators and targets with hillslope targets - measures of conditions within the watershed which are directly associated with waterbodies meeting their water quality standards for the pollutant(s) of concern."*

Within the context of this TMDL revision, this guidance is interpreted to mean that measures of hillslope, or watershed, conditions are directly associated with attainment of water quality standards in their downstream waterbodies. Similarly, since Lake Elsinore and Canyon Lake are downstream waterbodies within the San Jacinto River watershed, upstream reference watershed conditions may be used to establish appropriate TMDL targets for these waterbodies.

3.2.1.2 Spatio-temporal Variability

In a reference watershed condition, external nutrient loads are delivered with extreme temporal variation within a single wet season and with year to year variability extending over decadal timescales. The dynamic water quality response within the downstream lakes is even more variable because of other factors that control nutrient cycling, productivity, and sediment diagenesis. Also, Lake Elsinore and Canyon Lake are not completely mixed and exhibit naturally occurring spatial variability in nutrients and aquatic ecosystems. For these reasons, it is inappropriate to set lake-wide average numeric targets based on a static condition. The California approach considered for setting numeric nutrient endpoints (NNEs) came to this same conclusion for freshwaters, stating (Tetra Tech, Inc. 2006):

> *"Evaluation of a target also needs to consider questions of temporal and spatial applicability consistent with the desired use protection. Temporally, a chlorophyll a target can be defined as a point-in-time measurement (or frequency of such measurements) … Spatially, the target could be applied….in relation to specific sub-habitat areas."*

The TMDL requires reduction of nutrient sources to mitigate beneficial use impairments in excess of a frequency and magnitude (spatial extent) that would be expected for a reference watershed condition. A critical question for setting numeric targets is, how does one decide what is an excess level of a water quality constituent such that the beneficial use is impaired relative to a reference condition accounting for naturally occurring spatio-temporal variability? In short, this question is best addressed by expressing the Lake Elsinore and Canyon Lake TMDL numeric targets as CDFs.

A CDF is a plot of a statistical distribution for a set of data. **Figure 3-3** shows a series of historical depth integrated chlorophyll-*a* concentration converted to a CDF. Review of the time series history plot gives a sense for the long-term temporal variations in water quality. Translation to a CDF removes the consecutive order in a time series plot and instead expresses the long-term frequency of occurrence for different levels of water quality. It would be nearly impossible for future water quality to follow the same temporal pattern shown in the historical time series plot on the left. Fluctuations caused by short term weather phenomena and longer-term climate patterns are expected to be similar, but will occur in a unique order. However, over time, future water quality data converted to a CDF should align with the CDF of historical water quality, if no significant changes are made in the watershed or to the lakes that impact water quality in the lakes.

To interpret a CDF graph, pick a point on the curve. For example, as shown in Figure 3-3 chlorophyll-*a* exceeded 100 µg/L about 60 percent of the time based on historical monitoring over a 14-year monitoring period. Without any significant change in management practices, future water quality monitoring results over any other 14-year period would also be expected to have about 60 percent of samples exceeding 100 µg/L.

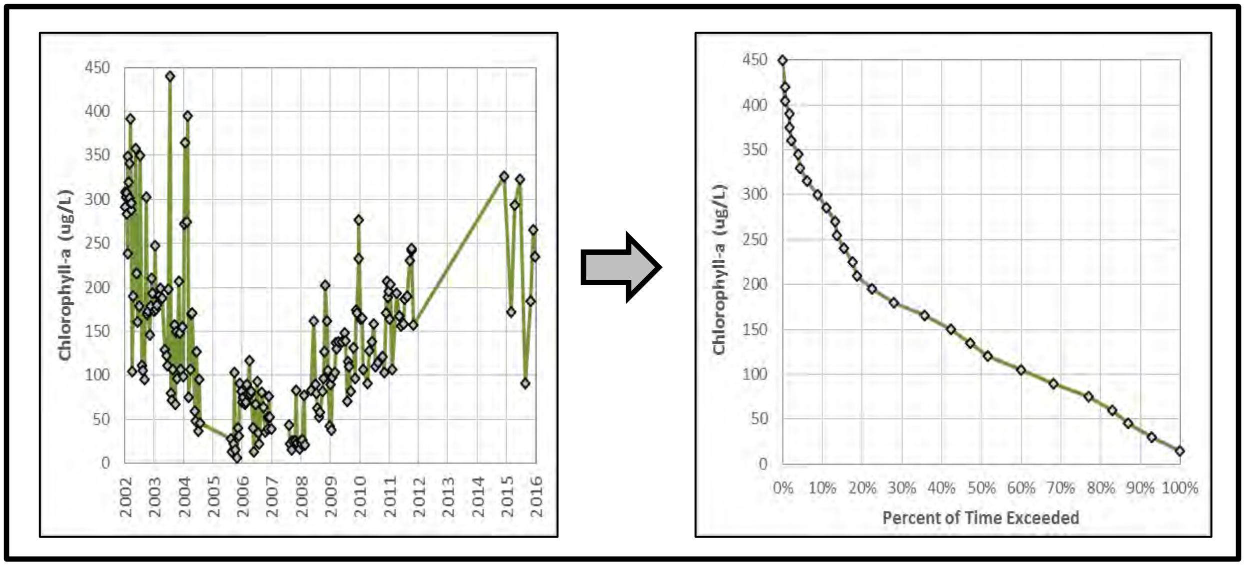

Figure 3-3. Conversion of a Long-term Routine Monitoring Data Set to a CDF Curve

In the case of CDF-based TMDL numeric targets, the data are daily average model results for a reference watershed scenario for beneficial use impairment indicators. This expression of the targets is based on the logical premise that returning loads from the watershed to reference levels would cause in-lake use impairment indicators to exhibit the same spatial and temporal variability expected for a reference watershed condition.[3] In other words, TMDL compliance will be achieved when CDFs developed from future long-term post-implementation monitoring are similar to the reference watershed model-based numeric target CDFs.

The concept for using CDF curves as a basis for defining expected water quality has been used elsewhere. For example, the State of Virginia adopted water quality standards for Chesapeake Bay segments that included a similar approach involving the use of a criteria reference curve for water quality standards attainment assessment. The reference curve was developed to account for naturally occurring conditions of hypoxia in Chesapeake Bay suggested from multiple lines of evidence (EPA, 2003). The guidance states:

> *"Attainment of these criteria shall be assessed through comparison of the generated cumulative frequency distribution of the monitoring data to the applicable criteria reference curve for each designated use. If the monitoring data cumulative frequency curve is completely contained inside the reference curve, then the segment is in attainment of the designated use."*

This EPA criteria guidance supporting the use of a reference criteria curve approach for making an attainment assessment was adopted in water quality standards for the States of Virginia (Virginia Administrative Code 2017) and Maryland (Code of Maryland Regulations 2017) for Chesapeake Bay segments. The approach described above and illustrated in Figure 3-3 is

[3] However, note that the true natural reference condition for Lake Elsinore is a terminal lake that dried up periodically (See Section 2.2.2). Modifications to the watershed (construction of Canyon Lake Reservoir) and changes to the physical structure of Lake Elsinore (implementation of LEMP) have created a modified reference condition that is irreversible.

appropriate for situations where the WQO is narrative. **Figure 3-4** portrays an alternative approach for using a CDF to establish a TMDL numeric target where the Basin Plan establishes a numeric WQO for a constituent, such as the WQO for DO not to be depressed to below 5 mg/L to support the WARM use. In this case, the CDF approach is modified to account for both frequency and spatial extent of impairments. This is accomplished by changing the value expression for the y-axis of the CDF from the spatially averaged concentration to the fraction of the total lake volume that is within the numeric WQO threshold (Figure 3-4).

This alternative method of expressing the CDF is apparent in the methods description for the development of reference criteria curves in the Chesapeake Bay (EPA 2003), as follows:

> *"The cumulative frequency distribution methodology for defining criteria attainment addresses the circumstances under which the criteria may be exceeded in a small percentage of instances…the frequency of instances in which the water quality threshold (e.g., dissolved oxygen concentration) is exceeded, as a function of the area or volume affected at a given place and over a defined period of time."*

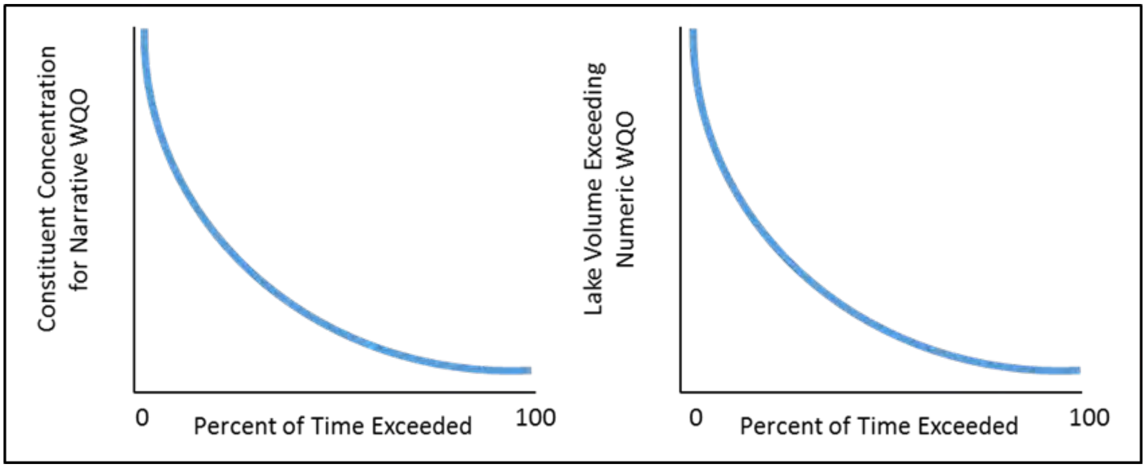

Figure 3-4. Numeric Targets Plotted as Constituent Concentration CDFs. Left - Narrative WQOs, e.g., Algae; Right - CDFs of Lake Volume Meeting Numeric WQOs for DO and TDS

3.2.1.3 Estimation Methods

Source Assessment

The reference watershed approach shown in Figure 3-2 above begins with a source assessment for nutrient loads in runoff from a reference watershed. Section 4 presents the source assessment for the TMDL revision, including data analysis and modeling of nutrients in watershed runoff for current land use conditions. The same database and watershed model was used to estimate nutrient loads reaching the lake segments for a reference watershed. For example, the watershed model includes simulation of runoff and associated nutrient loading from the remaining 66 percent of the watershed that is currently undeveloped.

Linkage Analysis

The impact of reference nutrient loads within each lake segment is assessed using a dynamic lake water quality model (see Figure 3-2 above). This step serves as the linkage analysis when developing a TMDL using a reference watershed approach. In other words, the linkage analysis estimates the water quality response of the lake segments to predetermined allowable external nutrient loads estimated for a reference watershed. Conversely, TMDLs that use a stressor-response approach use the linkage analysis to determine the allowable external nutrient load that can be delivered to the receiving waterbody to yield stressor concentrations that would not impair water quality standards.

Numeric Target Setting

The results of the linkage analysis are interpreted to develop TMDL numeric targets that account appropriately for spatial and temporal variability in water quality under a reference watershed condition. Different expressions of TMDL numeric targets are used depending upon whether the Basin Plan includes a narrative or numeric water quality objective. Lake Elsinore and Canyon Lake numeric targets associated with narrative Basin Plan objectives include the following:

- *Algae* - The linkage analysis employs a dynamic lake water quality model that assesses temporal variability of algae (measured as chlorophyll-a concentration) that may result from reference watershed nutrient load inputs. Laterally averaged chlorophyll-a concentrations for each lake segment from the top one meter of the water column are used to characterize a reference watershed condition. Dynamic simulation results of chlorophyll-a data are plotted as CDFs to represent the TMDL numeric targets to prevent excessive algae.

Lake Elsinore and Canyon Lake numeric targets associated with numeric Basin Plan objectives include the following:

- *Dissolved Oxygen* - For the TMDL revision, the TMDL numeric target will be expressed as a volume of lake expected to have dissolved oxygen concentrations within the thresholds required to support the WARM use under a reference watershed condition. Lake water quality, including dissolved oxygen concentrations in a reference condition, is dynamic, and the volume of the lake that would support WARM use varies temporally. This variability is accounted for by employing a dynamic lake water quality model to generate continuous simulation results reported as total lake volume with dissolved oxygen greater than 5 mg/L. These model results are converted to a CDF to serve as the numeric target. The resulting targets would represent conditions that may have occurred naturally, even if those conditions potentially result in periodic stress to fish populations from low dissolved oxygen.

- *Ammonia* - As described above, the fraction of total ammonia that is toxic is dependent upon pH and water temperature. It is not possible to calculate the toxicity of ammonia for all volume elements at a daily time-step, using the lake water quality models developed in the linkage analysis. Moreover, it would be infeasible for future monitoring to assess whether ammonia toxicity is at levels that would naturally occur at a comparable spatial scale. Instead, development of a TMDL numeric target was simplified to depth average concentrations of total ammonia-N, to be evaluated at compliance monitoring sites (see Section 8 on Monitoring Requirements). The technical basis for this approach is as follows: (1) total ammonia is controlled by the same nutrient cycling mechanisms that must be addressed to return total in-lake nutrient mass, algae, and dissolved oxygen to reference levels; (2) pH is expected to be returned to reference levels with control of algal productivity; and (3) water temperature is not impacted by development in the watershed and current levels are assumed to remain unchanged as a result of human development in the future. These assumptions will be evaluated in the future through implementation of a monitoring program.

In-lake nutrient concentrations for TN or total TP were not included as causal numeric targets in the revised TMDL. There are multiple combinations of these two nutrients that would effectively limit algal productivity to cause a return to reference levels for beneficial use impairment indicators (algae, DO, ammonia) higher in the hierarchy. Thus, in-lake nutrients will be evaluated in the implementation section. For example, one implementation alternative involves reduction of TP below reference levels to ensure it is the growth limiting nutrient and to achieve reference conditions for chlorophyll-*a* with or without returning total nitrogen to reference levels.

3.2.2 Characterization of Reference Conditions

Characteristics that define the reference watershed condition and serve as model inputs and assumptions include hydrology, water quality, and the physical structure of each lake segment. The following sections describe data and assumptions that represent a hypothetical reference watershed state for the drainage areas to Canyon Lake and Lake Elsinore. This condition provides inputs and boundary conditions for the linkage analysis to develop a continuous simulation of lake water quality that serves as the basis for determining TMDL numeric targets.

3.2.2.1 Lake Condition

Both Lake Elsinore and Canyon Lake look different than they would have under natural pre-development conditions. The existing physical condition of Canyon Lake and Lake Elsinore is an element of the reference watershed approach. Relevant assumptions for each lake include:

- Lake Elsinore - Projects to change the physical condition of the lake were implemented by LEMP in the early 1990s (see additional details in Section 2.2.2.3). The resulting physical changes to Lake Elsinore are irreversible and therefore included in the reference condition. These changes included: (a) Construction of a levee (1989-1990) to separate the main lake from the back basin, reducing the lake surface area from about 6,000 to 3,000 acres to prevent significant evaporative losses and improve water quality (**Figure 3-5**); and (b) Lowering the lake outlet channel (1993-1995) to increase outflow to downstream Temescal Creek to provide flood protection when the lake level exceeds an elevation of 1,255 ft.

- Canyon Lake did not exist prior to the construction of Railroad Canyon Dam, which was completed in 1929. This modification to the watershed is irreversible; accordingly, the reference condition assumes the existence of Railroad Canyon Dam.

Figure 3-5. Comparison of Current Lake Elsinore Hydrography with Approximate Pre-LEMP Hydrography (shapefile from NHD)

3.2.2.2 Watershed Hydrology

The runoff response from rainfall over a reference watershed is different than a developed watershed. Development increases impervious or compacted surfaces, which reduces attenuation by infiltration over undisturbed pervious areas. Surface conveyance features such as ditches and gutters serve to concentrate runoff for more efficient delivery to larger downstream flood control facilities. This also reduces infiltration of rainfall into watershed soils and increases the peak runoff from storm events. Conversely, runoff downstream of a reference watershed is characterized by less flashy hydrographs and lower total volume. Thus, use of continuous USGS flow gauge data from key inflows to Lake Elsinore and Canyon Lake over recent history (following 1916) is not appropriate for developing a reference watershed scenario given the extent of development that has occurred over this time frame. Estimates of runoff inflows from a hypothetical reference watershed to Lake Elsinore and Canyon Lake are presented in the following sections.

Lake Elsinore

The portion of the drainage area to Lake Elsinore that is downstream of Canyon Lake (~10 percent of the total watershed area) is referred to as the 'local Lake Elsinore' watershed. Runoff volume for a reference condition in the local watershed is estimated by removing imperviousness in the watershed model resulting in a reduction of inflow volume from 2,210 AFY to 1,450 AFY.

Estimation of runoff volume that may reach Lake Elsinore from Canyon Lake overflows in a hypothetical reference watershed condition could not be estimated using a watershed runoff model, because of the complexities of storage and overflow dynamics in Canyon Lake. An alternative approach was developed that compares average annual runoff in overflows from Canyon Lake prior to 1972, when the region was minimally developed with low impervious acreage, with years following 1972, when development increased throughout the San Jacinto River watershed upstream of Canyon Lake.

The average annual rainfall of 11.7 in/yr at the Lake Elsinore meteorological station from the first half of Canyon Lake's existence (1929-1972) is equivalent to the latter half from 1973-2016. Review of USGS gauge data from the San Jacinto River near Elsinore (Station 11070500) shows that overflows to Lake Elsinore from the first half of Canyon Lake's lifespan were ~40 percent lower than runoff from the second half (**Figure 3-6**). The difference between these periods may be attributed to development in the watershed; however, a diminishing storage capacity because of sedimentation within Canyon Lake may also play a role in rising overflow volumes for periods with functionally equivalent rainfall depths.

Assuming a constant rate of watershed development, a steady annual runoff increase of 0.5 percent would have accrued over time since the construction of Railroad Canyon Dam. Thus, for the reference watershed condition, annual runoff overflows from Canyon Lake to Lake Elsinore are estimated by reducing the downstream USGS gauged flow ($Q_{measured}$) as a function of the age of Canyon Lake (R_{age}), as follows;

$$Q_{reference} = Q_{measured} * (1 - 0.005 * R_{age})$$

The measured annual runoff volumes and estimated reference condition for Canyon Lake overflows are summarized in **Table 3-2**. Combined with watershed model results for the local Lake Elsinore watershed with and without imperviousness gives an estimate of the total runoff volume inflow to Lake Elsinore for existing and reference watershed conditions (Table 3-2).

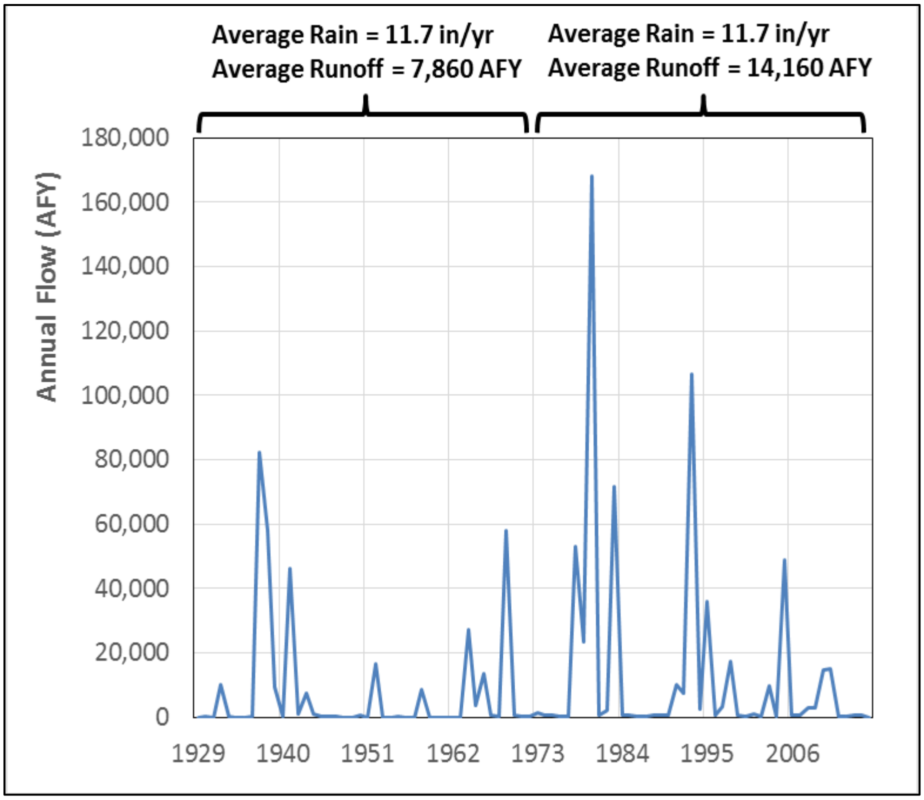

Figure 3-6. Annual Runoff from San Jacinto River near Elsinore (USGS 11070500) Showing Increases in Average Annual Runoff Before and After 1972 for Equivalent Average Annual Rainfall

Table 3-2. Estimated Average Annual Runoff for Existing and Reference Watershed Conditions to Lake Elsinore

Lake Segment	Condition	Local Watershed Runoff (AFY)	Canyon Lake Overflows (AFY)	Total Inflows to Lake Elsinore (AFY)
Lake Elsinore	Existing	2,210	10,980	13,190
	Reference	1,450	8,500	9,950

Canyon Lake

As presented in Section 4.1.3.2, a model for estimating runoff from subareas tributary to each lake segment was developed to support the source assessment for the TMDL. This model computes runoff as a function of rainfall and imperviousness of the upstream drainage area, as well as estimated retention of runoff within unlined channel bottoms. Model parameters were adjusted to fit long-term measured runoff volume. This same model was employed retrospectively, to predict the average annual runoff that may have reached each lake segment for a hypothetical reference watershed with no impervious area. Removal of impervious area reduced the estimated runoff inflows, as shown in **Table 3-3**.

Table 3-3. Estimated Average Annual Runoff for Existing and Reference Watershed Conditions to Canyon Lake

Lake Segment	Condition	Subarea Runoff (AFY)	Channel Recharge (AFY)	Inflows to Lake Segment (AFY)
Canyon Lake – Main Lake[1]	Existing	6,120	380	5,740
	Reference	4,380	510	3,870
Canyon Lake – East Bay	Existing	4,700	2,200[2]	2,490
	Reference	3,440	1,740	1,700

[1] Includes channel bottom recharge in both Perris Valley Channel and San Jacinto River

[2] Increase in channel recharge for existing condition relative to reference watershed is due to the storage impoundments created within Menifee Lakes golf course

In addition to removing impervious area, the reference watershed condition required an adjustment to estimate retention within Perris Valley Channel and Salt Creek (see Section 4.1.3.3 for detailed description), as follows:

- *Salt Creek* - Under current conditions, an estimated 800 AFY is captured, stored, and allowed to percolate beneath a series of water features at the Menifee Lakes golf course. Channel bottom recharge upstream and downstream of the golf course is estimated to recharge 1,400 AFY of runoff that would otherwise have been delivered to the East Bay of Canyon Lake. Thus, for current conditions, total estimates of recharge beneath Salt Creek is 2,200 AFY. In a reference watershed condition, the golf course impoundments of water upstream of Canyon Lake would not exist. Instead, the segment of Salt Creek that is within the current Menifee Lakes golf course boundary, would provide an additional 200 acres of natural channel bottom area for recharge during runoff events. The estimated total recharge beneath Salt Creek in a reference watershed condition is 1,740 AFY.

- *Perris Valley Channel* – Recharge within the existing unlined portion of Perris Valley Channel is estimated to be 250 AFY. In a reference watershed condition, there would no longer be any lined channels and the area available for channel bottom recharge would increase by approximately100 acres. This increase in unlined channel bottom results in an increase of 130 AFY for a total recharge of 380 AFY in the reference watershed condition.

- *San Jacinto River* – The San Jacinto River between Mystic Lake and Perris Valley Channel confluence is currently unlined and it is not likely to be significantly different than what would be expected for a reference watershed condition. Existing and reference condition models account for 130 AFY of channel bottom recharge in this segment of the San Jacinto River.

3.2.2.3 Nutrient Washoff

Nutrient concentrations representative of a reference watershed were estimated from water quality monitoring data collected from a site on the San Jacinto River at Cranston Guard Station. This site was added to the 2004 TMDL monitoring plan as a reference station. The 142 mi^2 watershed to this site is comprised of predominantly undeveloped forest or scrublands in the San Jacinto National Forest. The US Forest Service collected 54 samples from this reference site over the course of 11 wet weather events in 2003-2005, 2008, and 2010. The median concentrations of these samples were 0.32 mg/L TP and 0.92 mg/L TN. These median nutrient concentrations were applied to all runoff volume inflow to the lakes to estimate loads for a hypothetical reference watershed condition. Other monitoring programs in the San Jacinto River watershed have collected samples from sites downstream of mostly undeveloped lands: (a) LE/CL TMDL Task Force on the San Jacinto River at Ramona Expressway on January 21, 2010; (b) Post-fire sample collection by RCFC&WCD on Ortega Channel on February 28, 2014; and (c) WRCAC on Salt Creek on December 12, 2014. The range of nutrient concentrations from these sampling events was (a) TP, 1.0 – 13.0 mg/L; and (b) TN, 3.5 – 16.9 mg/L TN. These ranges exceed the median concentrations measured at Cranston Guard Station, thus the estimated value for a reference watershed could be considered conservative. It is important to note that this sampling represents expected water quality from an undeveloped watershed in the modern era and not a predevelopment condition. Other sources of nutrients may exist outside of the jurisdictional control of the TMDL, such as atmospheric deposition of nutrients that may be dominated by sources originating from outside of the watershed boundary.

3.2.2.4 Lake Water Quality Models

Water quality models provide an alternative means to estimate the response within the lakes for a hypothetical reference watershed condition. The Computational Aquatic Ecosystem Dynamics Model (CAEDYM) is a lake water quality model (Hipsey et al. 2006) developed to test management alternatives for Lake Elsinore and Canyon Lake (Anderson 2016a). This model is also used to develop the linkage analysis for this TMDL revision (see Section 5). With a reference watershed approach, the linkage analysis is used to estimate the long-term lake water quality that would be expected to have occurred in Lake Elsinore and Canyon Lake for a hypothetical scenario involving a reference upstream watershed, and without any of the existing in-lake nutrient management strategies.

For Lake Elsinore, water quality modeling to support the development of TMDL numeric targets involved a very long simulation period from 1916-2015. This was imperative to capture the full range of dynamic water quality conditions that naturally occur in Lake Elsinore, as presented in the Problem Statement. CAEDYM is an aquatic ecosystem model and is coupled with a hydrodynamic model to facilitate boundary conditions and simulation of spatially varying mechanisms. For Lake Elsinore, a simple 1-D hydrodynamic model, the Dynamics Reservoir Simulation Model (DYRESM), was used for development of laterally averaged vertical profiles. This is appropriate for Lake Elsinore because it has a fairly uniform morphology. For Canyon Lake, there is substantial variability in the lake basin morphology and water quality processes, which required the development of a 3-D hydrodynamic model, the Estuary and Lake Computer Model (ELCOM). These tools are described in Section 5 on Linkage Analysis.

3.3 TMDL Numeric Targets

The data used to establish the numeric targets for each of these constituents is illustrated in four ways: (a) time history or series of the data which illustrates how the concentration changes over time; (b) histogram that provides the frequency of occurrence of concentrations as binned; (c) box and whiskers, which illustrates the median value and range of observations; and (d) the CDF which shows the probability of a particular concentration being exceeded over time. The CDF is the numeric water quality target. To evaluate compliance with the numeric target CDF, a CDF of post-implementation long-term monitoring results should result in a curve that is equal to or better than the numeric target CDF.

3.3.1 Lake Elsinore

DYRESM-CAEDYM model results of water quality for the reference watershed scenario for the period from 1916-2014 serve as the basis for setting numeric targets for chlorophyll-*a*, DO, and ammonia-N in Lake Elsinore. The CDF numeric targets and associated time history, histogram, and box and whiskers for chlorophyll-*a*, DO, and ammonia-N in Lake Elsinore are as follows:

- *Chlorophyll-a*: Epilimnion average of daily model results plotted for the reference condition (**Figure 3-7**).
- *Dissolved Oxygen*: The fraction of the total volume of Lake Elsinore with daily average DO greater than 5 mg/L plotted for the reference condition (**Figure 3-8**).
- *Ammonia-N*: Water column depth average of daily model results plotted for the reference watershed condition (**Figure 3-9**).

3.3.2 Canyon Lake

ELCOM-CAEDYM model results of water quality for the reference watershed scenario for the period from 2000-2016 serve as the basis for setting numeric targets for chlorophyll-*a*, DO, and ammonia-N in Canyon Lake Main Lake and East Bay. The CDF numeric targets and associated time history, histogram, and box and whiskers for chlorophyll-*a*, DO, and ammonia-N in Canyon Lake (Main Lake and East Bay) are as follows:

3.3.2.1 Canyon Lake – Main Lake

- *Chlorophyll-a*: Epilimnion average of daily model results for Canyon Lake - Main Lake for the reference condition (**Figure 3-10**).
- *Dissolved Oxygen*: The fraction of the total volume of Canyon Lake – Main Lake with daily average DO greater than 5 mg/L plotted for the reference condition (**Figure 3-11**).
- *Ammonia-N*: Water column depth average of daily model results for Canyon Lake – Main Lake plotted for the reference watershed condition (**Figure 3-12)**.

3.3.2.2 Canyon Lake – East Bay

- *Chlorophyll-a*: Epilimnion average of daily model results for Canyon Lake – East Bay for the reference condition (**Figure 3-13**).
- *Dissolved Oxygen*: The fraction of the total volume of Canyon Lake – East Bay with daily average DO greater than 5 mg/L plotted for the reference condition (**Figure 3-14**).
- *Ammonia-N:* Water column depth average of daily model results for Canyon Lake – East Bay plotted for the reference watershed condition (**Figure 3-15**).

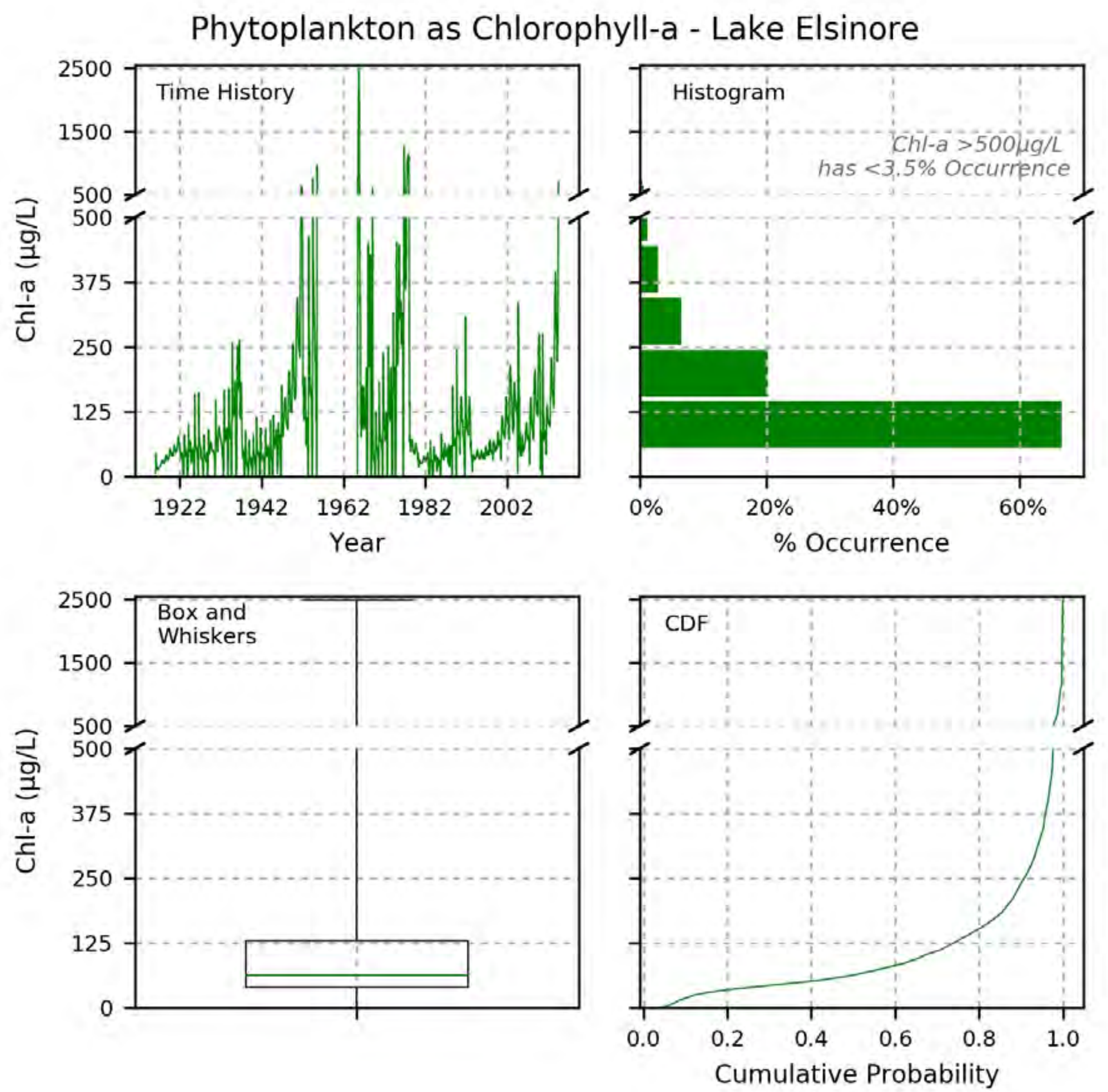

Figure 3-7. Chlorophyll-*a* Results for Lake Elsinore: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

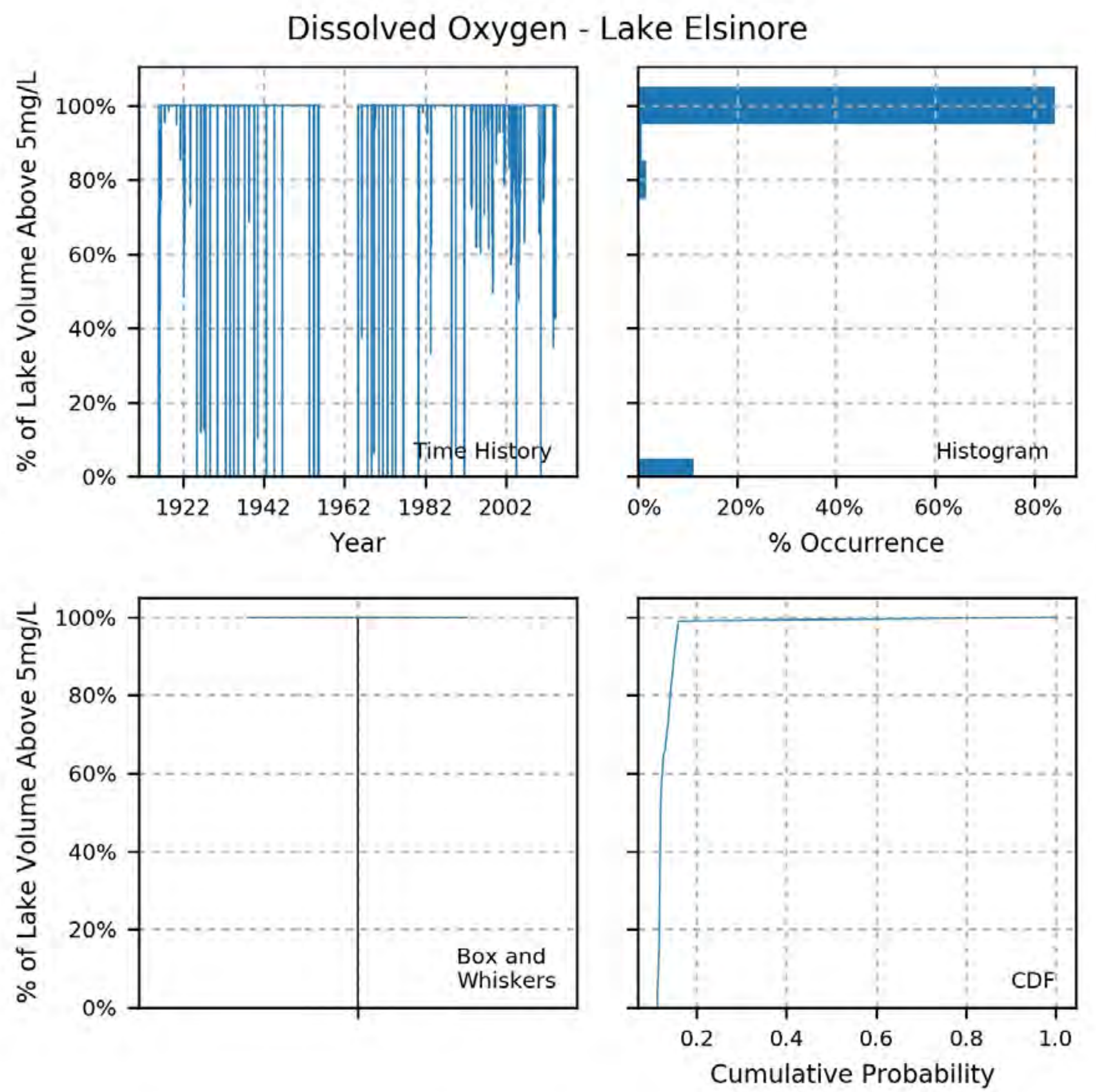

Figure 3-8. Dissolved Oxygen Results for Lake Elsinore: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

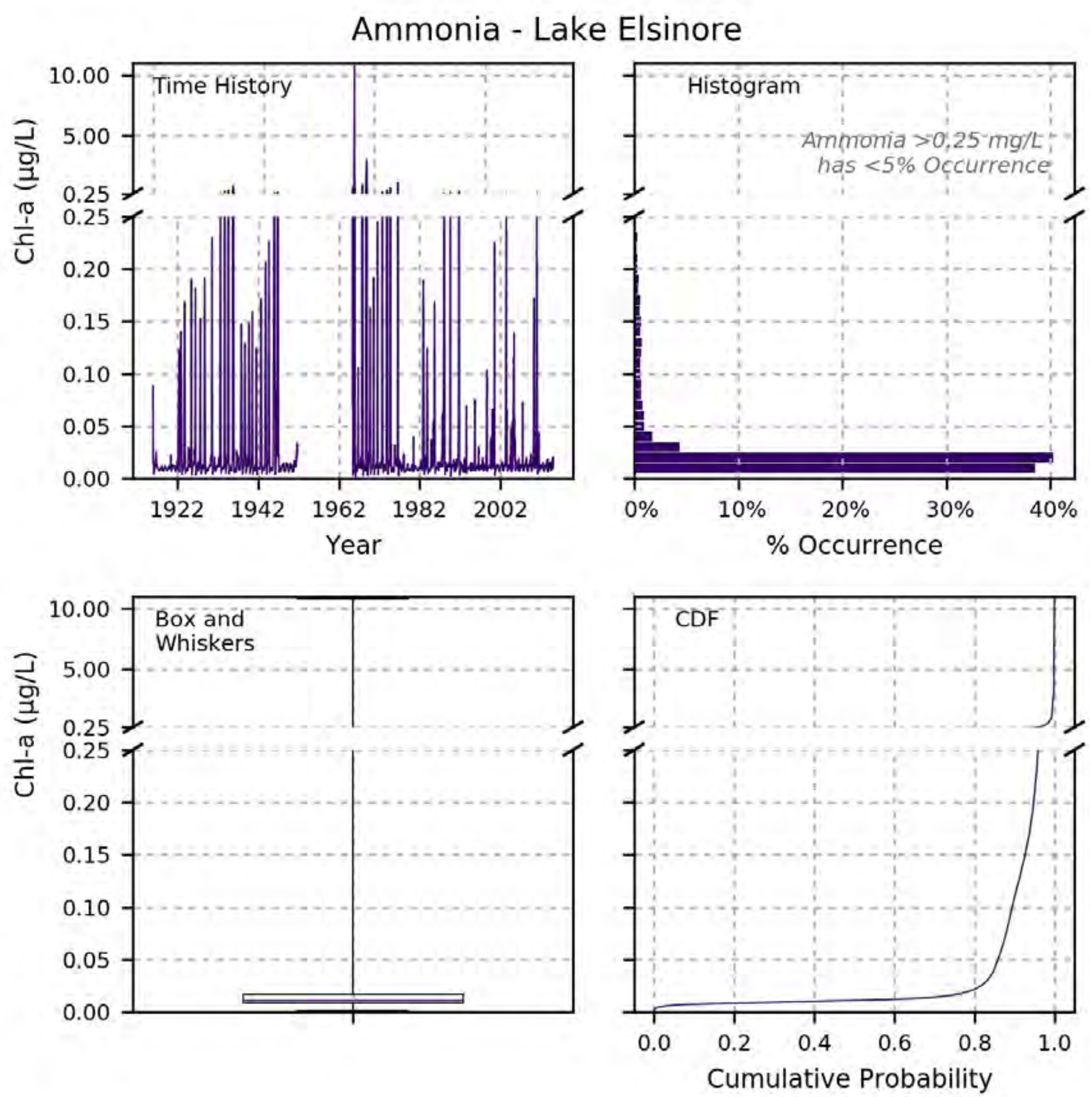

Figure 3-9. Ammonia-N Results for Lake Elsinore: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

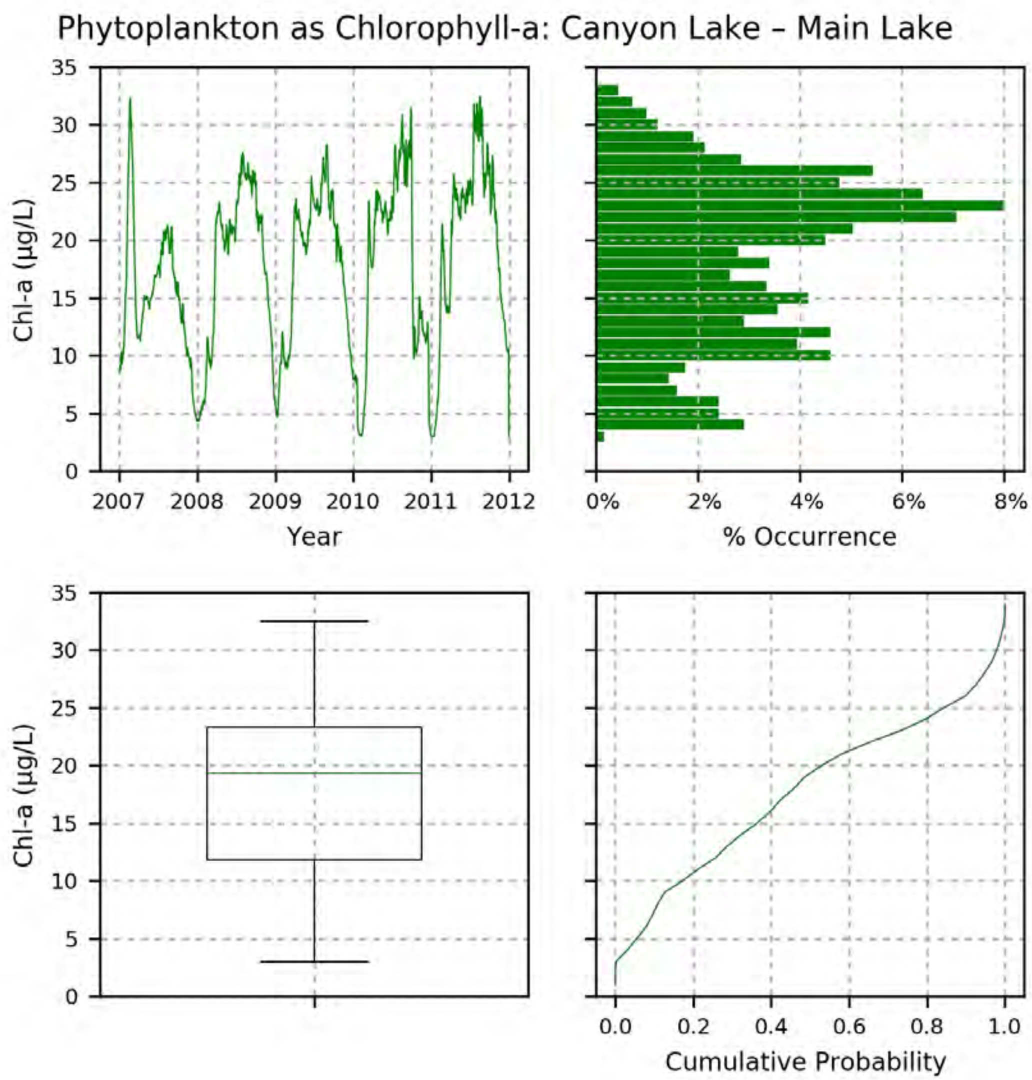

Figure 3-10. Chlorophyll-*a* Results for Canyon Lake – Main Lake: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

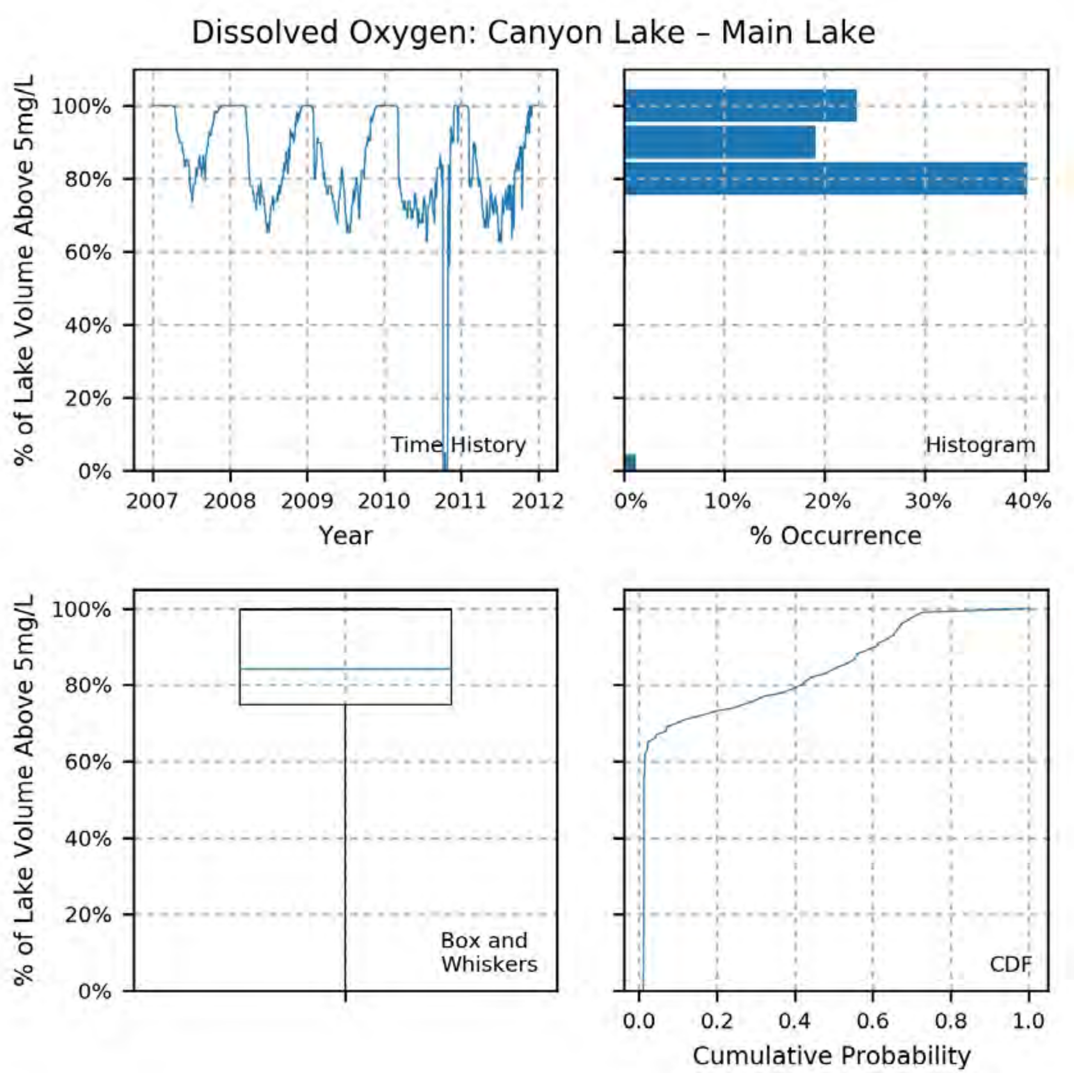

Figure 3-11. Dissolved Oxygen Results for Canyon Lake – Main Lake: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

PLACEHOLDER

Figure 3-12. Ammonia-N Results for Canyon Lake – Main Lake: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF ***(Note: these results are still in development)***

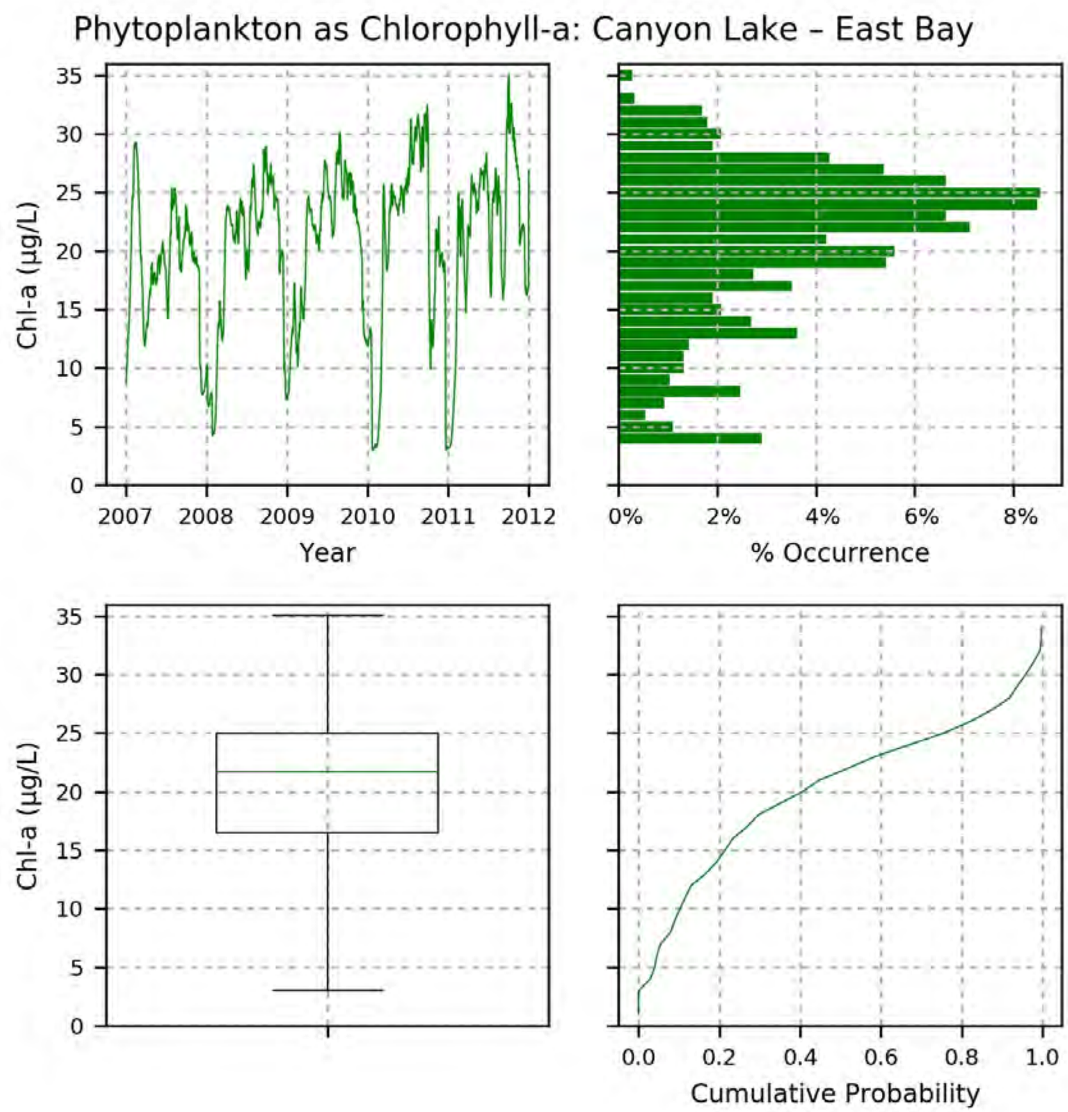

Figure 3-13. Chlorophyll-*a* Results for Canyon Lake – East Bay: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

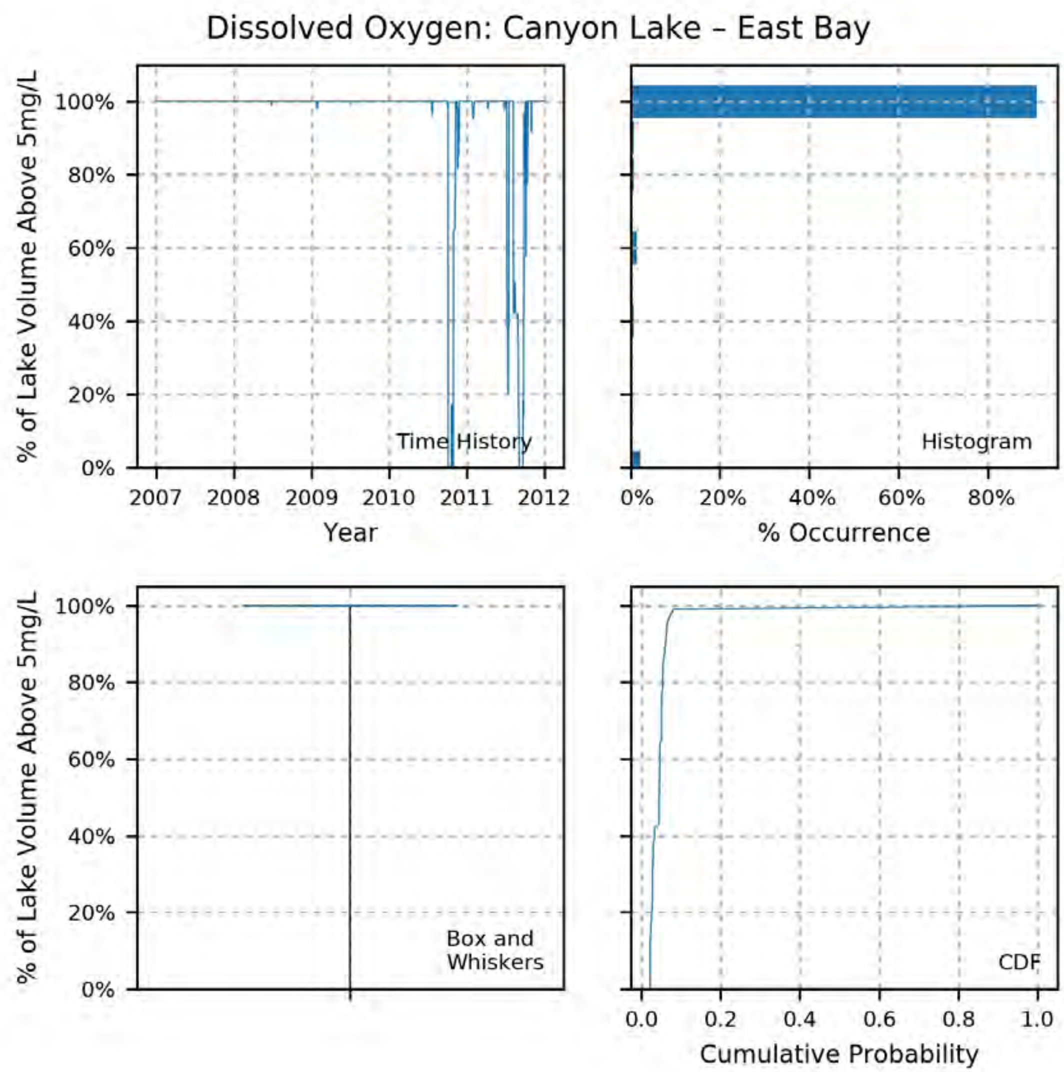

Figure 3-14. Dissolved Oxygen Results for Canyon Lake – East Bay: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF

PLACEHOLDER

Figure 3-15. Ammonia-N Results for Canyon Lake – East Bay: (a) Time History; (b) Histogram; (c) Box and Whiskers, and (d) the Numeric Target CDF ***(Note: these results are still in development)***

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Section 4

Source Assessment

Sources of nutrients to Lake Elsinore and Canyon Lake are characterized in this section. These lakes receive nutrients via two key external delivery mechanisms, watershed runoff and supplemental water deliveries, and internal sediment sources within the lakes. This section describes each of these key sources of nutrients:

- *Watershed Runoff (Section 4.1)* – Nutrients washed off from land areas in the watersheds to each lake segment; these land areas represent unique combinations of land use, jurisdiction, and subwatershed characteristics.
- *Supplemental Water (Section 4.2)* – Nutrients contained within supplemental water inputs to each lake; most notable being the addition of reclaimed water to Lake Elsinore by EVMWD.
- *Internal Sources (Section 4.3)* – Internal sources of nutrients within each lake. Mechanisms that influence the significance of these sources include physical (resuspension by wind or propeller driven turbulence or bioturbation), biological (diagenesis of externally loaded organic matter or decaying phytoplankton within the lake bottom), and chemical (diffusive flux from bottom sediments to water column). Deposition of nutrients from atmosphere directly on the surfaces of Lake Elsinore and Canyon Lake is also described in this section.

4.1 Watershed Runoff

Flow gauges are operated by the USGS that continuously record discharge rates at the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and from San Jacinto River inflows (mostly from Canyon Lake overflow)[1] to Lake Elsinore. This data characterizes the annual volumes of runoff that reached each lake segment over the period of record. Summary statistics for each of these gauges is presented in **Table 4-1**.

Table 4-1. Summary Data for USGS Flow Gauges at Inflows to Lake Elsinore and Canyon Lake

Station	Upstream Drainage Area (acres)	Period of Record	Average Annual Runoff (AFY)	Historical Peak Discharge (cfs)
San Jacinto River at Goetz Road (11070365)	358,400	2000 - 2016	5,900	3,470
Salt Creek at Murrieta Road (11070465)	74,200	1983 – 1984; 2000 - 2016	2,300	2,550
San Jacinto River near Elsinore (11070500)	462,700	1916 - 2016	11,400	16,000

[1] USGS Gauge 11070500, San Jacinto River near Elsinore, is approximately 2 miles downstream of the Canyon Lake spillway and therefore includes for runoff from a small subarea (~7,000 acres) between the two lakes in addition to Canyon Lake overflows. Thus, in years when no Canyon Lake overflows occurred, there is still runoff recorded at this gauge from the San Jacinto River into Lake Elsinore

Continuous flow data from these USGS gauges for the period of 2001 through 2016 was used to calibrate a watershed runoff model for the drainage areas to the lake segments (described in Section 4.1.3 below). **Figure 4-1** shows runoff inflows to Canyon Lake from the San Jacinto River and Salt Creek and to Lake Elsinore from San Jacinto River. Also shown in Figure 4-1 is an estimate of runoff volume retained within Canyon Lake during each wet season. Volume retention was estimated as the difference between the summed annual volume between USGS gauges upstream and downstream of Canyon Lake for years when Canyon Lake elevation data exceeded its spill water elevation of 1381.76 ft. (2003-2005, 2008, and 2010-2011), indicating that overflows occurred. In dry years when the lake did not reach its spill elevation, outflow was assumed to be zero (2002, 2006, 2007, 2009, and 2012-2014) equating to complete volume retention.

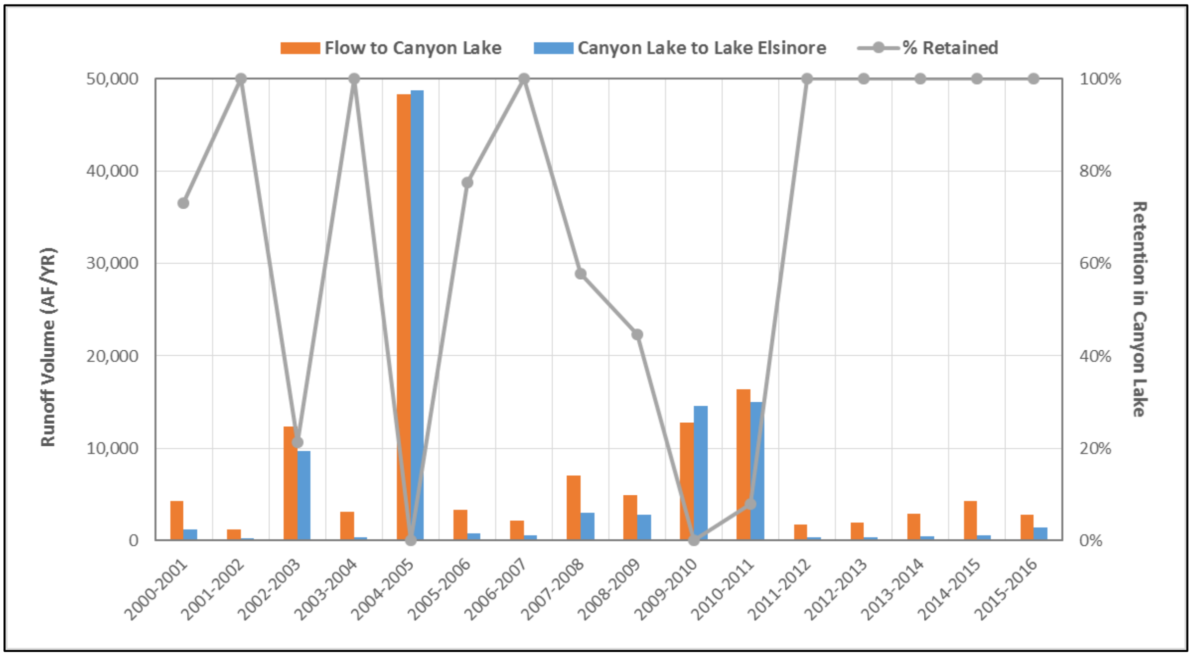

Figure 4-1. Annual Runoff Volume into Canyon Lake and Overflow to Lake Elsinore

4.1.1 Model Selection

The most significant external source of nutrients to the lakes is from rainfall driven runoff over watershed lands. To quantify the existing load of nutrients from watershed areas to the lakes, it is important to estimate the rainfall response for runoff volume (hydrology) and associated nutrient concentration (water quality). USGS gauge stations and Task Force watershed monitoring sites provide sound, representative measurements of nutrient loads, or mass emissions, delivered to Canyon Lake and in overflows to Lake Elsinore. Given a robust set of mass emission data at key inflows to the lake segments, a model is not needed for the purpose of estimation of downstream loads in watershed runoff for current conditions. Instead, downstream mass emission data allow for reasonable parameter adjustments to fit a model of runoff volume and quality to measured data.

This source assessment does require the development of a watershed model for other important functions. The primary objective for the watershed model that was developed to support the TMDL revision is to evaluate the origin of the nutrient loads across the large upstream drainage areas. The relative contribution to downstream loads from sources is used in setting allocations and determining load reductions needed from individual sources to meet those allocations. Also, the watershed model will be useful in implementation as it allows for detailed accounting of jurisdictional loadings to each lake segment.

There are different options for modeling watershed runoff volume and quality of varying complexity, which commonly determines the required levels of expertise needed for development, calibration, and management scenario evaluation. The Loading Simulation Program in C+ (LSPC) that was used for the 2004 TMDL and again in the 2010 watershed model update represents a more complex watershed model. This model involves a deterministic simulation of rainfall and runoff including complex soil hydrology processes that govern runoff generated from pervious land areas. For water quality, nutrients are simulated by buildup or accumulation of nutrients during dry periods and washoff during rain events. Continuous simulation at the daily time-step allows for variable buildup periods between events and thus variable accumulation of pollutant available for washoff. Also, the portion of accumulated nutrients that washes off during a rainfall event to downstream waters is a function of runoff depth.

For the source assessment for Lake Elsinore and Canyon Lake watersheds, the existing LSPC tool or a potential new complex dynamic rainfall-runoff and buildup / washoff water quality model was not updated / developed for the following reasons:

- Downstream lake segments are characterized as having limited flushing and significant internal loading of bioavailable nutrients, therefore variability between events does not significantly impact the pool of bioavailable nutrients for algae. Eutrophication occurs at seasonal timescales in Canyon Lake and it is the total wet season retained nutrient load that controls the magnitude and duration of early spring algae blooms. For Lake Elsinore, bioavailable nutrients are predominantly from internal sources (see Section 4.3.1 below) and lake water quality is frequently controlled by food web dynamics with multi-decadal trends, thus variability in nutrient loads between individual storm events exerts negligible differences.

- Review of watershed monitoring data show nutrient concentrations are not related to inter-event period (number of dry days prior to an event) nor runoff volume. In fact, dynamic calibration plots presented in the TMDL and watershed model update show simulation results that have comparable central tendencies and ranges to measured data, but significant error when comparing discrete events. Thus, other processes influence watershed nutrient loads that may not be characterized by buildup / washoff dynamics.

A static model of long-term average annual runoff volume and nutrient loads, EPA's Pollutant Loading Estimator tool (PLOAD) (EPA 2001), was selected to support this TMDL revision. PLOAD is a component of EPA's TMDL development framework, Better Assessment Science Integrating Point and Non-Point Sources (BASINS) (EPA 2017). For this TMDL revision, PLOAD was developed outside of the BASINS environmental in a Microsoft Excel spreadsheet to allow for greater flexibility and transferability to potential end users.

The use of a static model with empirically defined parameters is scientifically defensible for this watershed because of the limited flushing in the receiving waters, long-term timescales over which eutrophication occurs, apparent complexity of watershed runoff and nutrient loading that may be infeasible to represent in any EPA approved, dynamic, deterministic modeling tools, and robustness of mass emission data available for all major inflow to each lake segment.

4.1.2 Establishment of Model Subareas

The first step in the watershed runoff nutrient source analysis is to define the spatial discretization for simulation of rainfall driven runoff and associated washoff of nutrients. The selected modeling approach, comparable to PLOAD, is a spatially lumped parameter model. This means that commonality of key parameters, not geography, is used to define distinct subareas. Watershed runoff simulations were developed for land areas with common land use, jurisdiction, and subwatershed zone, referred to as model subareas. **Figure 4-2** shows the geographic distribution of these three defining attributes for the entire watershed to Lake Elsinore and Canyon Lake (a plot size version of this figure is attached in electronic form).

Hydrology and water quality modeling is performed separately for each model subarea. **Figure 4-3** shows the interconnectivity of model subareas and conveyance within receiving waters. Respectively, the green and red boxes along the outer perimeter represent agricultural and urban jurisdictional groups within each subwatershed zone. Within each of these watershed elements of this schematic, one or more land uses may exist. In total, there are over 500 distinct model subareas developed to support source assessment and development of allocations. These model subareas are not geographically contiguous, but rather they are spatially lumped portions of drainage area with common parameter sets. For example, a single model subarea exists to represent all commercial/industrial land area within the City of Moreno Valley within subwatershed zone 5. Appendix B provides a tabular summary of each model subarea and reports important characteristics used for parameterizing the watershed runoff model.

The schematic also shows how runoff is routed from model subareas to receiving waters. Subwatershed zone delineations were developed based on this routing, as indicated in each of the blue receiving water elements. Some model subareas drain directly to one of the three TMDL lake segments; Canyon Lake Main Lake and East Bay, and Lake Elsinore. Other model subareas are routed through the San Jacinto River, Perris Valley Channel, or Salt Creek prior to reaching a TMDL lake segment. The position of Mystic Lake as an important impoundment to be accounted in the source assessment is also shown in the schematic. Model subareas draining to Mystic Lake are treated differently as discussed in Section 4.1.3.4 below.

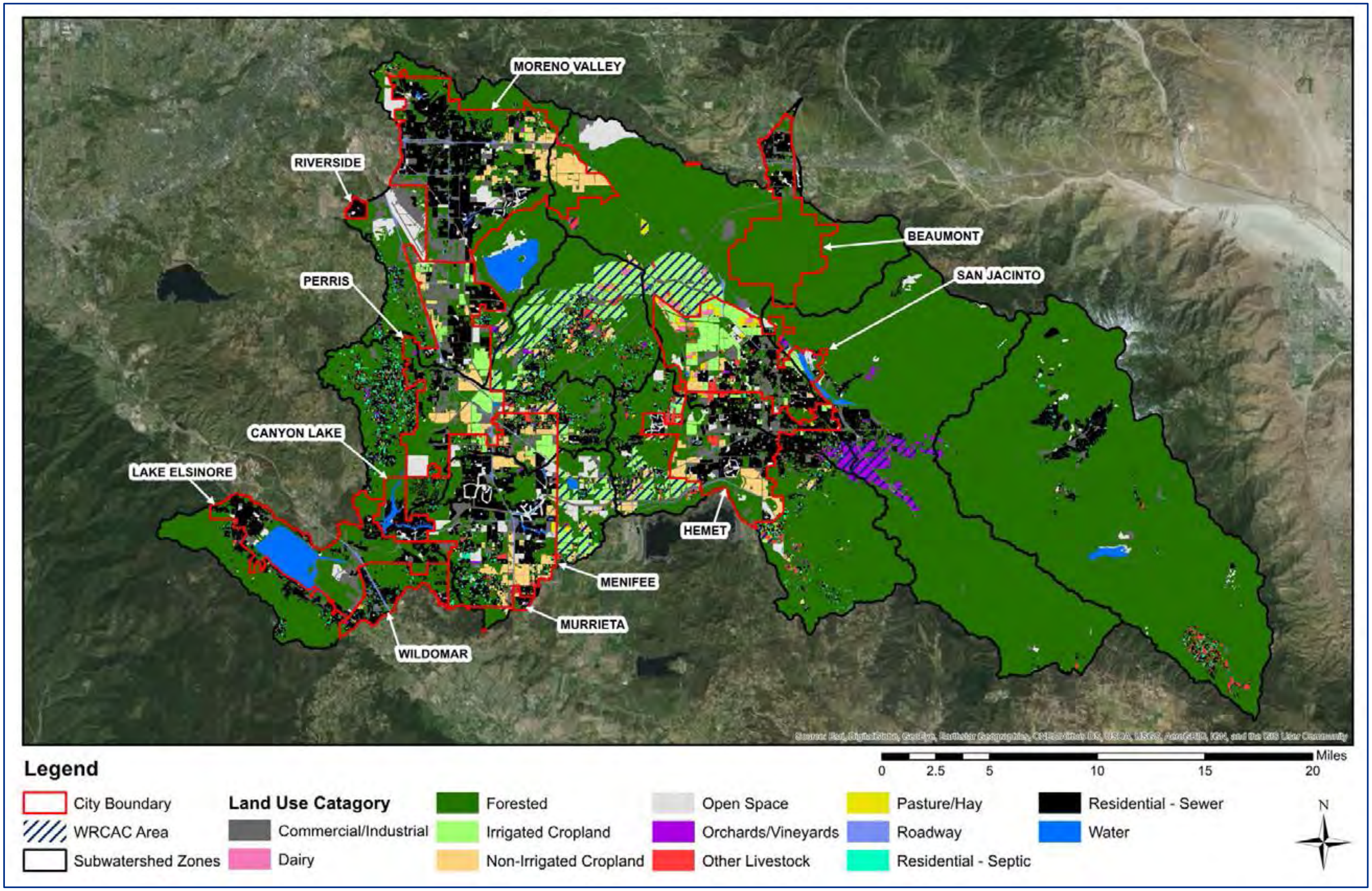

Figure 4-2. Map of Subwatershed Zones, Jurisdictions, and Land Use for Development of Watershed Model Subareas

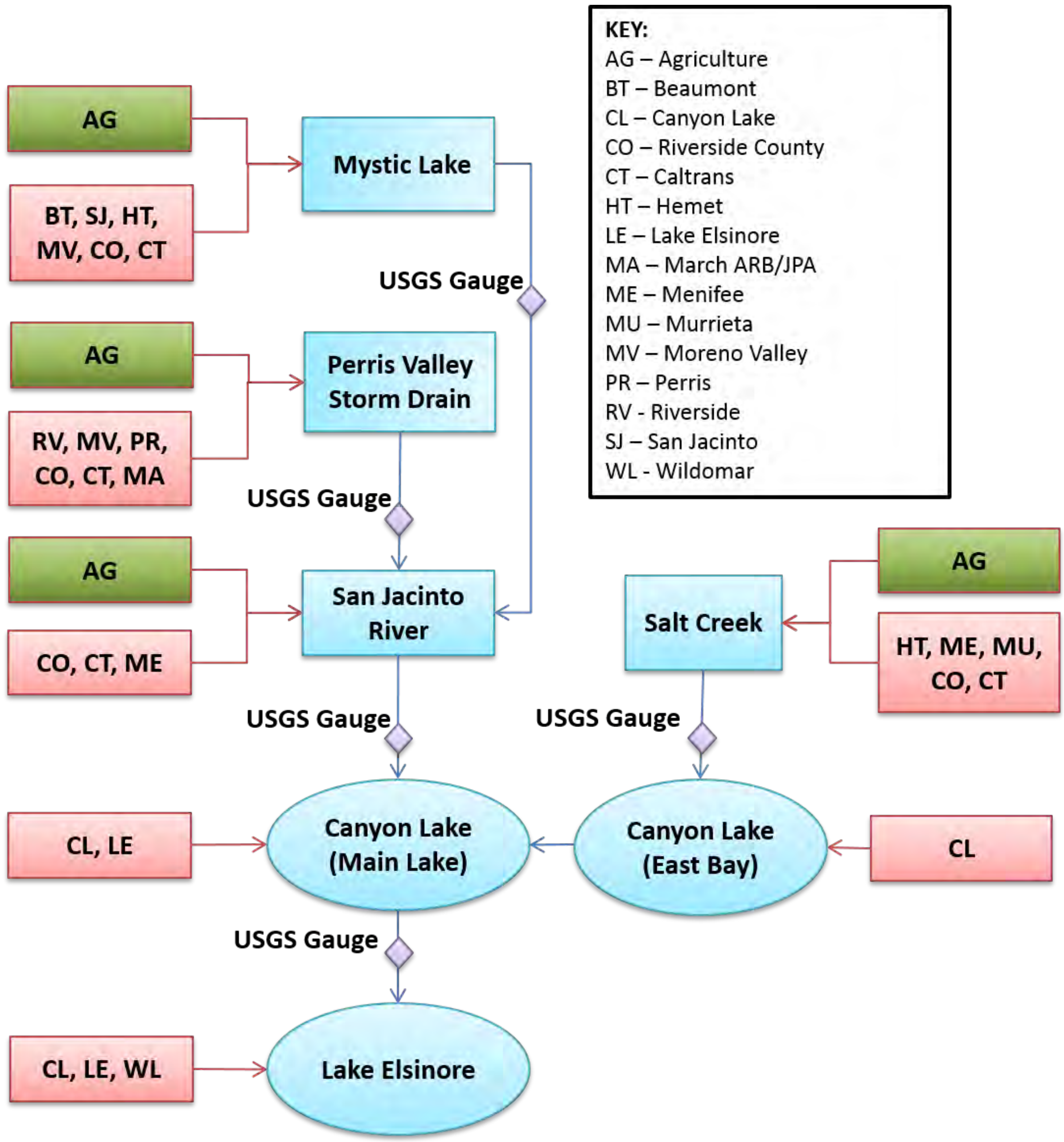

Figure 4-3. Schematic of External Runoff Loading Pathways for Watershed Runoff Sources and Receiving Waters that Retain, Convey, and Cycle Nutrients

For this TMDL revision, several subwatershed boundary revisions were incorporated to update the boundaries used in the 2004 TMDL and TMDL model update in 2010 (**Figure 4-4**). Hatched areas in Figure 4-4 show where boundaries are revised and labels indicate the change from the 2004 TMDL to this TMDL revision. The revisions are summarized below:

- *Mystic Lake tributary area correction* – The drainage area to Mystic Lake, subwatershed zones 7, 8, and 9 in the 2004 TMDL, was re-evaluated by WRCAC to support the TMDL revision. An elevation map of the region combined with knowledge of surface features was used to develop a new, technically correct delineation of the area tributary to Mystic Lake (CDM Smith 2013b). Revisions are shown in green (drainage area taken out of Zone 7) or purple (drainage area put into Zone 7) hatching in Figure 4-4. The revisions included removal of a large drainage area near the bend of the San Jacinto River that is not tributary to Mystic Lake; instead this area contributes runoff to Canyon Lake in most hydrologic years. Also, modification to the boundary near North Warren Rd in the vicinity of the Colorado River aqueduct. In total, the changes amount to a net reduction of ~5,000 drainage acres to subwatershed zone 7, and a net increase in the same amount for subwatersheds downstream of Mystic Lake.

- *Local Canyon Lake tributary area to East Bay / Main Lake* – Subwatershed zones 2 and 3 in the 2004 TMDL and 2010 watershed model update represent the downstream portions of San Jacinto River and Salt Creek, respectively. However, downstream of the USGS gauges / watershed monitoring stations, the boundary between these subwatershed zones does not properly delineate areas draining directly to the Main Lake of Canyon Lake (from the San Jacinto River) versus draining directly to the East Bay of Canyon Lake (from Salt Creek). The blue hatched area in Figure 4-4 indicate the areas that were revised to properly reflect drainage to East Bay.

4.1.3 Hydrology

A static model was developed within a Microsoft Excel spreadsheet to simulate the volume of average annual runoff in model subareas as a result of rainfall, presented in the equation below:

$$Q_{annual} = Precip_{annual} * RC$$

where,
Q_{annual} = annual flow volume
$Precip_{annual}$ = average annual rainfall depth
RC = runoff coefficient

This hydrologic method is used in an EPA approved public domain watershed model PLOAD. The following sections describe the methods used to develop the hydrologic model for the watersheds that drain to Lake Elsinore and Canyon Lake.

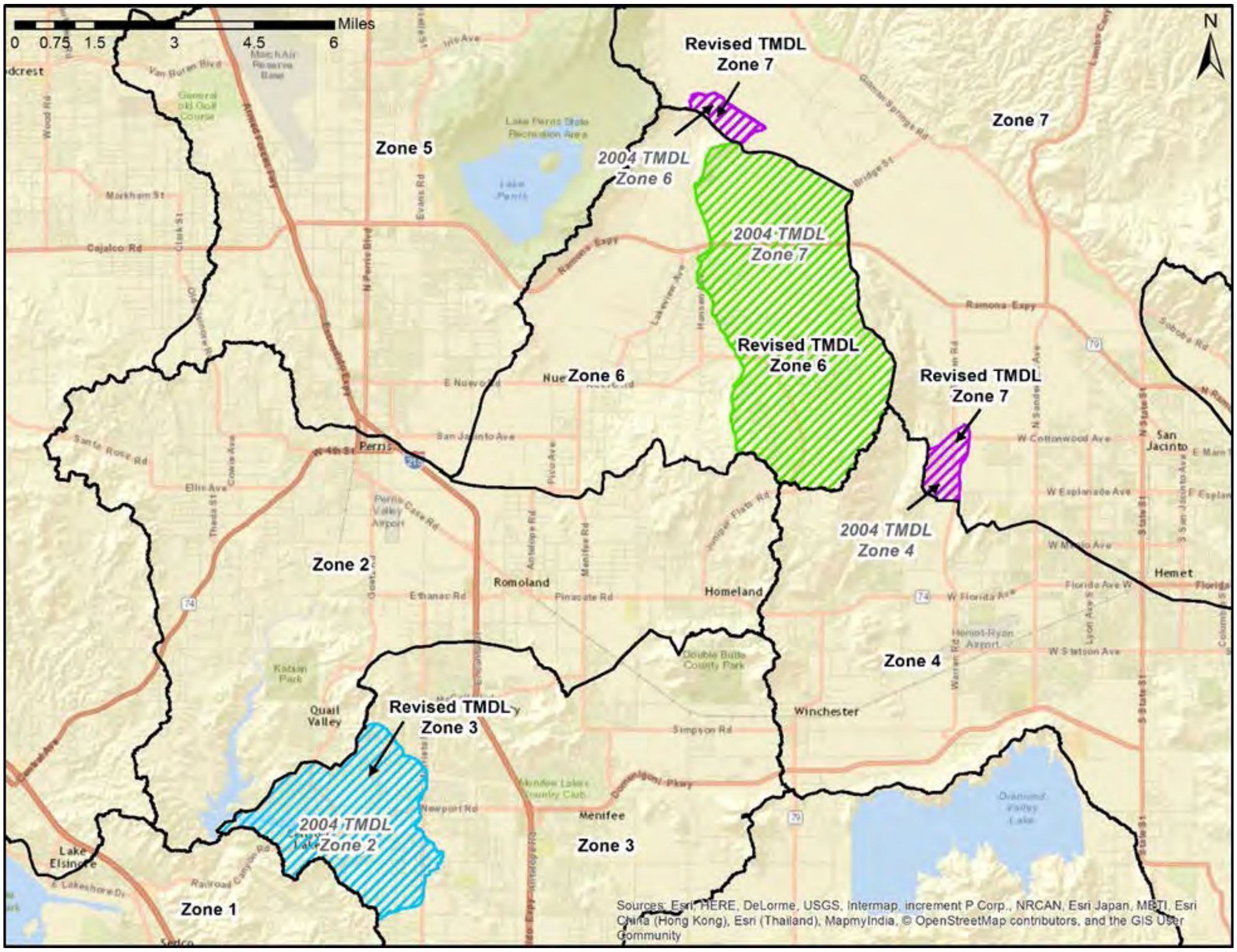

Figure 4-4. Map of Revisions to Subwatershed Zonal Boundaries

4.1.3.1 Precipitation

Precipitation input data for the model was extracted from RCFCWCD rainfall stations distributed throughout the watershed (**Figure 4-5**). **Table 4-2** presents long-term average annual rainfall from these stations, which are assigned to represent specific subwatershed zones. For subareas above Mystic Lake (i.e., subwatershed zones 7-9), rainfall from the San Jacinto Station 186 was used to represent drainage areas with elevations below 3,000 ft and rainfall from the Idyllwild Station 90 was used to represent areas with elevation greater than 3,000 ft. Table 4-2 provides average annual rainfall for different periods representing the full period of record at each station for comparison with the selected subsets for model calibration and allocation setting. The period used for model calibration (2000-2015) coincides with the period of record for USGS flow gauges at the two primary inflows to Canyon Lake; San Jacinto River at Goetz Road (USGS Station 11070365) and Salt Creek at Murrieta Road (USGS Station 11070465). The allocation setting period of 1948-2015 was selected as the period with continuous rainfall records with no missing data from all of the stations used in the watershed model. The average annual rainfall from this period is very similar to the average for the full period of record for each station.

CDM Smith

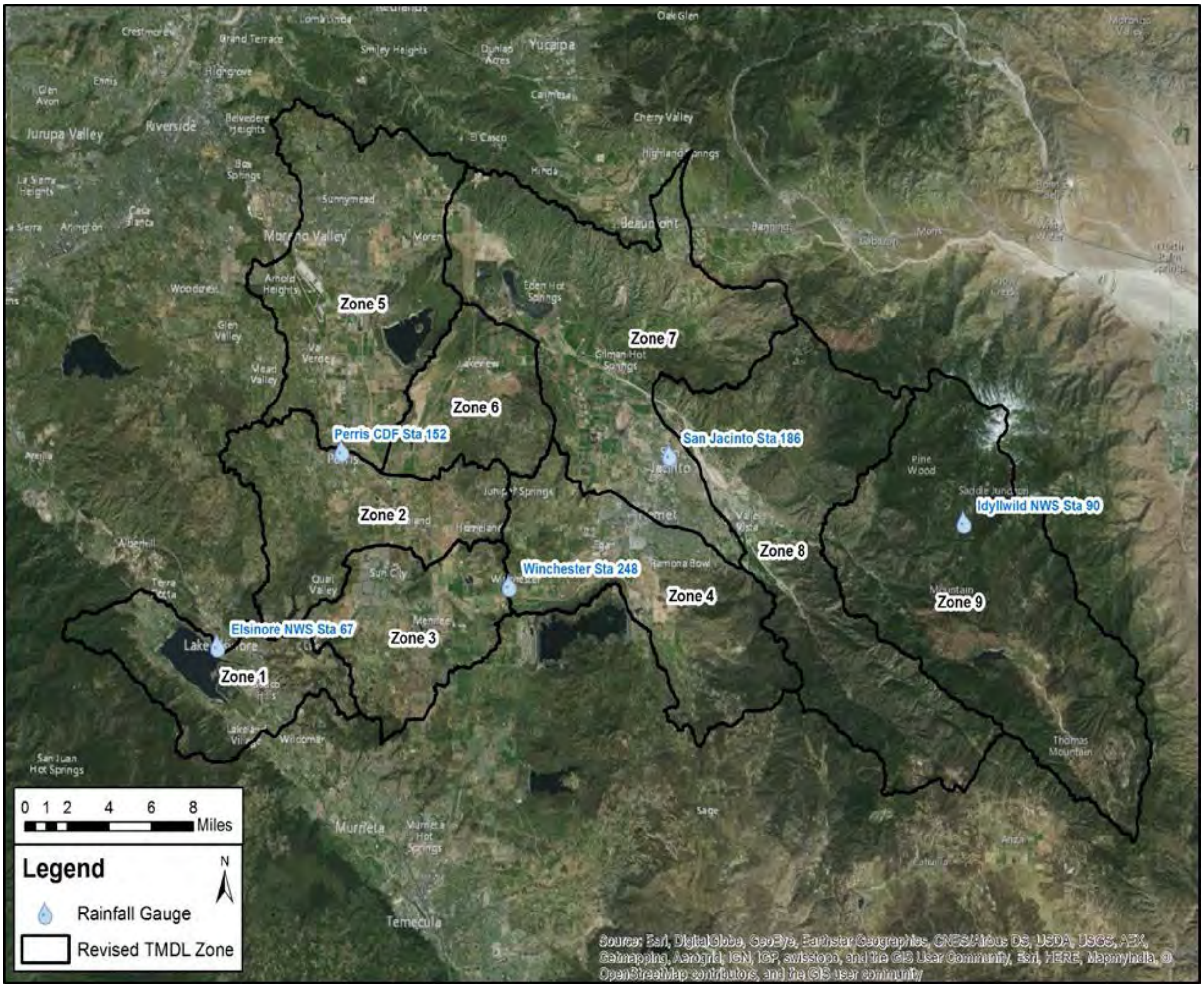

Figure 4-5. Map of Rainfall Stations Used for Long-term Rainfall Depth Inputs to the Watershed Model

Table 4-2. Rainfall Station Summary Statistics and Linkage to Model Subwatersheds

Station	Period of Record	Period of Record Average Rainfall (in/yr)	1948-2015 Average[1] Rainfall (in/yr)	2000-2015 Average[2] Rainfall (in/yr)	Subwatershed Zone
San Jacinto Station 186	1903 – Present	12.7	12.0	10.0	7, 8, 9 (blw 3,000')
Elsinore NWS Station 67	1896 - Present	12.1	11.4	10.0	1
Perris CDF Station 152	1910 – Present	10.5	10.3	8.9	2, 5, 6
Winchester Station 248	1940 - Present	10.9	10.8	9.4	3, 4
Idyllwild NWS Station 90	1929 – Present	25.8	25.7	22.8	7, 8, 9 (abv 3,000')

[1] Average annual rainfall used to estimate runoff volume for determining existing and allowable loads for TMDL

[2] Average annual rainfall used to fit watershed runoff model to measured data at USGS gauging stations

4.1.3.2 Runoff Coefficient

RC is a factor to express the ratio of rainfall to surface runoff. Simple hydrologic modeling methods, such as the Rational Method and derivations thereof, estimate the runoff coefficient as a function of watershed imperviousness. The connectivity of impervious land cover to MS4 inlets is an important consideration, especially in newer developments that employ LID site designs that strive to disconnect impervious areas to prevent runoff reaching surface waters. Similarly, lower density residential land use is characterized by unpaved or partially paved walkways and driveways that have less directly connected impervious area (DCIA). Given this, for the Lake Elsinore and Canyon Lake watersheds, an exponential function was selected to estimate runoff coefficients that best relates increased connectivity with increased imperviousness (Bochis-Micu and Pitt 2005). Two factors are included in the exponential function, including; (1) a watershed-wide estimate of runoff / rainfall ratio for pervious lands (a), and (2) exponent factor (b) for imperviousness (IMP).

$$RC = a * e^{(b*IMP)}$$

An initial parameter estimate of a = 0.05 was selected for model development based on typically measured runoff ratios for varying levels of imperviousness in 47 hydrology studies from across the nation (Schueler 1987). Pervious area runoff is variable and influenced by factors such as slope, soil health, and vegetative cover fraction, which can vary between watersheds. Thus, this value was allowed to be adjusted within +/- 50 percent (from 0.0 to 0.1) during model calibration. Bochis-Mitu and Pitt (2005) suggest that the coefficient in the exponent be set to meet an assumption of 90 percent runoff ratio for a completely impervious watershed. Thus, for the exponent coefficient b, a value of 2.3 was set as default when a = 0.05. These two factors are the primary variables used for fit results of the PLOAD model for the TMDL revision to approximate measured annual runoff volumes.

The Multi-Resolution Land Characteristics Consortium (MRLC)[2] maintains a national map of impervious surfaces with a spatial resolution of 30-m, most recently updated in 2011 (Homer et al. 2015). Imperviousness within the watersheds to Lake Elsinore and Canyon Lake was extracted from this national map and used for estimating runoff coefficients from model subareas with the above equation (**Figure 4-6**).

4.1.3.3 Downstream Retention in Unlined Channels

Not all rainfall that runs off into a surface water reaches Canyon Lake because of recharge that occurs in bottom sediments of unlined channel bottoms. **Figure 4-7** shows the unlined channel bottom segments throughout the watershed where downstream retention and groundwater recharge of runoff is known to occur. The major unlined channel segments that infiltrate upstream runoff include Salt Creek, San Jacinto River, and Perris Valley Channel.

[2] http://www.mrlc.gov/

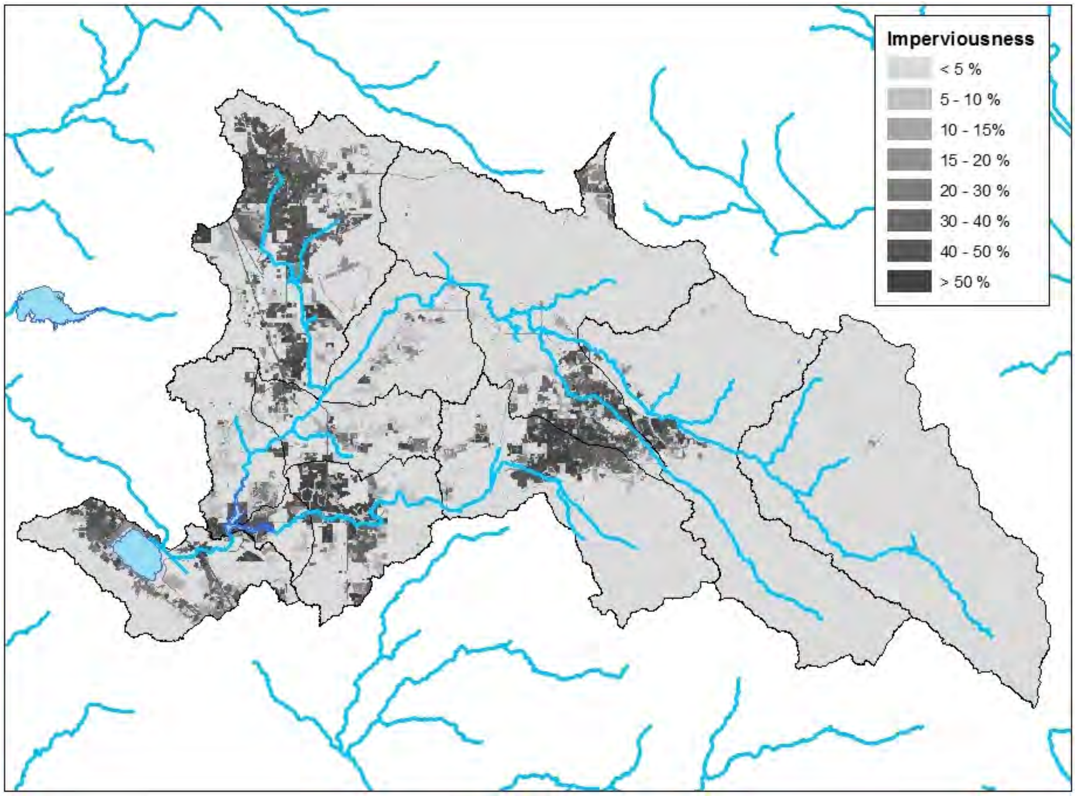

Figure 4-6. Imperviousness in the Lake Elsinore and Canyon Lake Watersheds

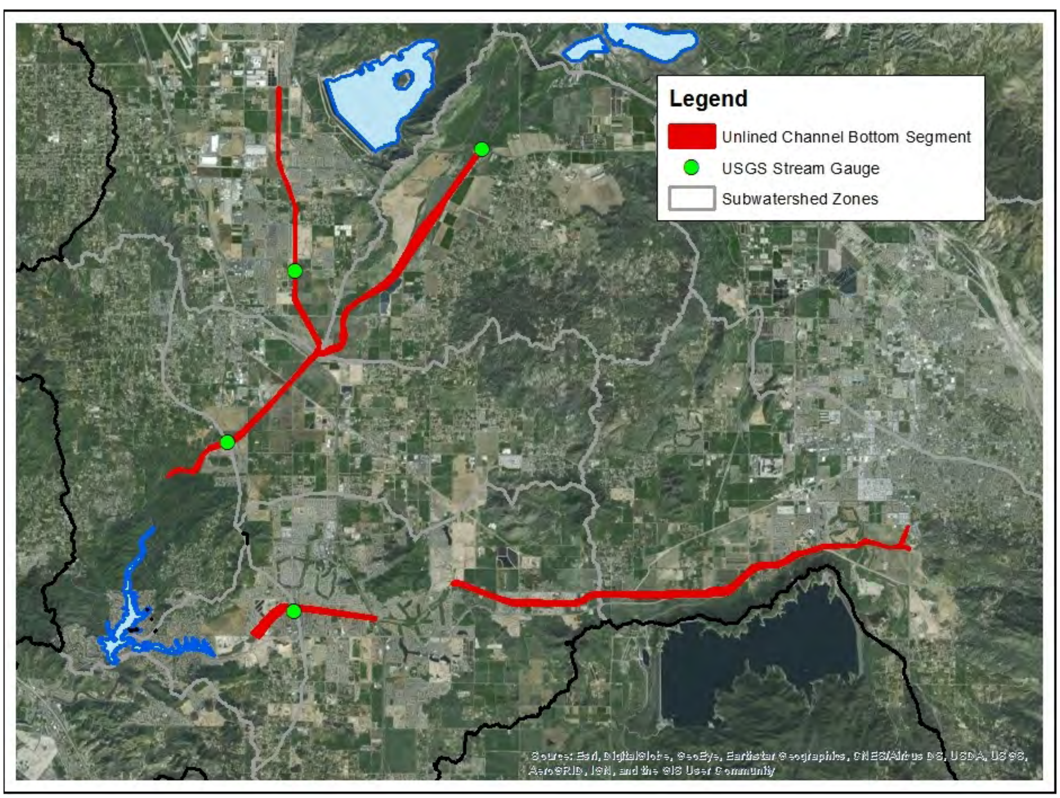

Figure 4-7. Unlined Channel Bottom Segments in the Lake Elsinore and Canyon Lake Watersheds

To estimate the annual loss of runoff within these channel bottoms, a separate hydrologic data analysis was completed. The potential daily infiltration volume into the channel bottom segments was approximated from typical percolation rates for soils and the extent of the unlined channel bottom (**Table 4-3**). Daily runoff data from the period of record at the inflows to Canyon Lake (2000 – 2016) was evaluated to estimate the number of days when channel bottoms may have actively infiltrated upstream runoff. This was accomplished by assuming infiltration within unlined channel bottoms only occurred on days when the nearest downstream gauged flow exceeded a threshold indicative of wet weather conditions. The final column of Table 4-3 presents the estimated average annual yield of infiltrated runoff in each channel bottom segment.

This estimated annual recharge volume (AFY) in Table 4-2 for each unlined channel bottom segment is converted into a depth of runoff from the upstream drainage areas within that subwatershed zone: (a) subwatershed zone 5 to Perris Valley Channel; (b) subwatershed zone 6 to San Jacinto River; and (c) subwatershed zone 4 to Salt Creek. The estimated depth of watershed runoff retained in channel bottoms ($D_{retention}$) is added into the hydrologic model for subareas in these zones as follows:

$$Q_{annual} = (Precip_{annual} * RC) - D_{retention}$$

Table 4-3. Unlined Channel Bottom Segments and Estimated Average Annual Runoff Retained from Upstream Drainage Areas

Channel	Bottom Area (acres)	Recharge Rate (ft/day)	Downstream Flow Threshold (cfs)[1]	Number of Recharge Days (2000-2015)	Estimated Annual Recharge (AFY)
San Jacinto River	111	0.1	20	257	150
Perris Valley Channel	222	0.1	20	257	300
Salt Creek	600	0.3	10	224	2800

[1] Downstream flow gauges for San Jacinto River and Perris Valley Channel is San Jacinto River at Goetz Rd (Station 11070365) and Salt Creek at Murrieta Rd (Station 11070465) for Salt Creek. The period of record for these gauges is 2000-2016.

4.1.3.4 Influence of Mystic Lake

Watershed runoff in the upper San Jacinto River is captured in Hemet Lake within the National Forest and ultimately Mystic Lake, a large shallow depression in the San Jacinto valley (**Figure 4-8**). Mystic Lake has a storage capacity of approximately 17,000 AF, which is sufficient to retain all runoff from the upper watershed in most years. In addition, runoff is captured for water supply at Lake Hemet and groundwater recharge by Eastern Municipal Water District (EMWD) in a series of spreading grounds (Figure 4-8).

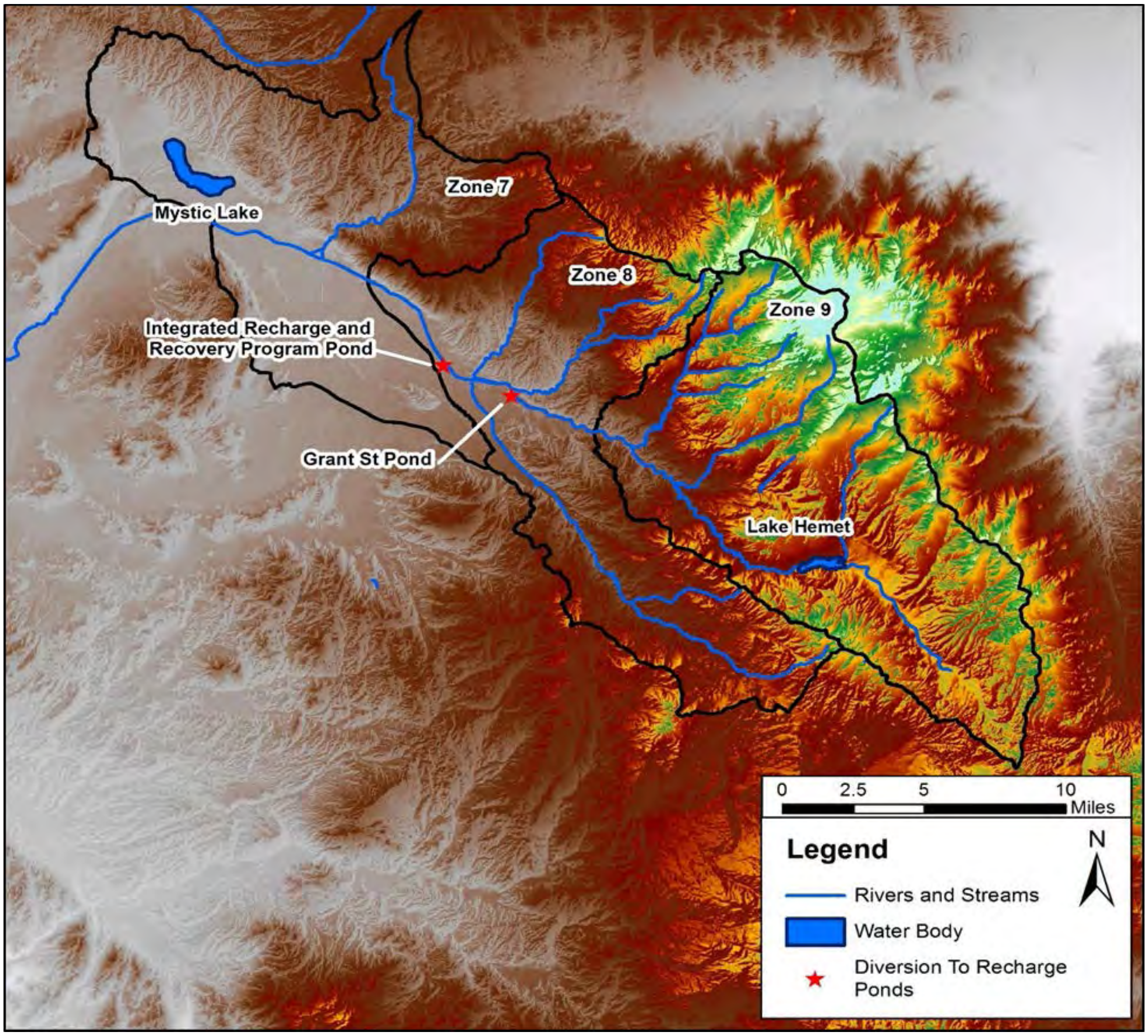

Figure 4-8. Drainage Area Upstream of Mystic Lake.

In years when Mystic Lake's storage volume is filled, large volumes of runoff may be delivered to Canyon Lake from the upper watershed, i.e. subwatershed zones 7-9. Mystic Lake overflows are known to have occurred in the 1993-1994, 1995-1996, and 1998-1999 water years (Hamilton and Boldt 2015) but not in subsequent wet years when flow gauge data showed no overflows occurred (notable being the 2004-2005 season). Given this, there is no downstream flow data for inflows to Canyon Lake during any overflow year (USGS gauge installed in 2000 after most recent known overflow in 1998). Thus, runoff from model subareas in subwatershed zones 7-9 is assumed to be entirely retained in Mystic Lake for the calibration of runoff for the 2000-2016 period. Runoff and associated nutrient loads that may potentially occur during future Mystic Lake overflows are estimated as described in this section.

Rainfall stations in the region have actively collected data for 112 years at RCFCWCD Station 186 San Jacinto and 86 years at RCFCWCD Station 90 Idyllwild (see Table 4-2 above). These two rainfall stations are used to estimate runoff in model subareas within subwatershed zones 7, 8, and 9 with San Jacinto rainfall used for subareas below 3000' elevation and Idyllwild rainfall used for subareas above 3000 feet elevation. The watershed model was used to conduct a time series analysis for years with concurrent rainfall data at both of these stations (1929 – 2016). The pervious area runoff coefficient was adjusted to account for significant attenuation in these subwatershed zones with retention in Lake Hemet and EMWD groundwater recharge basins that capture surface runoff from diversions in the upper San Jacinto River. The final parameters of a=0.034 and b=2.3 were determined to meet the conditions that would generate overflows in water years 1993-94, 1995-96, and 1998-99, and not in water year 2004-05 based on a reservoir water budget analysis described below. Modeled estimates of annual runoff over this period from San Jacinto River into Mystic Lake are plotted in **Figure 4-9.**

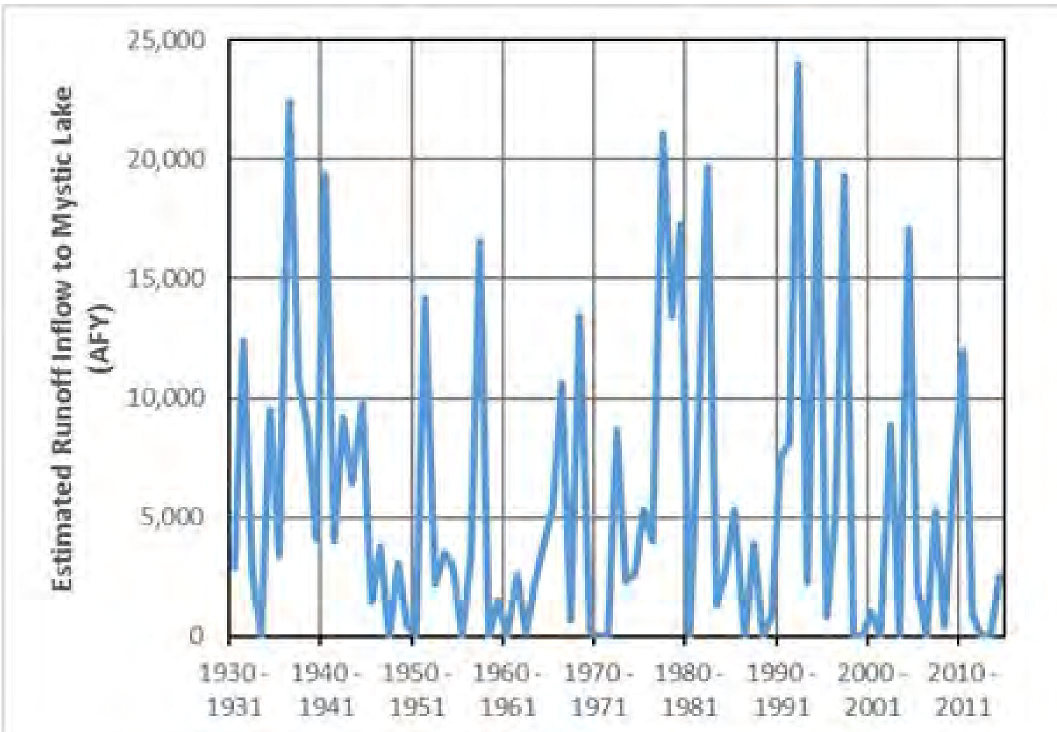

Figure 4-9. Modeled Runoff Inflow to Mystic Lake

A reservoir water budget analysis after Gilbert (1970) was developed to approximate the volume of overflow in a given wet season (O_i) from Mystic Lake to Canyon Lake by estimating key water budget components of runoff inflow (R), available storage capacity (S), and dry season evaporative losses (E), as follows:

$$O_i = R_i - (S_{MAX} - S_i)$$

$$S_i = R_{i-1} + S_{i-1} - E_{i-1} - O_{i-1}$$

Subsidence of land within the Mystic Lake basin bottom is continually adding an estimated 200 AF of storage capacity each year, as documented with review of historical bathymetric maps (Morton and Miller 2006). Looking forward, an estimated 5,000 additional AF of storage capacity may exist in 2040. To account for this future rise in storage capacity, the water budget analysis was developed with an assumed maximum storage capacity (S_{MAX}) of 22,000 AF, greater than the current estimate of 17,000 AF. The results predict that overflows from a future condition (with 22,000 AF of storage capacity) of Mystic Lake to Canyon Lake may have occurred in 10 of 86 years since 1929, with the most recent during the 1997-98 wet season. During the 2004-2005 wet season, Mystic Lake was very close to full capacity, but did not overflow based on field observations (Hamilton and Boldt 2015). More important than the frequency of overflows, is the volume of runoff that reaches Canyon Lake from the upper watershed. The reservoir routing analysis predicted that an average of ~4,000 AFY in overflow years and a range of less than 500 AFY to over 9,000 AFY (**Figure 4-10**).

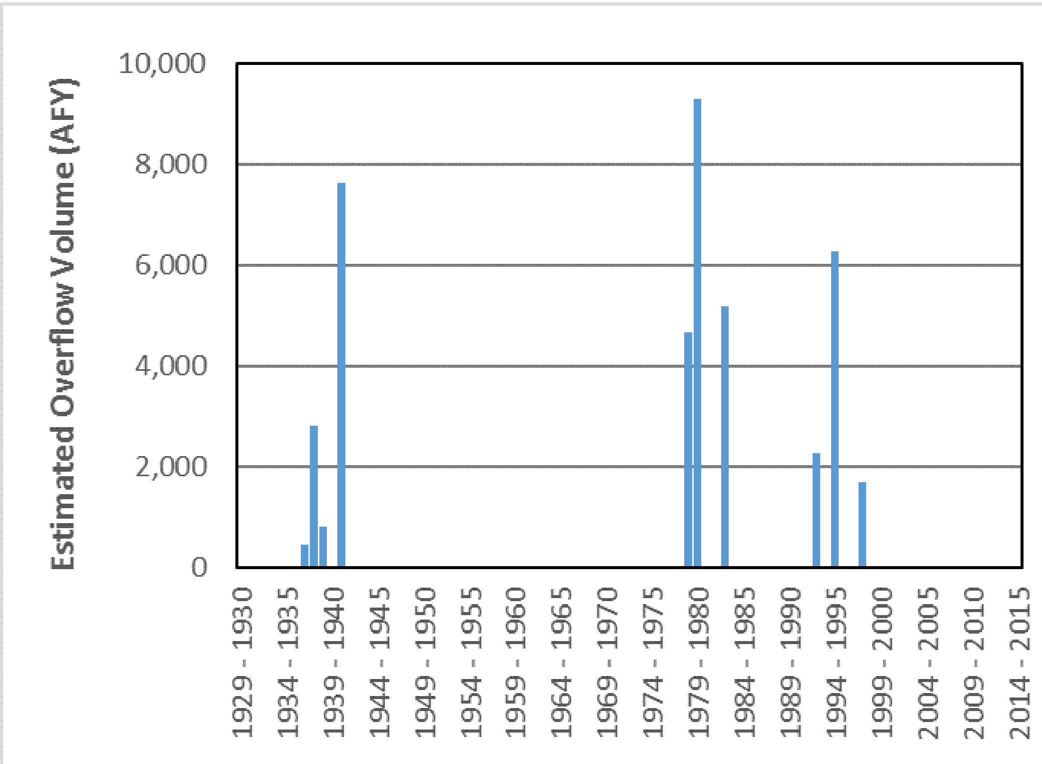

Figure 4-10. Modeled Overflow Volume from Mystic Lake to Canyon Lake (Note: Years not shown did not result in a spill)

The water budget analysis was used to assess the influence of subsidence and associated increase in storage capacity on long-term runoff overflow volume. **Figure 4-11** shows the estimated long-term overflow volume with assumed constant storage capacities ranging from 12,000 – 22,000 AF. Re-visiting the 2004-2005 wet season, a storage capacity of 17,000 AF for Mystic Lake was sufficient to result in a nearly full Mystic Lake with no overflow, which was the condition observed in the field and later reported by Hamilton and Boldt (2015). Thus, without subsidence, there may have been an overflow in the 2004-2005 wet season.

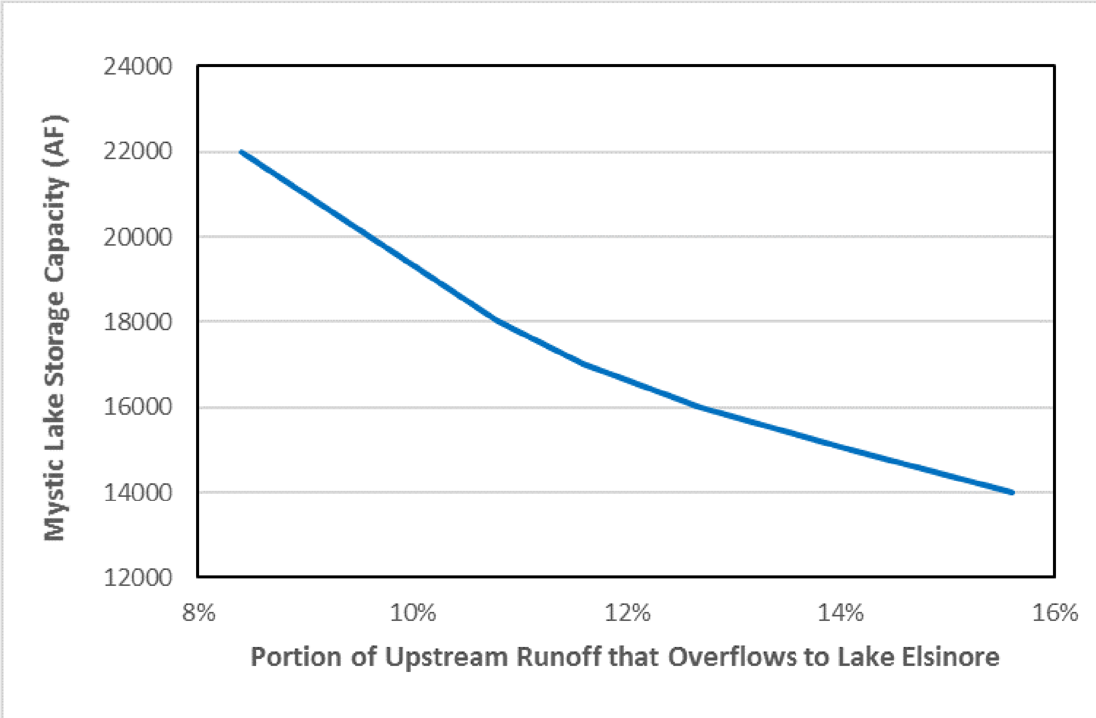

Figure 4-11. Modeled Overflow Ratio from Mystic Lake to Canyon Lake for Varying Levels of Storage Capacity in Mystic Lake

The water budget analysis showed that storage (S_{i-1}) was close to maximum capacity (S_{MAX}) in wet seasons leading up to each overflow year. Comparing the estimated overflow of ~500 AFY to the total runoff volume from the upper watershed (into Mystic Lake) for the 86-year simulation period of ~5,600 AFY suggests that nine percent of long term runoff from subwatershed zones 7-9 may reach Canyon Lake. Thus, an overflow ratio factor of 0.09 is applied in the model to estimate long term average runoff and associated pollutant loads from the upper watershed to the Main Lake of Canyon Lake.

4.1.3.5 Hydrologic Model Results

Comparisons were made between measured and modeled average annual runoff delivered to Canyon Lake from model subareas upstream of the USGS gauges on San Jacinto River at Goetz Road and Salt Creek at Murrieta Road. To make this comparison it was necessary to do an additional delineation for subwatershed zones 2 and 3 downstream of these gauges, in order to discount modeled runoff from portions of these subwatersheds that are downstream of the San Jacinto River at Goetz Road and Salt Creek at Murrieta Road USGS gauge stations. The ungauged portions comprise ~25,000 acres and amount to ~16 percent of the total drainage area to Canyon Lake below Mystic Lake. These ungauged areas include land areas that drain directly to the shoreline of Canyon Lake and a large tributary referred to as Meadow Brook (**Figure 4-12**).

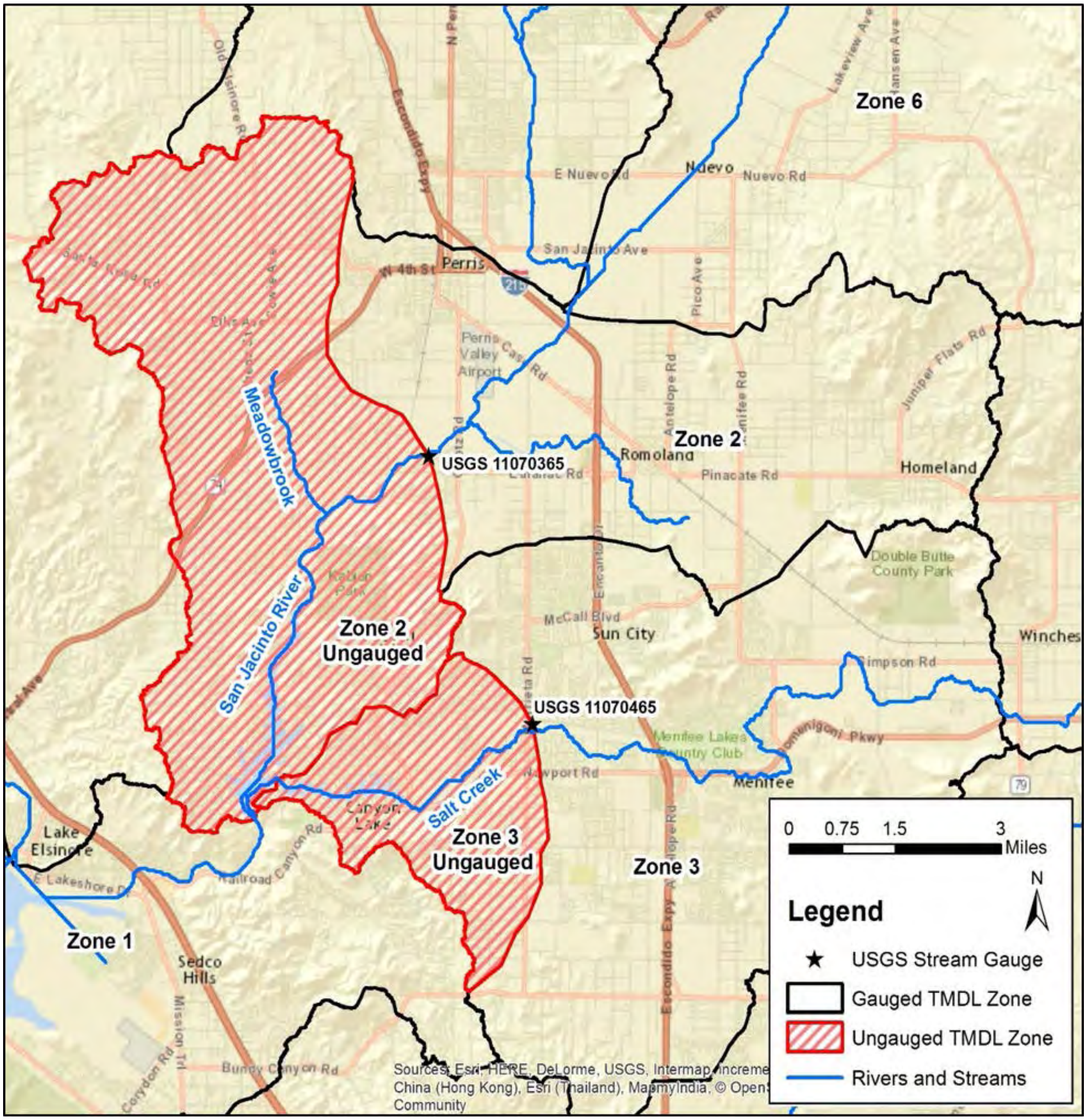

Figure 4-12. Drainage Areas Downstream of USGS Gauge Stations Not Included in Comparison of Modeled to Measured Runoff Volume

The factors used to estimate runoff coefficients as a function of subarea imperviousness were adjusted (a=0.065, b=2.3) to fit modeled long-term average annual runoff volume to averages from the USGS gauges (**Figure 4-13**). Fitting a static condition of annual average runoff volume allows for a very close fit of model estimates to measured data by attenuating the natural dynamic variability.

Average annual runoff volume was estimated using long-term average rainfall based on the entire period of concurrent rainfall data at RCFCWCD stations of 1948-2015 (shown in Table 4-2 above). Results shown in **Table 4-4** represent the estimated average annual volume of runoff delivered to

Canyon Lake, Main Lake and East Bay, and Lake Elsinore from all watershed lands. These results account for losses in unlined channel bottom segments and include the long-term average of runoff overflow volume (computed including years with zero values) from drainage areas upstream of Mystic Lake. The runoff inflow volume shown for Lake Elsinore is for the local drainage and does not include overflows from Canyon Lake.

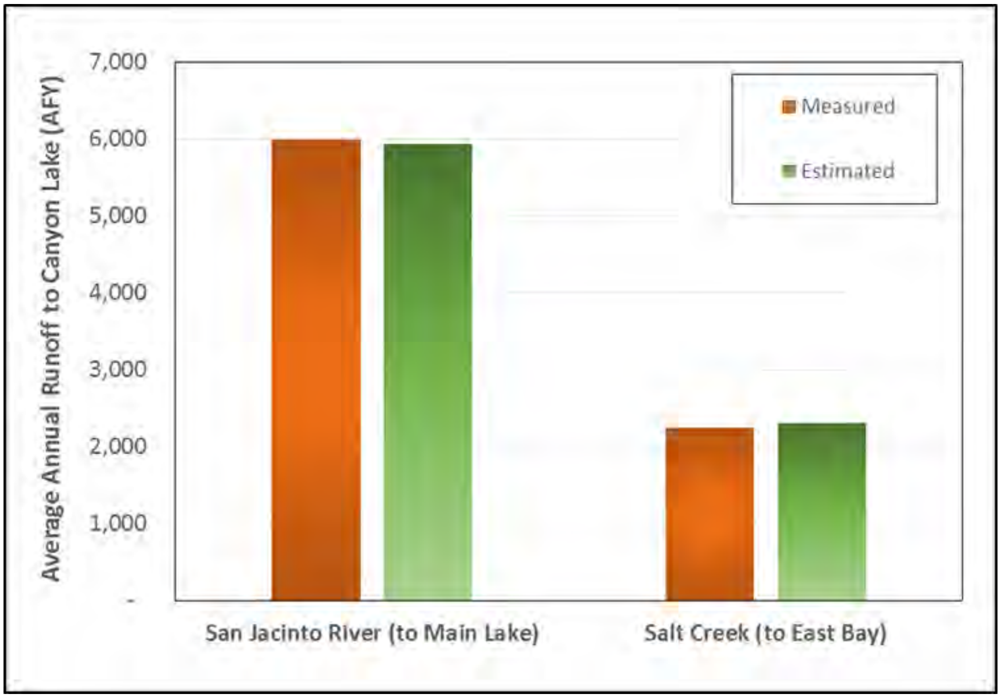

Figure 4-13. Comparison of Modeled and Measured Average Annual Runoff Volume (2000-2015) for Primary Inflows to Canyon Lake

Table 4-4. Estimated Long-Term (1948-2015) Average Runoff Volume Delivered to Lake Segments from All Watershed Lands

Average Annual Runoff Inflows to Lakes (AFY)	San Jacinto River (to Main Lake of Canyon Lake)	Salt Creek (to East Bay of Canyon Lake)	Local Lake Elsinore	Total
Modeled - Current Land use	11,310	3,585	3,002	17,897

4.1.4 Water Quality

The preceding section describes a static model for estimating volume of watershed runoff generated from different model subareas that is delivered to each lake segment. Watershed runoff contains nutrients, total phosphorus and total nitrogen, that are conveyed through drainage features to the downstream lake segments. In wet years, the greatest source of nutrients to the lakes segments comes from the watershed with runoff. The following sections describe types of nutrient sources in the model subareas, the concentration of nutrients washed off from different land use types, and the total load of nutrients delivered to the lake segments as external loads in watershed runoff.

4.1.4.1 Sources of Nutrients in Watershed Runoff

Specific sources of nutrients that may be available for washoff with runoff are listed below:

- Trash
- Fertilizers
- Green waste
- Pet waste
- Septic system failure
- Detergents
- Construction sites
- Erosion of exposed soils

The source assessment estimates total nitrogen and total phosphorus washoff from model subareas for generalized land use categories in drainage areas upstream of Canyon Lake (Main Lake and East Bay) and Lake Elsinore (local drainage downstream of Canyon Lake) (**Table 4-5**). Detailed land use distributions by subwatershed zone and jurisdiction are provided in Appendix B.

Table 4-5. Distribution of Land Use (Acres) in Areas that Drain to Lake Elsinore and Canyon Lake

Land Use	San Jacinto River (to Main Lake)[1]	Salt Creek (to East Bay)	Local Lake Elsinore	Total
Commercial / Industrial	18,582	5,157	1,854	25,594
Dairy	812	0	4	816
Forested	262,484	41,487	17,472	321,444
Irrigated Cropland	16,446	3,800	0	20,246
Non-Irrigated Cropland	8,085	5,278	22	13,386
Open Space	9,240	4,287	544	14,071
Orchards / Vineyards	3,953	322	56	4,330
Other Livestock	2,179	1,120	30	3,329
Pasture / Hay	2,473	646	53	3,173
Roadway	2,014	785	240	3,039
Water	3,717	427	3,183	7,327
Residential – Septic[2]	2,601	1,008	254	3,863
Residential – Sewer	41,623	17,450	6,652	65,726
Total	**374,210**	**81,768**	**30,365**	**486,342**

[1] Acres shown include drainage areas upstream of Mystic Lake in subwatersheds 7-9
[2] Residential land use on septic systems was approximated by intersecting GIS layers of Riverside County parcels containing a septic tank with 2014 land use areas mapped as low-density residential
[3] Acres shown includes agricultural parcels that are less than 20 acres in size

4.1.4.2 Nutrient Loading to Lake Segments

The existing loads to Canyon Lake and from Canyon Lake to Lake Elsinore can be approximated from historical flow and water quality data from the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and from San Jacinto River inflows to Lake Elsinore. The gauges are downstream of the majority of drainage area to the lake segments, although adjustments are made in the modeling approach to account for ungauged drainage areas, as described in the following section 4.1.4.3. The concentration of nutrients for inflows to and outflows from Canyon Lake have been monitored during 25 storm events between 2008 and 2016 by the Task Force. Data are sufficiently robust from these watershed monitoring activities to be considered representative of long term averages and to characterize most of the expected variability associated with seasonality and magnitude of storm events. Event based summary data is presented in **Table 4-6**.

Median event nutrient concentrations (C_{median}) from the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and overflow to Lake Elsinore, when active, are shown in Table 4-6. Use of a flow-weighted average was considered but not used because no significant relationship was found between flow rate and nutrient concentration when comparing events. The median values were applied to annual volumes measured at the USGS gauges to estimate loading to the lakes from most of the watershed, as follows:

$$L_{annual} = Q_{annual} * C_{median}$$

Figures 4-14 and 4-15 show estimated annual nutrient loads based on measurements of daily flow and average of water quality monitoring data. The estimated retention of nutrient loads within Canyon Lake is computed from measured data similarly to volume retention (see Figure 4-1 above). Retained nutrient loads are estimated as the difference between the summed annual loading for stations upstream and downstream of Canyon Lake for years when Canyon Lake elevation data exceeded its spill water elevation of 1,381.76 ft (2003-2005, 2008, and 2010-2011), indicating that overflows occurred. In dry years when the lake did not overflow, all nutrients loads are assumed to be retained.

4.1.4.3 Nutrient Washoff Model

PLOAD was employed to estimate nutrient washoff to downstream lake segments. This method computes downstream annual nutrient loads (L_{annual}) as a function of average annual runoff (Q_{annual}) and nutrient washoff concentrations for spatially lumped subareas with common land use (C_{LU}), subwatershed zone (Z), and jurisdiction (J), as follows:

$$L_{annual} = \sum_{LU,Z,J} Q_{annual} * C_{LU}$$

Table 4-6. Nutrient Concentrations from Storm Events at Watershed Monitoring Sites

Event	Date	San Jacinto River at Goetz Rd		Salt Creek at Murrieta Rd		Canyon Lake Overflow		Cranston Guard Station	
		TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)
1	1/11/2001	0.62	7.03	0.32	4.83				
2	1/26/2001	0.21	10.60	0.20	5.80				
3	2/13/2001	0.49	5.50	0.28	3.24				
4	2/25/2001	0.41	4.98	0.44	3.40	0.17	2.70		
5	2/12/2003	0.64	2.56	0.61	2.62			0.13	0.60
6	2/25/2003	1.94	2.93	0.82	2.83	1.00	1.69	0.92	1.41
7	10/27/2004	1.50	3.01	0.96	2.07	0.41	2.00	4.13	3.80
8	1/12/2005	1.47	2.95	1.35	2.05			0.16	0.98
9	3/23/2005	0.78	1.32	0.44	2.68			0.11	0.58
10	2/28/2006	0.69	2.82	0.37	2.36				
11	4/5/2006	0.32	1.80	0.62	2.49				
12	1/5/2008							0.39	1.15
13	1/27/2008	0.58	1.90	1.08	2.70	0.46	1.82	1.22	4.00
13	2/4/2008							0.43	1.03
14	11/26/2008	1.51	3.07	0.77	1.57				
15	2/16/2009	0.68	2.08	1.32	3.65	0.45	1.49		
16	12/12/2009	0.46	1.94	0.61	2.70				
17	1/20/2010	1.12	2.13	0.99	2.33	0.58	1.95	10.13	7.09
18	2/5/2010	1.12	3.81	0.77	2.20	0.80	2.43		
19	12/21/2010	0.72	2.01			0.46	1.56		
20	2/18/2011	1.87	3.60	0.42	2.81	0.56	1.38		
21	2/25/2011	4.19	3.56	0.54	2.11	0.94	2.21		
22	3/17/2012	0.94	2.56	0.33	2.12				
23	3/26/2012	0.26	1.85	0.23	1.73				
24	4/26/2012	0.56	2.58	0.41	2.18				
25	2/20/2013	0.73	2.39	0.30	2.11				
26	3/8/2013	0.56	2.57	0.33	1.70				
27	2/28/2014	0.85	2.16	1.15	3.32				
Median of all Samples		**0.71**	**2.58**	**0.54**	**2.49**	**0.51**	**1.89**	**0.32**	**0.92**

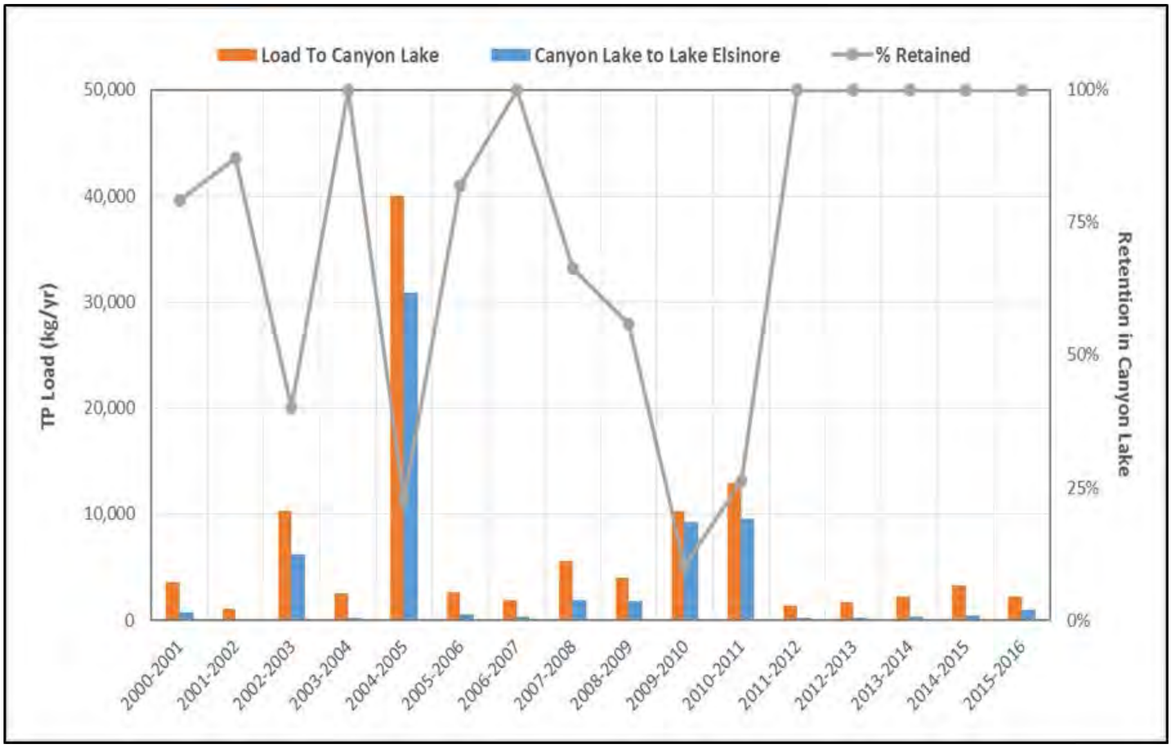

Figure 4-14. Annual Total Phosphorus Load into Canyon Lake and Overflow to Lake Elsinore

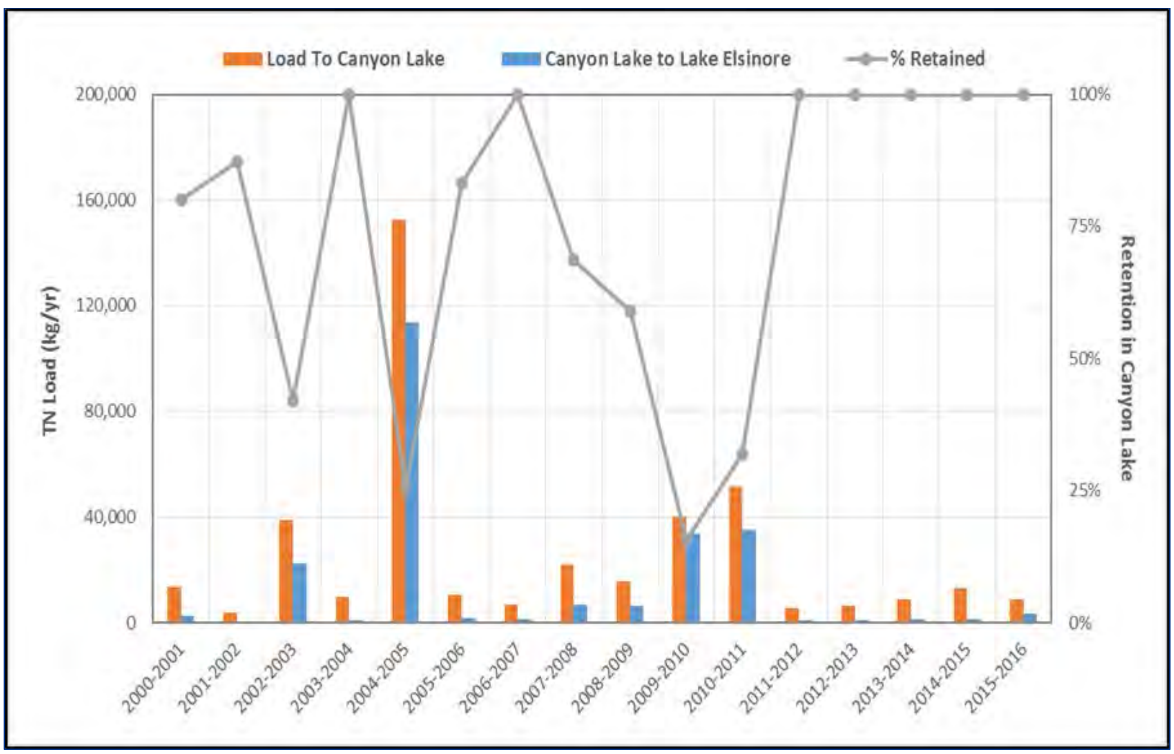

Figure 4-15. Annual Total Nitrogen Load into Canyon Lake and Overflow to Lake Elsinore

Thus, the estimation of nutrient loads delivered to downstream lake segments is based on hydrologic model results and assumed values for total phosphorus and total nitrogen concentrations in washoff from general land use categories. **Table 4-7** presents the land use-based nutrient washoff concentrations used to develop the source assessment for the TMDL revision. Table 4-7 also documents the monitoring data from sites in the vicinity of the San Jacinto River watershed that served as the basis for each of these nutrient washoff concentrations. These monitoring sites are representative of the general land use categories (**Figure 4-16**). Generally, urban land use groups were characterized from NPDES monitoring conducted by RCFCWCD at core monitoring sites (Riverside County Santa Ana Region Stormwater Program 2014) and agricultural land use groups were characterized by a special study of cropland plot scale nutrient BMP effectiveness conducted by UC Riverside (UCR 2011) through a 319(h) grant. In addition, the National Stormwater Quality Database (NSQD 2017) contained data from multiple sites from freeways in the vicinity of the San Jacinto River watershed that were used to characterize transportation land use in the watershed. Lastly, nutrient washoff concentrations for Pasture / Hay / Ranch and Other Livestock land use groups have not been published from studies in the watershed vicinity and are estimated from a study in Central Florida (Harper 1998). These two land use groups compromise approximately 1 percent of the total acreage in the drainage areas to the lakes based on mapping completed in 2014 (see Table 4-5 above), therefore values for these nutrient washoff concentrations are relatively insensitive to the estimate of downstream loads.

Table 4-7. Land Use Specific Nutrient Washoff Concentrations Used for Source Assessment ***(Note: Comment regarding potential update to ag values still being addressed)***

Land Use	TP (mg/L)	TN (mg/L)	Site Name	Source (No. of Samples; Period of Record)
Commercial / Industrial	0.54	3.89	Corona Storm Drain (Station 40)	RCFCWCD (N=30; 2004–2014)
Residential - Sewer	0.48	2.93	Sunnymead Channel (Station 316)	RCFCWCD (N=30; 2004–2015)
Residential - Septic	0.59	5.30	Canyon Lake at Sierra Park (Station 834)	RCFCWCD (n=21; 2000-2004)
Roadway	0.31	4.88	Freeway (FW) CACTA006, 011, 012, 013	NSQD (N=14; 1997-1999)
Irrigated Cropland	1.04	4.08	Pumpkin Control	UC Riverside (N=8; 2008)
Non-Irrigated Cropland	1.21	3.25	Wheat Control	UC Riverside (N=14; 2007-2009)
Orchards / Vineyards	1.13	1.71	Citrus Control	UC Riverside (N=17; 2007–2009)
Open Space / Forested	0.32	0.92	Cranston Guard Station	US Forest Service (N=54; 2001–2010)
Pasture / Other Livestock	0.48	2.48	Not reported	Harper (1998)
Dairy	6.48	12.97	Not reported	Tetra Tech 2003

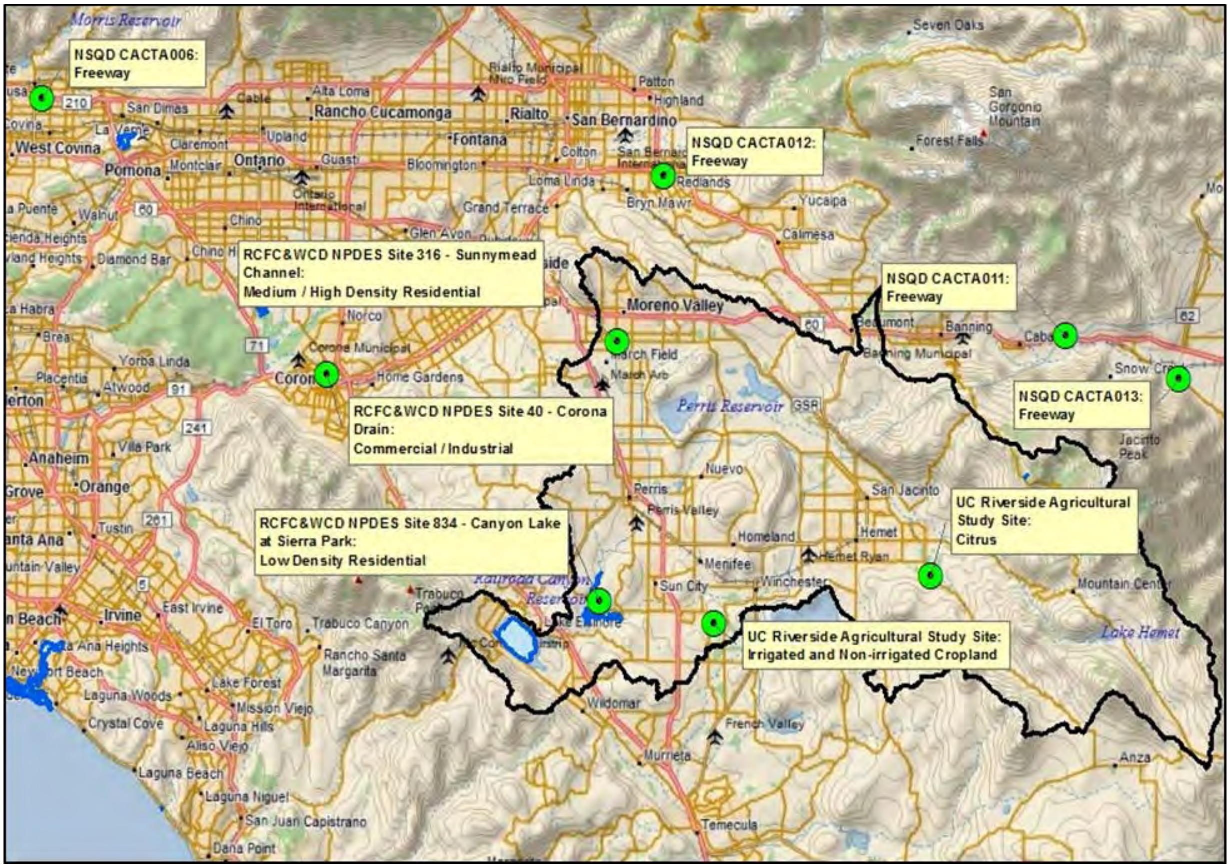

Figure 4-16. Map of Water Quality Monitoring Sites in the San Jacinto River Watershed and Vicinity Used to Estimate Land Use Based Washoff Concentrations for TP and TN

The RCFCWCD monitoring site at Canyon Lake at Sierra Park is located downstream of Quail Valley, a low density residential area that was not historically serviced by any centralized sewer system. A large project to bring sewer service to this area is currently underway. Monitoring at the downstream sample site was conducted prior to any sewer construction and therefore may be representative of residential land use with on-site sanitary treatment and disposal systems (OSTDS), referred to as septic systems in this report. The nutrient concentration data from this site show similar TP levels to sewered residential but roughly 80 percent greater TN concentration. This difference makes sense given that adsorption of nitrogen in soils is less efficient than phosphorus. A similar water quality response was observed from a smaller sample set collected from Meadow Brook, a tributary to the San Jacinto River just above the inflow to Canyon Lake Main Lake, with elevated TN concentrations averaging over 10 mg/L (CDM Smith 2013a, see Attachment B).

Both Quail Valley and Meadow Brook are situated over portions of the watershed with shallow (< 2 m) depths to bedrock, thereby posing a greater risk of short-circuiting septic leachfields during wet weather events. A review of regional SSURGO soil survey mapping (Natural Resources Conservation Service 2017) showed that most other residential – septic model subareas (displayed in Figure 4-2 above) in the watersheds to Lake Elsinore and Canyon Lake also overlay areas with shallow depth to bedrock. Thus, the TMDL revision applied a nutrient washoff concentration specifically for model subareas identified as residential – septic to account for nutrients from potentially failing septic systems watershed-wide. This approach differs from the method in the 2004 TMDL source assessment, which involved a separate loading analysis to attempt to quantify nutrient loads in potentially failing septic systems. The previously employed approach required rough assumptions about failure rates and how wet weather conditions mobilize incompletely treated sewage.

For each referenced monitoring station, the median of collected wet weather samples was computed and served as the nutrient washoff concentration value in the source assessment model. The full range of wet weather TP and TN concentrations are plotted as box/whisker plots in **Figure 4-17** for TP and **Figure 4-18** for TN. These plots show the median (black line through box), 25th and 75th percentiles (lower and upper bounds of box) and minimum and maximum values (whiskers) for the full dataset.

Applying these land use specific washoff concentrations to average annual runoff (see Section 4.1.2 above) provides an estimate of nutrient loads for all model subareas. Taking only model subareas from upstream of USGS gauges on San Jacinto River at Goetz Road and Salt Creek at Murrieta Road and simulating average annual rainfall for the period of 2000-2016 allows for comparison of modeled to measured loads (**Figure 4-19**). Ungauged subareas that are downstream of the monitoring sites and drain directly to the shoreline of Canyon Lake (see Figure 4-11 above) as well as all model subareas upstream of Mystic Lake (no overflows occurred in 2000-2015 period) are excluded from these calibration outputs.

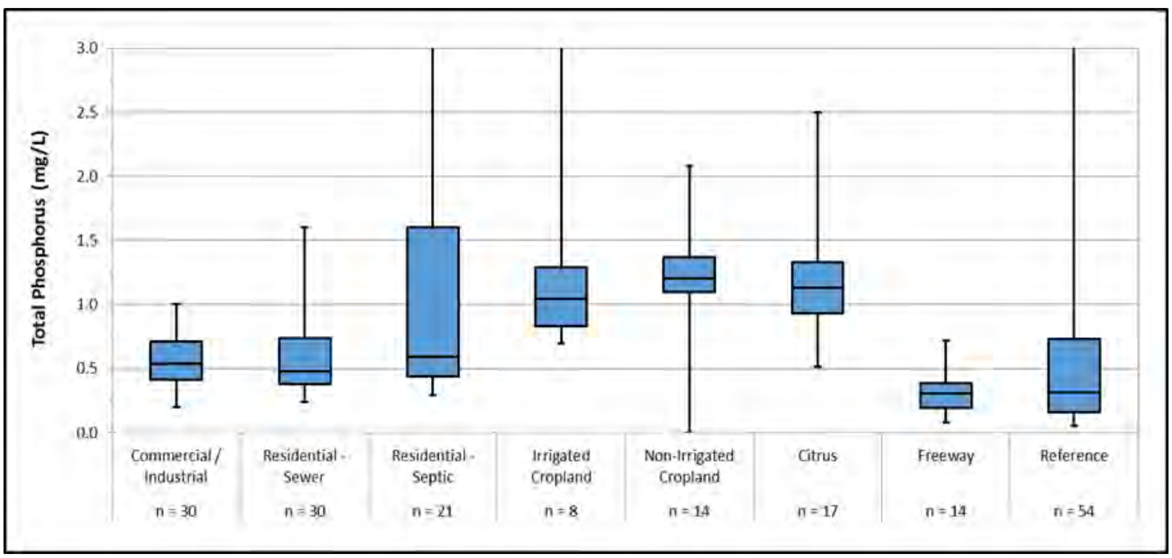

Figure 4-17. Box/Whisker Plots of Wet Weather Total Phosphorus from Land Use Specific Sites (Note: Data for Dairy, Other Livestock or Pasture/Hay/Ranch land uses not available) ***(Note: Figure may be updated if Table 4-7 is updated)***

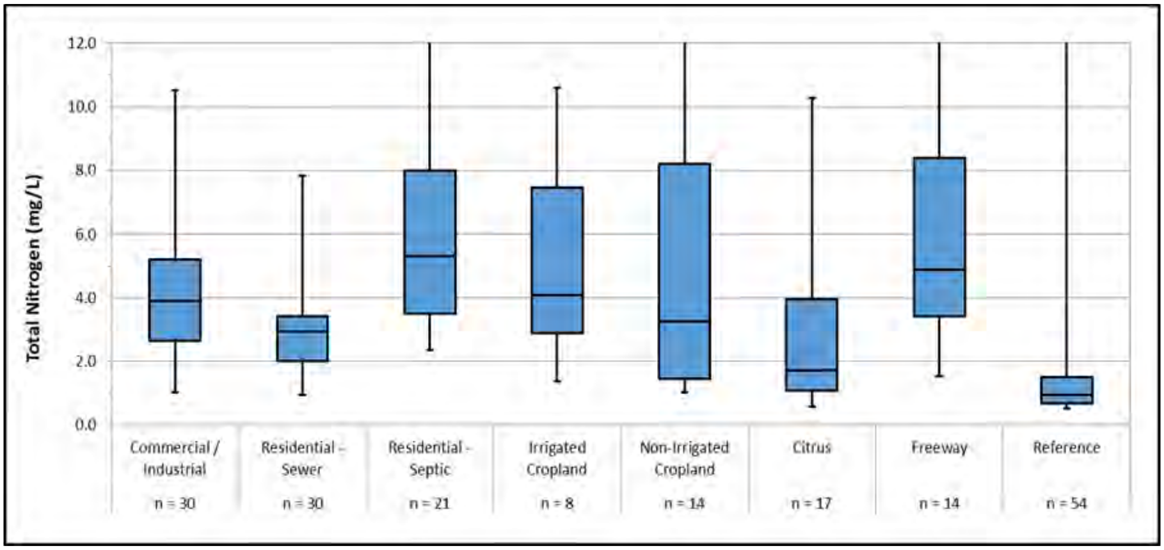

Figure 4-18. Box/Whisker Plots of Wet Weather Total Nitrogen from Land Use Specific Sites (Note: Data for Dairy, Other Livestock or Pasture/Hay/Ranch land uses not available) ***(Note: Figure may be updated if Table 4-7 is updated)***

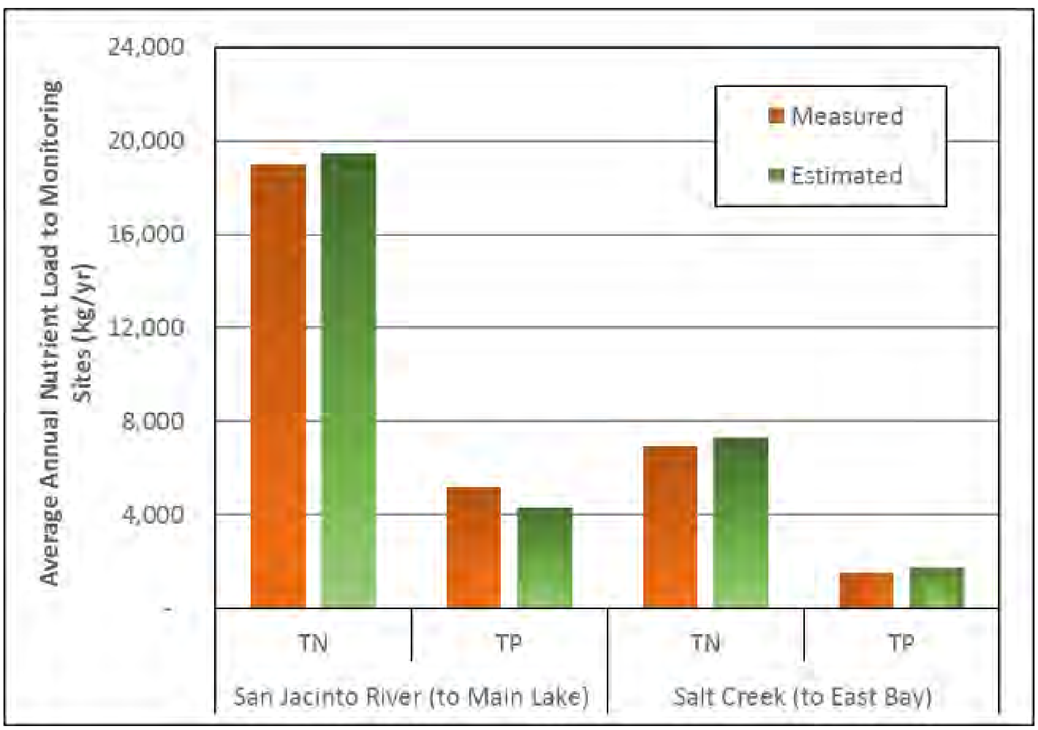

Figure 4-19. Comparison of Modeled and Estimated Average Annual Nutrient Loads (2000-2016) to Monitoring Sites for San Jacinto River at Goetz Road and Salt Creek at Murrieta Road (Note: Data include overflows from subwatershed zones 7-9)

Generally, the model performed well in predicting average annual nutrient loads when compared with estimated loads from measured data at the two downstream monitoring sites. The model did slightly under-predict annual TP loads to the San Jacinto River at Goetz Road. It is possible that another in-stream source is present in this drainage area to account for elevated concentrations (median TP of 0.71 mg/L) at the downstream station.

Results for nutrients loads delivered to the lake segments based on long-term average annual rainfall (1948-2015) and accounting for all model subareas are reported in **Table 4-8**. The results in Table 4-8 include runoff from ungauged subareas, offsite runoff from CAFOs, and overflows from Canyon Lake to Lake Elsinore and overflows from Mystic Lake to the San Jacinto River and ultimately the Main Lake of Canyon Lake.

Table 4-8. Model Results for Long-Term Average (1948-2016) Annual Runoff and Nutrient Load Delivered to Lake Segments

Receiving Lake Segment	Runoff Inflow (AFY)	TP (kg/yr)	TN (kg/yr)
Canyon Lake Main Lake[1]	10,975	5,007	23,540
Canyon Lake East Bay	3,768	1,516	7,397
Lake Elsinore[2]	9,530	5,037	19,931

[1] Includes estimated Mystic Lake average annual overflow volume (accounting for zero years) and associated nutrient loads from subwatershed zones 7-9

[2] Includes measured overflow volume from Canyon Lake to Lake Elsinore shown in Figure 3-1 and estimated loads based on medians of historical watershed monitoring data shown in Table 3-6 (median TP = 0.51 mg/L; TN = 1.89 mg/L)

Nutrient loading to lake segments from watershed runoff are summarized by subwatershed zone and by general land use category in **Figures 4-20 and 4-21**, respectively. Results show the greatest loading of nutrients originates in subwatershed zone 5, which comprises the entire drainage area of Perris Valley Channel. Nutrient loads from Zone 4 that are estimated to reach Canyon Lake East Bay are approximately half of washoff from model subareas as a result of significant channel bottom recharge in Salt Creek.

Land use categories with the greatest acreage in the watershed were the largest source of nutrient loading to the lake segments. This includes residential – sewered and commercial / industrial categories as well as forest and open space model subareas. Agricultural land uses in the San Jacinto River watershed have declined significantly since the existing TMDLs were developed. Moreover, with adoption of the Conditional Waiver of Waste Discharge Requirements for Agricultural Discharges (CWAD) in 2017 (Santa Ana Water Board 2017), the acreage of agricultural land use in the watershed is expected to continue to decline. Despite having relatively higher nutrient washoff concentrations, the lower imperviousness and reduction of total agricultural acreage has reduced the source contribution from agricultural land use categories to the lake segments relative to the 2004 TMDL.

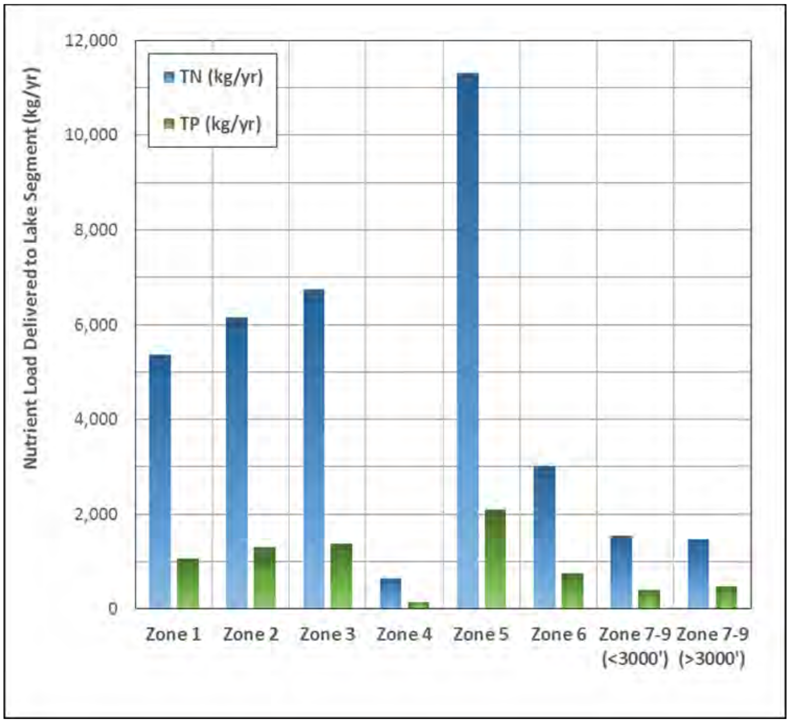

Figure 4-20. Nutrient Loading to Lake Segments by Subwatershed Zone (Note: Data include overflows from subwatershed zones 7-9; Zone 1 delivers load to Lake Elsinore; Zones 2, 5-9 deliver loads to Canyon Lake – Main Lake; Zone 3, 4 delivers load to Canyon Lake – East Bay)

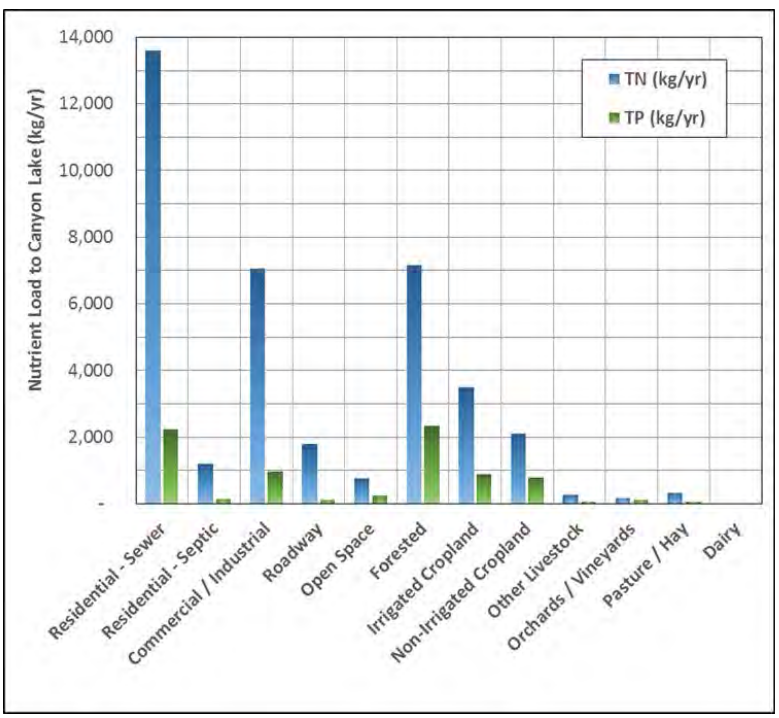

Figure 4-21. Nutrient Loading to Canyon Lake (Main Lake and East Bay Segments) by General Land Use Category

4.2 Supplemental Water

An additional source of volume and nutrient load exists for Lake Elsinore in the form of reclaimed wastewater from Elsinore Valley Municipal Water District's (EVMWD's) regional water reclamation facility (RWRF). Since 2008, EVMWD has added reclaimed wastewater to Lake Elsinore for lake level stabilization. A deeper lake provides multiple benefits including aesthetics, recreational use, and water quality. EVMWD's NPDES permit (Santa Ana Water Board 2013b) for this discharge to Lake Elsinore includes requirements for nutrient loads to the lake as follows:

- Total Nitrogen - 12-month running average TN concentration shall not exceed 1 mg/L, and the 5-year running average mass of TN discharged to the Lake shall not exceed 16,372 pounds/year (7,442 kilograms/year [kg/yr]), unless the discharger implements a plan, with the approval of the Regional Water Board or its Executive Officer, to offset TN discharges in excess of the TN limits.
- Total Phosphorus - Twelve-month running average TP concentration shall not exceed 0.5 mg/L, and the 5-year running average mass limit for TP discharged to the Lake shall not exceed 8,186 pounds/year (3,721 kg/yr), unless the discharger implements a plan, with the approval of the Regional Water Board or its Executive Officer, to offset TN discharges in excess of the TN limits.

The annual volumes of reclaimed water discharged and estimated total phosphorus and total nitrogen loads are reported in **Table 4-9**. The estimated load is based on an average annual concentration in effluent from 2014-2016 of 0.37 mg/L TP and 2.83 mg/L TN. Current treatment mechanisms at the RWRF reduce TP to meet the limit concentration of 0.5 mg/L. Conversely, typical TN concentrations exceed the allowable concentration of 1.0 mg/L. Therefore, EVMWD uses nitrogen offset credits accrued by operation of the LEAMS to meet the permit requirements. In years when there is little or no overflow from Canyon Lake, the discharge of reclaimed water to maintain lake levels is the largest source of new external nutrient loads to Lake Elsinore.

Table 4-9. Volume and Estimated Nutrient Load in Supplemental Water Additions to Lake Elsinore

Year	Reclaimed Water (AFY)	Island Wells (AFY)	Total Supplemental Volume (AFY)	Estimated TP Load (kg/yr)	Estimated TN Load (kg/yr)
2007	2,361		2,361	1070	8267
2008	5,365	359	5,724	2434	19357
2009	5,470	404	5,874	2485	19736
2010	6,039	385	6,425	2743	21792
2011	1,920	6	1,925	872	6926
2012	5,499	295	5,794	2507	19843
2013	5,843	264	6,106	2670	21698
2014	5,778	298	6,075	2651	21458
2015	1,930	50	1,981	891	7169
2016	5,075	90	5,165	2254	18085
2007-2016 Average	**4,528**	**239**	**4,743**	**2,058**	**16,433**

4.3 Internal Sources

Several sources of nutrients result from processes that happen within the lake ecosystem, including sediment nutrient flux and atmospheric deposition. The following sections describe these processes and estimates associated nutrient loads.

4.3.1 Sediment Nutrient Flux *(Note: this section and estimate loading is still under revision)*

Nutrients that settle to the bottoms of Lake Elsinore and Canyon Lake bound to organic matter or otherwise particle bound are not immediately available for phytoplankton uptake. Instead these nutrients undergo processes within the lake bottom to move from bound to more soluble forms (PO_4 and NH_4) referred to as diagenesis. Anoxic conditions in the lake bottom sediments increase the rate of digenesis by chemical reduction of iron bound phosphorus to a loosely bound ferrous form and by allowing for anaerobic bacterial decomposition of organic matter in sediments releasing ammonia into pore waters. Flux of these solubilized forms from the lake bottom across the sediment-water interface to the water column occurs by diffusion and physical resuspension.

4.3.1.1 Lake Elsinore

The 1-D approximation used for modeling of Lake Elsinore necessitates use of average internal loading rates for NH_4-N and PO_4-P across the lake, modulated by temperature and DO as described above. That is, based upon depth-area-volume information provided for the lake and dynamically simulated lake level, temperature and DO concentration with depth, nutrient flux rates are apportioned to allow for the fraction of the bottom sediments that are shallow, warm and generally well-aerated to release nutrients at a rate that is potentially quite different than deeper anoxic sediments. The nominal PO_4-P flux rate was taken as 8 mg/m_2/d while the nominal NH_4-N flux rate was taken as 80 mg/m^2/d based upon core-flux measurements (Anderson 2002). Assuming a lake area of approximately 3000 acres, this corresponds to annual PO_4-P and NH_4-N inputs to the water column of 35,452 kg and 354,520 kg, respectively.

4.3.1.2 Canyon Lake

Rates of nutrient flux from bottom sediment to the water column vary across Canyon Lake based upon bathymetry and relationship to inflows, and are further influenced by temperature and DO concentration. Based upon core-flux measurements made at a small number of sites (Anderson 2003), bathymetric survey results and hydroacoustic signature of the sediments, estimates of sediment nutrient flux rates were developed across the lake. Core-flux measurements indicated a modest positive increase in NH_4-N flux with water depth, while PO_4-P typically exhibited greater flux rates in shallower water, e.g., in East Bay where significant deposition of silt eroded from the watershed are typically deposited. Based upon these considerations, nominal flux rates across the lake for NH_4-N and PO_4-P were used in model simulations, shown in **Figures 4-22 and 4-23**, respectively.

Sediment nutrient flux rates in ELCOM-CAEDYM were specified at standard temperature and DO conditions for each bottom cell within the computational domain; the flux rate was then corrected for the temperature and DO condition present at each model time-step (Hipsey, 2014).

The average nominal flux rate for NH_4-N calculated from Figure 4-21 is 28.5 milligrams/square meter/day (mg/m^2/day), corresponding to a daily NH_4-N flux of 53.8 kg/day or 25,048 kg/year for the entire 436 acres of simulated lake bottom area. This represents an increase of 6,077 kg/yr over the estimated flux in the 2004 TMDL. The increase is most likely attributed to the larger bottom area involved in the lake water quality model simulation (436 acres compared with 300 acres). For PO_4-P flux, the estimated rate was 6.9 mg/m^2/d corresponding to an annual average load of 4,446 kg/yr. This load is very close to the load estimated for the 2004 TMDL despite the increased bottom area considered.

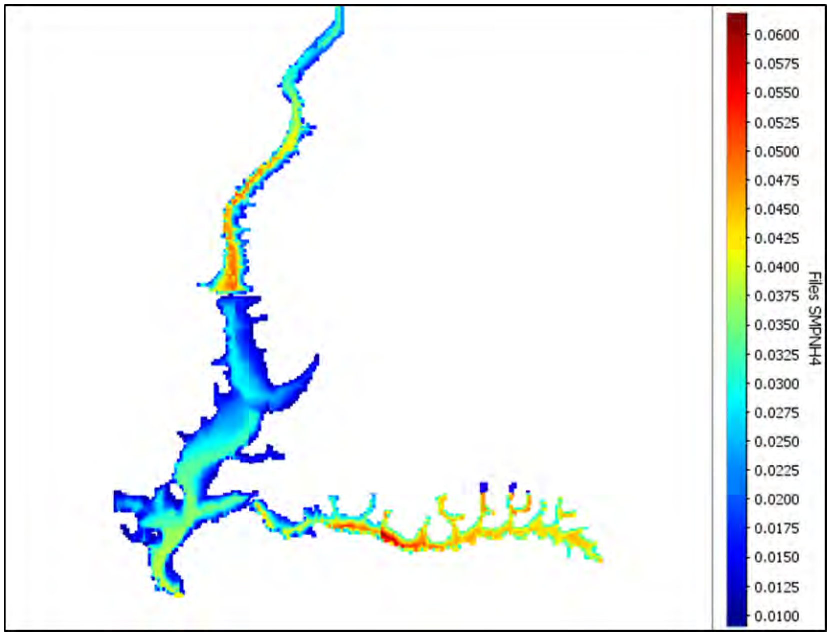

Figure 4-22. Modeled Flux rate (g/m^2/day) of NH_4-N from Canyon Lake Bottom Sediment to Overlying Water Column

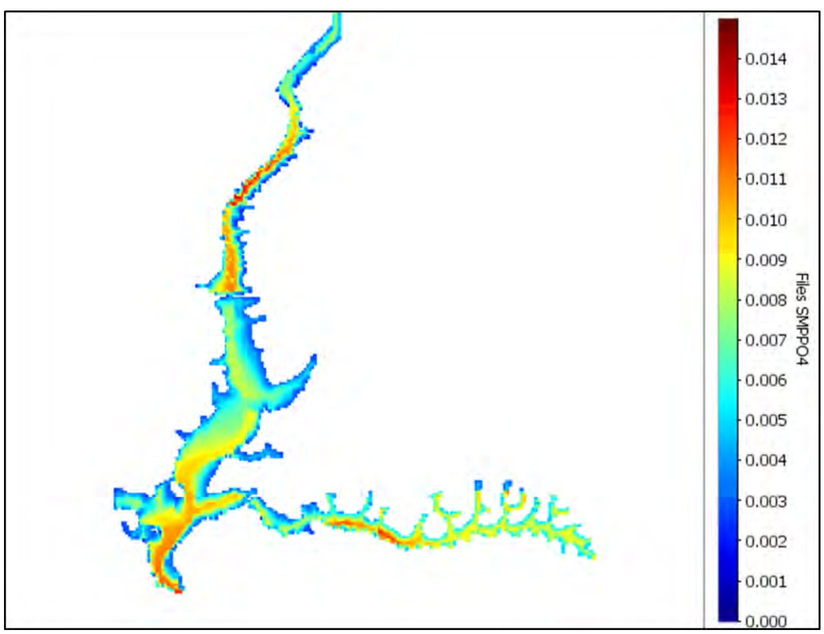

Figure 4-23. Modeled Flux Rate (g/m^2/day) of PO_4-P from Canyon Lake Bottom Sediment to Overlying Water Column

4.3.2 Atmospheric Deposition

Nutrients within air overlying the surface of the lakes settle onto the lake surface and act as a small source of nutrients to the lakes. Load estimates were developed for direct deposition from the atmosphere to the lake surfaces. Inconsistencies in the approach used to develop estimates for Canyon Lake and Lake Elsinore exist in the 2004 TMDL (Risk Sciences 2017). For example, depositional rates for TN employed for Canyon Lake and Lake Elsinore were based on differing regional literature values. The approach presented below is based on similar data used for the 2004 TMDL but ensures a consistent method for TN and TP is applied to each lake segment

Wet deposition of TP to each lake segment was estimated using literature values for TP wet deposition rates of 30 $kg/km^2/yr$ for Keystone Reservoir in Oklahoma (Walker 1996). Adjusting for differences in rainfall, average annual wet deposition for TP in Lake Elsinore and Canyon Lake was assumed to be 13 $kg/km^2/yr$ (0.05 kg/ac/yr). Assuming most TP deposition occurs as wet deposition, load allocations were developed as shown in **Table 4-10.**

Estimates for atmospheric deposition of TN are based on results of a wet and dry deposition sampling conducted as an element of a water quality study for Newport Bay conducted in 2002-2004 (Meixner et. al. 2004). Results showed that dry deposition accounts for most depositional load of TN, with seasonal average rates varying from 2 to 12 lbs/ac/yr (0.9 to 5.5 kg/ac/yr). The 2004 TMDL used a value of 7.1 lbs/ac/yr (3.2 kg/ac/yr) based on this study. No significant changes to atmospheric N deposition are expected nor is there any new regional data, therefore the same rates will be used in the TMDL revision. Table 4-10 shows the load allocation for TN in each lake segment.

Table 4-10. Estimated Nutrient Loads from Atmospheric Deposition onto Surface of Lake Elsinore and Canyon Lake

Lake Segment	Estimated TP Load (kg/yr)	Estimated TN Load (kg/yr)
Canyon Lake – Main Lake	17	1,077
Canyon Lake – East Bay	5	331
Lake Elsinore	156	9,682

4.4 Summary of Nutrient Sources

There are a several key sources of nutrients to Canyon Lake, Main Lake and East Bay, and Lake Elsinore. These sources vary seasonally and according to inter-annual climate patterns in their relative importance to water column nutrients. This source assessment describes the individual sources and quantifies long-term average loading of nutrients to each lake segment. **Table 4-11** presents a summary of all the general nutrient source categories for each lake segment. The relative contribution of each category is also shown as pie charts for Lake Elsinore in **Figure 4-24**, Canyon Lake Main Lake in **Figure 4-25**, and Canyon Lake East Bay in **Figure 4-26**.

The single most apparent finding when reviewing the relative source contributions shown in Figures 4-23 through 4-25 is that internal loads in the form of sediment nutrient flux dominate the long-term nutrient budget for Lake Elsinore, while external loads play a much greater role in the nutrient budgets for Canyon Lake, both in Main Lake and East Bay. This finding has profound consequences for developing compliance milestones and in specifying the most effective implementation approaches for each lake segment.

Recall the basis for setting numeric targets is to create a water quality condition that is equal to or better than what may occur without anthropogenic impacts in the San Jacinto River watershed. This chapter quantifies nutrient sources for the existing developed condition; however, the same general categories of nutrient sources would exist in a reference, or pre-developed, watershed condition. The difference between the nutrient loads expected from the reference watershed and what is currently occurring represents the reduction in nutrient loads that will be required and that will provide the basis for setting allocations. These allocations will be developed in Section 6.

Table 4-11. Summary of Nutrient Loads from All General Source Categories

General Source Category	Canyon Lake Main Lake		Canyon Lake East Bay		Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Watershed Runoff	6,160	29,065	2,109	10,105	5,222	20,898
Sediment Nutrient Flux	3,668	15,237	1,056	4,389	35,452	354,520
Atmospheric Deposition	144	1253	77	665	108	11,702
Supplemental Water	n/a	n/a	n/a	n/a	2,036	16,250
Total Average Annual Loading	**9,972**	**45,555**	**3,242**	**15,160**	**42,818**	**403,370**

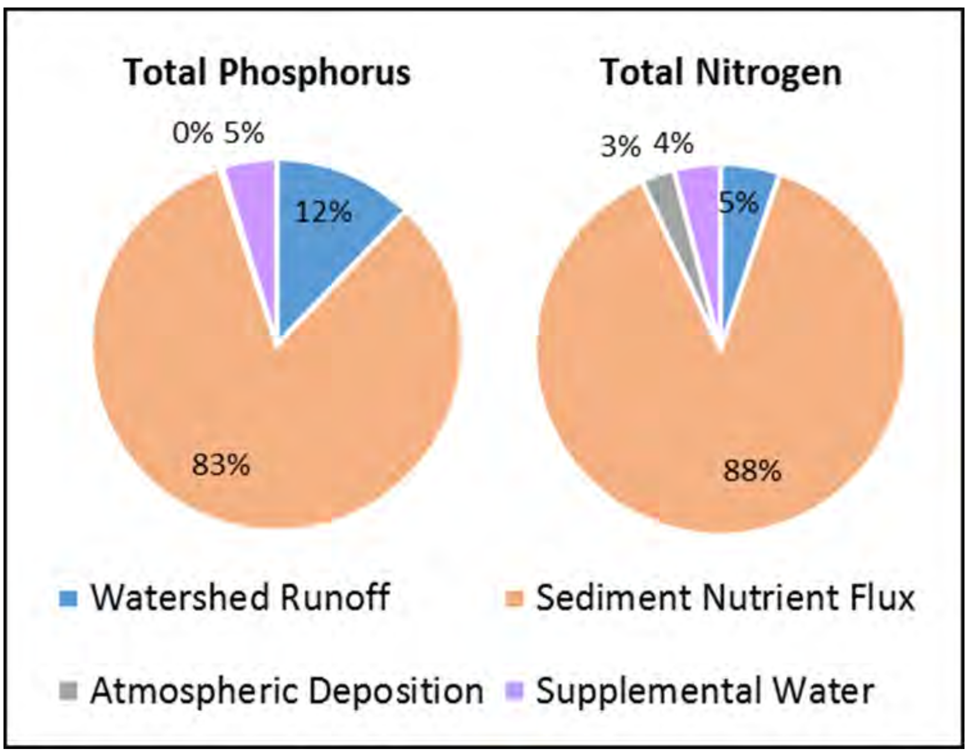

Figure 4-24. Relative Contribution of General Source Categories for Lake Elsinore Long-term Average Annual Nutrient Budget

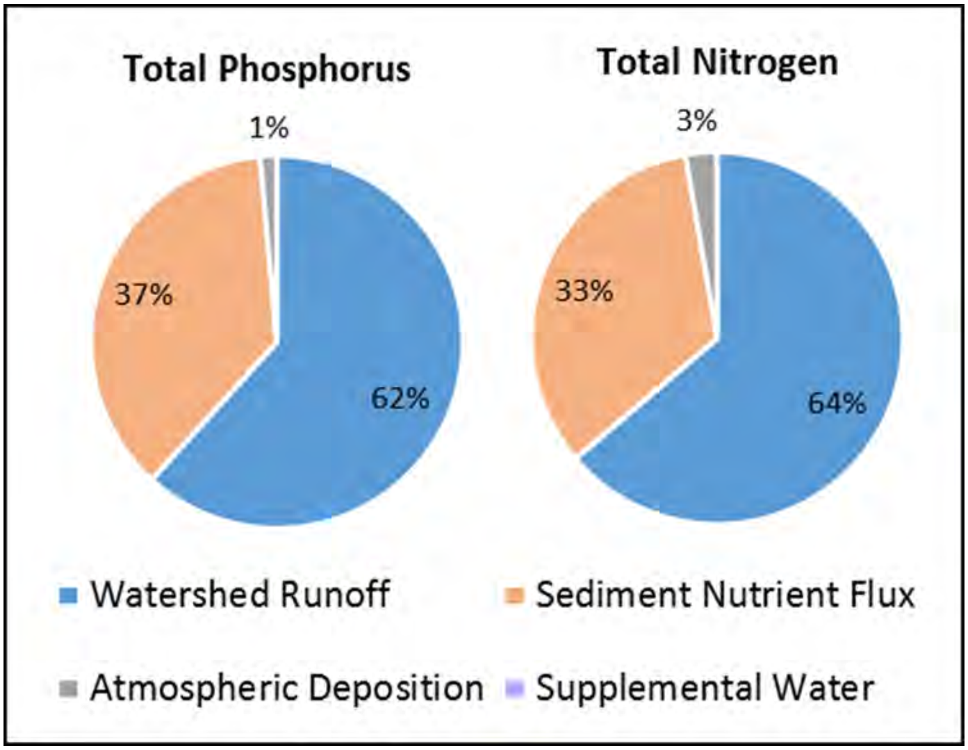

Figure 4-25. Relative Contribution of General Source Categories for Canyon Lake – Main Lake Long-term Average Annual Nutrient Budget

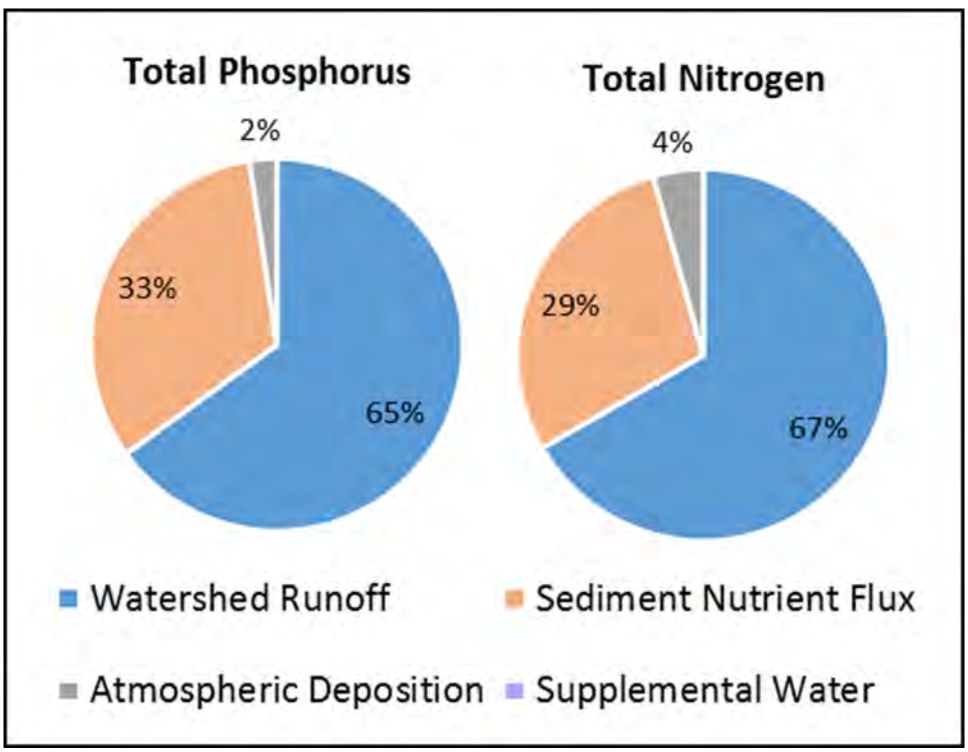

Figure 4-26. Relative Contribution of General Source Categories for Canyon Lake – East Bay Long-term Average Annual Nutrient Budget

Section 5

Linkage Analysis

The primary function of a TMDL linkage analysis is to establish a link between pollutant loading from multiple sources and water quality in receiving waters. The linkage analysis serves as a key step in the use of a reference watershed approach to determine numeric targets for the Lake Elsinore and Canyon Lake nutrient TMDLs. This reference watershed approach and its use to establish numeric targets was presented in Section 3. This section provides the following information:

- *Linkage Analysis Approach (Section 5.1)* - This section describes the role of the linkage analysis in the estimation of numeric targets for Lake Elsinore and Canyon Lake using the reference watershed approach. The basis for the Linkage Analysis involves application of lake models to simulate the biogeochemical processes within each lake segment.

- *Lake Model Descriptions (Section 5.2)* – The Lake Model Descriptions section describes the lake models employed in developing the linkage analysis. This effort involved coupling of a biogeochemical model with a hydrodynamic model to evaluate spatially and temporally varying water quality in each lake segment. The rationale for selection of CAEDYM to simulate biogeochemical processes in both lakes and use of different hydrodynamic models for each lake (DYRESM for Lake Elsinore; ELCOM for Canyon Lake) is discussed in this section.

- *Application of Lake Models in Lake Elsinore (Section 5.3) and Canyon Lake (Section 5.4)* – These sections are organized in the same way to present the simulation periods, boundary conditions, input data, and key parameter estimates for the Lake Elsinore and Canyon Lake models. It is important to develop a scenario representing current inflows and outflows and associated nutrient loads, to facilitate calibration of models to generate a good fit of hydrologic and water quality results with data measurements. The calibrated models are then subjected to runoff and nutrient loading from a hypothetical reference watershed to serve as the linkage between allowable loading and receiving water quality. Lastly, comparisons of modeled lake water quality for current and reference watershed conditions are presented to illustrate expected benefits within each lake segment anticipated with TMDL implementation.

5.1 Linkage Analysis Approach

The linkage analysis plays an important role in developing a revised TMDL using a reference watershed approach, which differs from a traditional stressor response TMDL. The following subsections describe how the linkage analysis fits into the revised TMDLs and provides a roadmap for the key inputs to the lake water quality models that have been used to conduct the linkage analysis.

5.1.1 Role of Linkage Analysis in TMDL Revision

The linkage analysis estimates water quality response variables, chlorophyll-*a* and DO, for different levels of external nutrient loading representing existing and reference watershed conditions. Results plotted as CDFs allow for an assessment of the difference between existing and reference watershed conditions. The expectation is that with implementation of BMPs to address the TMDLs, existing condition CDF curves will shift to be equal to or better than reference conditions, i.e., achieving the numeric targets (see Section 3 Numeric Targets).

Existing conditions approximate the current distribution of water quality in each of the three lake segments (Canyon Lake - Main Lake; Canyon Lake - East Bay; Lake Elsinore). A subset of the period of simulation for existing conditions is used to calibrate water quality model parameters to achieve a reasonable goodness-of-fit with measured data collected by the in-lake monitoring program. In the case of Lake Elsinore, the LEMP project was implemented to improve water quality by reducing the surface area of the lake and reclaimed water has been added to maintain water levels (see Section 2.2.2.3). LEMP and the addition of reclaimed water are accounted for as elements of the linkage analysis for existing conditions, but not as part of reference conditions.

The calibrated model developed for existing conditions was modified to evaluate water quality responses for alternative scenarios of reduced external or internal nutrient loads. For setting numeric targets, external nutrient loads to the lake models are reduced to levels expected for a reference nutrient concentration, as described in Sections 5.3.6 for Lake Elsinore and 5.4.6 for Canyon Lake. The lake models are also used to test the water quality benefits that may be achieved with existing and potential supplemental watershed BMPs and lake management scenarios (see Chapter 7: Implementation). The only physical structure included in the reference condition linkage analysis is Railroad Canyon Dam, because Canyon Lake would not exist without its presence. Simulation results for chlorophyll-*a* and DO, plotted as CDFs, serve as numeric targets for the revised TMDLs (see Section 3.3).

Lastly, the water quality models used to develop numeric targets for the lake segments will be used to test the potential benefits from existing and potential supplemental in-lake management strategies (see Section 7 Implementation).

5.1.2 Water Quality Model Development

The Problem Statement in Section 2 describes a unique condition for Lake Elsinore and Canyon Lake resulting from an El Nino-driven climate system within a drought-prone semi-arid region. For Lake Elsinore, climate and presence of upstream retention, including Canyon Lake, have created a natural cycle involving periods of complete lakebed desiccation. Numerical models were developed to characterize a full range of water quality responses for the greatest sources of variability, temporal in Lake Elsinore and spatial in Canyon Lake, as follows:

- *Lake Elsinore* – Lake models were developed to allow for multidecadal simulation periods needed to capture the full range of hydrologic conditions, including a period of known lakebed desiccation.

- *Canyon Lake* – Lake models were developed to allow for assessment of spatially variable water quality response, including vertical stratification and the presence of unique lake segments with limited mixing.

Numerical lake models leverage current scientific understanding of interactions among hydrology, nutrient loading, and resulting water quality in each lake. They also facilitate extrapolation of our current understanding out to hypothetical conditions in a reference watershed, or estimation of benefits from implementation of in-lake water quality control strategies. **Figure 5-1** provides a roadmap for the input data and model boundary conditions used to develop lake water quality models for Lake Elsinore and Canyon Lake.

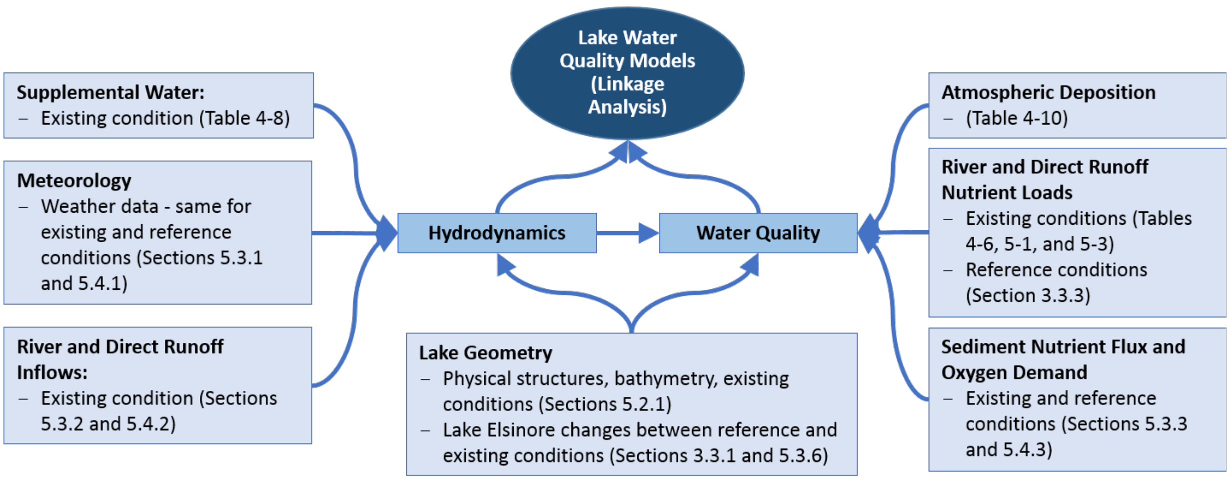

Figure 5-1. Document Location for Key Input Data and Boundary Conditions for Linkage Analysis

5.2 Essential Physical/Biogeochemical Processes and Model Selection

Water quality modeling involves evaluating both hydrodynamics and water quality. Hydrodynamic lake models solve energy, momentum and water budget equations to calculate density stratification, mixing, flow and transport, as well as lake level. Water quality models typically couple with hydrodynamic models, so that they can simulate water quality responses to changes in hydrodynamics. Several models have been developed to simulate hydrodynamics and water quality in lakes and reservoirs, including CE-QUAL-W2, Environmental Fluids Dynamic Code (EFDC), DYRESM-CAEDYM, and ELCOM-CAEDYM. These models vary in sophistication, with varying levels of dimensions represented and water quality processes included. The level of sophistication needed to capture water quality in Lake Elsinore and Canyon Lake depends on the key physical and biogeochemical processes in the lakes, which is discussed in the following sections.

5.2.1 Physical Model Characteristics

Mathematical representation of a lake or reservoir can in some cases be as simple as a 0-D continuous stirred tank reactor (CSTR) model (Thomann and Mueller 1987; Chapra 1997), or as detailed as a finely resolved 3-D model. In the case of a 0-D model, the total volume of a waterbody is considered to exhibit instantaneous, full mixing vertically and horizontally. This can be appropriate for a waterbody that is both shallow enough to show uniform characteristics throughout the water column and also shows little variation in water quality parameters in the horizontal direction.

Lakes and reservoirs tend to be more complex systems than a 0-D model can represent; water column variations in temperature tend to result from light penetration, and this often results in a layering effect in most inland waterbodies. The dynamics of the upper, mixed layer and the deeper, dense layer below are important for hydrodynamic and water quality evaluation, because primary production (and thus oxygen generation, among other things) only occurs where light is present. Buoyant forces derived from the density gradient limit vertical mixing of the water column, often resulting in an anoxic hypolimnion that is elevated in NH_4-N and PO_4-P and potentially also Mn^{2+}, Fe^{2+} and H_2S.

In lakes with relatively simple geometry and little horizontal differences in temperature or water quality, a 1-D model is often utilized. 1-D thermodynamic / hydrodynamic models such as DYRESM thus explicitly assume that the primary gradient in properties is in the vertical direction and treat the waterbody as uniformly mixed laterally. The advantage of a 1-D model is the low computational cost and high speed of simulations, thus allowing simulations of long periods of time and/or a large number of scenarios. As discussed below in more detail, this is the case with Lake Elsinore, which has simple enough geometry that lateral gradients in water quality parameters are not as important to water quality processes as capturing vertical variations.

For lakes and reservoirs with significant horizontal gradients in water column conditions, 2-D or 3-D representations are generally necessary. This is often the case with waterbodies that have complex geometry or spatial variations in water quality loadings. Geometric complexity of Canyon Lake, combined with its vertical stratification, require a 3-D model such as ELCOM to capture key processes of physical transport and vertical nutrient fluxes.

5.2.1.1 Lake Elsinore

Lake Elsinore is a relatively large lake (approximately 3,000 surface acres at a nominal lake surface elevation of 1240' above mean sea level [MSL]) that, including the channelized part of the lake linking it to the San Jacinto River, possesses a simple geometry (13.5 mile of shoreline, shoreline development number, D_L of 3.5). The relationship between depth and lake surface area is provided in **Figure 5-2**. As shown in lake monitoring reports (and summarized in Section 2.2.2.5),[1] measurements of temperature, DO, and TDS generally demonstrate limited lateral variation but stronger variation in the vertical direction. Satellite imagery sometimes demonstrates lateral gradients in chlorophyll-*a* concentrations that result from development and wind movement of algal blooms, but averaging over several days typically damps out short-term variability in chlorophyll-*a* concentrations. Apart from relatively rare large runoff events, pronounced lateral gradients in nutrients, TDS and other water quality properties are generally absent.

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[1] http://www.sawpa.org/collaboration/projects/lake-elsinore-canyon-lake-tmdl-task-force/

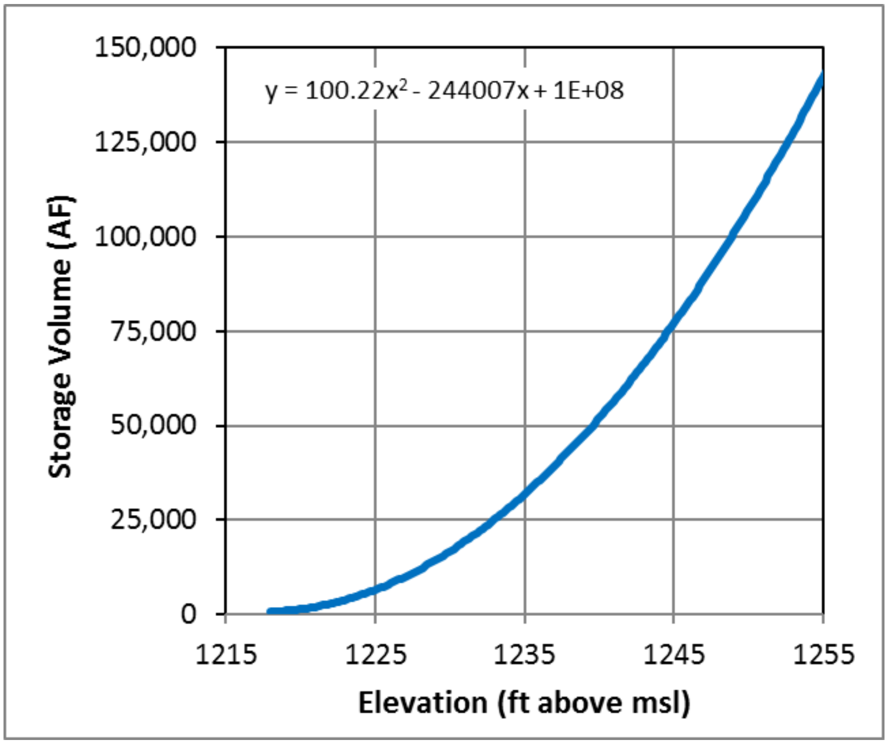

Figure 5-2. Lake Elsinore Elevation-Storage Volume Relationship

While strong lateral gradients are generally not persistent in Lake Elsinore, it is subject to extreme fluctuations in lake level and water quality over annual, decadal, and multidecadal scales (see Section 2.2.2.2 Problem Statement for history of lakebed desiccation). Thus, a long-term simulation that reflects several decades of hydrologic and meterologic variability is essential in representing the dynamics of lake water quality. The extreme fluctuations in lake volume also make calibration of a 3-D model difficult, as the model domain of a 3-D model itself would vary significantly as the lake volume changed. Because of the lake's limited horizontal gradients, significant vertical gradients, and extreme response to decade-scale forcings, the 1-D DYRESM Model v.4 for Lake Elsinore was adopted. DYRESM uses a Lagrangian approach in which the thickness of the vertical layer is calculated dynamically based upon heat inputs/losses at each time step, buoyancy/density differences between layers and available mixing energy that allows segregation or combination of adjacent layers.

5.2.1.2 Canyon Lake

The 3-D ELCOM model v.3 was adopted for use in Canyon Lake because of its complex, sinuous morphology (D_L=13.5). Strong gradients in properties exist in both vertical and lateral dimensions necessitating a 3-D model for the lake. A 20-m x 20-m lateral grid with 0.3-m vertical layers was developed for the model yielding 247 x 203 horizontal grid with 4,712 horizontal "wet" cells and 92,721 total cells in the simulation domain. To optimize hydraulic continuity and model processing time, a 40-second timestep was used for the simulations. Limitations on availability of USGS streamflow gage data above Canyon Lake and the intensive computational demand of a 3-D hydrodynamic/water quality model restricted the simulation to a 5-year time period. The period from 2007-2011 was selected based upon the wide range of hydrologic conditions and relatively complete water quality dataset over this period.

Canyon Lake is a smaller reservoir (436 acres, 19.7 mile shoreline) with a much more complex, sinuous morphology (D_L=13.5) reflecting impoundment of the San Jacinto River (to the north) near its confluence with Salt Creek (to the east). Lake bathymetry and geometry suggest that strong gradients in properties may exist in both vertical and lateral dimensions, necessitating a 3-D model for the lake (**Figure 5-3**). Thus, the 3-D ELCOM Model v.3 was adopted for use.

The TMDL revision includes separate allocations for Canyon Lake Main Lake and Canyon Lake East Bay. These lake segments have very different tributary drainage areas with San Jacinto River flowing to Main Lake and Salt Creek flowing to East Bay. There is minimal exchange between these two segments of Canyon Lake during dry weather conditions. They also have very different bathymetric characteristics as illustrated in the relationship between depth and lake surface area provided in Figure 5-3.

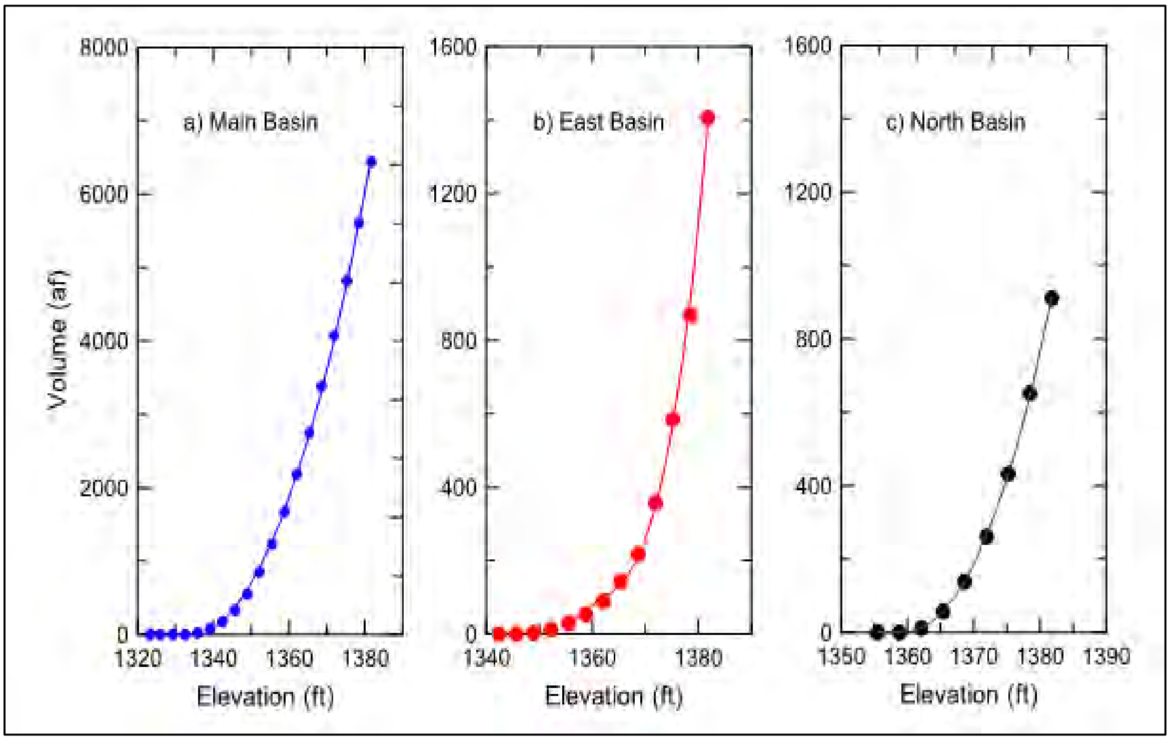

Figure 5-3. Canyon Lake Elevation-Volume Relationship for (a) Main Basin (Main Lake), (b) East Basin (East Bay), and (c) North Basin (North Ski Area)

5.2.2 Water Quality Model Characteristics

Water quality modeling can take many forms, from simple passive scalar transport to eutrophication models involving interactive kinetics and algal growth. A linked biogeochemical-ecological model can include a large number of interacting state variables, as described in Hersey et al. 2006.

For a scientifically defensible linkage analysis to support the development of numeric targets and estimation of nutrient reduction offset credits in Lake Elsinore and Canyon Lake, a eutrophication model is needed to simulate the relationships between nutrients, algae and DO. Nutrient fluxes into the water column from lake bottom sediments in both Lake Elsinore and Canyon Lake have been shown as an important source for water column concentrations (See Section 3.3 for discussion of Internal Sources). It is also critical that sediment fluxes be represented in the water quality model selected.

CAEDYM includes full eutrophication kinetics and can adequately represent water column water quality dynamics in both lakes. Water quality in Lake Elsinore and Canyon Lake was simulated using CAEDYM v.3. This model can be linked to both DYRESM and ELCOM, allowing for a consistent water quality solution between Lake Elsinore and Canyon Lake, while the hydrodynamics are tailored to the specific systems being modeled.

5.3 Lake Elsinore Model Configuration, Calibration and Scenario Simulations

The following subsections describe the meteorological, hydrologic, and water quality input data used to parameterize the DYRESM-CAEDYM model for Lake Elsinore. These subsections also (a) summarize the results after calibration of parameters to yield model simulation results for current conditions that approximate observations; and (b) describe how current condition (2000-2015) simulations used in calibration were modified to represent a reference condition for numeric target setting that account for long-term (1916-2016) lake water quality dynamics.

5.3.1 Meteorological Input Data

Meteorological inputs include the shortwave solar heat flux (300-3,000 nanometers [nm]) that includes photosynthetically available radiation (Photosynthetically Active Radiation [PAR], 400-700 nm), as well as near-ultraviolet (UV) (300-400 nm) and near-infrared (IR) and IR (700-3,000 nm), air temperature and windspeed.

Meteorological conditions for the calibration period were taken from the California Irrigation Management Information System (CIMIS) station #44 at UCR (**Figure 5-4**), which provided shortwave solar heat flux (300-3,000 nm) (Figure 5-4a), air temperature (Figure 5-4b) and windspeed (Figure 5-4c). Values are represented as daily average values in the model. A strong seasonal trend in solar shortwave heat flux is evident in the figure, with daily average shortwave flux values of about 350 watts/square meter (W/m^2) in the summer and 50-100 W/m^2 during the winter (Figure 5-4a). Daily average air temperatures exhibit a similar seasonal pattern, with daily-averaged summer temperatures near 30°C and daily average winter temperatures generally 7-10°C (Figure 5-4b). Daily average windspeeds averaged near 2 meters/second (m/s) and exhibited some seasonality as did daily rainfall rates that also showed annual variability (Figure 5-4c, d).

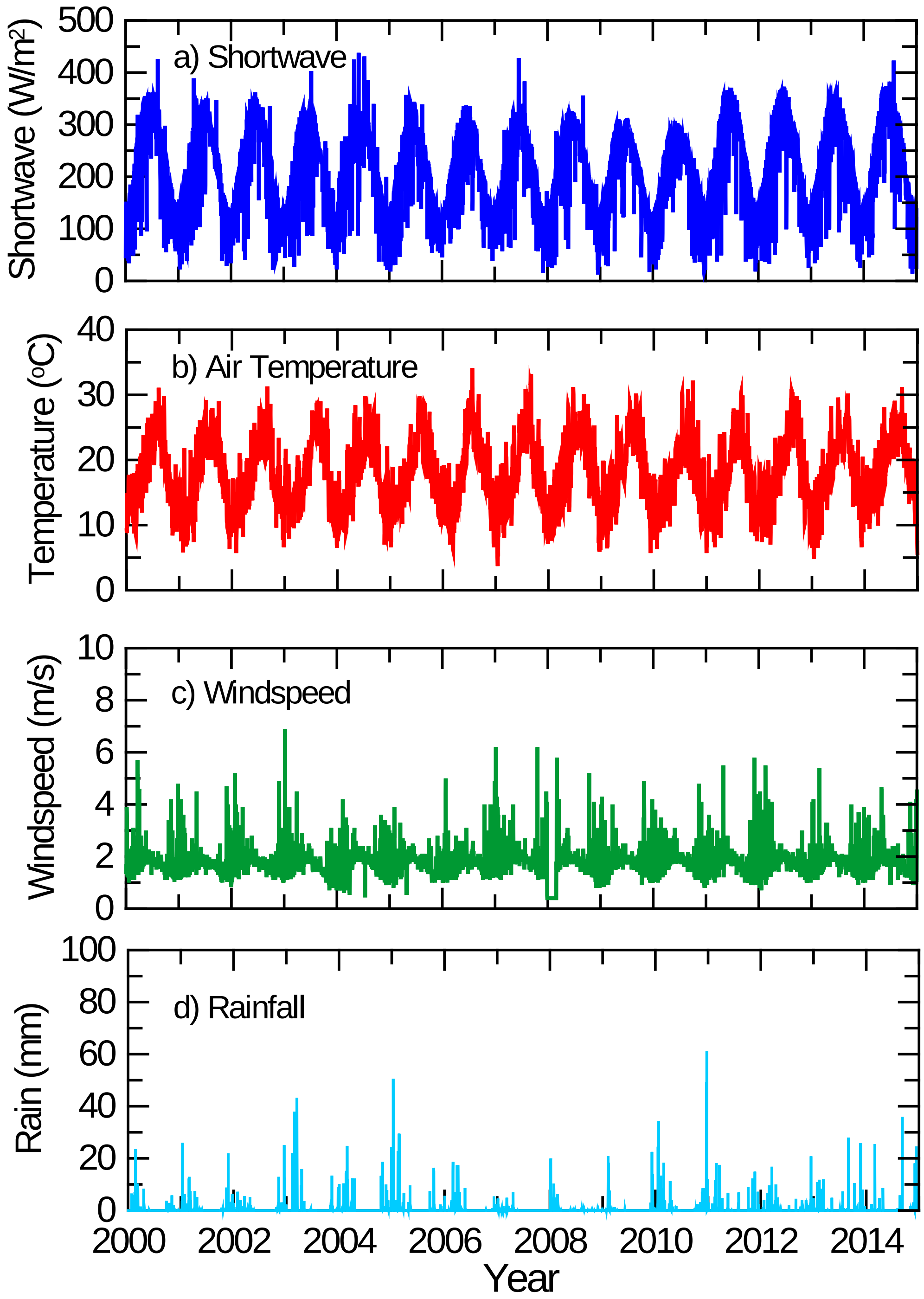

Figure 5-4. Daily Average (a) Shortwave Radiation, (b) Air Temperature, (c) Windspeed and (d) Rainfall Used in Model Simulations for the Calibration Period 2000-2014

5.3.2 Hydrologic Input Data

In addition to direct precipitation on the lake surface, water delivered to the lake included San Jacinto River flows, runoff from the local watershed, and supplemental water that includes recycled water from EVMWD and water pumped from island wells in 2003-2004 (collectively represented as recycled water in the model). Lake outflows include a lake outlet channel to downstream Temescal Creek.

The San Jacinto River is the primary watershed runoff inflow to Lake Elsinore and includes all overflow volume from Canyon Lake. Continuous flow data recorded at USGS Station 11070500 are input to the lake model. Daily runoff from the local watershed has been estimated in previous studies (Anderson 2015a), and yields are comparable to long-term average annual volume inflows (see Section 4, e.g., Table 4-4). Recycled water discharge to Lake Elsinore has been documented by EVMWD since production went on-line. All modeled inflows are shown in **Figure 5-5**.

A limited number of large runoff events delivered most of the flows from the San Jacinto River during this period, including the very large runoff events at the beginning of 2005, that included daily flow exceeding 8,000 acre-feet. Shorter duration high flow runoff events were also present in January 2010 and December 2011. Precipitation generated runoff from the local watershed contributed as well, although daily flows were much smaller than the very large runoff events noted in 2005, 2010 and 2011. Daily rates of recycled water flow are much lower than periods with wet weather runoff from the watershed. Presented as cumulative flows however, we see that recycled water inputs exceeded that of local runoff and contributed about 50,000 acre-feet since inputs began in late 2002 (**Figure 5-6**). Based upon these values, a total of 187,926 acre-feet of water was delivered to Lake Elsinore over this 2000-2014 period, with approximately 53% derived from San Jacinto River flows, 20% from local runoff and 27% from recycled water.

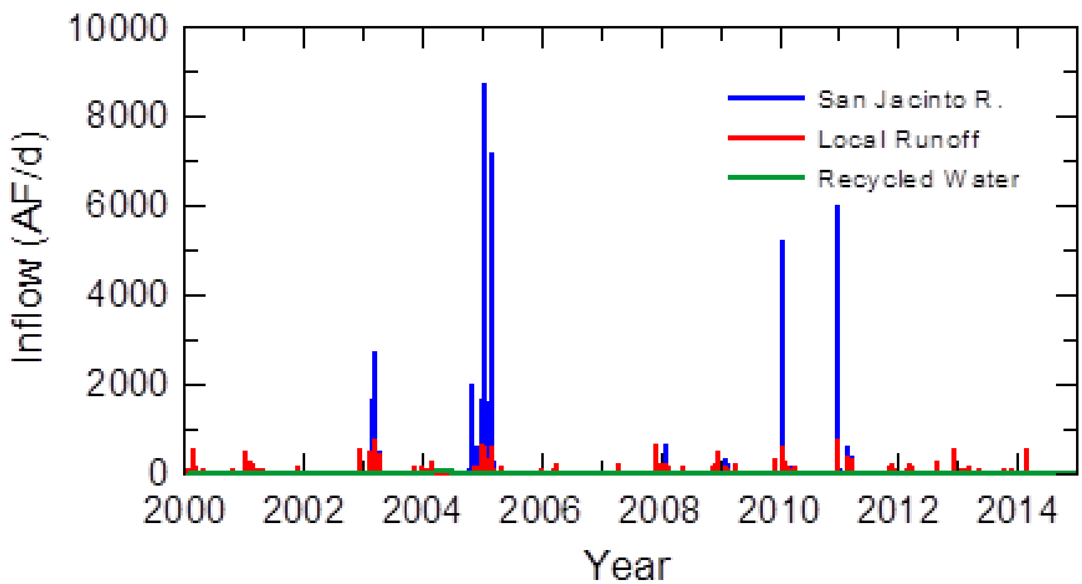

Figure 5-5. Inflows to Lake Elsinore for the Calibration Period 2000-2014

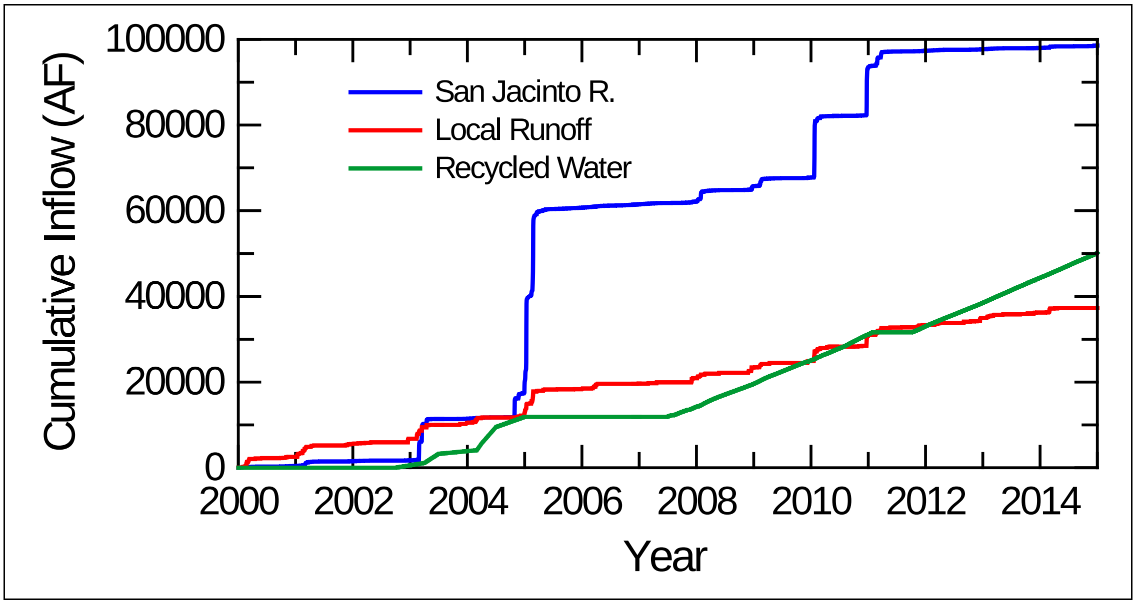

Figure 5-6. Cumulative Inflow to Lake Elsinore from the San Jacinto River, Local Runoff and Recycled Water for the Calibration Period 2000-2014

5.3.3 Nutrient Water Quality

Concentrations of nutrients in these inflows vary depending upon several factors, including intensity and duration of storms, interval of time between storms and other factors (including treatment plant operation for recycled water inputs). Average concentration values derived from storm runoff sampling within the watershed and treatment plant data were used in model simulations (**Table 5-1**). Total external nutrient loading over the calibration period was calculated from flow data (Figure 5-5) and nutrient concentrations (Table 5-1).

Table 5-1. Nutrient Concentrations (mg/L) of Inflows to Lake Elsinore Used in Model Simulations

Source	PO_4-P	Total P	NH_4-N	NO_3-N	Total N
San Jacinto River	0.28	0.51	0.22	0.57	1.89
Local Runoff	0.20	0.48	0.22	0.80	1.82
Recycled Water[1]	0.32	0.41	0.36	1.62	2.87

[1] Recycled water concentrations for EVMWD 2007-present

For internal water quality processes, default water quality parameters were used in CAEDYM (Hipsey et al. 2006) except for key parameters for bioavailable nutrient (soluble reactive phosphorus [SRP] and NH_4) fluxes and sediment oxygen demand (SOD), as follows:

- Internal loading of nutrients, i.e., the bioavailable nutrient flux from lake bottom sediment, is recognized as a very important process in Lake Elsinore, accounting for approximately 85 percent of long-term nutrient load (see Section 4). Measurements of internal loading have been conducted periodically at the lake using the core-flux method (Anderson 2001, 2010). Internal loading rates exhibit significant spatial and temporal variation based on core-flux estimates, largely driven by the non-uniformity of large rainfall events and settling of particulates to the lake bottom. For the TMDL revision, the average flux rates from previously collected core samples (100 milligrams/square meter/day [$mg/m^2/d$] NH_4-N and 10 $mg/m^2/d$ SRP) were assumed to approximate long-term average internal loading (see Section 4.3.1). The long-term average sediment nutrient flux rate is a constant input to CAEDYM for simulated nutrients for standard conditions. CAEDYM estimates a daily flux of dissolved nutrients as a function of dynamic changes in water temperature, DO, and pH.

- SOD is also high for this eutrophic lake (Anderson 2010); an average value of 0.8 grams/square meter/day ($g/m^2/d$) was used in the model calibration. To accommodate time constraints on modeling efforts, a static internal loading model was used in these simulations that allows internal loading rates to vary with temperature and DO, but does not explicitly simulate sediment deposition and associated biogeochemical changes resulting in nutrient recycling and efflux from sediments.

5.3.4 Model Calibration

The Lake Elsinore coupled DYRESM-CAEDYM model was calibrated against available data for 2000-2014. Model calibration was focused on assessing model-data agreement on an annual to decadal scale. For this reason, diurnal fluctuations in hydrodynamic and water quality parameters are not the focus of this calibration effort. The adequate representation of long-term trends implies representation of short-term trends for the purposes of this long-term TMDL study.

5.3.4.1 Lake Surface Elevation

Figure 5-7 contains a time series comparison between measured and modeled lake surface elevations during the calibration time period. Observations indicate a marked decline in elevation over the years 2000 through 2003, 2005 through 2010, and 2011 through 2014. A dramatic increase in elevation occurs at the end of 2004 and in early 2005. Modeled water surface elevations reflect all of these observed trends and also match closely in magnitude. Absolute model results match observations within a foot for the majority of the simulation.

5.3.4.2 Salinity

Salinity in the lake varied from approximately 700 – 2,600 mg/L TDS, with low concentrations following the very large runoff in winter 2005 (**Figure 5-8**, solid circles). The model captured trends in TDS reasonably well, including the high TDS concentrations measured in late fall 2002 and the marked decline in TDS in 2005 (Figure 5-8, line). The only discrepancy was found in 2014, when the model over-predicted TDS in the lake.

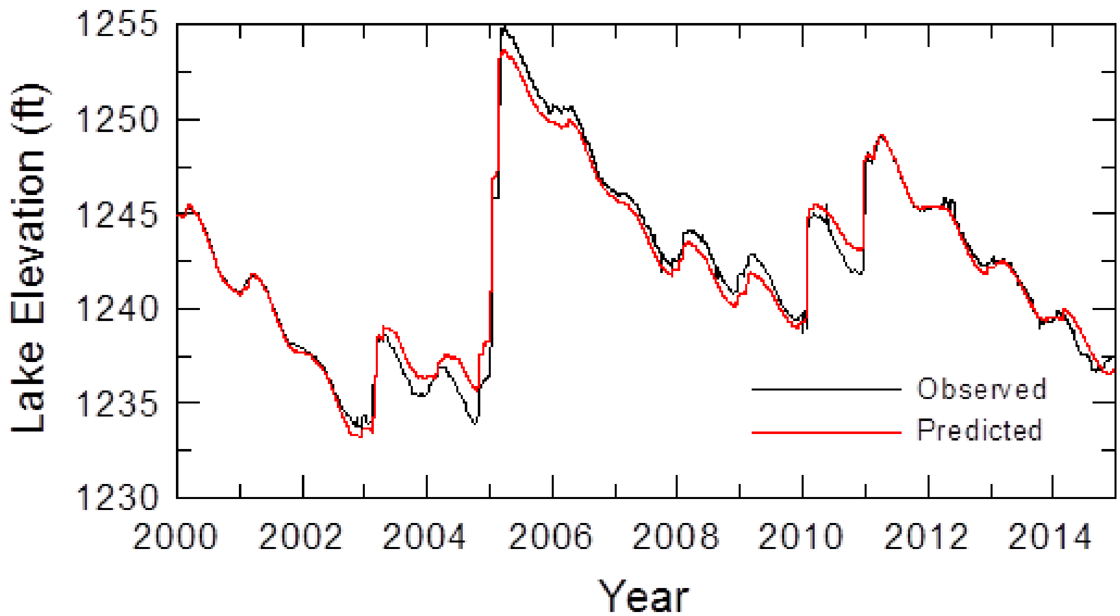

Figure 5-7. Predicted and Observed Lake Surface Elevation for the Calibration Period 2000-2014

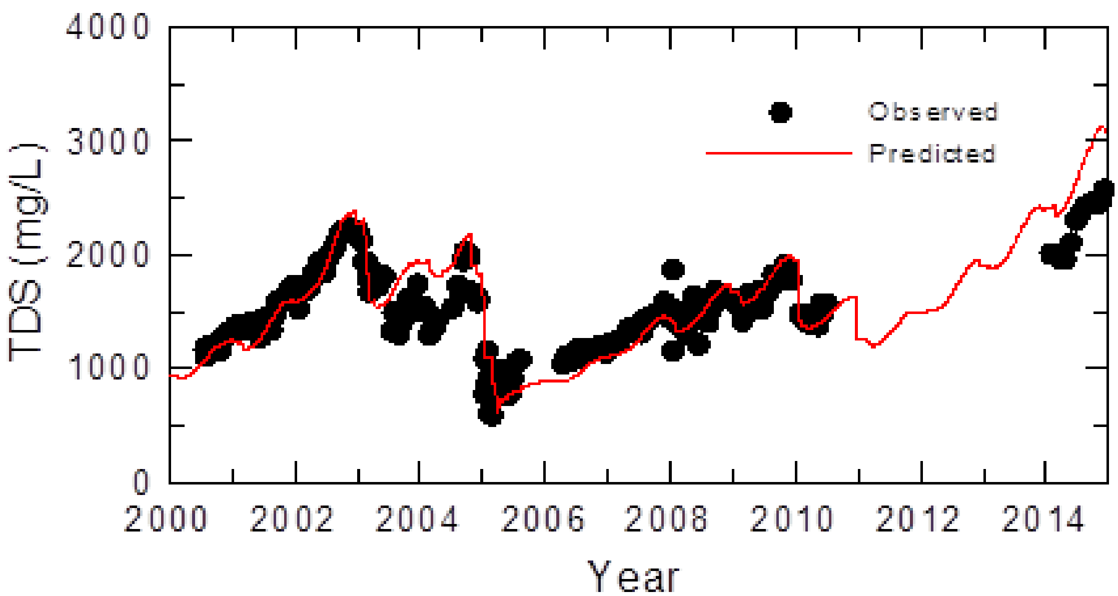

Figure 5-8. Predicted and Observed TDS Concentrations for the Calibration Period 2000-2014

5.3.4.3 Temperature

The model reasonably captured measured temperature values in Lake Elsinore (**Figure 5-9**). The model correctly predicted strong seasonal trends in water column temperature that reflects seasonal trends in solar shortwave heat flux (see Figure 5-4a) and air temperature (see Figure 5-4b). The model predicted summer values near 27°C and winter minimum values near 10°C, with little difference between depths reflecting weak stratification or mixed conditions commonly present in the lake (Figure 5-9).

5.3.4.4 Dissolved Oxygen

DO in the lake varied seasonally and with depth (**Figure 5-10**). The temperature effect on oxygen solubility was evident in model predictions for the 2-m depth, with DO values generally near 10 mg/L in the winter and 7-8 mg/L in the summer (Figure 5-10a). At the same time, supersaturation was periodically predicted (e.g., in spring 2011 when concentrations reached 17 mg/L). The model predicted DO concentrations deeper in the water column to be often quite similar to near-surface values, but did also correctly predict periods of anoxia in the summer of 2003, 2004, 2006 and 2010 (Figure 5-10b).

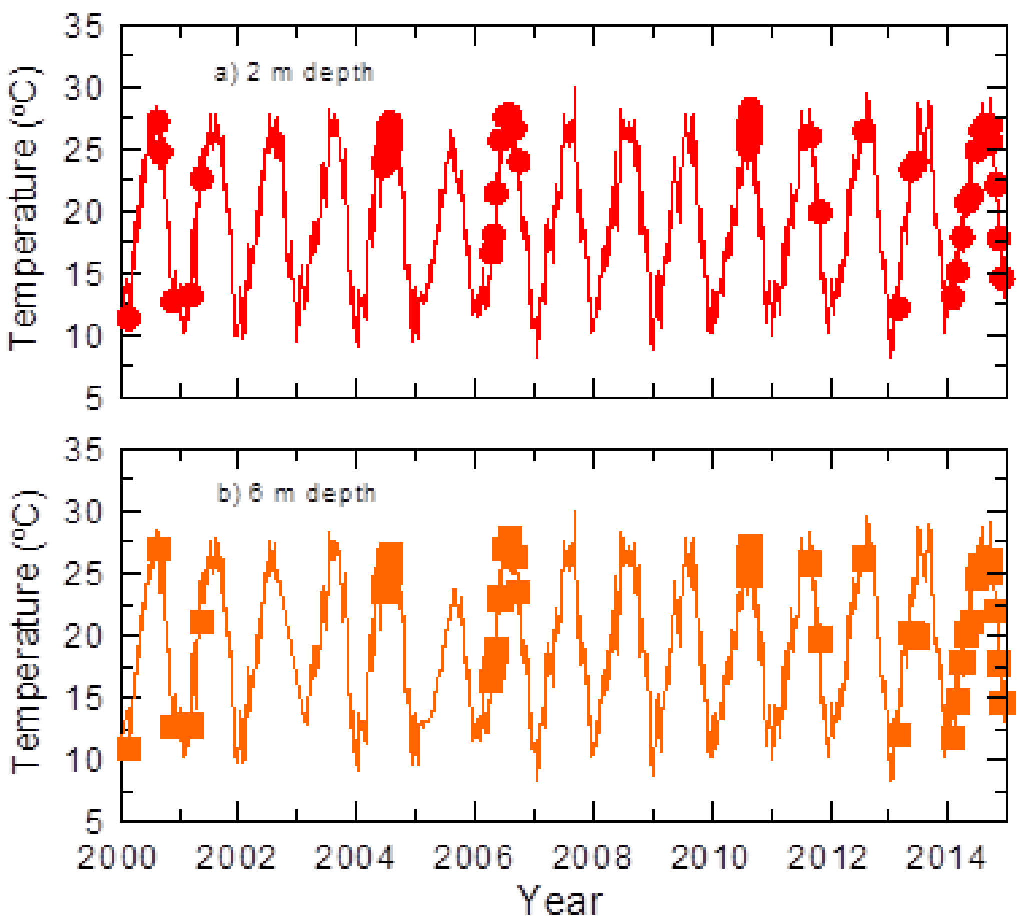

Figure 5-9. Predicted (line) and Observed (● or ■) Temperature at (a) 2-m and (b) 6-m Depths for the Calibration Period 2000-2014

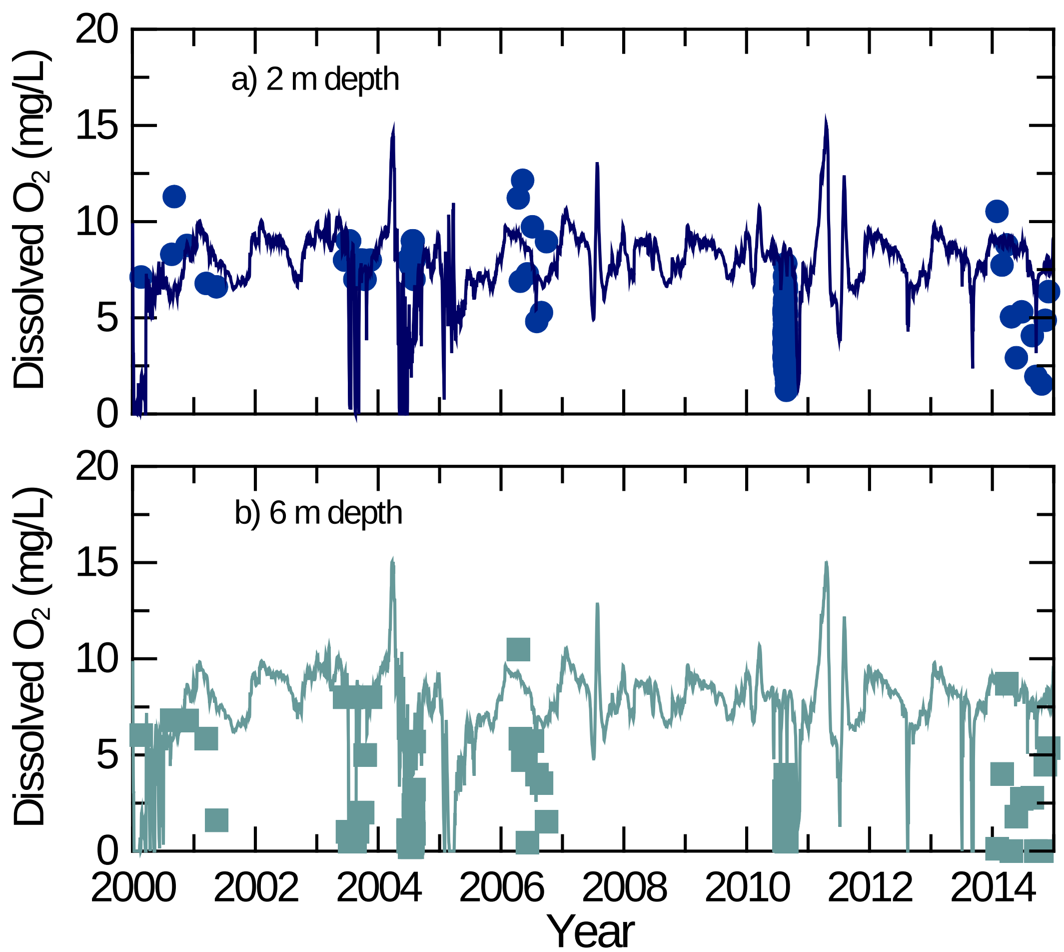

Figure 5-10. Predicted (line) and Observed (● or ■) Dissolved Oxygen Concentrations at (a) 2-m and (b) 6-m Depths for the Calibration Period 2000-2014

5.3.4.5 Total Nitrogen

The model did a fair job of capturing the dramatic trends in concentrations of TN in the lake between 2000 and 2015 (**Figure 5-11**). Concentrations increased from about 2 mg/L in 2000 to greater than 8 mg/L by late 2004, and then declined sharply with the very large runoff volumes delivered in winter of 2005 that quadrupled the volume of the lake. TN concentrations then edged up over several years before declining slightly in 2010 (Figure 5-11). While the model captured trends reasonably well, it did not reproduce the more significant apparent swings observed, e.g., in 2008, when reported concentrations over the period of a few months ranged from < 1 to > 8 mg/L. It may be that sampling bias or analytical challenges crept into the time series data, exaggerating short term trends.

5.3.4.6 Total Phosphorus

Total P concentrations also varied quite dramatically over this calibration period, from about 0.1 mg/L in 2000 to > 0.6 mg/L in late 2004 before declining to a value near 0.2 mg/L (**Figure 5-12**). The model generally captured trends but under predicted concentrations somewhat in 2003-2004, although it did predict a maximum value of about 0.6 mg/L in late 2004 (Figure 5-12).

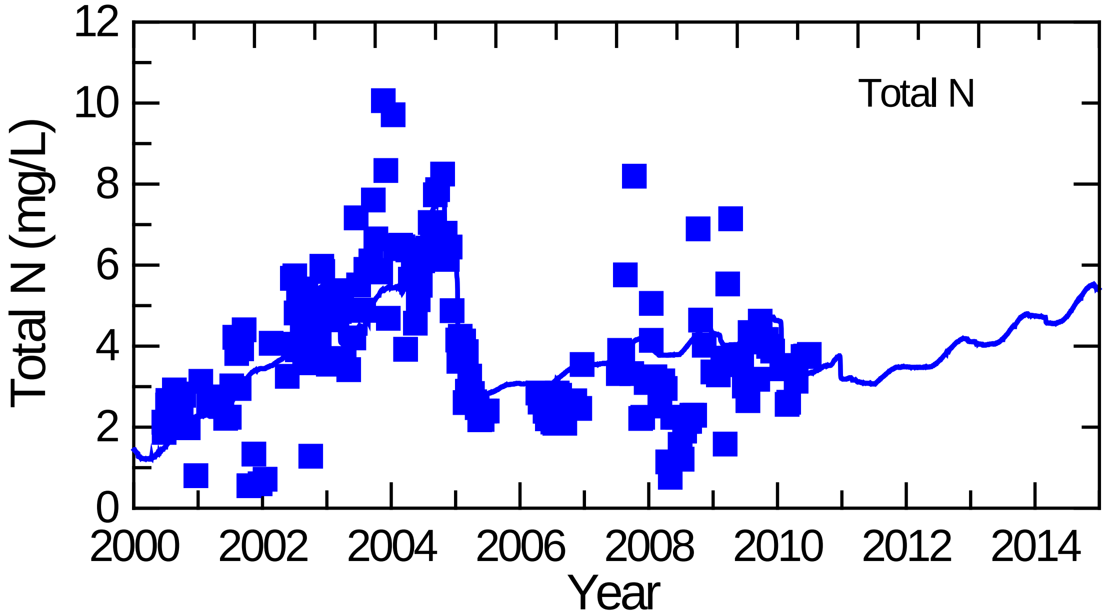

Figure 5-11. Predicted and Observed Total Nitrogen Concentrations for the Calibration Period 2000-2014

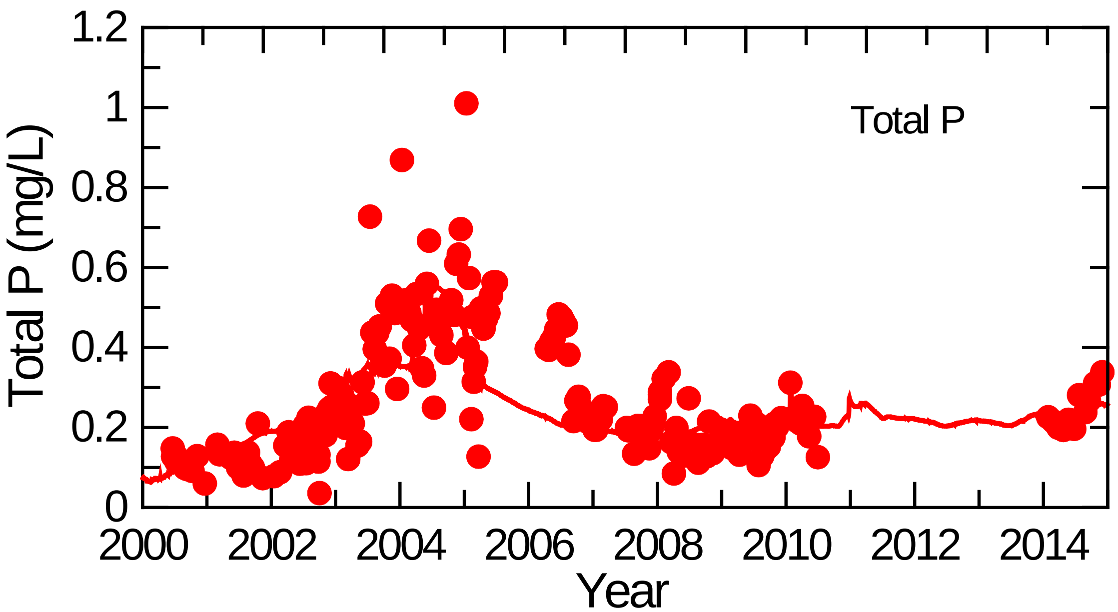

Figure 5-12. Predicted and Observed Total Phosphorus Concentrations for the Calibration Period 2000-2014

5.3.4.7 Chlorophyll-*a*

Measured chlorophyll-*a* concentrations exhibited pronounced seasonal and inter-annual variability, ranging from < 10 µg/L in some winters to > 300 µg/L in 2002, 2004 and 2014 (**Figure 5-13**, solid symbols). The model did a fair job overall in reproducing these complex trends and correctly predicted summer maximum chlorophyll-*a* concentrations in 2000-2004 (Figure 5-13, line). The model did not do as well predicting the winter minimum values however, and missed the particularly high concentrations observed in 2014 (Figure 5-13). Notwithstanding, the agreement between predicted and observed concentrations was considered acceptable given the highly dynamic algal community in the lake and the complex dependence of chlorophyll-*a* concentrations on nutrient availability and ecosystem structure.

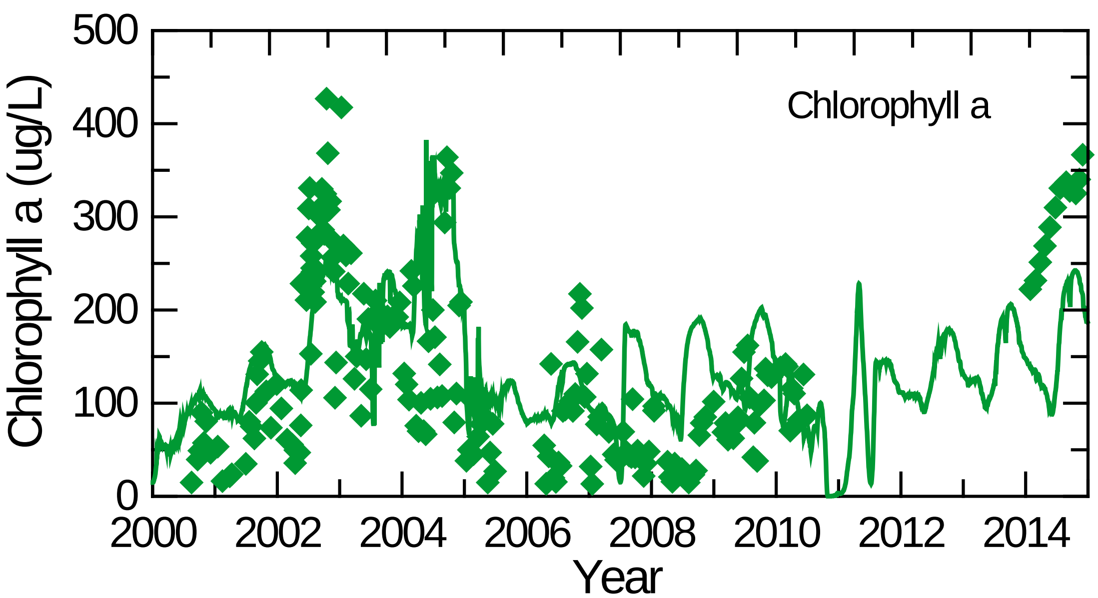

Figure 5-13. Predicted and Observed Chlorophyll-*a* Concentrations for the Calibration Period 2000-2014

5.3.5 Water Quality Model Summary Statistics

The overall goodness-of-fit of the model results to measured concentrations of TN, TP and chlorophyll-*a* was assessed using the relative percent error between predicted and observed average concentrations (**Table 5-2**). TN averaged 3.98 mg/L over this period, while the model yielded an average value of 3.88 mg/L, representing a 2.5% underestimate (Table 5-2). The average observed TP concentration over this period was 0.265 mg/L while the predicted average concentration was 0.235 mg/L, an 11.3% underestimate. Predicted and observed chlorophyll-*a* concentrations were 130 and 137 µg/L, corresponding to a % Relative Error (%RE) of 5.4%. Given the extreme range in conditions experienced at the lake over this 2000-2014 period, the model reasonably predicted water quality in Lake Elsinore under a wide range of hydrologic, chemical and ecological conditions, allowing for comparison of water quality under different conditions and scenarios.

Table 5-2. Mean Observed and Predicted Values of Key Water Quality Parameters for Calibration Period (2000-2014) for Lake Elsinore

Variable	Observed	Predicted	% Error
TN mg-N/L	3.98	3.88	-2.5
TP mg-P/L	0.265	0.235	-11.3
Chlorophyll-*a* µg/L	130	137	+5.4

5.3.6 Reference Condition Scenario Evaluation

The linkage analysis was used to evaluate the water quality conditions in Lake Elsinore for a scenario where external loads are reduced to levels representative of a reference watershed condition to develop numeric targets for response variables, ammonia-N, DO and chlorophyll-*a*. Section 3.2 describes the water quality input data and lakebed characteristics that define the reference condition for estimating numeric targets. This scenario was developed for a 99-year (1916-2015) simulation period coinciding with available daily flow data for the San Jacinto River near Elsinore USGS gauge 11070500. Watershed runoff from 90 percent of the Lake Elsinore watershed, including all Canyon Lake overflows, are recorded by this gauge. Rainfall records for Lake Elsinore (RCFCWCD Station# 067) also go back to 1916, facilitating estimation of daily runoff from the local Lake Elsinore watershed by applying a runoff coefficient model for this same period (Anderson 2015). Reference watershed nutrient concentrations are assumed to occur in the total (USGS gauge + local runoff model) daily inflow volume to Lake Elsinore.

A 1-D model allows simulation of conditions in the lake over long time periods due to relatively modest computational demands. A minimum layer thickness of 0.25 m and maximum layer thickness of 1.0 m was used for these simulations, with a 2-hr timestep. As discussed in Section 2.2.2.3, the LEMP involved construction of a levee to separate the main lake from the back basin, reducing the lake surface area from about 6,000 to 3,000 acres, thereby reducing evaporative losses and internal loading, and in turn improving water quality. This project is not included in the reference condition for Lake Elsinore, and therefore the much larger natural lake basin is used for the reference condition simulation. The respective elevation volume relationship for the reference condition lake basin is included in the plot of current conditions in Figure 5-2 above. **Figure 5-14** shows the footprint of the lake without the levee.

Results of the reference condition model for Lake Elsinore are plotted as time series in **Figure 5-15** for lake level, TDS, TP, TN, ammonia-N, DO and chlorophyll-*a*. The results for water quality response variables ammonia-N, DO, and chlorophyll-*a* are plotted as CDFs and serve as the basis for numeric targets (see Figures 3-6 through 3-8). The plots clearly show the impact of multidecadal trends in lake level upon TDS and nutrients, and in turn, upon response variables chlorophyll-*a* and DO for a naturally occurring reference watershed condition. While seasonal variability can be detected in the response variables, it is much less significant than longer-term trends, with highly productive periods (as indicated by rising chlorophyll-*a* concentrations and greater diurnal fluctuations in DO) persisting for multiple years or decades.

Figure 5-14. Comparison of Current Lake Elsinore Hydrography with Approximate Pre-LEMP Hydrography (shapefile from NHD)

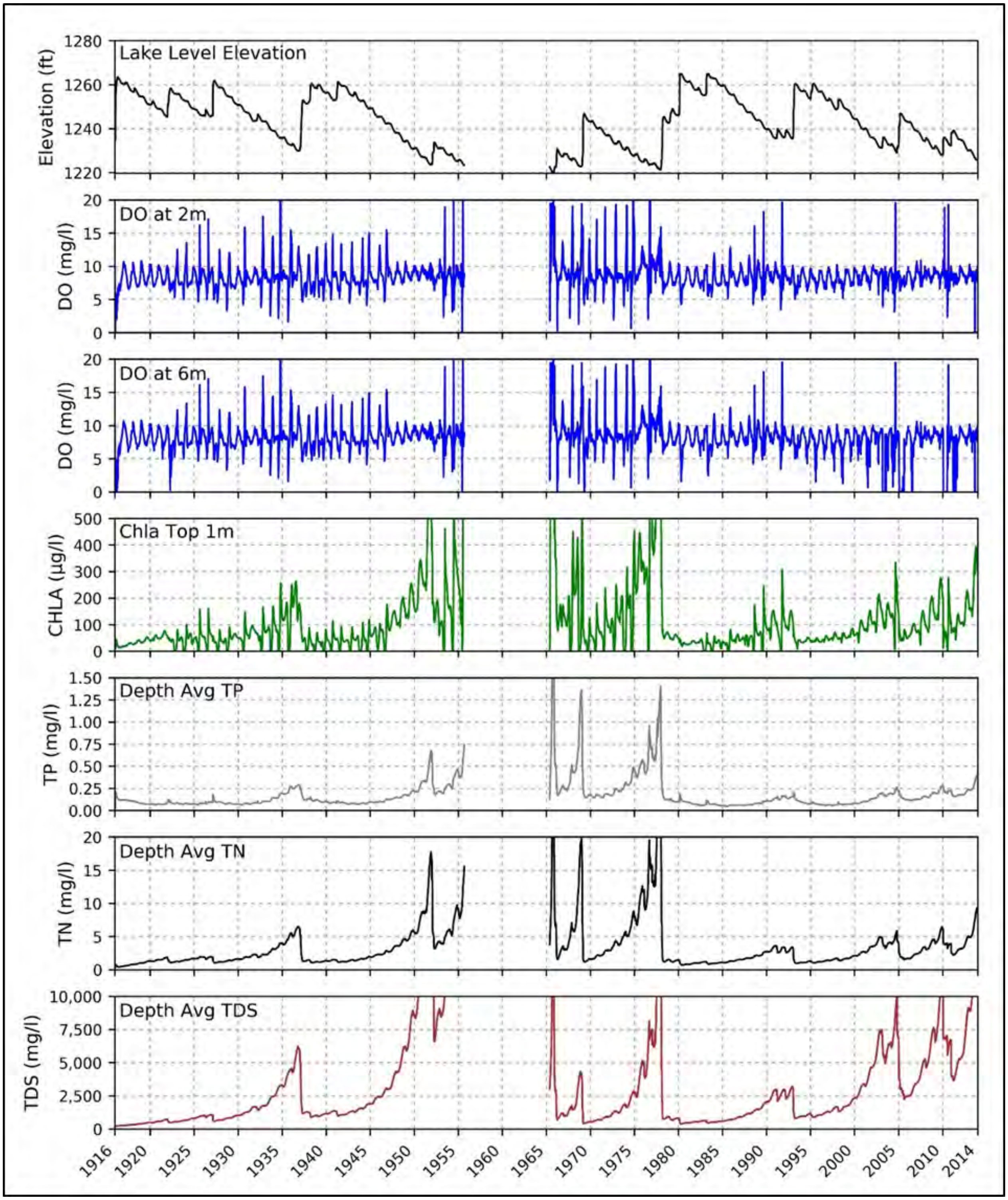

Figure 5-15. Time Series Output of Water Quality Parameters for Reference Condition Simulation for Lake Elsinore (1916-2015)

5.4 Canyon Lake Model Configuration, Calibration and Scenario Simulations

The following subsections describe the meteorological, hydrologic, and water quality input data used to parameterize the ELCOM-CAEDYM model for Canyon Lake. In addition, these subsection summarize the results after calibration of parameters to yield model simulation results for current conditions that approximate observations. Limitations on availability of USGS streamflow gage data above Canyon Lake and the intensive computational demand of the ELCOM 3-D hydrodynamic model restricted the simulation to a 5-year time period for calibration. The 2007-2011 period was selected based upon the wide range of hydrologic conditions and relatively complete water quality dataset over this period of time. The sections below also describe an ELCOM-CAEDYM reference condition scenario for numeric target setting that accounts for a longer simulation period (2000-2016) for lake water quality dynamics.

5.4.1 Meteorological Input Data

The model requires sufficient meteorological data to calculate instantaneous heat budgets for the lake and mixing due to wind shear and convective processes. Hourly meteorological data from the CIMIS station located near UCR, with correction for elevation difference, was used to drive the hydrodynamic-thermodynamic model. A wind-sheltering factor of 0.4 was applied for East Bay to account for the effects of steep topography on wind speed there. The model also requires information for inflows and withdrawals to account for turbulent kinetic energy inputs to the water column via these mechanisms. Flow data for the calibration period were taken from the USGS gaging stations on the San Jacinto River at Goetz Road (USGS gage #11070365) and on Salt Creek (USGS gage #11070465). Water quality measurements for the (limited) flows entering the lake over this period were not available, so average values from previous sampling conducted on the San Jacinto River and Salt Creek were used as inputs (Dyal and Anderson 2003). Information on volumetric withdrawals from the lake over this period were provided by EVMWD (J. Ma, personal communication).

Daily average meteorological data were calculated from hourly data and presented in **Figure 5-16**. As previously seen for Lake Elsinore, clear seasonal trends are evident in critical meteorological parameters. Daily solar shortwave radiation was low during the winter, with cloud cover during winter storms lowering the daily average flux to < 50 W/m^2 on numerous occasions (Figure 5-16a). Daily shortwave flux reached maximum values of > 300 W/m^2 in the early summer months (Figure 5-16a), although we note that maximum daily air temperatures were reached later in the summer (Figure 5-16b). Daily average wind speeds, while variable, were generally stronger during the winter months (Figure 5-16c), which in many cases coincided with rainfall events (Figure 5-16d).

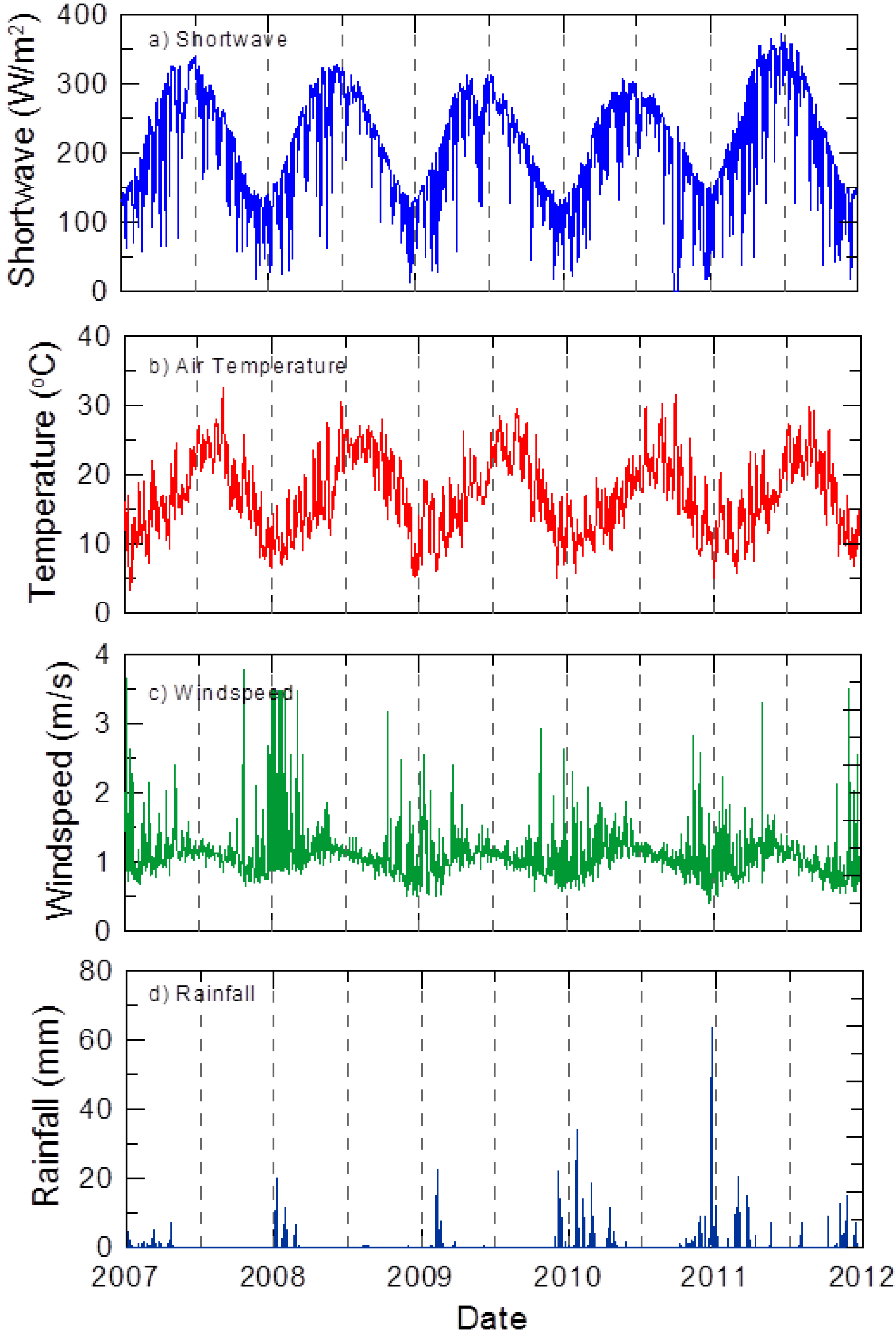

Figure 5-16. Daily Average (a) Shortwave Radiation, (b) Air Temperature, (c) Windspeed and (d) Rainfall Used in Model Simulations for Canyon Lake for the Calibration Period 2007-2011

5.4.2 Hydrologic Input Data

The majority of inflows for the Canyon Lake hydrologic budget involves runoff from the San Jacinto River and Salt Creek (**Figure 5-17**). Inflow data for the calibration period are taken from two USGS gauges; the San Jacinto River at Goetz Rd (Sta#11070365) and Salt Creek at Murrieta Road (Sta#11070465). These gauges measure runoff from 90 percent of the Canyon Lake drainage area, thus a scaling factor of 1.1 was applied to account for flows from the local Canyon Lake watershed (from lakeshore and Meadowbrook and Quail Valley tributaries). Generally, no flow is present during dry weather conditions as measured by USGS gauges. Rainfall driven runoff occurs in the wet season, and volume is dominated by few extremely large events (e.g., with > 2,000 and > 3,000 acre-feet/day (af/d) flows in Salt Creek and San Jacinto River in late December 2010) (Figure 5-17). It was previously noted that these extreme events are responsible for much of the external nutrient loading in a year, with large runoff years in turn dominating loading from the watershed for several years or more (Anderson 2012c).

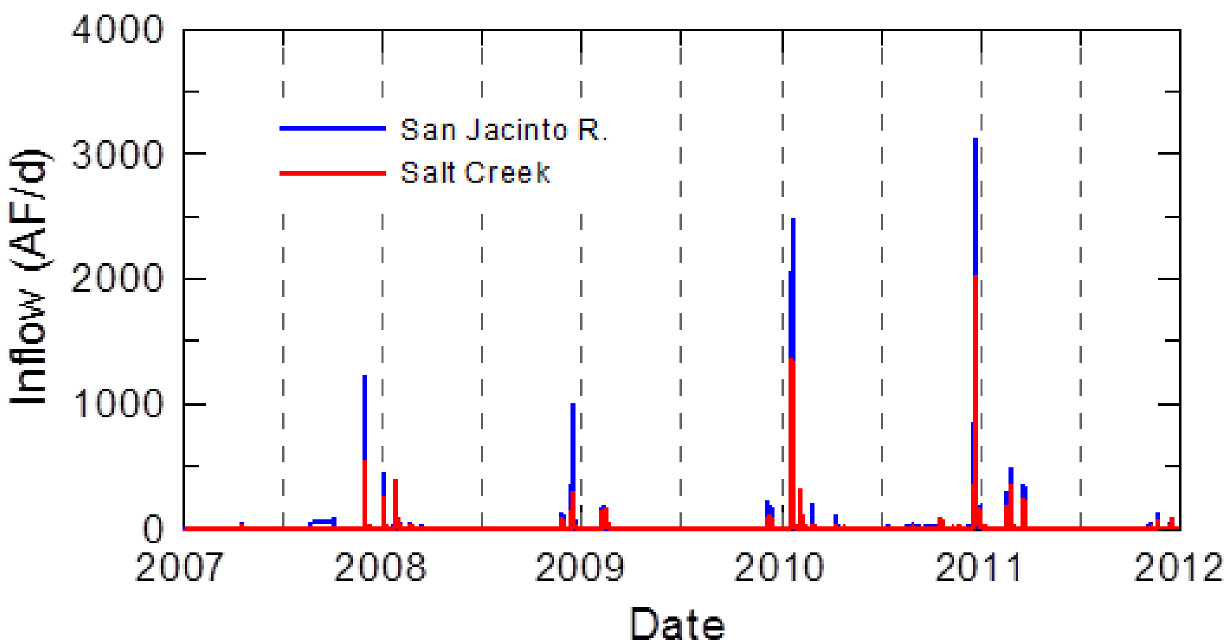

Figure 5-17. Daily Inflows to Canyon Lake for the Calibration Period 2007-2011

5.4.3 Nutrient Water Quality

Concentrations of nutrients in watershed runoff inflows vary depending upon a number of factors, including intensity and duration of storms, interval of time between storms and other factors (including retention in upstream lakes or channels). Average concentration values derived from runoff sampling within the watershed were used in model simulations (**Table 5-3**). Total external nutrient loading over the calibration period was calculated from flow data (see Figure 5-17) and nutrient concentrations (Table 5-3).

Table 5-3. Nutrient Concentrations (mg/L) of Inflows to Canyon Lake Used in Model Simulations

Source	PO_4-P	Total P	NH_4-N	NO_3-N	Total N
San Jacinto River	0.35	0.71	0.31	0.77	2.57
Salt Creek	0.27	0.54	0.29	0.75	2.49

For internal water quality processes, default water quality parameters were used in CAEDYM (Hipsey et al. 2006) except for key parameters for bioavailable nutrient (SRP and NH_4) fluxes and SOD, as follows:

- Rates of internal loading of nitrogen and phosphorus to the water column were separately measured in laboratory core-flux studies (Anderson 2001; Anderson 2007a). Samples collected prior to the commencement of alum addition in 2013, had average sediment nutrient flux rates of 43.3 mg/m^2/d for NH_4-N for the 3 main basin sites, with similar average flux rates also found for the two East Bay sites (45.0 mg/m^2/d). Average SRP flux from the sediments was lower than that of N (15.3 and 16.0 mg/m^2/d for the Main Lake and East Bay sites, respectively).

- SOD was determined based on Anderson (2001) and Anderson (2007a). Measurement conducted in July 2006 found SOD values of about 0.3 g/m^2/d, with very little difference between any of the sites (Anderson 2007a). Additional measurements made in April 2007 found slightly higher short-term SOD values (0.36-0.38 g/m^2/d), although longer-term SOD values were somewhat lower (0.22-0.25 g/m^2/d). An average SOD value of 0.3 g/m^2/d was used for the model calibration.

As with DYRESM, the ELCOM and CAEDYM models require a very large number of parameters; default values were used for almost all thermodynamic and chemical/biological/ecological values.

5.4.4 Model Calibration

The model was calibrated against water column data collected at Canyon Lake from January 2007 – December 2011. Samples were collected at varying intervals but were generally collected monthly to bimonthly. Hydrolab casts were made at five sites on the lake, providing vertical profile measurements of temperature, DO, pH, electrical conductance, oxidation-reduction potential, and turbidity. Depth-integrated surface samples were analyzed for chlorophyll-*a*, total and dissolved nutrients, and other constituents. Discrete samples were also collected at the thermocline, and composited discrete samples from two to three depths within the hypolimnion were also collected (except during the winter when the water column was well-mixed vertically and only a single depth-integrated sample was collected from each site). Section 2.2.3.3 summarizes monitoring program results from Canyon Lake; key data from this program were used for calibration in this section.

A large number of model simulations were conducted for the period January 1, 2007 – December 31, 2011; default model parameters were used in initial simulations and compared visually with observed data. Model parameters were varied to improve goodness-of-fit between observed and predicted values.

5.4.4.1 Lake Surface Elevation

The reported lake surface elevations (symbols) were reasonably well-reproduced in the simulation (solid red line). The model captured the evaporation and drawdown of about six feet that occurred each summer as well as the generally very rapid increase in lake surface elevation each winter to the spillway elevation (**Figure 5-18**).

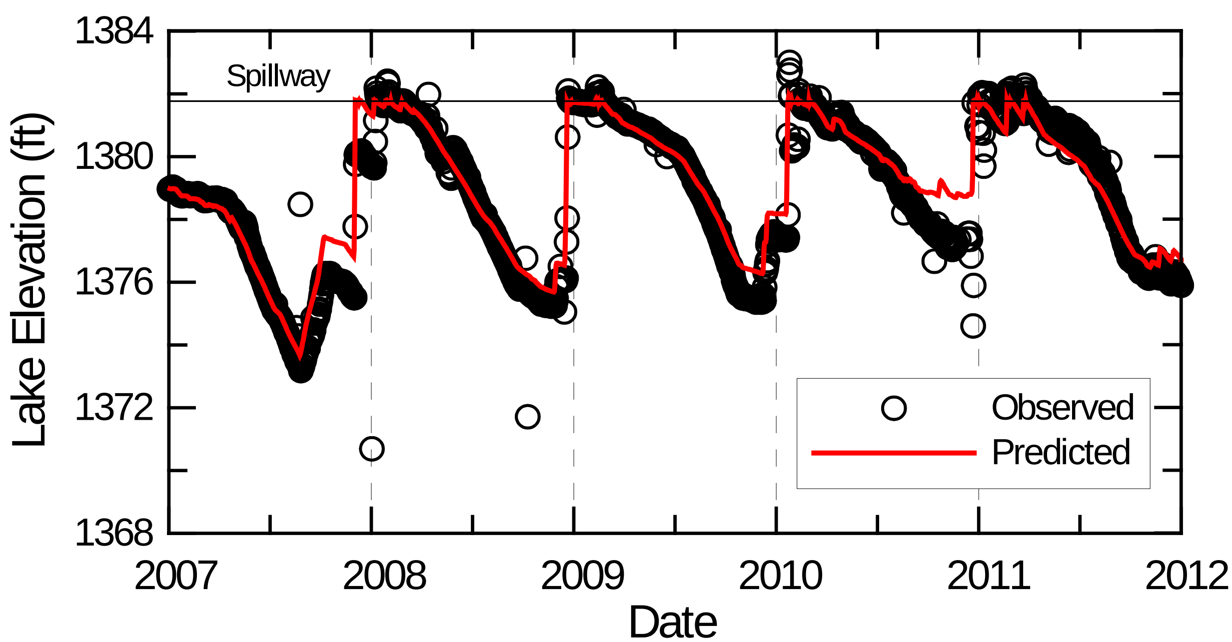

Figure 5-18. Lake Surface Elevation for the Calibration Period 2007-2011

Excluding some isolated outliers in the reported lake surface elevations, the only significant difference between observed and predicted values was found in late 2010, when the model predicted surface elevations near 1,379 ft., while reported values were closer to 1,377 ft. (Figure 5-18). The source of this discrepancy is not clear. Notwithstanding this anomaly, the model did a good job reproducing the average elevation over this period (1,378.71 vs. 1,378.79 ft. respectively), with %RE of 0.03%.

5.4.4.2 Temperature

Temperature is an important property in lakes, regulating stratification and governing rates of chemical and biological reactions. Observed temperature values at depths of 2-m (solid blue circles) and 12-m (open orange circles) for site Main Lake site M1 (and other sites) were reasonably reproduced in the simulation (**Figure 5-19**). The model captured the rapid increase in near-surface (2-m) temperature from about 10-12 °C in the winter to nearly 30°C in the summer, as well as the rapid decline in the fall (Figure 5-19) due to reduced solar shortwave radiation inputs and lower air temperatures (Figure 5-16 above). The %RE between predicted and observed temperatures for 2-m depth in the lake was 4.0% (n=80) with the mean predicted temperature of 21.3°C in good agreement with the observed mean value (21.5°C). The model (orange line) also reasonably reproduced temperatures at 12-m depth (orange symbols) that increased slowly during much of the year before increasing more dramatically in the fall during lake turnover (Figure 5-19). The model predicted a somewhat later turnover date in the fall of 2008 and 2010 compared with available temperature data, but reproduced turnover well in fall 2007 and 2009. The model discrepancy in fall 2010 was carried over somewhat in 2011, with the model predicting somewhat cooler conditions in the hypolimnion in the spring-summer of 2011 than observed. As a result, the %RE in temperature at 12-m depth was slightly higher (%RE of 8.7%), with the mean predicted value (12.6°) slightly lower than the mean observed value (13.3°C).

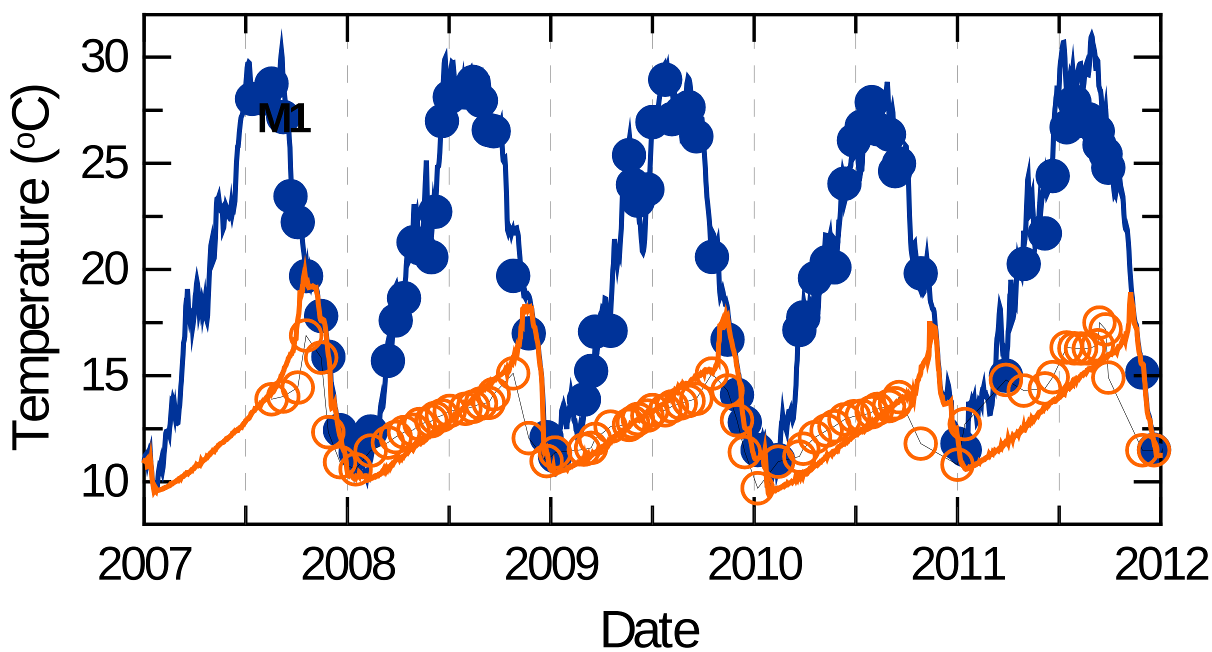

Figure 5-19. Measured and Model-Predicted Temperatures at 2-m (dark blue solid circles) and 12-m (orange open circles) Depths for the Calibration Period 2007-2011

5.4.4.3 Dissolved Oxygen

Unlike temperature, which can be simulated using ELCOM alone, prediction of DO requires CAEDYM due to the regulation of DO by biological and chemical processes. DO is specifically a function of photosynthetic production and respiratory loss by algae, sediment oxygen demand, microbial respiration in the water column, chemical demand by reduced substances, and other processes. Dissolved oxygen in Canyon Lake is highly dynamic, with concentrations in the epilimnion often supersaturated in the spring and very low in the fall following turnover. This can be seen in Figure 5-19, where the DO concentration at 2-m depth (solid symbols) reached nearly 14 mg/L or more in early spring in 2008 and late spring in 2009, but also dropped to 2 mg/L or lower in the surface water in the late fall following turnover (**Figure 5-20**). The model (dark red solid line) reproduced the trends reported for DO, with minima in the late fall and maximum values generally seen in the spring (Figure 5-20). The model did not always predict quite as high values in the summer as reported, and yielded a slightly lower mean predicted DO concentration at 2-m depth value of 7.28 mg/L compared with the mean observed value of 8.14 mg/L, and a %RE of 22.7%. Considerable effort was dedicated to calibrating the model while also retaining available laboratory measurements of SOD, internal nutrient loading rates, and other factors.

Dissolved oxygen at 12-m depth also exhibited strong seasonal variation, with concentrations often approaching saturation during the winter months when the lake was well-mixed vertically, but declining rapidly in the early spring and being typically < 0.1 mg/L most of the summer (Figure 5-20). The model reproduced this trend quite well, and yielded a mean DO concentration at 12-m depth of 1.27 mg/L, in pretty good agreement with the observed mean value of 0.99 mg/L, although %RE was quite high (75.6%) because of the large number of very low concentrations where even a modest difference yields a high relative error. Moreover, measurement values are also prone to error at very low concentrations, and concentrations near or below 1.0 mg/L exert similar biological effects so this model outcome is considered adequate.

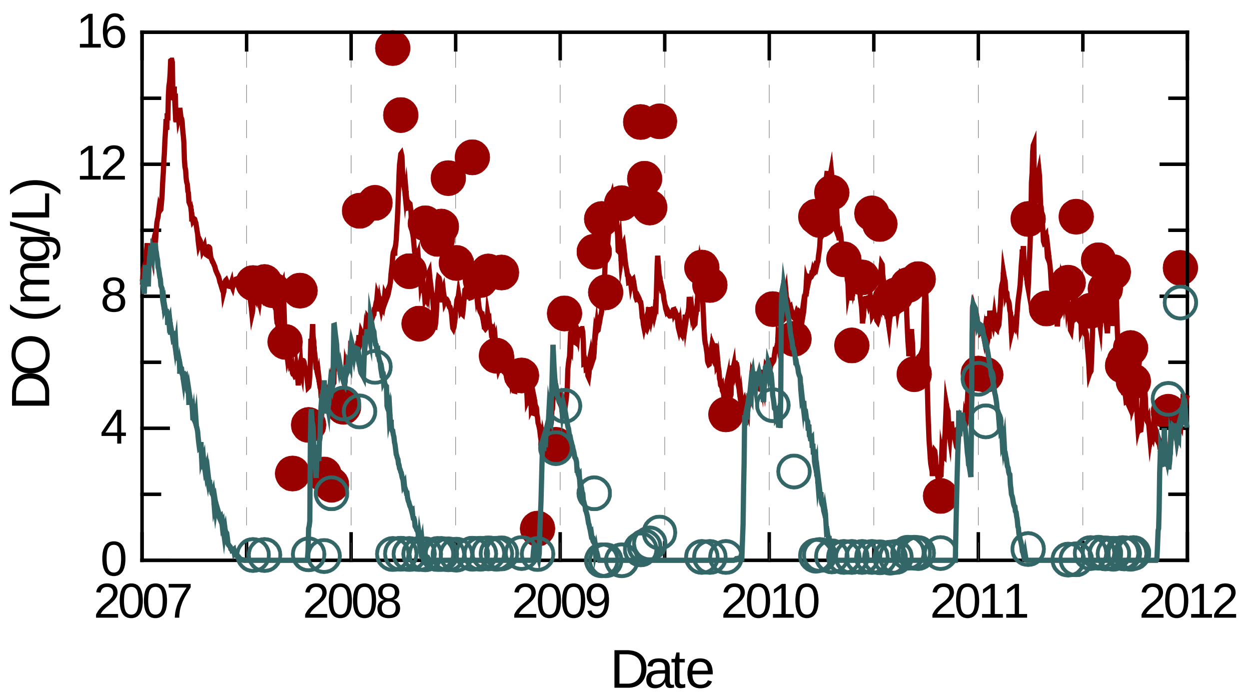

Figure 5-20. Measured and Model-Predicted Dissolved Oxygen at 2-m (dark red solid circles) and 12-m Depths (blue-green open circles) for the Calibration Period 2007-2011

5.4.4.4 Total Nitrogen

The observed concentrations over time of TN at 2-m depth and ammonium-N at 12-m depth are presented in **Figure 5-21** (solid blue symbols= TN at 2-m; open purple triangles=NH_4-N at 12-m). Most nitrogen in the hypolimnion during periods of stratification is expected be in the ammonia-N form. TN concentrations in the epilimnion tended to range from about 1-3 mg/L, although values < 0.5 and > 4 mg/L were also reported (Figure 5-21). The data showed seasonal trends in epilimnetic TN involving higher concentrations in the fall following lake overturn and with subsequent external loads from wet season runoff, followed by lower concentrations later in the spring and summer. This trend was difficult to reproduce in the model, however (%RE of 45.3% in Main Lake), and the predicted mean concentration of 1.24 mg/L was lower than the observed value. Ammonium-N in the hypolimnion was negligible during the winter following overturn of the water column while NH_4-N increased each spring and summer as a result of internal recycling and accumulation in the bottom waters (Figure 5-21). The model captured these general trends and yielded a mean predicted concentration of 0.85 mg/L in good agreement with the measured values on the same dates (0.81 mg/L) (n=61). The %RE between predicted and observed values across the available data for 2007-2011 was 41.3%. Observed nutrient concentrations were compared with predicted values at 12-m depth, although actual depth of samples tended to vary somewhat, so some error is thought to arise from that assumption.

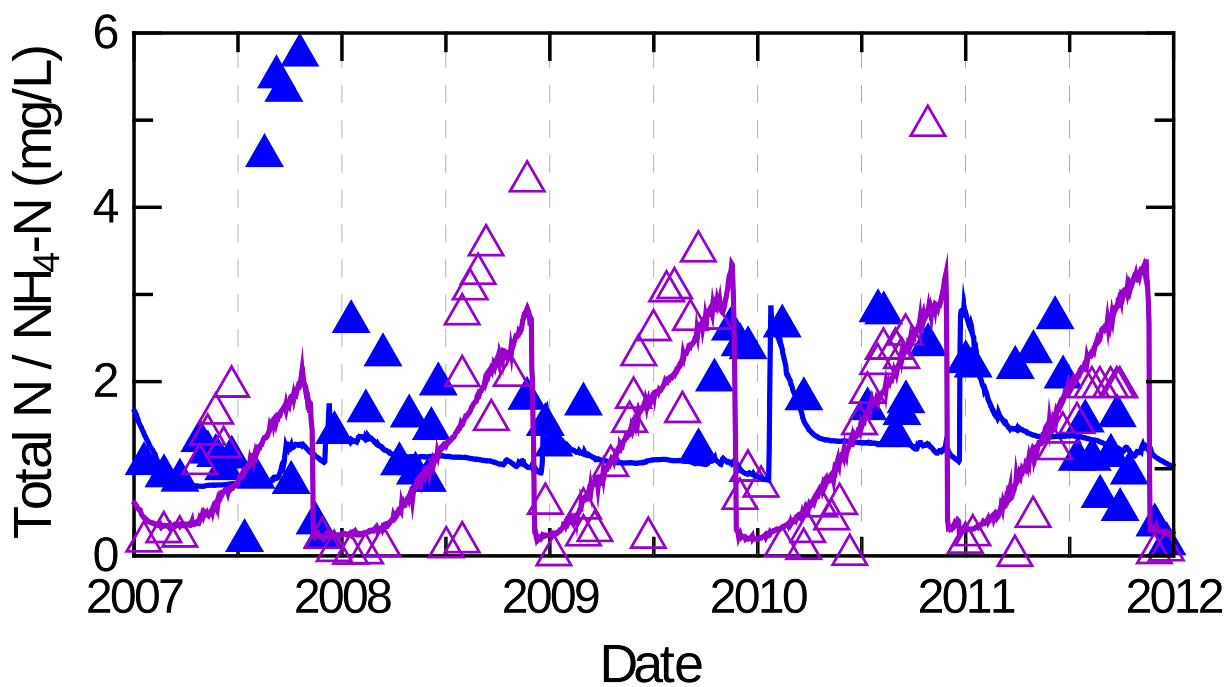

Figure 5-21. Measured and Model-Predicted Total Nitrogen at 2-m (blue, solid triangles) and 12-m Depths (purple, open triangle) for the Calibration Period 2007-2011

5.4.4.5 Total Phosphorus

TP in the epilimnion (2-m depth) exhibited temporal differences although a clearly defined seasonal trend was not readily evident, with concentrations ranging from 0.07 – 1.74 mg/L and a mean of 0.64 mg/L (**Figure 5-22**, solid red circles). The model did a good job of reproducing the average concentration of TP (0.66 mg/L), but did not capture the variability present in the data (modeled range of 0.40 – 1.2 mg/L) (Figure 5-22), with a %RE of 39.5%. Dissolved PO_4-P concentrations at 12-m depth exhibited clear seasonal trends similar to NH_4-N, with concentrations increasing each spring and summer to reach a maximum value in the fall immediately prior to turnover; concentrations often reached or exceeded 2 mg/L before fall sharply with mixing of the water column (Figure 5-22). The model predicted this seasonal trend but tended to underestimate the concentrations somewhat (mean measured and predicted concentrations of 1.15 and 0.71 mg/L, respectively, with a %RE of 47.2%). As with NH_4-N, some error between predicted and observed PO_4-P is also thought to arise from some differences in sampling depth.

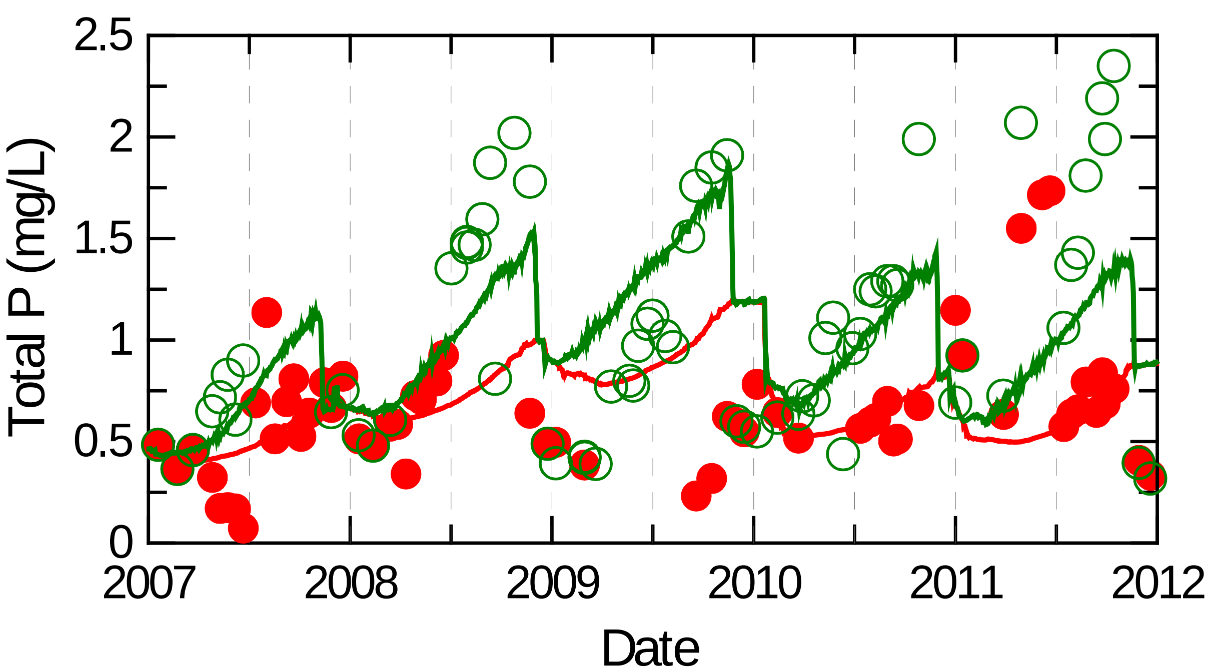

Figure 5-22. Measured and Model-Predicted Total Phosphorus at 2-m (red solid circles) and 12-m Depths (dark green open circles) for the Calibration Period 2007-2011

5.4.4.6 Chlorophyll-*a*

Chlorophyll-*a* concentrations exhibited strong seasonal differences, with low measured concentrations during the winter and much higher concentrations during the summer (**Figure 5-23**, solid symbols). Sampling was limited to a few dates in the winter of 2008 and 2009, so sampling in 2010 and 2011 offered the most complete sets of annual trends in chlorophyll-*a*. Model predictions reflected these seasonal trends in chlorophyll-*a*, with temporally-averaged concentrations in relative agreement between observed and predicted values (31.2 and 38.8

µg/L, respectively), similar minimum values (2.0 and 3.1 µg/L, respectively), and similar maximum values as well (73.1 and 77.6 µg/L, respectively). Notwithstanding, the timing of the phytoplankton blooms varied in some years, with a high %RE (66.8%). Given the complexity of reproducing the phytoplankton community in such a dynamic lake environment, the capacity to reproduce mean, minimum and maximum values suggests that the model can nonetheless be useful in describing water quality trends if not the specific timing of the blooms.

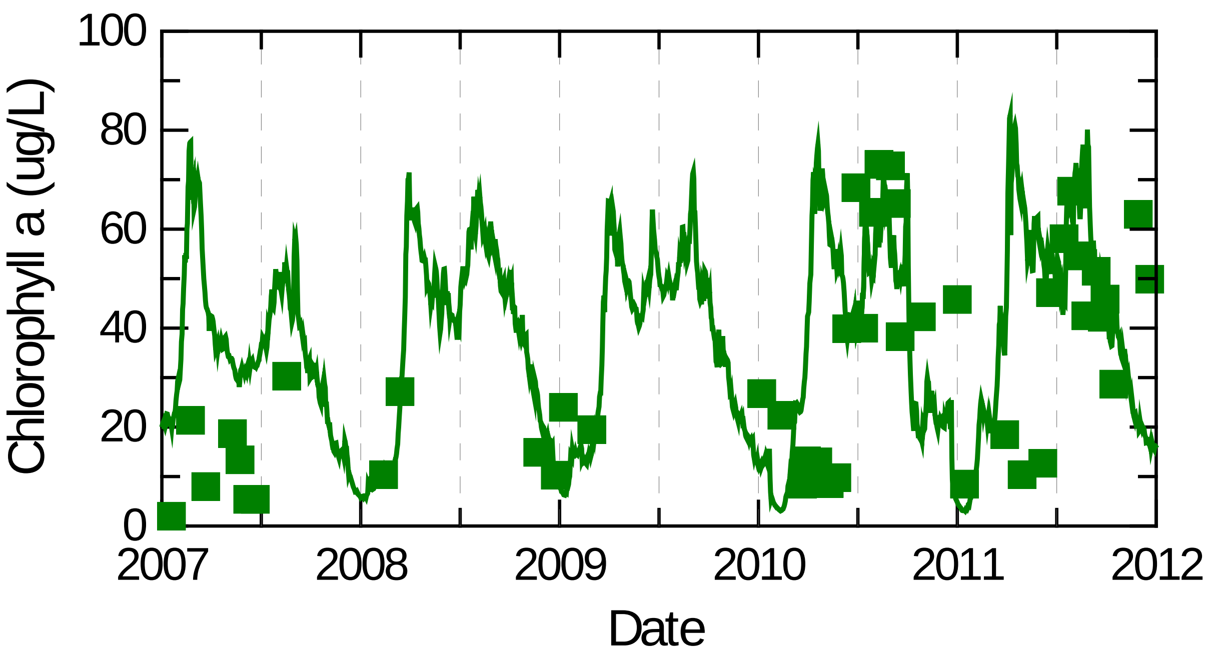

Figure 5-23. Measured and Model-Predicted Chlorophyll-*a* at 2-m Depth (green solid squares) for the Calibration Period 2007-2011

5.4.5 Water Quality Model Summary Statistics

The model could be calibrated to reproduce water quality for a single year, but disparities between predicted and observed properties generally increased when using a five-year calibration period (2007-2011). The comparatively long simulation period (5-yrs) with markedly different hydrology created extra challenges in simulating water quality in the lake. However, when looking at the five year means for water quality parameters, model results matched well with observed data in both Canyon Lake Main Lake (M1) and Canyon Lake East Bay (E2) (**Table 5-4**). On average, the model predicted similar mean DO and temperature within the hypolimnion of the Main Lake, based on results collected from 12-m depth below the lake surface.

Table 5-4. Mean Values for Observed and Predicted Water Quality Parameters (Observed / Predicted)

Site	Depth (m)	Temperature (°C)	DO (mg/L)	Chlorophyll-*a* (µg/L)	Total N (mg/L)	Total P (mg/L)
Main Lake (M1)	Epilimnion (2-m)	21.5 / 21.3	8.1 / 7.3	31.2 / 38.8	1.82 / 1.24	0.64 / 0.66
	Hypolimnion (12-m)	13.3 / 12.6	1.0 / 1.3	-	-	-
East Bay (E2)	Epilimnion (1-m)	-	-	53.3 / 53.7	1.88 / 1.35	0.55 / 0.64

The goodness-of-fit for trends in water quality parameters was assessed by computing the RE of model results with observed data on days when water quality samples were collected for TN, TP and chlorophyll-*a*. The average of REs for all discrete pairs of modeled and measured results for all water quality parameters ranged from 22.7 to 75.6 percent (**Table 5-5**). Discussion is provided above related to the goodness-of-fit for each parameter. Overall, the lake model calibration is considered acceptable given that a reference watershed approach, and not the linkage analysis, is used for estimating allowable external nutrient loads in the revised TMDL.

Table 5-5. Average of Percent Relative Errors Between Discrete pairs (sampled days) of Predicted and Observed Water Quality

Site	Depth (m)	Temperature (% error)	DO (% error)	Chlorophyll-*a* (% error)	Total N (% error)	Total P (% error)
Main Lake (M1)	Epilimnion (2-m)	4.0 (n=80)	22.7 (n=73)	66.8 (n=47)	45.3 (n=61)	39.5 (n=63)
	Hypolimnion (12-m)	8.7 (n=77)	75.6 (n=68)	-	-	-
East Bay (E2)	Epilimnion (1 m)	-	-	59.8 (n=66)	39.2 (n=73)	62.1 (n=73)

5.4.6 Reference Condition Scenario Evaluation

The linkage analysis was used to evaluate the water quality conditions in Canyon Lake for a scenario where external loads are reduced to be representative of a reference watershed condition to develop numeric targets for response variables, ammonia-N, DO and chlorophyll-*a*. Section 3.2.2 describes the water quality input data. This scenario was developed for a 15-year (2001-2016) simulation period coinciding with available daily flow data from USGS gauges for the San Jacinto River at Goetz Rd (Sta#11070365) and Salt Creek at Murrieta Road (Sta#11070465). Reference watershed nutrient concentrations are assumed to occur in the total daily inflow volume to Canyon Lake.

No changes were made to the Canyon Lake bathymetry or model resolution to run a reference condition scenario. Results of the reference condition model are plotted as time series in **Figure 5-24** for Canyon Lake Main Lake and **Figure 5-25** and Canyon Lake East Bay. Results include lake level, TDS, TP, TN, ammonia-N, DO and chlorophyll-*a*. The following observations were noted from these results:

- For both Main Lake and East Bay, algal productivity follows a seasonal pattern with an initial bloom toward the end of the wet season (February/March) that extends until the fall when days get shorter and wet weather provides some flushing of algae.
- Limited inter-annual variability exists in the magnitude of chlorophyll-*a* in both lake segments for a reference watershed condition.
- Apparent differences in nitrogen and phosphorus patterns can be attributed to both internal and external loading. Flux rates for nitrogen are about three times greater than for phosphorus, and this same proportion is reflected when comparing modeled depth average concentrations for nitrogen and phosphorus during dry seasons.
- Water column TP concentration resulting from sediment flux over the dry season is similar to the assumed concentration for external runoff inflows in a reference watershed condition; therefore, variability in phosphorus is much lower over the simulation period.
- Ammonia-N flux rates support a dry season depth average of about 0.5 mg/L, which is half of the TN assumed for external runoff inflows in a reference watershed condition. Therefore, external watershed runoff provides a considerable rise in water column TN concentration, especially for storm events with volumes in excess of the storage capacity (i.e., flushing the entire standing volume one or more times over a single storm).

Figures 5-26 through 5-29 illustrate vertical profiles of the ELCOM-CAEDYM Model results for DO, nutrients, and chlorophyll-*a* comparing existing with reference watershed conditions based on output from Station M1 in the Main Lake. Note the difference in magnitudes for the color ramps between existing and reference watershed conditions. One key observation is the persistence of low DO (below 5 mg/L) in the hypolimnion of Main Lake for both existing and reference watershed conditions. For nitrogen and phosphorus, the model estimated the greatest fluxes to occur in different years, with nitrogen fluxes increasing in dry seasons immediately following wet years and phosphorus fluxes greatest in drought years. Chlorophyll-*a* was found to grow deeper in the water column toward the end of the growing season which served to reduce the area of anoxia.

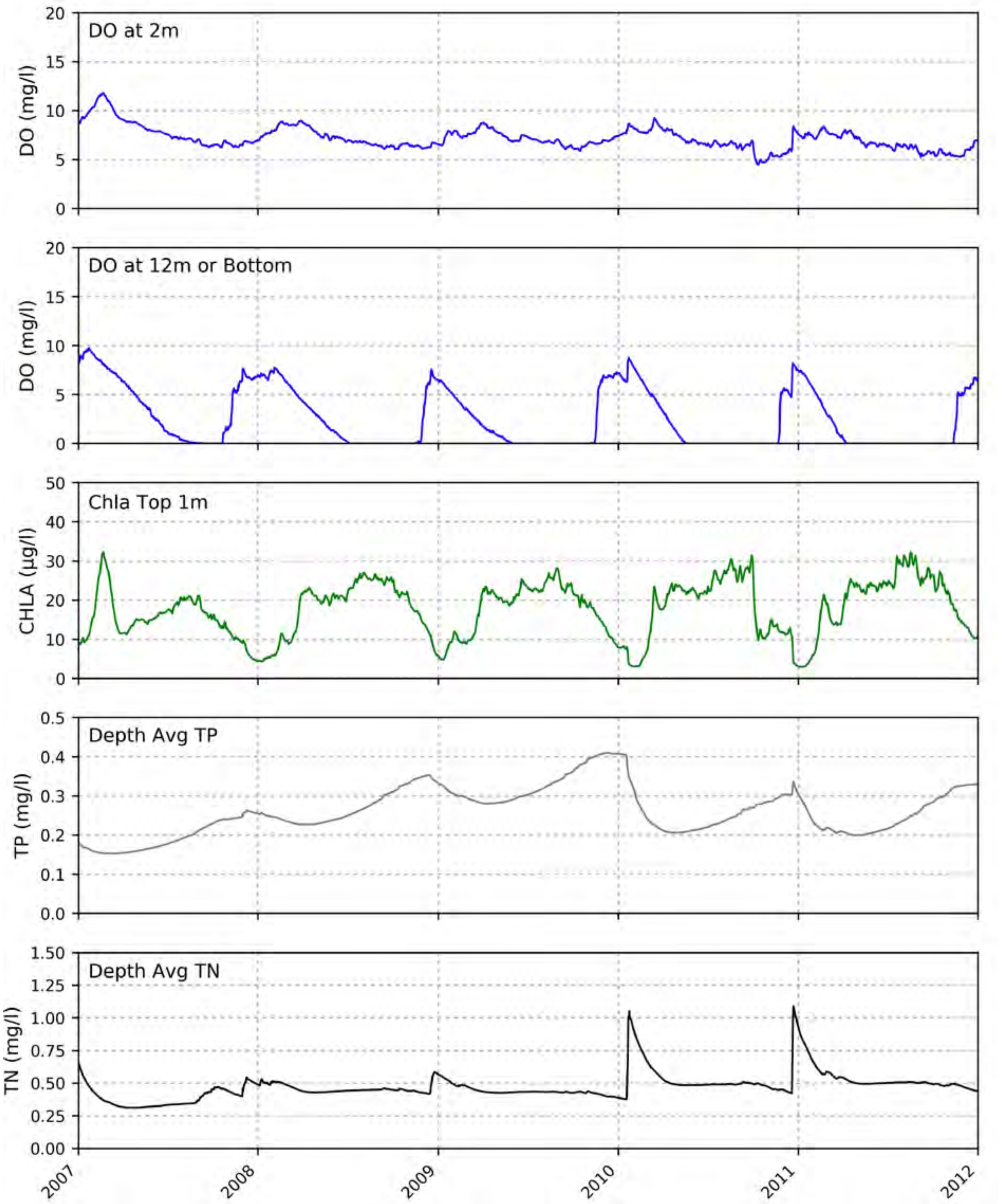

Figure 5-24. Time Series Output of Water Quality Parameters for Reference Condition Simulation for Canyon Lake Main Lake (2007 - 2011)

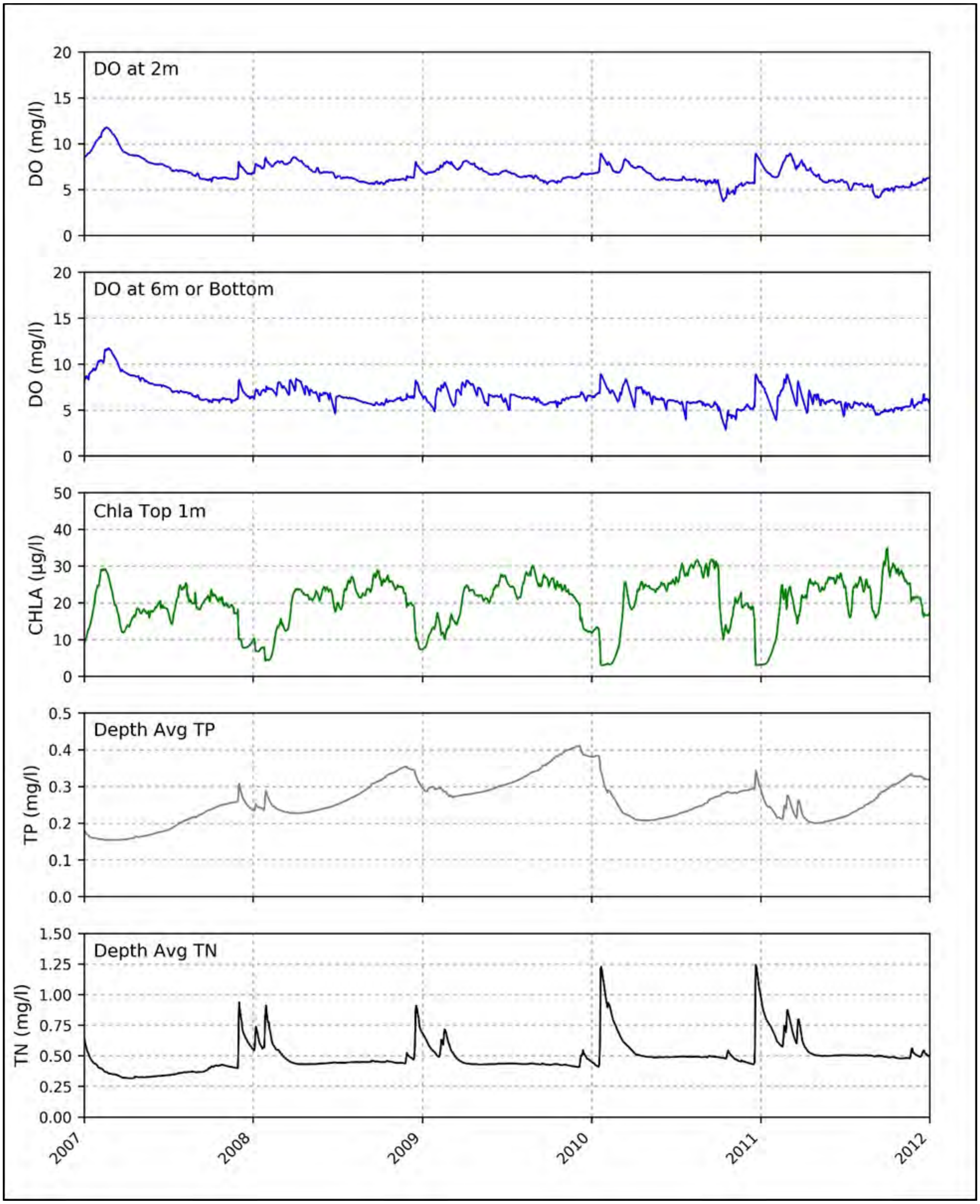

Figure 5-25. Time Series Output of Water Quality Parameters for Reference Condition Simulation for Canyon Lake East Bay (2007 - 2011)

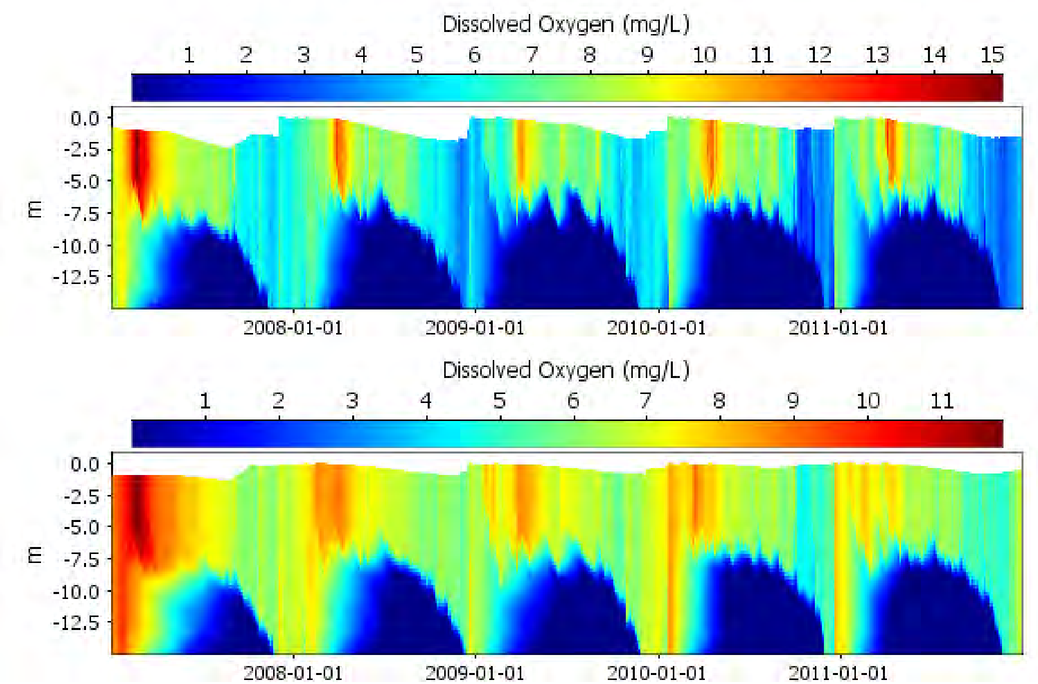

Figure 5-26. Vertical Profiles of ELCOM-CAEDYM Model Results for Dissolved Oxygen Comparing Existing Conditions (top) with Reference Watershed Conditions (bottom) Based on Output from Station M1 in Main Lake of Canyon Lake

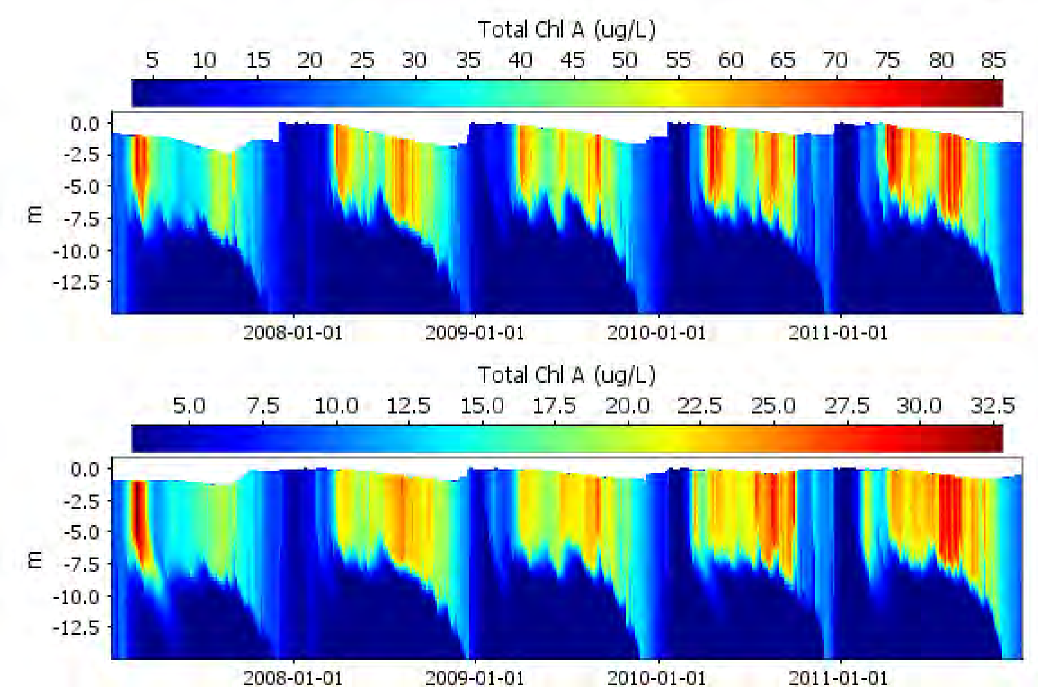

Figure 5-27. Vertical Profiles of ELCOM-CAEDYM Model Results for Chlorophyll-*a* Comparing Existing Conditions (top) with Reference Watershed Conditions (bottom) Based on Output from Station M1 in Main Lake of Canyon Lake

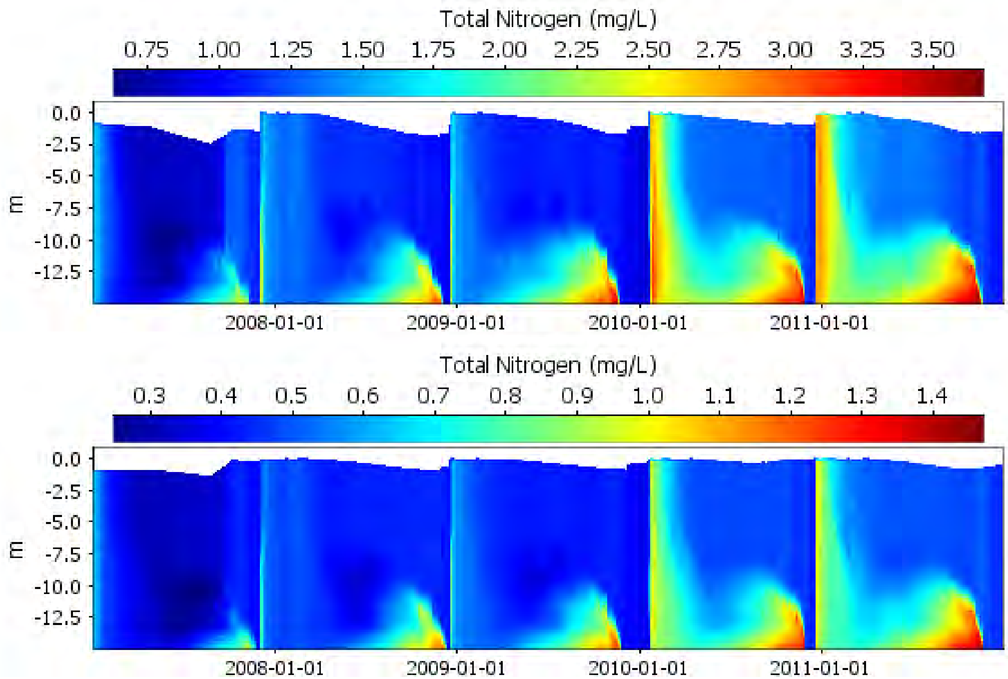

Figure 5-28. Vertical Profiles of ELCOM-CAEDYM Model Results for Total Nitrogen Comparing Existing Conditions (top) with Reference Watershed Conditions (bottom) Based on Output from Station M1 in Main Lake of Canyon Lake

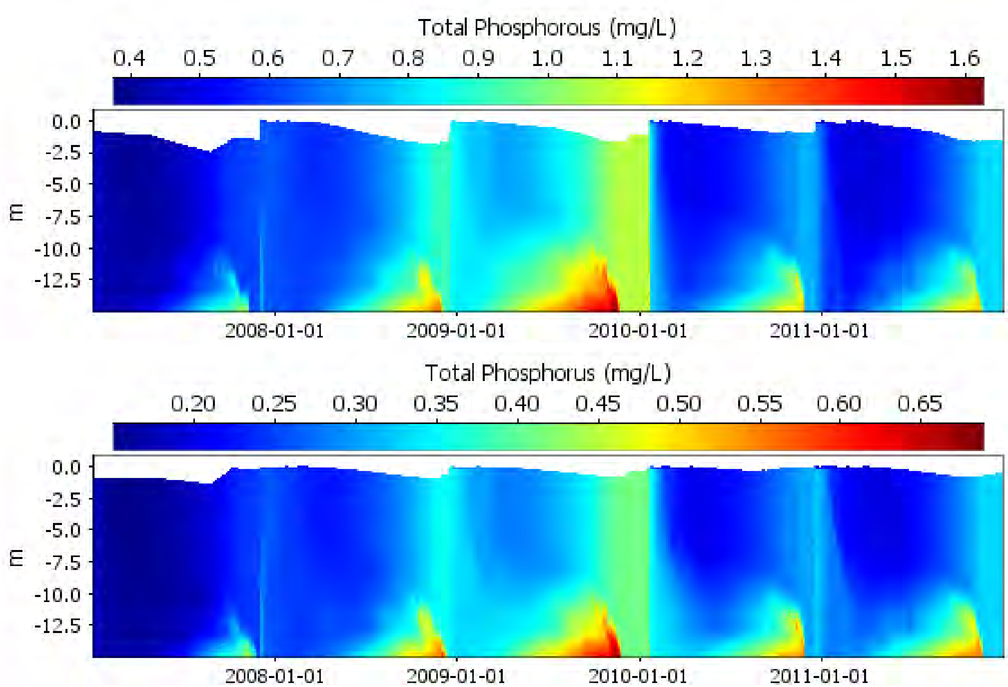

Figure 5-29. Vertical Profiles of ELCOM-CAEDYM Model Results for Total Phosphorus Comparing Existing Conditions (top) with Reference Watershed Conditions (bottom) Based on Output from Station M1 in Main Lake of Canyon Lake

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Section 6

Allocations

The allowable nutrient loading to three lake segments, Canyon Lake Main Lake, Canyon Lake East Bay and Lake Elsinore, is determined from analysis of the hydrology and water quality for the hypothetical reference watershed based on pre-development conditions (see Section 3.2 for description of the reference watershed condition). Specifically, this information was developed in the following sections:

- The loading of nutrients to the lakes under reference conditions was simulated by evaluating reference watershed conditions using the watershed runoff model developed to assess existing sources of nutrients from the watershed (Section 4, Source Assessment).
- Section 5 (Linkage Analysis) documents for a reference of watershed condition approximations of internal loads associated with sediment nutrient flux, the single greatest source of TP and TN in Lake Elsinore.
- Reference watershed conditions were approximated from modeling the watershed subareas by reducing washoff concentrations to natural background levels (see Section 3, Numeric Targets).

This section partitions the total allowable loads of TP and TN from point sources into WLAs and non-point sources into load LAs for individual jurisdictions.[1] The chapter includes the following sections:

- *Section 6.1 – Watershed Runoff*: Nutrient loads delivered to the lakes from watershed runoff are allocated to upstream jurisdictional areas in this section. A key element of this allocation involves allocation of watershed nutrient loads from upstream of both Canyon Lake and Lake Elsinore by way of overflows from Canyon Lake. The difference between current loads (as determined in Section 4, Source Assessment) and allowable loads is reported. This difference represents the reduction in TP and TN loads that must be achieved to meet WLAs and LAs.
- *Section 6.2 – Supplemental Water*: Allowable loads from the addition of supplemental water to the lakes is described in this section. While the addition of supplemental water to the lakes represents a discharge, it is important to recognize that the addition of supplemental water also represents a water quality management strategy. The WLA for supplemental water is based on a reference watershed runoff nutrient concentration (See Section 3.2.2.3) and does not consider additional water quality benefit for response targets that may be

[1] The WLA is the portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. The LA is the portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources.

achieved with a deeper lake. Potential offset credits from supplemental water addition are described in Section 7 on Implementation.

- *Section 6.3 – Internal Loads:* Estimates of allowable internal loads for atmospheric deposition and sediment nutrient flux are described in this section. Implementation of the TMDL will eventually return sediment nutrient flux rates to reference levels, but a significant lag time exists to account for legacy nutrient enrichment to cycle through the system. This section estimates the lag time for sediment nutrient flux rates to return to reference levels after the TMDL for external loads is achieved.

- *Section 6.4 – Summary of Allocated Loads.* This section summarizes the WLAs and LAs described in previous sections. In addition, this section discusses how compliance with allocations will be evaluated. As described in other chapters, the temporal variability associated with naturally occurring weather patterns results in significant variability in the delivery of nutrient loads to the lakes. Use of a 10-year averaging period for setting allocations in the revised TMDLs provides a more appropriate measure of progress toward TMDL compliance by reducing the influence of naturally occurring annual fluctuations.

6.1 Watershed Runoff

6.1.1 Allowable Runoff Loads

Nutrient loads estimated for watershed runoff under a reference watershed condition represent the total allowable load to each lake segment from external watershed runoff sources. Allowable nutrient loads are determined as the product of average annual runoff volume (V) and reference nutrient concentration (C) at the point of discharge into each lake segment, as follows:

$$Load_{allowable} = Q_{reference} * C_{reference}$$

Section 3.2 (Numeric Targets) describes how long-term average runoff volume and nutrient concentrations are estimated for a reference watershed condition. The numeric targets in the revised TMDL are expressed as CDFs of estimated water quality response targets, chlorophyll-a and DO, expected with external loads representative of a reference watershed condition. **Table 6-1** computes the allowable nutrient load from watershed runoff. These allowable loads represent the total allowable load from each of the individual subwatershed zones (**Figure 6-1**); however, these do not represent WLAs for any lake segment, since runoff from a subwatershed zone may be distributed among multiple lake segments.

6.1.2 Allocations of Allowable Nutrient Loads to Lake Segment TMDLs

Allocations for nutrient loads associated with each of the four lake segments were developed as follows: Canyon Lake Main Lake; Canyon Lake East Bay; overflows from Canyon Lake to Lake Elsinore; and Local Lake Elsinore. Although each lake segment is given an allocation, there are only three TMDLs; as Canyon Lake Overflows to Lake Elsinore and Local Lake Elsinore comprise one only Lake Elsinore TMDL (**Table 6-2**). Subwatershed zones upstream of Canyon Lake may contribute to multiple downstream waters and therefore will have allocations defined for more than one of the lake segments (see Figure 6-1).

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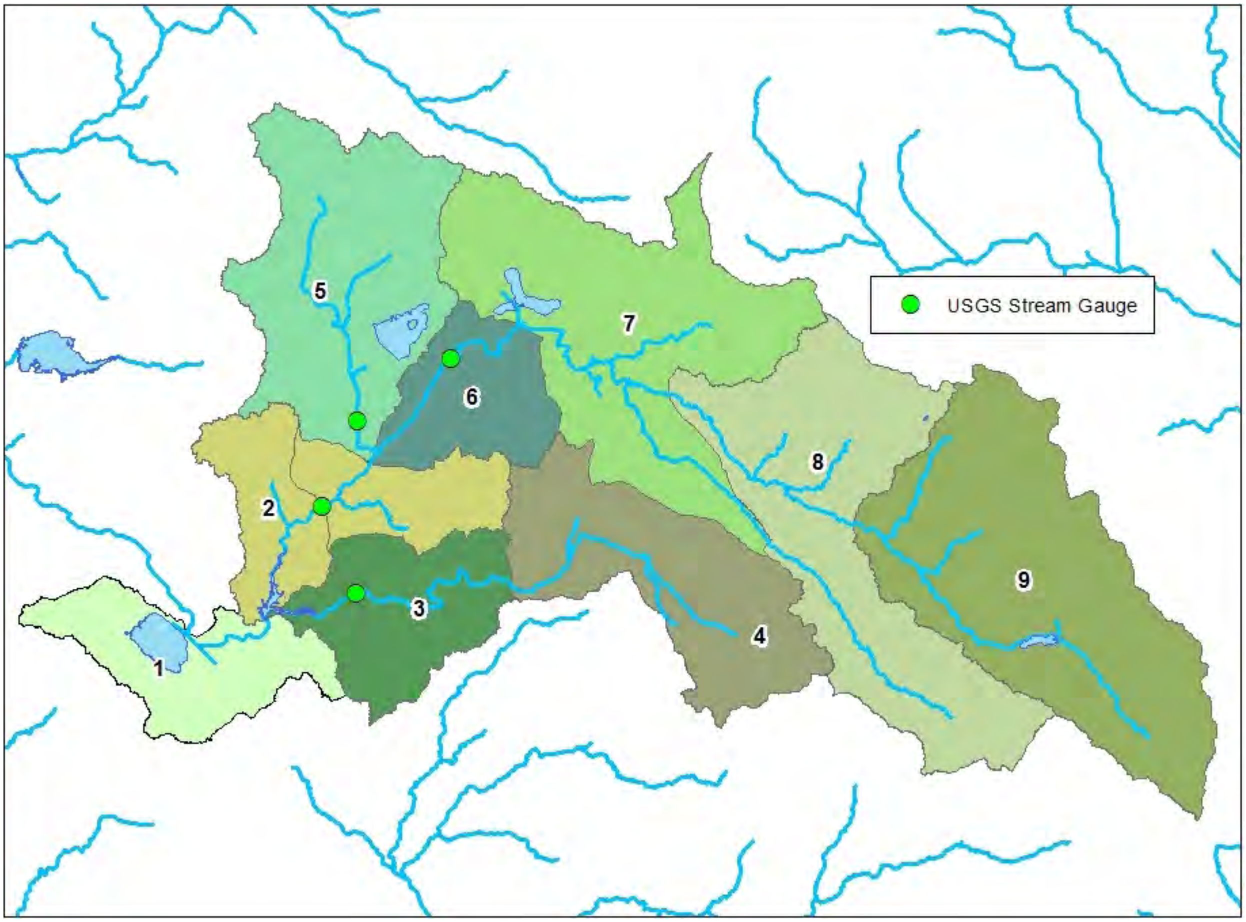

Figure 6-1. Location of Subwatershed Zones in the San Jacinto River Watershed (Zones 2, 5-9 drain to Canyon Lake – Main Lake [except note that Zones 7-9 may be intercepted by Mystic Lake]; Zones 3-4 drain to Canyon Lake – East Bay; and Zone 1 drains to Lake Elsinore)

The Source Assessment (Section 4) applied USGS gauge records and long-term watershed monitoring data to estimate nutrient mass inflow to Canyon Lake from two key stations on San Jacinto River at Goetz Rd and Salt Creek at Murrieta Rd as well nutrient mass overflow to Lake Elsinore from the San Jacinto River downstream of Railroad Canyon Dam (see Figures 4-13 and 4-14). The retention of nutrient loads was estimated as the difference between the summed annual loading for stations upstream and downstream of Canyon Lake for years when Canyon Lake overflows occurred. This analysis shows an average of 65 percent of nutrient loads that reach Canyon Lake are retained in the lake and 35 percent of the loads overflow to Lake Elsinore. Therefore, allowable loads from the Canyon Lake watershed are converted into WLAs and LAs involving a 65/35 split to Canyon Lake (either East Bay or Main Lake) or Lake Elsinore TMDLs (Table 6-2).

Table 6-1. Allowable Nutrient Loads from Watershed Runoff

Subwatershed	Modeled Reference Runoff (AFY)[1]	Reference Nutrient Concentration		Allowable Nutrient Loads from Runoff	
		TP (mg/L)	TN (mg/L)	TP (kg/yr)	TN (kg/yr)
1	1,868	0.31	0.95	715	2,190
2	2,189	0.31	0.95	837	2,565
3	1,880	0.31	0.95	719	2,203
4	885	0.31	0.95	338	1,037
5	2,717	0.31	0.95	1,039	3,184
6	1,243	0.31	0.95	475	1,457
7	442	0.31	0.95	169	518
8	415	0.31	0.95	159	486
9	1,058	0.31	0.95	405	1,240

[1] Runoff reported is the volume that reaches Canyon Lake after accounting for capture in Mystic Lake and channel bottom recharge

Table 6-2. Matrix Showing Three TMDLs and Allocation of Allowable Nutrient Loads by Subwatershed Zone

Subwatershed Zone	Canyon Lake		Lake Elsinore	
	Main Lake	East Bay	Canyon Lake Overflows	Local Watershed
1	--	--	--	100%
2	65%	--	35%	--
3[1]	--	65%	35%	--
4[1]	--	65%	35%	--
5	65%	--	35%	--
6	65%	--	35%	--
7	--	--	100%	--
8	--	--	100%	--
9	--	--	100%	--

[1] East Bay volume is transferred to Main Lake via a culvert under the Canyon Lake Drive causeway. The residence time of volume originating in East Bay that transfers to the Main Lake is limited prior to overflowing to Lake Elsinore and is considered negligible for the TMDL revision. Thus, no allocations are given to jurisdictions in subwatershed zones 3 and 4 (East Bay subwatershed) for Canyon Lake Main Lake

Allocations of nutrient loads were parsed by current estimates of the area within jurisdictional boundaries (**Figure 6-2**). Estimates of runoff and nutrient loading from these areas was done by removing all imperviousness and reducing nutrients to reference concentrations. The subwatershed zone for jurisdictional areas plays a role in reference loading, due to a number of factors specific to each subwatershed (i.e. variations in annual rainfall and levels of downstream retention in Mystic Lake and in channel bottom characteristics). Distributions of allowable load by subwatershed were converted to allocations to each TMDL and jurisdiction based on the factors presented in Table 6-2. The results of this analysis, presented in **Table 6-3** provides allocations for each of the TMDLs for each jurisdiction in the watershed. These allocations represent the nutrient load estimated to be delivered to each lake segment from upstream under the reference watershed condition.

6.1.3 Watershed Runoff Load Reductions to Meet TMDL Allocations

The incremental load above the allocations (see Table 6-3) represents the nutrient load attributable to anthropogenic watershed development. Thus, the difference between existing nutrient loads and allocations is the reduction needed for each watershed jurisdiction to comply with the TMDLs (**Table 6-4**).

6.2 Supplemental Water

Supplemental water is added to Lake Elsinore to maintain lake levels, as authorized by the Santa Ana Water by Order No. R8-2002-0008-A02 (Santa Ana Water Board 2002). The DYRESM-CAEDYM model for Lake Elsinore showed that without supplemental water additions since 2002, lakebed desiccation would have likely occurred in 2014 under reference conditions (**Figure 6-3**). A WLA for supplemental water additions to Lake Elsinore based on projected effluent rates for EVMWD reclaimed water is provided in **Table 6-5**. Additional sources of supplemental water for the lakes are provisionally allowable, as long as the concentration of nutrients is equal to or less than the reference watershed runoff. Further, the increased lake level that results from supplemental water addition may also provide water quality benefits of increased habitat for littoral zone aquatic communities and reducing bioavailable nutrient concentrations in the water column. These benefits will be translated into estimated nutrient offsets in Section 7, Implementation.

6.3 Internal Loads

6.3.1 Sediment Nutrient Flux *(Note: This section may be updated after updates to Section 4.3.1 are complete)*

Sediment cores have been collected to estimate the flux of nutrients, as NH_4-N and PO_4-P, from lake bottom sediments in Canyon Lake and Lake Elsinore. The results of these studies are presented in Section 4.3.1. Results from 2001-2014 show a significant year to year variability in flux rates, which is most likely caused by natural temporal variability in hydrology. Flux rates are greatest when sediment cores are collected shortly following years with significant rainfall and associated sediment retention in Canyon Lake and Lake Elsinore. The average flux rates measured from these studies provides an estimate of nutrient flux to be used as a load allocation in the TMDLs (**Table 6-6**).

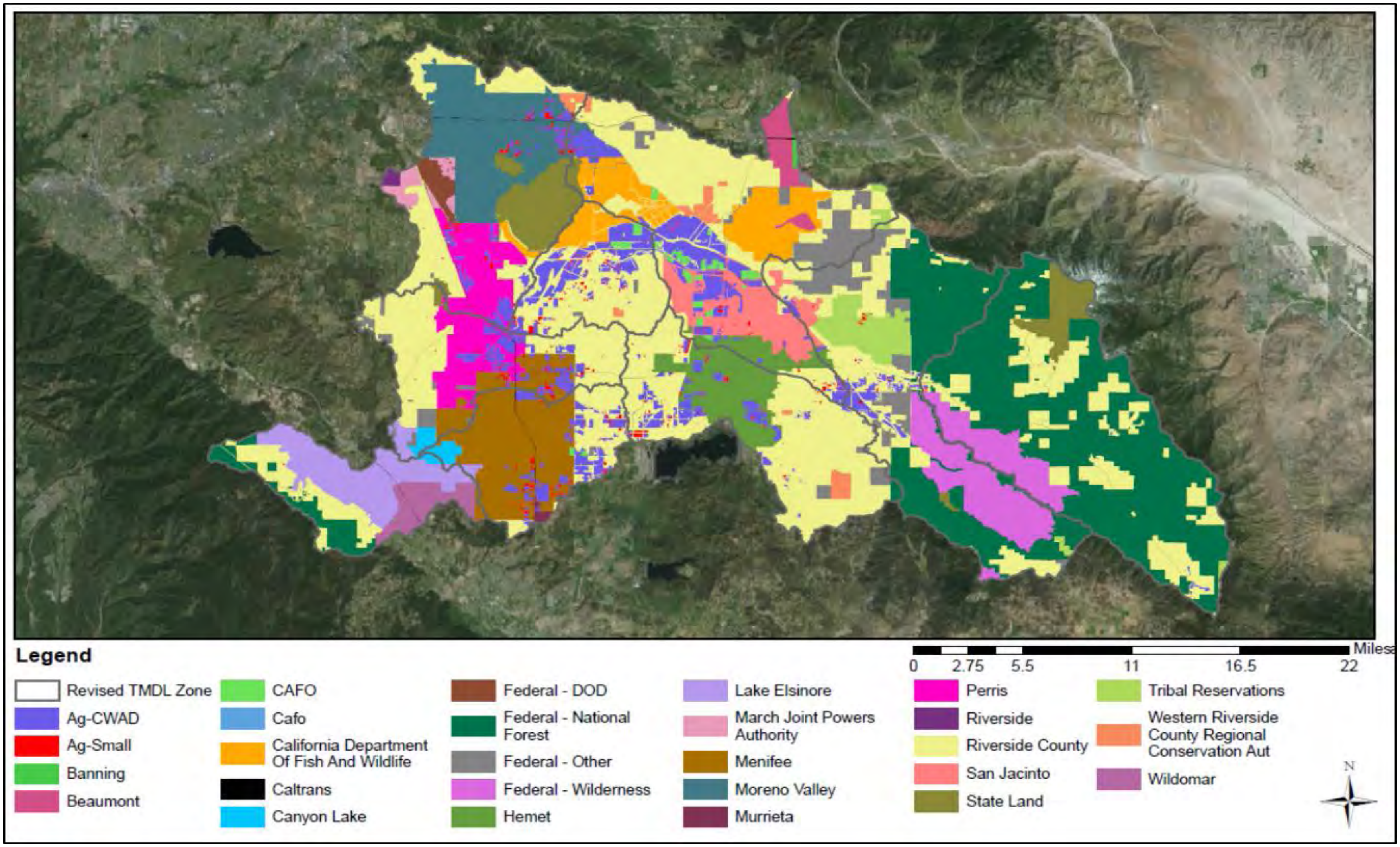

Figure 6-2. Jurisdictional Boundaries in the Lake Elsinore and Canyon Lake Watershed

Table 6-3. Allocations for Watershed Runoff in Lake Elsinore and Canyon Lake Nutrient TMDLs

Responsible Agency	Canyon Lake Main Lake		Canyon Lake East Bay		Local Lake Elsinore[1]		Canyon Lake Overflow to Lake Elsinore[1]	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Wasteload Allocations								
Banning	-	-	-	-	-	-	1	2
Beaumont	-	-	-	-	-	-	9	27
CAFO	5	14	2	6	0	0	7	22
Caltrans	11	33	4	12	6	17	12	35
Canyon Lake	12	36	14	44	7	23	14	43
Federal – Dept. of Defense	26	79	-	-	-	-	14	43
Hemet	-	-	48	147	-	-	34	104
Lake Elsinore	15	44	6	19	317	971	11	34
March Joint Powers Authority	28	87	-	-	-	-	15	47
Menifee	74	227	279	854	10	30	190	582
Moreno Valley	278	851	-	-	-	-	151	462
Murrieta	-	-	5	16	-	-	3	9
Perris	198	607	1	2	-	-	107	328
Riverside	6	18	-	-	-	-	3	9
Riverside County	559	1,712	220	674	139	427	587	1,799
San Jacinto	1	2	1	2	-	-	24	74
Wildomar	-	-	0	0	113	345	0	0
Load Allocations								
Agriculture (CWAD)	171	523	80	246	0	1	163	500
Agriculture (Small)	26	79	14	43	1	4	23	71
CA Dept. of Fish and Wildlife	44	134	-	-	-	-	54	165
Federal - National Forest	-	-	2	5	121	371	318	976
Federal – Other	32	97	7	21	-	-	51	157
Federal – Wilderness	-	-	-	-	-	-	62	190
State Land	38	115	-	-	-	-	45	139
Tribal Reservations	-	-	-	-	-	-	17	53
Western Riv. Co. Reg. Con.	8	24	4	13	-	-	9	29
Total Allowable Watershed Load (WLAs and LAs)	**1,528**	**4,684**	**687**	**2,106**	**715**	**2,190**	**1,925**	**5,900**

[1] Allocations for Local Lake Elsinore and Canyon Lake Overflow to Lake Elsinore are combined into a single Lake Elsinore TMDL. However, the allocations are reported separately here since source controls in the Canyon Lake watershed can be used to estimate credits toward reducing loads in Overflows from Canyon Lake to Lake Elsinore.

Table 6-4. Nutrient Load Reduction Required for Watershed Jurisdictions to Comply with Lake Elsinore and Canyon Lake Nutrient TMDLs

Responsible Agency	Canyon Lake Main Lake		Canyon Lake East Bay		Local Lake Elsinore		Canyon Lake Overflow to Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Point Sources with NPDES Permits								
Banning	-	-	-	-	-	-	2	12
Beaumont	-	-	-	-	-	-	6	53
CAFO	10	16	1	1	0	1	12	17
Caltrans	19	344	5	106	9	141	15	268
Canyon Lake	23	159	37	271	13	94	32	231
Federal – Dept. of Defense	35	444	-	-	-	-	19	239
Hemet	-	-	108	683	-	-	83	532
Lake Elsinore	25	159	2	28	224	1,961	15	101
March Joint Powers Authority	19	143	-	-	-	-	10	77
Menifee	94	631	489	3,186	4	29	314	2,055
Moreno Valley	654	4,794	-	-	-	-	353	2,584
Murrieta	-	-	15	109	-	-	8	59
Perris	269	2,139	0	0	-	-	145	1,152
Riverside	27	183	-	-	-	-	15	99
Riverside County	418	2,310	202	688	96	724	440	2,072
San Jacinto	0	0	0	2	-	-	31	221
Wildomar	-	-	0	0	103	837	0	0
Nonpoint Sources								
Agriculture (CWAD)	407	755	251	469	2	4	417	759
Agriculture (Small)	82	160	59	114	4	7	80	154
CA Dept. of Fish and Wildlife	2	7	-	-	-	-	2	6
Federal - National Forest	-	-	(0)	(0)	1	5	3	12
Federal – Other	(0)	1	1	1	-	-	1	2
Federal – Wilderness	-	-	-	-	-	-	0	1
State Land	9	28	-	-	-	-	5	16
Tribal Reservations	-	-	-	-	-	-	1	8
Western Riv. Co. Reg. Con.	1	2	(0)	(1)	-	-	3	6
Total Allowable Watershed Load	**2,093**	**12,275**	**1,171**	**5,657**	**457**	**3,802**	**2,010**	**10,736**

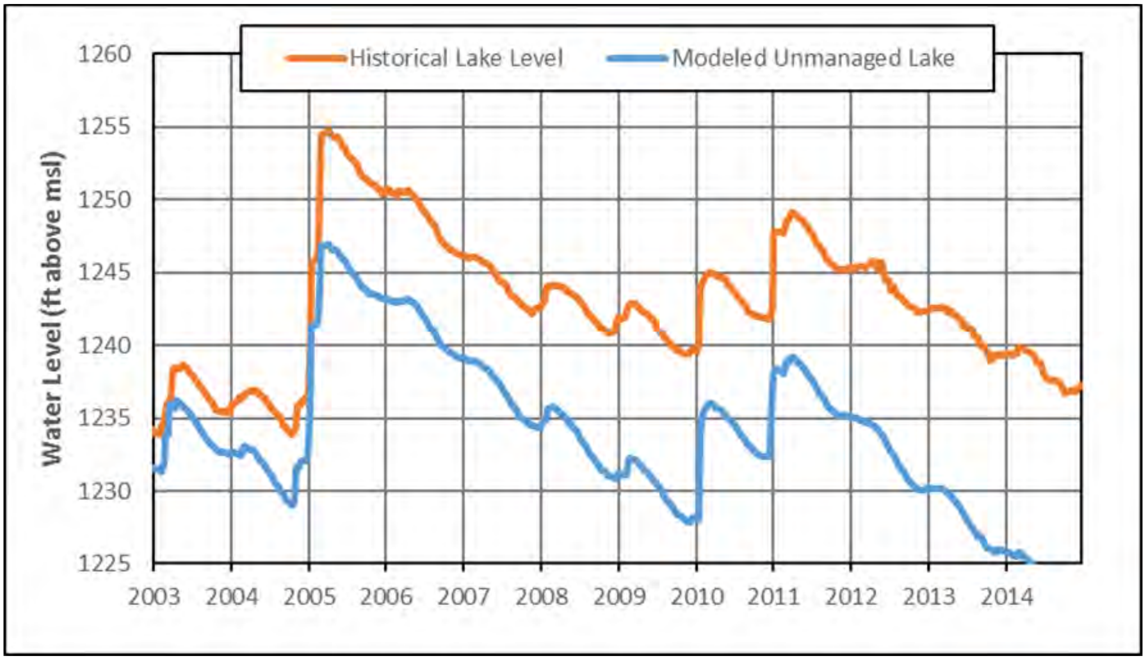

Figure 6-3. Actual Lake Level Compared to Reference Condition (without supplemental water and without LEMP basin)

Table 6-5. WLAs for EVMWD Reclaimed Water Additions to Lake Elsinore

EVMWD Reclaimed Water Additions	Flow		Concentration		Nutrient Load	
	MGD	AFY	TP (mg/L)	TN (mg/L)	TP (kg/yr)	TN (kg/yr)
Current Permit	8.0	6,037	0.50	1.00	3,721	7,442
TMDL Revision	9.5	10,642	0.31	0.95	4,067	12,463

Table 6-6. Load Allocations for Sediment Nutrient Flux *(Note: Data in this table is still undergoing additional analysis, esp. for Lake Elsinore)*

Lake Segment	Acres	Sediment Nutrient Flux (mg/m^2/day)		Load Allocation (kg/yr)	
		TP	TN	TP	TN
Canyon Lake (Main Lake)[1]	334	6.9	28.5	3,401	16,267
Canyon Lake (East Bay)	103	6.9	28.5	1,045	8,782
Lake Elsinore	3,000	8	80	35,452	354,520

[1] Includes North Ski Area, the portion of the Lake north of the causeway, but no sediment data has been collected to date to characterize flux rates from this zone.

6.3.2 Atmospheric Deposition

Load allocations were developed for direct deposition from the atmosphere to the lake surfaces. Inconsistencies in the approach used to develop estimates for Canyon Lake and Lake Elsinore exist in the 2004 TMDL (Risk Sciences 2017). For example, depositional rates for TN employed for Canyon Lake and Lake Elsinore were based on differing regional literature values. The approach presented below is based on similar data used for the 2004 TMDL but ensures a consistent method for TN and TP is applied to each lake segment.

6.3.2.1 Total Phosphorus

Wet deposition of TP to each lake segment was estimated using literature values for TP wet deposition rates of 30 $kg/km^2/yr$ for Keystone Reservoir in Oklahoma (Walker 1996). Adjusting for differences in rainfall, average annual wet deposition for TP in Lake Elsinore and Canyon Lake was assumed to be 13 $kg/km^2/yr$ (0.05 kg/ac/yr). Assuming most TP deposition occurs as wet deposition, load allocations were developed as shown in **Table 6-7**.

6.3.2.2 Total Nitrogen

Estimates for atmospheric deposition of TN are based on results of a wet and dry deposition sampling conducted as an element of a water quality study for Newport Bay conducted in 2002-2004 (Meixner et. al. 2004). Results showed that dry deposition accounts for most depositional load of TN, with seasonal average rates varying from 2 to 12 lbs/ac/yr (0.9 to 5.5 kg/ac/yr). The 2004 TMDL used a value of 7.1 lbs/ac/yr (3.2 kg/ac/yr) based on this study. No significant changes to atmospheric N deposition are expected nor is there any new regional data, therefore the same rates will be used in the TMDL revision. **Table 6-7** shows the load allocation for TN in each lake segment.

Table 6-7. Load Allocations for Atmospheric Deposition

Lake Segment	Acres	Atmospheric Deposition Rate (kg/ac/yr)		Load Allocation (kg/yr)	
		TP	TN	TP	TN
Canyon Lake (Main Lake)[1]	334	0.05	3.23	17	1,077
Canyon Lake (East Bay)	103	0.05	3.23	5	331
Lake Elsinore	3,000	0.05	3.23	156	9,682

[1] Includes North Ski Area portion of Canyon Lake, north of causeway

CDM Smith

6.4 Summary of Allocated Loads

6.4.1 Total for Point and Nonpoint Source Allocations

Table 6-8 presents the total allocated load, considering both point and nonpoint sources of nutrients, to each lake segment. These total loads are also shown by the major categories of nutrient sources contributing to the total load. **Table 6-9** compares these allocations with the 2004 TMDL, showing a reduced allowable loading with the reference watershed approach for TP and TN in all but the local Lake Elsinore watershed.

Table 6-8. Summary of WLAs and LAs for Major Categories of Nutrient Sources to Each Lake Segment

Lake Segment	Wasteload Allocation (kg/yr)		Load Allocation (kg/yr)	
	TP	TN	TP	TN
Canyon Lake (Main Lake)				
Watershed Runoff	1,211	3,711	317	973
Supplemental Water	As needed		n/a	
Atmospheric Deposition	n/a		13	1147
Sediment Nutrient Flux	n/a		3,401	16,267
Canyon Lake (East Bay)				
Watershed Runoff	580	1,778	107	328
Supplemental Water	As needed		n/a	
Atmospheric Deposition	n/a		4	331
Sediment Nutrient Flux	n/a		1,045	8,782
Lake Elsinore				
Watershed Runoff (Canyon Lake overflows)	1,181	3,620	744	2,280
Watershed Runoff (local)	592	1,814	123	376
Supplemental Water	4,067	12,463	n/a	
Atmospheric Deposition	n/a		108	9,682
Sediment Nutrient Flux	n/a		35,452	354,520

Table 6-9. Comparison of Allocations Between the Proposed Revised TMDLs and Existing 2004 TMDLs

Allowable External Loads	Total Phosphorus		Total Nitrogen	
	2004 TMDL	TMDL Revision	2004 TMDL	TMDL Revision
Main Lake	1,899	1,528	10,951	4,684
East Bay	1,899	687	10,951	2,106
Total Canyon Lake	3,797	2,216	21,902	6,790
Local Lake Elsinore	431	715	1,737	2,190
Overflow from CL to LE	2,770	1,925	20,774	5,900

6.4.2 Consideration of Averaging Periods

The nutrient load from the reference watershed to each lake segment will vary significantly from year to year because of prevailing climate patterns. In southern California, annual rainfall is influenced by water temperature patterns in the Pacific Ocean, which cause most rainfall and runoff from the San Jacinto River watershed in 'El Nino' years and droughts with limited runoff to the lakes in 'La Nina' years. Thus, mass-based allocations of allowable nutrient loads cannot be imposed based on the expected nutrient load in a single hydrologic year. To address this reality, the existing 2004 TMDLs used a 10-year period to determine whether annual average nutrient loads are being reduced to allowable levels. This approach allowed for consideration of fluctuations in rainfall and runoff above and below the 10-year average in any given year.

As part of the revision of the existing TMDLs the basis for an appropriate averaging period has been reevaluated. This reevaluation uses gauged runoff inflow volumes for Canyon Lake (period of record is 2000-2016 from USGS gauges on Salt Creek and the San Jacinto River) that provide 17 years of annual runoff volumes) and overflows from Canyon Lake to Lake Elsinore (period of record is 1916-2016 from USGS gauge on San Jacinto River below Canyon Lake). From these USGS gauges long-term annual average runoff inflow (for their respective period of records) to Canyon Lake is 8,200 AFY and overflow from Canyon Lake to Lake Elsinore is 11,400 AFY.[2]

Ideally, a multi-year averaging period for TMDL allocations would yield a runoff volume that is comparable to the long-term average. One way to assess the length of multi-year averaging periods is to compute averages from resampling of historical data. In the case of runoff volume, resampling must be done for consecutive years. The resampling can be implemented for all unique subsets of the longer time series, which generates a running average.

There exists eight unique 10-year periods in the historical record of runoff inflows to Canyon Lake (i.e., 2000-09, 2001-10, 2002-11, 2003-12, 2004-13, 2005-14, 2006-15, and 2007-16). The difference between the long-term average and each unique 10-year period average was computed and the maximum deviation for each averaging period is plotted in **Figure 6-4**. For example, the average annual runoff inflow to Canyon Lake from 2003-2012 was 11,200 AFY, which is 33%

[2] USGS gauge for San Jacinto River near Elsinore has an annual average runoff volume of 5,800 AFY based on the years 2000-2016, showing that volume retention occurs in Canyon Lake.

greater than the long-term average of 8,200 AFY. This was the greatest absolute difference of any unique 10-year period averages. The resampling analysis suggests that an allocation based on the 2004 TMDL mandated 10-year period would likely result in non-compliance in the future even if nutrient concentrations were maintained at the reference watershed levels. However, Figure 6-4 shows that increasing the averaging period to 14 years would limit potential deviations to less than 10 percent for both Canyon Lake inflows and overflows to Lake Elsinore.

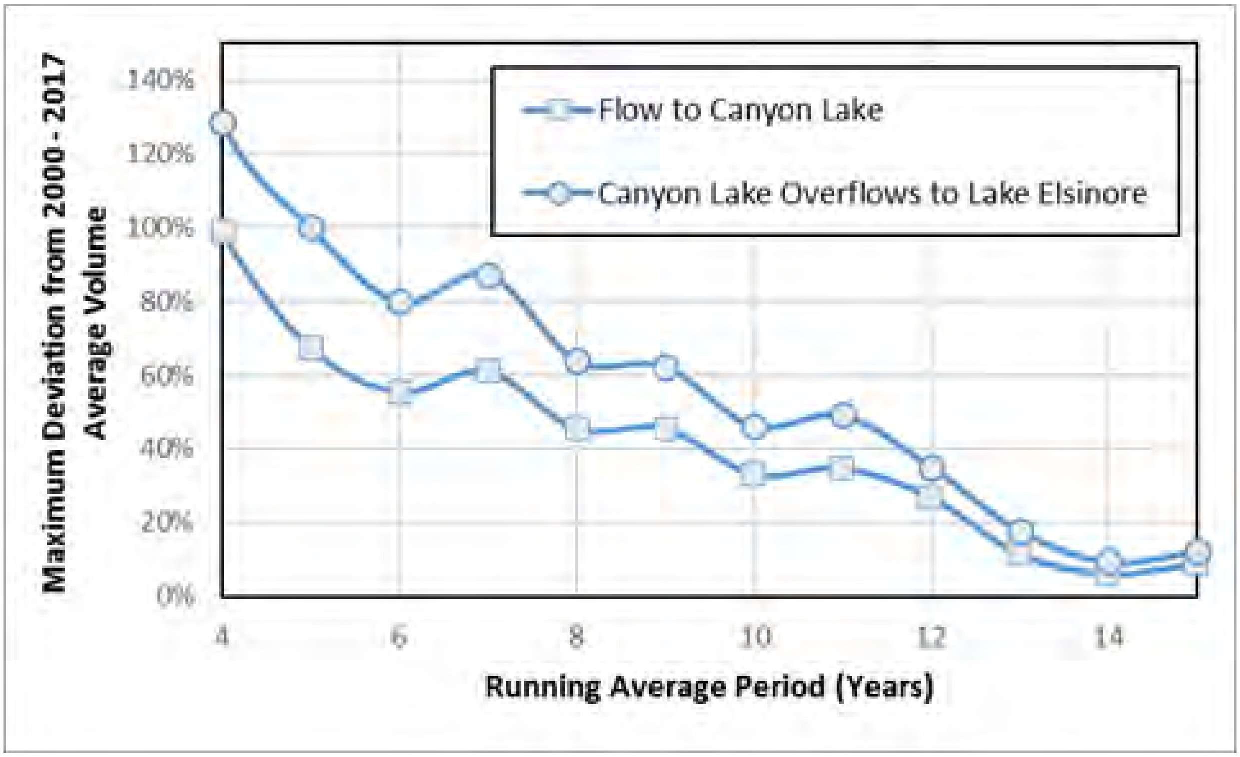

Figure 6-4. Maximum Deviation from Long-Term (2000-2017) Average Annual Runoff Volume for Different Averaging Periods

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Section 7

Implementation lan

TBD

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Section 8

Monitoring Requirements

TBD

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Section 9

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Appendix A

Supporting Biological Data

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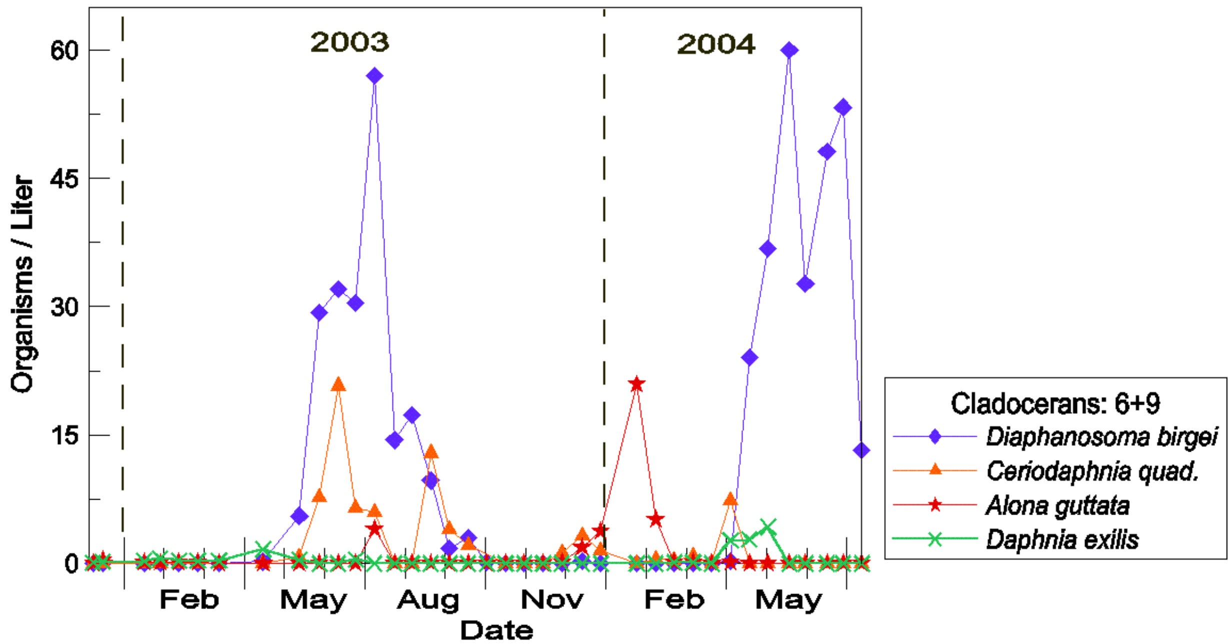


Figure A-1. Cladoceran Population Density at Deep Sites in Lake Elsinore (Sites 6+9) (Veiga Nascimento 2004)

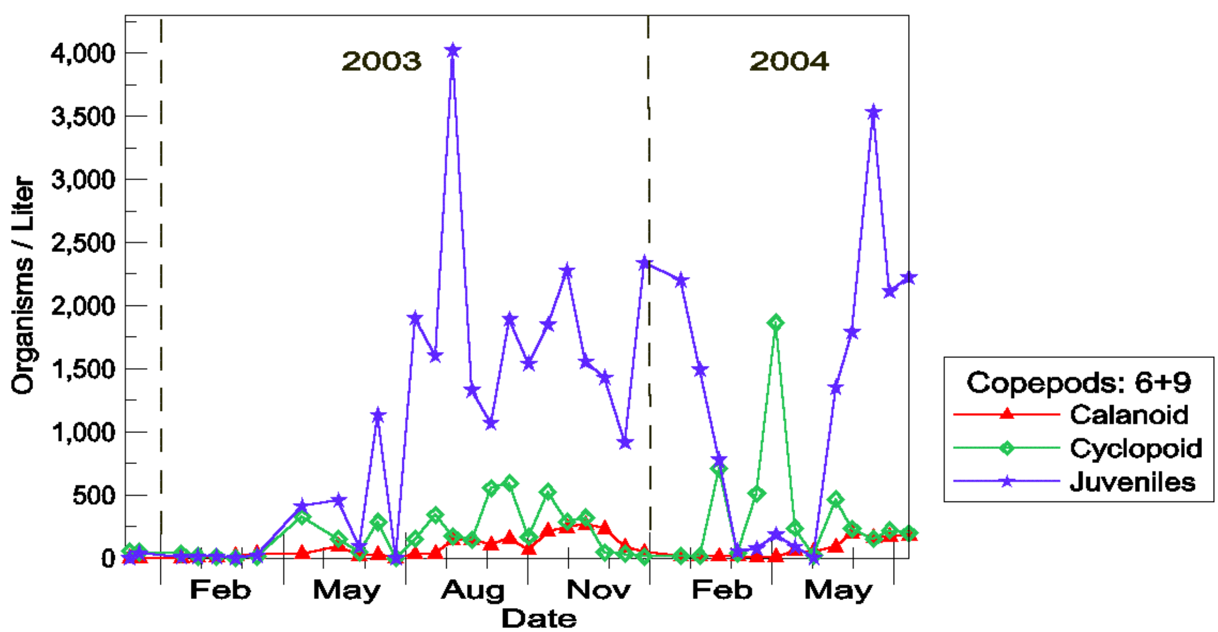


Figure A-2. Copepod Population Density at Deep Sites in Lake Elsinore (Sites 6+9) (Veiga Nascimento 2004)

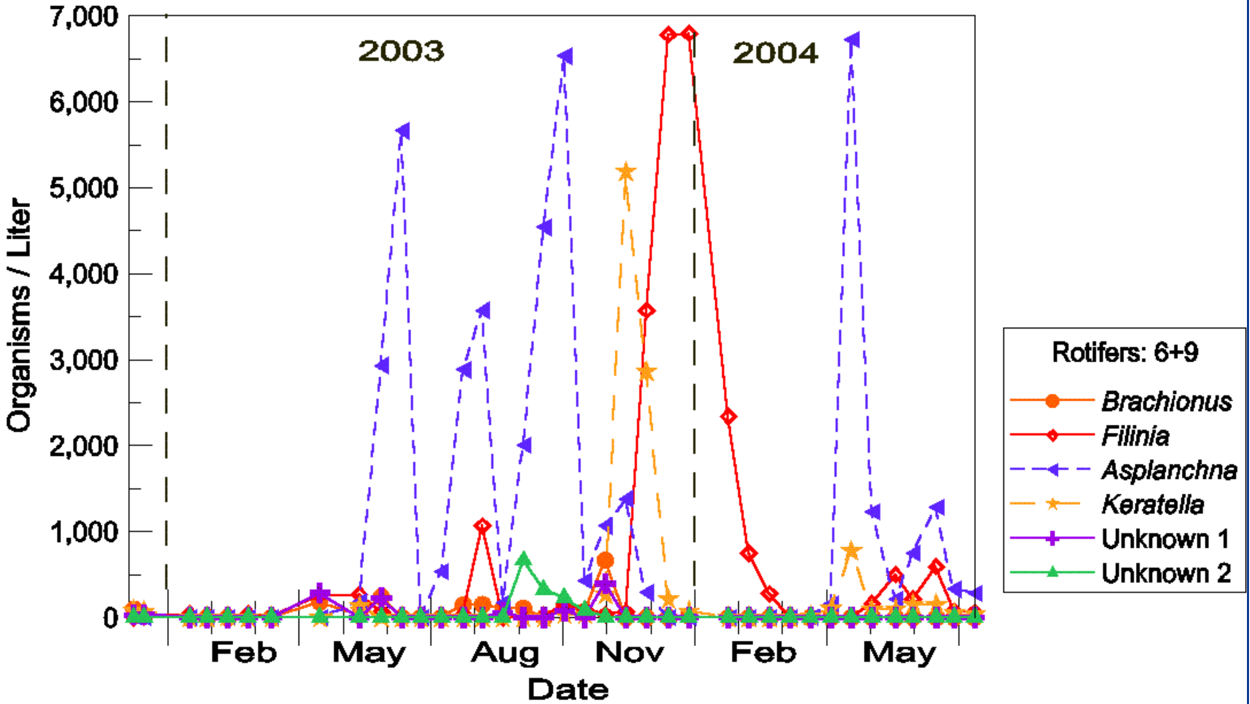


Figure A-3. Rotifer Population Density at Deep Sites in Lake Elsinore (Sites 6+9) (Veiga Nascimento 2004)

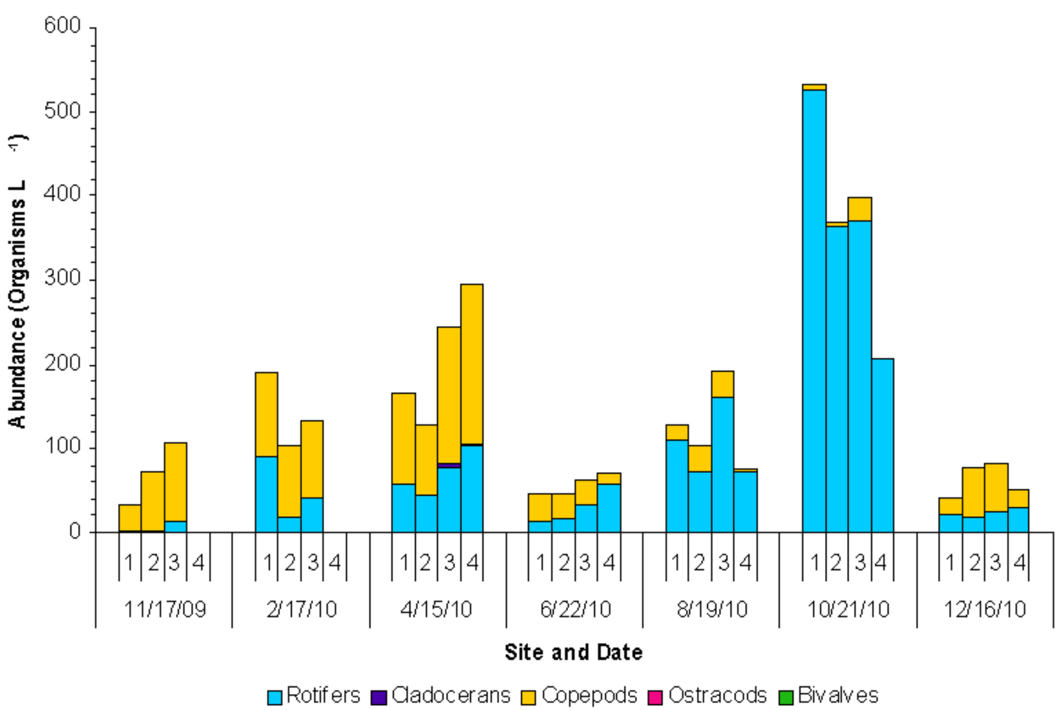


Figure A-4. Zooplankton Abundance by Major Groups at the Four Sampling Sites in Lake Elsinore from November 2009 through December 2010 (Tobin 2011)

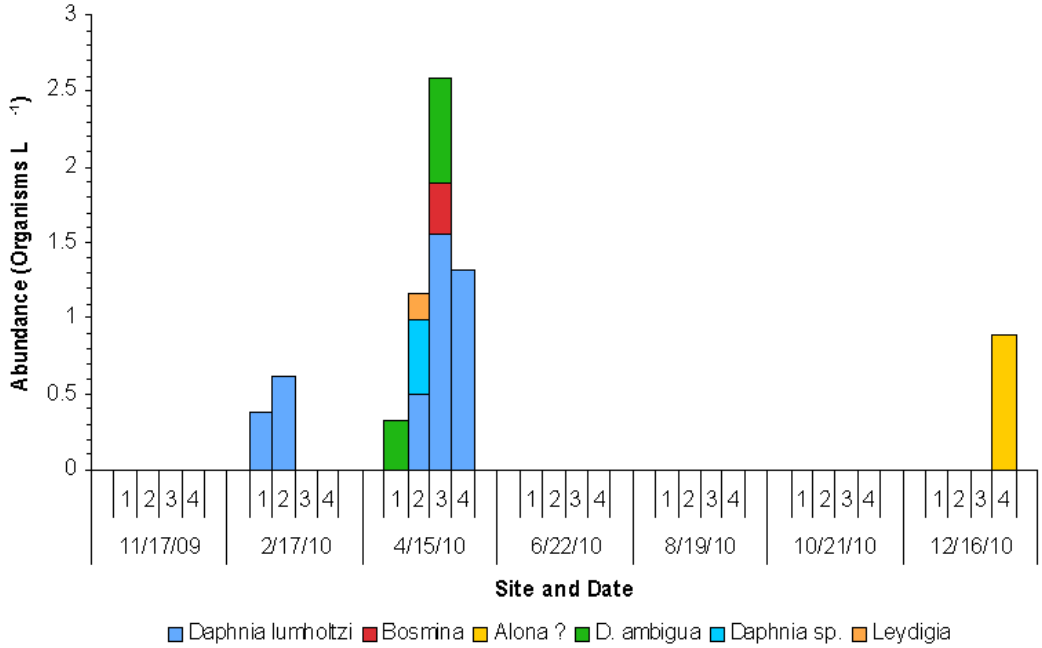


Figure A-5. Cladoceran Abundances by Species at the Four Sampling Sites in Lake Elsinore from November 17, 2009 through December 16, 2010 (Tobin 2011)

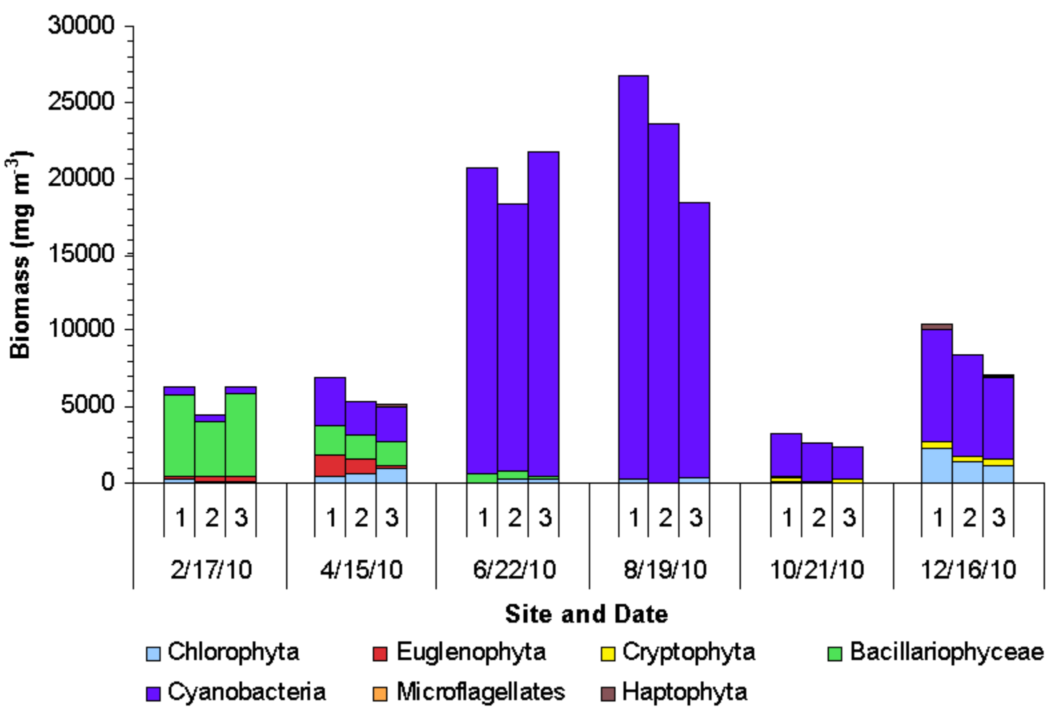


Figure A-6. Phytoplankton Biomass by Major Algal Groups at the Three Sampling Sites in Lake Elsinore during 2010 (Tobin 2011)

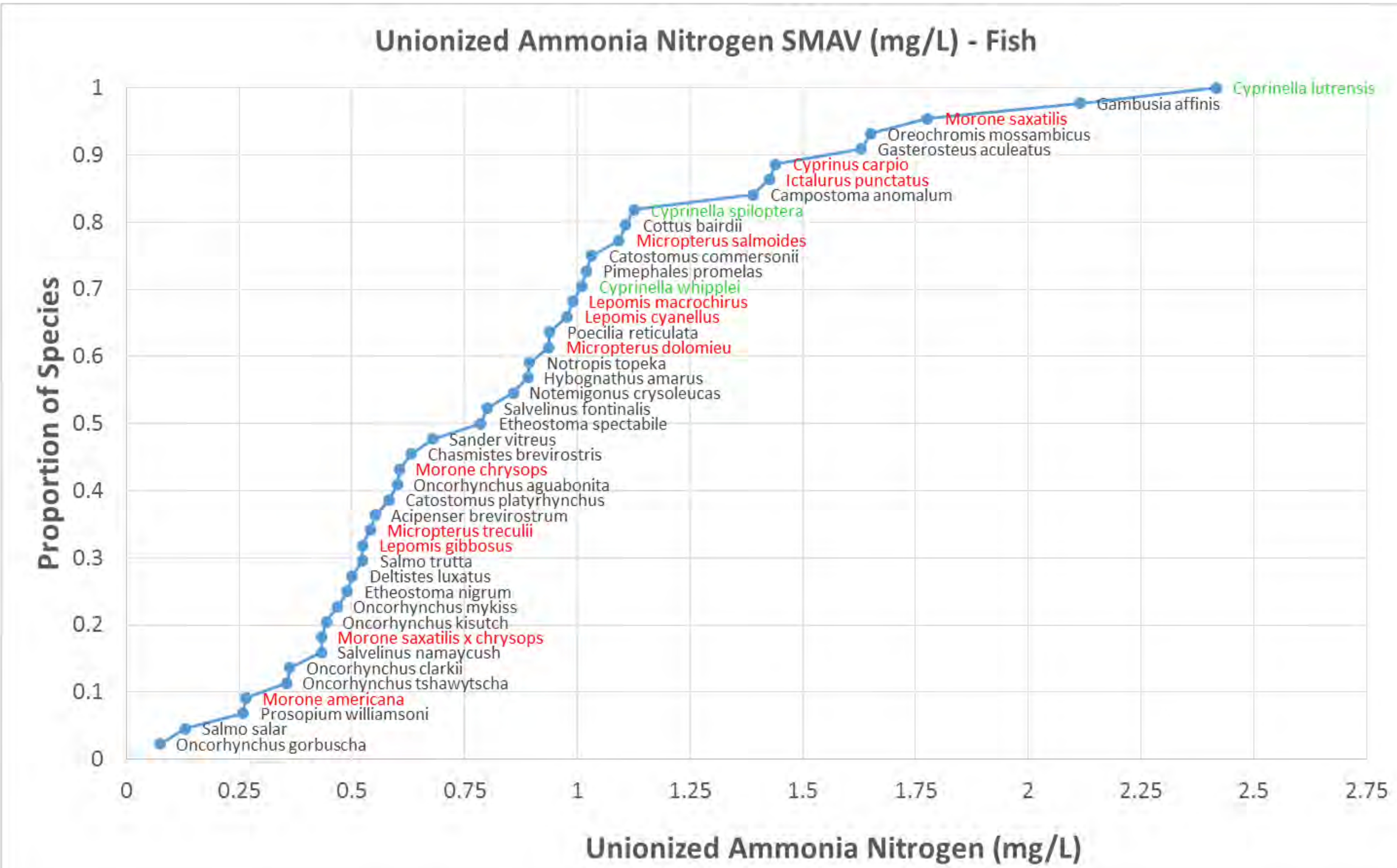


Figure A-7. Species Sensitivity Distribution (SSD) of Fish Species, Plotting the Species Mean Acute Value (SMAV) Relative to Un-ionized Ammonia (those highlighted in red and green are species found in the lakes [red], or closely related species [green])

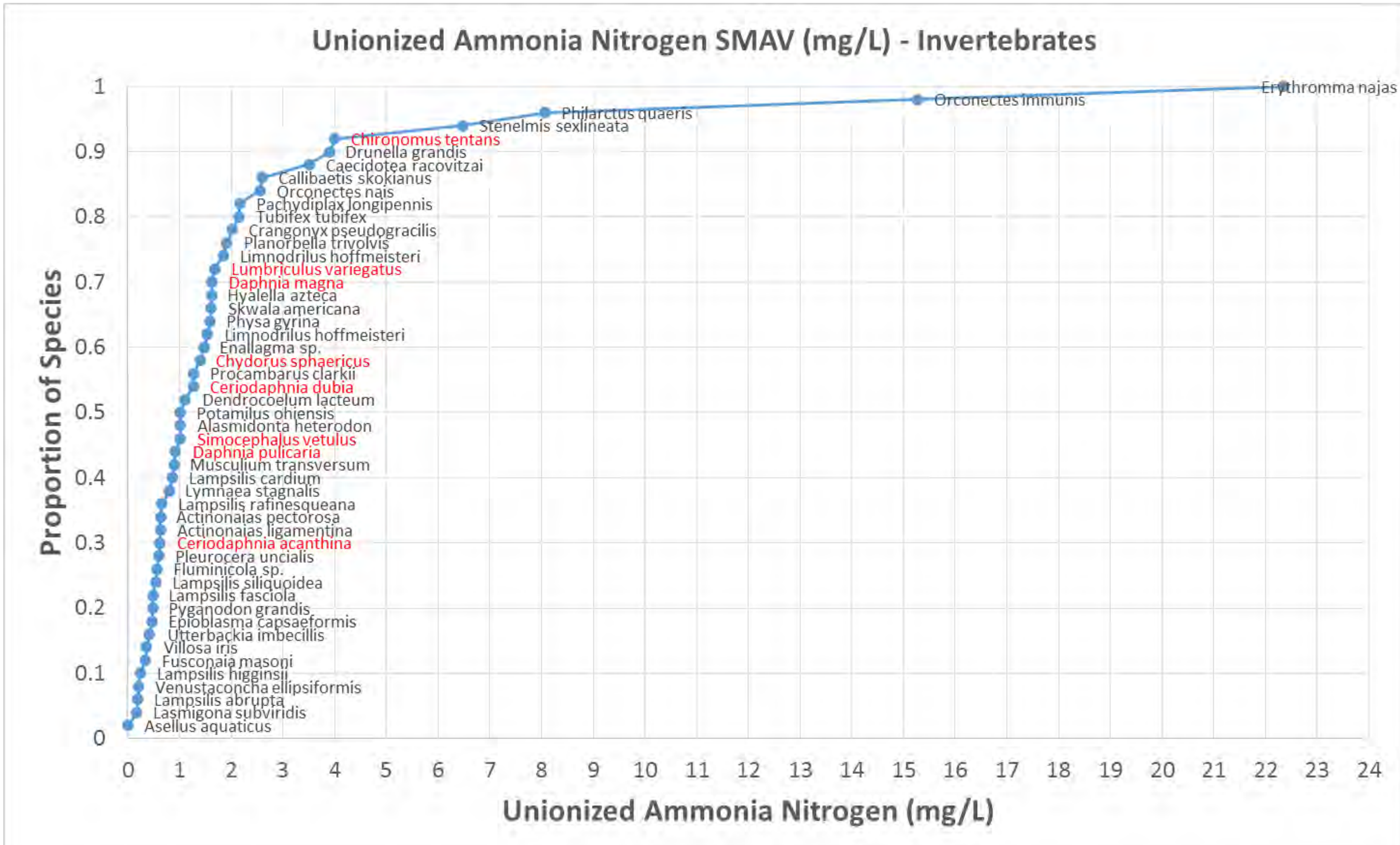


Figure A-8. SSD of Various Aquatic Invertebrate Species, Plotting the Species Mean Acute Value (SMAV) Relative to Un-ionized Ammonia (those highlighted in red are species either found in the lakes or closely related species [i.e., same genus]).

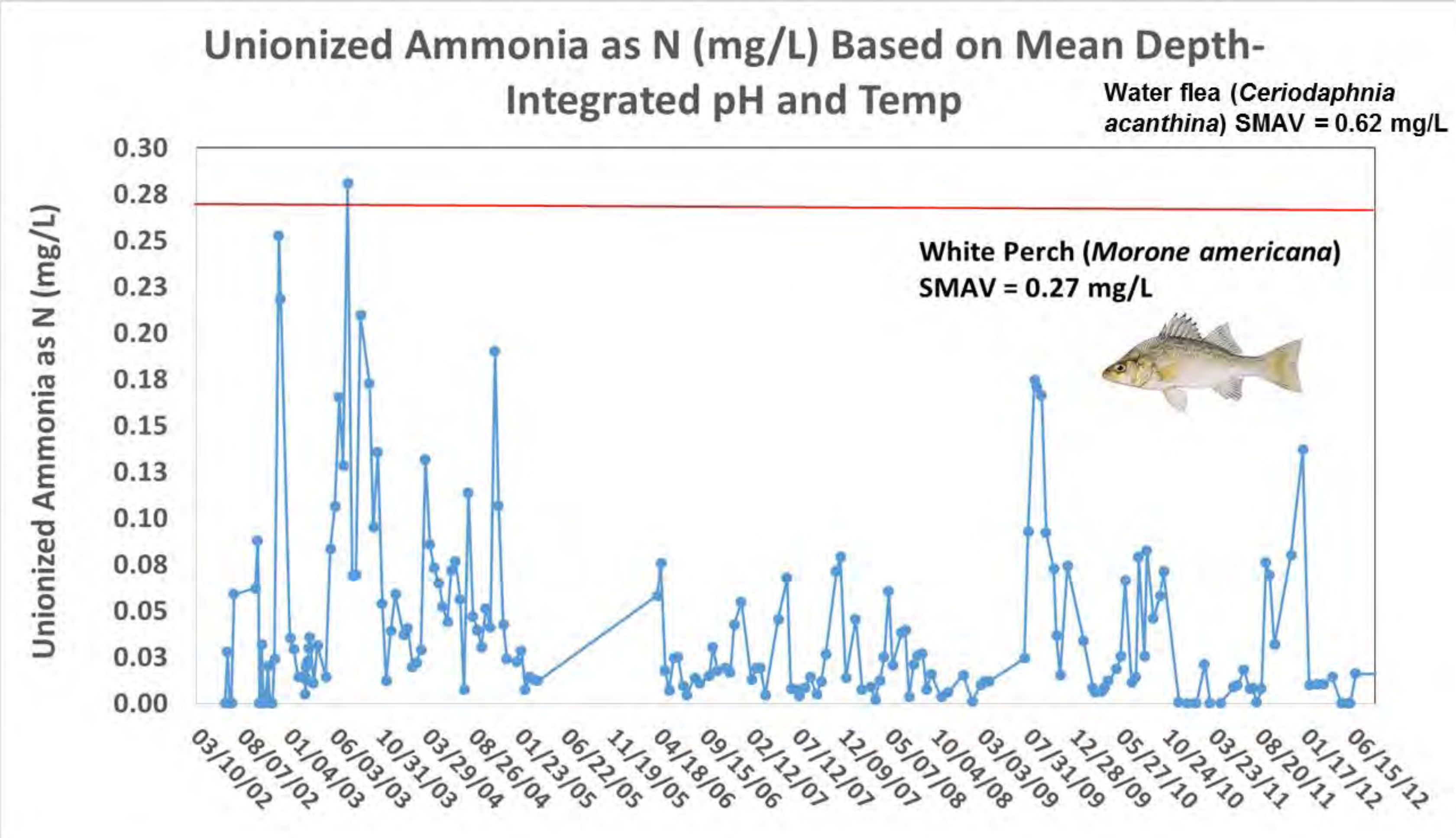


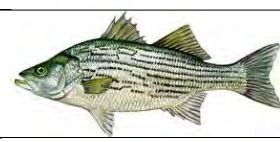
Figure A-9. Historical Un-ionized Ammonia Concentrations for Lake Elsinore (Site LEE2) Calculated from Depth Integrated Total Ammonia, pH, Temperature, and Salinity

Table A-1. Hydroacoustic Fish Survey Results from Lake Elsinore Comparing Most Current Survey (April 2015) with Surveys Conducted in 2008 and 2010 (Anderson 2016b)

Date	Population (fish/acre)	Mean Size[a] (cm)	Size Range[a] (cm)	Fish >20 cm[a] (fish/acre)
April 24, 2008	18,090	4.7	0.5 - 100	1,050 (5.8%)
March 15, 2010[b]	2,867	4.0	0.5 – 29	6 (0.2%)
December 1, 2010	27,720	4.3	0.5 – 61	273 (1.0%)
April 2, 2015	56,600	1.8	0.5 - 30	12 (0.02%)

[a] Based on Loves' equation (Love 1970).
[b] March 2010 survey was conducted after fish kill in summer of 2009.

Table A-2. Conductivity Thresholds of Common Fish Taxa found in Lake Elsinore and Canyon Lake

Common Name	Example Photograph	Species	Endpoint	Salinity Threshold (ppt)	Conductivity Threshold (µS/cm)
Black Crappie		*Pomoxis nigromaculatus*	Presence	Up to 4.7	Up to 8,457
Channel Catfish		*Ictalurus punctatus*	No effect	Up to 8	13,855
Common Carp		*Cyprinus carpio*	Lethality	7.2	12,568
			LD_{50}	12.8	21,356
Gizzard shad		*Dorosoma cepedianum**	No effect	2.0 – 34	4,130 – 51,714
Striped Bass		*Morone saxatilis*	LC_{50}	> 22	> 34,981
Largemouth Bass		*Micropterus salmoides*	Decline in abundance	> 4.0	> 7,276

*Same genus as the Threadfin Shad, *Dorosoma petenense*

Table A-3. Conductivity Thresholds of Common Invertebrate Taxa found in Lake Elsinore and Canyon Lake

Common Name	Species	Survival Conductivity Threshold (LC_{50} µS/cm)	Reproduction Conductivity Threshold (EC_{50} µS/cm)	Comment
Water flea	*Daphnia pulex*	1,820	< 1,070 < 2,680	10-day LC_{50}, tiered reproduction response
Water flea	*Diaphanosoma brachyurum*	< 1,968		48-hr LC_{50}
Water flea	*Daphnia pulex*	2,480 < 3,280	2,480 < 3,280	17-day LC_{50}/EC_{50}
Water flea	*Daphnia middendorffiana*	2,856		96-hr LC_{50}, field collected organisms
Water flea	*Moinodaphnia macleayi*	2,893		48-hr LC_{50}
Water flea	*Ceriodaphnia rigaudii*	3,075		48-hr LC_{50}
Water flea	*Daphnia magna*	3,120		No *Daphnia* in lakes > 3,120 µS/cm
Water flea	*Daphnia pulex*	3,318		96-hr LC_{50}, field collected organisms
Water flea	*Ceriodaphnia dubia*	3,350	2,890	7-day chronic LC_{50}, EC_{50} not reported for reproduction
Water flea	*Daphnia magna*	4,284		96-hr LC_{50}, field collected organisms
Water flea	*Ceriodaphnia dubia*	4,620	3,830	7-day chronic
Water flea	*Simocephalus sp.*	4,900		48-hr LC_{50}
Water flea	*Daphnia longispina*	5,384	4,153	48-hr LC_{50}; 21-day EC_{50} reproduction
Water flea	*Chydoridae*	6,000		24-hr LC_{50}
Rotifer	*Epiphanes macrourus*	6,100	2,000 < 4,000	96-hr LC_{50}, EC_{50} 120-hrs population growth
Calanoid Copepod	*Leptodiaptomus tyrelli*	8,591		96-hr LC_{50}, field collected organisms
Water flea	*Daphnia magna*	9,125		
Water flea	*Daphnia magna*	10,449	8,959	48-hr LC_{50}; 21-day EC_{50} reproduction
Cyclopoid Copepod	*Eucyclops sp.*	12,000		72-hr LC_{50}
Calanoid Copepod	*Hesperodiaptomus arcticus*	12,332		96-hr LC_{50}, field collected organisms
Cyclopoid Copepod	*Acanthocyclops sp.*	> 15,000		72-hr LC_{50}

Table A-4. Dissolved Oxygen (DO) Thresholds of Common Fish Taxa found in Lake Elsinore and Canyon Lake

Common Name	Species	Endpoint	DO Threshold (mg/L)	Comment
Largemouth Bass	*Micropterus salmoides*	distress	5.0	adults
Black Crappie	*Pomoxis nigromaculatus*	lethality	4.3	caged at 26 degrees
Common Carp	*Cyprinus carpio*	increased respiration	4.2	at 10 degrees
Common Carp	*Cyprinus carpio*	reduced metabolic rate	3.4	at 10 degrees
Channel Catfish	*Ictalurus punctatus*	retarded growth	3.0	
Striped Bass	*Morone saxatilis*	lethality	3.0	juvenile
Striped Bass	*Morone saxatilis*	lethality	3.0	at 16 degrees, juvenile
Largemouth Bass	*Micropterus salmoides*	lethality	2.5	larval
Largemouth Bass	*Micropterus salmoides*	reduced metabolic rate	2.3	adults at 20 degrees
Gizzard Shad	*Dorosoma cepedianum*	lethality	2.0	
White Bass	*Morone chrysops*	distress	2.0	at 24 degrees
White Bass	*Morone chrysops*	reduced survival	1.8	larvae at 16 degrees
American Shad	*Alosa sapidissima*	lethality	1.6	juvenile at 23 degrees
Striped Bass	*Morone saxatilis*	LC_{50}	1.6	juvenile & adult
Bluegill	*Lepomis macrochirus*	avoidance	1.5	adults
Largemouth Bass	*Micropterus salmoides*	avoidance	1.5	adult
Black Crappie	*Pomoxis nigromaculatus*	lethality	1.4	
Largemouth Bass	*Micropterus salmoides*	lethality	1.2	at 25 degrees
Gizzard Shad	*Dorosoma cepedianum*	lethality	1.0	at 16 degrees
White Bass	*Morone chrysops*	lethality	1.0	at 24 degrees
Bluegill	*Lepomis macrochirus*	LC_{50}	0.9	at 30 degrees
Channel Catfish	*Ictalurus punctatus*	lethality	0.9	juvenile at 25-35 degrees
Common Carp	*Cyprinus carpio*	lethality	0.7	juveniles at 18 degrees
Common Carp	*Cyprinus carpio*	gulping air at surface	0.5	

Table A-5. Un-ionized Ammonia Thresholds of Common Fish Taxa Observed in Lake Elsinore and Canyon Lake

Common Name	Species	Endpoint	Un-ionized Ammonia as N Threshold (mg/L)
White Perch	*Morone americana*	Species Mean Acute Value (LC_{50})	0.27
Hybrid Striped Bass	*Morone saxatilis x chrysops*		0.43
Pumpkinseed	*Lepomis gibbosus*		0.52
Guadalupe bass	*Micropterus treculii*		0.54
White Bass	*Morone chrysops*		0.61
Smallmouth bass	*Micropterus dolomieu*		0.94
Green sunfish	*Lepomis cyanellus*		0.98
Bluegill	*Lepomis macrochirus*		0.99
Steelcolor shiner	*Cyprinella whipplei*		1.01
Largemouth Bass	*Micropterus salmoides*		1.09
Spotfin shiner	*Cyprinella spiloptera*		1.13
Channel Catfish	*Ictalurus punctatus*		1.43
Common Carp	*Cyprinus carpio*		1.44
Striped Bass	*Morone saxatilis*		1.78
Rainbow dace	*Cyprinella lutrensis*		2.42

Table A-6. Un-ionized Ammonia Thresholds of Common Invertebrate Taxa Observed in Lake Elsinore and Canyon Lake (or those closely related)

Common Name	Species	Endpoint	Unionized Ammonia as N Threshold (mg/L)
Water flea	*Ceriodaphnia acanthina*	Species Mean Acute Value (LC_{50})	0.6
Water flea	*Daphnia pulicaria*		0.9
Water flea	*Simocephalus vetulus*		1.0
Water flea	*Ceriodaphnia dubia*		1.3
Water flea	*Chydorus sphaericus*		1.4
Water flea	*Daphnia magna*		1.6
Oligochaete Worm	*Lumbriculus variegatus*		1.7
Midge	*Chironomus tentans*		4.0

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Appendix B-1: Zone Acreage by Owner and Land Use

Owner	Land Use	Zone 1 (Acres)	Zone 2 (Acres)	Zone 3 (Acres)	Zone 4 (Acres)	Zone 5 (Acres)	Zone 6 (Acres)	Zone 7 (Acres)	Zone 8 (Acres)	Zone 9 (Acres)
Ag-CWAD	Commercial / Industrial	1.56	0.00	12.41	30.91	3.42	87.04	129.79	25.79	0.00
Ag-CWAD	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Irrigated Cropland	0.00	1673.51	1905.48	1615.97	953.89	5674.33	6726.33	305.54	0.00
Ag-CWAD	Non-Irrigated Cropland	15.80	1896.16	2194.35	2135.77	2034.35	626.73	2351.06	0.00	0.00
Ag-CWAD	Open Space	0.00	0.00	0.00	0.00	7.68	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	0.00	0.92	2.40	114.40	9.68	11.75	505.10	2241.17	65.54
Ag-CWAD	Other Livestock	0.00	130.35	124.24	301.12	1.05	280.89	512.14	0.00	189.10
Ag-CWAD	Pasture / Hay	0.00	0.00	10.40	0.00	0.00	0.00	2.57	0.00	7.16
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-Small	Commercial / Industrial	6.73	6.08	12.98	55.13	40.24	21.54	16.72	22.29	0.00
Ag-Small	Irrigated Cropland	0.00	241.03	128.96	149.18	221.77	424.57	209.92	12.90	0.00
Ag-Small	Non-Irrigated Cropland	5.91	300.23	572.54	403.08	523.32	158.07	166.64	1.64	0.00
Ag-Small	Orchards / Vineyards	42.62	33.76	31.93	52.59	24.24	12.49	140.25	220.80	15.93
Ag-Small	Other Livestock	0.00	0.00	0.00	24.76	0.00	11.29	0.07	0.00	0.00
Ag-Small	Pasture / Hay	0.00	11.65	8.89	12.16	1.11	11.30	4.16	0.00	0.00
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	48.16	0.00	0.00
BANNING	Forested	0.00	0.00	0.00	0.00	0.00	0.00	70.45	0.00	0.00
BANNING	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	45.45	0.00	0.00
BANNING	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.00
BANNING	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	142.19	0.00	0.00
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	672.50	0.00	0.00
BEAUMONT	Forested	0.00	0.00	0.00	0.00	0.00	0.00	2031.18	0.00	0.00
BEAUMONT	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	87.46	0.00	0.00
BEAUMONT	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	10.11	0.00	0.00
BEAUMONT	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	1328.41	0.00	0.00
CAFO	Dairy	4.03	0.00	0.00	0.00	0.00	195.27	616.75	0.00	0.00
CAFO	Pasture / Hay	2.52	0.00	123.81	14.55	0.00	181.83	1090.56	0.00	0.00
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.00	0.00	0.00	1.84	0.00	2.10	0.00	0.00
California Department of Fish and Wildlife	Forested	0.00	0.00	0.00	0.00	513.02	3013.13	14267.15	122.44	0.00
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	33.33	0.00	0.00
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Commercial / Industrial	17.63	47.53	2.19	53.91	17.78	0.00	74.18	14.89	24.82
Caltrans	Forested	82.43	84.10	16.74	72.44	20.46	0.00	166.14	87.42	460.34
Caltrans	Non-Irrigated Cropland	0.00	0.00	0.00	0.94	0.00	0.00	0.00	1.15	1.81
Caltrans	Open Space	7.96	0.30	0.00	3.83	1.61	0.00	16.82	7.67	6.10
Caltrans	Orchards / Vineyards	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1.09
Caltrans	Pasture / Hay	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00
Caltrans	Roadway	118.01	155.35	204.82	0.49	455.61	0.00	170.39	0.15	0.00
Caltrans	Sewered Residential	11.01	40.32	0.01	20.39	12.80	0.00	9.36	19.34	62.54

Appendix B-1: Zone Acreage by Owner and Land Use

Owner	Land Use	Zone 1 (Acres)	Zone 2 (Acres)	Zone 3 (Acres)	Zone 4 (Acres)	Zone 5 (Acres)	Zone 6 (Acres)	Zone 7 (Acres)	Zone 8 (Acres)	Zone 9 (Acres)
Caltrans	Unsewered Residential	0.00	1.02	0.00	0.53	0.00	0.00	0.11	0.00	1.29
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00
CANYON LAKE	Commercial / Industrial	24.24	9.16	19.79	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Forested	104.58	72.79	53.67	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	77.43	32.73	43.86	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Other Livestock	0.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Roadway	8.37	4.12	12.91	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Sewered Residential	101.92	442.87	731.89	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Water	0.00	287.37	127.97	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	0.00	0.00	0.00	524.69	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	0.00	0.00	0.00	1120.84	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	0.00	0.00	0.00	495.40	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.54	59.82
Federal - National Forest	Forested	5125.56	0.00	0.00	385.14	0.00	0.00	0.00	27891.88	57401.18
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	43.22
Federal - National Forest	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.42	102.50
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88
Federal - National Forest	Pasture / Hay	3.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.68
Federal - National Forest	Sewered Residential	12.77	0.00	0.00	0.00	0.00	0.00	0.00	1.91	111.72
Federal - National Forest	Unsewered Residential	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.15	4.95
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.94	113.76
Federal - Other	Commercial / Industrial	0.00	0.13	0.00	0.00	0.00	8.32	1.56	0.83	0.00
Federal - Other	Forested	0.00	1969.52	118.94	1130.44	61.15	198.36	6820.29	7700.05	0.00
Federal - Other	Non-Irrigated Cropland	0.00	0.00	0.01	55.43	0.00	0.00	0.00	0.00	0.00
Federal - Other	Open Space	0.00	0.07	0.00	0.00	0.00	0.00	0.00	2.02	0.00
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00
Federal - Other	Pasture / Hay	0.00	0.00	0.00	0.22	0.00	0.00	0.00	2.04	0.00
Federal - Other	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.00	4.83	0.62	1.22	0.00	0.15	0.00	9.77	0.00
Federal - Other	Unsewered Residential	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Water	0.00	75.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12538.08	7994.02
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
HEMET	Commercial / Industrial	0.00	0.00	0.00	1681.01	0.00	0.00	685.32	17.95	0.00
HEMET	Forested	0.00	0.00	0.00	3141.65	0.00	0.00	580.27	18.66	0.00
HEMET	Non-Irrigated Cropland	0.00	0.00	0.00	1020.79	0.00	0.00	129.40	2.60	0.00
HEMET	Open Space	0.00	0.00	0.00	938.53	0.00	0.00	98.41	24.02	0.00
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00
HEMET	Other Livestock	0.00	0.00	0.00	3.45	0.00	0.00	32.20	0.00	0.00

Appendix B-1: Zone Acreage by Owner and Land Use

Owner	Land Use	Zone 1 (Acres)	Zone 2 (Acres)	Zone 3 (Acres)	Zone 4 (Acres)	Zone 5 (Acres)	Zone 6 (Acres)	Zone 7 (Acres)	Zone 8 (Acres)	Zone 9 (Acres)
HEMET	Pasture / Hay	0.00	0.00	0.00	5.21	0.00	0.00	39.02	0.01	0.00
HEMET	Roadway	0.00	0.00	0.00	177.54	0.00	0.00	2.47	0.05	0.00
HEMET	Sewered Residential	0.00	0.00	0.00	3961.68	0.00	0.00	1986.04	255.29	0.00
HEMET	Unsewered Residential	0.00	0.00	0.00	9.70	0.00	0.00	20.68	0.00	0.00
HEMET	Water	0.00	0.00	0.00	21.06	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	1402.29	12.77	143.68	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Forested	5657.66	706.84	215.70	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Open Space	423.94	24.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Roadway	56.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Sewered Residential	2845.05	301.26	71.46	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Unsewered Residential	6.05	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Water	3073.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	0.00	0.00	0.00	542.91	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	0.00	0.00	0.00	1496.74	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	0.00	0.00	0.00	185.49	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.00	0.00	0.00	9.49	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	0.00	0.00	0.00	116.21	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	844.40	1853.74	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Forested	273.38	1806.57	5352.43	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Non-Irrigated Cropland	7.03	95.31	712.33	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Open Space	0.00	227.88	1891.65	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Orchards / Vineyards	0.00	15.16	59.94	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Other Livestock	2.68	78.00	108.96	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Pasture / Hay	4.56	94.11	204.65	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Roadway	0.00	54.76	209.60	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Sewered Residential	99.56	1985.50	8247.63	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Unsewered Residential	23.64	136.14	398.38	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Water	0.00	1.47	148.94	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	0.00	0.00	0.00	3718.05	0.00	40.41	0.00	0.00
MORENO VALLEY	Forested	0.00	0.00	0.00	0.00	6112.74	0.00	448.11	0.00	0.00
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	0.00	0.00	0.00	814.83	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	0.00	0.00	0.00	64.15	0.00	8.74	0.00	0.00
MORENO VALLEY	Other Livestock	0.00	0.00	0.00	0.00	14.53	0.00	4.32	0.00	0.00
MORENO VALLEY	Pasture / Hay	0.00	0.00	0.00	0.00	78.44	0.00	3.56	0.00	0.00
MORENO VALLEY	Roadway	0.00	0.00	0.00	0.00	318.37	0.00	2.76	0.00	0.00
MORENO VALLEY	Sewered Residential	0.00	0.00	0.00	0.00	11821.07	0.00	5.64	0.00	0.00
MORENO VALLEY	Unsewered Residential	0.00	0.00	0.00	0.00	93.82	0.00	0.00	0.00	0.00
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	72.35	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	76.90	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Forested	0.00	0.00	83.31	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-1: Zone Acreage by Owner and Land Use

Owner	Land Use	Zone 1 (Acres)	Zone 2 (Acres)	Zone 3 (Acres)	Zone 4 (Acres)	Zone 5 (Acres)	Zone 6 (Acres)	Zone 7 (Acres)	Zone 8 (Acres)	Zone 9 (Acres)
MURRIETA	Open Space	0.00	0.00	8.38	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Pasture / Hay	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Roadway	0.00	0.00	5.79	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Sewered Residential	0.00	0.00	184.69	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Commercial / Industrial	0.00	1455.68	0.00	0.00	2329.47	8.20	0.00	0.00	0.00
PERRIS	Forested	0.00	3730.21	52.28	0.00	2234.12	0.46	0.00	0.00	0.00
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	731.24	0.06	0.00	390.44	0.81	0.00	0.00	0.00
PERRIS	Orchards / Vineyards	0.00	23.89	0.00	0.00	14.60	0.00	0.00	0.00	0.00
PERRIS	Pasture / Hay	0.00	1.03	0.00	0.00	12.04	0.00	0.00	0.00	0.00
PERRIS	Roadway	0.00	106.65	0.00	0.00	191.97	0.00	0.00	0.00	0.00
PERRIS	Sewered Residential	0.00	1240.78	0.00	0.00	2846.79	0.00	0.00	0.00	0.00
PERRIS	Unsewered Residential	0.00	10.45	0.00	0.00	0.26	0.00	0.00	0.00	0.00
PERRIS	Water	0.00	24.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	0.00	0.00	0.00	30.40	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.00	0.00	0.00	2.71	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.00	0.00	0.00	15.01	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	0.00	0.00	0.00	428.72	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	159.29	447.56	383.28	847.15	586.22	773.48	1507.57	607.89	612.42
Riverside County	Forested	3748.56	10396.13	3331.47	19282.38	7833.55	8592.17	20295.98	11267.72	11352.16
Riverside County	Non-Irrigated Cropland	0.00	0.00	316.23	5428.78	860.92	438.11	1026.88	713.71	1693.62
Riverside County	Open Space	13.13	105.90	1009.31	391.29	924.89	37.63	1609.44	415.68	384.05
Riverside County	Orchards / Vineyards	0.99	179.41	19.74	40.60	116.53	121.34	15.12	79.78	0.00
Riverside County	Other Livestock	27.25	68.80	50.84	535.75	56.43	215.13	16.95	26.45	330.80
Riverside County	Pasture / Hay	24.52	320.66	14.98	270.21	142.67	299.58	33.26	38.75	30.62
Riverside County	Roadway	2.74	10.34	64.34	110.50	117.17	126.07	133.70	29.13	0.00
Riverside County	Sewered Residential	1725.30	4983.34	308.77	3941.40	1159.38	2453.61	1021.14	1816.72	3224.59
Riverside County	Unsewered Residential	110.94	1033.43	44.83	566.28	325.71	540.62	58.51	33.02	308.60
Riverside County	Water	108.54	17.32	123.52	5.29	14.16	0.00	31.76	158.37	342.92
SAN JACINTO	Commercial / Industrial	0.00	0.00	0.00	42.06	0.00	0.00	1691.38	30.27	0.00
SAN JACINTO	Forested	0.00	0.00	0.00	100.44	0.00	51.42	3720.66	883.00	0.00
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
SAN JACINTO	Open Space	0.00	0.00	0.00	16.14	0.00	0.00	577.22	199.49	0.00
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	26.02	4.41	0.00
SAN JACINTO	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	170.61	0.00	0.00
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	42.59	0.00	0.00
SAN JACINTO	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	87.64	24.30	0.00
SAN JACINTO	Sewered Residential	0.00	0.00	0.00	7.34	0.00	0.00	3248.25	194.23	0.00
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	16.13	0.00	0.00
SAN JACINTO	Water	0.00	0.00	0.00	14.74	0.00	0.00	0.74	233.74	0.00
State Land	Commercial / Industrial	0.00	0.46	0.00	0.00	22.02	0.00	0.00	17.70	2.30
State Land	Forested	0.00	386.23	0.00	0.00	1948.89	150.56	639.71	230.96	5148.87
State Land	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	58.94	0.00	0.00	0.00	0.00

Appendix B-1: Zone Acreage by Owner and Land Use

Owner	Land Use	Zone 1 (Acres)	Zone 2 (Acres)	Zone 3 (Acres)	Zone 4 (Acres)	Zone 5 (Acres)	Zone 6 (Acres)	Zone 7 (Acres)	Zone 8 (Acres)	Zone 9 (Acres)
State Land	Open Space	0.00	0.00	0.00	0.00	469.81	0.00	0.00	0.00	29.45
State Land	Orchards / Vineyards	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Roadway	0.00	0.00	0.00	0.00	1.27	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	1.59	0.00	0.00	21.73	0.00	0.00	2.45	6.46
State Land	Unsewered Residential	0.00	3.43	0.00	0.00	0.00	0.00	0.00	0.00	0.04
State Land	Water	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.53	0.00
Tribal Reservations	Forested	0.00	0.00	0.00	0.00	0.00	0.00	718.55	6623.40	219.71
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00
Tribal Reservations	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.45	0.00
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.42	0.00
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	284.14	0.00
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	98.83	0.00
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	7.69	0.00	0.00
Western Riverside County Regional Conservation Aut	Forested	0.00	0.00	0.00	979.81	508.62	131.85	1081.31	0.00	0.00
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	235.26	0.00	0.00
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	33.63	0.00	0.00
Western Riverside County Regional Conservation Aut	Sewered Residential	0.00	0.00	0.00	4.73	0.27	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	242.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Forested	2473.22	0.00	6.51	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Open Space	21.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Orchards / Vineyards	12.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Pasture / Hay	16.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Roadway	54.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Sewered Residential	1856.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Unsewered Residential	112.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Water	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-2: Zone Imperviousness by Owner and Land Use

Owner	Land Use	Zone 1 Imperv (Acres)	Zone 2 Imperv (Acres)	Zone 3 Imperv (Acres)	Zone 4 Imperv (Acres)	Zone 5 Imperv (Acres)	Zone 6 Imperv (Acres)	Zone 7 Imperv (Acres)	Zone 8 Imperv (Acres)	Zone 9 Imperv (Acres)
Ag-CWAD	Commercial / Industrial	0.09	0.00	0.42	0.72	0.03	3.14	5.24	1.80	0.00
Ag-CWAD	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Irrigated Cropland	0.00	17.89	16.80	18.63	11.97	46.78	31.21	2.55	0.00
Ag-CWAD	Non-Irrigated Cropland	0.13	11.35	25.39	11.01	18.83	4.54	17.30	0.00	0.00
Ag-CWAD	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	0.00	0.00	0.14	0.09	0.09	0.43	7.52	31.02	0.02
Ag-CWAD	Other Livestock	0.00	1.74	3.35	1.42	0.00	26.16	9.83	0.00	2.56
Ag-CWAD	Pasture / Hay	0.00	0.00	0.42	0.00	0.00	0.00	0.07	0.00	0.08
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-Small	Commercial / Industrial	0.37	0.12	0.84	1.83	1.15	0.86	1.32	1.21	0.00
Ag-Small	Irrigated Cropland	0.00	3.10	4.50	1.47	3.70	4.77	4.48	0.11	0.00
Ag-Small	Non-Irrigated Cropland	0.06	3.57	7.87	2.58	5.57	2.76	1.89	0.00	0.00
Ag-Small	Orchards / Vineyards	3.52	0.57	0.80	1.80	1.02	0.23	7.83	4.85	0.00
Ag-Small	Other Livestock	0.00	0.00	0.00	0.60	0.00	2.16	0.01	0.00	0.00
Ag-Small	Pasture / Hay	0.00	0.10	0.15	0.37	0.04	0.14	0.31	0.00	0.00
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	23.32	0.00	0.00
BANNING	Forested	0.00	0.00	0.00	0.00	0.00	0.00	4.96	0.00	0.00
BANNING	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	3.34	0.00	0.00
BANNING	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
BANNING	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	62.68	0.00	0.00
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	82.53	0.00	0.00
BEAUMONT	Forested	0.00	0.00	0.00	0.00	0.00	0.00	21.08	0.00	0.00
BEAUMONT	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	4.79	0.00	0.00
BEAUMONT	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	3.44	0.00	0.00
BEAUMONT	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	230.32	0.00	0.00
CAFO	Dairy	0.08	0.00	0.00	0.00	0.00	4.07	8.50	0.00	0.00
CAFO	Pasture / Hay	0.00	0.00	6.20	0.29	0.00	16.82	35.26	0.00	0.00
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.00	0.00	0.00	0.07	0.00	0.02	0.00	0.00
California Department of Fish and Wildlife	Forested	0.00	0.00	0.00	0.00	10.26	30.32	47.95	0.00	0.00
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Commercial / Industrial	8.93	19.26	0.75	26.58	6.86	0.00	40.05	6.73	3.47
Caltrans	Forested	8.21	14.82	3.71	11.43	3.79	0.00	23.49	7.90	25.95
Caltrans	Non-Irrigated Cropland	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.13	0.12
Caltrans	Open Space	2.66	0.02	0.00	0.55	0.31	0.00	2.26	0.71	0.56
Caltrans	Orchards / Vineyards	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Caltrans	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Roadway	49.59	50.15	64.50	0.18	176.43	0.00	47.79	0.08	0.00

Appendix B-2: Zone Imperviousness by Owner and Land Use

Owner	Land Use	Zone 1 Imperv (Acres)	Zone 2 Imperv (Acres)	Zone 3 Imperv (Acres)	Zone 4 Imperv (Acres)	Zone 5 Imperv (Acres)	Zone 6 Imperv (Acres)	Zone 7 Imperv (Acres)	Zone 8 Imperv (Acres)	Zone 9 Imperv (Acres)
Caltrans	Sewered Residential	3.31	10.44	0.00	5.66	4.62	0.00	4.07	6.98	4.66
Caltrans	Unsewered Residential	0.00	0.21	0.00	0.04	0.00	0.00	0.01	0.00	0.12
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Commercial / Industrial	12.90	4.78	10.69	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Forested	13.81	21.61	6.69	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	5.03	10.82	7.05	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Other Livestock	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Roadway	3.77	1.70	6.38	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Sewered Residential	41.20	192.53	302.71	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Water	0.00	19.74	25.59	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	0.00	0.00	0.00	166.57	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	0.00	0.00	0.00	51.51	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	0.00	0.00	0.00	199.33	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	2.31
Federal - National Forest	Forested	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Federal - National Forest	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.07
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - National Forest	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - National Forest	Sewered Residential	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.55
Federal - National Forest	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.49
Federal - Other	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Federal - Other	Forested	0.00	16.60	0.00	0.00	0.22	0.85	0.02	0.52	0.00
Federal - Other	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Open Space	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Federal - Other	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.09	0.00
Federal - Other	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Water	0.00	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HEMET	Commercial / Industrial	0.00	0.00	0.00	557.89	0.00	0.00	297.41	7.07	0.00
HEMET	Forested	0.00	0.00	0.00	108.84	0.00	0.00	47.99	1.96	0.00
HEMET	Non-Irrigated Cropland	0.00	0.00	0.00	11.32	0.00	0.00	4.63	0.18	0.00
HEMET	Open Space	0.00	0.00	0.00	139.81	0.00	0.00	16.17	1.97	0.00

Appendix B-2: Zone Imperviousness by Owner and Land Use

Owner	Land Use	Zone 1 Imperv (Acres)	Zone 2 Imperv (Acres)	Zone 3 Imperv (Acres)	Zone 4 Imperv (Acres)	Zone 5 Imperv (Acres)	Zone 6 Imperv (Acres)	Zone 7 Imperv (Acres)	Zone 8 Imperv (Acres)	Zone 9 Imperv (Acres)
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
HEMET	Other Livestock	0.00	0.00	0.00	0.03	0.00	0.00	1.09	0.00	0.00
HEMET	Pasture / Hay	0.00	0.00	0.00	0.10	0.00	0.00	1.79	0.00	0.00
HEMET	Roadway	0.00	0.00	0.00	30.55	0.00	0.00	0.28	0.03	0.00
HEMET	Sewered Residential	0.00	0.00	0.00	1863.59	0.00	0.00	781.29	107.71	0.00
HEMET	Unsewered Residential	0.00	0.00	0.00	0.08	0.00	0.00	2.99	0.00	0.00
HEMET	Water	0.00	0.00	0.00	6.21	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	316.60	7.20	0.91	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Forested	341.60	69.06	1.92	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Open Space	47.21	4.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Roadway	21.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Sewered Residential	1065.40	163.43	3.10	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Unsewered Residential	1.72	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Water	92.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	0.00	0.00	0.00	76.76	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	0.00	0.00	0.00	72.12	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	0.00	0.00	0.00	15.20	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	0.00	0.00	0.00	20.44	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	152.19	366.51	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Forested	1.41	116.22	189.31	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Non-Irrigated Cropland	0.00	1.19	28.96	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Open Space	0.00	6.38	172.61	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Orchards / Vineyards	0.00	0.39	3.01	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Other Livestock	0.00	1.10	7.15	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Pasture / Hay	0.01	4.86	7.51	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Roadway	0.00	7.89	58.98	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Sewered Residential	2.96	346.82	2804.80	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Unsewered Residential	0.39	13.71	25.10	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Water	0.00	0.03	12.60	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	0.00	0.00	0.00	1075.81	0.00	6.46	0.00	0.00
MORENO VALLEY	Forested	0.00	0.00	0.00	0.00	203.65	0.00	16.78	0.00	0.00
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	0.00	0.00	0.00	81.65	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	0.00	0.00	0.00	2.61	0.00	0.75	0.00	0.00
MORENO VALLEY	Other Livestock	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00
MORENO VALLEY	Pasture / Hay	0.00	0.00	0.00	0.00	2.26	0.00	0.03	0.00	0.00
MORENO VALLEY	Roadway	0.00	0.00	0.00	0.00	135.45	0.00	0.52	0.00	0.00
MORENO VALLEY	Sewered Residential	0.00	0.00	0.00	0.00	4511.43	0.00	0.34	0.00	0.00
MORENO VALLEY	Unsewered Residential	0.00	0.00	0.00	0.00	11.81	0.00	0.00	0.00	0.00

Appendix B-2: Zone Imperviousness by Owner and Land Use

Owner	Land Use	Zone 1 Imperv (Acres)	Zone 2 Imperv (Acres)	Zone 3 Imperv (Acres)	Zone 4 Imperv (Acres)	Zone 5 Imperv (Acres)	Zone 6 Imperv (Acres)	Zone 7 Imperv (Acres)	Zone 8 Imperv (Acres)	Zone 9 Imperv (Acres)
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	11.18	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	19.52	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Forested	0.00	0.00	3.95	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Open Space	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Roadway	0.00	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Sewered Residential	0.00	0.00	95.08	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Commercial / Industrial	0.00	263.32	0.00	0.00	522.96	0.08	0.00	0.00	0.00
PERRIS	Forested	0.00	98.10	0.15	0.00	94.26	0.02	0.00	0.00	0.00
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	10.81	0.00	0.00	29.29	0.13	0.00	0.00	0.00
PERRIS	Orchards / Vineyards	0.00	2.51	0.00	0.00	2.30	0.00	0.00	0.00	0.00
PERRIS	Pasture / Hay	0.00	0.02	0.00	0.00	0.39	0.00	0.00	0.00	0.00
PERRIS	Roadway	0.00	15.98	0.00	0.00	41.85	0.00	0.00	0.00	0.00
PERRIS	Sewered Residential	0.00	377.21	0.00	0.00	1042.06	0.00	0.00	0.00	0.00
PERRIS	Unsewered Residential	0.00	0.33	0.00	0.00	0.10	0.00	0.00	0.00	0.00
PERRIS	Water	0.00	2.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	0.00	0.00	0.00	6.59	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	0.00	0.00	0.00	218.65	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	43.66	40.13	8.67	93.88	111.78	57.87	88.75	57.17	25.72
Riverside County	Forested	51.28	118.51	32.48	30.90	72.75	91.91	69.80	26.75	1.61
Riverside County	Non-Irrigated Cropland	0.00	0.00	5.05	14.12	5.91	3.19	19.78	14.17	2.91
Riverside County	Open Space	2.73	5.06	8.23	9.48	26.16	0.63	12.85	19.91	11.68
Riverside County	Orchards / Vineyards	0.18	15.14	0.97	1.62	24.71	3.47	2.85	23.03	0.00
Riverside County	Other Livestock	0.53	1.71	0.73	7.85	0.65	5.25	0.25	0.00	1.89
Riverside County	Pasture / Hay	0.35	5.98	0.43	3.21	2.68	6.85	0.85	0.93	0.26
Riverside County	Roadway	0.25	0.31	1.34	2.50	17.35	14.40	19.38	6.96	0.00
Riverside County	Sewered Residential	401.09	434.14	31.08	612.79	88.15	257.55	283.88	623.75	34.97
Riverside County	Unsewered Residential	14.65	54.04	1.84	20.81	18.84	36.08	6.36	3.59	3.48
Riverside County	Water	18.51	2.77	11.12	0.56	1.14	0.00	1.94	0.56	0.01
SAN JACINTO	Commercial / Industrial	0.00	0.00	0.00	3.32	0.00	0.00	356.56	2.13	0.00
SAN JACINTO	Forested	0.00	0.00	0.00	1.22	0.00	0.00	113.60	14.10	0.00
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Open Space	0.00	0.00	0.00	3.71	0.00	0.00	42.67	10.97	0.00
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	4.45	0.90	0.00
SAN JACINTO	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	2.79	0.00	0.00
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.00
SAN JACINTO	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	14.14	1.70	0.00
SAN JACINTO	Sewered Residential	0.00	0.00	0.00	0.73	0.00	0.00	1100.23	86.16	0.00
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	1.65	0.00	0.00

Appendix B-2: Zone Imperviousness by Owner and Land Use

Owner	Land Use	Zone 1 Imperv (Acres)	Zone 2 Imperv (Acres)	Zone 3 Imperv (Acres)	Zone 4 Imperv (Acres)	Zone 5 Imperv (Acres)	Zone 6 Imperv (Acres)	Zone 7 Imperv (Acres)	Zone 8 Imperv (Acres)	Zone 9 Imperv (Acres)
SAN JACINTO	Water	0.00	0.00	0.00	1.77	0.00	0.00	0.09	5.04	0.00
State Land	Commercial / Industrial	0.00	0.11	0.00	0.00	1.46	0.00	0.00	2.12	0.04
State Land	Forested	0.00	0.78	0.00	0.00	11.60	0.19	0.00	2.31	0.04
State Land	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.00	0.00
State Land	Open Space	0.00	0.00	0.00	0.00	9.86	0.00	0.00	0.00	0.35
State Land	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Roadway	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	0.03	0.00	0.00	5.58	0.00	0.00	0.15	0.01
State Land	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Water	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.71	0.00
Tribal Reservations	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.54	0.00
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34	0.00
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00
Western Riverside County Regional Conservation Aut	Forested	0.00	0.00	0.00	0.00	0.71	0.58	0.33	0.00	0.00
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	5.38	0.00	0.00
Western Riverside County Regional Conservation Aut	Sewered Residential	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	74.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Forested	41.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Open Space	2.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Orchards / Vineyards	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Pasture / Hay	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Roadway	19.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Sewered Residential	406.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Unsewered Residential	13.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Water	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-3: Zone Runoff Coefficent by Owner and Land Use

Owner	Land Use	Zone 1 RC	Zone 2 RC	Zone 3 RC	Zone 4 RC	Zone 5 RC	Zone 6 RC	Zone 7 RC	Zone 8 RC	Zone 9 RC
Ag-CWAD	Commercial / Industrial	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.00
Ag-CWAD	Forested	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00
Ag-CWAD	Irrigated Cropland	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00
Ag-CWAD	Non-Irrigated Cropland	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00	0.00
Ag-CWAD	Open Space	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	0.00	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07
Ag-CWAD	Other Livestock	0.00	0.07	0.07	0.07	0.07	0.08	0.07	0.00	0.07
Ag-CWAD	Pasture / Hay	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.00	0.07
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.09	0.10	0.07	0.00
Ag-CWAD	Sewered Residential	0.00	0.07	0.00	0.07	0.00	0.07	0.07	0.07	0.07
Ag-Small	Commercial / Industrial	0.07	0.07	0.08	0.07	0.07	0.07	0.08	0.07	0.00
Ag-Small	Irrigated Cropland	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00
Ag-Small	Non-Irrigated Cropland	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00
Ag-Small	Orchards / Vineyards	0.08	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.07
Ag-Small	Other Livestock	0.00	0.00	0.00	0.07	0.00	0.11	0.09	0.00	0.00
Ag-Small	Pasture / Hay	0.00	0.07	0.07	0.07	0.07	0.07	0.08	0.00	0.00
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00
BANNING	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
BANNING	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
BANNING	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00
BANNING	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00
BEAUMONT	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
BEAUMONT	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
BEAUMONT	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00
BEAUMONT	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
CAFO	Dairy	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CAFO	Pasture / Hay	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00	0.00
California Department of Fish and Wildlife	Forested	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.00
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.08	0.00	0.07	0.00	0.00
Caltrans	Commercial / Industrial	0.23	0.18	0.15	0.22	0.17	0.00	0.25	0.20	0.09
Caltrans	Forested	0.08	0.10	0.11	0.10	0.10	0.00	0.09	0.08	0.08
Caltrans	Non-Irrigated Cropland	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.09	0.08
Caltrans	Open Space	0.15	0.08	0.00	0.09	0.11	0.00	0.09	0.08	0.08
Caltrans	Orchards / Vineyards	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.08
Caltrans	Pasture / Hay	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.07
Caltrans	Roadway	0.19	0.15	0.14	0.16	0.17	0.00	0.13	0.22	0.00

Appendix B-3: Zone Runoff Coefficent by Owner and Land Use

Owner	Land Use	Zone 1 RC	Zone 2 RC	Zone 3 RC	Zone 4 RC	Zone 5 RC	Zone 6 RC	Zone 7 RC	Zone 8 RC	Zone 9 RC
Caltrans	Sewered Residential	0.14	0.12	0.10	0.13	0.16	0.00	0.19	0.16	0.08
Caltrans	Unsewered Residential	0.00	0.11	0.00	0.08	0.00	0.00	0.09	0.17	0.08
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
CANYON LAKE	Commercial / Industrial	0.25	0.24	0.25	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Forested	0.09	0.14	0.09	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	0.08	0.15	0.10	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Other Livestock	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Roadway	0.20	0.18	0.22	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Sewered Residential	0.18	0.19	0.18	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Water	0.00	0.08	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Forested	0.07	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Federal - National Forest	Pasture / Hay	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Federal - National Forest	Sewered Residential	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Unsewered Residential	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - Other	Commercial / Industrial	0.00	0.07	0.00	0.00	0.00	0.07	0.07	0.08	0.00
Federal - Other	Forested	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.00
Federal - Other	Non-Irrigated Cropland	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.07	0.00
Federal - Other	Open Space	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Federal - Other	Pasture / Hay	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.00
Federal - Other	Roadway	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.00	0.07	0.07	0.07	0.00	0.07	0.00	0.07	0.00
Federal - Other	Unsewered Residential	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Water	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
HEMET	Commercial / Industrial	0.00	0.00	0.00	0.15	0.00	0.00	0.19	0.17	0.00
HEMET	Forested	0.00	0.00	0.00	0.07	0.00	0.00	0.08	0.08	0.00
HEMET	Non-Irrigated Cropland	0.00	0.00	0.00	0.07	0.00	0.00	0.07	0.08	0.00
HEMET	Open Space	0.00	0.00	0.00	0.09	0.00	0.00	0.10	0.08	0.00

Appendix B-3: Zone Runoff Coefficent by Owner and Land Use

Owner	Land Use	Zone 1 RC	Zone 2 RC	Zone 3 RC	Zone 4 RC	Zone 5 RC	Zone 6 RC	Zone 7 RC	Zone 8 RC	Zone 9 RC
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
HEMET	Other Livestock	0.00	0.00	0.00	0.07	0.00	0.00	0.07	0.00	0.00
HEMET	Pasture / Hay	0.00	0.00	0.00	0.07	0.00	0.00	0.07	0.07	0.00
HEMET	Roadway	0.00	0.00	0.00	0.10	0.00	0.00	0.09	0.26	0.00
HEMET	Sewered Residential	0.00	0.00	0.00	0.21	0.00	0.00	0.17	0.19	0.00
HEMET	Unsewered Residential	0.00	0.00	0.00	0.07	0.00	0.00	0.09	0.00	0.00
HEMET	Water	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	0.11	0.27	0.07	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Forested	0.08	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Open Space	0.09	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Other Livestock	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Roadway	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Sewered Residential	0.17	0.25	0.07	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Unsewered Residential	0.13	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Water	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Forested	0.07	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Non-Irrigated Cropland	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Open Space	0.00	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Orchards / Vineyards	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Other Livestock	0.07	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Pasture / Hay	0.07	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Roadway	0.00	0.09	0.13	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Sewered Residential	0.07	0.10	0.15	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Unsewered Residential	0.07	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Water	0.00	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	0.00	0.00	0.00	0.13	0.00	0.10	0.00	0.00
MORENO VALLEY	Forested	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00	0.00
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.07	0.00	0.08	0.00	0.00
MORENO VALLEY	Other Livestock	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00	0.00
MORENO VALLEY	Pasture / Hay	0.00	0.00	0.00	0.00	0.07	0.00	0.07	0.00	0.00
MORENO VALLEY	Roadway	0.00	0.00	0.00	0.00	0.19	0.00	0.11	0.00	0.00
MORENO VALLEY	Sewered Residential	0.00	0.00	0.00	0.00	0.17	0.00	0.08	0.00	0.00
MORENO VALLEY	Unsewered Residential	0.00	0.00	0.00	0.00	0.09	0.00	0.10	0.00	0.00

Owner	Land Use	Zone 1 RC	Zone 2 RC	Zone 3 RC	Zone 4 RC	Zone 5 RC	Zone 6 RC	Zone 7 RC	Zone 8 RC	Zone 9 RC
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Forested	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Open Space	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Pasture / Hay	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Roadway	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Sewered Residential	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Commercial / Industrial	0.00	0.10	0.00	0.00	0.11	0.07	0.00	0.00	0.00
PERRIS	Forested	0.00	0.07	0.07	0.00	0.07	0.07	0.00	0.00	0.00
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	0.07	0.07	0.00	0.08	0.10	0.00	0.00	0.00
PERRIS	Orchards / Vineyards	0.00	0.08	0.00	0.00	0.10	0.00	0.00	0.00	0.00
PERRIS	Pasture / Hay	0.00	0.07	0.00	0.00	0.07	0.00	0.00	0.00	0.00
PERRIS	Roadway	0.00	0.09	0.00	0.00	0.11	0.00	0.00	0.00	0.00
PERRIS	Sewered Residential	0.00	0.14	0.00	0.00	0.16	0.00	0.00	0.00	0.00
PERRIS	Unsewered Residential	0.00	0.07	0.00	0.00	0.17	0.00	0.00	0.00	0.00
PERRIS	Water	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	0.13	0.08	0.07	0.09	0.11	0.08	0.08	0.08	0.07
Riverside County	Forested	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Riverside County	Non-Irrigated Cropland	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Riverside County	Open Space	0.11	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Riverside County	Orchards / Vineyards	0.10	0.08	0.07	0.07	0.11	0.07	0.10	0.13	0.00
Riverside County	Other Livestock	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Riverside County	Pasture / Hay	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Riverside County	Roadway	0.08	0.07	0.07	0.07	0.09	0.09	0.09	0.12	0.00
Riverside County	Sewered Residential	0.12	0.08	0.08	0.10	0.08	0.08	0.13	0.15	0.07
Riverside County	Unsewered Residential	0.09	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.07
Riverside County	Water	0.10	0.10	0.08	0.09	0.08	0.00	0.08	0.07	0.07
SAN JACINTO	Commercial / Industrial	0.00	0.00	0.00	0.08	0.00	0.00	0.11	0.08	0.00
SAN JACINTO	Forested	0.00	0.00	0.00	0.07	0.00	0.07	0.07	0.07	0.00
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
SAN JACINTO	Open Space	0.00	0.00	0.00	0.12	0.00	0.00	0.08	0.07	0.00
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.11	0.00
SAN JACINTO	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
SAN JACINTO	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.08	0.00
SAN JACINTO	Sewered Residential	0.00	0.00	0.00	0.08	0.00	0.00	0.15	0.20	0.00
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00

Appendix B-3: Zone Runoff Coefficent by Owner and Land Use

Owner	Land Use	Zone 1 RC	Zone 2 RC	Zone 3 RC	Zone 4 RC	Zone 5 RC	Zone 6 RC	Zone 7 RC	Zone 8 RC	Zone 9 RC
SAN JACINTO	Water	0.00	0.00	0.00	0.09	0.00	0.00	0.09	0.07	0.00
State Land	Commercial / Industrial	0.00	0.12	0.00	0.00	0.08	0.00	0.00	0.09	0.07
State Land	Forested	0.00	0.07	0.00	0.00	0.07	0.07	0.07	0.07	0.07
State Land	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
State Land	Open Space	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07
State Land	Orchards / Vineyards	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Roadway	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	0.07	0.00	0.00	0.12	0.00	0.00	0.08	0.07
State Land	Unsewered Residential	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.07
State Land	Water	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00
Tribal Reservations	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Tribal Reservations	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00
Western Riverside County Regional Conservation Aut	Forested	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.00	0.00
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
Western Riverside County Regional Conservation Aut	Sewered Residential	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Forested	0.07	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Open Space	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Orchards / Vineyards	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Pasture / Hay	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Roadway	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Sewered Residential	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Unsewered Residential	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Water	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
Ag-CWAD	Commercial / Industrial	0.11	0.00	0.79	1.92	0.54	0.20	0.18	5.34	4.82	9.39	2.01	0.00	0.96
Ag-CWAD	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Irrigated Cropland	0.00	96.43	114.38	97.66	27.40	55.22	52.13	324.98	292.94	445.10	20.41	0.00	39.18
Ag-CWAD	Non-Irrigated Cropland	1.00	107.99	132.62	127.03	35.64	116.81	110.27	35.80	32.28	156.63	0.00	0.00	13.18
Ag-CWAD	Open Space	0.00	0.00	0.00	0.00	0.00	0.43	0.41	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	0.00	0.05	0.16	6.73	1.89	0.56	0.52	0.72	0.65	34.29	151.75	9.17	16.43
Ag-CWAD	Other Livestock	0.00	7.56	7.80	17.89	5.02	0.06	0.06	19.89	17.93	35.14	0.00	27.35	5.26
Ag-CWAD	Pasture / Hay	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	1.03	0.10
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-Small	Commercial / Industrial	0.48	0.36	0.90	3.52	0.99	2.42	2.29	1.34	1.20	1.33	1.67	0.00	0.25
Ag-Small	Irrigated Cropland	0.00	13.96	8.26	8.98	2.52	12.97	12.25	24.50	22.08	14.48	0.86	0.00	1.29
Ag-Small	Non-Irrigated Cropland	0.37	17.35	34.79	24.05	6.75	30.15	28.46	9.26	8.35	11.21	0.11	0.00	0.95
Ag-Small	Orchards / Vineyards	3.24	1.98	2.00	3.36	0.94	1.51	1.43	0.73	0.66	10.55	15.26	2.23	2.36
Ag-Small	Other Livestock	0.00	0.00	0.00	1.55	0.43	0.00	0.00	1.02	0.92	0.01	0.00	0.00	0.00
Ag-Small	Pasture / Hay	0.00	0.67	0.54	0.77	0.22	0.07	0.06	0.65	0.59	0.33	0.00	0.00	0.03
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.57	0.00	0.00	0.89
BANNING	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50	0.00	0.00	0.46
BANNING	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.30
BANNING	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.02
BANNING	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.00	0.00	0.00	2.36
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.01
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	59.78	0.00	0.00	5.03
BEAUMONT	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	136.35	0.00	0.00	11.48
BEAUMONT	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.56	0.00	0.00	0.55
BEAUMONT	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	0.13
BEAUMONT	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	134.03	0.00	0.00	11.28
CAFO	Dairy	0.05	0.00	0.00	0.00	0.00	0.00	0.00	2.35	2.12	8.65	0.00	0.00	0.73
CAFO	Pasture / Hay	0.03	0.00	1.56	0.18	0.05	0.00	0.00	2.19	1.97	15.29	0.00	0.00	1.29
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00	0.14	0.00	0.00	0.01
California Department of Fish and Wildlife	Forested	0.00	0.00	0.00	0.00	0.00	30.26	28.56	173.35	156.27	941.07	8.01	0.00	79.88
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.26	0.00	0.00	0.19
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Commercial / Industrial	3.87	7.34	0.30	10.86	3.05	2.62	2.47	0.00	0.00	18.71	3.01	4.92	2.24
Caltrans	Forested	6.54	7.33	1.71	6.31	1.77	1.82	1.72	0.00	0.00	15.48	7.17	74.09	8.14
Caltrans	Non-Irrigated Cropland	0.00	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.10	0.30	0.03

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
Caltrans	Open Space	1.13	0.02	0.00	0.32	0.09	0.15	0.14	0.00	0.00	1.54	0.63	1.07	0.27
Caltrans	Orchards / Vineyards	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.02
Caltrans	Pasture / Hay	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Roadway	20.86	19.53	26.43	0.07	0.02	67.30	63.53	0.00	0.00	22.47	0.03	0.00	1.89
Caltrans	Sewered Residential	1.44	4.32	0.00	2.40	0.67	1.77	1.67	0.00	0.00	1.81	3.12	10.53	1.30
Caltrans	Unsewered Residential	0.00	0.10	0.00	0.04	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.23	0.02
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
CANYON LAKE	Commercial / Industrial	5.67	1.89	4.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Forested	8.99	8.58	4.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	5.63	4.20	3.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Other Livestock	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Roadway	1.59	0.65	2.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Sewered Residential	17.31	73.67	120.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Water	0.00	19.14	12.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	65.10	61.46	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.00	0.00	0.00	0.00	0.20	0.19	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	0.00	0.00	0.00	0.00	70.54	66.59	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	0.00	0.00	0.00	0.00	76.00	71.75	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	9.21	0.85
Federal - National Forest	Forested	316.95	0.00	0.00	22.61	6.35	0.00	0.00	0.00	0.00	0.00	1824.53	8024.48	828.97
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.05	0.51
Federal - National Forest	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	14.71	1.31
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.02
Federal - National Forest	Pasture / Hay	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.02
Federal - National Forest	Sewered Residential	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	15.81	1.34
Federal - National Forest	Unsewered Residential	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.72	0.06
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	16.07	1.37
Federal - Other	Commercial / Industrial	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.47	0.42	0.10	0.06	0.00	0.01
Federal - Other	Forested	0.00	112.85	6.98	66.37	18.62	3.46	3.27	11.25	10.14	446.11	503.74	0.00	79.95
Federal - Other	Non-Irrigated Cropland	0.00	0.00	0.00	3.25	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Open Space	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.01
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Federal - Other	Pasture / Hay	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.01
Federal - Other	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.00	0.29	0.04	0.07	0.02	0.00	0.00	0.01	0.01	0.00	0.65	0.00	0.06
Federal - Other	Unsewered Residential	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Water	0.00	4.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	820.10	1117.54	163.09

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
HEMET	Commercial / Industrial	0.00	0.00	0.00	226.29	63.49	0.00	0.00	0.00	0.00	132.65	3.14	0.00	11.43
HEMET	Forested	0.00	0.00	0.00	201.15	56.44	0.00	0.00	0.00	0.00	46.67	1.59	0.00	4.06
HEMET	Non-Irrigated Cropland	0.00	0.00	0.00	61.62	17.29	0.00	0.00	0.00	0.00	9.26	0.20	0.00	0.80
HEMET	Open Space	0.00	0.00	0.00	79.97	22.44	0.00	0.00	0.00	0.00	9.71	1.93	0.00	0.98
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
HEMET	Other Livestock	0.00	0.00	0.00	0.21	0.06	0.00	0.00	0.00	0.00	2.29	0.00	0.00	0.19
HEMET	Pasture / Hay	0.00	0.00	0.00	0.32	0.09	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.24
HEMET	Roadway	0.00	0.00	0.00	16.03	4.50	0.00	0.00	0.00	0.00	0.21	0.01	0.00	0.02
HEMET	Sewered Residential	0.00	0.00	0.00	753.99	211.56	0.00	0.00	0.00	0.00	347.33	47.95	0.00	33.27
HEMET	Unsewered Residential	0.00	0.00	0.00	0.58	0.16	0.00	0.00	0.00	0.00	1.94	0.00	0.00	0.16
HEMET	Water	0.00	0.00	0.00	2.59	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	152.43	2.94	8.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Forested	406.73	50.63	12.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Open Space	34.62	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Roadway	9.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Sewered Residential	448.52	65.61	4.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Unsewered Residential	0.76	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Water	204.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	43.37	40.95	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	0.00	0.00	0.00	0.00	94.72	89.42	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	0.00	0.00	0.00	0.00	12.77	12.06	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.00	0.00	0.00	0.00	0.59	0.56	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	0.00	0.00	0.00	0.00	10.12	9.55	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	74.34	178.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Forested	17.12	119.04	343.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Non-Irrigated Cropland	0.43	5.52	46.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Open Space	0.00	13.71	139.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Orchards / Vineyards	0.00	0.91	3.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Other Livestock	0.17	4.53	7.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Pasture / Hay	0.28	6.01	13.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Roadway	0.00	4.40	24.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Sewered Residential	6.63	172.39	1133.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Unsewered Residential	1.52	9.82	27.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MENIFEE	Water	0.00	0.09	10.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	429.99	405.93	0.00	0.00	3.94	0.00	0.00	0.33
MORENO VALLEY	Forested	0.00	0.00	0.00	0.00	0.00	372.73	351.88	0.00	0.00	32.19	0.00	0.00	2.71
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	0.00	0.00	0.00	0.00	58.73	55.44	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	3.98	3.76	0.00	0.00	0.71	0.00	0.00	0.06

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
MORENO VALLEY	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.87	0.83	0.00	0.00	0.28	0.00	0.00	0.02
MORENO VALLEY	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	4.73	4.46	0.00	0.00	0.24	0.00	0.00	0.02
MORENO VALLEY	Roadway	0.00	0.00	0.00	0.00	0.00	51.74	48.85	0.00	0.00	0.29	0.00	0.00	0.02
MORENO VALLEY	Sewered Residential	0.00	0.00	0.00	0.00	0.00	1721.91	1625.55	0.00	0.00	0.43	0.00	0.00	0.04
MORENO VALLEY	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	7.21	6.81	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	0.00	5.97	5.64	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	8.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Forested	0.00	0.00	5.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Open Space	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Pasture / Hay	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Roadway	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Sewered Residential	0.00	0.00	39.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Commercial / Industrial	0.00	128.37	0.00	0.00	0.00	229.08	216.26	0.47	0.42	0.00	0.00	0.00	0.00
PERRIS	Forested	0.00	223.50	3.09	0.00	0.00	139.28	131.49	0.03	0.03	0.00	0.00	0.00	0.00
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	42.57	0.00	0.00	0.00	26.42	24.94	0.07	0.06	0.00	0.00	0.00	0.00
PERRIS	Orchards / Vineyards	0.00	1.74	0.00	0.00	0.00	1.21	1.15	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Pasture / Hay	0.00	0.06	0.00	0.00	0.00	0.73	0.69	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Roadway	0.00	8.70	0.00	0.00	0.00	18.57	17.53	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Sewered Residential	0.00	148.86	0.00	0.00	0.00	398.82	376.50	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Unsewered Residential	0.00	0.63	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Water	0.00	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	2.93	2.77	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.00	0.00	0.00	0.00	0.26	0.24	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.00	0.00	0.00	0.00	1.14	1.07	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	0.00	0.00	0.00	0.00	86.08	81.26	0.00	0.00	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	19.54	31.42	23.81	65.62	18.41	52.98	50.01	52.32	47.16	114.24	50.30	95.09	21.85
Riverside County	Forested	239.79	600.12	200.44	1136.72	318.95	449.81	424.64	495.12	446.31	1339.00	741.40	1587.56	308.72
Riverside County	Non-Irrigated Cropland	0.00	0.00	19.32	320.83	90.02	49.14	46.39	25.03	22.56	70.48	49.06	237.78	30.08
Riverside County	Open Space	1.36	6.70	60.48	24.41	6.85	55.69	52.58	2.20	1.98	107.39	30.65	57.93	16.49
Riverside County	Orchards / Vineyards	0.10	12.43	1.31	2.63	0.74	11.11	10.49	7.31	6.59	1.59	10.74	0.00	1.04
Riverside County	Other Livestock	1.77	4.11	3.09	32.63	9.16	3.26	3.08	12.83	11.56	1.15	1.73	46.91	4.19
Riverside County	Pasture / Hay	1.57	18.85	0.94	16.34	4.59	8.39	7.92	17.80	16.04	2.32	2.69	4.37	0.79
Riverside County	Roadway	0.21	0.63	3.98	6.87	1.93	9.52	8.99	9.41	8.48	12.56	3.46	0.00	1.35
Riverside County	Sewered Residential	190.71	347.62	23.32	341.36	95.78	78.66	74.26	178.96	161.32	133.83	280.35	463.18	73.85
Riverside County	Unsewered Residential	9.54	66.08	2.92	36.45	10.23	21.12	19.93	35.84	32.31	5.02	2.83	44.37	4.40
Riverside County	Water	10.28	1.45	9.08	0.40	0.11	0.97	0.92	0.00	0.00	2.42	10.45	47.94	5.12
SAN JACINTO	Commercial / Industrial	0.00	0.00	0.00	3.01	0.84	0.00	0.00	0.00	0.00	187.40	2.36	0.00	15.97
SAN JACINTO	Forested	0.00	0.00	0.00	6.08	1.71	0.00	0.00	2.88	2.60	262.67	60.11	0.00	27.17
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Open Space	0.00	0.00	0.00	1.68	0.47	0.00	0.00	0.00	0.00	45.42	14.97	0.00	5.08
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.48	0.00	0.26

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
SAN JACINTO	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.63	0.00	0.00	0.98
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.05	0.00	0.00	0.26
SAN JACINTO	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.58	1.89	0.00	0.88
SAN JACINTO	Sewered Residential	0.00	0.00	0.00	0.55	0.16	0.00	0.00	0.00	0.00	495.50	38.51	0.00	44.95
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.11
SAN JACINTO	Water	0.00	0.00	0.00	1.17	0.33	0.00	0.00	0.00	0.00	0.07	16.13	0.00	1.36
State Land	Commercial / Industrial	0.00	0.05	0.00	0.00	0.00	1.46	1.38	0.00	0.00	0.00	1.56	0.34	0.16
State Land	Forested	0.00	21.78	0.00	0.00	0.00	110.98	104.77	8.47	7.64	41.84	15.49	719.81	65.41
State Land	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	3.39	3.20	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Open Space	0.00	0.00	0.00	0.00	0.00	27.78	26.22	0.00	0.00	0.00	0.00	4.24	0.36
State Land	Orchards / Vineyards	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Roadway	0.00	0.00	0.00	0.00	0.00	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	0.09	0.00	0.00	0.00	2.32	2.19	0.00	0.00	0.00	0.19	0.90	0.09
State Land	Unsewered Residential	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
State Land	Water	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.72	0.00	0.90
Tribal Reservations	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.00	433.23	30.72	43.01
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01
Tribal Reservations	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.95	0.00	0.33
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.02
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.57	0.00	1.73
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.86	0.00	0.58
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.08
Western Riverside County Regional Conservation Aut	Forested	0.00	0.00	0.00	57.53	16.14	28.64	27.03	7.48	6.74	70.78	0.00	0.00	5.96
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.45	0.00	0.00	1.30
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.28	0.00	0.00	0.28
Western Riverside County Regional Conservation Aut	Sewered Residential	0.00	0.00	0.00	0.28	0.08	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	32.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Forested	159.49	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Open Space	1.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Orchards / Vineyards	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Pasture / Hay	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Roadway	8.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Sewered Residential	198.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Unsewered Residential	9.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-4: Simulated Zone Watershed Runoff and Actual Runoff by Owner and Land Use

Owner	Land Use	Zone 1 Q (AFY)	Zone 2 Q (AFY)	Zone 3 Q (AFY)	Zone 4 Qshed (AFY)	Zone 4 Q (AFY)	Zone 5 Qshed (AFY)	Zone 5 Q (AFY)	Zone 6 Qshed (AFY)	Zone 6 Q (AFY)	Zone 7 Qshed (AFY)	Zone 8 Qshed (AFY)	Zone 9 Qshed (AFY)	Zone 7-9 Q (AFY)
WILDOMAR	Water	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-5: Simulated Zone Annual Total Phosphorus Load By Owner and Land Use

Owner	Land Use	Zone 1 TP (kg/yr)	Zone 2 TP (kg/yr)	Zone 3 TP (kg/yr)	Zone 4 TP (kg/yr)	Zone 5 TP (kg/yr)	Zone 6 TP (kg/yr)	Zone 7-9 TP (kg/yr)
Ag-CWAD	Commercial / Industrial	0.36	0.12	3.21	0.64	0.53	0.00	3.81
Ag-CWAD	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Irrigated Cropland	13.52	25.72	144.55	19.33	0.00	118.96	141.10
Ag-CWAD	Non-Irrigated Cropland	83.54	258.46	75.65	30.90	4.91	532.85	654.43
Ag-CWAD	Open Space	0.00	0.16	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	2.63	0.73	0.91	22.90	0.00	0.11	0.34
Ag-CWAD	Other Livestock	15.48	0.17	55.30	16.22	0.00	46.64	48.13
Ag-CWAD	Pasture / Hay	0.00	0.00	0.00	0.31	0.00	0.00	4.16
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-Small	Commercial / Industrial	0.66	1.52	0.80	0.17	2.29	1.72	4.30
Ag-Small	Irrigated Cropland	1.24	6.04	10.90	0.64	0.00	17.23	10.19
Ag-Small	Non-Irrigated Cropland	15.82	66.72	19.57	2.23	1.85	85.62	171.68
Ag-Small	Orchards / Vineyards	1.32	1.99	0.92	3.29	6.83	4.17	4.21
Ag-Small	Other Livestock	1.34	0.00	2.84	0.00	0.00	0.00	0.00
Ag-Small	Pasture / Hay	0.67	0.20	1.82	0.09	0.00	4.12	3.36
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.59	0.00	0.00	0.00
BANNING	Forested	0.00	0.00	0.00	0.18	0.00	0.00	0.00
BANNING	Open Space	0.00	0.00	0.00	0.12	0.00	0.00	0.00
BANNING	Roadway	0.00	0.00	0.00	0.01	0.00	0.00	0.00
BANNING	Sewered Residential	0.00	0.00	0.00	1.40	0.00	0.00	0.00
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	3.35	0.00	0.00	0.00
BEAUMONT	Forested	0.00	0.00	0.00	4.39	0.00	0.00	0.00
BEAUMONT	Open Space	0.00	0.00	0.00	0.21	0.00	0.00	0.00
BEAUMONT	Roadway	0.00	0.00	0.00	0.05	0.00	0.00	0.00
BEAUMONT	Sewered Residential	0.00	0.00	0.00	6.68	0.00	0.00	0.00
CAFO	Dairy	0.00	0.00	16.94	5.82	0.85	0.00	0.00
CAFO	Pasture / Hay	0.16	0.00	6.08	3.97	0.21	0.00	9.61
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.07	0.00	0.01	0.00	0.00	0.00
California Department of Fish and Wildlife	Forested	0.00	10.92	59.76	30.55	0.00	0.00	0.00
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.45	0.00	0.00	0.00
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Commercial / Industrial	2.03	1.65	0.00	1.49	18.56	35.24	1.46
Caltrans	Forested	0.68	0.66	0.00	3.11	7.66	8.59	2.00
Caltrans	Non-Irrigated Cropland	0.05	0.00	0.00	0.08	0.00	0.00	0.00
Caltrans	Open Space	0.03	0.05	0.00	0.10	1.33	0.02	0.00
Caltrans	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Caltrans	Pasture / Hay	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Roadway	0.01	23.90	0.00	0.71	125.44	117.48	158.92
Caltrans	Sewered Residential	0.40	0.99	0.00	0.77	5.22	15.63	0.00

Appendix B-5: Simulated Zone Annual Total Phosphorus Load By Owner and Land Use

Owner	Land Use	Zone 1 TP (kg/yr)	Zone 2 TP (kg/yr)	Zone 3 TP (kg/yr)	Zone 4 TP (kg/yr)	Zone 5 TP (kg/yr)	Zone 6 TP (kg/yr)	Zone 7-9 TP (kg/yr)
Caltrans	Unsewered Residential	0.01	0.00	0.00	0.01	0.00	0.63	0.00
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Commercial / Industrial	0.00	0.00	0.00	0.00	27.19	9.08	21.52
CANYON LAKE	Forested	0.00	0.00	0.00	0.00	10.54	10.05	5.04
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	0.00	0.00	0.00	0.00	6.60	4.92	4.51
CANYON LAKE	Other Livestock	0.00	0.00	0.00	0.00	0.00	5.86	0.00
CANYON LAKE	Roadway	0.00	0.00	0.00	0.00	9.59	3.90	15.68
CANYON LAKE	Sewered Residential	0.00	0.00	0.00	0.00	62.63	266.54	437.27
CANYON LAKE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	40.94	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	25.47	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	26.99	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Federal - National Forest	Forested	2.43	0.00	0.00	317.02	371.45	0.00	0.00
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	1.19	0.00	0.00	0.00
Federal - National Forest	Open Space	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Federal - National Forest	Pasture / Hay	0.00	0.00	0.00	0.06	1.42	0.00	0.00
Federal - National Forest	Sewered Residential	0.00	0.00	0.00	0.79	2.95	0.00	0.00
Federal - National Forest	Unsewered Residential	0.00	0.00	0.00	0.04	0.13	0.00	0.00
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Commercial / Industrial	0.00	0.00	0.28	0.01	0.00	0.03	0.00
Federal - Other	Forested	7.12	1.25	3.88	30.57	0.00	132.25	8.18
Federal - Other	Non-Irrigated Cropland	2.14	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Open Space	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Federal - Other	Pasture / Hay	0.01	0.00	0.00	0.03	0.00	0.00	0.00
Federal - Other	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.01	0.00	0.00	0.03	0.00	1.05	0.13
Federal - Other	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.21	0.00
Federal - Other	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	62.37	0.00	0.00	0.00
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Commercial / Industrial	42.30	0.00	0.00	7.61	0.00	0.00	0.00
HEMET	Forested	21.58	0.00	0.00	1.55	0.00	0.00	0.00
HEMET	Non-Irrigated Cropland	40.53	0.00	0.00	1.87	0.00	0.00	0.00
HEMET	Open Space	8.58	0.00	0.00	0.37	0.00	0.00	0.00
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Other Livestock	0.18	0.00	0.00	0.59	0.00	0.00	0.00

Appendix B-5: Simulated Zone Annual Total Phosphorus Load By Owner and Land Use

Owner	Land Use	Zone 1 TP (kg/yr)	Zone 2 TP (kg/yr)	Zone 3 TP (kg/yr)	Zone 4 TP (kg/yr)	Zone 5 TP (kg/yr)	Zone 6 TP (kg/yr)	Zone 7-9 TP (kg/yr)
HEMET	Pasture / Hay	0.28	0.00	0.00	0.74	0.00	0.00	0.00
HEMET	Roadway	1.69	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Sewered Residential	125.27	0.00	0.00	19.70	0.00	0.00	0.00
HEMET	Unsewered Residential	0.12	0.00	0.00	0.12	0.00	0.00	0.00
HEMET	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	0.00	0.00	0.00	0.00	731.49	14.09	41.13
LAKE ELSINORE	Forested	0.00	0.00	0.00	0.00	476.66	59.33	15.18
LAKE ELSINORE	Open Space	0.00	0.00	0.00	0.00	40.57	2.62	0.00
LAKE ELSINORE	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	0.00	0.00	0.00	0.00	1.09	0.00	0.00
LAKE ELSINORE	Roadway	0.00	0.00	0.00	0.00	54.16	0.00	0.00
LAKE ELSINORE	Sewered Residential	0.00	0.00	0.00	0.00	1622.84	237.38	16.92
LAKE ELSINORE	Unsewered Residential	0.00	0.00	0.00	0.00	4.99	0.00	0.05
LAKE ELSINORE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	27.28	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	34.20	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	4.61	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.21	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	5.66	0.00	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	356.74	856.25
MENIFEE	Forested	0.00	0.00	0.00	0.00	20.06	139.51	402.36
MENIFEE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	2.14	27.22	228.46
MENIFEE	Open Space	0.00	0.00	0.00	0.00	0.00	16.07	163.52
MENIFEE	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	1.91	8.42
MENIFEE	Other Livestock	0.00	0.00	0.00	0.00	1.02	27.96	46.50
MENIFEE	Pasture / Hay	0.00	0.00	0.00	0.00	1.75	37.06	81.24
MENIFEE	Roadway	0.00	0.00	0.00	0.00	0.00	26.48	149.56
MENIFEE	Sewered Residential	0.00	0.00	0.00	0.00	23.99	623.74	4100.20
MENIFEE	Unsewered Residential	0.00	0.00	0.00	0.00	9.96	64.23	179.02
MENIFEE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	270.41	0.00	0.22	0.00	0.00	0.00
MORENO VALLEY	Forested	0.00	134.56	0.00	1.04	0.00	0.00	0.00
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	21.20	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	5.24	0.00	0.08	0.00	0.00	0.00
MORENO VALLEY	Other Livestock	0.00	2.55	0.00	0.07	0.00	0.00	0.00
MORENO VALLEY	Pasture / Hay	0.00	13.77	0.00	0.06	0.00	0.00	0.00
MORENO VALLEY	Roadway	0.00	18.38	0.00	0.01	0.00	0.00	0.00
MORENO VALLEY	Sewered Residential	0.00	962.55	0.00	0.02	0.00	0.00	0.00
MORENO VALLEY	Unsewered Residential	0.00	4.95	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	40.87
MURRIETA	Forested	0.00	0.00	0.00	0.00	0.00	0.00	6.45

Appendix B-5: Simulated Zone Annual Total Phosphorus Load By Owner and Land Use

Owner	Land Use	Zone 1 TP (kg/yr)	Zone 2 TP (kg/yr)	Zone 3 TP (kg/yr)	Zone 4 TP (kg/yr)	Zone 5 TP (kg/yr)	Zone 6 TP (kg/yr)	Zone 7-9 TP (kg/yr)
MURRIETA	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.78
MURRIETA	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.04
MURRIETA	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	2.56
MURRIETA	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	142.11
PERRIS	Commercial / Industrial	0.00	144.06	0.28	0.00	0.00	616.01	0.00
PERRIS	Forested	0.00	50.28	0.01	0.00	0.00	261.93	3.62
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	9.54	0.02	0.00	0.00	49.89	0.00
PERRIS	Orchards / Vineyards	0.00	1.60	0.00	0.00	0.00	3.68	0.00
PERRIS	Pasture / Hay	0.00	2.13	0.00	0.00	0.00	0.37	0.00
PERRIS	Roadway	0.00	6.60	0.00	0.00	0.00	52.33	0.00
PERRIS	Sewered Residential	0.00	222.94	0.00	0.00	0.00	538.59	0.00
PERRIS	Unsewered Residential	0.00	0.03	0.00	0.00	0.00	4.15	0.00
PERRIS	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	1.84	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.09	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.41	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	48.12	0.00	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	12.27	33.32	31.42	14.56	93.76	150.77	114.28
Riverside County	Forested	121.97	162.39	170.68	118.06	281.02	703.31	234.90
Riverside County	Non-Irrigated Cropland	211.00	108.73	52.89	70.49	0.00	0.00	95.36
Riverside County	Open Space	2.62	20.11	0.76	6.31	1.60	7.85	70.88
Riverside County	Orchards / Vineyards	1.03	14.62	9.19	1.45	0.20	26.22	2.76
Riverside County	Other Livestock	28.24	9.49	35.66	12.92	10.91	25.34	19.08
Riverside County	Pasture / Hay	14.14	24.42	49.47	2.44	9.69	116.26	5.83
Riverside County	Roadway	0.72	3.38	3.19	0.51	1.28	3.76	23.94
Riverside County	Sewered Residential	56.71	43.97	95.52	43.73	690.04	1257.74	84.37
Riverside County	Unsewered Residential	7.44	14.51	23.51	3.20	62.38	432.02	19.07
Riverside County	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Commercial / Industrial	0.56	0.00	0.00	10.64	0.00	0.00	0.00
SAN JACINTO	Forested	0.65	0.00	0.99	10.39	0.00	0.00	0.00
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Open Space	0.18	0.00	0.00	1.94	0.00	0.00	0.00
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.36	0.00	0.00	0.00
SAN JACINTO	Other Livestock	0.00	0.00	0.00	3.02	0.00	0.00	0.00
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.79	0.00	0.00	0.00
SAN JACINTO	Roadway	0.00	0.00	0.00	0.33	0.00	0.00	0.00
SAN JACINTO	Sewered Residential	0.09	0.00	0.00	26.61	0.00	0.00	0.00
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.08	0.00	0.00	0.00
SAN JACINTO	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Commercial / Industrial	0.00	0.92	0.00	0.11	0.00	0.23	0.00
State Land	Forested	0.00	40.07	2.92	25.01	0.00	25.52	0.00
State Land	Non-Irrigated Cropland	0.00	7.50	0.00	0.00	0.00	0.00	0.00

Appendix B-5: Simulated Zone Annual Total Phosphorus Load By Owner and Land Use

Owner	Land Use	Zone 1 TP (kg/yr)	Zone 2 TP (kg/yr)	Zone 3 TP (kg/yr)	Zone 4 TP (kg/yr)	Zone 5 TP (kg/yr)	Zone 6 TP (kg/yr)	Zone 7-9 TP (kg/yr)
State Land	Open Space	0.00	10.03	0.00	0.14	0.00	0.00	0.00
State Land	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.03	0.00
State Land	Roadway	0.00	0.03	0.00	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	1.30	0.00	0.05	0.00	0.34	0.00
State Land	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	1.26	0.00
State Land	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.60	0.00	0.00	0.00
Tribal Reservations	Forested	0.00	0.00	0.00	16.45	0.00	0.00	0.00
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Tribal Reservations	Open Space	0.00	0.00	0.00	0.13	0.00	0.00	0.00
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	1.03	0.00	0.00	0.00
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Forested	6.17	10.34	2.58	2.28	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	3.05	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Sewered Residential	0.05	0.01	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	0.00	0.00	0.00	0.00	154.84	0.00	0.00
WILDOMAR	Forested	0.00	0.00	0.00	0.00	186.92	0.00	0.45
WILDOMAR	Open Space	0.00	0.00	0.00	0.00	2.19	0.00	0.00
WILDOMAR	Orchards / Vineyards	0.00	0.00	0.00	0.00	2.78	0.00	0.00
WILDOMAR	Pasture / Hay	0.00	0.00	0.00	0.00	7.14	0.00	0.00
WILDOMAR	Roadway	0.00	0.00	0.00	0.00	49.57	0.00	0.00
WILDOMAR	Sewered Residential	0.00	0.00	0.00	0.00	717.82	0.00	0.00
WILDOMAR	Unsewered Residential	0.00	0.00	0.00	0.00	60.91	0.00	0.00
WILDOMAR	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix B-6: Simulated Zone Annual Total Nitrogen Load By Owner and Land Use

Owner	Land Use	Zone 1 TN (kg/yr)	Zone 2 TN (kg/yr)	Zone 3 TN (kg/yr)	Zone 4 TN (kg/yr)	Zone 5 TN (kg/yr)	Zone 6 TN (kg/yr)	Zone 7-9 TN (kg/yr)
Ag-CWAD	Commercial / Industrial	0.36	0.12	3.21	0.64	0.53	0.00	3.81
Ag-CWAD	Forested	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Irrigated Cropland	13.52	25.72	144.55	19.33	0.00	118.96	141.10
Ag-CWAD	Non-Irrigated Cropland	83.54	258.46	75.65	30.90	4.91	532.85	654.43
Ag-CWAD	Open Space	0.00	0.16	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Orchards / Vineyards	2.63	0.73	0.91	22.90	0.00	0.11	0.34
Ag-CWAD	Other Livestock	15.48	0.17	55.30	16.22	0.00	46.64	48.13
Ag-CWAD	Pasture / Hay	0.00	0.00	0.00	0.31	0.00	0.00	4.16
Ag-CWAD	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-CWAD	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ag-Small	Commercial / Industrial	0.66	1.52	0.80	0.17	2.29	1.72	4.30
Ag-Small	Irrigated Cropland	1.24	6.04	10.90	0.64	0.00	17.23	10.19
Ag-Small	Non-Irrigated Cropland	15.82	66.72	19.57	2.23	1.85	85.62	171.68
Ag-Small	Orchards / Vineyards	1.32	1.99	0.92	3.29	6.83	4.17	4.21
Ag-Small	Other Livestock	1.34	0.00	2.84	0.00	0.00	0.00	0.00
Ag-Small	Pasture / Hay	0.67	0.20	1.82	0.09	0.00	4.12	3.36
BANNING	Commercial / Industrial	0.00	0.00	0.00	0.59	0.00	0.00	0.00
BANNING	Forested	0.00	0.00	0.00	0.18	0.00	0.00	0.00
BANNING	Open Space	0.00	0.00	0.00	0.12	0.00	0.00	0.00
BANNING	Roadway	0.00	0.00	0.00	0.01	0.00	0.00	0.00
BANNING	Sewered Residential	0.00	0.00	0.00	1.40	0.00	0.00	0.00
BANNING	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BEAUMONT	Commercial / Industrial	0.00	0.00	0.00	3.35	0.00	0.00	0.00
BEAUMONT	Forested	0.00	0.00	0.00	4.39	0.00	0.00	0.00
BEAUMONT	Open Space	0.00	0.00	0.00	0.21	0.00	0.00	0.00
BEAUMONT	Roadway	0.00	0.00	0.00	0.05	0.00	0.00	0.00
BEAUMONT	Sewered Residential	0.00	0.00	0.00	6.68	0.00	0.00	0.00
CAFO	Dairy	0.00	0.00	16.94	5.82	0.85	0.00	0.00
CAFO	Pasture / Hay	0.16	0.00	6.08	3.97	0.21	0.00	9.61
California Department of Fish and Wildlife	Commercial / Industrial	0.00	0.07	0.00	0.01	0.00	0.00	0.00
California Department of Fish and Wildlife	Forested	0.00	10.92	59.76	30.55	0.00	0.00	0.00
California Department of Fish and Wildlife	Non-Irrigated Cropland	0.00	0.00	0.00	0.45	0.00	0.00	0.00
California Department of Fish and Wildlife	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
California Department of Fish and Wildlife	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Commercial / Industrial	2.03	1.65	0.00	1.49	18.56	35.24	1.46
Caltrans	Forested	0.68	0.66	0.00	3.11	7.66	8.59	2.00
Caltrans	Non-Irrigated Cropland	0.05	0.00	0.00	0.08	0.00	0.00	0.00
Caltrans	Open Space	0.03	0.05	0.00	0.10	1.33	0.02	0.00
Caltrans	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Caltrans	Other Livestock	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Caltrans	Pasture / Hay	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Caltrans	Roadway	0.01	23.90	0.00	0.71	125.44	117.48	158.92
Caltrans	Sewered Residential	0.40	0.99	0.00	0.77	5.22	15.63	0.00

Appendix B-6: Simulated Zone Annual Total Nitrogen Load By Owner and Land Use

Owner	Land Use	Zone 1 TN (kg/yr)	Zone 2 TN (kg/yr)	Zone 3 TN (kg/yr)	Zone 4 TN (kg/yr)	Zone 5 TN (kg/yr)	Zone 6 TN (kg/yr)	Zone 7-9 TN (kg/yr)
Caltrans	Unsewered Residential	0.01	0.00	0.00	0.01	0.00	0.63	0.00
Caltrans	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Commercial / Industrial	0.00	0.00	0.00	0.00	27.19	9.08	21.52
CANYON LAKE	Forested	0.00	0.00	0.00	0.00	10.54	10.05	5.04
CANYON LAKE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CANYON LAKE	Open Space	0.00	0.00	0.00	0.00	6.60	4.92	4.51
CANYON LAKE	Other Livestock	0.00	0.00	0.00	0.00	0.00	5.86	0.00
CANYON LAKE	Roadway	0.00	0.00	0.00	0.00	9.59	3.90	15.68
CANYON LAKE	Sewered Residential	0.00	0.00	0.00	0.00	62.63	266.54	437.27
CANYON LAKE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Commercial / Industrial	0.00	40.94	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Forested	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Irrigated Cropland	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Open Space	0.00	25.47	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Roadway	0.00	26.99	0.00	0.00	0.00	0.00	0.00
Federal - DOD	Sewered Residential	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Federal - National Forest	Commercial / Industrial	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Federal - National Forest	Forested	2.43	0.00	0.00	317.02	371.45	0.00	0.00
Federal - National Forest	Non-Irrigated Cropland	0.00	0.00	0.00	1.19	0.00	0.00	0.00
Federal - National Forest	Open Space	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Federal - National Forest	Other Livestock	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Federal - National Forest	Pasture / Hay	0.00	0.00	0.00	0.06	1.42	0.00	0.00
Federal - National Forest	Sewered Residential	0.00	0.00	0.00	0.79	2.95	0.00	0.00
Federal - National Forest	Unsewered Residential	0.00	0.00	0.00	0.04	0.13	0.00	0.00
Federal - National Forest	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Commercial / Industrial	0.00	0.00	0.28	0.01	0.00	0.03	0.00
Federal - Other	Forested	7.12	1.25	3.88	30.57	0.00	132.25	8.18
Federal - Other	Non-Irrigated Cropland	2.14	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Open Space	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Federal - Other	Orchards / Vineyards	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Federal - Other	Pasture / Hay	0.01	0.00	0.00	0.03	0.00	0.00	0.00
Federal - Other	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Other	Sewered Residential	0.01	0.00	0.00	0.03	0.00	1.05	0.13
Federal - Other	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.21	0.00
Federal - Other	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Federal - Wilderness	Forested	0.00	0.00	0.00	62.37	0.00	0.00	0.00
Federal - Wilderness	Pasture / Hay	0.00	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Commercial / Industrial	42.30	0.00	0.00	7.61	0.00	0.00	0.00
HEMET	Forested	21.58	0.00	0.00	1.55	0.00	0.00	0.00
HEMET	Non-Irrigated Cropland	40.53	0.00	0.00	1.87	0.00	0.00	0.00
HEMET	Open Space	8.58	0.00	0.00	0.37	0.00	0.00	0.00
HEMET	Orchards / Vineyards	0.00	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Other Livestock	0.18	0.00	0.00	0.59	0.00	0.00	0.00

Appendix B-6: Simulated Zone Annual Total Nitrogen Load By Owner and Land Use

Owner	Land Use	Zone 1 TN (kg/yr)	Zone 2 TN (kg/yr)	Zone 3 TN (kg/yr)	Zone 4 TN (kg/yr)	Zone 5 TN (kg/yr)	Zone 6 TN (kg/yr)	Zone 7-9 TN (kg/yr)
HEMET	Pasture / Hay	0.28	0.00	0.00	0.74	0.00	0.00	0.00
HEMET	Roadway	1.69	0.00	0.00	0.01	0.00	0.00	0.00
HEMET	Sewered Residential	125.27	0.00	0.00	19.70	0.00	0.00	0.00
HEMET	Unsewered Residential	0.12	0.00	0.00	0.12	0.00	0.00	0.00
HEMET	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Commercial / Industrial	0.00	0.00	0.00	0.00	731.49	14.09	41.13
LAKE ELSINORE	Forested	0.00	0.00	0.00	0.00	476.66	59.33	15.18
LAKE ELSINORE	Open Space	0.00	0.00	0.00	0.00	40.57	2.62	0.00
LAKE ELSINORE	Other Livestock	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LAKE ELSINORE	Pasture / Hay	0.00	0.00	0.00	0.00	1.09	0.00	0.00
LAKE ELSINORE	Roadway	0.00	0.00	0.00	0.00	54.16	0.00	0.00
LAKE ELSINORE	Sewered Residential	0.00	0.00	0.00	0.00	1622.84	237.38	16.92
LAKE ELSINORE	Unsewered Residential	0.00	0.00	0.00	0.00	4.99	0.00	0.05
LAKE ELSINORE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Commercial / Industrial	0.00	27.28	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Forested	0.00	34.20	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Open Space	0.00	4.61	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Roadway	0.00	0.21	0.00	0.00	0.00	0.00	0.00
March Joint Powers Authority	Sewered Residential	0.00	5.66	0.00	0.00	0.00	0.00	0.00
MENIFEE	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	356.74	856.25
MENIFEE	Forested	0.00	0.00	0.00	0.00	20.06	139.51	402.36
MENIFEE	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	2.14	27.22	228.46
MENIFEE	Open Space	0.00	0.00	0.00	0.00	0.00	16.07	163.52
MENIFEE	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	1.91	8.42
MENIFEE	Other Livestock	0.00	0.00	0.00	0.00	1.02	27.96	46.50
MENIFEE	Pasture / Hay	0.00	0.00	0.00	0.00	1.75	37.06	81.24
MENIFEE	Roadway	0.00	0.00	0.00	0.00	0.00	26.48	149.56
MENIFEE	Sewered Residential	0.00	0.00	0.00	0.00	23.99	623.74	4100.20
MENIFEE	Unsewered Residential	0.00	0.00	0.00	0.00	9.96	64.23	179.02
MENIFEE	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Commercial / Industrial	0.00	270.41	0.00	0.22	0.00	0.00	0.00
MORENO VALLEY	Forested	0.00	134.56	0.00	1.04	0.00	0.00	0.00
MORENO VALLEY	Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Open Space	0.00	21.20	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Orchards / Vineyards	0.00	5.24	0.00	0.08	0.00	0.00	0.00
MORENO VALLEY	Other Livestock	0.00	2.55	0.00	0.07	0.00	0.00	0.00
MORENO VALLEY	Pasture / Hay	0.00	13.77	0.00	0.06	0.00	0.00	0.00
MORENO VALLEY	Roadway	0.00	18.38	0.00	0.01	0.00	0.00	0.00
MORENO VALLEY	Sewered Residential	0.00	962.55	0.00	0.02	0.00	0.00	0.00
MORENO VALLEY	Unsewered Residential	0.00	4.95	0.00	0.00	0.00	0.00	0.00
MORENO VALLEY	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MURRIETA	Commercial / Industrial	0.00	0.00	0.00	0.00	0.00	0.00	40.87
MURRIETA	Forested	0.00	0.00	0.00	0.00	0.00	0.00	6.45

Appendix B-6: Simulated Zone Annual Total Nitrogen Load By Owner and Land Use

Owner	Land Use	Zone 1 TN (kg/yr)	Zone 2 TN (kg/yr)	Zone 3 TN (kg/yr)	Zone 4 TN (kg/yr)	Zone 5 TN (kg/yr)	Zone 6 TN (kg/yr)	Zone 7-9 TN (kg/yr)
MURRIETA	Open Space	0.00	0.00	0.00	0.00	0.00	0.00	0.78
MURRIETA	Pasture / Hay	0.00	0.00	0.00	0.00	0.00	0.00	0.04
MURRIETA	Roadway	0.00	0.00	0.00	0.00	0.00	0.00	2.56
MURRIETA	Sewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	142.11
PERRIS	Commercial / Industrial	0.00	144.06	0.28	0.00	0.00	616.01	0.00
PERRIS	Forested	0.00	50.28	0.01	0.00	0.00	261.93	3.62
PERRIS	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERRIS	Open Space	0.00	9.54	0.02	0.00	0.00	49.89	0.00
PERRIS	Orchards / Vineyards	0.00	1.60	0.00	0.00	0.00	3.68	0.00
PERRIS	Pasture / Hay	0.00	2.13	0.00	0.00	0.00	0.37	0.00
PERRIS	Roadway	0.00	6.60	0.00	0.00	0.00	52.33	0.00
PERRIS	Sewered Residential	0.00	222.94	0.00	0.00	0.00	538.59	0.00
PERRIS	Unsewered Residential	0.00	0.03	0.00	0.00	0.00	4.15	0.00
PERRIS	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Commercial / Industrial	0.00	1.84	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Forested	0.00	0.09	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Open Space	0.00	0.41	0.00	0.00	0.00	0.00	0.00
RIVERSIDE	Sewered Residential	0.00	48.12	0.00	0.00	0.00	0.00	0.00
Riverside County	Commercial / Industrial	12.27	33.32	31.42	14.56	93.76	150.77	114.28
Riverside County	Forested	121.97	162.39	170.68	118.06	281.02	703.31	234.90
Riverside County	Non-Irrigated Cropland	211.00	108.73	52.89	70.49	0.00	0.00	95.36
Riverside County	Open Space	2.62	20.11	0.76	6.31	1.60	7.85	70.88
Riverside County	Orchards / Vineyards	1.03	14.62	9.19	1.45	0.20	26.22	2.76
Riverside County	Other Livestock	28.24	9.49	35.66	12.92	10.91	25.34	19.08
Riverside County	Pasture / Hay	14.14	24.42	49.47	2.44	9.69	116.26	5.83
Riverside County	Roadway	0.72	3.38	3.19	0.51	1.28	3.76	23.94
Riverside County	Sewered Residential	56.71	43.97	95.52	43.73	690.04	1257.74	84.37
Riverside County	Unsewered Residential	7.44	14.51	23.51	3.20	62.38	432.02	19.07
Riverside County	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Commercial / Industrial	0.56	0.00	0.00	10.64	0.00	0.00	0.00
SAN JACINTO	Forested	0.65	0.00	0.99	10.39	0.00	0.00	0.00
SAN JACINTO	Non-Irrigated Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAN JACINTO	Open Space	0.18	0.00	0.00	1.94	0.00	0.00	0.00
SAN JACINTO	Orchards / Vineyards	0.00	0.00	0.00	0.36	0.00	0.00	0.00
SAN JACINTO	Other Livestock	0.00	0.00	0.00	3.02	0.00	0.00	0.00
SAN JACINTO	Pasture / Hay	0.00	0.00	0.00	0.79	0.00	0.00	0.00
SAN JACINTO	Roadway	0.00	0.00	0.00	0.33	0.00	0.00	0.00
SAN JACINTO	Sewered Residential	0.09	0.00	0.00	26.61	0.00	0.00	0.00
SAN JACINTO	Unsewered Residential	0.00	0.00	0.00	0.08	0.00	0.00	0.00
SAN JACINTO	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Land	Commercial / Industrial	0.00	0.92	0.00	0.11	0.00	0.23	0.00
State Land	Forested	0.00	40.07	2.92	25.01	0.00	25.52	0.00
State Land	Non-Irrigated Cropland	0.00	7.50	0.00	0.00	0.00	0.00	0.00

Appendix B-6: Simulated Zone Annual Total Nitrogen Load By Owner and Land Use

Owner	Land Use	Zone 1 TN (kg/yr)	Zone 2 TN (kg/yr)	Zone 3 TN (kg/yr)	Zone 4 TN (kg/yr)	Zone 5 TN (kg/yr)	Zone 6 TN (kg/yr)	Zone 7-9 TN (kg/yr)
State Land	Open Space	0.00	10.03	0.00	0.14	0.00	0.00	0.00
State Land	Orchards / Vineyards	0.00	0.00	0.00	0.00	0.00	0.03	0.00
State Land	Roadway	0.00	0.03	0.00	0.00	0.00	0.00	0.00
State Land	Sewered Residential	0.00	1.30	0.00	0.05	0.00	0.34	0.00
State Land	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	1.26	0.00
State Land	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tribal Reservations	Commercial / Industrial	0.00	0.00	0.00	0.60	0.00	0.00	0.00
Tribal Reservations	Forested	0.00	0.00	0.00	16.45	0.00	0.00	0.00
Tribal Reservations	Non-Irrigated Cropland	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Tribal Reservations	Open Space	0.00	0.00	0.00	0.13	0.00	0.00	0.00
Tribal Reservations	Pasture / Hay	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Tribal Reservations	Sewered Residential	0.00	0.00	0.00	1.03	0.00	0.00	0.00
Tribal Reservations	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Commercial / Industrial	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Forested	6.17	10.34	2.58	2.28	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Non-Irrigated Cropland	0.00	0.00	0.00	3.05	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Open Space	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Sewered Residential	0.05	0.01	0.00	0.00	0.00	0.00	0.00
Western Riverside County Regional Conservation Aut	Unsewered Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WILDOMAR	Commercial / Industrial	0.00	0.00	0.00	0.00	154.84	0.00	0.00
WILDOMAR	Forested	0.00	0.00	0.00	0.00	186.92	0.00	0.45
WILDOMAR	Open Space	0.00	0.00	0.00	0.00	2.19	0.00	0.00
WILDOMAR	Orchards / Vineyards	0.00	0.00	0.00	0.00	2.78	0.00	0.00
WILDOMAR	Pasture / Hay	0.00	0.00	0.00	0.00	7.14	0.00	0.00
WILDOMAR	Roadway	0.00	0.00	0.00	0.00	49.57	0.00	0.00
WILDOMAR	Sewered Residential	0.00	0.00	0.00	0.00	717.82	0.00	0.00
WILDOMAR	Unsewered Residential	0.00	0.00	0.00	0.00	60.91	0.00	0.00
WILDOMAR	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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