Application of watershed loading and estuary water quality models to inform nutrient management in the Santa Margarita River Watershed

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Southern California Coastal Water Research Project

SCCWRP Technical Report 933

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SYNTHESIS OF FINDINGS AND RECOMMENDATIONS

The Santa Margarita River Estuary (SMRE) and various tributaries within the Santa Margarita River watershed are listed on the 2010 Clean Water Act (CWA) section 303(d) list of water quality limited segments as impaired due to nutrients and eutrophication. The Santa Margarita River Watershed Nutrient Initiative (NMI), a stakeholder group formed in 2011, has supported the development of science to support improved assessments of nutrient-related impairment, and if warranted, identify nutrient targets and management actions as needed for the river, estuary, and tributaries. The SMR Stakeholder Group is funded largely through the Integrated Regional Water Management (IRWM) process and is currently receiving a Proposition 84 grant from the State of California with matching funding and in-kind services by the Counties of Riverside and San Diego and U.S. Marine Corps (USMC) Base Camp Pendleton, with the first phase focused on the SMRE.

In order to support nutrient management discussions for the SMRE, a watershed loading model (Hydrologic Simulation Program Fortran-HSPF) and receiving water model (Environmental Fluid Dynamics Code-EFDC and Water Quality Simulation Program-WASP) were applied in order to inform five major science objectives of the Santa Margarita River Watershed Nutrient Management Initiative (Phase I), focused on the SMRE:

Using the SMRE EFDC+WASP Model

1) Summarize understanding of the major pathways that supply nutrients that can fuel eutrophication in the SMRE

2) Estimate the range of allowable loads to SMRE, including wet versus dry weather

3) Illustrate how choices in selection and interpretation of numeric target(s) affect estimates of allowable loads

4) Conduct a preliminary set of scenarios to inform what kind of nutrient management activities should be considered to support SMRE beneficial uses

Using the HSPF Watershed Loading Model

5) Estimate the nutrient sources and amounts of nutrient loads delivered to the SMRE and the uncertainties in those estimates

A summary of findings and recommendations relevant for nutrient management are provided below.

Major Findings

<u>Major Pathways of Nutrient Loads that Can Support Eutrophication in the SMRE</u>

- Eutrophication is a dry weather issue in SMRE. Eutrophication symptoms are present during dry weather, and exhibit their peak during summer dry weather. As simulated by the WASP model, wet weather does not have a major impact on eutrophication symptoms in SMRE, contributing < 5 % to eutrophication symptoms <u>during an open tidal inlet</u> condition. However, wet weather can influence groundwater concentrations and ultimately baseflow during dry weather, a pathway that is inadequately captured by the model. Because groundwater has a long residence time in the aquifer, the magnitude, timing and source of nutrients to groundwater are not easily extrapolated from surface water runoff. In addition, if SMRE is more often in a semi-closed or closed state, wet weather flows that do not open the mouth may result in the appearance of eutrophication symptoms. Thus, wet weather discharges are a factor to consider in nutrient management strategies.

- As configured in WASP model, major external source of TN to the estuary during dry weather are watershed SW and local groundwater inputs, while major P sources include watershed SW and upstream aquifer discharge. Uncertainties exist in estimates of groundwater exchanges from local agricultural fields and from upstream aquifer. Calculated inputs of groundwater from the upstream aquifer are particularly constrained by the lack of phosphorus data, so the concentration was back-calculated based on the residual required to calibrate TP concentration in the Estuary. In addition, uncertainty exists in the estimates of local groundwater inputs to SMRE from agricultural fields found along the northern bank, for three reasons: 1) Groundwater discharge measurements began in 2010, after the ag fields had been fallowed from active production and thus were temporally offset from calibration year; 2) independent data from 2008 show ag-dominated groundwater inputs in an area more spatially expansive than measured just at I-5 bridge and what was used to model local ag groundwater inputs; and 3) groundwater discharge and concentration data are limited in temporal resolution. Even so, SPAWAR groundwater monitoring data provides solid evidence that local groundwater loading to the estuary has been declining over time.

- Benthic flux can be an internal source of nutrients to surface waters during dry weather. As configured in the WASP model, benthic flux presents a large contribution to available nutrients. This component appears to be largely driven by the accumulation and settling of organic matter to the sediment bed as macroalgal blooms die and decay. The importance of benthic flux in supporting eutrophication symptoms in the estuary is likely overestimated, for the following reasons: First, the magnitude of modeled benthic effluxes (out of the sediment) appear high and in the opposite direction from measured influxes (into the sediment) in winter dry weather and early summer dry weather. This is due to the fact that the benthic microalgae were not simulated as a component of benthic primary producers. Second, the model does not simulate sediment transport, deposition and scouring that are important to the spatial patterns of eutrophication in the estuary. It also does not capture the interannual scouring of sediments that occur during extreme high flow events that can cause the removal of accumulated organic matter, which fuels benthic flux. Third, the observed flux data may include a potential source from advective groundwater, but that advective groundwater fluxes cannot be simulated in the SFM. For this reason, the WASP model is likely overestimating the importance of benthic flux in driving eutrophication in this river mouth estuary.

Choice of Indicators of Eutrophication for Numeric Targets and Science Supporting the Selection and Interpretation of Numeric Targets

- Use of existing TN and TP numeric translators of SD Diego Water Board basin plan objectives is not recommended because 1) ambient TN and TP concentrations do not have a strong linkage to beneficial use impairments, and 2) exceedances of dry weather TP concentrations are driven by the concentrations of TP imposed on upstream aquifer discharge in order to calibrate the WASP model. No data are yet available to inform what these concentrations should be.

- Dissolved oxygen (DO) and macroalgal biomass and cover have demonstrated linkages to beneficial uses, have a predictive relationship with nutrient loading to the estuary, and have a practical and generally cost-effective methods for measurement and interpretation of data. These two indicators seem to be well suited for further consideration as numeric targets for SMRE.

- Existing science relevant to California native fish and invertebrates supports the use of 5.0 mg L^{-1} DO as an upper bound to protect long-term survival and reproduction in non-salmonid, warm-water fisheries in California estuaries. Documentation of DO conditions in minimally disturbed "reference" bar-built estuaries similar to SMRE indicate that during the period of April-October, the average period of time bottom waters spent below 5 mg/L was 32%. The SD Water Board should consider setting expectations for percentage of the time in which SMRE attains the DO WQO, taking into account tidal inlet status (open, closed) and what can be attained in reference estuaries.

- Sutula et al. (2016b) provides a synthesis of the status of science on adverse effect thresholds of macroalgae on benthic habitat quality, and proposes an assessment classification scheme based on the use of macroalgal biomass and cover. For the purposes of assessment, we strongly urge the use of both biomass and cover in <u>assessing</u> attainment of beneficial uses. However, the WASP model does not predict % cover, but rather assumes uniform distribution within each grid cell. Therefore, we recommend reliance on the synthesis of threshold supporting decisions on <u>biomass only</u> for interpretation of model output to determine allowable loads. It is unclear the threshold at which macroalgal biomass of 30 to 90 g dw m^{-2} causes adverse effects to benthic habitat quality. Analysis of collateral data on benthic macroinvertebrate (BMI) community composition shows the BMI to be in moderate to low ecological condition during a year in which monitored macroalgae exceeded 90 g dw m^{-2}. Given the lack of evidence in the macroalgal biomass thresholds that are protective of estuaries beneficial uses in the range of 30-90 g dw m^{-2}, a bioconfirmation approach using benthic macroinvertebrates is recommended.

<u>Estimated Ranges of Allowable Loads</u>

- As modeled by EFDC + WASP, very little difference existed between wet and dry weather reductions of nutrient loads versus dry weather load reductions only that met the range of DO and macroalgal targets under consideration. At face value, the implication of this finding is that wet weather structural BMPs, which generally cost an order of magnitude or more to implement, may not provide any additional environmental benefit to SMRE than implementation of dry weather BMPs alone. That said, the complexity of the fate and transport of wet weather nutrient loading and its influence on nutrients in watershed dry weather baseflow as well as the groundwater aquifers at the top of the Gorge and on Camp Pendleton is not captured by WASP, nor by the HSPF watershed loading model. At a macroalgal biomass target of 50 g dw m^{-2}, the WASP model predicts 91 ± 4 % reduction of dry weather 2008 loads would be required; at a biomass target of 90, the required reduction of dry weather loads would be in the range of 52 ± 4 %; at a biomass target of 110, the required reduction of dry weather loads would be in the range of 20 ± 5. At a whole estuary scale and during an open mouth condition, a macroalgal biomass of 71 ± 2 g dw m^{-2} would meet 5 mg L^{-1} 90% of the time, based on the 10^{th} percentile of 7-day DO minima. Meeting this target would require a 73 ± 46 % reduction in dry weather loads. A TP target of 0.1 mg/L drives the most stringent load reductions, but the use of such a target is unreasonable because the load reduction is driven by the concentration of TP in groundwater discharge from the upstream aquifer, for which no data are available.

<u>Watershed Nutrient Loads and Sources</u>

The watershed loading (HSPF) model provides a quantitative basis for summarizing the nutrient loads and sources for the Santa Margarita watershed, for the purpose of supporting nutrient management discussions. The tools can be improved, but the basics are there. However, there are many nuances for how the data are summarized for its applicability to nutrient management.

- Nutrient loading from the watershed varies greatly by season. During winter wet weather, high land-based loads are generated, and these are largely transported through to the Estuary, except for the amount removed by diversions onto Camp Pendleton; however, a significant portion of these loads are transported through SMRE to the ocean. During winter dry weather, there is less load generation and lower rates of transport; however, loads during winter dry weather are likely to be flushed through to SMRE if there are succeeding wet weather events. Summer dry weather loads are strongly affected by water management on Camp Pendleton, including diversions, recharge, and pumping from the alluvial aquifer. Santa Margarita River is intermittent, so flow to SMRE is often discontinuous. During early summer, discharge from the Lower Santa Margarita aquifer to the stream becomes an important source of nutrient load. During later summer, loads from the upper watershed are largely disconnected from the aquifer because most flow past Camp Pendleton is depleted by aquifer demand. While wet and dry weather loads serve to recharge groundwater, there is not a direct linkage between surface runoff and groundwater nutrient loads, because the residence time of groundwater is substantially higher than surface water and the connectivity between the aquifer and surface water exchange is complex and not captured by the watershed loading model in its current form.

- The interpretation of the model into delivered loads from individual sources is dependent on the period that is analyzed – both the scope of years and the division into seasons. The current analyses divide the year into winter (Oct.-Apr.) and summer (May-Sept.) and dry and wet periods. Actual delivery ratios vary by month and by event. It is necessary to make some assumptions to interpret the model results, as individual sources are not tracked through the model to the Estuary, and indeed cannot be due to interactions and cycling with algae. The Mediterranean climate of Southern California is highly variable from year to year, and which years are included makes a difference in the relative importance of different sources. To incorporate a more representative sampling of potential conditions, it may be advisable to conduct simulations that cover multiple decades of weather input, while maintaining current conditions for controlled discharges.

Science Recommendations

Existing uncertainty in the watershed loading can be further constrained by the following:

- Better representation of precipitation and associated improvements in hydrologic simulation through use of PRISM topographically adjusted precipitation time series instead of relying on sparse gauge measurements.

- Extension of both the hydrologic and water quality calibration to 2012 to make use of monitoring conducted since 2012.
- Integration of the simulation output of Camp Pendleton Lower SMR Groundwater Model, developed by Stetson Engineers (hereto referred to as the CP MODFLOW model), for the Pauba and Temecula aquifers (Murrieta vicinity) to improve watershed model simulation of groundwater exchanges, similar to what has been done with the model of the Lower Santa Margarita aquifer.
- More detailed and data-based representation of irrigation and irrigation return flows.
- Incorporation of results of other recent studies on conditions and nutrient loading sources in the watershed.

Existing uncertainty in the estuary hydrodynamic and water quality model can be further constrained by:

- Improvement in the resolution of the model grid to better capture effects of light availability on macroalgal growth.
- Inclusion of benthic microalgae as a primary producer in the WASP model to better capture magnitude and direction of winter and springtime nutrient fluxes and sediment oxygen demand.
- Comparison of macroalgal and cover biomass in the subtidal versus in the intertidal habitat of the estuary.
- Field data collection of concentratons of nitrogen and phosphorus in the upstream aquifer and calibration of the CP MODFLOW model to better estimate loads to the SMRE.
- Synoptic collection of monitoring data to represent inputs (local groundwater, upstream aquifer, ocean boundary, surface water temperature, dissolved oxygen, salnlity, nitrogen and phosphorus forms), major state variables (benthic macro- and microalgae, dissolved oxygen), benthic flux and sediment oxygen demand).

Management Recommendations

- Regulatory action taken should consider taking into account the considerable variability in SMRE tidal inlet dynamics and uncertainty in estimates of loads by pathway, particularly with respect to groundwater, in establishing allowable loads. Regulatory strategies should be flexible and encourage adaptive management practices in the face of such uncertainty. Examples of this flexibility include, but are not limited to, the following: (1) Exploration of inlet management scenarios vis-à-vis habitat support for SMRE resident fauna should be encouraged, with the flexibility to alter the allowable loads to SMRE pending conclusions of such analysis, and (2) an opportunity to revise limits or reductions required in 2-3 years should be considered, pending new watershed data collection and improvement of the EFDC+ WASP model, CP MODFLOW, and watershed loading models.

- The use of the TN and TP numeric translator as the basis for interpretation of the biostimulatory numeric targets should be removed from consideration, given the scientific issues with this guidance.

- Given unknowns in the range of macroalgae that can impact beneficial uses (30-90 g dw m^{-2}) and the interpretation of DO objective in estuaries that are intermittently open to tidal exchange, benthic macroinvertebrate community health as an additional line of evidence should be used in determining attainment with the macroalgal numeric target that may be established.

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1. INTRODUCTION

1.1 Introduction and Background

The Santa Margarita River Estuary (SMRE) is a 192-acre estuary located one mile north of the City of Oceanside, in the southwest corner of the Camp Pendleton Marine Corps base (Figure 1.1). The Lower River and SMRE have largely escaped the development typical of other regions of coastal Southern California, and are therefore able to support a relative abundance of functional habitats and wildlife, including populations of federally- or state-listed endangered species such as the Least Tern, Western Snowy Plover, Tidewater Goby and Belding's Savannah Sparrow. The estuary drains the Santa Margarita River watershed, which encompasses approximately 750 square miles in northern San Diego and southwestern Riverside counties. The Santa Margarita River is formed near the City of Temecula in Riverside County at the confluence of the Temecula and Murrieta Creek systems, one of the fastest-growing areas in California. Once formed, the majority of the Santa Margarita River main stem flows within San Diego County through unincorporated areas, the community of Fallbrook, and the Marine Corps Base Camp Pendleton. These urban and agricultural land uses in the watershed resulted in hydrological modifications to the SMRE and have led to increased nutrient loading to the estuary.

Increased nutrient loads are known to fuel the productivity of primary producers, such as macroalgae or phytoplankton in estuaries, in a process known as eutrophication, defined as the increase in the rate of supply and/or *in situ* production of organic matter (from aquatic plants) in a water body. While these primary producers are important in estuarine nutrient cycling and food web dynamics (Kwak and Zedler 1997, Mayer 1967, McGlathery 2001), their excessive abundance can reduce the habitat quality of a system. Increased primary production can lead to depletion of dissolved oxygen from the water column, causing hypoxia (low O_2) or anoxia (no O_2) (Diaz 2001, Diaz and Rosenberg 1995), which can be extremely stressful to resident organisms. An overabundance of macroalgae or phytoplankton can also shade out or smother other primary producers and reduce benthic habitat quality through the stimulation of sulfide and ammonium production (Diaz 2001).

The SMRE and various reaches within the Santa Margarita River (SMR) watershed are listed on the 2010 Clean Water Act (CWA) section 303(d) list of water quality limited segments as impaired due to nutrients and eutrophication. The Santa Margarita River Watershed Nutrient Initiative (NMI)-Stakeholder Group (SMR Stakeholder Group) is a collaboration of stakeholders within the watershed formed in 2011 for the purpose of monitoring and developing modeling tools in order to determine levels of impairment, develop site specific objectives, if warranted, and identify nutrient management actions as needed for the river, estuary, and tributaries. The SMR Stakeholder Group is funded largely through the Integrated Regional Water Management (IRWM) process and is currently receiving a Proposition 84 grant from the State of California with matching funding and in-kind services by the Counties of Riverside and San Diego and U.S. Marine Corps (USMC) Base Camp Pendleton.

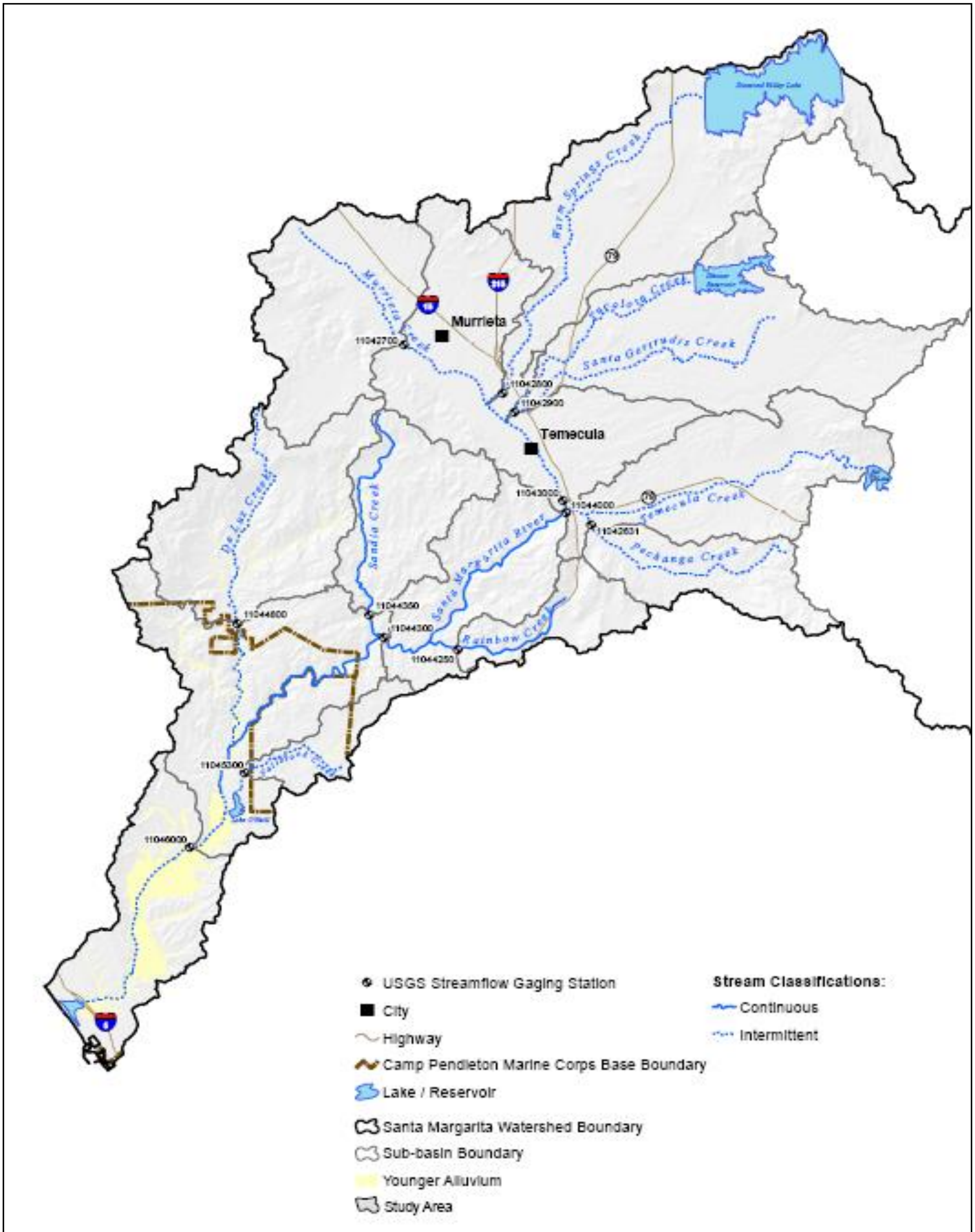


Figure 1.1 Santa Margarita Watershed downstream of major dams, including estuary at terminus of the watershed.

The first phase of collaborative technical activities by the SMR NMI was to undertake the development, calibration and application of models to inform nutrient management actions that can promote the support of SMRE beneficial uses. These models consist of a watershed loading model and estuary receiving water model capable of simulating the sources, pathways and fate of nutrients that are transported to the estuary, and the ecological response to those exchanges (Figure 1.2). Camp Pendleton Marine Corps Base funded the Navy's Environmental Sciences Branch of the Space and Naval Warfare Systems Center Pacific (SSC-PAC) to develop and calibrate the SMRE Hydrodynamic and Water Quality model (SSC-PAC 2016). Model development and calibration of an Environmental Fluid Dynamic Code (EFDC) hydrodynamic model and a Water Quality Simulation Program-FORTRAN (WASP) model was based on data collected through the Lagoon Monitoring Order (CDM 2009), a Prop 13 Grant to the SCCWRP (McLaughlin et al. 2013a), data called through the Bight 2008 Eutrophication Assessment (McLaughlin et al. 2013b), and additional monitoring conducted by SCC-PAC in 2009-2012. The State Water Resources Control Board funded Tetra Tech to complete the development and calibration of a Hydrologic Simulation Program-FORTRAN (HSPF) model for the Santa Margarita River watershed. This model was calibrated in 2013 for hydrology and in 2014 for water quality, based on available gaging and monitoring data for the watershed. Model development, calibration, and status are documented at length in two earlier reports (Tetra Tech 2013, Tetra Tech 2014), to which the reader is referred for additional detail.

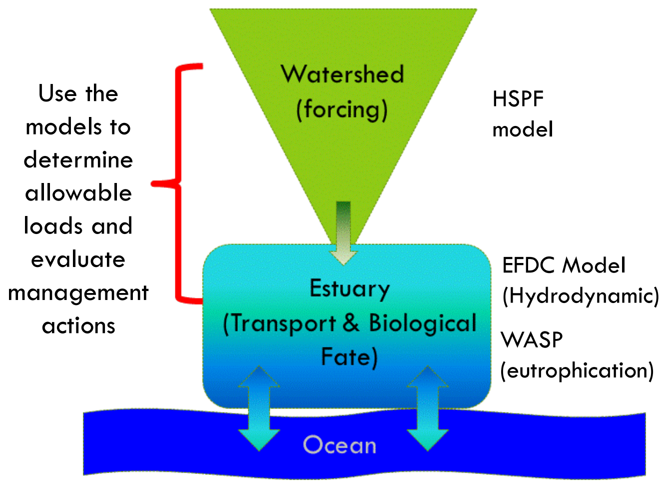


Figure 1.2. Conceptual approach to modeling the sources, transport and biological fate of nutrients in the SMR watershed and estuary.

1.2 Purpose of Report and Key Questions

This report summarizes the use of the calibrated watershed loading and estuary receiving water models used to begin to support discussions among the SMR NMI SAG on appropriate estuary numeric targets, the range of allowable nutrient loads to SMRE to support estuarine beneficial uses, and the types of implementation activities that may be helpful in creating the implementation plan. These discussions occurred during a set of interative meetings between December 2015 and April 2016.

Analyses were conducted specifically to inform discussions surrounding the following key questions:

1) What are the appropriate indicators and numeric targets for SMRE?

2) What are the range of allowable loads of total nitrogen (TN) and total phosphorus (TP) that achieve these candidate numeric targets?
3) Because the cost implications of best management practices to control wet weather (rainfall + 72 hours) are orders of magnitude higher than that for dry weather runoff, to what extent can problems in the estuary be addressed through focused reductions in dry weather?
4) What are the loads and sources of nutrients to the estuary from the watershed, and how do they partition by wet weather, winter dry and summer dry weather?
5) To what extent can the implementation plan be informed by targeted reductions of dominant pathways by which these watershed nutrients enter the estuary?

1.3 Document Organization

The document is organized as follows:

Chapter 1: Introduction and Background, Purpose and Key Questions, and Organization of Document

Chapter 2: Use of Estuary Water Quality Model to Inform Discussions of Nutrient Management

This chapter summarizes technical work intended to:

- Summarize understanding of the relative importance of pathways of nutrient loading to the SMRE
- Estimate the range of allowable loads to SMRE, including wet versus dry weather
- Illustrate how choices in selection and interpretation of numeric target(s) affect estimates of allowable loads
- Conduct a preliminary set of scenarios to inform what kind of nutrient management activities should be considered to support SMRE beneficial uses

Chapter 3: Use of Watershed Loading Model to Quantify Sources of Nutrients in the Santa Margarita River Watershed

This chapter summarizes technical work to estimate the nutrient sources and amounts of nutrient loads delivered to the SMRE and the uncertainties in those estimates.

2. Application of Estuary Water Quality Model to Inform the Range of Numeric Targets and Allowable Nutrient Loads to the Estuary

2.1 Introduction and Key Questions

The hydrodynamic model Environmental Fluid Dynamics Code (EFDC) and WASP Version 7.4 (Water Quality Analysis Simulation Program V7.4) was developed and calibrated to simulate the transport and fate of nutrients in SMRE (SSC-PAC 2016). This model was then used for a series of simulations to inform the discussion, in interactive fashion, among SMR, NMI, and SAG members specifically with respect to the following questions:

1) What are the appropriate indicators and numeric targets for SMRE?
2) What are the dominant pathways by which the loads of total nitrogen (TN) and total phosphorus (TP) enter and leave the estuary, and how does this change by season?
3) What are the range of allowable loads of total nitrogen (TN) and total phosphorus (TP) that achieve these candidate numeric targets?
4) Because the cost implications of best management practices to control wet weather (rainfall + 72 hours) are orders of magnitude higher than that for dry weather runoff, to what extent can problems in the estuary be addressed through focused reductions in dry weather?
5) To what extent can the implementation plan be informed by targeted reductions of dominant pathways by which these watershed nutrients enter the estuary?

2.2 Background and Approach to Addressing Questions

October 2007-November 2008 represented a time period for which the most comprehensive monitoring dataset was available for both the estuary and contributing watershed. For this reason, it was selected as the focal period for model calibration. Ideally, model simulations would have been conducted to explore the effect of tidal inlet opening on allowable loads and to simulate conditions that represents a range of water-years. However, due to time limitations involving additional EFDC model runs, only scenarios which involved reconfiguration of WASP model files alone were considered to support nutrient management discussions at this time. For this reason, the 2008 calibration year was considered the base model run, against which all scenarios would be compared. It was also used for the estuary mass balance. Calculation of allowable loads needed to reach designated numeric targets and the estuary mass balance would likely change as a function of how open the tidal inlet is to tidal exchange, which during 2008 was mostly open.

2.2.1 Background and Context: Candidate Indicators for Numeric Targets and Relevant Background for Interpretation of Candidate Numeric Targets

During WASP model development, SAG agreed to consider three major categories of indicators for use as potential numeric targets, in order to understand the implications of their use for determination of allowable loads to the estuary:

- Biostimulatory narrative objectives, with numeric translator for TN and TP
- Dissolved oxygen objectives
- Macroalgal biomass and cover

Use of these indicators in the context of calculation of allowable loads should consider magnitude (numeric endpoint), extent (spatial variability), frequency and duration (temporal variability). Raw WASP model output represents a four-dimensional data stream that can be used to make calculations of allowable loads in a variety of different ways. How these data are aggregated can make the change to the calculated allowable loads either more or less stringent. During meetings of the SAG that occurred from December 2015-April 2016, the group came to partial consensus on the ways in which the candidate indicators should be used to evaluate the range of estuary allowable loads. Table 2.1 summarizes this information, noting in particular where consensus was lacking and discussion was still ongoing as of April 2016. Additional background on reasons for the selection as candidate numeric targets and information pertinent to their application to SMRE is presented in subsequent sections below. Appendix 1 summarizes the order of operations used to aggregate model output for application for each indicator.

Table 2.1. Summary of how candidate numeric targets were evaluating, using SMR Estuary WASP model output.

Issues	Total Nitrogen (TN) and Total Phosphorus (TP)	Dissolved Oxygen (DO)	Macroalgal Biomass
What threshold?	Use 1 mg/L TN and 0.1 mg/L TP (Basin Plan Biostimulatory Objective)	Use 5 mg/L (Basin Plan Objective for WARM Bus)	Evaluate range from 110 to 30 g dw m^{-2}
How to account for cross channel and vertical (water column) variability?	Model output does not capture spatial variability, so should average model output across vertical water column and channel cross section; for macroalgae, vertical model output should be summed (to represent g dw m^{-2}).		
How should calculations account for variability along longitudinal axis?	Model exhibits considerable variability along spine of the estuary, so initially output was calculated in two different ways: 1) aggregate across whole estuary, 2) aggregate for two segments representing up and downstream of I-5 (2 segments). Decision was to use whole estuary, because of considerable influence and uncertainty in groundwater concentrations from local ag runoff and upstream aquifer.		
How should numeric target deal with frequency/duration?	Use daily average, then apply a 10% exceedance frequency	Calculate percent of time less than 5 mg/L, using 10% allowable frequency of non-attainment	Use growing season maximum
Is there a critical period?	Make calculations for 1) wet and dry weather together, 2) dry weather only, 3) winter and summer dry separately	Because of calibration issues, model can't be used to assess November-March, so discuss later how to address overly conservative assessment	Macroalgae only peaks in model during growing season, so no calculations specified to look at this question

Existing Basin Plan Objectives

Selection of the numeric targets to address eutrophication in SMRE should take into account what is required by the San Diego Water Board Basin Plan, as well as alternative targets if warranted. The Basin Plan contains DO objectives, as well as a narrative objective for biostimulatory conditions with guidance for translation of that objective with numeric limits for TN and TP (Table 2.1). Because the Basin Plan objectives were established in the 1970s, regulatory and scientific approaches to controlling biostimulatory conditions have evolved since that time. In particular, approaches to regulating nutrients now recognize that the N and P concentrations/loads that can impact beneficial uses vary greatly among streams (Fevold 1998, Chételat et al. 1999, Heiskary and Markus 2001, Dodds and Welch 2000) and estuaries (Cloern 2001), due to site-specific co-factors (e.g., hydrology, shading, temperature, etc.). Use of ambient, surface water nutrient concentrations is generally not effective for assessing eutrophication and the subsequent impact on beneficial use because ambient concentrations reflect the biological processing that has already occurred. For example, macroalgae can take up nutrients with such high efficiency that they leave near non-detectable concentrations in the surface waters (Sutula 2011). For this reason, traditional nutrient WQOs that take a “one-size-fits-all” approach are problematic. San Diego Water Board acknowledges that the Basin Plan WQOs may not be appropriate for all water bodies and for that reason placed consideration of numeric targets in the Santa Margarita River watershed on the list of high priority for its Basin Plan triennial review process.

Table 2.1. San Diego Water Board Basin Plan (1994) objectives for oxygen and biostimulatory substances.

Indicator	Objectives
Dissolved Oxygen	Dissolved oxygen levels shall not be less than 5.0 mg L^{-1} in inland surface waters with designated MAR or WARM beneficial uses or less than 6.0 mg L^{-1} in waters with designated COLD beneficial uses. The annual mean dissolved oxygen concentration shall not be less than 7 mg L^{-1} more than 10% of the time.
Bio-stimulatory Substances	Inland surface waters, bays and estuaries and coastal lagoon waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growths cause nuisance or adversely affect beneficial uses. Threshold total phosphorus (P) concentrations shall not exceed 0.05 mg L^{-1} in any stream at the point where it enters any standing body of water, nor 0.025 mg L^{-1} in any standing body of water. A desired goal in order to prevent plant nuisance in streams and other flowing waters appears to be 0.1 mg L^{-1} total P. These values are not to be exceeded more than 10% of the time unless studies of the specific water body in question clearly show that water quality objective changes are permissible and changes are approved by the Regional Board. Analogous threshold values have not been set for nitrogen compounds; however, natural ratios of nitrogen to phosphorus are to be determined by surveillance and monitoring and upheld. If data are lacking, a ratio of N:P = 10:1, on a weight to weight basis shall be used. Note: Certain exceptions to the above water quality objectives are described in Section 4 in the subsections titled Discharges to Coastal Lagoons from Pilot Water Reclamation Projects and Discharges to Inland Surface Waters.

Need for Alternative Targets

Over the past decade, the California State Water Resources Control Board (State Water Board) has been developing a science-based approach to control nutrient pollution in lakes, streams, and estuaries (Tetra Tech 2006). The State Water Board staff strategy is to develop a narrative objective for nutrients and biostimulatory objectives, plus numeric guidance that would be incorporated by default into the Basin Plans of the Regional Water Quality Control Boards. This numeric guidance is referred to as the Nutrient Numeric Endpoint (NNE) Framework. The NNE framework consists of two key tenets:

1) Use of ecological response indicators rather than nutrients to assess risk to beneficial uses from eutrophication
2) Models to link response indicator endpoints to waterbody-specific nutrient targets

Numeric endpoints are developed for indicators of the ecological response of the waterbody to eutrophication (e.g., algal biomass, dissolved oxygen, pH), rather than nutrients. Though an overarching NNE assessment framework is not yet adopted into policy by the State Water Board, technical information that provides a scientific synthesis useful for discussion of numeric targets in SMRE is available (Sutula 2011, Sutula et al. 2013, Sutula et al. 2016b, McLaughlin et al. 2013a, McLaughlin et al. 2013b).

A simple conceptual model of estuarine ecological response to eutrophication can be described (Figure 2.1). The increased nutrient loads and alterations in co-factors can result in three types of ecological response: 1) Changes to aquatic primary producers – in this case, an overabundance of macroalgae and a propensity towards harmful algal blooms and associated toxins, 2) altered water and sediment biogeochemistry, including hypoxia or suboptimal concentrations of dissolved oxygen in surface waters and sediment, and 3) altered community structure of benthic and water column invertebrates and tertiary consumers (fish, birds, mammals). These ecological responses include adverse effects on both ecological and human endpoints of concern. This cascade of effects has a direct effect on the ecosystem services and beneficial uses an estuary provides, including reduced: 1) habitat for aquatic life (including EST, MAR, WILD), 2) protection of biodiversity including rare, threatened and endangered species and migratory and spawning habitat (RARE, SPWN, MIGR), 3) productivity of commercial and recreational fisheries (SHELL, COMM, AQUA), 4) good aesthetics and lack of odors (REC2), and 5) maintenance of good water quality and taste (REC1, COMM, AQUA, SHELL) as well as aesthetics (REC2). REC-1, REC-2, EST, WILD, RARE, MAR, MIGR, and SPWN are listed beneficial uses for SMRE (SMR NMI Process Plan 2016). For a list of beneficial use designations and definitions, see Appendix 2.

In SMRE, as in most other southern California estuaries, macroalgae is the dominant primary producer in eutrophic conditions, with biomass several orders of magnitude higher than phytoplankton (McLaughlin et al. 2013a, McLaughlin et al. 2013b). Particularly for SMRE, synthesis of this new science points to the utility of using macroalgal biomass and cover, in addition to DO, for assessment of the adverse effects of eutrophication. Scientific synthesis and studies supported by the State Water Board that are relevant for consideration of DO and macroalgae as candidate numeric targets for SMRE are presented below.

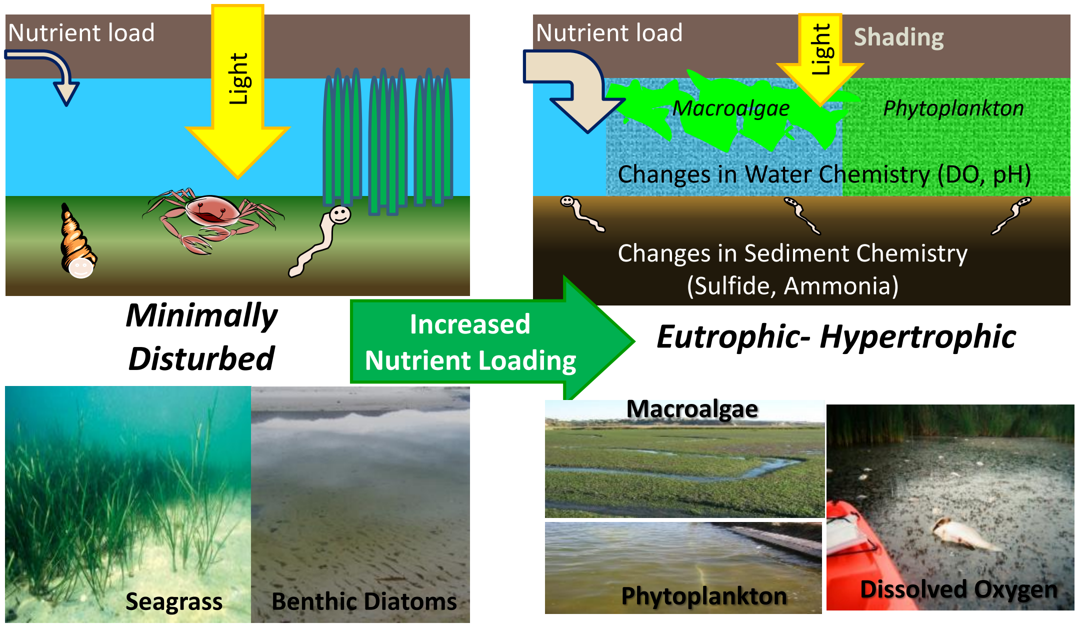


Figure 2.1 Conceptual model of eutrophication in Mediterranean estuaries, showing key indicators applicable for consideration of numeric targets (macroalgae and phytoplankton biomass, DO).

Synthesis of New Science Relevant to Candidate Indicators for SMRE Numeric Targets

Dissolved Oxygen. The State Water Board acknowledges the inconsistency of DO WQO for estuaries across the seven coastal Regional Water Boards and for this reason commissioned SCCWRP to complete a review of science supporting alternative targets in California estuaries. There are three major findings of this study that are relevant for SMRE and other similar estuaries in Southern California (Sutula et al. 2013):

1) Existing DO objectives of ~5 mg/L for non-salmonid (WARM) and ~6.3 mg/L for salmonid (COLD) are reasonable, given existing science. Objectives based on averages are less adequate because in estuaries with large diurnal DO variation; the average of such values will be ~7 mg/L, even though nightly hypoxia and anoxia can occur.

2) It is reasonable to allow deviation from these chronic criteria by examining the frequency and duration at which larval survival and recruitment is protected at a 95% population level; however, data to support these analyses are largely unavailable for California native species or their family surrogates.

3) Hypoxia in bottom waters is a natural occurrence in bar-built estuaries, particularly when the mouth is closed due to salinity stratification. Therefore, application of the DO basin plan objective throughout the water column may be unreasonable. In addition, the determination of the percent of time in which existing basin plan objectives should be attained can be further informed by an ongoing study of natural background concentrations of DO and algae in reference estuaries, which is in the final stages of completion (Sutula et al. 2016a).

Macroalgae. Sutula et al. (2016b) provides a synthesis of the status of science on thresholds of macroalgae on benthic habitat quality (Figure 2.2) and proposed an assessment classification scheme based on the use of macroalgal biomass and cover, adapted from the EU Water Framework Directive approach (Table 2.2, Scanlan et al. 2007). While Sutula et al. (2016b) provides additional details on the rationale for this framework, several points are essential for application of this information to SMRE:

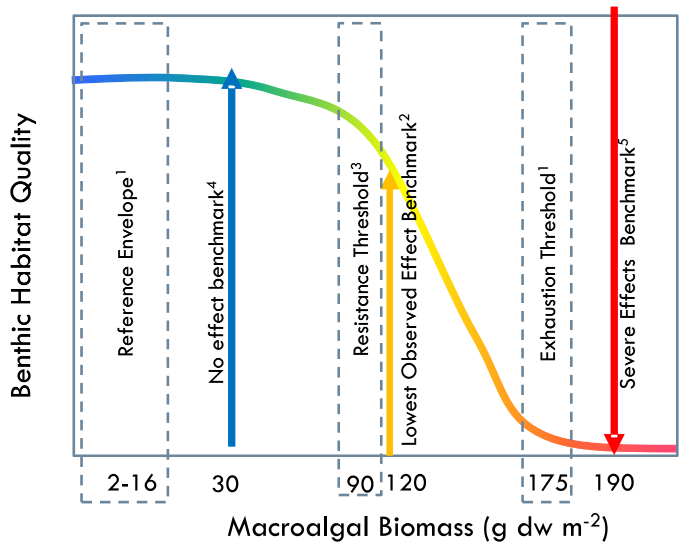
1) Application of the Sutula et al. (2016b) framework to intertidally dominated estuaries relies on use of the lower intertidal flat and shallow subtidal habitat as an index area for monitoring. Monitoring is typically conducted in three or more transects of ~50 m in length at MLHW or 0.75 m below Mean Low Tide (MTL). Biomass results are typically expressed on an areal basis (g dw m^{-2}) based on five random samples of fixed surface area along this transect, while percent cover is assessed at ten points along transect using a point intercept method. Macroalgae occurs throughout the subtidal area, but the logistics of sampling subtidal macroalgal biomass are difficult and costly. Therefore, the SMRE model was calibrated to predictions of macroalgae at these index area transects (SCC-PAC 2016), but the biomass of macroalgae in SMRE subtidal habitats is unknown, introducing unquantifiable uncertainty.

2) The assessment framework intentionally forces <u>a continuum of</u> increasing risk of declining ecological condition into categories or bins in order to more easily translate this information for management applications. The authors note that while this is generally helpful, fixating on a specific threshold ignores the fact that this is a continuum, with site-specific co-factors that can play into severity of the effect associated with abundance at any given level. For example, river mouth estuaries with coarse sediment grain size will tend to experience fewer impacts to benthic infauna, because the physical mixing inherent to such estuaries will tend to remove the fine grain organic matter that is associated with adverse impacts to benthic habitat quality.

3) With respect to biomass, we note that there is a lack of understanding of effects 30 g dw m^{-2} (benchmark of no observed effect) to 90 g dw m^{-2} (resistance threshold detected in Venice Lagoon, Italy), at which point sediments began to experience the loss of large bivalves and surface deposit feeders important to foraging fish and birds (Bona 2006, Sutula et al. 2014).

4) Green et al. (2013) found in field experiments that impacts of macroalgae on benthic invertebrates occur as soon as 2-4 weeks at treatments of ~110 -120 g dw m^{-2}. Given this rapid response of the invertebrate community to macroalgal blooms, assessment of the peak biomass (if monitoring only every 2 months) or the average of two consecutive peak months (if monitoring every month) is advised.

5) The assessment framework is based on the use of biomass and cover, but the model can only predict biomass. Averaging model output over portions of the estuary or over the entire estuary therefore assumes 100% cover for the purposes of application of the framework to model output.



Literature Cited

1. California Field Study, Sutula et al. 2014
2. California Experiments, Green et al. 2013
3. Venice Lagoon Field Study, Bona 2006
4. European Mediterranean Experiment, Cardoso et al. 2004
5. California Experiment, Green (2011)

Figure 2.2. Synthesis of literature informing range of macroalgal biomass that represents "reference," benchmarks of no observed effects and lowest observed effects established by controlled experiments. Thresholds are established by statistical analyses of field studies demarking intial points of decline of benthic habitat quality ("resistence") and points at which sediments were azoic (without any benthic invertebrates, "exhaustion").

Table 2.2. Proposed classification of macroalgal abundance as a function of dry weight biomass and percent cover. Combination of biomass are cover are ranked from low macroalgal abundance = very high ecological condition (blue) to high macroalgal abundance = very low ecological condition (red).

	(g dw m^{-2})	%Percent Cover				
		< 10 %	10-25 %	25-40 %	40-70 %	> 70 %
Biomass	>175	Moderate	Low	Low	Very Low	Very Low
	100-175	Moderate	Moderate	Low	Very low	Very Low
	70-100	Moderate	Moderate	Low	Low	Low
	50-70	High	High	Moderate**	Moderate**	Low
	15-50	Very High	High	High	Moderate	Moderate
	< 15	Very High	Very High	High	High	Moderate

** downgrade if moderate for 2 consecutive sampling periods

Sutula et al. (2014) found that percent cover was not significantly linked to adverse effects on benthic habitat quality because high cover is possible at all levels of biomass. However, they note that the risk of exceeding 100 g dw m^{-2} increases with cover > 70%. Bona (2006) establish cover > 60% associated with adverse effects. While there is no published information on percent cover of floating algae in estuaries that becomes undesirable from a recreational perspective, several studies have been done on streams in New Zealand and Montana, indicating that when macroalgae reaches levels of 50-80% cover, the stream becomes undesirable to recreate (Biggs 2000a, Biggs 2000b, Supplee et al. 2009).

2.2.2 Methods to Quantify Estuary Nutrient Mass Balance During Wet and Dry Weather

The estuary EFDC and WASP model simulates ecosystem response to water and nutrient exchanges from four major modeled external pathways in SMRE (SSC-PAC 2016): 1) watershed surface water, 2) (watershed) groundwater from the upstream aquifer, 3) local ag-driven groundwater exchanges that occur on bluffs along the northern flank of the estuary, and 4) oceanic exchange (Figure 2.3).

These external pathways of nutrient loading are supplemented by the internal cycling of particulate bound nutrients in sediment, through a process known as benthic flux. Nutrients associated with organic matter produced *in situ* or left over from wet-season deposition during storm events can be remobilized to the water column. Benthic flux have been shown to provide a significant source of nutrients that can fuel excessive growth of algae as a result of bacterial recycling of organic matter and changes in redox potential of the sediments (Berner 1980, Sutula et al. 2006).

In order to inform management actions, it is important to understand two questions: 1) Since wet weather brings the majority of the loads to the estuary, how much of these wet weather loads are retained versus lost to the ocean, and 2) what is the relative importance dry weather inputs versus wet weather particle deposition in driving benthic flux? WASP simulates both the deposition of particles (during storm and non-storm conditions) as well as the settling of algae as it dies and decays; it also simulates the processes of sediment diagenesis by which benthic flux of nutrients and oxygen (i.e., sediment oxygen demand) can occur. Therefore, the SMRE WASP model was used in an exploratory mode to quantify the mass balance of inputs, outputs, and net storage of nutrients within the estuary. We refer to this as a “mass balance,” governed by the Eqn. 1, where M is the mass load of either N or P from watershed surface water (*ws*), upstream aquifer (*wg*), localized input of groundwater from ag-fields (*ag*), exchange with the ocean (*o*), and losses or exchanges via deposition to the sediment bed (*dep*) and benthic flux (*bf*):

$$Eqn.1 \sum \quad Mws + Mwg + Mag \pm \ Mo - Mdep \ \pm Mbf = 0$$

Model mass balance was aggregated to a daily timestep, then synthesized to determine the mass balance for wet weather (rain + 72 hours) and dry weather days during the 2008 model year, in which the estuary mouth was predominantly open. Dry weather was further aggregated into winter dry (October 1-April 30) and summer dry weather (May 1-September 30).

Figure 2.3 Schematic depicting four important external pathways through which nutrients and water are exchanged with the estuary: 1) watershed surface water, 2) groundwater aquifer discharge from upstream (Camp Pendleton), 3) local groundwater inputs from agricultural fields on northern face of estuary, and 4) surface water tidal exchange with the ocean.

2.2.3 Methods to Conduct Model Scenario Analyses to Inform Calculation of Allowable Loads and Selection of Numeric Target

The intent of these analyses was two-fold: 1) Quantify the effect of wet weather nutrient loads in creating eutrophication symptoms within SMRE, and 2) quantify the range of allowable loads that would be required to achieve the candidate numeric target and understand how the interpretation of that target (magnitude, extent, duration) affects the calculation of allowable loads.

In order to achieve this, three sets of scenarios were run:

- **Remove particles from watershed inputs.** Particle deposition via in surface water input to SMRE occurs during both wet and dry weather, but the bulk of the mass load occurs during wet weather. Removing particles (and associated nutrients) from watershed inputs represents an upper bound on the contribution of wet weather to benthic nutrient flux. Particles were removed from the input file of the 2008 base model run to test this effect. The results of this run were compared to the 2008 base run to quantify the net effect on TN, TP, macroalgal biomass and DO.
- **Reduce N and P loads during both wet and dry weather**. WASP N and P concentrations were reduced by 25%, 50%, 75%, and 90% to investigate the effect on TN, TP, macroalgal biomass and DO.
- **Reduce N and P loads only during dry weather.** WASP N and P concentrations were reduced by 25%, 50%, 75%, and 90% to investigate the effect on TN, TP, macroalgal biomass and DO.

For the wet and dry versus dry-only load reduction scenarios, the calculated TN, TP, macroalgal biomass and DO for each of the original run and load reduction scenarios were regressed against the percent load reduction (0-90%) in order to calculate the load reduction required to achieve the candidate (range of) numeric targets under consideration.

Overall, regression of TN and TP load reductions produced linear relationships with high model fits and small confidence intervals, a consequence of the fact that the load reductions were done by reducing concentrations of each of the pathways. For DO and macroalgae, nonlinear models were fitted and confidence intervals generated. We note that the standard errors on the load reductions and 95% confidence intervals on regressons represent model fit of the regression, rather than a qualified statement of uncertainty in the load reduction itself.

2.2.4 Methods to conduct supplemental analyses informing selection of numeric targets

Supplemental analyses were conducted in order to inform the selection or interpretation of numeric targets for macroalgae and dissolved oxygen.

For macroalgae, there is a lack of understanding in the range at which macroalgal biomass transitions from no observed effect (~30 g dw m^{-2}; Green 2011) to adverse effects on benthic habitat (~90-110 g dw m^{-2}; Bona 2006, Green et al. 2013). In order to provide better understanding of the range of effects, two types of analyses were conducted:

1) **Calculation from WASP model output the macroalgae biomass at which DO objective of 5 mg/L is met greater than 90% of the time.** To calculate this, summertime maximum macroalgal biomass from the 25%, 50%, 75%, and 90% load reduction scenarios was regressed against the 10^{th} percentile of DO (April-November). The regression relationship that resulted was used to determine that biomass met a numeric target of 5 mg/L. These analyses were conducted on both sets of scenarios (wet and dry weather reductions versus dry-only reductions).
2) **Analyses of existing benthic macroinvertebrate data taken in the SMRE during 2003, 2004, 2005, 2008 and 2013, with particular attention to 2008, the year in which macroalgae data are available.** The purpose of such analyses is to document whether, at levels of macroalgae exceeding the lowest observed effect levels in literature, such effects on benthic macroinvertebrates can be documented in SMRE. To do this, two types of analyses were conducted: 1) calculation of benthic habitat quality scores, using the California Sediment Quality Objectives (SQO) Benthic Line of Evidence (BLOE) assessment framework (Bay et al. 2012) and 2) analyses of benthic community composition data for information on possible stressors, such as eutrophication (low DO, organic matter accumulation) versus other stressors that might depress benthic habitat quality scores but are unrelated to eutrophication-related stress.

Interpretation of numeric targets can also be informed by the exceedance frequencies of those constituents in “reference” waterbodies. Here, we utilized data from a study of natural background concentrations of DO and macroalgae in minimally disturbed, or “reference,” estuaries to inform what might be a more reasonable interpretation of frequency of non-attainment of the numeric target, particularly when an estuary mouth is either open to tidal exchange or closed (Sutula et al. 2016a). In this study, six bar-built estuaries in watersheds with > 90% or undeveloped land were monitored continuously for dissolved oxygen, macroalgal, and phytoplankton biomass for a year period. Estuaries were located in the North Coast, Central Coast, and South Coast of California. While a draft report from this study is forthcoming, data from the study were procured in order to answer two questions: 1) What is the magnitude, frequency and duration of time the estuary is below 5 mg/L and below the threshold for hypoxia (2.8 mg/L), and 2) what are the natural background concentrations of macroalgal biomass and percent cover?

2.2.5 Methods to Conduct Model Scenario Analyses to Inform Implementation Plan

A set of scenarios were also performed in order to begin informing the implementation plan for nutrient management. Two types of scenarios were considered:

1) Reduction of single pathways (watershed surface water, groundwater discharge from upstream aquifer, and local groundwater inputs) in order to determine whether one pathway in particular was most effective in reducing eutrophication symptoms.

2) Manipulation of the estuary mouth to keep it open to tidal exchange for a longer period.

Reduction of single pathways were investigated by reducing only N and P dry weather loads by 50% and 75%. Scenarios involving manipulation of the mouth required additional resources for SPAWAR to rework the EFDC model configuration. Additional funding for this work was under discussion as this report was under draft; these additional scenarios may be appended to the report when completed after the report is finalized.

2.2.6 Uncertainties in EFDC+WASP Model and Supporting Data and Relevance for Nutrient Management Discussions

As noted in Chapter 3, and like all environmental simulation models, the Santa Margarita River EFDC+WASP model is subject to uncertainty. An important exercise is determining the appropriate applications, given those uncertainties. Here we provide a summary of the uncertainties that exist in the EFDC+WASP model, the supporting field observations, and the groundwater model output that are relevant for the use of the WASP model to support nutrient management discussions. These key uncertainties can be grouped into two broad categories: 1) External loads and 2) model setup and calibration vis-à-vis available field data. The intent of such a summary is not to discourage use of the model for decision-making, but to ground discussions of model application in the context of qualitative and quantitative uncertainty.

External TN and TP loads. SMRE, like most Southern California Bight estuaries, is heavily influenced in part by groundwater inputs from the upstream aquifer, as well as the lateral exchanges with groundwater along its northern and southern flanks. However, this is one of few estuaries within the Bight for which groundwater models and observational data have ever been available. The groundwater models and observational programs that produced the data were not scoped for direct application as external inputs to an EFDC+ WASP model and thus introduce important uncertainties.

- For the Camp Pendleton Lower SMR Groundwater Model developed by Stetson Engineers, the surface water and groundwater model was the basis of "calibrated" watershed inputs to the EFDC and WASP model (SSC-PAC 2016). This model is hereto referred to as the "CP MODFLOW model." The model output was monthly, so surface water discharge was interpolated to daily input by matching daily amplitude of flows to the Ysidora Gauge hydrograph. No phosphorus data were available for groundwater inputs to SMRE, so the concentration was back-calculated based on the residual required to calibrate TP concentration in the Estuary.

- Camp Pendleton has invested in monitoring of local groundwater inputs from agricultural fields found along the northern bank of the estuary since 2010. The trend shows a steady decline in discharge loading from that source (SCC-PAC 2015). That said, uncertainty exists in the estimates of local groundwater inputs to SMRE for four reasons: 1) Groundwater discharge measurements began in 2010, after the ag fields had been fallowed from active production and thus were temporally offset from calibration year, 2) stable isotope data from 2008 show ag-dominated groundwater inputs likely to SMRE between I-5 bridge and Stuart Mesa Road, representing an area more spatially expansive than measured in 2010 (just at I-5 bridge) and what was used to model local ag inputs, 3) groundwater TP data from SSC-PAC were limited and set 2-6 times lower in the WASP model input than field observations (SSC-PAC 2015), because they were judged to be influenced by sediment diagenesis and therefore were anomalously high, and 4) groundwater discharge and concentration data were limited in temporal resolution. The offset between calibration year (2008) and the initiation of groundwater monitoring (2010) is important because 1) significant reductions in local groundwater loads may have already occurred due to fallowing of ag fields and drought, and 2) use of 2010 local groundwater loads during the 2008 may have forced a higher phosphorus concentration to be imposed on the upstream aquifer, in order to achieve calibration.
- Surface water inputs were based on limited field observations with acknowledged quality assurance problems (Santa Margarita River Estuary Monitoring Order Data; CDM 2009).

Model Set Up and Calibration. Use of the model to predict the estuary eutrophication symptoms, and ultimately the nutrient mass balance, is constrained by uncertainties in the model setup and calibration vis-à-vis supporting field data.

- The mass balance analyses are based on a "calibrated model" of the period of October 2007-September 2008. The condition captured by this period is a year in which the mouth of the estuary was relatively open, with lower than average TN but higher than average TP loads (Chapter 3). The degree of mouth openness and the ratio of TN to TP loads will ultimately affect eutrophication symptoms predicted by the model.
- The model does not simulate sediment transport, deposition and scouring. The sediment deposition captured by the model is a simple representation of particle settling; the model does not capture the bed load transport, the accumulation of organic matter, redistribution of fines versus sands, and other aspects of sediment transport that are important to the spatial patterns of eutrophication in the estuary. It also does not capture the interannual scouring of sediments that occurs during extreme high-flow events that can cause the removal of accumulated organic matter.
- The WASP does not include benthic microalgal production and the effect that this type of primary producer has in stimulating denitrification, retention of sediment P and ammonia efflux, and on net sediment oxygen demand (SCC-PAC 2016). Benthic microalgae are most important in the winter and springtime (McLaughlin et al. 2013a). Measured fluxes of DIN and PO4 during the early spring through early summer were largely negative (into the sediment), while model predicted fluxes were positive. Benthic algae take up nutrients and produce oxygen, due to photosynthesis, under lighted conditions, while releasing nutrients and consuming oxygen, due to respiration, under dark conditions; these conditions have been shown to greatly alter benthic fluxes (An and Joye 2001). The sediment flux module of WASP does not alter benthic fluxes as a result of benthic algal biomass.

- For the above reason, the WASP model is likely overestimating the importance of benthic flux in driving eutrophication. McLaughlin et al. (2013a) noted that the benthic fluxes showed anomalously high N efflux, given the low organic matter content of sandy sediments throughout most of the estuary; they suggested that the benthic chambers could be capturing advective fluxes from groundwater inputs, particularly upstream of the I-5 Bridge. However, there was low replication in the benthic flux measurements (two light and two dark chambers at each of two sites within SMRE), with benthic flux estimates showing high variability (McLaughlin et al. 2013b).
- Model calibration is constrained by the lack of temporal and spatial variability of estuary “condition” observations. Measures of ambient nutrients and macroalgae were taken four times per year in 2008 and six times per year in 2009. Macroalgal biomass is spatially patchy (±10-30% at biomass greater than 70 g dw m^{-2}) and was only sampled in the index area (lower intertidal zone), rather than throughout the subtidal habitat. Thus, available data represents a limited sampling of modeled area. Continuous DO data from October 2007-2008 had QA issues, so the October 2008-2009 data were used to calibrate the 2008-year base run (SCC-PAC 2016).

The combination of these uncertainties provided the rationale for why model output in general was utilized on a whole estuary scale rather than as two or three segments, despite the acknowledgement that monitoring for assessment of condition and future modeling will want to focus on a finer resolution.

The relevance of these uncertainties and the likely bias is noted where possible in subsequent sections that involved model application to answer key management questions.

2.3 Synthesis of 2008 Nutrient Mass Balance

The WASP model can be used to synthesize and compare the magnitude and timing of pathways of external nutrient loads to the SMRE and to compare external loads to internal loads (i.e., benthic flux). We note that the estuary mass balance of N and P sources, sinks and residual loads (Tables 2.3-2.4) during the model year October 1, 2007-September 20, 2008 represents watershed inputs that are driven by observational data rather than watershed loading model output; therefore, some important differences exist between the summary provide here versus the summary of net loads to the estuary estimated using the watershed loading model (Chapter 3, Table 3.23). For example, the watershed loading model estimates are 30% higher for TN loads and a factor of 10 higher for TP loads than those derived from empirical observations used in the WASP model (Tables 3.23 and 3.24). Particularly for TP, these differences are largely driven by wet weather loads which carry the bulk of the particulate P and that are highly uncertain in both modeled and empirical estimates of loads.

Table 2.3 Summary of mass balance of SMRE sources and sinks for TN (lbs.) during the modeled year October 1, 2007-September 30, 2008

Terms	Wet Weather	Dry Weather	Winter Dry	Summer Dry
Sources				
Watershed SW	169,466	43,229	38,958	4,269
Upstream Aquifer	86	1,790	1,098	683
Local Ag Groundwater	134	6,777	2,583	4,163
Total External Input	169,686	51,798	42,639	9,116
Benthic Flux	264	12,040	5,880	6,118
Sinks				
Sediment Deposition	-6,515	-16,717	-9,429	-7,240
Denitrification	-1,448	-4,906	-3,471	-1,426
Ocean Export	-156,475	-47,719	-41,301	-6,381
Residual				
Change in Water Column Storage	-5,512	5,506	5,682	-187

Table 2.4 Summary of mass balance of SMRE sources and sinks for TP (lbs.) during the modeled year October 1, 2007-September 30, 2008

	Wet Weather	Dry Weather	Winter Dry	Summer Dry
Sources				
Watershed SW	16,285	6,314	5,261	1,054
Upstream Aquifer	88	2,574	1,221	1,353
Local Ag Groundwater	0	9	4	7
Total External Input	16,374	8,898	6,486	2,411
Benthic Flux	646	8,571	4,199	4,373
Sinks				
Sediment Deposition	-3,573	-7,628	-5,078	-2,548
Ocean Export	-13,751	-9,552	-5,257	-4,296
Residual				
Change in Water Column Storage	302	-291	-350	60

Eutrophication is a dry weather issue in SMRE (McLaughlin et al. 2013a). Eutrophication symptoms are present during dry weather, and exhibit their peak during summer dry weather. Therefore, the degree to which wet weather loads, which represents the vast majority of loads to SMRE, are retained within the estuary and are responsible for producing eutrophication symptoms is a key point of interest among stakeholders. The mass balance of inputs, sinks and exports shows that during wet weather, most of the loads are exported to the ocean. During this condition, high flow within the estuary will generally scour the mouth open and keep it open to tidal exchange. Any organic matter (e.g., algae) produced *in situ* will be scoured out, and sediment deposition can occur and will be contain particulate nutrients from the watershed (McLaughlin et al. 2013a). According to the WASP model, during these wet weather events in the period October 1, 2008-September 30, 2009, on average 92% of TN loads and 80% of TP loads were lost to ocean exchange, while 4% of TN loads and 20% of the TP loads were deposited to the sediment bed. The greater percentage of TP loads deposited is due to a greater proportion of TP that is particle-bound, relative to TN.

During dry weather, and summer dry weather in particular, particulates in riverine input are low, so "sediment deposition" is likely dominated by the settling of decaying algae produced *in situ* from nutrients. During winter dry weather, 76% of the internal and external TN loads are lost to the ocean, versus 17% deposited to the sediment bed; during summer dry weather, ocean export (42%) is roughly equivalent to sediment deposition (48%). Denitrification loss to the atmosphere, as captured by this model, was roughly equivalent during both winter and summer dry (6-9%). Compared to TN, more of the external TP load was retained within SMRE during summer and winter dry weather (38-44%), because a greater proportion of P is particle-bound. During winter dry weather, 49% of the internal and external TN loads are lost to the ocean, versus 48% deposited to the sediment bed; during summer dry weather, ocean export (63%) is roughly double that of sediment deposition (38%).

The dominance of the transport pathways (watershed surface water, groundwater discharge from upstream aquifer, local ag-dominated groundwater discharge) versus internal recycling (benthic flux) varied substantially by season and nutrient (N or P). During wet weather, watershed surface waters inputs dominated, representing > 99% of external TN and TP inputs to the estuary. Internal recycling (benthic efflux) accounted for very little load to surface waters during these conditions (< 1% TN and 4% of TP total external and internal loads to surface waters). During winter dry weather, watershed surface water flow to SMRE dominated external TN and TP loads (91% and 81%, respectively). Groundwater discharge from the upstream aquifer comprised a small contribution to TN load (3%), but a more substantial one for TP (19%). Local ag-dominated groundwater inputs provided 13% of external TN loads, but a negligible amount of TP loads (< 1%). Conversely, during summer dry weather, TN loads from watershed surface water and local ag-dominated groundwater inputs were roughly equivalent (47% and 46%, respectively), while watershed surface water and groundwater inputs from the upstream aquifer yielded roughly equivalent loads of TP (44% and 56%, respectively). Internal recycling (benthic efflux) accounted for 13% of total internal and external TN loads and 39% of TP loads during winter dry weather, but represented 40% of TN and 64% of loads to surface water during summer dry weather.

There are two major sources of uncertainty that play into the application of this mass balance information for nutrient management, as noted in section 2.2.6: 1) Magnitude and direction of benthic flux, and 2) magnitude of groundwater inputs and their spatial distribution.

Benthic flux appears to be largely driven by the accumulation and settling of organic matter to the sediment bed as macroalgal blooms die and decay. The importance of benthic flux in supporting eutrophication symptoms in the estuary is likely overestimated for the following reasons: First, the magnitude of modeled benthic flux appear high related to measured fluxes in winter dry weather and early summer dry weather. During these time periods, flux was largely into the sediments, because the benthic microalgae were not simulated as a component of benthic primary producers and because denitrification is likely underestimated (Figure 2.4, Table 2.5). Second, the model does not simulate sediment transport, deposition and scouring that are important to the spatial patterns of eutrophication in the estuary. It also does not capture the interannual scouring of sediments that occur during extreme high flow events that can cause the removal of accumulated organic matter, which fuels benthic flux. For this reason, the WASP model is likely overestimating the importance of benthic flux in driving eutrophication.

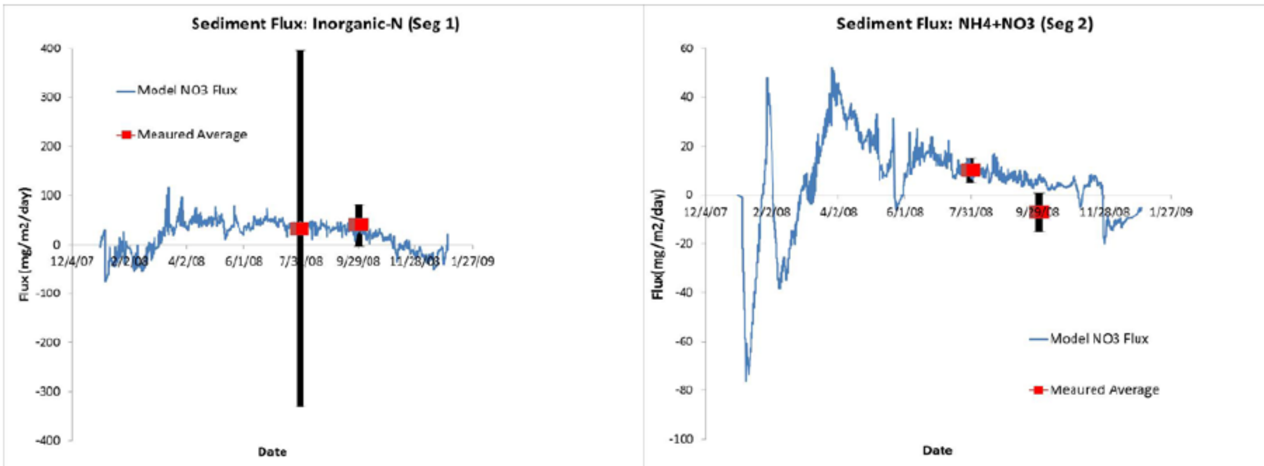


Figure 2.4. Simulated and measured sediment fluxes of nitrogen for Segment 1 and 2 for 2008. Black bars show the range in measured values (From SCC-PAC (2016)). Note that the benthic flux data for January and March 2008 are not shown in the figure, but are given in Table 2.5.

Table 2.5. Dissolved Inorganic Nitrogen and Phosphorus net fluxes and standard deviations from light and dark chamber fluxes (n=4) by index period. All fluxes are in mg N or P m^{-2} d^{-1}. From McLaughlin et al. (2013a).

Index Period	Segment	NH4	NO3	DIN	PO4
Jan-08	Segment 2	-0.42±1.4	-8.4±5.6	-8.4±5.6	-6.2±1.86
Mar-08		0.14±0.01	-14±32.2	-12.6±32.2	-2.48±1.55
Jul-08		12.6±0.1	-2.8±0.14	9.8±0.14	12.4±6.2
Sep-08		-2.8±26.6	-4.2±2.8	-7±26.6	12.4±12.4
Jan-08	Segment 1	175±46.2	-368.2±86.8	-193.2±98	18.6±12.4
Mar-08		-4.2±0.56	-105±117.6	-109.2±117.6	-9.3±6.2
Jul-08		392±58.8	-359.8±127.4	32.2±140	46.5±43.4
Sep-08		72.8±22.4	-32.2±26.6	40.6±35	21.7±9.3

Major uncertainties exist in estimates of groundwater exchanges from local agricultural fields and from upstream aquifer, constraining use of WASP model to drive fixed limits on allowable loads for several reasons. Calculated inputs of groundwater from the upstream aquifer are particularly constrained by the lack of phosphorus data, so the concentration was back-calculated based on the residual required to calibrate TP concentration in the Estuary. In addition, uncertainty exists in the estimates of local groundwater inputs to SMRE from agricultural fields found along the northern bank for three reasons: 1) Groundwater discharge measurements began in 2010, after the ag fields had been fallowed from active production and thus were temporally offset from calibration year. If 2010 GW inputs are less than 2008, then use of 2010 values would force the upstream aquifer load to be artificially high in order to calibrate the 2008 model. Furthermore, use of the 2010 and onward values does not give CP credit for the load reduction that it has already made through removal of ag production on these headlands; monitoring data have shown that local groundwater discharges have steadily declined from 2010 values (SCC-PAC 2014). 2) Independent data from 2008 show ag-dominated groundwater inputs in an area more spatially expansive than measured just at I-5 bridge and what was used to model local ag groundwater inputs (McLaughlin et al. 2013a). 3) Groundwater discharge and concentration data were limited in temporal resolution.

2.4 Importance of Wet Weather Particulate Deposition During an Open Tidal Inlet Condition in Driving Macroalgal Blooms and Low DO

For SMR NMI stakeholders, understanding the importance of wet versus dry weather loads on the eutrophication symptoms in SMRE is important because the nutrient best management practices (BMPs) associated with wet weather are structural in nature and therefore typically an order of magnitude more expensive than dry weather BMPs. In addition, sources of nutrients to SMRE vary greatly in wet weather versus dry weather. Therefore, WASP simulations were made in order to answer better understand the relative importance of wet versus dry weather in supporting eutrophication symptoms.

According to how it's configured, the WASP model, because greater than 80% of TP and 90% TN to SMRE during wet weather are exported to the ocean, the pathway by which wet weather can still contribute to eutrophication via sediment deposition and subsequent benthic flux of nutrients during dry weather, particularly during the summer (McLaughlin et al. 2013a; Figure 2.5). The sediment deposition that drives benthic flux can be caused by both wet weather deposition and the settling of decaying algal organic produced *in situ* during dry weather conditions. Thus, it's important to tease apart the contribution of wet weather particulate deposition versus organic matter particle settling during dry weather.

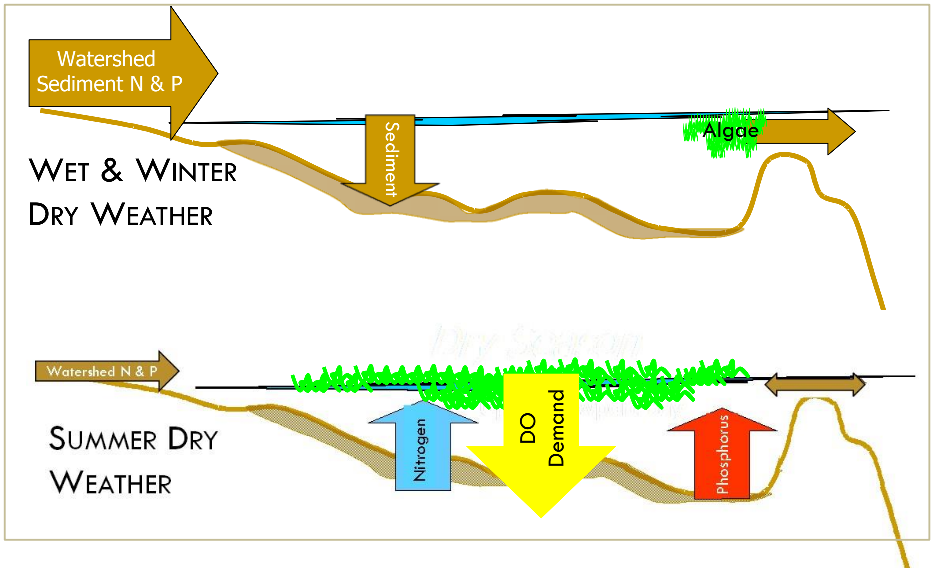


Figure 2.5. Schematic of the importance of wet weather particle deposition in supporting eutrophication symptoms in Mediterranean estuaries. During wet and winter dry weather, most watershed inputs are exported to the ocean, except what is deposited in sediment. During dry weather, those wet weather sediment nutrients, in addition to dry weather inputs, can contribute to internal recycling (benthic flux), that can fuel macroalgal blooms and dissolved oxygen problems in estuaries.

Here we quantified the effect of wet weather particle deposition on the benthic flux and subsequent eutrophication symptoms by removing the input of particulate N and P from any local or watershed-derived N and P loads during wet and dry weather, knowing that wet weather is the bulk of the mass particle load. As noted previously, this estimate represents an upper bound on the contribution of wet weather particulate deposition to benthic flux.

As configured in the WASP model, comparison of a scenario with watershed particulate N and P inputs removed to the 2008 base run showed that watershed particle deposition contributed only to < 5 % of peak summertime macroalgal biomass and < 1% of the amount of time that DO fell below 5 mg/L (Table 2.6).

Table 2.6. Summary of Effects of Particle Deposition on Macroalgae (2008) and Dissolved Oxygen (April-November 2008) at Whole Estuary Scale (Via Benthic Flux)

Parameter	Original 2008 Base Run	2008 Base Run Without Particle Inputs	% Contribution of Particle Inputs
Maximum Macroalgal Biomass (g m^{-2} dry weight)	122	116.1	4.5%
10^{th} %ile of DO (mg/L)	4.0	4.0	0.8%

Uncertainty in this answer exists, because the EFCD+WASP model doesn't simulate sediment deposition, redistribution, sorting, and scouring processes within the estuary. McLaughlin et al. (2013a) measured net particulate nutrient deposition using Be^7 isotopes and found that during the late wet season, much of the deposited load was eroded from the estuary. Similarly, the model doesn't simulate seasonal or interannual scouring of accumulated organic matter during high flow years, a self-cleansing mechanism that is important in river mouth estuaries as SMRE. Therefore, our opinion is that during an open tidal inlet conditions, this simulation provides a reasonably-bounded estimate to answer the question.

2.5 Comparison of Allowable Loads Given Nutrient Load Reductions in Wet and Dry Weather Versus Dry Weather Only

The intent of these scenario analyses to estimate estuary allowable loads were three-fold:

1) Compare estimated ranges of allowable loads among the three set of candidate numeric targets: Biostimulatory objectives for TN and TP concentrations, macroalgal biomass, and dissolved oxygen
2) Understand how the selection of numeric target for macroalgae affects the range of allowable loads
3) Compare the allowable load reductions required if both wet and dry weather loads were made, versus only dry weather reductions

As captured by the WASP model during open tidal inlet condition, we found that very little difference existed between wet and dry weather reductions of nutrient loads versus dry weather only load reductions that met the range of DO and macroalgal targets, but a much bigger difference was observed for TN and TP biostimulatory objectives. Among candidate numeric targets, a TP target of 0.1 mg/L drives the most stringent load reductions, with ~94 % reduction of 2008 loads required. Conversely, the biostimulatory TN target of 1.0 mg/L required ~54% load reduction, while meeting a DO target of 5 mg/L greater than 90% of the time would require ~70% reduction. The range of load reduction required for macroalgal biomass depended on the numeric target chosen; for example, a 50% dry weather reduction of 2008 loads fell below a 90 g dw m^{-2} summertime maximum biomass, while a 90% reduction fell below a 50 g dw m^{-2} summertime maximum biomass.

The detailed results of each indicator set (nutrients, dissolved oxygen, and macroalgal biomass) and the associated uncertainties are given in the sections below.

2.5.1 Allowable Loads to Meet TN and TP Biostimulatory Objectives

As captured by the WASP modeling during the period of October 1, 2008-September 30, 2008, when both wet and dry weather concentrations are held to a 1.0 TN mg/L numeric target, ~30% of 2008 wet and dry weather loads would need to be reduced, but 54% of TN loads if only dry weather load reductions were required (Table 2.7, Figures 2.6 and 2.7). Because most of the TN concentration exceedances occurred during wet weather, if only dry weather flows were required to meet the numeric target, much lower load reductions would be required (10-17%).

Conversely, for a TP numeric target of 0.1 mg/L, much greater reductions would be required, in part because of high flow-weighted mean concentrations that were applied to upstream aquifer discharge (~0.3 mg/L TP) in order to calibrate the estuary water quality model, such that during dry weather, > 94% load reduction would be required to meet this target, regardless of whether exceedances or load reduction focused on dry only, or wet and dry weather. This result illustrates the importance of groundwater in driving dry weather concentrations and highlights the importance of the large uncertainty in groundwater TP, particularly in the upstream aquifer that discharges to SMRE. For this reason, as well as the fact that ambient TN and TP do not have a strong linkage to beneficial use impairments (Sutula 2011), we discourage the use of the biostimulatory objective to establish numeric targets for SMRE.

Table 2.7. Percentage reduction of 2008 loads that met the TN and TP biostimulatory objectives within a 10% exceedance frequency and the range of allowable load (lbs.) based on that target for wet and dry weather versus dry weather only simulations.

Candidate Numeric Target	% Wet and Dry Weather Load Reductions ± 95% CI	Mean Wet and Dry Weather Load Target ± 95% CI (lbs.)	% Dry Weather Load Reductions ± 95 %CI	Mean Dry Only Load Target ± 95% CI (lbs.)
TN of 1.0 mg/L				
Wet & Dry Exceedances	29.8 ± 1.6	155,481 ± 3,543	53.8 ± 8.0	23,930 ± 4143
Dry Exceedances	9.9 ± 0.2	199,557 ± 442	10.1 ± 2.2	46,565 ± 1139
TP of 0.1 mg/L				
Wet & Dry Exceedances	94.0 ± 6.0	1,526 ± 1,526	105.1 ± 1.5	0 ± 133
Dry Exceedances	94.3 ± 4.9	1,440 ± 1, 238	97.2 ± 3.1	249 ± 275

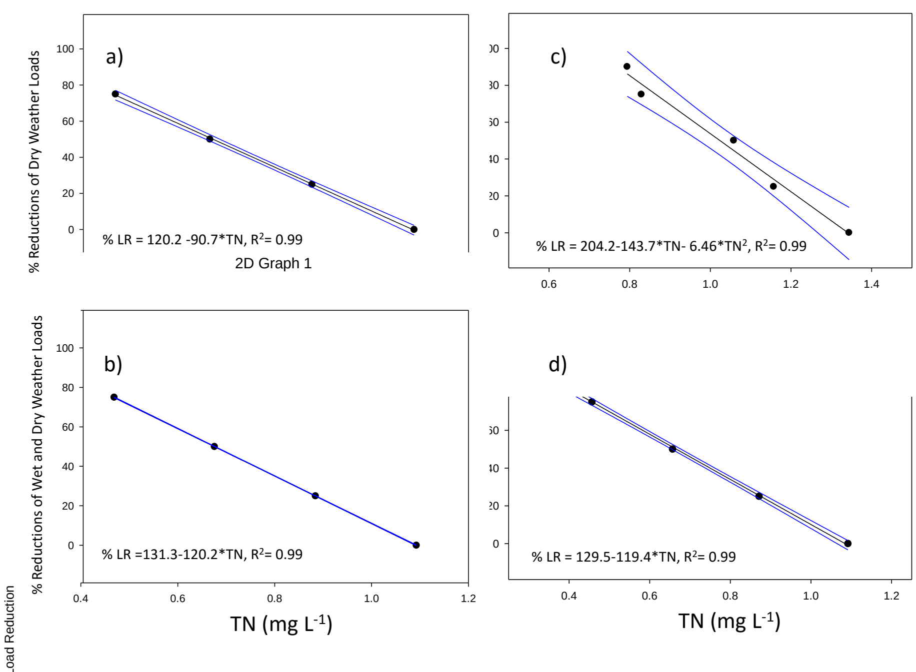


Figure 2.6 Least square regressions representing relationship between percent load reduction and the 90th percentile of TN concentration, whole estuary, for the following combinations: a) concentrations during wet and dry weather condition, based on <u>dry weather</u> load reductions, b) concentrations during dry weather only conditions, based on <u>dry weather</u> load reductions, c) concentrations during wet and dry weather condition, based on <u>wet and dry weather only</u> load reductions, and d) concentrations during dry weather only conditions, based on <u>wet and dry weather only</u> load reductions.

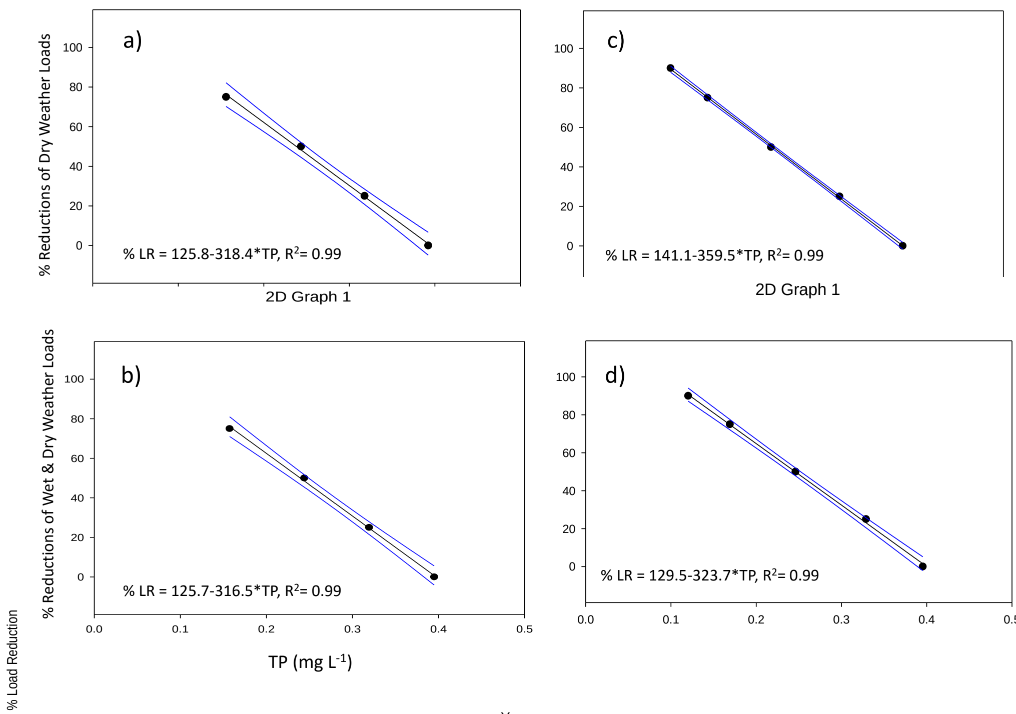


Figure 2.7 Least square regressions representing relationship between percent load reduction and the 90th percentile of TP concentration, whole estuary, for the following combinations: a) concentrations during wet and dry weather condition, based on dry weather load reductions, b) concentrations during dry weather only conditions, based on dry weather load reductions, c) concentrations during wet and dry weather condition, based on wet and dry weather load reductions, and d) concentrations during dry weather only conditions, based on wet and dry weather load reductions.

2.5.2 Allowable Loads to Meet DO Objectives

Overall, an approximately 70% reduction of TN and TP loads would be needed to achieve DO concentrations greater than 5 mg/L 90% of the time (Figure 2.8, Table 2.9). The difference between reductions of wet and dry weather loads versus dry only reductions was negligible (~3%), implying that wet weather nutrient inputs do not greatly influence attainment of DO objectives during an open tidal inlet condition.

Several sources of uncertainty influence this answer (See Section 2.2.3), including: 1) degree of openness of tidal inlet, 2) WASP model was only demonstrated calibration during the April-November period, which could make the requirement for load reductions more stringent, 3) general aforementioned uncertainty in nutrient inputs, particularly groundwater, which drive macroalgal biomass and organic matter accumulation in the modeled estuary, and 4) lack of spatial resolution and the temporal offset in DO observational data, which was calibrated based on data from one continuous data sonde collected during October 2008-2009, rather than 2007-2008.

Table 2.8. Percentage reduction of 2008 loads and estimated allowable TN and TP loads (lbs.) that met DO WQO of 5 mg/L greater than 90% of the time. Estimated reductions are shown for scenarios in which wet and dry weather loads were reduced versus dry weather only; 95 percent confidence intervals are shown representing error in regression model fit and allowable load range.

Candidate Numeric Target	% Wet and Dry Weather Load Reductions ± 95% CI	Mean TN and TP Wet and Dry Weather Load Target (lbs.)	% Dry Weather Load Reductions ± SE	Mean TN and TP Dry Only Load Target (lbs.)
Meets 5 mg/L 90% of time or greater	70.4 ± 6.7	65,559 ± 14,839 TN 7,479 ± 1,693 TP	73.3 ± 3.6	13,829 ± 1896 TN 2,375 ± 320 TP

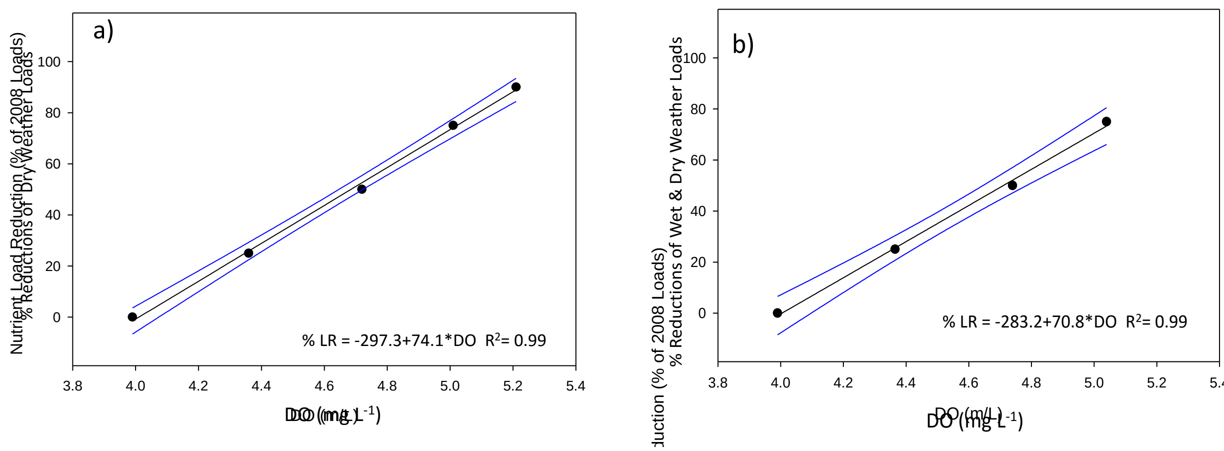


Figure 2.8 Least square regressions representing relationship between percent load reduction and the 10th percentile of DO concentration, whole estuary, for the following combinations: a) based on dry weather load reductions, b) based on wet and dry weather only load reductions.

2.5.3 Allowable Loads to Meet a Range of Macroalgal Numeric Targets

As would be expected, the selection of the dry weather maximum macroalgal biomass numeric target has a large effect on the load reduction required (reductions of ~20% to 100% load reductions required fall below targets in the range of 110 to 30 g dw m^{-2}) (Table 2.9, Figure 2.9). The difference between reductions of wet and dry weather loads versus dry only reductions was negligible (~1-3%), implying that wet weather nutrient inputs do not greatly influence attainment of macroalgal biomass during an open tidal inlet condition.

Several factors influence the confidence in this answer (See Section 2.2.3), including: 1) a lack of clarity in level of adverse effects of macroalgal biomass between 30 to 90 g m^{-2}, which is further explored in Section 2.6, 2) limitations in macroalgal calibration because of resolution of model grid (SSC-PAC) and limited spatial data on macroalgal biomass in subtidal habitats, and 3) aforementioned uncertainty in nutrient inputs, particularly groundwater, which drives macroalgal biomass.

Table 2.9. Percentage reduction of 2008 loads and estimated allowable TN and TP loads that met a range of dry weather maximum macroalgal biomass numeric targets under consideration from 110-50 g dw m^{-2}. Estimated reductions are shown for scenarios in which wet and dry weather loads were reduced versus dry weather only. 95 percent confidence intervals in percent reduction and targeted loads (lbs.) are shown, representing error in regression model fit.

Biomass Numeric Target (g dw m^{-2})	Wet and Dry Weather			Dry Weather Only		
	% Reductions ± 95%CI	Mean TN Target ± 95%CI (lbs.)	Mean TP Target ± 95%CI (lbs.)	% Reductions ± 95%CI	Mean TN Target (lbs.) ± 95%CI	Mean TP Target (lbs.) ± 95%CI
110	20 ± 10	177,187 ± 22,148	20,216 ± 2,527	22 ± 3	40,401 ± 1,559	6,939 ± 266
100	36 ± 9	141,749 ± 19,933	16,172 ± 2,274	38 ± 3	32,114 ± 1,559	5,516 ± 266
90	50 ± 8	110,742 ± 17,718	12,635 ± 2,021	52 ± 4	24,862 ± 2,079	4,270 ± 355
80	63 ± 11	81,949 ± 24,363	9,349 ± 2,779	65 ± 4	18,128 ± 2,079	3,113 ± 355
70	74 ± 14	57,585 ± 31,007	6,570 ± 3,537	76 ± 3	12,431 ± 1,559	2135 ± 266
60	83 ± 12	37,652 ± 26,578	4,295 ± 3,032	84± 3	8,287 ± 1,559	1424 ± 266
50	90 ± 13	22,148 ± 28,792	2,527 ± 3,285	91 ± 4	4,661 ± 2,079	800 ± 355
40	96 ± 15	8,859 ± 33,222	1,010 ± 3,790	96 ± 4	2,071 ± 2,079	355 ± 355
30	100 ± 16	0 ± 35,437	0 ± 4,043	99 ± 5	517 ± 2,598	88 ± 444

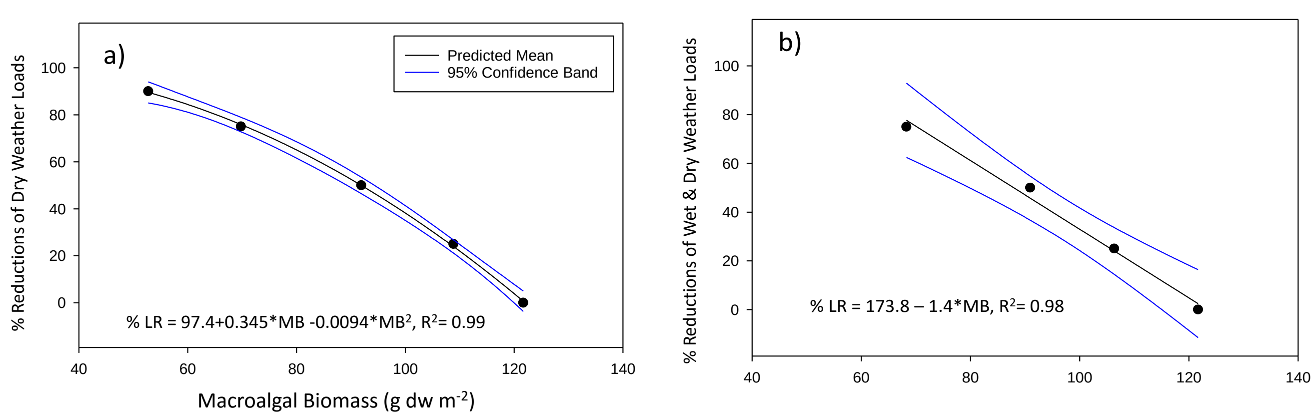


Figure 2.9 Regressions representing relationship between percent load reduction and maximum percentile of macroalgal biomass, whole estuary, for the following combinations: a) based on <u>dry weather</u> load reductions, b) based on <u>wet and dry weather only</u> load reductions.

2.6 Analyses and Information Informing Selection or Interpretation of Numeric Targets

2.6.1 Dissolved Oxygen

Sutula et al. (2013) review science supporting DO WQO among California coastal Regional Boards. They found that using the Virginia Province Approach, existing information relevant to California native fish and invertebrates supports the use of 5.0 mg L^{-1} as an upper bound to protect long-term survival and reproduction in for non-salmonid, warm water fisheries. They noted, however, that in bar-built estuaries typical of California's Mediterranean climate and wave-exposed coastline, periods of natural hypoxia may be possible in these estuaries, especially during periods of mouth closures.

Towards this end, preliminary results of the estuary reference study and additional long-term monitoring of DO in SMRE shed additional light on the need for additional consideration of allowable periods of non-attainment of the DO WQO.

Estuary Reference Study

We used continuous monitoring of bottom water DO in six estuaries to document the percent of time that DO fell below 5 mg/L (San Diego Water Board basin plan WQO) and below 2.8 mg/L, the definition of hypoxia (Diaz 2001). Overall, among the six estuaries, the average period of time below 5 mg/L was 32%, with a range of 2-61% (Table 2.10). During this same time period, these estuaries experienced hypoxia in their bottom waters 21% of the time. During the time periods captured, all of these estuaries were closed at their tidal inlet, with only occasional overtopping observed during spring tides.

Table. 2.10 Percent of time that minimally disturbed "reference" estuaries fell below existing SD Water Board basin plan objectives of 5 mg/L and the defined limit of hypoxia (2.8 mg/L), for the period of April-October 2015, based on continuous (15-min) data.

Estuary and Time Period of DO Record	Percent of Time DO Fell Below	
	< 2.8 mg/L	< 5 mg/L
Salmon Creek (April-October 2015)	11	15
Navarro River (April-October 2015)	0.3	2
Laguna Creek (April-October 2015)	29	46
Waddell Creek (April-October 2015)	48	60
Topanga (April-October 2009)	28	52
Topanga (April-October 2014)	10	19
Apr 2015-Aug 2015	20	32

Two things should be considered in applying the reference study data: 1) The reference study data represent estuaries largely in a closed mouth condition, so it's not comparable to SMRE during an open mouth condition (2008), but would be comparable during later years when the estuary mouth was largely closed, and 2) the reference study data could be used to derive alternative expectations for attainment during a "closed mouth" condition.

SMRE Long Term Monitoring Data

SCC-PAC conducted an analysis of continuous DO monitoring data collected from the period of September 2014-February 2016 to analyze the effect of tidal inlet status (open/closed) on frequency of attainment of DO WQOs at the I-5 and Stuart Mesa Bridges (SMB). For the purposes of this analysis, tidal inlet closure was defined as water surface elevation data with diurnal variation of < 5 cm. Supporting documentation for this analysis is presented in Appendix 4.

Two key points are visible from these data: 1) Frequency of non-attainment of DO WQO range from 2-10 times higher during tidal inlet closure than when the mouth is open, and 2) the frequency of non-attainment is greater in the upper SMRE than in the lower portion. Estuary reference data did not provide a spatial picture of frequency of attainment, making this second point more difficult to interpret.

Table 2.11. Percent of time continuous DO records from September 2014 through February 2016 fell below 5 mg/L by status of tidal inlet (open or closed)

Location of DO Data Sonde	Percent of Time < 5 mg/L (and Data Record Count)	
	Tidal Inlet Open	**Tidal Inlet Closed**
I-5 Bridge	3.1% (of 23,970 records)	28.6% (of 25,362 records)
Stuart Mesa Bridge	13.2% (of 23,435 records)	33.0% (of 24,154 records)

2.6.2 Macroalgae

In addition to the synthesis of information presented in section 2.2, additional sources of information and context of application of the assessment framework to SMRE can inform the selection of the macroalgal numeric target in four ways: 1) What are the natural background levels of macroalgae in California bar-built estuaries, similar to SMRE, 2) at levels of macroalgae documented in 2008, what does historic benthic macroinvertebrate data say about the degree to which benthic habitat was adversely affected, 3) if the Sutula et al. (2016b) macroalgal assessment framework was based on pathways of adverse effects to benthic habitat, and there is a lack of clarity in the biomass at which benthic habitat is protected, at what levels of macroalgae can we predict would support good DO concentrations in surface waters, and 4) what are the constraints placed on the application of the assessment framework in SMRE in a water quality modeling context?

Estuary Reference Study

Documentation of the natural background levels of macroalgal biomass was made as a part of the study of primary producers, nutrients and DO in six California bar-built estuaries in North Coast, Central Coast and South Coast (Sutula et al. 2016a). In this study, macroalgal biomass was sampled 4-6 times throughout an eight-month growing period. During each event, the biomass and cover were documented at 15 points in the estuary laid out in a grid format, so that all subtidal habitat was equitably sampled. All estuaries were closed throughout the period of sampling.

Reference estuary data support the concept that natural background concentrations of macroalgae are ≤ 20 g dw m^{-2} in either open or closed tidal inlet condition. We found that the growing season maximum biomass of the four estuaries in which macroalgal blooms were found averaged 8.1 ± 2.2 (Table 2.12).

Two of the estuaries were dominated by phytoplankton and had no macroalgal blooms. Peak biomass of 11-12 g dw m^{-2} was found in both the North Coast (Navarro River) and South Coast estuaries (San Onofre Creek). This peak biomass is consistent with previous estimates of reference levels of algal biomass on intertidal flats in California estuaries (Sutula et al. 2014) and the European Union estuaries (Scanlan et al. 2007).

Table 2. Growing season maximum macroalgal biomass in minimally disturbed "reference" estuaries. From Sutula et al. 2016a.

Estuary	Peak Macroalgal Biomass (g dw m^{-2}) ± 95% CI
Salmon Creek (April-October 2015)	5.4 ± 4.4
Navarro River (April-October 2015)	11.3 ± 9.5
Laguna Creek (April-October 2015)	0
Waddell Creek (April-October 2015)	3.1 ± 3.7
Topanga Creek (April-October 2009, April-October 2014)	0
San Onofre Creek (April-August 2015)	1.9 ± 3.9

Benthic Invertebrate Historical Data

Interpretation of benthic macroinvertebrate community composition data can be translated through the lens of the CA SQO BLOE index. In this assessment framework, categories of reference and low to high impact refer to levels of benthic ecological condition, from excellent (reference) to poor ecological condition (high impact).

Analyses of mean BLOE scores indicate benthic habitat in SMRE varied from low to high impact during 2003-2013 (Figure 2.9). During 2008, historical benthic macroinvertebrate data from 2008 suggest that benthic habitat is being impacted from a low to moderate extent by eutrophication and salinity, but that productivity was maintained, despite an estuary-wide average peak macroalgae that exceeded 90 g dw m^{-2} during the late fall (Table 2.13). One reason for this discrepancy could be due the fact that river mouth estuaries don't accumulate organic matter in sediment, thus reducing the risk of adverse effects to benthic infauna. Another is the fact that macroalgae was monitored in the lower intertidal habitat, while benthic macroinvertebrates are sampled in subtidal habitat. No strong spatial pattern in the condition of the benthic macroinvertebrate community across the SMRE was visible (Figure 2.10), despite the strong gradient in macroalgae observed in 2008 (Table 2.13).

Benthic macroinvertebrates can be impacted by a variety of stressors in addition to nutrients and/or eutrophication. Analyses of potential stressors indicate that depression of benthic SQO scores from toxic contaminants and physical disturbance was unlikely. The potential for impacts by highly variable salinity and hypersalinity is unknown. Impacts to the benthic macroinvertebrate community from low DO appear unlikely for the periods of 2003-2008, during which crustaceans were diverse and abundant. The notable exception to this is 2013, which exhibited extremely low abundances. Impacts from eutrophication appear possible, because of periodic high abundances of *Grandidierella japonica* and *Capitella capitatata*. However, even when these organisms were present, there was still reasonable trophic diversity, suggesting a potential fertilization effect from euthrophication without strong deleterious effects (e.g., Nixon and Buckley 2002, Rakocinski and Zapfe 2005). In addition, no apparent accumulation of particulate total organic carbon and total nitrogen was noted in the sediment, a causal factor related to eutrophication that can result in impacts to benthic macroinvertebrates.

Thus the conclusion of this analysis is two-fold: 1) The benthic macroinvertebrate community composition is in poor to moderate ecological condition, but shows evidence of good diversity in trophic levels as well as living position, indicating that it is functioning as a productivity community, and 2) eutrophication and salinity are the most probable stressors to the benthic macroinvertebrate community in SMRE, but are not clearly impacting the benthic community, especially in 2008.

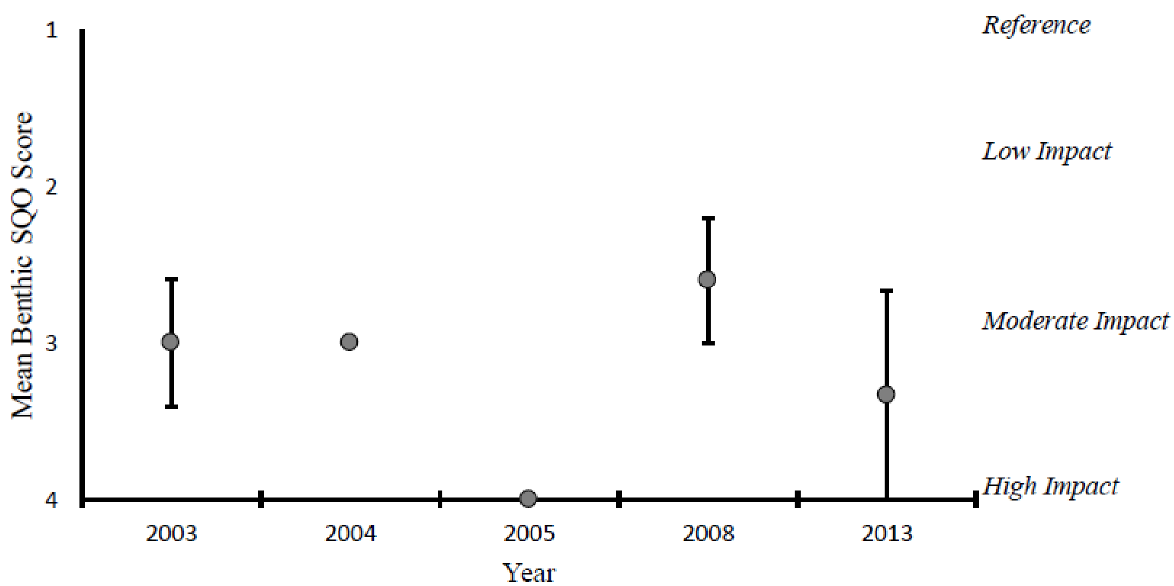


Figure 2.9 Temporal trends in mean benthic sediment quality objective (SQO) score. Categories of reference and low to high impact refer to levels of benthic ecological condition, from high (reference) to low (high impact).

Table 2.13. Macroalgal biomass (mean±SD) measured in lower intertidal habitat in Segment 1 and 2 during TMDL monitoring studies and the Bight ’08 Eutrophication Assessment, in g dw m^{-2}. ND = no data (not sampled).

Study	Time Period	Segment 1	Segment 2
TMDL Field Study	**Jan-08**	0 ± 0	0 ± 0
	Mar-08	0 ± 0	1 ± 1
	Jul-08	76 ± 12	46 ± 43
	Sept-08	238 ± 88	40 ± 12
Bight ’08 Study	**Nov-08**	173 ± 260	ND
	Jan-09	1 ± 4	ND
	Mar-09	0 ± 0	ND
	May-09	13 ± 43	ND
	Jul-09	26 ± 29	ND
	Oct-09	94 ± 56	ND

Figure 2.10 Spatial patterns in mean benthic SQO scores. Color designates condition category, where yellow = low impact, orange = moderate impact, and red = high impact.

Relationship of Macroalgae with DO

Sutula et al. (2016b) proposed an assessment framework for macroalgae based on the studies linking macroalgae to adverse effects to benthic macroinvertebrates. Another pathway of impact is to determine at what level of macroalgae the WASP model predicts attaining DO WQOs in SMRE. To estimate this, dry weather maximum macroalgal biomass was regressed against DO concentration at the whole estuary scale for the dry weather loads reduction scenarios (base run, 25%, 50%, 75%, 90%). The resulting nonlinear relationship (Figure 2.9) was fit with a quadratic equation and solved for a DO numeric target of 5.0 mg/L. Three interpretations of the DO WQO were tested:

- 10^{th} percentile of the 7-day mean of DO minima
- 10^{th} percentile of DO minima
- 10^{th} percentile of instantaneous DO

The WASP model predicts that, at a whole estuary scale and during an open mouth condition, a macroalgal biomass of 71 ± 2 g dw m^{-2} would meet a 5 mg L^{-1} target based on the 10^{th} percentile of 7-day mean DO daily minima; this is similar to the macroalgal biomass that would meet target based on an instantaneous measure (70 ± 3 g dw m^{-2}). A much lower biomass would be required to meet the target based on the 10^{th} percentile of daily DO minima (57 ± 6 g dw m^{-2}).

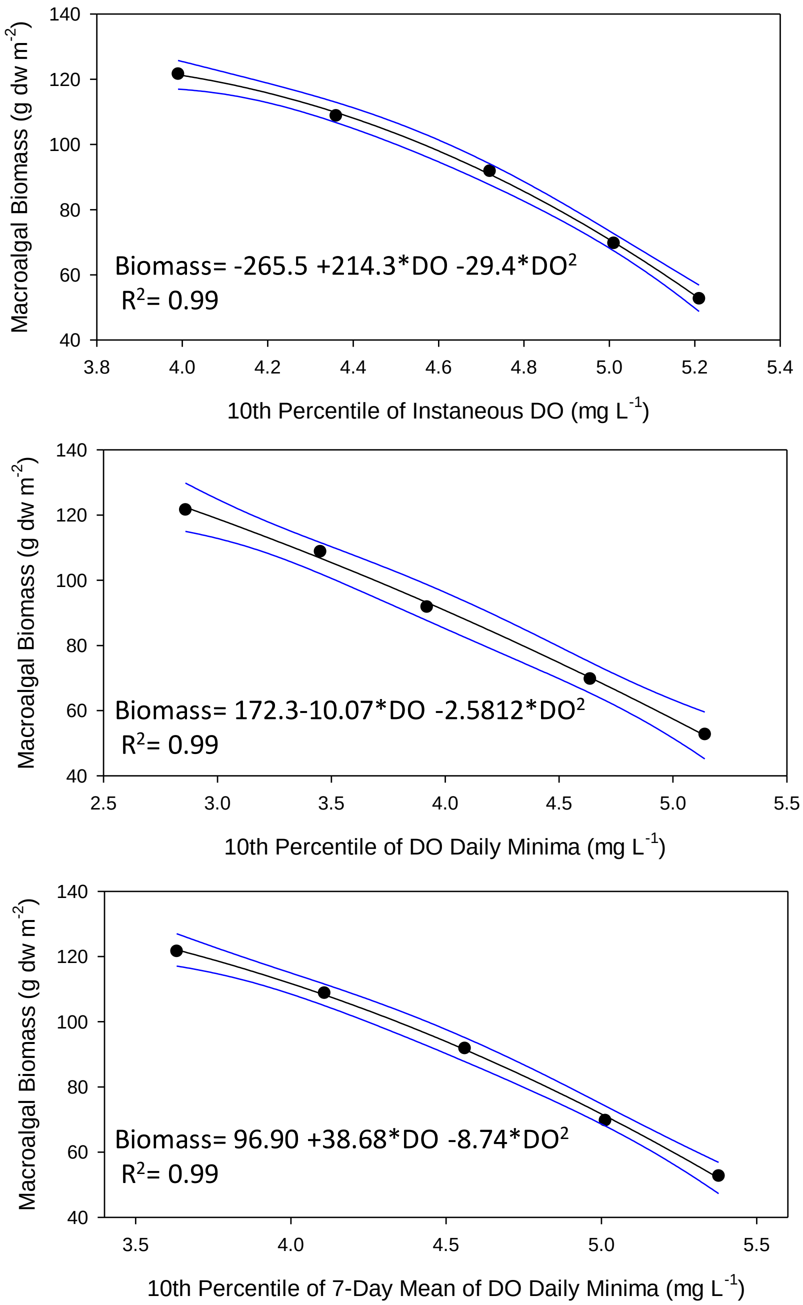


Figure 2.11 Non-linear regression representing relationship between dry weather maximum macroalgal biomass versus DO concentrations, using three interpretations of the DO target, based on scenarios of dry weather load reductions. Top panel= 10th percentile of instantaneous DO, middle panel= 10th percentiel of DO daily minima; bottom panel= 10th percentile of 7-day dauly DO minima.

Other Reflections on the Use of Macroalgal Biomass as a Numeric Target for Nutrient Management in SMRE

Sutula et al. (2016b) provides a synthesis of the status of science on adverse effect thresholds of macroalgae on benthic habitat quality (Figure 2.2) and proposed an assessment classification scheme (Table 2.2) based on the use of macroalgal biomass and cover. High biomass at low percent cover is a natural occurrence in estuaries, because macroalgae can raft and be deposited in one area that is favored by circulation patterns or post storm deposition (Sutula et al. 2014). For the purposes of assessment, we strongly urge the use of both biomass and cover in assessing attainment of beneficial uses (Table 2.2).

Conversely, the WASP model does not predict % cover, but rather assumes uniform distribution within each grid cell. The model output was also averaged across estuary. Therefore, we recommend reliance on biomass only as a numeric target for interpretation of model output to determine allowable loads, using the synthesis of threshold information rather than the assessment framework.

Finally, although model output was not reliable to interpret at a segment scale, it is strongly recommended that monitoring and interpretation of attainment of a macroalgal numeric target be conducted at this scale.

2.7 Analyses informing Management Actions in the Implementation Plan

Model scenario analyses that involved reduction of single nutrient transport pathways (watershed surface water, groundwater discharge from upstream aquifer, and local groundwater inputs) were conducted in order to determine whether one pathway in particular was most effective in reducing eutrophication symptoms. The effect of reducing ocean nutrient concentrations was also simulated in order to investigate the sensitivity of available concentration data on this exchange pathway. Reduction of single pathways were investigated by reducing only N and P dry weather loads by 50% and 75%. Results for only the 50% reduction are shown for macroalgae and DO (Table 2.14).

Overall, reductions of 50% of concentrations of single transport pathways resulted in improvements in DO in the range of 5-8% and macroalgae in the range of 2-16%. The fact that no single pathway was singularly effective support the conclusions that the implementation plan focus on reductions of multiple pathways in order to be effective in managing eutrophication symptoms within SMRE.

Table 2.14. Simulated whole estuary macroalgal biomass and dissolved oxygen concentrations in 2008 base run versus 50% reductions in N and P concentrations for single pathways, as absolute value, and as percent change from 2008 base run.

Model Run	Dry Weather Macroalgal Biomass		Dissolved Oxygen (April-November)	
	Maximum, Whole Estuary (g dw/m2)	% Change From 2008 Model Run	10th percentile DO, Whole Estuary	% Change From 2008 Model Run
2008 Base Run	122	--	3.99	--
50% Reductions in N and P Concentrations in Single Pathway				
Local Ag Ground Water	113	7%	4.24	6%

Upstream Aquifer	119	2%	4.32	8%
Watershed Surface Water	102	16%	4.19	5%
Ocean Exchange	119	3%	4.23	6%

2.8 Summary and Recommendations

The EFDC + WASP model was applied in order to inform four major objectives of the Santa Margarita River Watershed Nutrient Management Initiative (Phase I), focused on the SMRE:

1) Summarize understanding of the major drivers of eutrophication in the SMRE
2) Derive estimates of the range of allowable loads to SMRE, including consideration of wet versus dry weather loads
3) Illustrate how choices in selection of and interpretation of numeric target affect estimates of allowable loads
4) Conduct a preliminary set of scenarios to inform what kind of nutrient management activities should be considered to support SMRE beneficial uses

A summary of findings, related uncertainty, and recommendations relevant for nutrient management are provided below.

2.7.1 Major pathways of nutrient loading supporting eutrophication in the SMRE

- Eutrophication symptoms occur in the SMRE during dry weather, and exhibit their peak during summer dry weather. Both wet and dry weather loading to surface and groundwater can contribute to these eutrophication symptoms.

- Greater than 99% of TN and TP loads during wet weather are exported to ocean during the period of October 2007-September 2008, a year in which the mouth of the estuary was relatively open. During this simulated period, wet weather deposition of particulate nutrient in SMRE does not appear to be an important mechanism for fueling summer dry weather algal blooms and low DO, contributing < 5% to eutrophication symptoms. This is consistent with its typology as a river mouth estuary, which has a greater capacity to scour fine-grained sediments during flood flow and export them to the coastal ocean. However, the duration and extent of tidal inlet closure will ultimately affect eutrophication symptoms.

- As configured in WASP model, major source of TN to the estuary during dry weather are watershed SW and local groundwater inputs, while major P sources include watershed SW and upstream aquifer discharge. Both wet and dry weather watershed inputs contribute to the loading of the upstream groundwater aquifer. Major uncertainties exist in estimates of groundwater exchanges from local agricultural fields and from upstream aquifer to the SMRE, constraining use of WASP model to drive fixed limits on allowable loads for several reasons. Calculated inputs of groundwater from the upstream aquifer are particularly constrained by the lack of phosphorus data, so the concentration was back-calculated based on the residual required to calibrate TP concentration in the Estuary. In addition, uncertainty exists in the estimates of local groundwater inputs to SMRE from agricultural fields found along the northern bank for three reasons: 1) Groundwater discharge measurements began in 2010, after the ag fields had been fallowed from active production and thus were temporally offset from calibration year, 2) independent data from 2008 show ag-dominated groundwater inputs in an area more spatially expansive than measured just at I-5 bridge and what was used to model local ag groundwater inputs, and 3) groundwater discharge and concentration data were limited in temporal resolution.

- Benthic flux can be an internal source of nutrients to surface waters during dry weather. As configured in the WASP model, benthic flux presents a large contribution to available nutrients. This component appears to be largely driven by the accumulation and settling of organic matter to the sediment bed as macroalgal blooms die and decay. The importance of benthic flux in supporting eutrophication symptoms in the estuary is highly uncertain and likely overestimated for the following reasons: First, the magnitude of modeled benthic flux appear high related to measured fluxes in winter dry weather and early summer dry weather, because the benthic microalgae were not simulated as a component of benthic primary producers. Second, the model does not simulate sediment transport, deposition and scouring that are important to the spatial patterns of eutrophication in the estuary. It also does not capture the interannual scouring of sediments that occur during extreme high flow events that can cause the removal of accumulated organic matter, which fuels benthic flux. For this reason, the WASP model is likely overestimating the importance of benthic flux in driving eutrophication.

2.7.2 Choice of Indicators of Eutrophication for Numeric Targets

- Use of existing TN and TP numeric translators of SD Diego Water Board basin plan objectives is not recommended because 1) ambient TN and TP do not have a strong linkage to beneficial use impairments (Sutula 2011) and 2) exceedances of dry weather TP concentrations are driven by the concentrations of TP imposed on upstream aquifer discharge in order to calibrate the WASP model. No data are yet available to inform the nutrient concentrations modeled in the upstream aquifer discharge.

- Dissolved oxygen, macroalgal biomass and percent cover have demonstrated linkages to beneficial uses (Sutula 2011), have a predictive relationship with nutrient loading to the estuary, and have a practical and generally cost-effective methods for measurement and interpretation of data. These indicators seem to be well-suited for further consideration as numeric targets for SMRE.

2.7.3 Science Supporting Selection and Interpretation of Numeric Targets

Dissolved Oxygen

- Sutula et al. (2013) found that existing information relevant to California native fish and invertebrates supports the use of 5.0 mg L^{-1} as an upper bound to protect long-term survival and reproduction for non-salmonid, warm-water fisheries in California estuaries.

- Sutula et al. (2013) noted that, in bar-built estuaries typical of California's Mediterranean climate and wave-exposed coastline, periods of natural hypoxia can occur, especially during periods of mouth closures. Documentation of continuous dissolved oxygen conditions in minimally disturbed "reference" bar-built estuaries similar to SMRE indicate that during the period of April-October, the average period of time bottom waters spent below 5 mg/L was 32%, with a range of 2-61%. The San

Diego Regional Board may want to consider setting expectations for percentage of the time in which SMRE attains the DO WQO, taking into account tidal inlet status (open, closed) and what can be attained in reference estuaries similar to SMRE.

Macroalgal Biomass

- Sutula et al. (2016b) provides a synthesis of the status of science on adverse effect thresholds of macroalgae on benthic habitat quality (Figure 2.2) and proposed an assessment classification scheme (Table 2.2) based on the use of macroalgal biomass and cover. For the purposes of assessment, we strongly urge the use of both biomass and cover in assessing attainment of beneficial uses (Table 2.2).
- The WASP model does not predict % cover, but rather assumes uniform distribution within each grid cell. The model output was also averaged across estuary. Therefore we recommend reliance on the biomass only (Figure 2.2) for interpretation of model output to determine allowable loads.
- Although model output was not reliable to interpret at a segment scale, it is strongly recommended that monitoring and interpretation of attainment of a macroalgal numeric target be conducted at this scale.
- A lack of understanding exists in the macroalgal biomass of range 30-90 g dw m^{-2} that causes adverse effects to benthic habitat quality (Sutula et al. 2016b). Analyses of reference study data from North, Central and South Coast estuaries suggest that growing season maximum macroalgal biomass of 8 ± 2 g dw m^{-2} can be considered natural background, particularly when the estuaries are closed to tidal exchange, a number equivalent to that found in a study conducted in California estuaries open to tidal exchange. Historical benthic macroinvertebrate data from 2008 suggest that benthic habitat is being impacted from a low to moderate extent by eutrophication and salinity, but that productivity was maintained, despite an estuary-wide average peak macroalgae exceeded 90 g dw w m^{-2}. One reason for this discrepancy could be due the fact that river mouth estuaries don't accumulate organic matter in sediment, thus reducing the risk of adverse effects to benthic infauna. Finally, it is noteworthy that macroalgal biomass is often extremely patchy, such that variability can reach 10-30% at biomass of ~70 g dw m^{-2}. It may be advisable to use benthic macroinvertebrate data as a bioconfirmation target, such that if macroalgal numeric target is not met but benthic habitat quality is low impact or reference, then the numeric target could be considered to be attained.

2.7.4 Estimated Ranges of Allowable Loads

- As captured by the WASP model, very little difference existed between wet and dry weather reductions of nutrient loads versus dry weather load reductions that met the range of DO and macroalgal targets during an open tidal inlet condition, but a much bigger difference was observed for TN and TP biostimulatory objectives. The implication of this finding is that wet weather structural BMPs, which generally cost an order of magnitude or higher to implement, may not provide any additional environmental benefits to the Estuary than implementation of dry weather BMPs alone. However, this finding ignores the importance of wet weather recharge of the upstream groundwater aquifer; therefore wet weather nutrient loading cannot be ignored.
- Among candidate numeric targets, a TP target of 0.1 mg/L drives the most stringent load reductions, with ~94 % reduction of 2008 loads required. Conversely, the biostimulatory TN target of 1.0 mg/L

required ~54% load reduction, while meeting a DO target of 5 mg/L greater than 90% of the time would require ~70% reduction. The load reduction required to meet TP is driven by the concentration of TP in groundwater discharge from the upstream aquifer, for which no data are available.

- The WASP model predicts that, at a whole estuary scale and during an open tidal inlet condition, a macroalgal biomass of 70 ± 3 g dw m^{-2} would meet 5 mg L^{-1} 90% of the time. At a biomass target of 50 g dw m^{-2}, the WASP model predicts 91 ± 4% reduction of dry weather loads would be required; at a biomass target of 90 g dw m^{-2}, the required reduction of dry weather loads would be in the range of 52 ± 4%.
- Meeting a DO numeric target of 5 mg/L 90% of the time or greater would require a 73.3 ± 3.6 % reduction in dry weather loads.

2.7.5 Recommendations

Science Recommendations

Existing uncertainty in the estuary hydrodynamic and water quality model can be further contrained by:

- Improvement in the resolution of the model grid to better capture effects of light availability on macroalgal growth
- Inclusion of benthic microalgae as a primary producer in the WASP model to better capture magnitude and direction of winter and springtime nutrient fluxes and sediment oxygen demand
- Comparison of macroalgal and cover biomass in the subtidal versus in the intertidal habitat of the estuary
- Field data collection of concentratons of nitrogen and phosphorus in the upstream aquifer and calibration of the CP MODFLOW model to better estimate loads to the SMRE
- Synpotic collection of monitoring data to represent inputs (local groundwater, upstream aquifer, ocean boundary, surface water temperature, dissolved oxygen, salnlity, nitrogen and phosphorus forms), major state variables (benthic macro- and microalgae, dissolved oxygen), benthic flux and sediment oxygen demand) for further model validation

Management Recommendations

- Nutrient management actions taken should consider taking into account the variability inherent in SMRE tidal inlet dynamics and the uncertainty of estimates of loads by pathway, particularly with respect to groundwater, in establishing allowable loads. Nutrient management strategies that are flexible and that encourage adaptive management practices in the face of such uncertainty are critical, particularly in the face of climate change. Examples of this flexibility include, but are not limited to:
    - The load reductions required will vary entirely on the estuary tidal inlet status and the balance of freshwater flow and oceanic exchange. Estuary tidal inlet management is a tremendous management tool that can be used to improve water quality within SMRE, but that also has major ramifications for the support for threatened and endangered species. Exploration of inlet management scenarios vis-à-vis habitat support for SMRE resident fauna

should be allowed, with the flexibility to alter the allowable loads to SMRE pending conclusions of such analysis.

  - Adding flexibility to adaptively manage to targeted biological response endpoints (e.g., DO and macroalgae) should be considered, pending new watershed data collection, ongoing estuary model refinement, CP MODFLOW model and watershed loading model improvement that will occur in Phase II of Prop 84 funding, focused on the lower River. Collectively, this work will improve understanding of how to approach nutrient management in the estuary.

- The use of TN and TP numeric translator as the basis for interpretation of the biostimulatory numeric targets should be removed from consideration, given the general conceptual issues with this guidance, as well as specific issues with tremendous uncertainty in TP concentrations in aquifer and local ag-dominated groundwater discharge.

- Given the lack of clarity of the point of adverse effects of macroalgae in the range of 30-90 g dw m^{-2} and the interpretation of DO objective in estuaries that are intermittently open to tidal exchange, benthic macroinvertebrate community health in a bioconfirmation approach should be used to determine attainment with the numeric target.

3. USE OF WATERSHED LOADING MODEL TO ESTIMATE LOADS AND SOURCES OF NUTRIENTS FROM SANTA MARGARITA RIVER WATERSHED

3.1 Introduction

This section documents estimates of nutrient sources and amounts of nutrient loads delivered to the Santa Margarita Estuary based on the existing Hydrologic Simulation Program-FORTRAN (HSPF) model (Bicknell et al. 2005) of the watershed. The Santa Margarita River watershed HSPF model was developed by Tetra Tech in 2013 (hydrology) and updated in 2014 (water quality calibration) based on available gaging and monitoring data for the watershed.

A primary purpose of the watershed model application is to estimate the origin of nutrient loads from source areas in the watershed and their delivery to the Santa Margarita Estuary under a variety of flow conditions. The HSPF model thus links conditions and activities throughout the watershed to inputs to the Estuary model, which in turn estimates responses within the Santa Margarita Estuary.

The HSPF model provides a representation of flow, sediment, and nutrient concentrations in the Santa Margarita watershed and simulates loading and transport from the river to the Estuary. Output from the HSPF model is used to estimate Total Nitrogen (TN) and Total Phosphorous (TP) loadings for various land uses and jurisdictional areas of interest. Covering 750 square miles within Riverside and San Diego Counties, CA, the watershed also includes the incorporated municipalities of Wildomar, Murrieta, and Temecula, as well as U.S. Marine Corps Camp Pendleton along with other federal and state lands.

HSPF is a comprehensive, EPA-supported and widely applied watershed modeling package that can simulate water quantity and quality for a wide range of pollutants. HSPF was selected for this study because of its capability to assess the impact of point and nonpoint sources in a large watershed with varying land cover and management conditions. The HSPF model has been applied throughout the U.S. and has a long history of application for nutrient management, Total Maximum Daily Load, and water supply protection studies.

HSPF divides the larger watershed into smaller sub-basins, each of which is conceptualized as a group of various land uses routed to a representative stream reach. The sub-basins are linked together by the stream reach network to represent the larger watershed drainage. A variety of instream modules describe flow, sediment transport, and water quality kinetics for nutrients, dissolved oxygen, algae, and other components, including exchanges with the sediment bed and kinetic transformations simulated at an hourly time step.

Upland land processes are simulated on a unit area basis and multiplied by area to provide input to the stream reach simulation, with separate modules for pervious and directly connected impervious areas. These include routines to dynamically simulate the water budget, sediment erosion and transport, and water quality constituents. Hydrology is modeled as a water balance in multiple surface and soil layer storage compartments. Interception, infiltration, evapotranspiration, interflow, groundwater loss, and overland flow processes are considered. Sediment production is based on detachment and/or scour from a soil matrix and transport by overland flow in pervious areas, whereas solids buildup and washoff is simulated for impervious areas. Nutrient loads from the land surface are represented either by buildup/washoff processes or as a function of sediment transport, while the pervious land simulation also incorporates transport via interflow and shallow groundwater.

The HSPF model of the Santa Margarita watershed contains 78 sub-basins and associated model stream reaches, which are shown in Figure 3.1. Each sub-basin and its main stream reach are referred to by the same number. The model is currently developed for the period of January 1, 1990-December 31, 2010, using an hourly time step. Extension of the model simulation past 2010 is feasible and desirable, but development of extended meteorological and water management time series past 2010 has not yet been authorized.

Calibration for water quality in the HSPF model is documented in Tetra Tech (2014) and focused on the portion of the watershed downstream of the three major reservoirs (Figure 3.1), which effectively cut off most nutrient transport from upstream areas. Diamond Valley Lake (completed in 1999) and Lake Skinner contain primarily imported Colorado River project water, while Vail Lake contains water derived from the Santa Margarita watershed, but has mostly highly regulated outflows to groundwater recharge basins controlled by water rights obligations. Similarly, Lake O'Neill, on Camp Pendleton, intercepts flow from Fallbrook Creek (sub-basins 177 and 178) and controls the contribution of these areas to the Estuary. While the total flow volume from Fallbrook Creek is released downstream, Lake O'Neill mixes Fallbrook Creek water with water diverted from the Santa Margarita, and nutrient transformations occur within the lake; thus, the water quality of outflow from the lake is not directly tied to upstream loads from Fallbrook Creek. For all four lakes, water quality in the releases that do occur is based on observed in-lake water quality and not on the upstream simulation; thus, nutrient loads from upstream parts of the watershed are not simulated in this application.

The overall watershed model does not provide estimates of direct loading from agricultural fields adjacent to the Santa Margarita Estuary. Those loads, however, have already been analyzed as part of the estuary modeling project and are incorporated into the load tabulations presented below.

A watershed model is a tool to aid understanding of processes and consequences of human activities in a river basin, but is only one among a variety of tools. In particular, watershed models are not substitutes for the direct monitoring of physical and biological conditions. When properly calibrated to represent observations, a watershed model can, however, provide a reasonable mechanism for the extrapolation of monitoring data in space (to unmonitored locations) and in time (to unmonitored or future time periods). The watershed model also enables experiments to investigate how changes (such as changes in land use, management practices, or climate) may affect conditions in the watershed and allow stakeholders to plan accordingly.

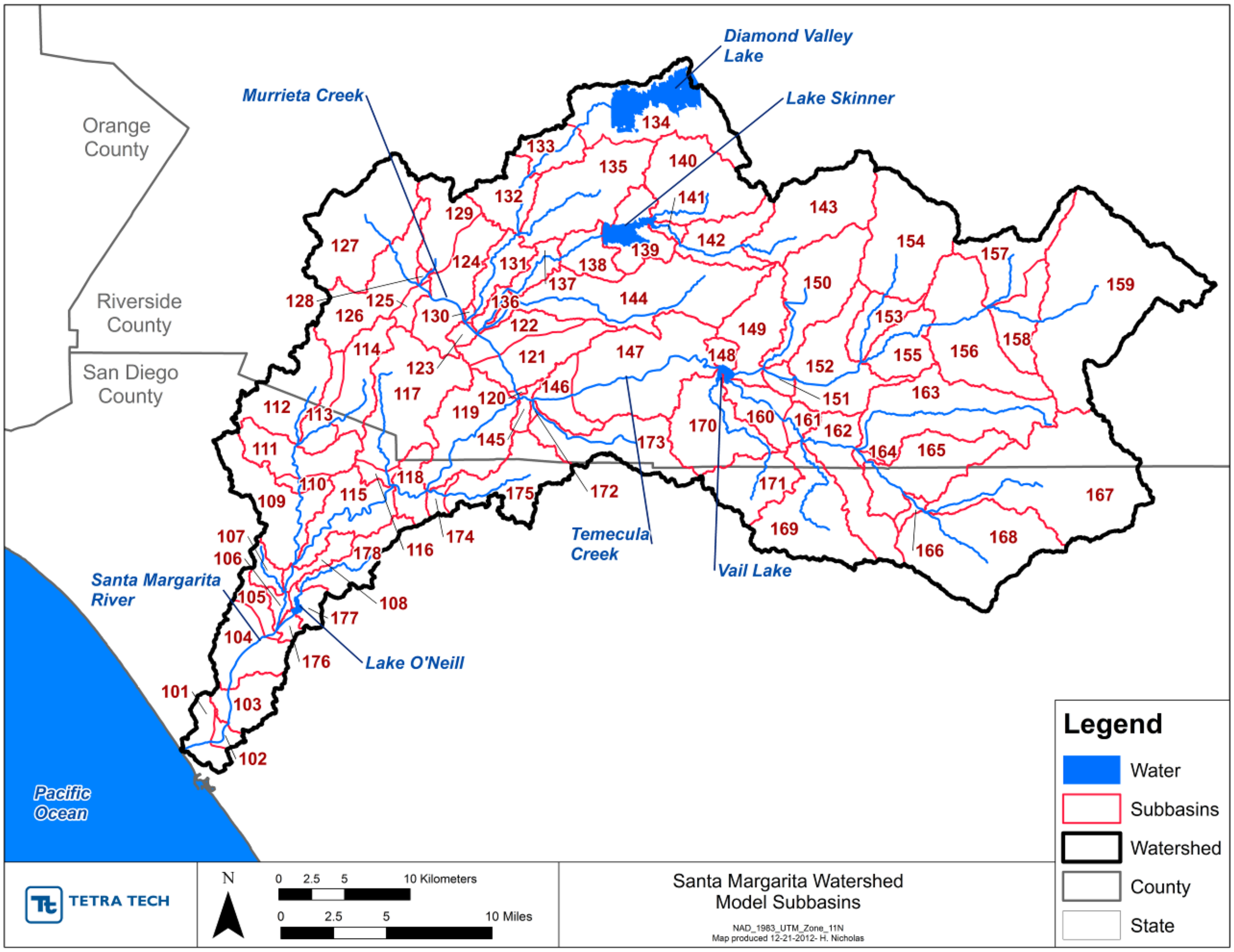


Figure 3.1. Santa Margarita HSPF Model Sub-basins

3.2 Model Enhancements

The existing watershed model provides a credible representation of flow, sediment, and nutrient transport in the Santa Margarita River, as documented by Tetra Tech (2013, 2014). The model is also known to contain considerable uncertainty (see Section 3.6), and model performance could likely be improved through additional research and analysis. One area of particular importance for estimating nutrient delivery to the Estuary is the representation of water management on Camp Pendleton. Camp Pendleton exercises water rights to divert flow from the Santa Margarita River, much of which is infiltrated into the Lower Santa Margarita alluvial aquifer for storage and subsequently pumped to meet water supply needs on the base. The existing HSPF model incorporates records of diversions and releases on Camp Pendleton, but incorporates only limited information on exchanges between surface and ground water in this region. For the current analysis, Tetra Tech was authorized to update the existing model in light of results from a groundwater model of the Lower Santa Margarita alluvial aquifer developed for Camp Pendleton by Stetson Engineers and documented as part of the Camp Pendleton Salt and Nutrient Management Plan ("SNMP"; Brown and Caldwell 2012). This model is hereto referred to as the “CP MODFLOW” model. The integration of the groundwater model results is described in Section 3.2.1 and results in significant refinements to the model simulation of nutrient load delivery to the Estuary.

It should be noted that there are also significant surface and groundwater interactions with the Pauba and Temecula aquifers in the vicinity of Murrieta Creek. While groundwater modeling has also been undertaken in this area, at the time of this report, output from a groundwater model of these aquifers has not been made available. As a result, exchanges with the aquifers in this area are represented only approximately in the model, as previously documented by Tetra Tech (2013). Other potentially important refinements to the model, most notably the development of improved precipitation time series that better account for orographic and rain shadow effects, have also not been authorized at this time. Despite these caveats, the existing model is believed to provide a reasonable and credible representation of the relative contribution of different source areas to the nutrient loads that reach the Santa Margarita Estuary.

The hydrology of the watershed, including the diversions, releases, and interaction with alluvial aquifers, is a key factor in determining the importance of different load sources. A comprehensive summary of the water balance as currently represented in the model is provided in Section 3.2.2.

3.2.1 Integration with MODFLOW Groundwater Model Results

The hydrogeology of the Santa Margarita River basin near Marine Corps Camp Pendleton is complex and has significant consequences for the transport of water, sediment, and nutrients from the upper river to the Estuary. Water from the river is diverted to groundwater recharge ponds, as well as to Lake O’Neill on Camp Pendleton. The recharge ponds are designed to supply water to the alluvial groundwater basin, which is pumped for water supply and irrigation. Streambed recharge contributes water to the groundwater aquifer, and the groundwater aquifer recharges the river as baseflow, depending on the height of the seasonal water table relative to the river surface.

The major components of the water balance in the Lower Santa Margarita River Basin are summarized in Figure 3.2 (from Brown and Caldwell 2012). Appendix E in the Salt and Nutrient Management Plan (Brown and Caldwell 2012) provides a detailed summary of the water budget for water years (WY) 2008-2009. During this period, the upstream inflow in the Santa Margarita River amounted to 32,800 AF/yr. Of this inflow, 7,330 AF/yr was diverted to recharge ponds on Camp Pendleton and 2,260 AF/yr was diverted to Lake O’Neill, together constituting 29% of the river flow in WY 2008-2009; however, releases from Lake O’Neill returned 2,160 AF/yr to the river (including all upstream flow from Fallbrook Creek; 570 AF/yr on average). Groundwater pumping from the Lower Santa Margarita River groundwater basin amounted to 6,640 AF/yr. There are multiple other fluxes, such as evapotranspiration, channel underflow, and local tributary discharges. The balance between these fluxes has a strong seasonal component, with most diversions occurring during the winter wet period and the highest pumping demand during the summer. Describing these complex interactions is best accomplished through use of a groundwater model.

Camp Pendleton MODFLOW Model

Stetson Engineers extended Camp Pendleton’s existing water supply MODFLOW model of the alluvial aquifer on for the Salt and Nutrient Management Plan (SNMP), as documented in Brown and Caldwell (2012). The alluvial aquifer in the vicinity of Camp Pendleton consists of three sub-basins (Upper

Ysidora, Chappo, and Lower Ysidora; see Figure 3.3), which correspond closely (although not exactly) to HSPF river reaches 106 (Upper Ysidora from above Camp Pendleton diversion to Fallbrook Creek), 105 (Upper Ysidora from Fallbrook Creek to Ysidora Gage), 104 (Chappo), and 103 (Lower Ysidora). The three groundwater sub-basins are separated by narrows with shallow bedrock that can cause subsurface water to resurface.

The CP MODFLOW model was calibrated to groundwater conditions on Camp Pendleton for water years 2008 and 2009 and was subsequently extended (although not calibrated) through water year 2010 to support Santa Margarita River estuary model development (Stetson 2015). The MODFLOW application successfully represents the water balance on Camp Pendleton and in the adjacent segments of the river.

An important part of the MODFLOW model is simulation of exchanges between the aquifer and surface water cells. The MODFLOW model operates at a monthly time interval (referred to as a “stress period”) and, for each month, estimates streambed recharge and streambed discharge, which is sufficient for developing an aquifer water budget, but does not provide a detailed prediction of streamflow or exchanges between the river and aquifer at the hourly time step required by the watershed model.

In addition to the results of the model calibration run provided in Brown and Caldwell (2012), Stetson (2015, 2016) Engineers provided via Camp Pendleton a monthly time series of external forcing streamflow exchange rate results, and simulated monthly flows in the Santa Margarita River from the MODFLOW model.

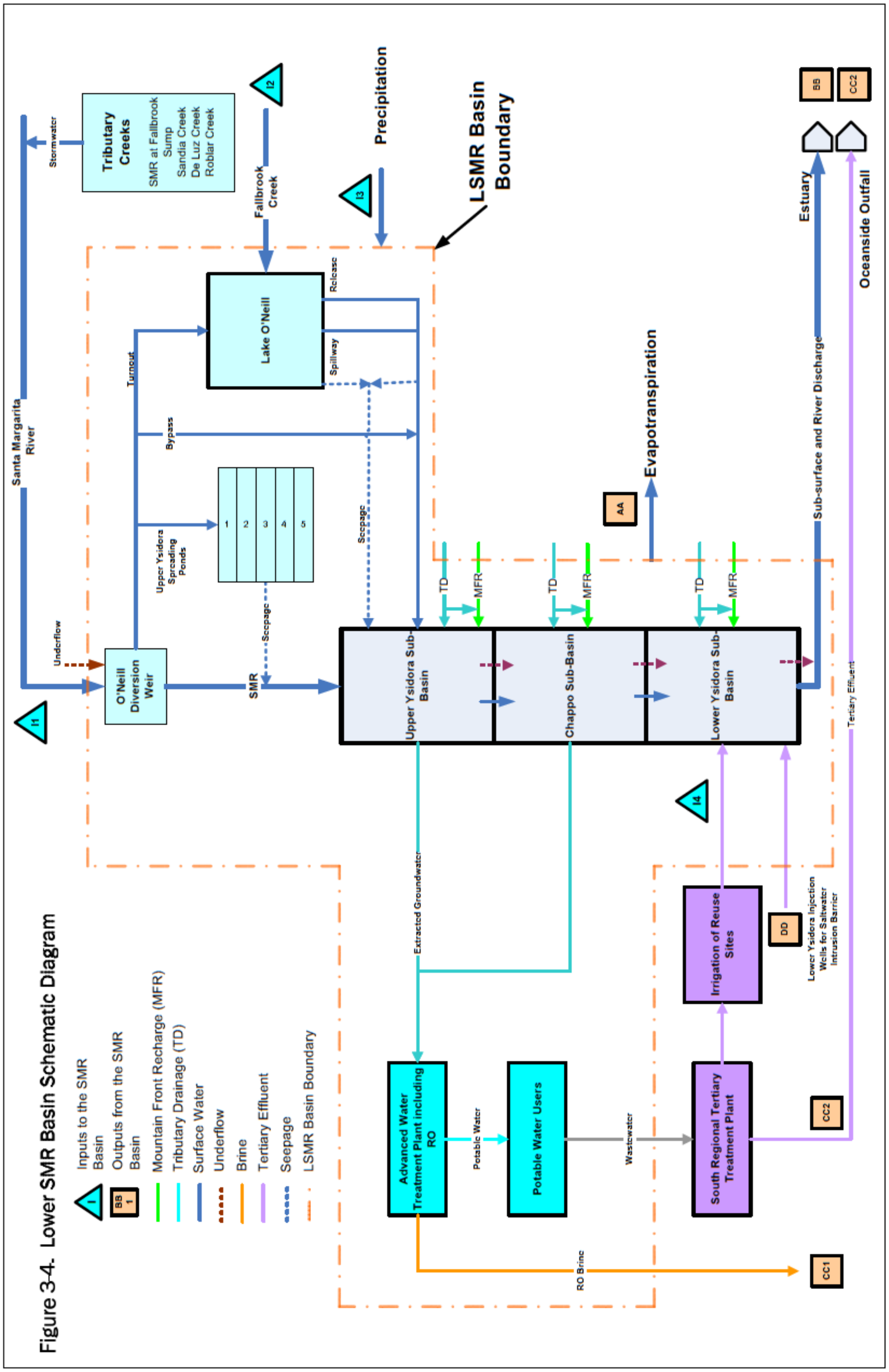


Figure 3.2. Water Balance Components of the Lower SMR Basin (from Brown and Caldwell 2012)

Note: Input from Tributary Creeks should be indicated as containing both surface and subsurface flows.

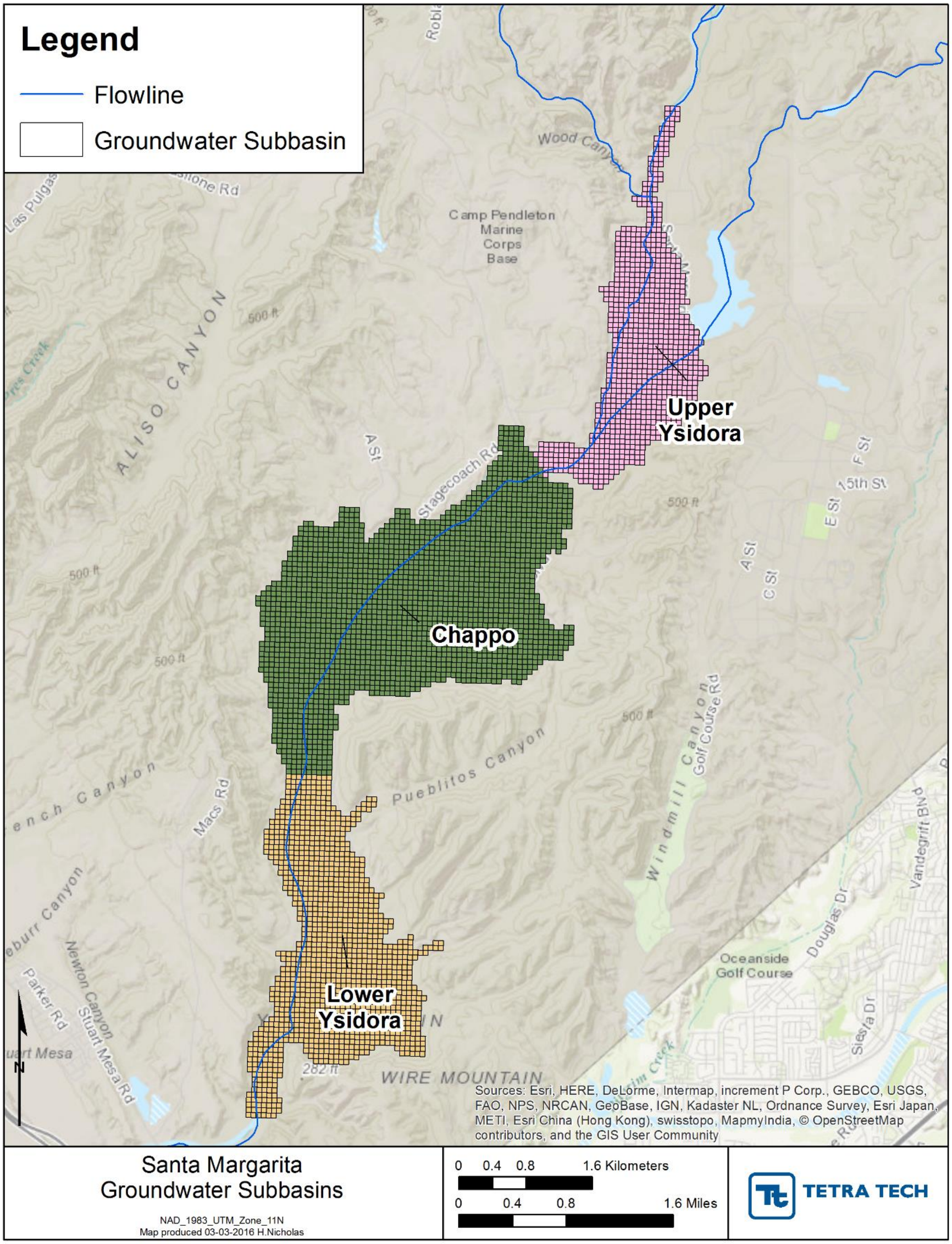


Figure 3.3. Lower Santa Margarita Groundwater Sub-basins in the MODFLOW Model

Integration with the HSPF Model

The MODFLOW model successfully achieves its intended purpose of evaluating the surface and subsurface water balance in the area of Camp Pendleton. The MODFLOW application was not intended for direct integration with a surface flow model like HSPF that operates at a sub-daily time step. Nonetheless, the MODFLOW application provides important information that can help constrain the HSPF watershed model representation of channel processes and exchanges in the vicinity of Camp Pendleton. Integration of the two models is not, however, straightforward or easy for a number of reasons:

1. The HSPF model operates on an hourly time step, whereas the MODFLOW model represents a mass balance on a monthly time step.
2. The MODFLOW model uses gaged flow as a model input, including flows at the Santa Margarita River at FPUD sump (USGS 11044300) and De Luz Creek (11044800), plus an estimated incremental gain or loss between those two gages and the MODFLOW model boundary. In contrast, the HSPF model simulates flows upstream of the MODFLOW domain based on precipitation inputs and runoff calibration at the USGS gage locations in the watershed. As a result, the gaged flows are not a direct input to HSPF, and the HSPF model simulation approximates, but does not fully match, the observed flows at FPUD sump and De Luz Creek.
3. There is overlap in mass balance accounting between the two models, as HSPF simulates a local shallow groundwater cycle driven by percolation from the overlying soil, but does not simulate the water balance of the regional aquifer. The MODFLOW model was developed as a water supply model and simulates water leaving the aquifer (below the groundwater table) due to evapotranspiration from phreatophytes. It does not simulate the moisture in the soil zone or water use from non-phreatophyte vegetation. Because of the overlap in the accounting of shallow ground water, it is not appropriate to directly link fluxes from one model to the other, but rather to ensure that they are approximately consistent.
4. MODFLOW output for stream exchanges covers both the main stem of the Santa Margarita and numerous ephemeral tributaries. “The streambed recharge and streambed discharge used for the SNMP groundwater aquifer budget are based on the stream leakance term from the MODFLOW volumetric budget terms. Stream leakance represents the exchange of water between the main stem and tributary stream cells and the groundwater table” (Stetson 2016). This is not the same as additions to or losses from surface flow, as a portion of the “streambed” discharge simulated by MODFLOW goes to evapotranspiration from the riparian zones of the Santa Margarita River and tributaries without becoming surface flow. The MODFLOW “streambed discharge” term should thus not be interpreted as being equivalent to a direct inflow to the river.
5. The MODFLOW calibration is focused on the aquifer water and dissolved solids mass balance. It is calibrated to surface flows in the sense that the model attempts to reproduce monthly streamflow observed at the USGS gage for the Santa Margarita River at Ysidora (11046000, corresponding to the outflow from the Upper Ysidora groundwater sub-basin), based on gaged upstream flows in the Santa Margarita River at FPUD sump (11045300) and measured diversions to the Camp Pendleton recharge ponds and Lake O’Neill. Surface flows leaving the Chappo and Lower Ysidora sub-basins are not gaged and thus are not truly calibrated. As noted by Stetson (2016): “The difference in simulated streamflow at different points along the river is not equal to the net stream leakance term calculated by MODFLOW. Other factors such as evapotranspiration, rainfall, mountain front recharge, pumping, and changes of groundwater in storage affect the simulated flow.”

Based on discussions with Jean Moran of Stetson Engineers (personal communication, February 3, 2016), the Santa Margarita River streambed discharge and recharge terms cannot be directly exported from the MODFLOW volumetric budget of the aquifer. The bulk budget term can be misleading because of the multiple network of stream segments representing ditches and side tributary flow. The recommendation from Stetson was that it would be better to work starting with the simulated streamflow at the exit of each of the three groundwater sub-basins as a measure of the net changes in surface flow across each sub-basin.

The surface flow inputs to the MODFLOW model at the upstream end are calculated as the sum of flows at the FPUD sump (11044300) and De Luz Creek (11044800), plus an estimated incremental gain or loss between those two gages and the MODFLOW model boundary. Diversions from the river to the recharge ponds are simulated in a reservoir operations model (ROM), and monthly diversions and recharge are incorporated on a monthly basis into the MODFLOW model as inputs. This direct forcing means that the MODFLOW model should provide a very close match to wet weather flows at the Ysidora gage. However, it is important to note that the MODFLOW model is not a perfect predictor of the surface water balance at the Ysidora gage, and indeed tends to over-estimate dry weather flows while closely matching peak flows (due to assimilation of the upstream gage data; Figure 3.4).

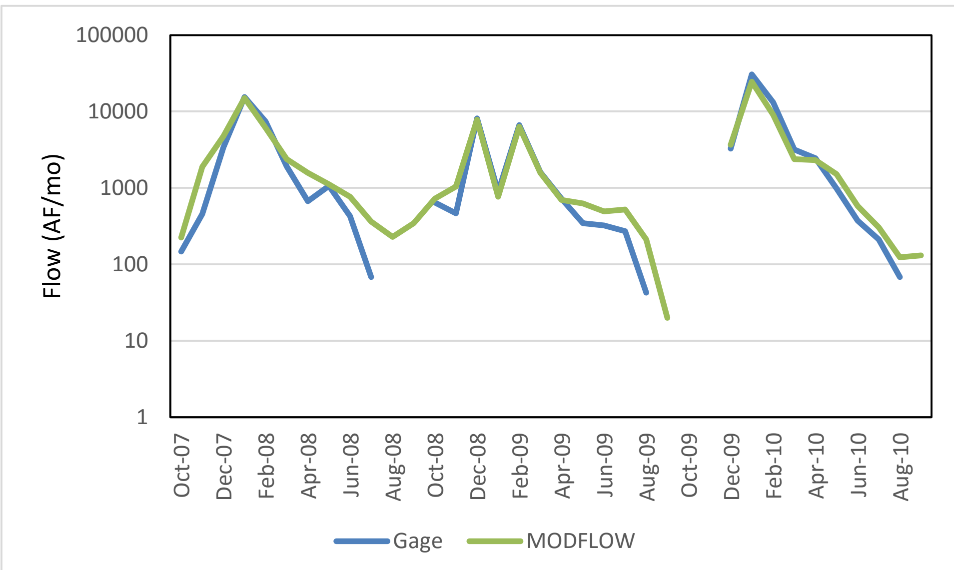


Figure 3.4. Comparison of MODFLOW and Gaged Flow Volumes, Santa Margarita River at Ysidora

As the HSPF model reaches correspond approximately to the MODFLOW groundwater sub-basins in this area, the final approach adopted was to calculate the net residual surface flow balance (in MODFLOW) for each sub-basin as the outflow at the downstream point minus the net sum of inflows, which quantifies the net monthly exchanges with groundwater (as predicted by the MODFLOW application). The calculation is adjusted to use the HSPF simulation of local inflows and reach evaporation and provides the basis for estimating the hourly average exchanges needed for the HSPF model. A schematic illustration of the process is shown in Figure 3.5.

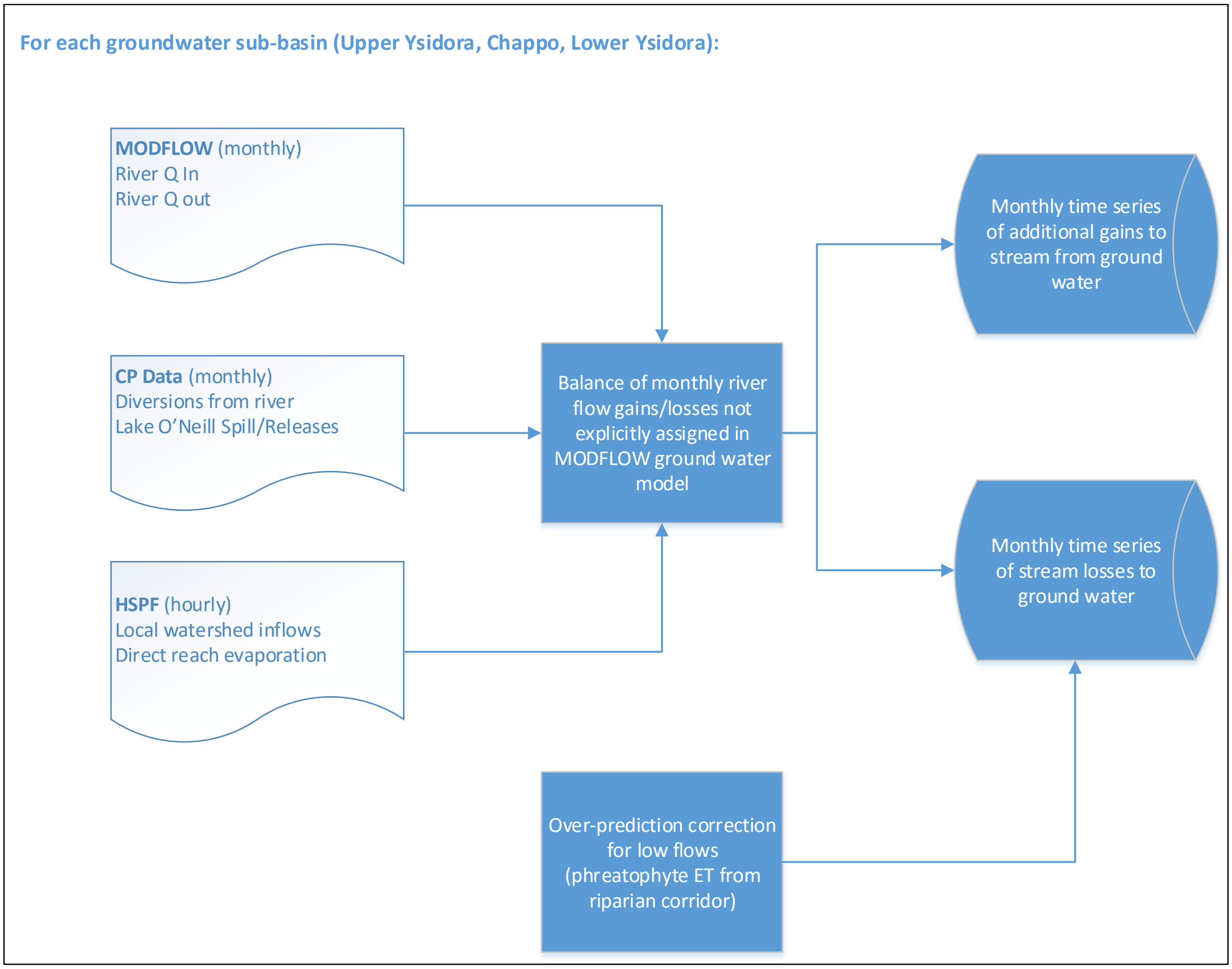


Figure 3.5. Schematic for Reconciliation of MODFLOW and HSPF Simulations

For the Upper Ysidora groundwater sub-basin downstream of the Camp Pendleton diversions, corresponding to HSPF reach 105 (see Figure 3.1 above), this residual balance is given by: (MODFLOW simulated flow at Ysidora) – Sum {(gaged flow into model at FPUD sump) + (Lake O'Neill spill/release series) + (local inflow direct to this sub-basin simulated by HSPF) – (gaged diversion to recharge) – (HSPF simulated evaporation from reach)}. The residual balance is applied to HSPF reach 105, rather than 106 plus 105, because the HSPF model simulates the Camp Pendleton diversion within reach 106 (as a fully mixed segment) and the corrections must be applied after accounting for this diversion.

For the Chappo and Lower Ysidora sub-basins, corresponding to HSPF reaches 104 and 103, the balance is given by: (MODFLOW simulated surface outflow) – Sum {(MODFLOW simulated inflow from upstream) + (local inflow simulated by HSPF) – (HSPF simulated evaporation from reach)}.

If the resulting monthly term is negative, indicating a loss to ground water, this term is assigned as a demand-based outflow on the HSPF reach that goes to ground water rather than being transmitted downstream. If the resulting monthly term is positive, indicating a gain from groundwater, this term is assigned as an external inflow to the surface water model. In both cases, the monthly result is assumed to be evenly distributed over that month for the hourly HSPF model to create hourly inflow or reach loss time series. These two time series will replace the estimate of a constant net channel loss rate applicable to July through November that was incorporated into the previous version of the model. Note that the use of monthly averages for channel losses in HSPF may introduce some inaccuracies into the simulation of the surface flow hydrograph on a sub-monthly scale (i.e., the daily or hourly hydrograph), especially for a runoff event that occurs after an extended period of dry conditions; however, the monthly average estimates of fluxes between the surface water model and groundwater are the best information that is currently available.

The initial application to the 2008-2009 MODFLOW calibration period showed that the HSPF model (like the MODFLOW model) tended to over-predict dry weather flows in the river. The over-prediction suggests that somewhat more water from the river is likely being taken up and diverted to evapotranspiration by phreatophytes. Assigning additional losses from the river of 4 cfs for January-September in the Upper Ysidora sub-basin brought predictions at the Ysidora gage into much closer agreement. This value was pro-rated to the Chappo and Lower Ysidora sub-basins using the ratio of MODFLOW annual evapotranspiration for these basins shown in Appendix E of Brown and Caldwell (2012).

The HSPF model with these exchanges included provides a good fit to the observed volumetric flows at the Ysidora gage (Figure 3.6). Note that there are still discrepancies present at high flows. This is due to the uncertainty in the current model's simulation of wet weather events, as the HSPF model, unlike the MODFLOW application, is not fixed to the gaged flow at FPUD sump, but instead generates the upstream flow from simulation of the entire watershed.

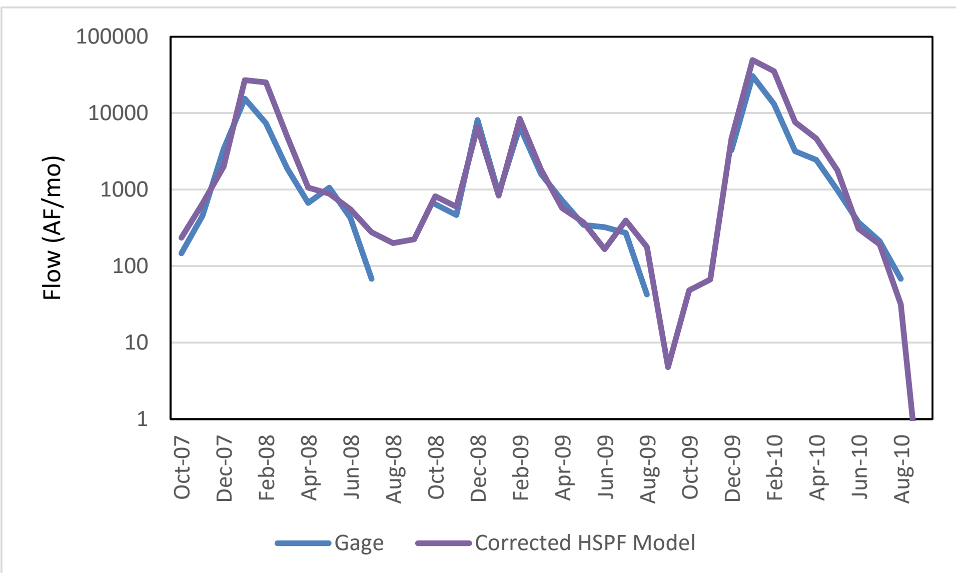


Figure 3.6. Comparison of Corrected HSPF and Gaged Flow Volumes, Santa Margarita River at Ysidora

Extension beyond MODFLOW Calibration Period

The MODFLOW model is only developed for water years 2008-2010 (and only calibrated for water years 2008-2009, which are above normal hydrologic years). In contrast, the HSPF model is run for scenario applications for calendar years 2000-2010.

Lacking a groundwater model application for other years is liable to decrease the accuracy of simulation, but does not make it impossible. To accomplish this, we first developed surrogate models that predict the MODFLOW results (specifically, the residual surface flow balances for each sub-basin) from other variables that are available for the entire period.

For the Upper Ysidora basin, the residual surface flow balance (ΔS) follows a seasonal sinusoidal pattern. It also implicitly depends on the recent water input, which can be linked to the lagged flow volume at FPUD sump.

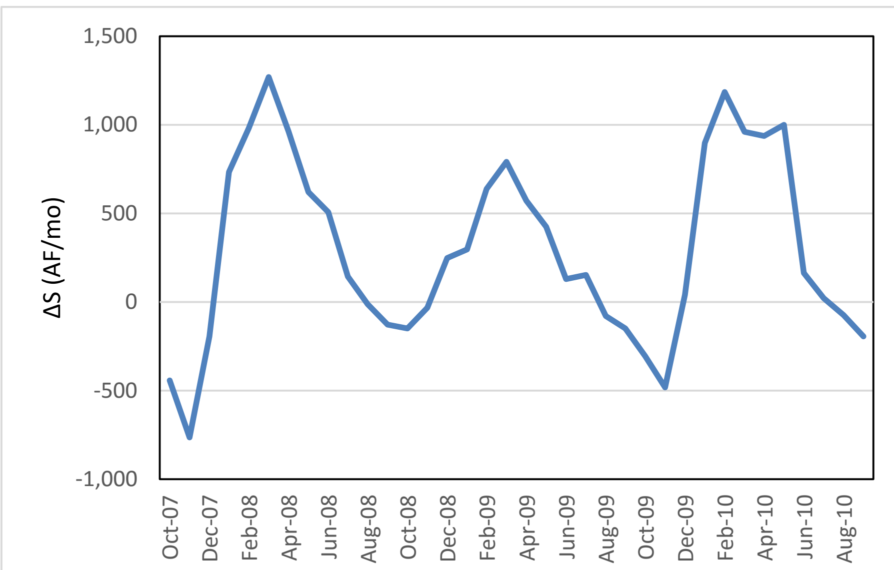


Figure 3.7. Residual Surface Flow Balance Pattern, Upper Ysidora

The following surrogate model was fit to describe the Stetson model results:

$$\Delta S_{i,t} = [\propto + \beta_1 \cdot FPUD_t + \beta_2 \cdot FPUD_{t-1}] \cdot M_i$$

Here $\Delta S_{i,t}$ is the residual in the surface flow balance (AF) in calendar month *i* and sequential month *t*, $FPUD_t$ and $FPUD_{t-1}$ are the current and one month lagged flow volumes at FPUD sump, and M_i is an adjustment applicable to month *i*. Parameters were fit by minimizing sum of squared differences, resulting in the following parameter set:

$\alpha = 1983$, $\beta_1 = 0.449$, $\beta_2 = 0.208$, and M = {0.090, 0.157, 0.290, 0.313, 0.268, 0.104, 0.037, -0.032, -0.079, -0.140, -0.167, 0.007}

This provides an excellent fit to the MODFLOW output, explaining over 90% of the observed variability in ΔS, as is shown in Figure 3.8.

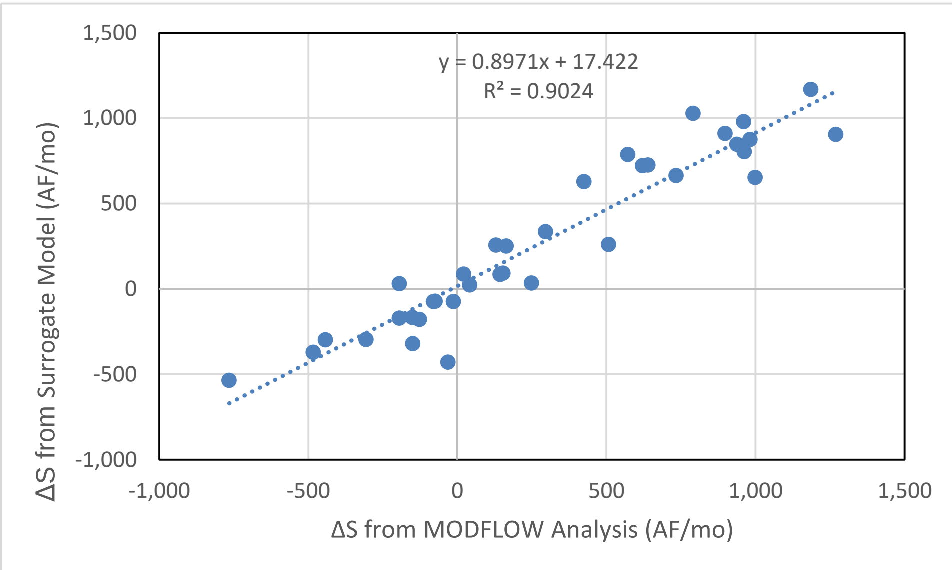


Figure 3.8. Surrogate Model for ΔS, Upper Ysidora Sub-Basin

Results for the Chappo and Lower Ysidora Basins are more difficult to fit with a surrogate model, but the exchanges are also of smaller magnitude than those in the Upper Ysidora Basin. Reasonable surrogate model results are obtained for both using a current and lagged regression on the simulated ΔS for Upper Ysidora (see Figure 3.9 and 3.10):

$$\Delta S_{i,t} = [\propto + \beta_1 \cdot YSD_t + \beta_2 \cdot YSD_{t-1}] \cdot M_i$$

Chappo: $\alpha = -53$, $\beta_1 = 0.0764$, $\beta_2 = -0.297$, and
M = {0.303, -0.082, 1.382, 1.297, 1.811, 2.551, 5.500, 4.053, 4.515, -6.987, -3.421, -0.544}.

Lower Ysidora: $\alpha = 820$, $\beta_1 = 1.743$, $\beta_2 = -0.287$, and
M = {0.019, 0.010, -0.004, -0.006, -0.033, -0.049, -0.026, 0, -0.001, -0.051, -0.061, -0.002}.

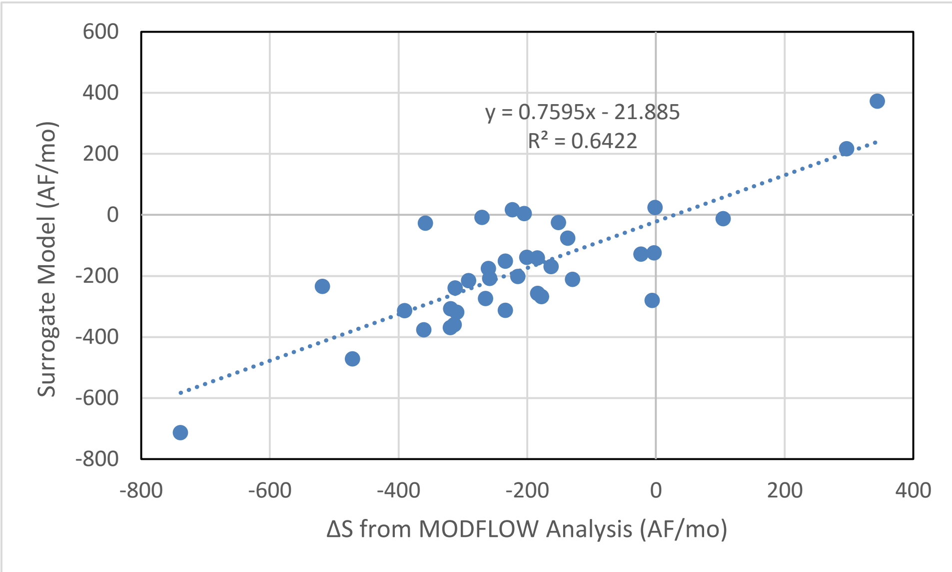


Figure 3.9. Surrogate Model for ΔS, Chappo Sub-Basin

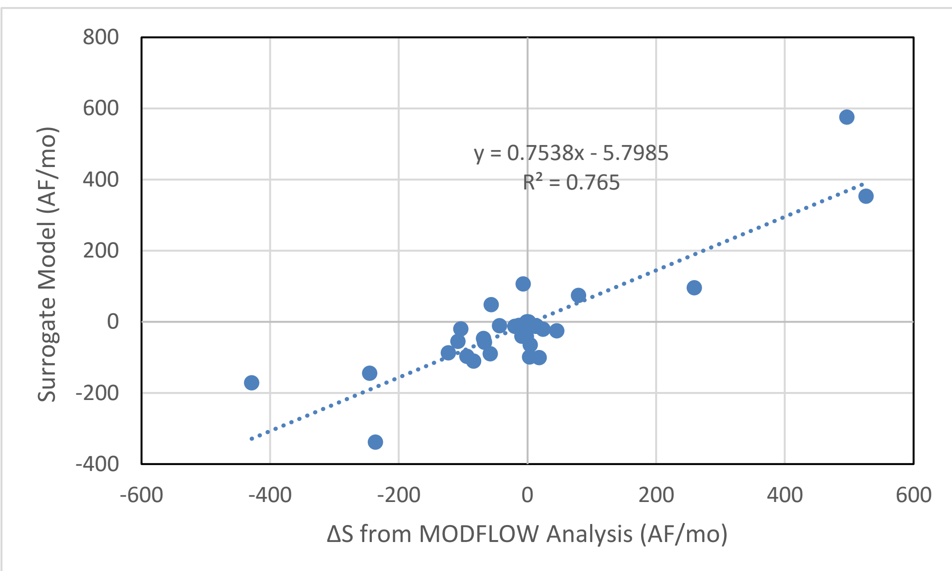


Figure 3.10. Surrogate Model for ΔS, Lower Ysidora Sub-Basin

The surrogate models depend only upon the month and gaged flows at FPUD Sump, which are complete for the period of interest. They can therefore be used to create reasonable time series for the whole 2000-2010 simulation period and continued through 2012 (Figure 3.11), although the results will of course be less certain than if a full groundwater model simulation were available for all those years.

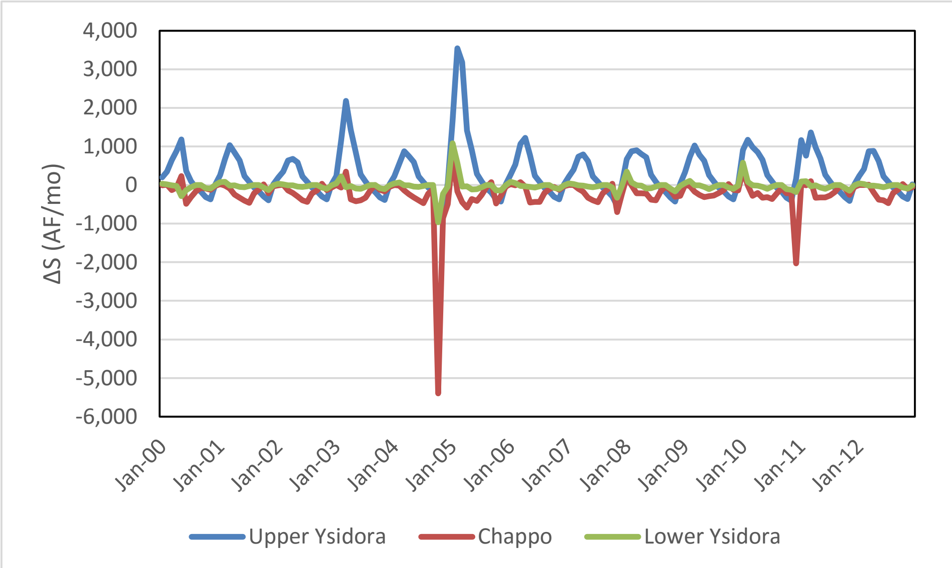


Figure 3.11. Surrogate Model Results, 2000-2012

For application in the HSPF model, the results from the direct analysis of MODFLOW are used for water years 2008-2010, combined with the surrogate model results for the remainder of the 2000-2010 simulation period, allowing exploration of a broader range of climate conditions[1]. As with the direct analysis of MODFLOW, the surrogate model results are split into additions to and subtractions from the simulated reach flow and small additional reach losses are added for January-September. Note that because the streambed losses are specified to the model as an outflow demand, any periods in which the projected losses exceed available flow will simply result in zero simulated flows in the model.

While the surrogate model provides a reasonable statistical approximation, results are more reliable for the period for which the actual MODFLOW model is available. The surrogate model analysis is based on MODFLOW results for water years 2008-2010, which are all "above normal" flow years. Extrapolation of the surrogate model to "below normal" conditions (e.g., water years 2004, 2007, and 2012) is subject to greater uncertainty.

Water Quality Associated with Groundwater Discharges

Nitrogen contained in water discharging from the aquifer to the river is considered to be predominantly in the form of nitrate in this coarse-grained, highly transmissive aquifer. Nitrate is addressed in the SNMP, and aquifer concentrations are monitored (Brown and Caldwell 2012, Table 3-12). These concentrations are applied to ground water discharging from the aquifer to the river and amount to 2.74 mg/L NO_3-N for the Upper Ysidora sub-basin, 0.2 mg/L for the Chappo sub-basin, and 0.14 mg/L for

[1] As noted by Stetson, on average, the period from 2000-2012 was wetter than the historical average for the Santa Margarita River and does not include any "very dry" years or extended dry periods. Therefore, results presented for this period will be skewed somewhat toward representing wetter-than-average conditions.

the Lower Ysidora groundwater sub-basin. In contrast, phosphorus data are not available for the aquifer. A concentration of 0.1 mg/L is assumed, as this is consistent with observed concentrations in the river during summer baseflow conditions. Sensitivity to this assumption is investigated in Section 3.5.2.

3.2.2. Water Balance Analysis

The Santa Margarita watershed is characterized by a Mediterranean type of climate, with most precipitation occurring during the winter months. There is wide variability from year to year, with very high flows in some years punctuated by multi-year drought conditions. The water balance in individual years in large part determines the importance of different load sources. To understand system behavior, it is important to analyze a suite of years that represent a variety of hydrologic conditions. As noted above, the watershed model is currently developed through the end of calendar year 2010. Watershed conditions differed substantially from the present prior to 2000 due to differences in land use, closure of Diamond Valley Lake (1999), and the presence of multiple point source discharges. Therefore, the water balance is first presented for 2000-2010. Rancho California Water District had reclaimed wastewater discharges in the Murrieta area through 2002 and one of the Camp Pendleton wastewater treatment plants continued to discharge to the river into 2003. In January 2003, RCWD began releasing raw water from Lake Skinner near the confluence of Murrieta and Temecula Creeks to satisfy water rights claims under the Comprehensive Water Rights Management Agreement (CWRMA). Therefore, the water balance is also presented for calendar years 2003-2010 and 2004-2010. Finally, a water balance tabulation is also presented for WY 2008-2009, the period for which the Stetson MODFLOW model is calibrated for surface and groundwater exchanges on Camp Pendleton. Table 3.1 and Figure 3.12 provide a simplified representation of the annual water balance with various components integrated. Additional details are provided below.

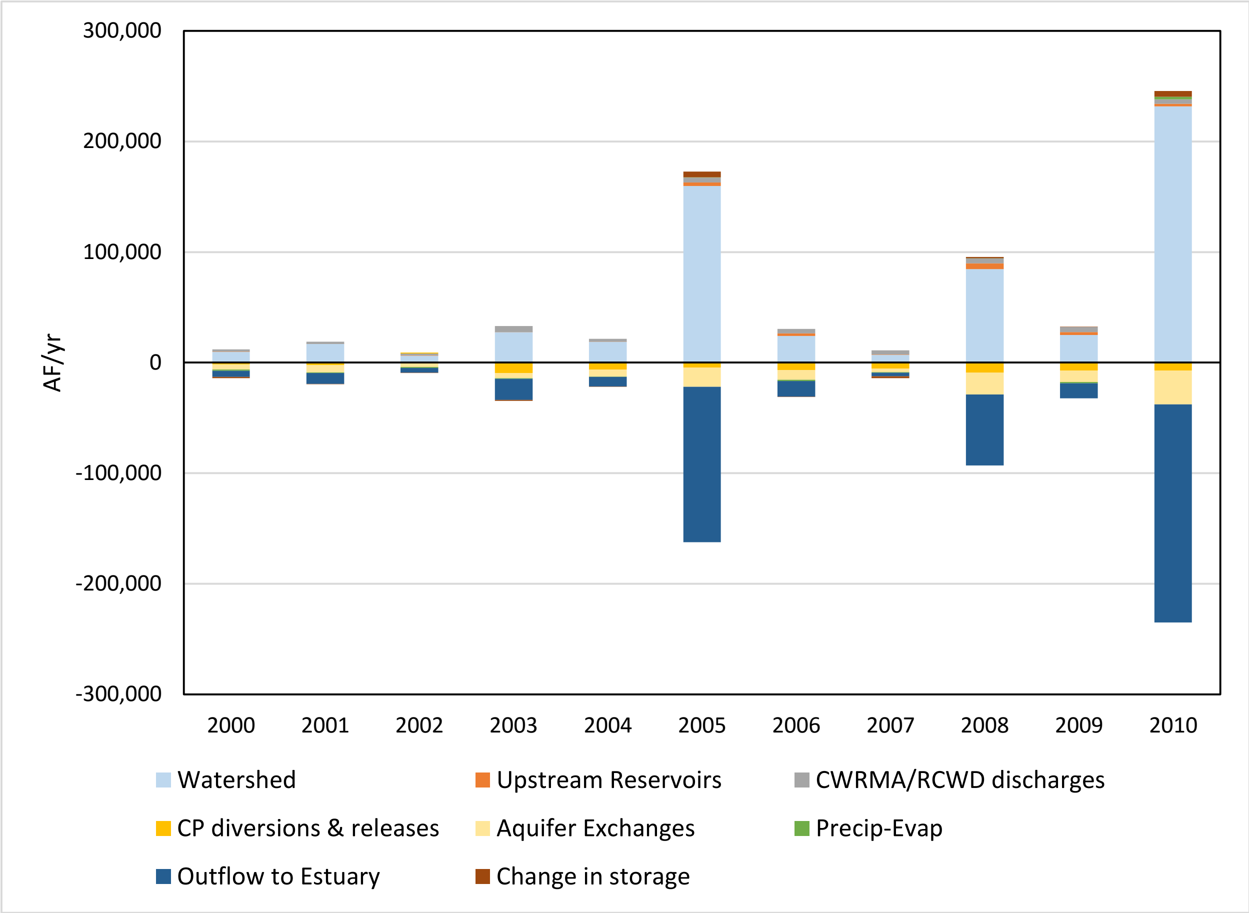


Figure 3.12. Graphical Representation of Annual Water Balance for the Santa Margarita River

Note: Positive terms indicate net additions to the river; negative terms are losses and outflow.

Table 3.1. Simplified Annual Water Balance Summary for the Santa Margarita Watershed, 2000-2010 (AF/yr)

Year	Watershed Runoff	Upstream Reservoirs	CWRMA/ RCWD	CP Diversions/ Releases	Aquifer Exchanges	Precip-Evap	Outflow to Estuary	Change in Storage
2000	9,524	515	1,994	-1,659	-4,608	-1,045	-5,682	-961
2001	16,746	93	2,068	-2,260	-6,476	-627	-9,943	-399
2002	6,263	114	1,731	900	-4,015	-821	-4,215	-43
2003	27,539	136	5,483	-9,355	-4,773	-673	-19,071	-714
2004	18,780	157	2,525	-6,311	-6,411	-242	-8,519	-21
2005	159,591	3,285	4,397	-4,396	-17,563	237	-140,380	5,170
2006	24,116	2,316	3,997	-6,881	-8,681	-1,212	-14,013	-358
2007	6,911	417	3,609	-5,279	-3,211	-786	-3,175	-1,514
2008	84,587	5,233	4,432	-9,238	-19,638	21	-64,228	1,169
2009	24,967	2,454	4,795	-7,189	-10,305	-1,073	-13,646	3
2010	231,723	2,343	3,974	-7,234	-30,481	2,298	-197,419	5,204
Total	*610,746*	*17,062*	*39,004*	*-58,901*	*-116,162*	*-3,923*	*-480,291*	*7,535*
Average	*55,522*	*1,551*	*3,546*	*-5,355*	*-10,560*	*-357*	*-43,663*	*685*

Notes: Watershed Runoff includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. Upstream Reservoirs includes releases and spills from Diamond Valley, Skinner, and Vail Lake, while Lake O'Neill is summarized with the Camp Pendleton releases. CWRMA/RCWD includes reclaimed water discharges from RCWD through 2002 and CWRMA releases from 2003 onward. CP Diversions/ Releases is the net of diversions onto Camp Pendleton and spills/releases from Lake O'Neill and also includes wastewater discharges through 2003. Aquifer Exchanges includes the exchanges with the Lower Santa Margarita aquifer estimated from MODFLOW and the approximate estimate of exchanges with the Pauba and Temecula aquifers. Precip-Evap is the net of direct precipitation to and evaporation from the stream network. Outflow to Estuary is the simulated flow out of reach 101 to the Santa Margarita Estuary. Change in Storage is the residual at January 1 of each year. As the simulation begins in a dry period and ends with a high flow in December 2010 the change in storage is positive across the simulation period.

Total outflow to the Estuary is not gaged, so a direct evaluation of model estimates of this component of the water balance is not possible. Comparisons can be made at the flow monitoring gage nearest the Santa Margarita Estuary, the Santa Margarita River at Ysidora (USGS 11046000). The percent difference in total flow volume between modeled and gaged flows for water years 2000-2010 at this site is 7.89%, indicating that this component of the water balance is well-represented.

From the preceding table and figure, it is evident that the long-term mass balance is dominated by runoff from the watershed and outflow to the Estuary; however, this is primarily due to the high flow conditions present in the wet years of 2005, 2008, and 2010. Further, within individual years, the water balance is dominated by winter wet weather, and the balance during summer dry weather is quite different. This shown in the detailed monthly water balances presented in Table 3.2 through Table 3.5.

Table 3.2. Detailed Monthly Average Water Balance for Santa Margarita Watershed, 2000-2010 (AF/mo)

Inputs												Outputs						Storage
Month	Watershed Impervious	Watershed Pervious	CWRMA/ RCWD	Reservoir releases	Lake O'Neill Release	CP WWTPs	Lower SMR Aquifer	Pauba/ Temecula	Direct Precip	Total In		Diversion to CP	Lower SMR Aquifer	Pauba/ Temecula Aquifer	Reach Evap	To Estuary	Total out	Change in Storage
1	2,400	13,425	341	224	89	71	817	215	336	17,918		892	788	1,938	104	13,744	17,466	451
2	3,002	12,605	241	222	163	75	1,070	196	404	17,979		1,183	841	2,724	134	12,454	17,337	642
3	593	4,457	325	240	211	76	1,248	215	67	7,432		1,271	1,036	1,591	205	3,772	7,874	-442
4	684	1,851	329	175	165	74	950	208	84	4,521		1,104	1,061	871	208	1,421	4,665	-144
5	88	829	327	29	26	72	762	215	10	2,357		668	1,054	360	193	274	2,549	-191
6	0	396	387	25	15	69	258	208	1	1,358		403	673	164	168	17	1,425	-67
7	108	257	362	110	18	71	87	215	8	1,236		231	544	193	188	96	1,252	-16
8	3	205	296	130	7	71	0	215	4	931		126	460	184	170	5	945	-14
9	49	157	280	54	14	61	7	208	7	836		79	488	113	137	17	833	3
10	722	307	267	127	133	51	6	215	87	1,914		208	604	326	116	558	1,813	102
11	625	291	220	152	55	50	0	208	57	1,658		382	434	378	81	238	1,511	146
12	2,732	9,736	171	64	174	50	57	215	365	13,564		665	279	1,255	82	11,067	13,348	216
Total	*11,007*	*44,516*	*3,546*	*1,551*	*1,069*	*789*	*5,262*	*2,536*	*1,429*	*71,705*		*7,213*	*8,262*	*10,096*	*1,786*	*43,663*	*71,020*	*685*

Table 3.3. Detailed Monthly Average Water Balance for Santa Margarita Watershed, 2003-2010 (AF/mo)

Inputs												Outputs						Storage
Month	Watershed Impervious	Watershed Pervious	CWRMA releases	Reservoir releases	Lake O'Neill Release	CP WWTPs	Lower SMR Aquifer	Pauba/ Temecula	Direct Precip	Total In		Diversion to CP	Lower SMR Aquifer	Pauba/ Temecula Aquifer	Reach Evap	To Estuary	Total out	Change in Storage
1	3,042	18,397	411	307	121	22	1,022	215	430	23,968		1,186	782	2,582	118	18,650	23,319	649
2	3,259	17,063	270	304	223	22	1,285	196	467	23,090		1,328	859	3,480	149	16,450	22,267	823
3	579	5,527	386	327	286	24	1,427	215	69	8,840		1,308	1,051	1,963	225	4,781	9,328	-488
4	754	2,301	386	239	221	25	1,005	208	96	5,234		1,249	1,074	1,056	221	1,758	5,358	-124
5	120	993	383	27	36	24	718	215	12	2,528		782	1,040	430	201	296	2,748	-220
6	0	465	467	20	20	21	252	208	1	1,456		498	659	187	170	14	1,528	-71
7	149	294	432	139	24	23	87	215	11	1,373		317	518	234	197	131	1,397	-24
8	4	234	339	172	10	24	0	215	4	1,003		173	436	229	179	6	1,023	-21
9	52	176	318	51	19	12	10	208	7	853		108	464	114	142	22	850	2
10	939	382	312	169	183	0	2	215	108	2,309		286	680	416	125	689	2,196	113
11	688	364	258	202	39	0	0	208	59	1,818		485	390	447	83	190	1,595	222
12	3,258	13,238	191	85	167	0	72	215	452	17,677		812	367	1,591	84	14,568	17,421	256
Total	*12,844*	*59,433*	*4,151*	*2,043*	*1,349*	*198*	*5,880*	*2,536*	*1,715*	*90,149*		*8,532*	*8,321*	*12,728*	*1,894*	*57,556*	*89,032*	*1,117*

Table 3.4. Detailed Monthly Average Water Balance for Santa Margarita Watershed, 2004-2010 (AF/mo)

Inputs											**Outputs**						**Storage**
Month	**Watershed Impervious**	**Watershed Pervious**	**CWRMA releases**	**Reservoir releases**	**Lake O'Neill Release**	**CP WWTPs**	**Lower SMR Aquifer**	**Pauba/ Temecula**	**Direct Precip**	**Total In**	**Diversion to CP**	**Lower SMR Aquifer**	**Pauba/ Temecula Aquifer**	**Reach Evap**	**To Estuary**	**Total out**	**Change in Storage**
1	3,477	20,957	374	346	139	0	1,128	215	490	27,126	1,202	797	2,923	120	21,301	26,344	782
2	3,127	18,977	261	347	198	0	1,272	196	457	24,835	1,321	861	3,777	153	17,870	23,982	853
3	385	5,252	371	371	264	0	1,270	215	44	8,173	1,300	1,069	1,966	218	4,243	8,795	-622
4	651	2,172	368	272	209	0	944	208	80	4,904	1,114	1,050	1,028	213	1,614	5,019	-115
5	128	939	357	31	41	0	701	215	12	2,424	645	1,009	415	202	324	2,594	-171
6	0	437	461	23	23	0	249	208	1	1,403	409	659	177	174	15	1,434	-31
7	170	284	422	159	28	0	86	215	11	1,376	253	524	249	200	149	1,375	0
8	0	227	318	191	11	0	0	215	3	966	116	441	240	180	6	983	-17
9	60	170	298	59	21	0	11	208	7	835	56	486	120	143	25	829	5
10	1,073	409	290	188	209	0	2	215	123	2,508	266	738	461	128	787	2,380	128
11	683	379	262	231	21	0	0	208	60	1,844	459	383	470	85	178	1,575	269
12	3,613	15,099	179	97	176	0	80	215	506	19,965	846	411	1,783	86	16,543	19,668	297
Total	*13,367*	*65,300*	*3,961*	*2,315*	*1,340*	*0*	*5,743*	*2,536*	*1,794*	*96,357*	*7,987*	*8,428*	*13,607*	*1,902*	*63,054*	*94,978*	*1,379*

Table 3.5. Detailed Monthly Average Water Balance for Santa Margarita Watershed, WY 2008-2009 (MODFLOW Calibration Period; AF/mo)

Inputs											Outputs						Storage
Month	Watershed Impervious	Watershed Pervious	CWRMA releases	Reservoir releases	Lake O'Neill Release	CP WWTPs	Lower SMR Aquifer	Pauba/ Temecula	Direct Precip	Total In	Diversion to CP	Lower SMR Aquifer	Pauba/ Temecula Aquifer	Reach Evap	To Estuary	Total out	Change in Storage
1	3,659	13,483	418	566	140	0	906	215	416	19,803	1,604	892	2,658	116	13,777	19,046	756
2	3,080	18,834	177	621	134	0	829	198	434	24,307	1,781	1,024	4,864	153	16,301	24,123	184
3	89	4,385	501	679	183	0	1,010	215	12	7,075	1,174	1,107	2,236	229	2,685	7,431	-357
4	0	998	476	684	27	0	760	208	2	3,155	970	979	991	182	138	3,262	-107
5	282	626	361	7	24	0	519	215	21	2,055	826	775	326	149	114	2,190	-135
6	0	436	621	7	49	0	309	208	1	1,630	653	607	173	179	5	1,617	14
7	0	275	610	187	66	0	130	215	0	1,483	415	590	248	220	2	1,475	8
8	0	211	367	435	29	0	1	215	0	1,258	149	506	445	180	2	1,282	-24
9	7	165	322	182	21	0	1	208	7	912	35	511	206	157	3	913	-1
10	0	101	344	0	546	0	7	215	4	1,216	266	698	34	128	111	1,236	-21
11	1,473	161	302	0	47	0	0	208	124	2,316	550	304	273	63	189	1,379	937
12	3,055	2,369	130	8	33	0	142	215	280	6,232	1,171	250	1,068	79	4,577	7,146	-914
Total	*11,645*	*42,045*	*4,629*	*3,376*	*1,297*	*0*	*4,611*	*2,538*	*1,300*	*71,441*	*9,594*	*8,245*	*13,523*	*1,835*	*37,904*	*71,100*	*341*

3.3 Preliminary Source Loading Analysis Approach

This section describes the analytical approach used to attribute land-based source loads to jurisdictions and to land uses in the Santa Margarita River watershed. We begin with an analysis of land use-based loading at the source. This includes loads associated with storm runoff, irrigation return flow, and subsurface flow associated with the shallow groundwater pathways that are simulated within the HSPF model. Results are provided in Section 3.4.1. The analysis of land-based sources does not include loads due to discharges and water releases (both regulated point source discharges and CWRMA water rights releases), releases/spills from upstream lakes/reservoirs, or subsurface discharges direct to the Estuary incorporated in the estuary model. These loads are added to the total and compared to the land use-based loads in Section 3.4.2.

Loads from the land surface upstream of Diamond Valley, Vail, Skinner, and Lake O'Neill are not included in this tabulation because these lakes/reservoirs are effective nutrient traps with limited releases. In addition, Diamond Valley Lake and Lake Skinner primarily store Colorado River Project water, the nutrient content of which is unrelated to activities in the Santa Margarita watershed. Loadings in outflows from these lakes are treated as point sources based on monitored concentrations for the purpose of this analysis. Therefore, the land-based analysis covers the area downstream of these lake outlets, as shown in Figure 3.13.

Loading analyses are reported for calendar years 2003-2010 to provide a range of hydrometeorological conditions and also for WY 2008-2009, corresponding to the period for which the MODFLOW groundwater model is calibrated. While there were discharges to the river from one Camp Pendleton wastewater treatment plant during 2003, these discharges are not relevant to the land-based load tabulation. The analysis of delivered load from all sources omits the wastewater treatment plant load from the tabulation to reflect current conditions in the watershed.

Model outputs from the HSPF model of the Santa Margarita Watershed were used to estimate the source and delivered TN and TP loads of various land uses and jurisdictional areas in the watershed (Section 3.4.1). Land use-based loads can vary significantly by season and in accordance with precipitation in the watershed. Nutrient load analyses were requested for a combination of seasons and hydrological conditions in the watershed, defined as follows:

- Winter: October 1-April 30
- Summer: May 1-September 30
- Wet days: ≥ 0.1 inch of precipitation observed on that day or on any of the three previous days
- Dry days: < 0.1 inch of precipitation observed on that day or on any of the three previous days

The number of days defined as Wet-Winter, Dry-Winter, Wet-Summer, and Dry-Summer for the years of interest is shown in Table 3.6 based on records at the Temecula precipitation gauge (CA8844). For years 2003-2010, approximately 39.3% of days are classified as Dry-Summer and 38.7% as Dry-Winter. Zero to 22 days per year were classified as Wet-Summer conditions.

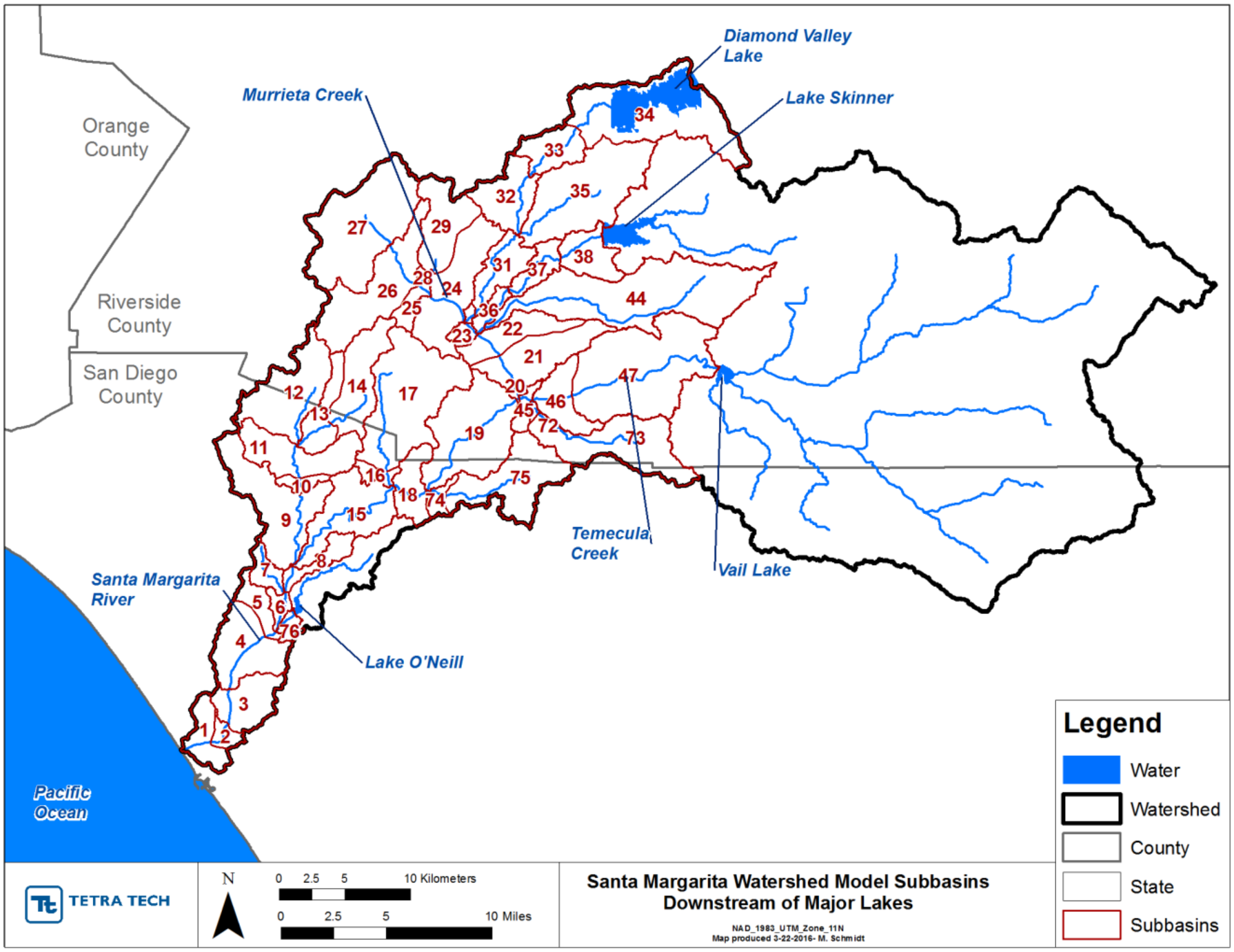


Figure 3.13. Santa Margarita Watershed Model Sub-basins Downstream of Diamond Valley, Skinner, Vail, and Lake O'Neill

Table 3.6. Number of Days with Wet-Winter, Dry-Winter, Wet-Summer, and Dry-Summer Conditions in the Santa Margarita Watershed (2003-2010)

	Wet-Winter	Dry-Winter	Wet-Summer	Dry-Summer
2003	63	149	18	135
2004	77	136	0	153
2005	72	140	22	131
2006	65	147	12	141
2007	65	147	8	145
2008	61	152	6	147
2009	50	162	4	149
2010	115	97	5	148
Average	71	141	9	144

3.3.1 Land Use and Jurisdictions

One goal of this analysis is to identify the relative fraction of nutrient loads that are potentially the responsibility of each jurisdiction or geographic area and land use. Acknowledging that there is significant uncertainty in the existing model, the best use of the model is to determine the relative importance of different source areas.

Land uses in the Santa Margarita watershed were identified by combining and reconciling the classes in local SANDAG, SCAG, and LANDFIRE coverages as described in Tetra Tech (2013). The spatial distribution of land use in the lower Santa Margarita watershed is displayed in Figure 3.14. The primary land uses in the Santa Margarita watershed are grassland, chaparral/shrub, and high-density residential areas. Generalizing, the primary location of orchards occurs along DeLuz, Sandia, Rainbow, Stone, and Devils Creek and on the southwest side of Murrieta Creek. Vineyards are primarily on Temecula, Tuculota, and Santa Gertrudis Creeks. Nurseries predominate on Rainbow Creek. Most other irrigated agricultural land is found northeast of Murrieta Creek.

The 18 land-use categories shown in Figure 3.14 are differentiated in the HSPF model as Hydrologic Response Units (HRU). At-source loads were tabulated for each land-use category by calculating the unit loading rate for each HRU (lb/acre/day) from model output and multiplying by the area (acres) of the land use in a particular region of interest; land use-based loads were tabulated for the entire watershed (below the major lakes) and by sub-basin.

At-source land-use-based loading rates were also established for various jurisdictions in the watershed. The jurisdictions that were the focus of this analysis include unincorporated areas in San Diego County, unincorporated areas in Riverside County, incorporated municipalities, California Transportation (CALTRANS), Camp Pendleton, Fallbrook Naval Weapons Station, and other federal lands (Forest Service, Bureau of Land Management, Bureau of Indian Affairs), which are shown in Figure 3.15 and Figure 3.16. The area of each HRU located within the boundary of each of these jurisdictions was established in ArcGIS™. The HRU tabulation accounted for overlapping areas to ensure that the analysis doesn't duplicate at-source or delivered loads. The approach used to assign overlapping areas to a particular jurisdiction or geographic area is summarized in

Table 3.7.

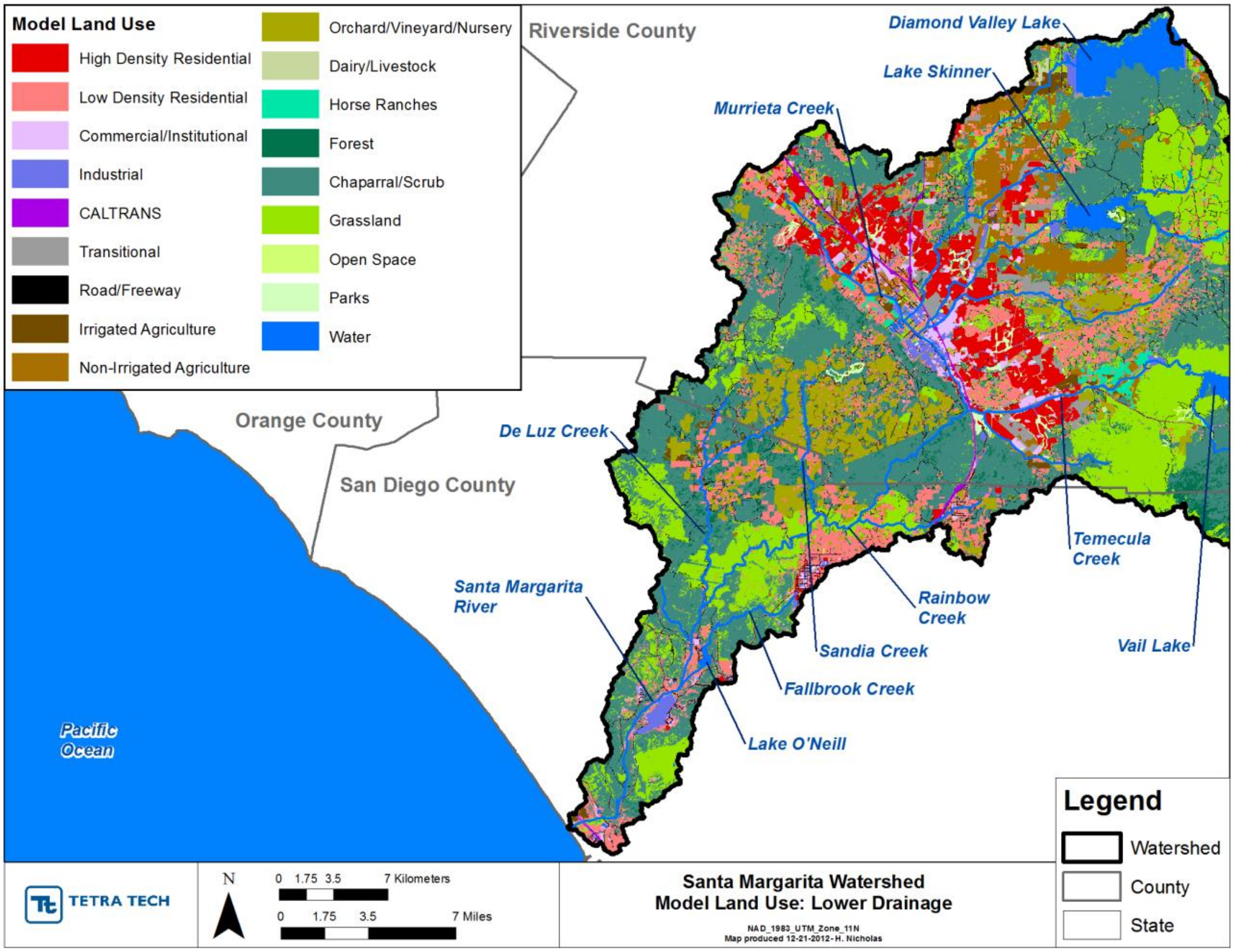


Figure 3.14. Modeled Land Use in the Lower Santa Margarita Watershed

Table 3.7. HRU Tabulation Approach for Overlapping Jurisdictions and Geographic Areas

Overlapping Areas	Jurisdiction or Geographic Area Assigned the Overlapping Area
CALTRANS that overlap with cities, counties, or federal land	CALTRANS
Incorporated municipalities that overlap with a county	Municipality
Federal land that overlaps with a county	Federal land

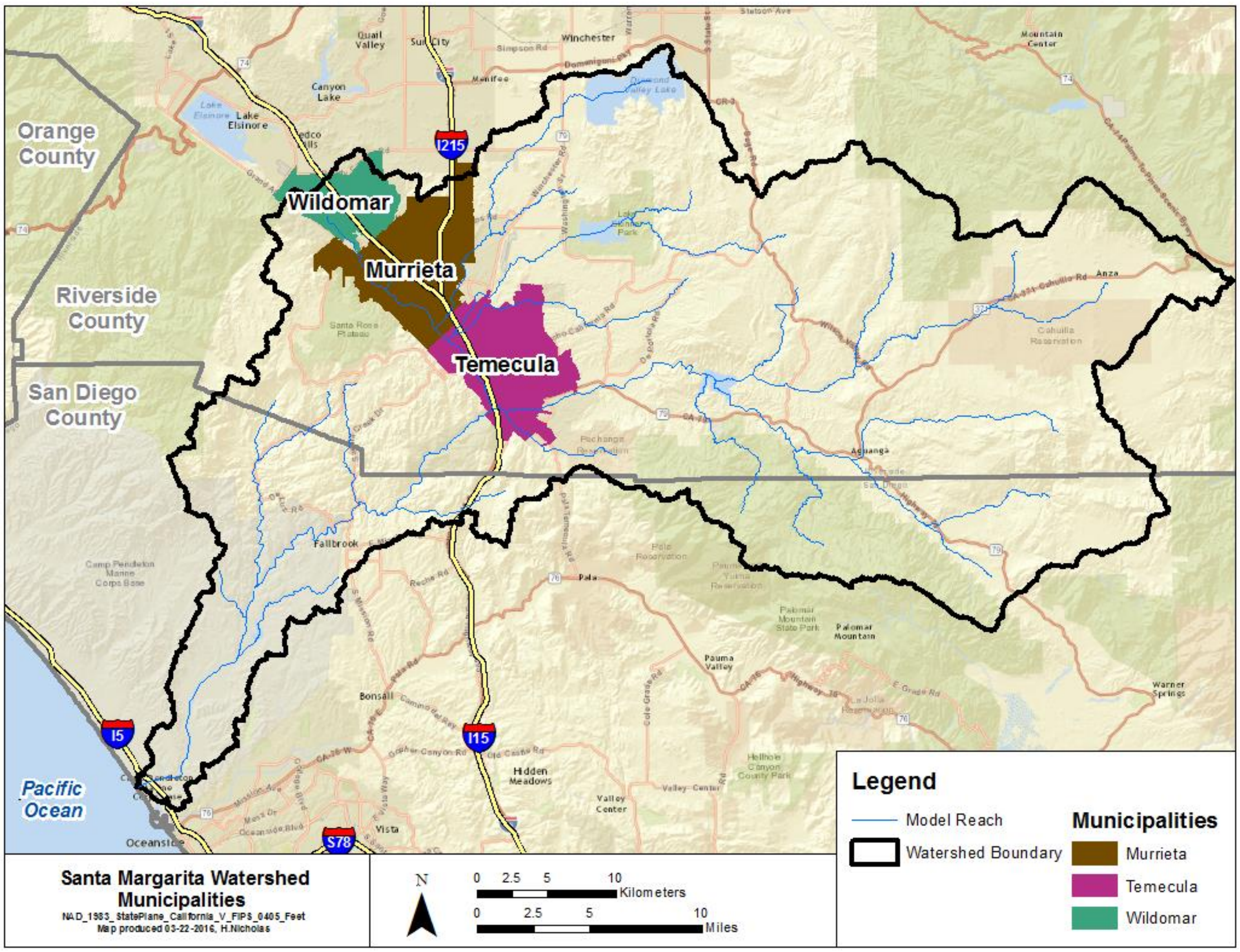


Figure 3.15. Counties and Incorporated Municipalities within the Santa Margarita Watershed

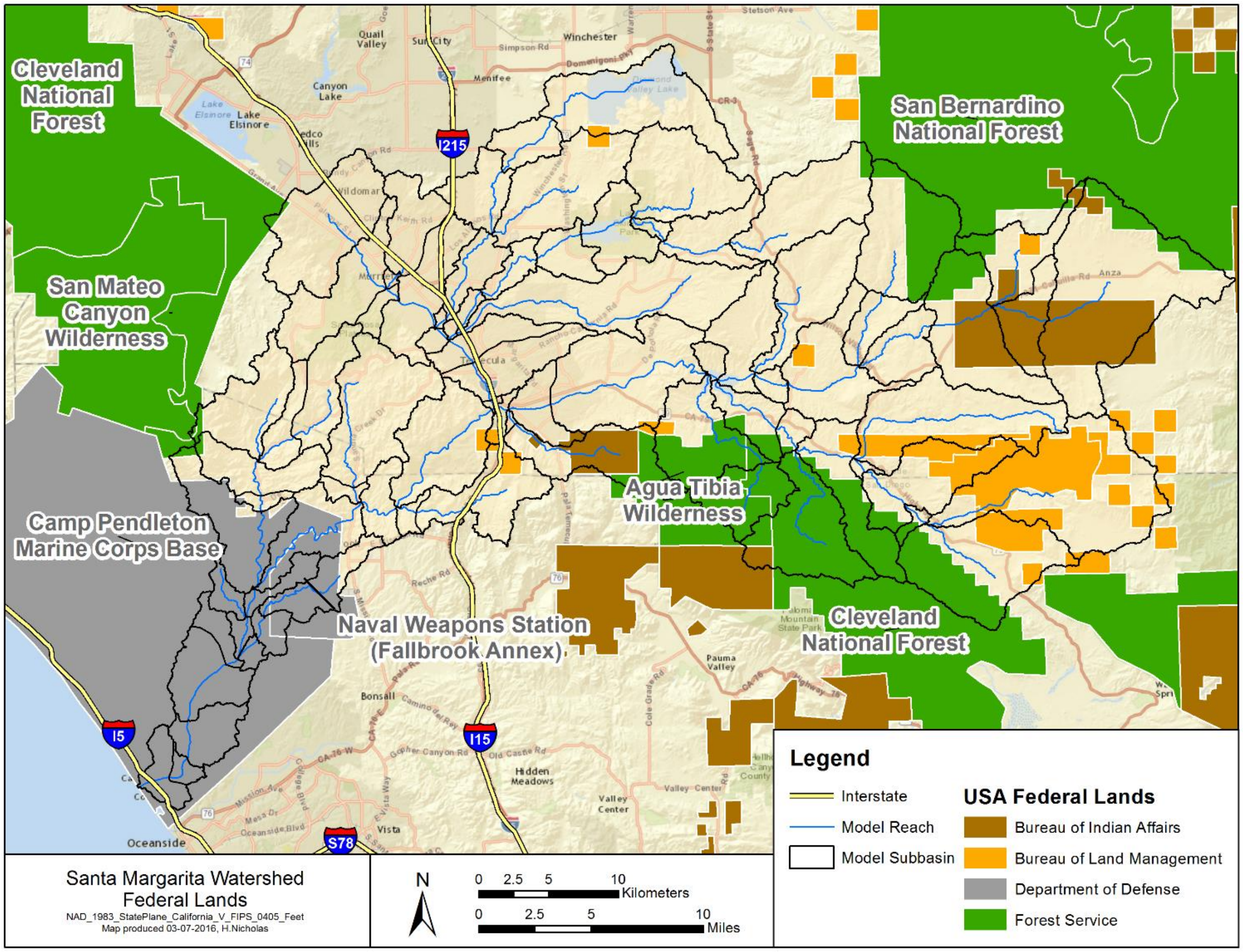


Figure 3.16. Santa Margarita Watershed Federal Lands

3.3.2 Nutrient Loads Delivered to the Estuary

At-source loads are not an accurate estimator of risk of loading to the Santa Margarita Estuary. Sources that have only a distant hydrologic connection with the Estuary may reasonably be expected to deliver less of their source load downstream. Conversely, loads generated in the immediate area of the Estuary may suffer no diminution during transport, and may thus be more important to control. Finally, water management on Camp Pendleton introduces significant complexities to the load analysis. During 2003-2010, Camp Pendleton diverted significant amounts of water (and associated nutrients) from the river for recharge and also released groundwater back to the river. The diversions remove significant amounts of nutrient load transported from the upstream watershed by the Santa Margarita River and thus reduce direct, wet-weather transport to the Estuary; however, the diverted water is recharged to groundwater and may thus ultimately contribute nutrient loads to the Estuary via subsurface pathways[2].

Delivered loads to the Estuary were estimated from the at-source loads by applying attenuation rates or "discount" factors for transport through the stream network based on the model-simulated input and output load ratios for each stream reach (by season), along with removal through diversions or losses to groundwater and additions from discharges and gains from deep groundwater not directly simulated by the watershed model. The watershed model provided time series for each of these components, either by direct simulation or as an externally added source. Thus, the full mass balance was established for each stream reach to determine the average attenuation rate over time.

Delivery factors were established for each sub-basin based on throughput (1 minus retention). Input, output, and diversions for each reach are calculated to determine percentage throughput, R. Then, delivered load, D, is equal to the local load, L, as processed through each intervening reach (i = 1 to n):

$$D = L\,x \prod_{i=1}^{n} R_i$$

Separate delivery factors were developed for winter and summer seasons. Delivery factors are not additionally subset by dry versus wet conditions, as nutrients loaded to the stream network during dry conditions are likely to be delivered by subsequent wet events. Actual delivery rates vary by individual events. As a result, loading tabulations based on delivery factors approximate, but do not exactly match, the simulated load to the estuary during individual years.

The TN and TP delivery factors are summarized in Figure 3.17-Figure 3.20. For a majority of the sub-basins, a high percentage of the at-source loads generated in the winter are delivered to the Estuary; this is the case for both TN and TP. Sub-basins located northeast of Murrieta Creek, for example, have winter TN delivery factors that range from 26%-70%. In this region of the watershed, a higher percentage of the at-source TP loads are delivered to the Estuary in the winter compared to TN loads. The winter TP delivery factors for almost all of the sub-basins located northeast of the Murrieta Creek are greater than 81%. Winter TP delivery factors for sub-basins located downstream of the confluence of the Murrieta Creek and Temecula Creek range from 91% to 99%. TP that is generated in the lower portion of the watershed during the winter, therefore, is essentially fully delivered to the Estuary.

In general, delivery factors are lower in the summer than in the winter; this is due to a variety of factors, including losses to groundwater, diversions, and phytoplankton and benthic algae activity in the stream network, especially in streams with perennial flow. At-source summer TN and TP loads from sub-basins upstream of Camp Pendleton are substantially reduced during transport through the stream network. For example, the summer TN and TP delivery factors for all of the sub-basins located in Riverside County are < 9% and < 8%, respectively.

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[2] Note that loads associated with surfacing groundwater are tabulated separately in Section 3.4.2. A large portion of these loads are ultimately derived from the land surface. We do not, however, have sufficient mass balance accounting within the aquifers to attribute those loads back to original sources.

In contrast, the at-source loads of sub-basins in the immediate vicinity of the Estuary are predicted to be largely conserved during transport to the Estuary. As a result, the TN and TP delivery factors for the most downstream sub-basin are greater than 94% in both the summer and the winter.

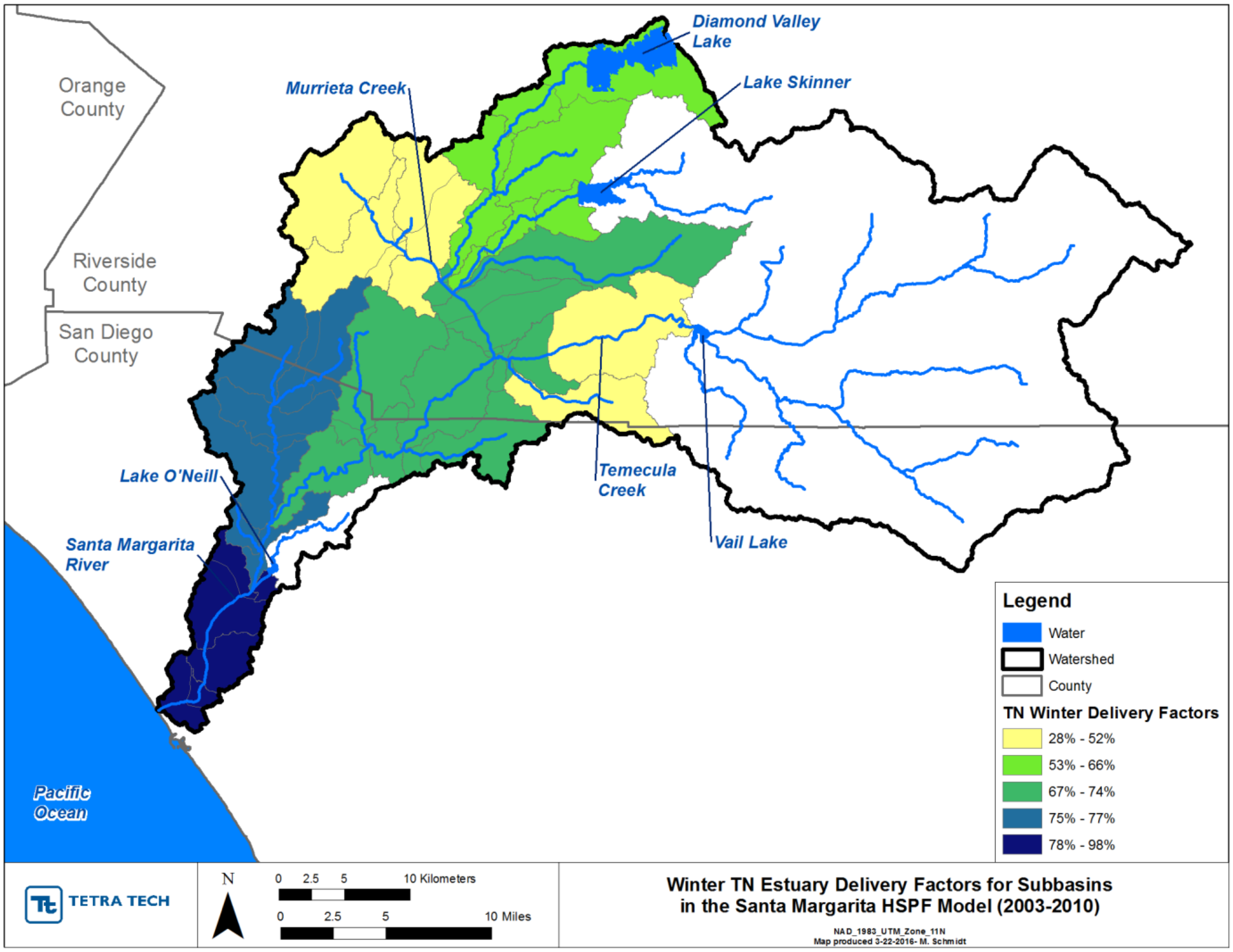

Figure 3.17. Winter TN Delivery Factors for Sub-basins in the Santa Margarita HSPF Model (2003-2010)

Note: Delivery factors quantify the percent of an at-source load delivered to the Santa Margarita Estuary in the HSPF model. Areas intercepted by upstream lakes are not included in the tabulation.

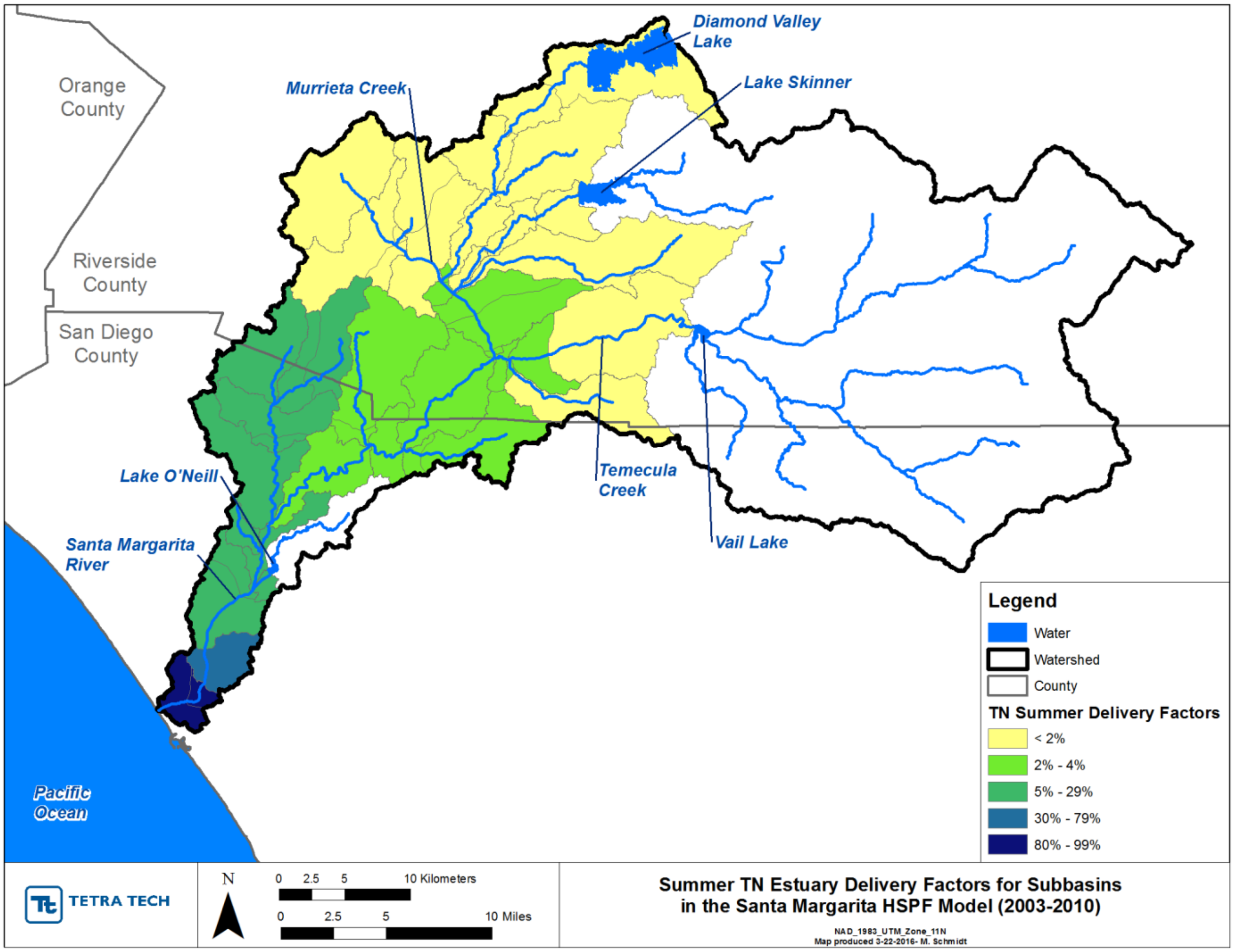

Figure 3.18. Summer TN Delivery Factors for Sub-basins in the Santa Margarita HSPF Model (2003-2010)

Note: Delivery factors quantify the percent of an at-source load delivered to the Santa Margarita Estuary in the HSPF model. Areas intercepted by upstream lakes are not included in the tabulation.

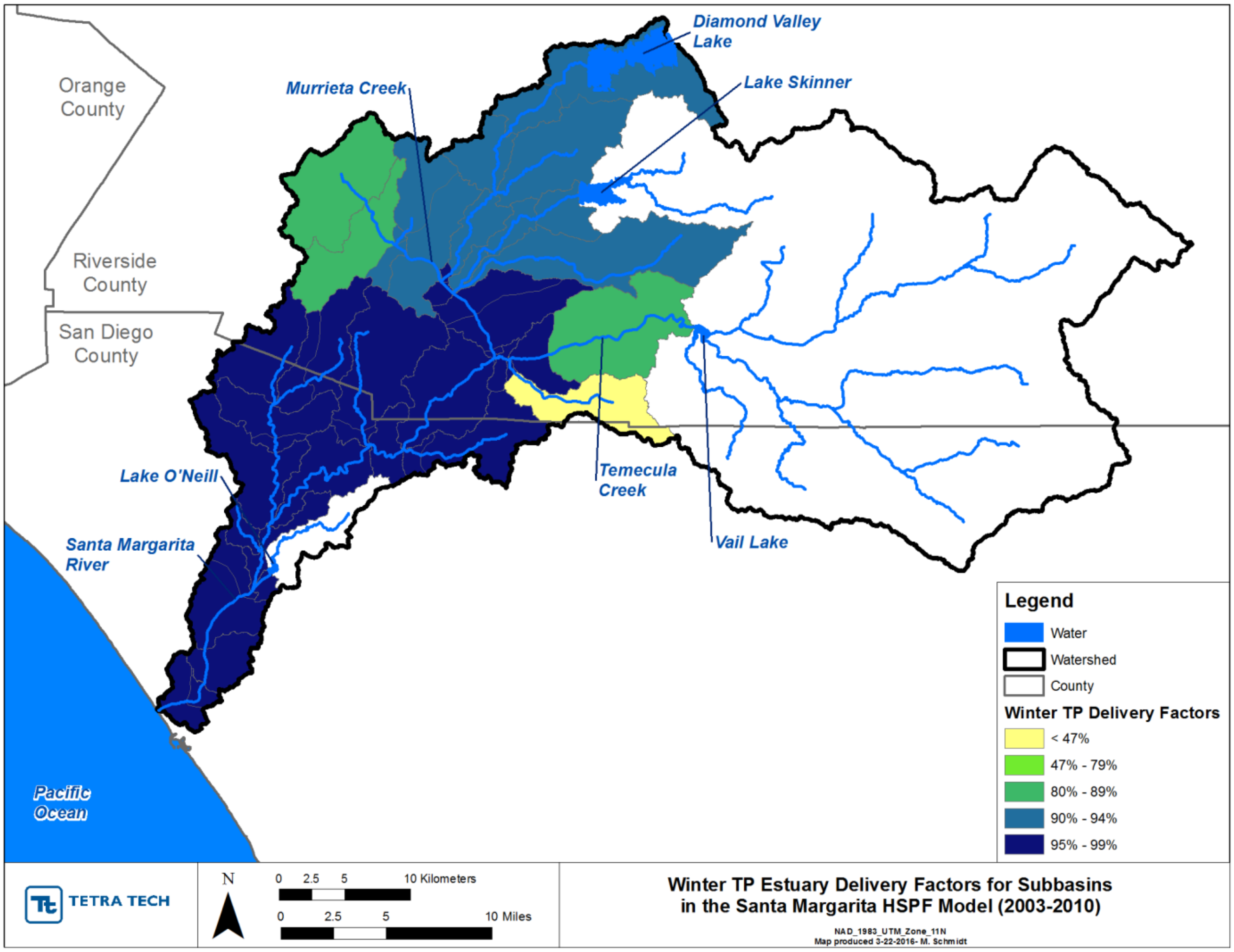

Figure 3.19. Winter TP Delivery Factors for Sub-basins in the Santa Margarita HSPF Model (2003-2010)

Note**:** Delivery factors quantify the percent of an at-source load delivered to the Santa Margarita Estuary in the HSPF model. Areas intercepted by upstream lakes are not included in the tabulation.

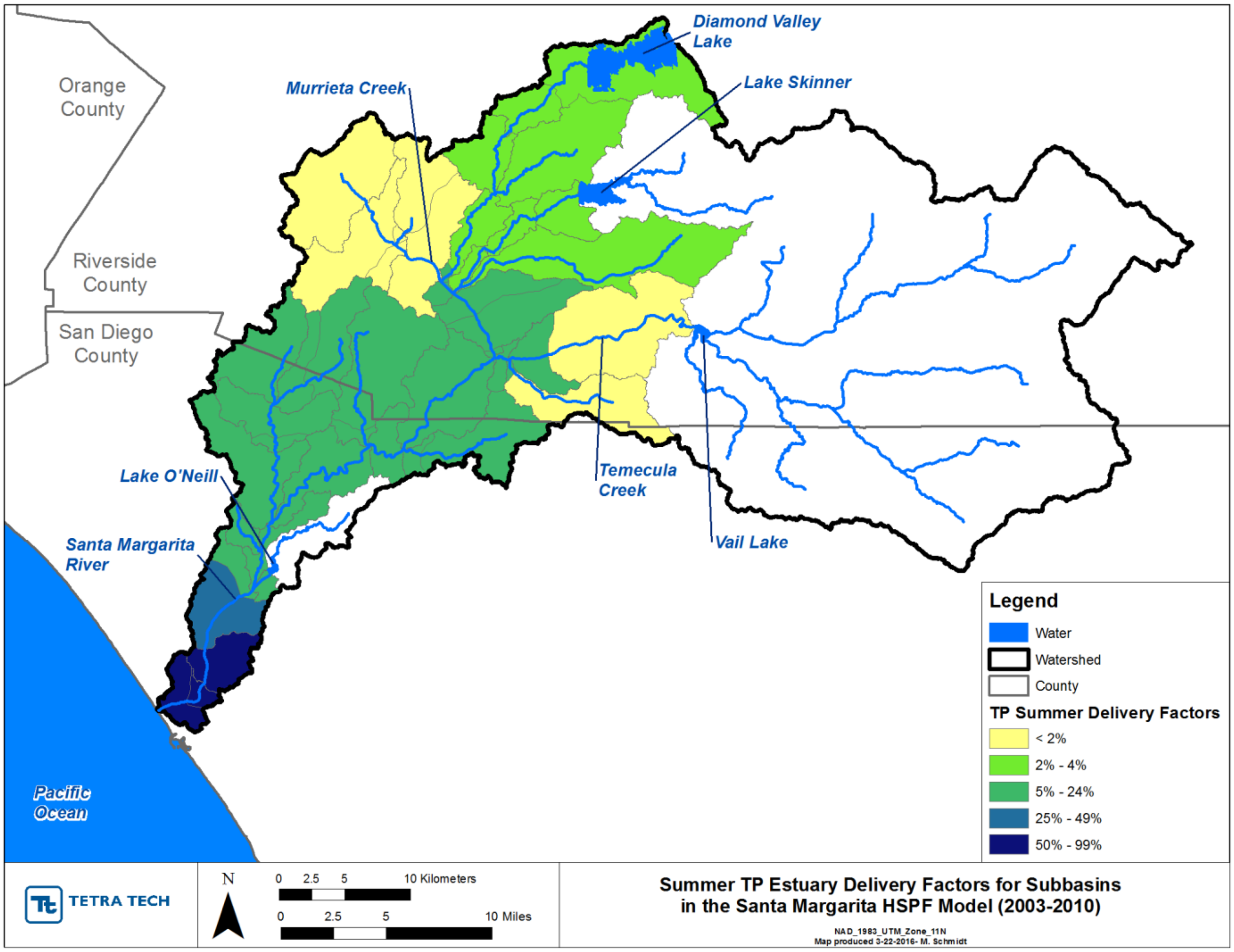

Figure 3.20. Summer TP Delivery Factors for Sub-basins in the Santa Margarita HSPF Model (2003-2010)

Note: Delivery factors quantify the percent of an at-source load delivered to the Santa Margarita Estuary in the HSPF model. Areas intercepted by upstream lakes are not included in the tabulation.

The delivery factors presented in Figure 3.17-Figure 3.20 were developed based on the model period of 2003-2010. The MODFLOW model is calibrated for the period of 2008-2009. Delivery factors for sub-basins 101-106 are compared for the periods of 2003-2010 and 2008-2009 in Table 3.6 (refer to Figure 3.21).

The average winter delivery factors for the period of 2003-2010 are slightly higher than those for the period of 2008-2009, but differ by < 7%. The summer delivery factors differ more for the two periods, reflecting differences in the timing and magnitude of flows. The summer TN delivery factors for sub-basin 102, for example, are 98% and 79% for the periods of 2003-2010 and 2008-2009, respectively.

Table 3.8. Comparison of Delivery Factors from Camp Pendleton to the Santa Margarita Estuary for Model Periods of 2003-2010 and 2000-2008

	Total Nitrogen				Total Phosphorus			
	2003-2010		2008-2009		2003-2010		2008-2009	
Model Sub-basin	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
101	99%	99%	98%	85%	100%	93%	99%	88%
102	98%	98%	98%	79%	100%	90%	99%	84%
103	96%	65%	94%	55%	99%	72%	98%	68%
104	90%	15%	87%	2%	98%	31%	96%	14%
105	88%	10%	84%	1%	98%	23%	95%	9%
106	78%	5%	71%	1%	97%	14%	91%	4%

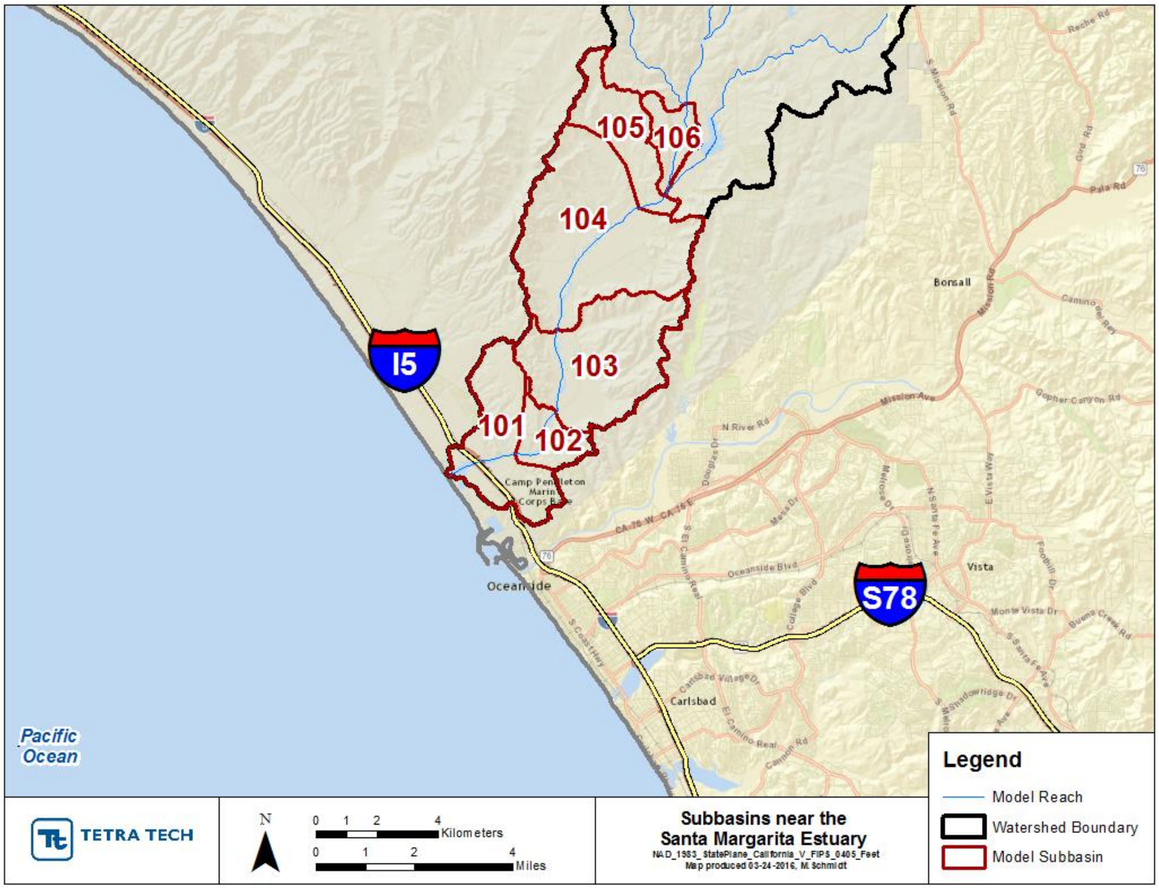

Figure 3.21. Model Sub-basins from Camp Pendleton to the Santa Margarita Estuary

3.4 Preliminary Loading Analysis Results

3.4.1 Land Use-based Loads

At-source nutrient loads are tabulated for land uses in the Santa Margarita watershed (below the four lakes and reservoirs) using the approach described in Section 3.3. Nutrients are generated and transported to the stream network by surface and subsurface flows. During periods of wet weather, land use-based loads are dominated by surface runoff. The opposite is true for dry weather; land use-based loads are primarily from subsurface flows. The annual TN and TP land use-based loads are dominated by the loads associated with high flows during wet winter weather (Table 3.10 and Table 3.11). The land use of orchards, vineyards, and nurseries produced the highest at-source TN loads, despite occupying a relatively small portion of the watershed. This occurs because these lands are fertilized and irrigated and have the highest estimated per-acre loading rates of all land uses. Orchards, vineyards, and nurseries also had relatively high TP loads during wet-winter conditions[3]. In addition, high TP at-source loads were generated by low-density residential, chaparral, and scrub land during wet winter periods. TP loads are sediment-associated, and the erosion loads from these land uses dominate the annual TP load.

The land use-based loads delivered to the Santa Margarita Estuary were estimated following the approach described in Section 3.2. The delivery factors are greater for the winter season compared to the summer season and, consequently, a higher percentage of the at-source loads is delivered to the Estuary during the winter (Table 3.9 and Table 3.10). The spatial distribution of at-source and delivered TN and TP loads is shown in Figure 3.22-Figure 3.25. Orchards, vineyards, and nurseries are largely found in the central portion of the watershed near Rainbow, De Luz, and Sandia creeks. This results in hotspots of at-source and delivered TN and TP in this region of the watershed.

Annual at-source and delivered land use-based loads are tabulated by jurisdictions in Table 3.11 and Table 3.12. The relative attribution to jurisdictions is summarized graphically in Figure 3.26. On an average annual basis over the years 2003-2010, the land use-based contributions from San Diego County and incorporated plus unincorporated areas in Riverside County are similar.

At-source TN and TP loads were further tabulated by jurisdiction, land-use, and season. Results from these tabulations are shown in Table 3.13-Table 3.20. The net seasonal contributions to delivered load by jurisdiction are summarized in Figure 3.27 and Figure 3.28. The TN and TP loads produced by unincorporated areas in Riverside County were more important in the winter than in the summer; the at-source loads and delivery factors were higher in the winter compared to the summer, which makes Riverside County the largest contributor in the winter. In the summer, the at-source loads from unincorporated areas in Riverside County were comparatively small. San Diego County is nearer to the

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[3] It was not possible to quantitatively separate nutrient loads associated with nurseries from those associated with orchards/vineyards for this report because the San Diego County land use coverage does not separate these land use types. The 2005 land use coverage for Riverside County does separate these classes and indicates that only 3.4% of the combined class (within Riverside County) is identified as nurseries. Distinct loading rates have also not been established for nurseries compared to orchards/vineyards. Stakeholders also requested separate tabulation of agricultural loads that are covered by the agricultural discharge Order. That tabulation can be provided pending clarification of which lands are covered.

Santa Margarita Estuary and, consequently, had a higher fraction of delivered loads in the dry summer season. More detailed breakdowns by month and jurisdiction are provided in Appendix 3.

Table 3.9. Mean Annual At-Source and Delivered Land Use-based Total Nitrogen Loads (lb/year) by Land Use in the Santa Margarita Watershed (2003-2010)

	Wet-Winter (71 days)		Dry-Winter (141 days)		Wet-Summer (9 days)		Dry-Summer (144 days)		Annual Load	
Land Use Category	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**
Low density residential	33,085	21,045	6,066	3,853	291	13	1,765	91	41,207	25,002
Commercial, institutional	3,066	1,930	661	418	89	3	166	10	3,982	2,361
Industrial	2,850	1,782	630	392	60	2	163	5	3,703	2,181
Road, freeway	5,958	3,717	950	586	51	2	202	7	7,160	4,312
Parks and recreation	2,150	1,293	211	127	20	0	35	1	2,416	1,421
Irrigated agriculture	20,379	12,666	2,740	1,816	67	2	61	3	23,246	14,488
Forest	1,156	782	145	97	3	0	25	1	1,330	881
CALTRANS	913	532	147	86	6	0	32	1	1,098	619
Open and recreation	162	91	14	8	2	0	2	0	180	98
Non-irrigated agriculture	2,822	1,638	179	106	17	0	33	0	3,050	1,745
Orchard, vineyard, and nursery	114,211	79,443	20,818	14,735	318	9	1,106	38	136,452	94,224
Dairy, livestock	277	168	43	27	1	0	0	0	321	195
Horse ranches	10,646	4,119	1,582	646	70	0	233	2	12,531	4,767
Chaparral, scrub	38,461	26,355	10,151	7,264	226	8	1,991	74	50,829	33,702
Grassland, herbaceous	19,244	12,256	4,500	3,096	111	4	621	26	24,476	15,381
Water	0	0	0	0	0	0	0	0	0	0
Transitional	5,911	3,380	584	327	66	1	106	2	6,667	3,709
High density residential	14,331	8,005	2,246	1,286	327	5	550	9	17,454	9,306

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Table 3.10. Mean Annual At-Source and Delivered Land Use-based Total Phosphorus Loads (lb/year) by Land Use in the Santa Margarita Watershed (2003-2010)

	Wet-Winter (71 days)		Dry-Winter (141 days)		Wet-Summer (9 days)		Dry-Summer (144 days)		Annual Load	
Land Use Category	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**
Low density residential	74,648	69,020	609	561	58	5	179	15	75,495	69,601
Commercial, institutional	4,667	4,269	67	62	19	1	17	2	4,770	4,333
Industrial	4,800	4,369	65	60	14	1	17	1	4,896	4,431
Road, freeway	15,054	13,816	96	88	18	1	20	1	15,189	13,906
Parks and recreation	3,897	3,574	21	19	5	0	3	0	3,927	3,594
Irrigated agriculture	9,388	8,557	275	250	12	1	8	1	9,682	8,809
Forest	4,746	4,366	22	20	1	0	4	0	4,773	4,386
CALTRANS	2,826	2,594	15	13	2	0	3	0	2,846	2,607
Open and recreation	169	148	1	1	0	0	0	0	171	150
Non-irrigated agriculture	5,501	4,976	27	25	4	0	5	0	5,537	5,000
Orchard, vineyard, and nursery	78,194	73,792	2,089	1,971	64	4	117	8	80,464	75,774
Dairy, livestock	39	35	4	4	0	0	0	0	43	39
Horse ranches	2,550	2,206	158	137	7	0	23	0	2,739	2,344
Chaparral, scrub	93,151	85,012	420	383	15	1	86	7	93,672	85,403
Grassland, herbaceous	46,193	38,109	199	166	11	1	37	3	46,441	38,279
Water	0	0	0	0	0	0	0	0	0	0
Transitional	10,079	9,057	58	52	14	0	11	0	10,161	9,110
High density residential	25,135	22,763	224	204	58	2	55	2	25,472	22,971

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

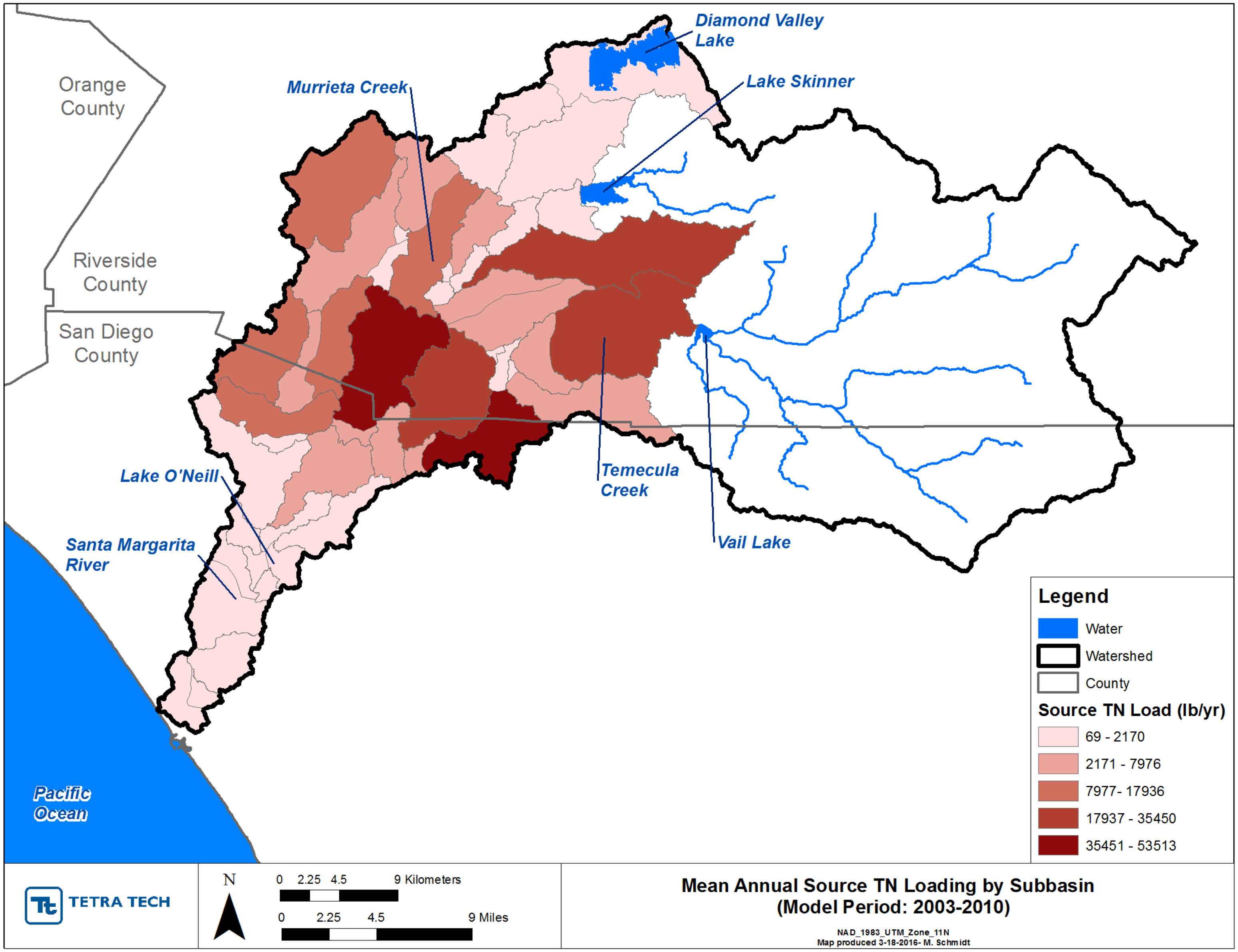


Figure 3.22. At-Source Land Use-based Total Nitrogen Loads by Sub-basin

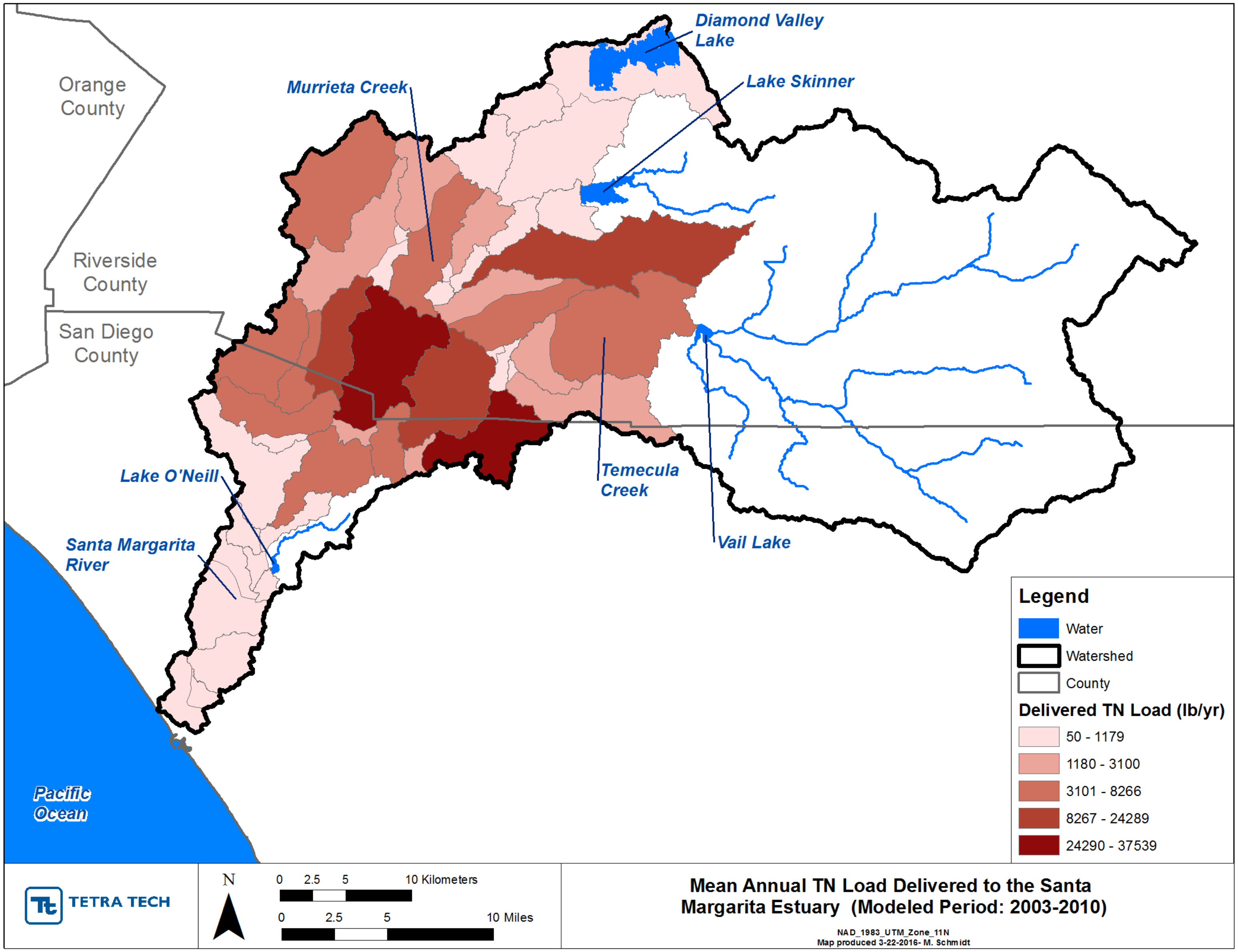


Figure 3.23. Land Use-based Total Nitrogen Load Delivered to the Estuary by Sub-basin

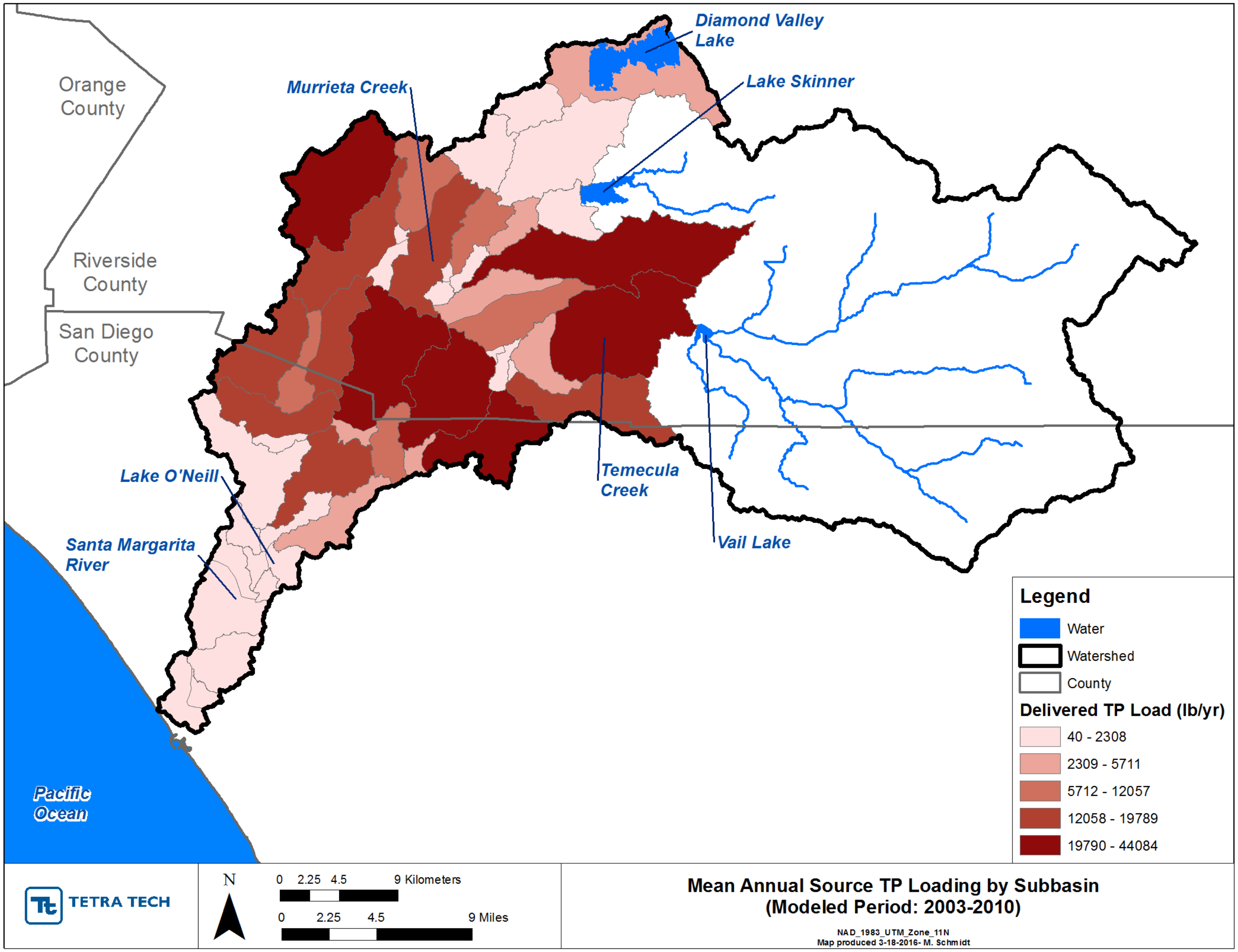


Figure 3.24. At-Source Land Use-based Total Phosphorus Loads by Sub-basin

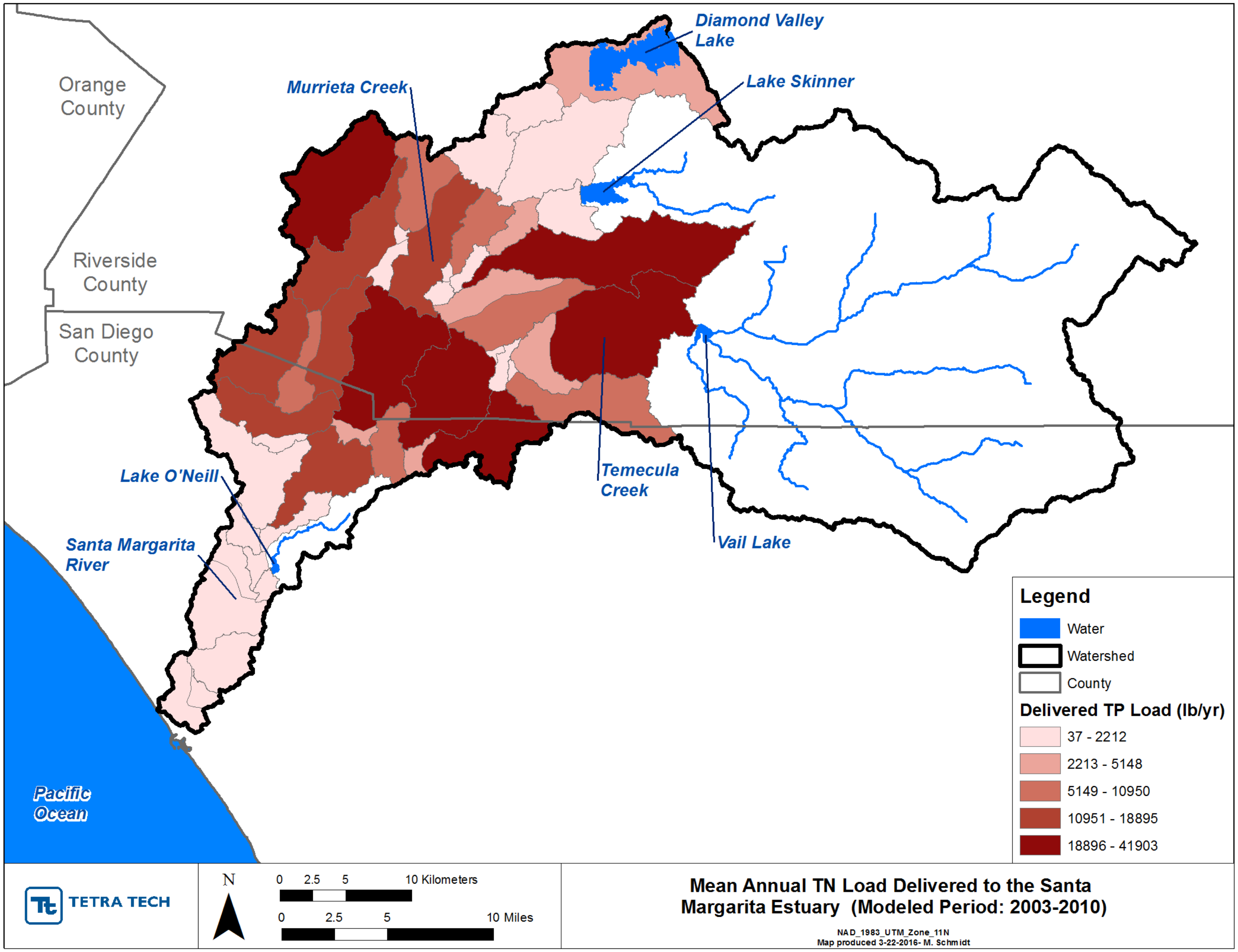


Figure 3.25. Total Phosphorus Load Delivered to the Estuary by Sub-basin

Table 3.11. Mean Annual At-Source and Delivered Land Use-based Total Nitrogen Loads (lb/year) by Jurisdiction in the Santa Margarita Watershed (2003-2010)

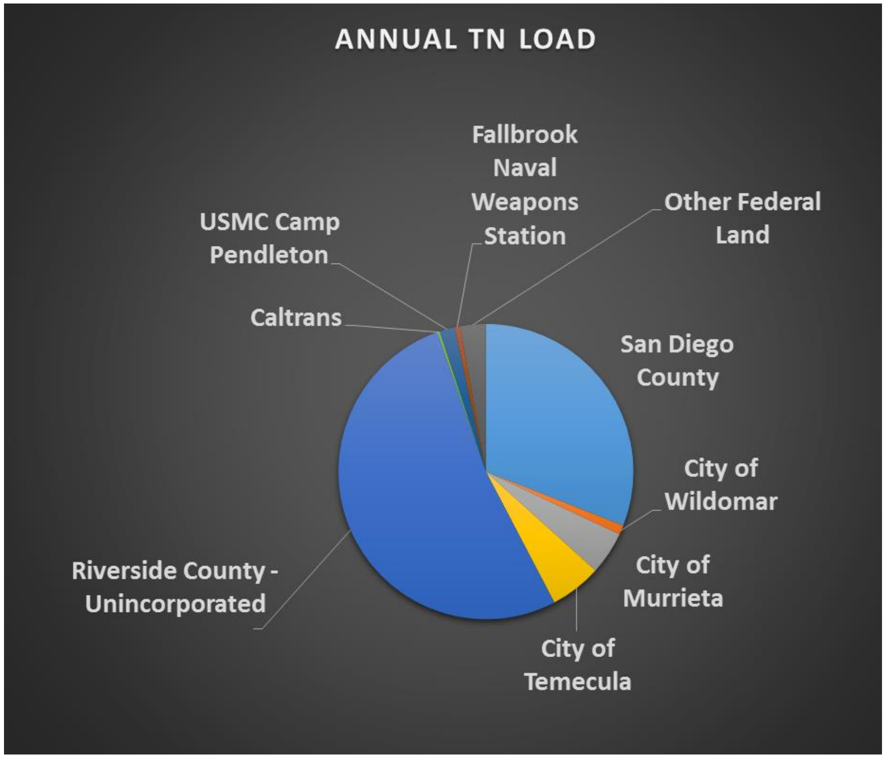
	Wet-Winter (71 days)		Dry-Winter (141 days)		Wet-Summer (9 days)		Dry-Summer (144 days)		Annual Load	
Jurisdiction or Geographic Area	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**
San Diego County										
Unincorporated	69,442	52,063	16,550	12,375	399	15	2,756	100	89,147	64,553
Total San Diego County	69,442	52,063	16,550	12,375	399	15	2,756	100	89,147	64,553
Riverside County										
City of Wildomar	5,499	1,989	839	302	54	0	174	0	6,566	2,292
City of Murrieta	17,980	9,011	2,594	1,318	232	2	499	3	21,304	10,334
City of Temecula	15,346	10,283	2,573	1,765	260	7	576	16	18,754	12,071
Other Unincorporated	154,951	97,535	26,080	16,948	679	12	2,313	45	184,023	114,541
Total Riverside County	193,775	118,818	32,086	20,333	1,225	21	3,562	65	230,647	139,237
State of California										
CALTRANS	913	532	147	86	6	0	32	1	1,098	619
Federal										
USMC Camp Pendleton	3,052	2,551	625	535	38	12	258	89	3,972	3,188
Fallbrook Naval Weapons Station	853	641	109	82	5	0	21	1	988	724
Other Federal Lands	7,586	4,594	2,150	1,459	54	2	461	15	10,251	6,070
Total Federal	11,491	7,787	2,884	2,077	96	14	740	104	15,211	9,982

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from all land uses within each geographic boundary in the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Table 3.12. Mean Annual At-Source and Delivered Land Use-based Total Phosphorus Loads (lb/year) by Jurisdiction in the Santa Margarita Watershed (2003-2010)

	Wet-Winter (71 days)		Dry-Winter (141 days)		Wet-Summer (9 days)		Dry-Summer (144 days)		Annual Load	
Jurisdiction or Geographic Area	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**	**Source Load**	**Delivered Load**
San Diego County										
Unincorporated	90,699	86,439	989	944	54	4	180	13	91,921	87,401
Total San Diego County	90,699	86,439	989	944	54	4	180	13	91,921	87,401
Riverside County										
City of Wildomar	12,424	10,703	91	78	10	0	19	0	12,543	10,781
City of Murrieta	30,081	26,897	267	241	43	1	51	1	30,443	27,140
City of Temecula	22,077	20,427	262	245	48	3	59	3	22,446	20,678
Other Unincorporated	203,654	180,677	2,553	2,350	130	6	226	9	206,563	183,042
Total Riverside County	268,236	238,704	3,174	2,915	231	9	354	13	271,995	241,641
State of California										
CALTRANS	2,826	2,594	15	13	2	0	3	0	2,846	2,607
Federal										
USMC Camp Pendleton	6,784	6,461	86	84	9	4	32	13	6,911	6,562
Fallbrook Naval Weapons Station	2,962	2,836	15	15	1	0	3	0	2,981	2,851
Other Federal Lands	15,492	9,630	72	46	4	0	14	1	15,582	9,676
Total Federal	25,238	18,927	173	144	14	4	49	14	25,474	19,089

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from all land uses in the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.



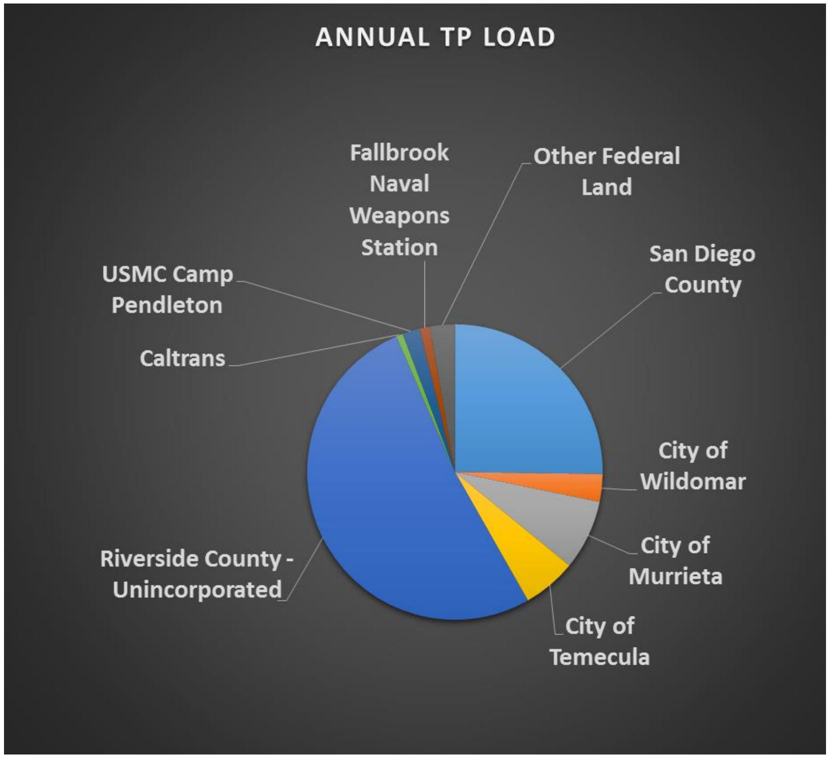


Figure 3.26. Annual Land Use-based Delivered Nutrient Loads by Jurisdiction, 2003-2010

Note: Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for details by month.

Table 3.13. At-Source Land Use-based Total Nitrogen (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Wet-Winter (71 days)

	Jurisdiction or Geographic Area								
Land Use Category	San Diego County	City of Wildomar	City of Murrieta	City of Temecula	Riverside County – Unincor-porated	CALTRANS	USMC Camp Pendleton	Fallbrook Naval Weapons Station	Other Federal Land
Low density residential	11,544	1,833	3,062	3,208	12,256	0	782	157	245
High density residential	221	892	4,685	4,986	3,492	0	9	0	46
Commercial, institutional	91	128	797	1,363	483	0	101	3	100
Industrial	162	23	612	977	882	0	168	0	27
Road, freeway	1,217	322	618	457	3,075	0	170	2	96
Parks and recreation	9	12	504	809	803	0	0	0	12
Open and recreation	8	4	39	60	42	0	0	0	9
Irrigated agriculture	5,857	86	1,210	520	12,421	0	269	0	17
Non-irrigated agriculture	0	234	391	116	2,065	0	2	0	13
Orchard, vineyard, and nursery	25,484	267	1,767	210	86,452	0	0	0	32
Dairy, livestock	0	0	100	0	176	0	0	0	0
Horse ranches	0	380	2,298	193	7,775	0	0	0	0
Forest	523	0	16	34	493	0	13	1	75
Chaparral, scrub	14,305	711	748	399	16,769	0	421	167	4,941
Grassland, herbaceous	10,016	294	290	322	4,747	0	1,113	521	1,941
Transitional	5	314	842	1,693	3,020	0	4	2	31
CALTRANS	0	0	0	0	0	913	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.14. At-Source Land Use-based Total Nitrogen (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Dry-Winter (141 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County - Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	1,925	361	616	687	2,150	0	237	33	57
High density residential	36	144	666	901	489	0	2	0	7
Commercial, institutional	18	27	162	299	105	0	25	1	25
Industrial	33	6	143	208	203	0	31	0	6
Road, freeway	188	56	116	95	446	0	32	1	17
Parks and recreation	1	1	48	71	90	0	0	0	1
Open and recreation	1	0	4	5	4	0	0	0	1
Irrigated agriculture	785	10	96	36	1,779	0	34	0	1
Non-irrigated agriculture	0	13	22	6	137	0	0	0	1
Orchard, vineyard, and nursery	5,630	32	212	25	14,916	0	0	0	2
Dairy, livestock	0	0	7	0	36	0	0	0	0
Horse ranches	0	42	298	22	1,220	0	0	0	0
Forest	62	0	2	5	63	0	3	0	10
Chaparral, scrub	4,601	84	88	49	3,443	0	98	19	1,769
Grassland, herbaceous	3,269	33	29	30	671	0	163	56	249
Transitional	1	31	86	134	328	0	1	0	3
CALTRANS	0	0	0	0	0	147	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.15. At-Source Land Use-based Total Nitrogen (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Wet-Summer (9 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	89	18	31	35	97	0	17	2	2
High density residential	2	18	103	113	90	0	0	0	1
Commercial, institutional	2	3	23	42	14	0	3	0	2
Industrial	1	0	13	27	16	0	4	0	0
Road, freeway	8	3	7	6	25	0	2	0	1
Parks and recreation	0	0	5	8	7	0	0	0	0
Open and recreation	0	0	0	1	1	0	0	0	0
Irrigated agriculture	17	0	6	3	41	0	0	0	0
Non-irrigated agriculture	0	1	2	0	14	0	0	0	0
Orchard, vineyard, and nursery	126	1	7	1	183	0	0	0	0
Dairy, livestock	0	0	0	0	0	0	0	0	0
Horse ranches	0	2	15	1	51	0	0	0	0
Forest	1	0	0	0	2	0	0	0	0
Chaparral, scrub	89	2	4	2	83	0	5	0	39
Grassland, herbaceous	64	2	3	2	25	0	6	2	8
Transitional	0	3	12	18	32	0	0	0	0
CALTRANS	0	0	0	0	0	6	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.16. At-Source Land Use-based Total Nitrogen (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Dry-Summer (144 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	549	87	152	167	645	0	139	10	14
High density residential	9	36	161	218	122	0	1	0	2
Commercial, institutional	5	7	38	70	26	0	14	0	6
Industrial	7	1	33	48	59	0	14	0	1
Road, freeway	32	11	23	19	102	0	11	0	3
Parks and recreation	0	0	8	11	15	0	0	0	0
Open and recreation	0	0	1	1	1	0	0	0	0
Irrigated agriculture	14	0	5	2	37	0	2	0	0
Non-irrigated agriculture	0	2	3	1	27	0	0	0	0
Orchard, vineyard, and nursery	966	1	5	1	134	0	0	0	0
Dairy, livestock	0	0	0	0	0	0	0	0	0
Horse ranches	0	4	36	2	191	0	0	0	0
Forest	8	0	0	1	13	0	1	0	2
Chaparral, scrub	790	13	16	12	732	0	38	3	388
Grassland, herbaceous	376	6	5	4	142	0	36	8	44
Transitional	0	5	13	19	68	0	0	0	1
CALTRANS	0	0	0	0	0	32	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.17. At-Source Total Phosphorus (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Wet-Winter (71 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	31,147	3,988	6,404	5,605	25,922	0	862	346	372
High density residential	550	1,530	9,796	6,743	6,452	0	3	0	61
Commercial, institutional	150	223	1,782	1,589	742	0	30	3	148
Industrial	563	81	924	1,270	1,802	0	44	0	116
Road, freeway	3,560	884	1,708	820	7,635	0	216	2	228
Parks and recreation	14	10	782	1,089	1,989	0	0	0	14
Open and recreation	7	3	53	52	44	0	0	0	11
Irrigated agriculture	3,181	35	315	112	5,700	0	40	0	5
Non-irrigated agriculture	0	535	717	164	4,066	0	2	0	18
Orchard, vineyard, and nursery	18,924	117	761	90	58,296	0	0	0	6
Dairy, livestock	0	0	14	0	25	0	0	0	0
Horse ranches	0	60	479	34	1,977	0	0	0	0
Forest	2,250	1	60	132	1,946	0	40	3	314
Chaparral, scrub	22,311	3,206	3,214	1,756	55,892	0	980	766	5,025
Grassland, herbaceous	7,916	1,148	891	809	19,951	0	4,514	1,838	9,126
Transitional	17	601	1,879	1,720	5,807	0	2	4	48
CALTRANS	0	0	0	0	0	2,826	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.18. At-Source Total Phosphorus (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Dry-Winter (141 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	194	36	61	69	215	0	26	3	6
High density residential	4	14	66	90	49	0	0	0	1
Commercial, institutional	2	3	16	30	10	0	4	0	2
Industrial	3	1	14	21	20	0	5	0	1
Road, freeway	19	6	12	9	44	0	4	0	2
Parks and recreation	0	0	5	7	9	0	0	0	0
Open and recreation	0	0	0	0	0	0	0	0	0
Irrigated agriculture	79	1	10	4	179	0	3	0	0
Non-irrigated agriculture	0	2	3	1	21	0	0	0	0
Orchard, vineyard, and nursery	565	3	21	2	1,496	0	0	0	0
Dairy, livestock	0	0	1	0	4	0	0	0	0
Horse ranches	0	4	30	2	122	0	0	0	0
Forest	9	0	0	1	10	0	0	0	2
Chaparral, scrub	86	13	14	9	253	0	18	3	23
Grassland, herbaceous	27	5	4	5	89	0	25	8	35
Transitional	0	3	9	13	32	0	0	0	0
CALTRANS	0	0	0	0	0	15	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.19. At-Source Total Phosphorus (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Wet-Summer (9 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRANS**	**USMC Camp Pendleton**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	25	3	5	5	16	0	3	0	0
High density residential	0	3	18	20	16	0	0	0	0
Commercial, institutional	0	1	5	9	3	0	1	0	0
Industrial	0	0	3	6	3	0	2	0	0
Road, freeway	2	1	3	2	9	0	1	0	0
Parks and recreation	0	0	1	2	2	0	0	0	0
Open and recreation	0	0	0	0	0	0	0	0	0
Irrigated agriculture	3	0	1	0	7	0	0	0	0
Non-irrigated agriculture	0	0	0	0	3	0	0	0	0
Orchard, vineyard, and nursery	19	0	1	0	43	0	0	0	0
Dairy, livestock	0	0	0	0	0	0	0	0	0
Horse ranches	0	0	2	0	5	0	0	0	0
Forest	0	0	0	0	0	0	0	0	0
Chaparral, scrub	2	0	1	1	9	0	1	0	1
Grassland, herbaceous	1	0	1	0	5	0	1	0	2
Transitional	0	1	3	3	7	0	0	0	0
CALTRANS	0	0	0	0	0	2	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

Table 3.20. At-Source Total Phosphorus (lb/year) Loads by Jurisdiction and Land Use in the Santa Margarita Watershed – Dry-Summer (144 days)

	Jurisdiction or Geographic Area								
Land Use Category	**San Diego County**	**City of Wildomar**	**City of Murrieta**	**City of Temecula**	**Riverside County – Unincor-porated**	**CALTRA NS**	**USMC Camp Pendleto n**	**Fallbrook Naval Weapons Station**	**Other Federal Land**
Low density residential	57	9	15	17	65	0	15	1	1
High density residential	1	4	16	22	12	0	0	0	0
Commercial, institutional	0	1	4	7	3	0	2	0	1
Industrial	1	0	3	5	6	0	2	0	0
Road, freeway	3	1	2	2	10	0	1	0	0
Parks and recreation	0	0	1	1	2	0	0	0	0
Open and recreation	0	0	0	0	0	0	0	0	0
Irrigated agriculture	2	0	0	0	5	0	0	0	0
Non-irrigated agriculture	0	0	0	0	4	0	0	0	0
Orchard, vineyard, and nursery	99	0	1	0	18	0	0	0	0
Dairy, livestock	0	0	0	0	0	0	0	0	0
Horse ranches	0	0	4	0	19	0	0	0	0
Forest	1	0	0	0	2	0	0	0	0
Chaparral, scrub	13	2	2	2	55	0	6	0	5
Grassland, herbaceous	4	1	1	1	19	0	5	1	6
Transitional	0	1	1	2	7	0	0	0	0
CALTRANS	0	0	0	0	0	3	0	0	0

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. See Appendix 3 for detailed tabulation by month.

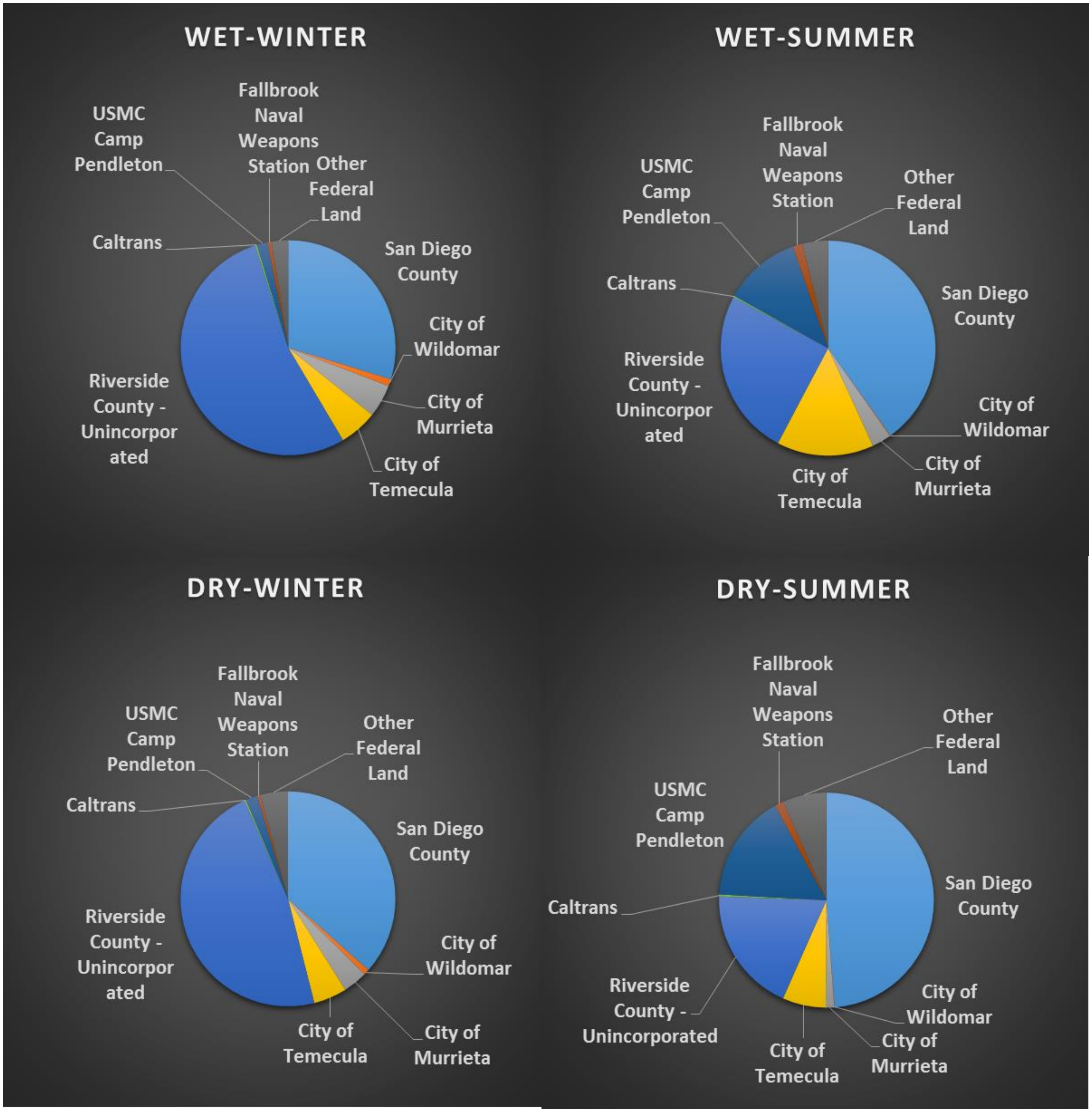


Figure 3.27. Land Use-based Delivered Total Nitrogen Load by Jurisdiction, Season, and Hydrologic Condition

Note: Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. Refer to Appendix 3 for a detailed tabulation of loads by jurisdiction, hydrologic condition, and month.

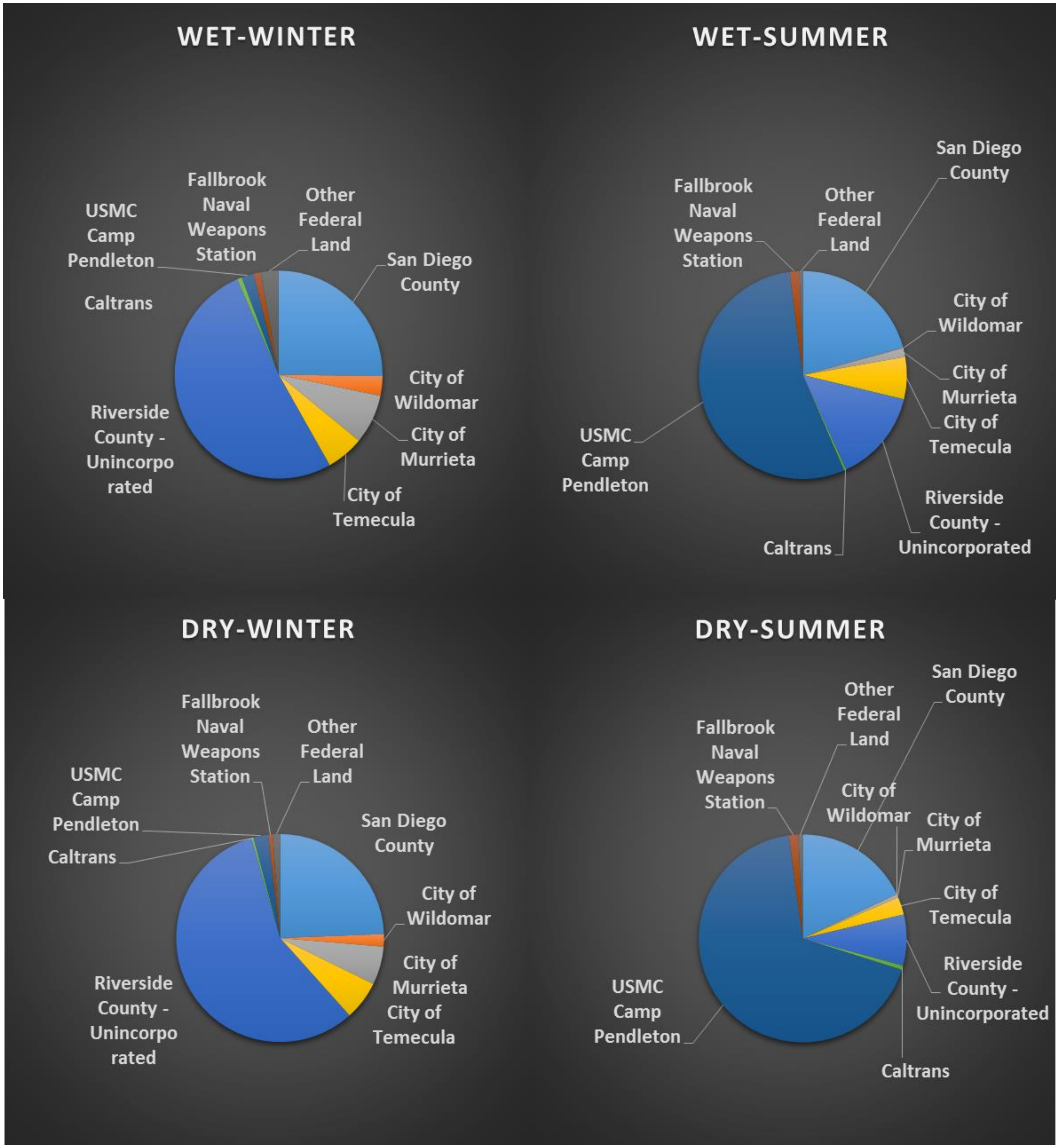


Figure 3.28. Land Use-based Delivered Total Phosphorus Load by Jurisdiction, Season, and Hydrologic Condition

Note: Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill. Refer to Appendix 3 for a detailed tabulation of loads by jurisdiction, hydrologic condition, and month.

3.4.2 Total Loads: Comparison of Land Use-based Loads to other Nutrient Sources

Section 3.4.1 evaluated only the land use-based loads. Total loading of nutrients to the Estuary also includes contributions from reservoir releases, water discharges, surfacing groundwater from alluvial aquifers, and direct subsurface loading from local agricultural fields to the Estuary[4]. The relative importance of land use-based loads can be explored by putting these loads in context with the other sources of nutrient loads to the Santa Margarita Estuary.

At-source loads from these source are calculated based on discharge records and available concentration monitoring data. The loads are represented as subject to the same estimated delivery factors as the land-based loads (Section 3.3.2), depending on their point of discharge into the system. This provides a consistent basis for comparison. It should be d that the delivered load estimates are in part conditional on the way the delivery factor is calculated. For this exercise, delivery factors are estimated for summer and winter periods, whereas in fact they vary on a finer time scale. This can result in some biases in the summary – for instance, there is likely a greater delivery of released loads during the relatively wet month of May compared to the average delivery calculated for all summer months, which includes periods in which there is frequently no continuous flow to the estuary.

Keeping in mind these caveats, average month-by-month summaries of all loads for total nitrogen and for total phosphorus are provided in Table 3.21 and Table 3.22, respectively. Additional details are provided in Appendix 3.

[4] The loads from agricultural fields adjacent to the Estuary are as specified in the modeling report for the Santa Margarita Estuary (Section 2) and are not simulated by the HSPF model. These loads have changed over time and are believed to be representative of conditions ca. 2010.

Table 3.21. Summary of Average Total Nitrogen Source Load and Delivery for All Sources, 2003-2010 (lbs/mo)

TN	CWRMA releases		Upstream Reservoirs		Lake O'Neill		Aquifer Discharge		Land use-based		Direct Groundwater Input	
Month	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered
1	506	374	913	24	418	365	4,167	3,859	106,667	70,092	21	21
2	332	245	751	22	595	673	7,314	7,361	117,962	77,629	1	1
3	475	351	755	23	795	861	8,214	8,988	31,681	21,134	0	0
4	475	351	652	17	760	665	7,482	6,547	13,762	8,986	0	0
5	472	16	60	0	124	12	5,348	508	4,083	177	0	0
6	576	20	34	0	70	7	1,880	179	1,820	97	207	207
7	507	17	435	1	84	8	647	61	1,606	76	207	207
8	378	13	542	1	33	3	0	0	917	56	207	207
9	377	13	166	0	64	6	5	1	772	51	207	207
10	384	284	544	13	630	551	1	1	2,739	1,809	207	207
11	318	235	667	16	134	117	0	0	2,314	1,522	207	207
12	235	173	279	7	573	502	502	439	57,196	37,073	207	207
Sum	5,035	2,092	5,798	125	4,280	3,770	35,559	27,945	341,520	218,702	1,471	1,471

Notes: Estimates of direct groundwater inputs to the Estuary are as calculated for the WASP model application (Section 2) for 2008 conditions. Estimates for other years are not available. For Lake O'Neill, "source" loads refer to loads released from the lake, which ultimately derive in large part from intercepted land use-based loads from the larger watershed, plus additional loading from Fallbrook Creek, less losses within the lake.

Table 3.22. Summary of Average Total Phosphorus Source Load and Delivery for All Sources, 2003-2010 (lbs/mo)

TP	CWRMA releases		Upstream Reservoirs		Lake O'Neill		Aquifer Discharge		Land use-based		Direct Groundwater Input	
Month	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered
1	27	26	25	24	100	98	268	273	106,056	68,285	0	0
2	18	17	23	22	143	181	303	343	53,025	34,440	0	0
3	25	24	24	23	191	231	302	380	5,965	3,936	0	0
4	25	24	18	17	182	179	273	268	3,282	2,134	0	0
5	25	2	2	0	30	7	195	45	413	19	0	0
6	31	2	1	0	17	4	69	16	155	9	0	0
7	73	5	11	1	20	5	24	5	194	9	1	1
8	93	6	17	1	8	2	0	0	83	6	1	1
9	46	3	4	0	15	4	3	1	96	8	1	1
10	20	19	13	13	151	148	0	0	864	579	1	1
11	17	16	16	16	32	31	0	0	380	244	1	1
12	12	12	7	7	138	135	20	19	231,775	144,585	1	1
Sum	413	155	161	125	1,027	1,024	1,456	1,351	402,287	254,254	6	6

Notes: Estimates of direct groundwater inputs to the Estuary are as calculated for the WASP model application (Section 2) for 2008 conditions. Estimates for other years are not available. For Lake O'Neill, "source" loads refer to loads released from the lake, which ultimately derive in large part from intercepted land use-based loads from the larger watershed, plus additional loading from Fallbrook Creek, less losses within the lake.

The relative distribution of delivered load sources is first shown for all wet weather conditions (Figure 3.29 and Figure 3.30) and for all dry weather conditions (Figure 3.31 and Figure 3.32). For non-land use-based loads, land and reservoir releases are defined as wet weather loads, while CWRMA releases, loading from the aquifers, and direct subsurface inputs to the Estuary from local agricultural fields are explicitly defined to be dry weather sources, regardless of the weather conditions, because they are not directly related to stormwater runoff processes. For wet weather conditions, land use-based loads from the watershed dominate all other sources of load. Runoff from the watershed is limited during dry periods, as the balance of loads delivered to the Estuary shifts to other sources. For dry weather conditions, aquifer discharges associated with resurfacing groundwater and CWRMA releases (which augment dry weather flows) become more important contributors to the total delivered load. Note that loads from aquifer discharges and Lake O'Neill in the Camp Pendleton area are in large part ultimately derived from the upstream portions of the watershed.

Dry weather loads behave differently during the winter and summer periods. During the winter flow, loading is generally continuous down to the Estuary, and the system is periodically flushed by wet weather events, allowing efficient delivery of loads (except for those diverted onto Camp Pendleton). In contrast, there are few wet weather events during the summer, and flow is often intermittent, resulting in much lower delivery rates. The relative importance of sources contributing TN and TP to the Estuary in the summer are shown in Figure 3.33 and Figure 3.34. In the summer, local agricultural field groundwater discharge and resurfacing groundwater in the lower Santa Margarita River aquifer area contributed relatively large TN loads. Resurfacing ground water from the Lower Santa Margarita alluvial aquifers is estimated to be a significant source of summer TP, predominantly in the early part of the season. The loads delivered to the Estuary from land use-based loads and from CWRMA releases are also important sources of summer TP loads.

It should be noted that the estimated TP load delivered to the Estuary from the upstream watershed during summer for WY 2008 is only 123 lb. This contrasts to a load of 1,850 lb from the watershed (not including groundwater inputs directly to the Estuary) assumed for the same period in the Santa Margarita Estuary model.

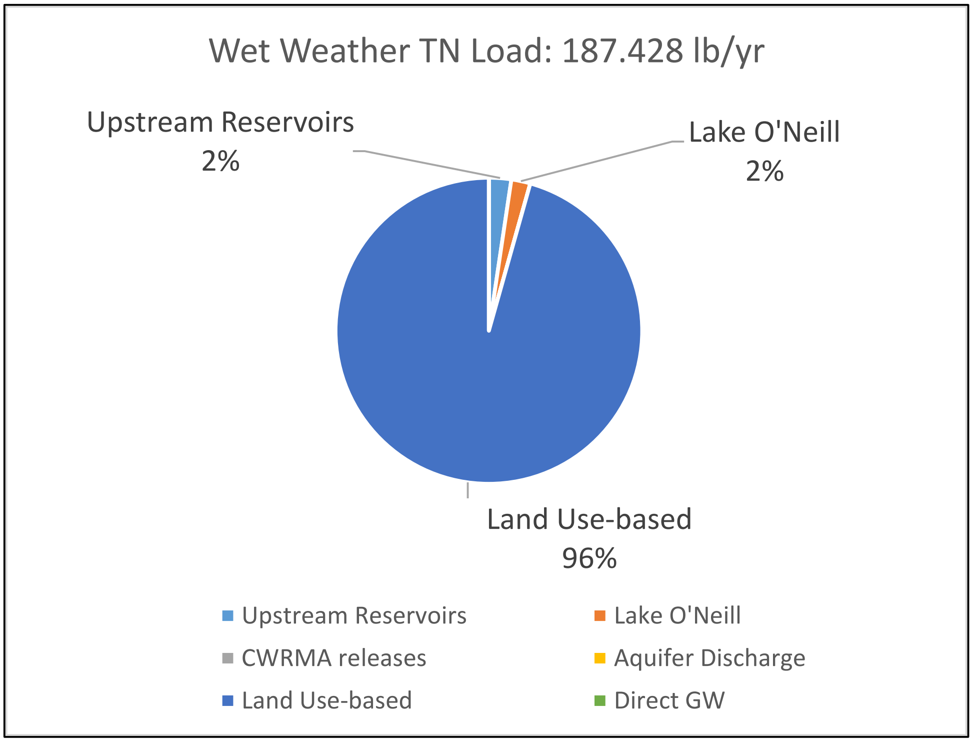


Figure 3.29. Wet Weather Delivered Total Nitrogen Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

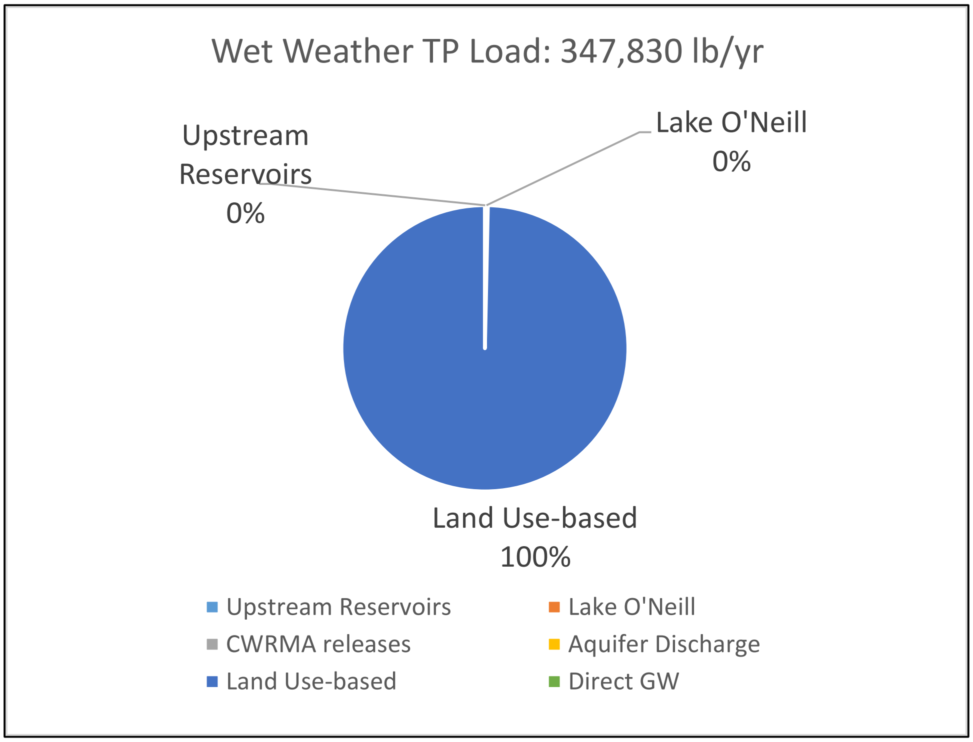


Figure 3.30. Wet Weather Delivered Total Phosphorus Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

Note: Loads associated with releases from Lake O'Neill are ultimately derived in large part from the watershed.

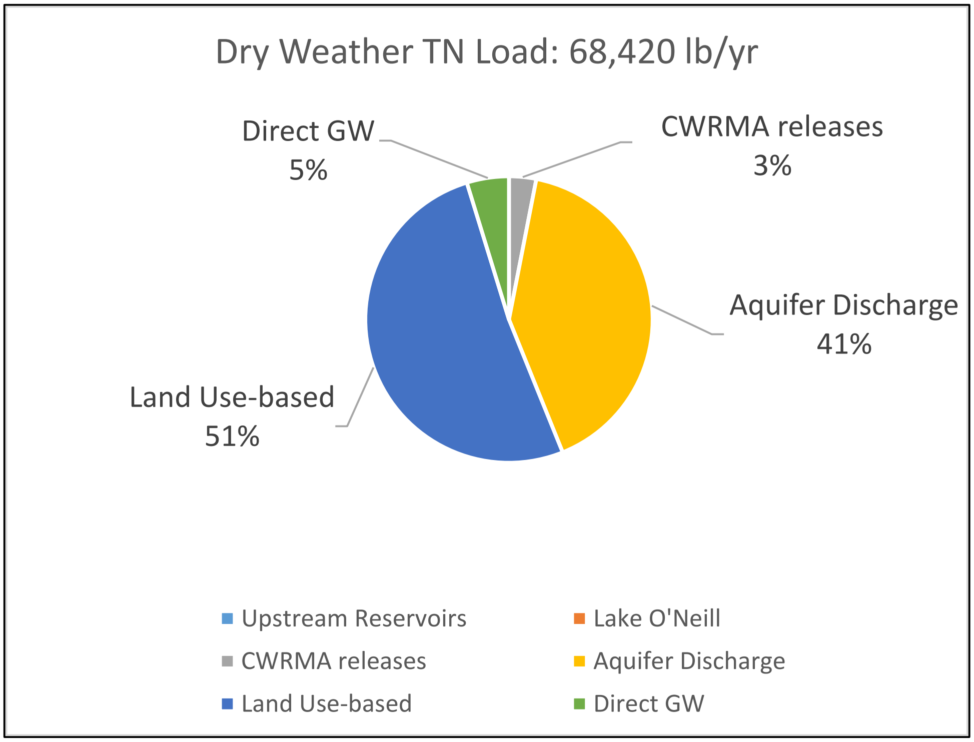


Figure 3.31. Dry Weather Delivered Total Nitrogen Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

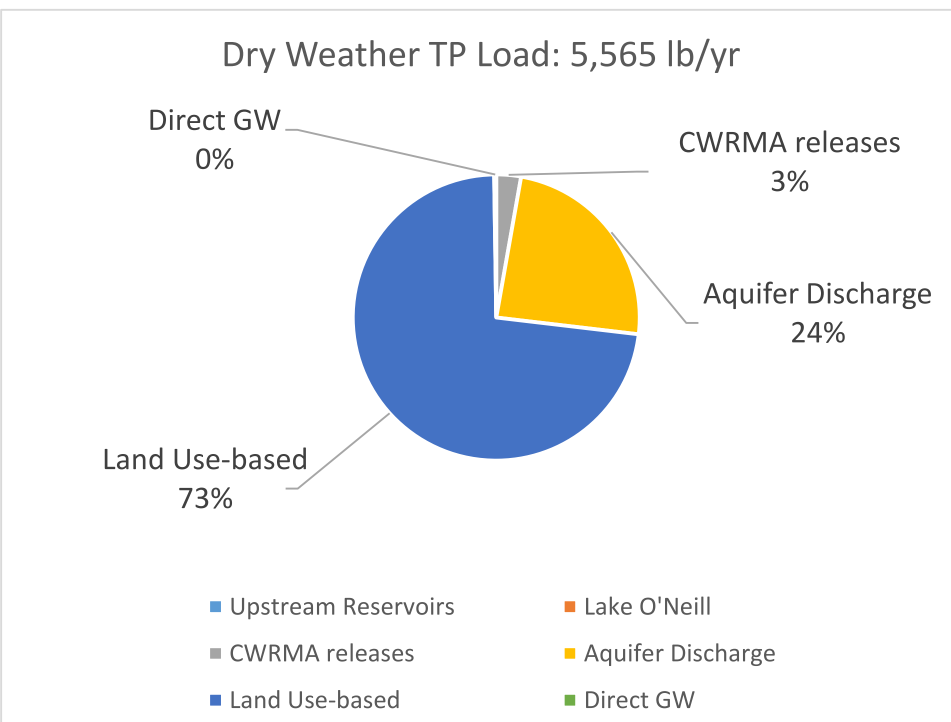


Figure 3.32. Dry Weather Delivered Total Phosphorus Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

Note: Loads associated with releases from Lake O'Neill are ultimately derived in large part from the watershed.

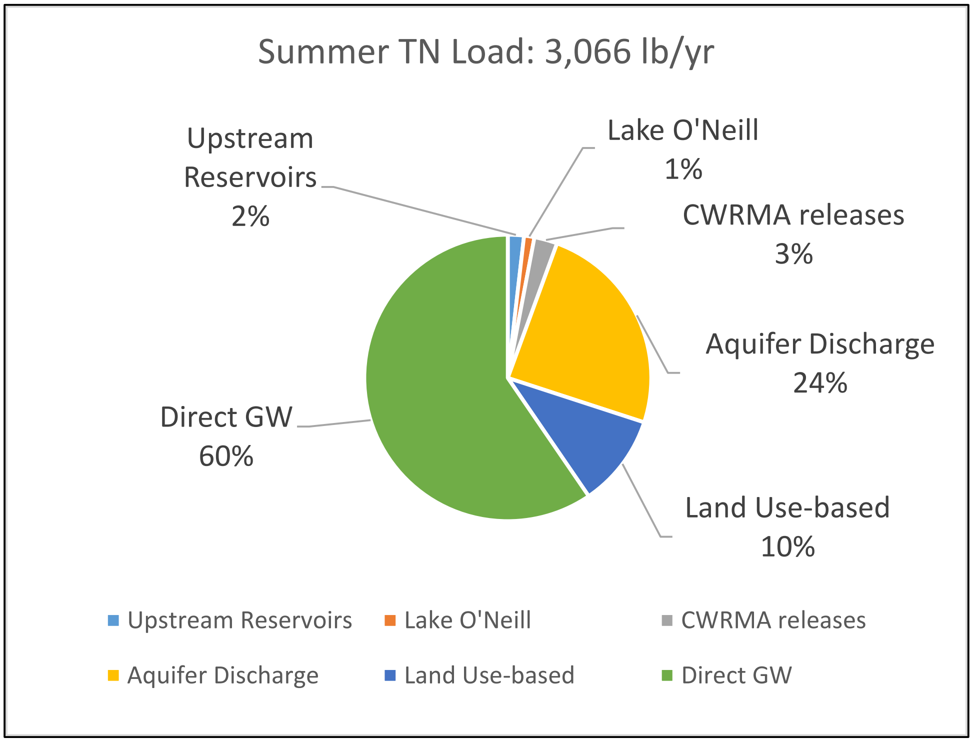


Figure 3.33. Summer Delivered Total Nitrogen Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

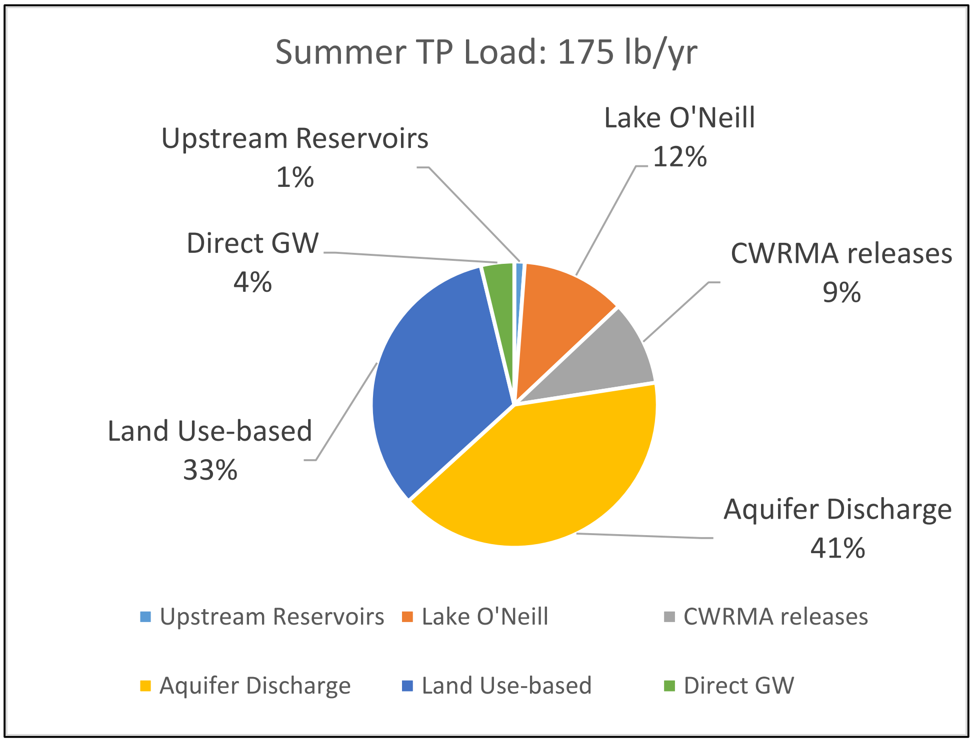


Figure 3.34. Summer Delivered Total Phosphorus Loads (lb/yr) from Land Use-based and Other Nutrient Sources in the Santa Margarita Watershed (2003-2010)

Note: Loads associated with releases from Lake O'Neill are ultimately derived in large part from the watershed.

3.4.3 Temporal Variability

In the Mediterranean climate of Southern California, the flow balance and thus the relative importance of different nutrient load sources can change drastically from year to year. The estimates of source attribution thus depend on the period that is examined.

The model simulation period of 2000-2010 includes three wet years (2005, 2009, and 2010), with the remainder representing moderate to very dry conditions. Total loading responds similarly, as is shown in Figure 3.35 and Figure 3.36, except that a very high phosphorus load is predicted in December 2010 associated with a channel erosion event. Note that years 2000-2002 had low flows and small loads; the decision to omit these years (due to the presence of various discharges) thus tends to bias the total load estimate high; similarly, if the model included the drought years after 2010, the load estimates would be lower. Table 3.23 provides the load estimates by year and compares them to WY 2008, the period for which both the groundwater model and estuary model are calibrated. Figure 3.37 compares WY 2008 to the longer-term average loads and shows that the watershed model predicted loads of total nitrogen that were higher and loads of total phosphorus that were lower than the longer-term averages. There is also substantial within-year variability in patterns. WY 2008 had elevated winter loads, but generally lower summer loads than the long-term average (Figure 3.38). If the Estuary responds primarily to total annual loads, WY 2008 would be a high-impact period; however, if the Estuary response is primarily associated with summer loads, this might not be the case. All this suggests that selecting an appropriate baseline period for future planning analysis will require significant thought.

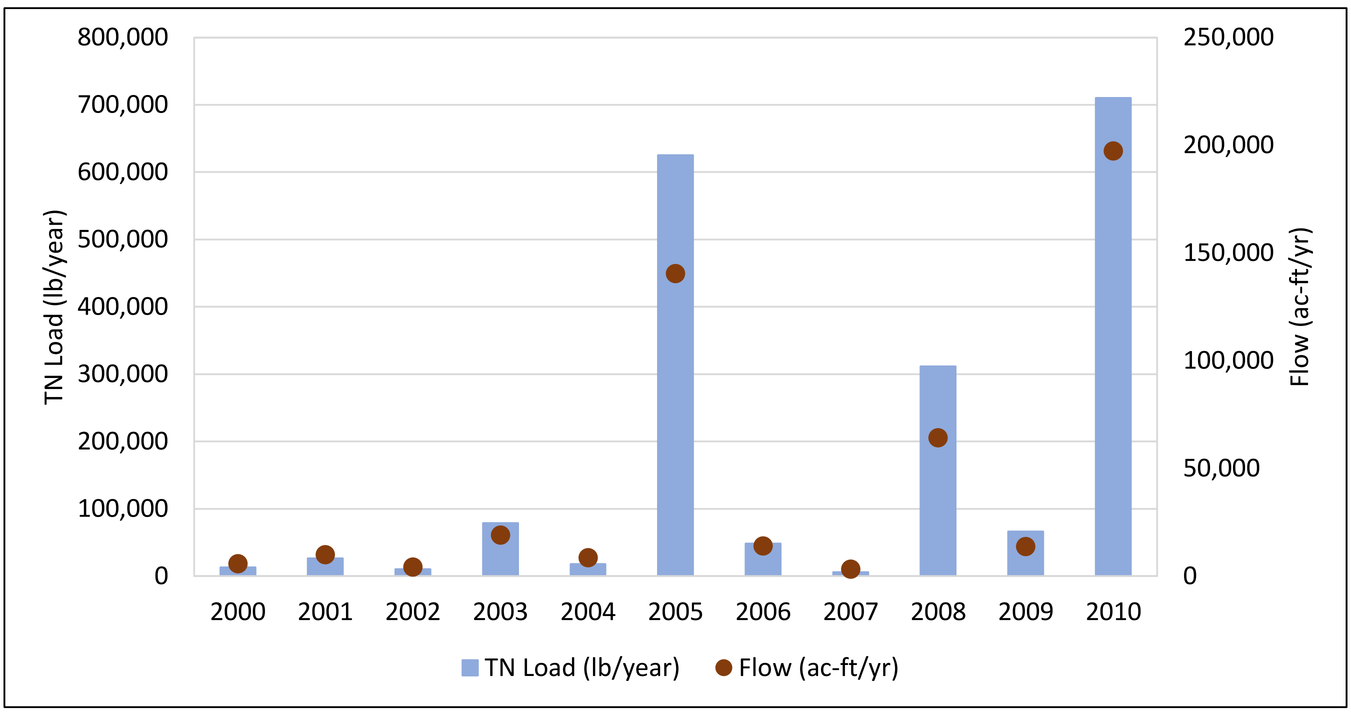


Figure 3.35. Annual Total Nitrogen Load Delivered to the Santa Margarita Estuary (Calendar Year)

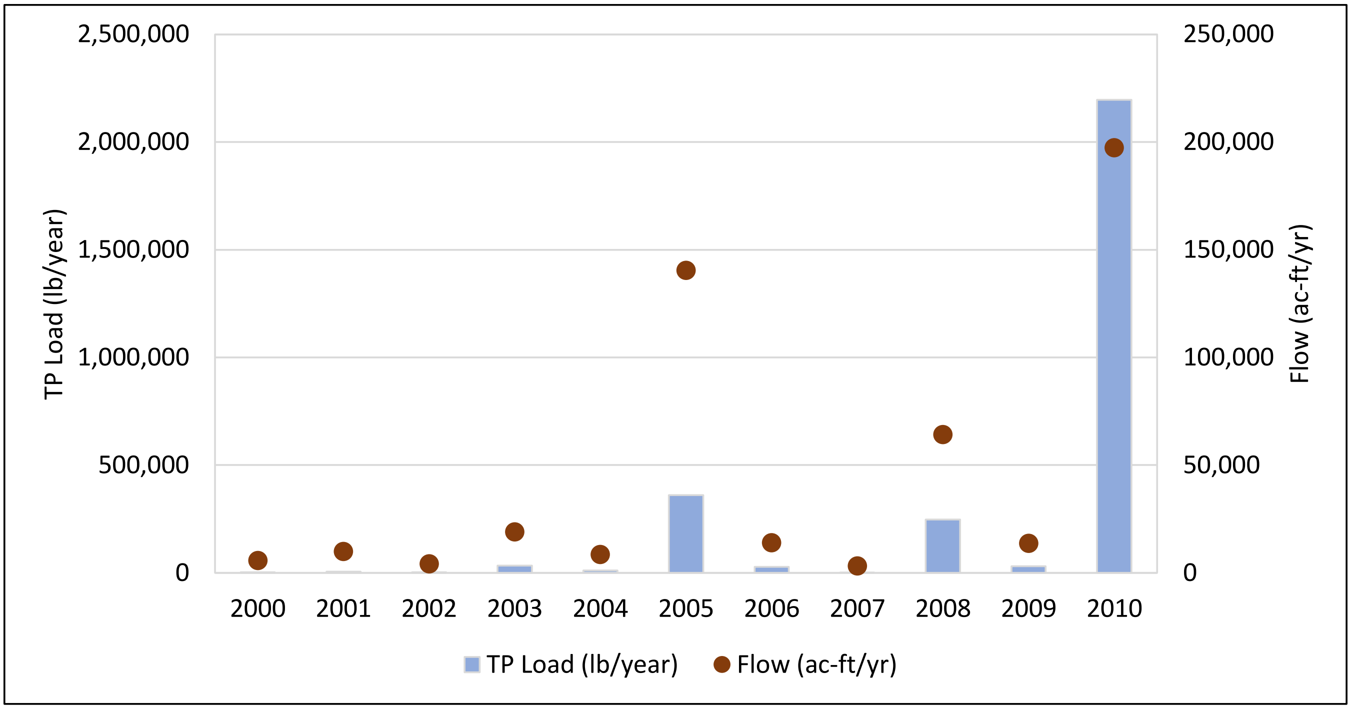


Figure 3.36. Annual Total Phosphorus Load Delivered to the Santa Margarita Estuary (Calendar Year)

Table 3.23. Annual Total Nitrogen and Total Phosphorus Load Delivered to the Santa Margarita Estuary

Year	Flow (AF/yr)	TN Load (lb/yr)	TP Load (lb/yr)
2000	5,682	13,012	2,554
2001	9,943	26,192	5,667
2002	4,215	10,045	2,781
2003	19,071	78,925	33,583
2004	8,519	17,932	10,582
2005	140,380	625,190	360,909
2006	14,013	48,435	28,333
2007	3,175	5,933	1,630
2008	64,228	311,346	247,119
2009	13,646	66,218	30,364
2010	197,419	710,111	2,195,505
2000-2010	43,663	173,940	265,366
2003-2010	57,556	233,011	363,503
WY 2008	63,054	255,024	410,635

Note: Loads are as simulated by the watershed model with the addition of 3,243 lb/yr total nitrogen and 13 lb/yr total phosphorus estimated as deriving from direct discharges to the Lagoon from local fields as part of the estuary modeling.

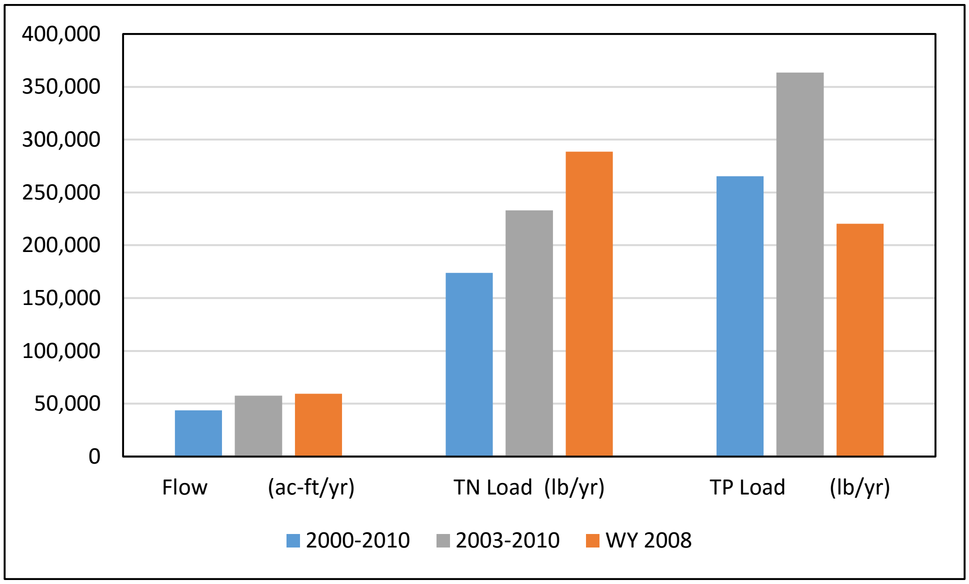


Figure 3.37. Comparison of WY 2008 to Long-term Average Loads

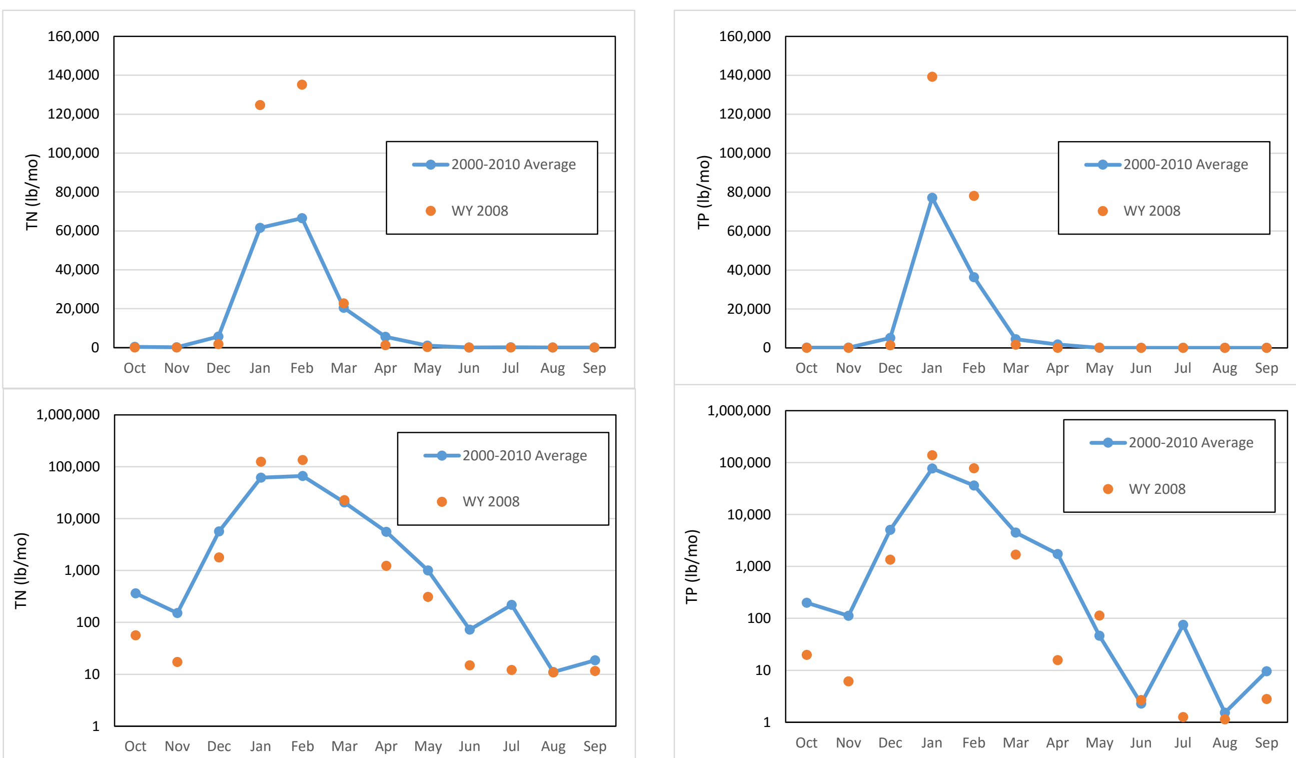


Figure 3.38. Seasonal Pattern in Nutrient Loads Delivered from the Watershed to the Santa Margarita Estuary for WY 2008

3.5 Evaluating Uncertainty

Like all environmental simulation models, the Santa Margarita River HSPF model is subject to uncertainty. The more important question is not whether it is "certain," but whether it is useful. In the case of the Santa Margarita model, the levels of uncertainty are relatively high at present, as has been discussed at some length in the model calibration documents (Tetra Tech 2013, Tetra Tech 2014). A fundamental issue is that the model has been constructed using available rain gage data, which clearly do not fully represent the range of variability of precipitation across the watershed due to orographic and rain shadow effects. Uncertainty in the data driving the rainfall-runoff relationship propagates throughout all other aspects of the model and places a limit on the accuracy that could be achieved in the water quality calibration. Tetra Tech previously identified this as a primary issue to be pursued if funding is available to improve model performance.

As reported in Tetra Tech (2014), the current calibration results for observed nutrient concentrations are at best fair and exhibit high levels of uncertainty. Relatively sparse monitoring data hampered calibration. Tetra Tech (2014) also noted that there are issues related to observed data, in which the central tendency of concentrations of some analytes at some locations appear to undergo a shift of up to an order of magnitude at certain points in time without a known explanation. Whether these shifts are due to changes in analytical methods, errors in data processing for the tables provided to Tetra Tech, or actual (but unidentified) changes in watershed processes is not known at this time. The best recourse here would likely be to extend the model forward in time so that observations obtained after 2010 can be used in the calibration process.

3.5.1 FLUX Analysis of Nutrient Loads

Analyses of the watershed relative to the Santa Margarita Estuary focus on delivered load, whether annual or seasonal. It is therefore the uncertainty in load that is of most concern for decision purposes. Unfortunately, load is not directly observed, but must be inferred from flow and concentration measurements. This has been done at the two locations that combine a significant number of water quality observations with continuous flow gaging – Santa Margarita at Temecula and Santa Margarita at FPUD Sump. (Insufficient data through 2010 are available for a reliable estimate of loads at the Ysidora gage.) These load estimates were made with the FLUX model.

FLUX is an interactive program developed by the U.S. Army Corps of Engineers' Waterways Experiment Station and designed for use in estimating loads of nutrients or other water quality constituents from concentration monitoring data (Walker 1987). The model may be used to estimate long-term load estimates or daily series based on relationships between concentration and flow. Data requirements include (a) point-in-time water quality concentration measurements, (b) flow measurements coincident with the water quality samples, and (c) a complete flow record (mean daily flows) for the period of interest.

Estimating constituent mass loads from point-in-time measurements of water-column concentrations presents many difficulties. Load is determined from concentration multiplied by flow, and while measurements of flow are continuous (daily average), only intermittent (e.g., monthly or tri-weekly grab) measurements of concentration are available. Calculating total load therefore requires "filling in" concentration estimates for days without samples. The process is further complicated by the fact that concentration and flow are often highly correlated with one another, and many different types of correlation may apply. For instance, if a load occurs primarily as a result of nonpoint soil erosion, flow and concentration will tend to be positively correlated; that is, concentrations will increase during high flows, which correspond to precipitation-washoff events. On the other hand, if load is attributable to a relatively constant point discharge, concentration will decrease as additional flow dilutes the constant load. In most cases, a combination of processes is found.

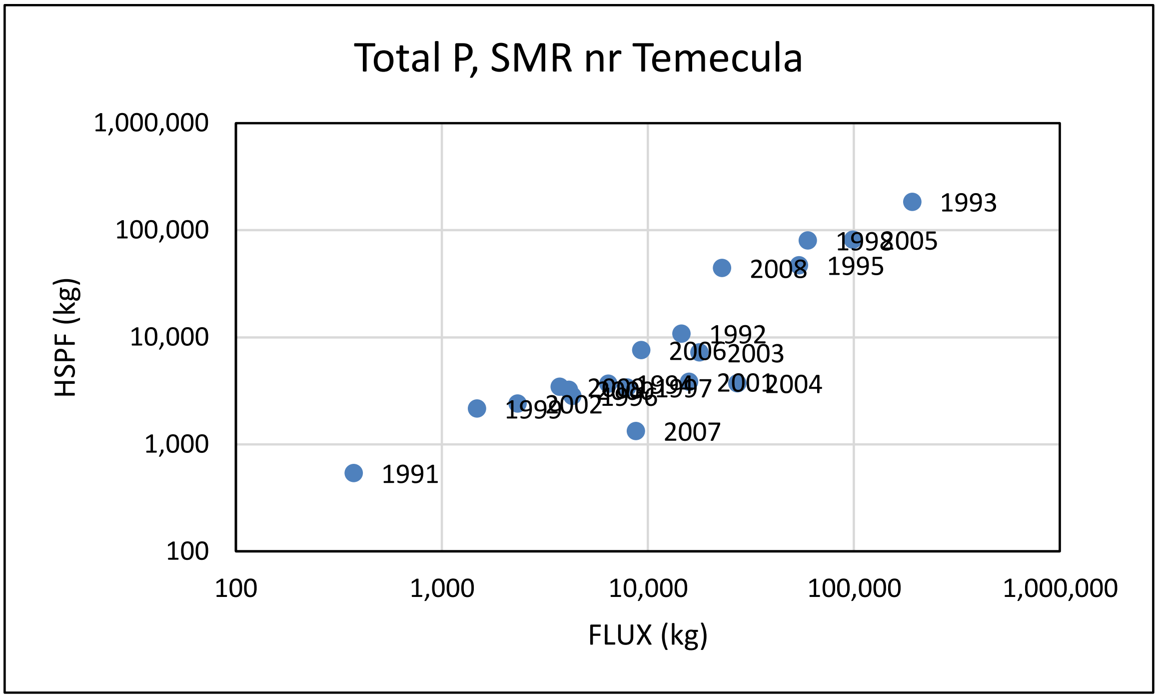
Preston et al. (1989) undertook a detailed study of advantages and disadvantages of various methods for calculating annual loads from tributary concentration and flow data. Their study demonstrates that simply calculating load for days when both flow and concentration have been measured and using results as a basis for averaging is seldom a good choice. Depending on the nature of the relationship between flow and concentration, more reliable results may be obtained by one of three approaches:

1. *Averaging Methods:* An average (e.g., yearly, seasonal, or monthly) concentration value is combined with the complete time series of daily average flows
2. *Regression Methods:* A linear, log-linear, or exponential relationship is assumed to hold between concentration and flow, thus yielding a rating-curve approach
3. *Ratio Methods:* Adapted from sampling theory, load estimates by this method are based on the flow-weighted average concentration times the mean flow over the averaging period, and performs best when flow and concentration are only weakly related

No single method provided superior results in all cases examined by Preston et al. (1989); the best method for extrapolating from limited sample data depends on the nature of the relationship between flow and concentration, which is typically not known in detail. Preston et al. (1989) show that *stratification* of the sample data and analysis method, however, can reduce error in estimation. Stratification refers to dividing the sample into two or more parts, each of which is analyzed separately to determine the relationship between flow, concentration, and load. Sample data are usually stratified into high- and low-flow portions, allowing a different relationship between flow and load at low-flow (e.g., diluting a constant base load) and high-flow regimes (e.g., increasing load and flow during nonpoint washoff events). Stratification could also be based on time or season to account for temporal or seasonal changes in loading.

FLUX analyses suggest that the watershed model is approximately unbiased for total phosphorus, although imprecise (Figure 3.39). For nitrate as N, the model appears approximately unbiased at Temecula, but appears to underestimate observed loads at Fallbrook PUD (Figure 3.40). The 95th percentile confidence intervals about the FLUX annual load series are on the order of 20-40%, reflecting the fact that the data do not strongly constrain the loads during large-volume, wet season events. In contrast to phosphorus and nitrate nitrogen, the FLUX analysis suggests that the HSPF model tends to underestimate organic nitrogen loads during high flow events at both stations.

These load analyses suggest the need for model refinements, especially as regards to the nitrogen simulation; however, this would primarily be a concern for the use of the model if the total annual loads are an important decision criterion. It appears likely, however, that the responses in the Santa Margarita Estuary are more strongly dependent on summer nutrient loads and concentrations in the reaches immediately upstream of the estuary. As was seen in previous sections, nutrients in this area during summer are strongly affected by diversions, streambed losses, and resurfacing groundwater in the area of the Lower Santa Margarita aquifer. Model performance in this time period cannot be effectively evaluated with FLUX due to limited monitoring and intermittent flows. Instead, the significance of uncertainty relative to uses of the model is best evaluated through a sensitivity analysis approach.



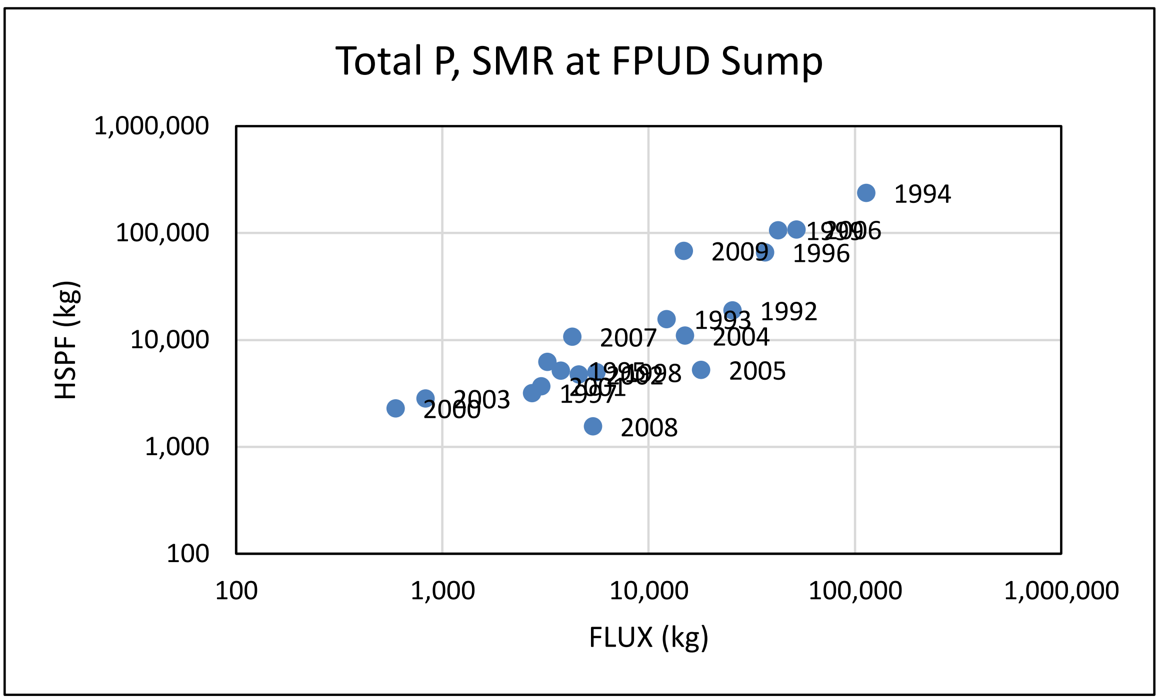
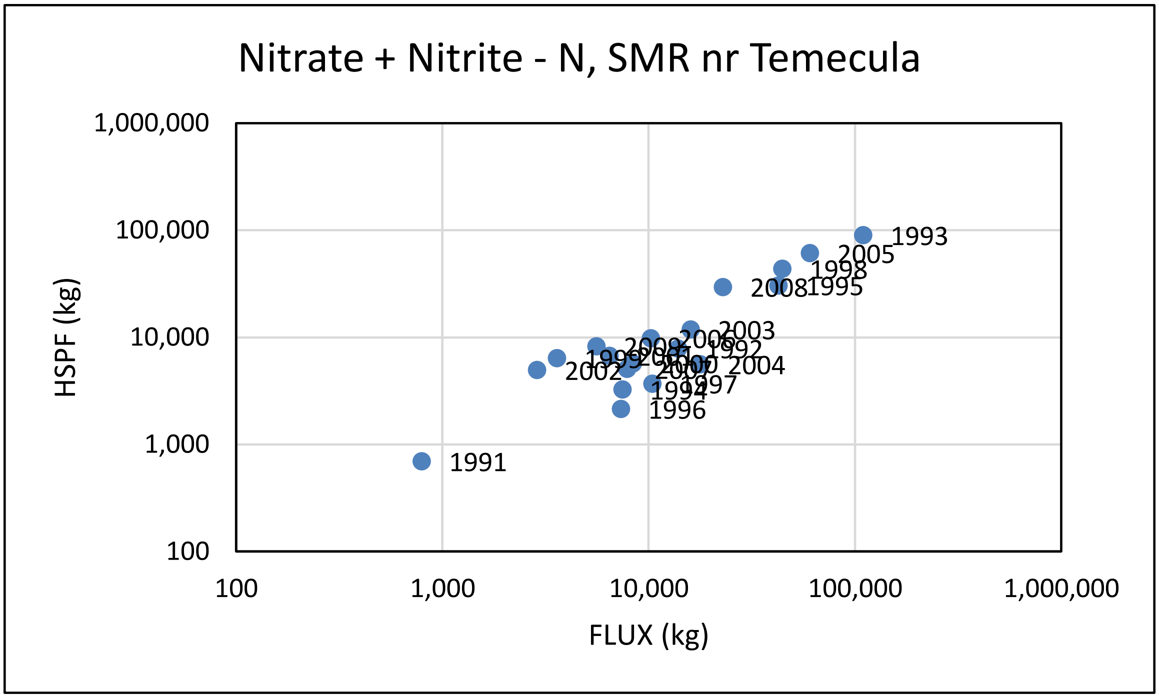


Figure 3.39. Comparison of HSPF and FLUX Annual Loads for Total Phosphorus



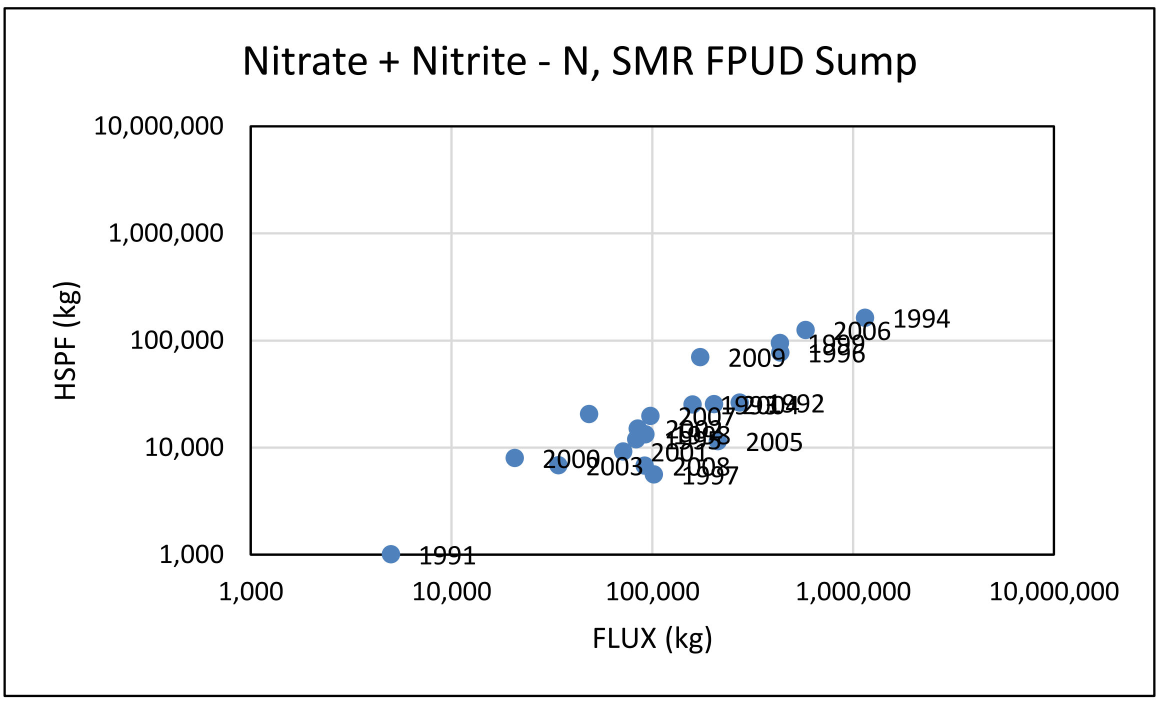


Figure 3.40. Comparison of HSPF and FLUX Annual Loads for Nitrate Nitrogen

3.5.2 Sensitivity Analyses

Sensitivity analyses were developed to test the sensitivity of model results to input assumptions. There are a vast number of sensitivity analyses that could be attempted, but the available level of effort precluded a comprehensive investigation. Rather, a targeted subset of sensitivity analyses is presented. In these analyses, a single factor is varied by a fixed percentage. Results are reported in terms of changes in estimated annual and summer loads as delivered to the Estuary. Results are also reported in terms of the resulting impacts on the percentage of load attributed to Riverside (unincorporated area plus municipalities) and San Diego County. This is used as an indicator of whether the *relative* magnitude of source attribution is responsive to a sensitized parameter. In both cases, results can be summarized in dimensionless leverage coefficients that are calculated as the percent change in the endpoint divided by the percent change in the sensitized input. All sensitized inputs are varied by ±20%.

Description of Sensitivity Analyses

Run 1. Sensitivity to Nursery/Orchard/Vineyard Loading Rate

The nursery/orchard/vineyard aggregate land use class has the highest loading rates, both in terms of concentration and total mass per acre. One concern is that uncertainty in the loading rate for this class might bias the attribution of sources of loads between jurisdictions. Both surface and subsurface loading rates for this land use are increased by 20%.

Run 2. Sensitivity to Land Area Assignment between Residential and Orchard/Vineyard Land Uses

Anecdotal information suggests that the land use coverage may underestimate the area in orchard and vineyards, especially for small plots within rural residential areas. This sensitivity analysis increases the area in the orchard and vineyard land use class and deducts a corresponding amount of acreage from the low-density residential land use class.

Run 3. Sensitivity to Watershed Nutrient Loading

The FLUX analysis suggests that the model may underestimate organic N loading during wet weather. This analysis tests the model sensitivity to a 20% increase in the loading rates of both nitrogen and phosphorus in surface runoff.

Run 4. Sensitivity to Watershed Delivery Factors upstream of Camp Pendleton

Analysis using delivery factors tends to discount the influence of sources in the upper watershed. For this analysis, the delivery factors for individual reaches upstream of Camp Pendleton are decreased by 20%.

Run 5. Sensitivity to Losses Lower Santa Margarita River Aquifer

Losses to the aquifer reduce the throughput of loads during the summer. Sensitivity is tested by increasing the demand exerted by the aquifer on the stream by 20%. Note that not all of this demand will be fulfilled, depending on the amount of water present in the river.

Run 6. Sensitivity to Discharges from the Lower Santa Margarita River Aquifer

During early summer, discharges from the aquifer to the stream may be a significant source of nutrient load. This is examined by increasing the discharge rate by 20%.

Run 7. Sensitivity to Phosphorus Concentration in Discharges from Aquifer

Phosphorus concentrations in groundwater are not available. The model uses an assumed concentration of 0.1 mg/L. This test increases the concentration by 20%.

Sensitivity Analysis Results

Table 3.24 and Table 3.25 show the sensitivity analysis results for annual and summer delivered loads, respectively. Sensitivity analyses 1 through 3, which involve increasing loading rates in areas of high-loading upland load sources, have a moderate impact on annual delivered loads, although leverage factors are less than 1. In contrast, these scenarios have very little impact on summer delivered loads. The largest impact on annual loads comes from reducing the delivery factors in run 4 (i.e., simulating greater retention of nutrients) in the reaches upstream of Camp Pendleton, although the effect is again muted during the summer.

Not surprisingly, sensitivity analyses that investigate the effect of changing the losses to or discharges from the Lower Santa Margarita aquifer (runs 5-7) have a noticeable impact on summer loads, but only a small effect on annual loads. The solution is not particularly sensitive to the specification of phosphorus concentration in water discharging from the aquifer (run 7), which is reassuring as monitoring data are not available.

Increasing water losses to the alluvial aquifer in the Lower Santa Margarita reduces land use-based nitrogen loads, but has little effect on land-use based phosphorus loads. This is because nitrogen loads from the land continue to be contributed by shallow seepage through the summer, while phosphorus loads from the land are mostly associated with wet weather events, which are rare during the period when loss to the aquifer occurs. Increasing aquifer discharge rates decreases the throughput of loads from the upstream watershed somewhat, likely due to increased water availability resulting in more algal growth and nutrient retention.

The relative attribution of loads to San Diego and Riverside Counties varies by less than a percentage point among sensitivity analyses for annual delivered loads, with the exception of run 4. This run demonstrates that higher retention rates within the watershed would reduce the relative importance of Riverside County loads. The summer results are similar, although increasing the loss rates to the aquifer also has the effect of reducing the percent contribution from the counties. These results suggest that the model estimates of percent contributions from different sources are relatively robust despite uncertainties in the quantitative estimates of delivered loads.

Table 3.24. Results for Sensitivity Analyses for Total Annual Load Delivered to Santa Margarita Estuary (2003-2010 average in lb/yr)

Total Nitrogen								Total Phosphorus						
Sensitivity Run	**San Diego Co.**	**Riverside Co.**	**Other land-based**	**Other loads**	**% San Diego**	**% Riverside**	**Leverage**	**San Diego Co.**	**Riverside Co.**	**Other land-based**	**Other loads**	**% San Diego**	**% Riverside**	**Leverage**
Baseline	64,553	139,237	10,601	41,457	25.23%	54.42%		87,401	241,641	21,696	2,658	24.73%	68.38%	
1	69,239	153,384	10,603	41,457	25.21%	55.84%	0.368	91,125	253,067	21,697	2,658	24.73%	68.67%	0.214
2	67,298	150,956	10,584	41,457	24.90%	55.85%	0.282	85,022	247,150	21,644	2,658	23.85%	69.33%	0.044
3	67,285	146,399	11,215	41,457	25.26%	54.96%	0.205	104,070	287,101	25,932	2,658	24.79%	68.40%	0.939
4	24,930	37,254	5,129	37,010	23.90%	35.71%	-2.961	35,499	55,585	9,192	2,463	34.55%	54.10%	-3.546
5	64,621	139,219	9,732	41,004	25.38%	54.69%	-0.025	87,320	242,125	21,676	2,641	24.68%	68.44%	0.005
6	65,032	140,288	10,656	46,879	24.74%	53.37%	0.137	86,868	240,171	21,565	2,890	24.71%	68.33%	-0.027
7	64,553	139,237	10,601	41,457	25.23%	54.42%	0.000	87,401	241,641	21,696	2,926	24.71%	68.33%	0.004

Notes: The Riverside County total includes the municipalities of Murrieta, Temecula, and Wildomar. “Other land-based” loads include State and Federal lands. “Other loads” includes contributions from resurfacing groundwater from the alluvial aquifer, CWRMA releases, and reservoir releases. Leverage coefficients show the change in total load per change in sensitized parameter.

Table 3.25. Results for Sensitivity Analyses for Summer (May-September) Load Delivered to Santa Margarita Estuary (2003-2010 average in lb/yr)

Total Nitrogen								***Total Phosphorus***						
Sensitivity Run	**San Diego Co.**	**Riverside Co.**	**Other land-based**	**Other loads**	**% San Diego**	**% Riverside**	**Leverage**	**San Diego Co.**	**Riverside Co.**	**Other land-based**	**Other loads**	**% San Diego**	**% Riverside**	**Leverage**
Baseline	114	86	120	2,746	3.73%	2.80%		18	22	18	118	10.12%	12.75%	
1	122	87	120	2,746	3.98%	2.84%	0.015	19	23	18	118	10.89%	12.98%	0.066
2	117	82	120	2,746	3.83%	2.68%	-0.001	18	22	18	118	10.25%	12.44%	-0.012
3	115	88	120	2,746	3.74%	2.86%	0.004	18	24	18	118	10.29%	13.33%	0.068
4	41	23	107	2,655	1.46%	0.81%	-0.392	7	5	17	105	5.08%	4.07%	-1.190
5	81	59	112	2,579	2.85%	2.08%	-0.383	17	22	18	103	10.67%	13.91%	-0.430
6	104	78	112	2,817	3.34%	2.50%	0.074	15	19	17	112	9.39%	11.83%	-0.332
7	114	86	120	2,746	3.73%	2.80%	0.000	18	22	18	132	9.36%	11.79%	0.407

Notes: Riverside County total includes the municipalities of Murrieta, Temecula, and Wildomar. “Other land-based” loads include State and Federal lands. “Other loads” includes contributions from resurfacing groundwater from the alluvial aquifer, CWRMA releases, and reservoir releases. Leverage coefficients show the change in total load per change in sensitized parameter.

3.6 Summary of Nutrient Loading Analysis

The analyses presented in this report demonstrate that the HSPF watershed model can provide a reasonable basis for understanding the relative importance of different sources of nutrient loads to the Santa Margarita Estuary. It should be noted, however, that the current analysis is based on a model that is known to be uncertain and that can clearly be improved. As has previously been presented, key areas for potential improvement include the following:

- Better representation of precipitation and associated improvements in hydrologic simulation through use of PRISM topographically adjusted precipitation time series, instead of relying on sparse gage measurements.
- Extension of both the hydrologic and water quality calibration to make use of monitoring conducted since 2012.
- Integration of the simulation output of the MODFLOW model of the Pauba and Temecula aquifers (Murrieta vicinity) to improve watershed model simulation of groundwater exchanges, similar to what has been done with the model of the Lower Santa Margarita aquifer.
- More detailed and data-based representation of irrigation and irrigation return flows.
- Incorporation of results of other recent studies on conditions and nutrient loading sources in the watershed.

Despite these potential improvements, the existing model is believed to provide a reasonable representation of the relative contribution of different load sources, even though the exact amounts might differ in a revised model. The interpretation of the model into delivered loads from individual sources is, however, dependent on the period that is analyzed – both the scope of years and the division into seasons. The current analyses divide the year into winter (Oct.-Apr.) and summer (May-Sept.) and dry and wet periods. Actual delivery ratios vary by month and by event. It is necessary to make some assumptions to interpret the model results, as individual sources are not tracked through the model to the Estuary, and indeed cannot be due to interactions and cycling with algae. Early summer delivery factors are likely greater than the average summer delivery factor because there is more continuous flow to the estuary in early summer. The way in which the model output is best analyzed relative to categories of interest for source attribution depends on the definition of the critical period. For instance, a focus on early summer loads, versus full summer loads, versus all dry weather loads, would all yield somewhat different results. Stakeholders have been engaged in discussion on the best approach for evaluating loads relevant to impacts in the Estuary, but have not at this point reached a final conclusion as to the critical conditions to be analyzed.

It is clear that the dynamics of the system vary greatly by season. During winter wet weather, high land-based loads are generated, and these are largely transported through to the Estuary, except for the amount removed by diversions onto Camp Pendleton; however, a significant portion of these loads are transported through the Estuary to the ocean. During winter dry weather, there is less load generation and lower rates of transport; however, loads during winter dry weather are likely to be flushed through to the Estuary if there are succeeding wet weather events. Summer loads are predominantly dry weather loads, and these loads are strongly affected by water management on Camp Pendleton, including diversions, recharge, and pumping from the alluvial aquifer. Santa Margarita River is intermittent, so flow to SMRE is often discontinuous. During early summer, discharge from the Lower Santa Margarita aquifer to the stream becomes a source of nutrient load. During later summer, the dominant source of nitrogen to the Estuary appears to be the load attributed to direct groundwater inputs from adjacent agricultural fields based on the direct loading estimates for ca. 2010 conditions[5], while delivered phosphorus load from all sources is quite low. Under these conditions, loads from the upper watershed are largely disconnected from the aquifer because most flow past Camp Pendleton is depleted by aquifer demand.

The results also depend on the years that are selected for analysis. The Mediterranean climate of Southern California is highly variable from year to year, and which years are included makes a difference in the relative importance of different sources. For instance, the influence of loads from the upper watershed will be greater in years of ample rainfall, during which consistent throughflow is maintained for a longer period during the summer. To incorporate a more representative sampling of potential conditions, it may be advisable to conduct simulations that cover multiple decades of weather input, while maintaining current conditions for controlled discharges.

In sum, the existing modeling tools provide a quantitative basis to quantify nutrient loads and source for the Santa Margarita watershed. The tools can be improved, but the basics are there.

[5] This input source has been evaluated by SPAWAR over a number of years, and more recent data (post-2010) are reported to show an approximate order-of-magnitude decrease in nitrate nitrogen loading. The significance of this source relative to other sources under current conditions should be re-evaluated with respect to newer data.

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APPENDIX 1: ORDER OF OPERATIONS TO AGGREGATE WASP MODEL OUTPUT TO SUPPORT DECISIONS ON ALLOWABLE LOADS

We used simulations of the SMRE WASP to develop load-response curves for each of the candidate numeric target indicators of interest (nutrient concentrations, DO, and macroalgal biomass). In order to do this, decisions were made, based on stakeholder input and consensus, about the ways in which model output should be processed to perform these calculations. Because raw WASP model output represents a four-dimensional data stream, the output can be used to make these calculations in a variety of different ways that collectively can make the calculated allowable loads either more or less stringent.

This appendix provides a detailed description of how model output was manipulated in order to prepare it for the analyses of allowable loads for indicators: 1) TN and TP, 2) dissolved oxygen, and 3) macroalgal biomass.

WASP model output used for these analyses is provided in ~ 2-hour time steps over 2007-2009 for each of the 140 grid cells that represent the estuary model domain. Grid cell #1 is the most seaward surface cell (Figure A1), while grid cell #70 is at the head of estuary. Grid cells #71 through #140 are the corresponding bottom cells from seaward to head of estuary, respectively.

Order of Operations for TN and TP. The following gives the order of operations to aggregate model output for TN and TP:

1. For each time step, average the top and bottom grid cell for each spatial point in the estuary.
2. Average across the channel cross section (see Figure A1).
3. Calculate the daily average concentrations of 12:01 a.m.-12:00 midnight.
4. Identify which days are wet versus dry weather, using rainfall data where wet = > 0.2 inches per day, plus 72 hours.
5. Using the following data combinations, calculate the 90th percentile of the TN or TP concentrations over the period of October 2007-October 2008 simulations.
   a. Wet and dry weather together
   b. Dry weather only (wet weather days (day of storm + 72 hours) removed from the data set)
   c. Winter dry weather (October 1-April 30) only
   d. Summer dry weather (May 1-September 30)
6. Perform steps 1-5 for each of the load reduction scenarios.

Figure A1. Numbering of model domain surface grid cells, from #1 (seaward grid cell) to #70 (head of estuary). Grid cells #71 through #140 represent the bottom cell across that same longitudinal gradient from seaward to head of estuary, respectively.

Order of Operations for DO. The following gives the order of operations to aggregate model output for DO:

1. For each time step, average the top and bottom grid cell for each spatial point in the estuary.
2. Average across the channel cross section (see Figure A1).
3. Reduce the data set to the period in which the calibration was deemed acceptable (April 1-November 1, 2008).
4. Calculate the 10th percentile of the DO concentrations over the period of acceptable model output.
5. Perform steps 1-4 for each of the load reduction scenarios.

Order of Operations for macroalgae. The following gives the order of operations to aggregate model output for macroalgal biomass:

1. For each time step, sum the top and bottom grid cell for each spatial point in the estuary. This gives a mass per square meter.
2. Average across the channel cross section (see Figure A1).
3. Calculate the daily average biomass for November 2007-November 2008.
4. Calculate the maximum daily biomass from each calendar month.
5. Calculate the single maximum of the summer peak macroalgal biomass (maximum of the monthly maximum).
6. Perform steps 1-5 for each of the load reduction scenarios.

Appendix 2. Definitions of Beneficial Uses Applicable to Nutrient Management in SMRE

Marine Habitat (MAR) - Uses of water that support marine ecosystems including, but not limited to, preservation or enhancement of marine habitats, vegetation such as kelp, fish, shellfish, or wildlife (e.g., marine mammals, shorebirds).

Estuarine Habitat (EST) - Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Cold Freshwater Habitat (COLD) - Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.

Warm Freshwater Habitat (WARM) - Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.

Wildlife Habitat (WILD) - Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Rare, Threatened, or Endangered Species (RARE) - Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.

Spawning, Reproduction, and/or Early Development (SPWN) - Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish. This use is applicable only for the protection of anadromous fish.

Migration of Aquatic Organisms (MIGR) - Uses of water that support habitats necessary for migration, acclimatization between fresh and salt water, or other temporary activities by aquatic organisms, such as anadromous fish

Commercial and Sport Fishing (COMM) - Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Shellfish Harvesting (SHELL) - Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters and mussels) for human consumption, commercial, or sport purposes.

Aquaculture (AQUA) - Uses of water for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, or harvesting of aquatic plants and animals for human consumption or bait purposes.

Contact Water Recreation (REC-1) - Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and SCUBA diving, surfing, white water activities, fishing, or use of natural hot springs.

Non-contact Water Recreation (REC-2) – Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

APPENDIX 3: DETAILED TABULATIONS OF NUTRIENT LOADING

This section provides more detailed tabulations of both at-source and delivered nutrient loadings by jurisdiction, hydrologic condition, and month. The first section presents the at-source land use-based loads – one table per month/nutrient combination based on the average of 2003-2010 simulations. This is followed by a similar tabulation land use-based loads delivered to the estuary. The final tables show the at-source and delivered loads from other sources such as reservoir releases, CWRMA releases, and resurfacing ground water from the alluvial aquifer. These latter sources are not directly driven by precipitation events and are best compared to the dry hydrologic condition loads for land use-based sources.

Average At-Source Land Use-based TN Loads (lb/month) for January (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	3,598	405	6,654	775	281	57
	High Density	71	7.8	4,107	455	15	1.8
	Transitional	1.7	0.1	1,890	120	11	0.8
Residential Total		3,671	413	12,652	1,350	307	60
Commercial/Industrial	Commercial, Institutional	30	3.8	765	124	47	9.5
	Horse Ranches	0.0	0.0	3,218	329	0.0	0.0
	Industrial	53	7.4	754	121	35	6.9
Commercial/Industrial Total		84	11	4,737	574	82	16
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	3.2	0.2	686	44	4.2	0.2
Forest	Forest	192	15	187	14	31	2.6
Agriculture	Irrigated Agriculture	2,037	238	4,922	627	74	14
	Non-irrigated Agriculture	0.0	0.0	955	40	5.4	0.2
	Orchard, Vineyard, and Nursery	8,785	1,552	31,176	4,505	11	0.5
	Dairy, Livestock	0.0	0.0	84	18	0.0	0.0
Agriculture Total		10,822	1,790	40,355	5,519	90	15
Open Space	Open and Recreation	3.0	0.1	47	2.6	2.7	0.1
	Chaparral, Scrub	4,896	1,031	6,377	760	1,789	373
	Grassland, Herbaceous	3,353	801	1,960	162	1,220	106
Open Space Total		8,252	1,831	8,384	924	3,012	479
CALTRANS	CALTRANS (within each jurisdiction)	57	5.4	216	26	3.9	0.5
Total Land Use-based Load		22,889	4,051	63,812	8,107	3,500	571

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for February (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	4,173	440	7,589	910	503	45
	High Density	80	8.5	5,025	548	20	2.0
	Transitional	2.0	0.2	2,059	140	14	0.9
Residential Total		4,255	449	14,672	1,597	538	48
Commercial/Industrial	Commercial, Institutional	30	4.2	947	149	78	8.3
	Horse Ranches	0.0	0.0	4,011	428	0.0	0.0
	Industrial	57	8.3	842	132	80	3.7
Commercial/Industrial Total		87	13	5,800	710	158	12
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	3.3	0.2	735	52	4.1	0.3
Forest	Forest	220	19	230	19	38	3.2
Agriculture	Irrigated Agriculture	1,890	261	4,764	618	118	11
	Non-irrigated Agriculture	0.0	0.0	1,107	43	4.3	0.2
	Orchard, Vineyard, and Nursery	8,959	1,758	31,394	5,709	9.8	0.6
	Dairy, Livestock	0.0	0.0	137	13	0.0	0.0
Agriculture Total		10,849	2,018	41,413	6,812	132	12
Open Space	Open and Recreation	2.8	0.1	50	3.0	3.0	0.2
	Chaparral, Scrub	5,467	1,308	7,638	972	2,202	490
	Grassland, Herbaceous	3,546	948	2,205	191	1,480	116
Open Space Total		9,015	2,256	9,894	1,166	3,685	606
CALTRANS	CALTRANS (within each jurisdiction)	74	6.4	263	30	7.3	0.5
Total Land Use-based Load		24,284	4,743	68,766	9,939	4,524	679

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for March (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	883	618	1,402	1,332	89	115
	High Density	16	12	945	782	3.4	3.4
	Transitional	0.4	0.2	365	173	2.2	1.3
Residential Total		899	630	2,712	2,287	95	119
Commercial/Industrial	Commercial, Institutional	6.3	5.9	214	207	14	18
	Horse Ranches	0.0	0.0	679	479	0.0	0.0
	Industrial	12	10	181	182	11	13
Commercial/Industrial Total		18	16	1,074	868	25	31
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.6	0.3	124	61	0.7	0.3
Forest	Forest	17	19	20	26	3.8	4.8
Agriculture	Irrigated Agriculture	312	132	765	339	7.7	3.4
	Non-irrigated Agriculture	0.0	0.0	73	59	0.5	0.2
	Orchard, Vineyard, and Nursery	1,532	1,226	5,168	3,222	1.6	0.4
	Dairy, Livestock	0.0	0.0	13	7.7	0.0	0.0
Agriculture Total		1,844	1,358	6,698	4,106	9.8	4.0
Open Space	Open and Recreation	0.4	0.1	7.5	3.7	0.5	0.2
	Chaparral, Scrub	1,074	1,474	954	1,266	460	665
	Grassland, Herbaceous	789	929	244	250	148	152
Open Space Total		0.0	0.0	0.0	0.0	0.0	0.0
CALTRANS	CALTRANS (within each jurisdiction)	14	7.5	49	40	1.2	1.1
Total Land Use-based Load		4,639	4,415	11,183	8,403	739	973

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for April (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	590	280	752	526	57	54
	High Density	10.0	5.1	616	290	2.4	1.3
	Transitional	0.3	0.1	277	90	1.6	0.7
Residential Total		600	285	1,645	905	61	56
Commercial/Industrial	Commercial, Institutional	3.8	2.6	131	79	11	8.0
	Horse Ranches	0.0	0.0	427	232	0.0	0.0
	Industrial	7.6	4.6	114	79	13	6.1
Commercial/Industrial Total		11	7.2	672	390	24	14
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.4	0.1	103	31	0.5	0.2
Forest	Forest	6.5	5.9	7.4	7.9	1.4	1.6
Agriculture	Irrigated Agriculture	181	44	414	91	7.1	1.0
	Non-irrigated Agriculture	0.0	0.0	43	24	0.3	0.1
	Orchard, Vineyard, and Nursery	731	527	1,946	724	1.3	0.2
	Dairy, Livestock	0.0	0.0	6.2	1.3	0.0	0.0
Agriculture Total		912	571	2,835	1,072	8.7	1.3
Open Space	Open and Recreation	0.3	0.1	6.0	2.0	0.5	0.1
	Chaparral, Scrub	432	523	388	438	171	233
	Grassland, Herbaceous	424	382	157	100	98	59
Open Space Total		856	905	551	540	270	291
CALTRANS	CALTRANS (within each jurisdiction)	11	3.2	33	16	0.8	0.4
Total Land Use-based Load		2,391	1,772	5,413	2,723	365	363

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for May (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	53	224	96	427	12	50
	High Density	0.9	3.8	91	228	0.4	1.1
	Transitional	0.0	0.1	30	50	0.2	0.4
Residential Total		54	228	217	706	12	51
Commercial/Industrial	Commercial, Institutional	0.6	1.9	25	62	2.3	6.7
	Horse Ranches	0.0	0.0	56	116	0.0	0.0
	Industrial	0.7	3.1	19	58	2.3	4.8
Commercial/Industrial Total		1.3	5.0	100	236	4.6	12
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.1	8.5	17	0.0	0.1
Forest	Forest	0.9	4.4	1.2	6.2	0.3	1.2
Agriculture	Irrigated Agriculture	13	6.7	34	18	0.3	0.6
	Non-irrigated Agriculture	0.0	0.0	6.6	15	0.0	0.1
	Orchard, Vineyard, and Nursery	82	340	118	77	0.1	0.0
	Dairy, Livestock	0.0	0.0	0.5	0.2	0.0	0.0
Agriculture Total		95	347	215	227	0.5	0.7
Open Space	Open and Recreation	0.0	0.0	0.7	1.0	0.1	0.0
	Chaparral, Scrub	67	365	62	329	31	174
	Grassland, Herbaceous	53	214	20	69	11	41
Open Space Total		121	579	83	399	43	215
CALTRANS	CALTRANS (within each jurisdiction)	0.4	2.1	2.1	12	0.1	0.4
Total Land Use-based Load		271	1,162	570	1,479	60	279

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for June (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.0	141	0.0	263	0.0	41
	High Density	0.0	2.3	0.0	134	0.0	0.8
	Transitional	0.0	0.0	0.0	23	0.0	0.2
Residential Total		0.0	144	0.0	420	0.0	42
Commercial/Industrial	Commercial, Institutional	0.0	1.2	0.0	35	0.0	5.0
	Horse Ranches	0.0	0.0	0.0	51	0.0	0.0
	Industrial	0.0	1.5	0.0	34	0.0	3.7
Commercial/Industrial Total		0	3	0	119	0	9
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	7.5	0.0	0.0
Forest	Forest	0.0	1.9	0.0	3.4	0.0	0.7
Agriculture	Irrigated Agriculture	0.0	3.7	0.0	11	0.0	0.5
	Non-irrigated Agriculture	0.0	0.0	0.0	7.7	0.0	0.0
	Orchard, Vineyard, and Nursery	0.0	260	0.0	29	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.1	0.0	0.0
Agriculture Total		0.0	264	0.0	99	0.0	0.6
Open Space	Open and Recreation	0.0	0.0	0.0	0.5	0.0	0.0
	Chaparral, Scrub	0.0	187	0.0	186	0.0	104
	Grassland, Herbaceous	0.0	84	0.0	37	0.0	21
Open Space Total		0.0	271	0.0	223	0.0	125
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.9	0.0	6.3	0.0	0.3
Total Land Use-based Load		0.0	683	0.0	825	0.0	177

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for July (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	24	79	56	151	3.3	28
	High Density	0.5	1.2	187	74	0.7	0.5
	Transitional	0.0	0.0	27	12	0.0	0.1
Residential Total		24	81	269	237	4.0	29
Commercial/Industrial	Commercial, Institutional	0.8	0.6	45	19	1.3	3.3
	Horse Ranches	0.0	0.0	6.9	26	0.0	0.0
	Industrial	0.4	0.8	28	20	0.3	2.5
Commercial/Industrial Total		1.2	1.4	80	65	1.6	5.8
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	9.0	4.0	0.0	0.0
Forest	Forest	0.1	0.9	0.2	1.9	0.0	0.4
Agriculture	Irrigated Agriculture	3.7	1.8	13	6.3	0.1	0.4
	Non-irrigated Agriculture	0.0	0.0	6.6	4.1	0.0	0.0
	Orchard, Vineyard, and Nursery	23	155	67	16	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.2	0.1	0.0	0.0
Agriculture Total		0.0	0.0	0.0	0.0	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.8	0.3	0.1	0.0
	Chaparral, Scrub	8.5	100	14	105	5.1	61
	Grassland, Herbaceous	4.6	34	6.7	20	2.4	11
Open Space Total		0.0	0.0	0.0	0.0	0.0	0.0
CALTRANS	CALTRANS (within each jurisdiction)	0.1	0.5	2.7	3.5	0.0	0.2
Total Land Use-based Load		66	374	469	462	13	107

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Average At-Source Land Use-based TN Loads (lb/month) for August (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	6.6	60	14	118	3.0	23
	High Density	0.1	0.9	8.5	57	0.1	0.4
	Transitional	0.0	0.0	3.0	11	0.0	0.1
Residential Total		6.7	60	25	186	3.0	24
Commercial/Industrial	Commercial, Institutional	0.1	0.5	2.3	14	0.4	2.7
	Horse Ranches	0.0	0.0	5.0	23	0.0	0.0
	Industrial	0.1	0.6	2.5	16	0.4	2.0
Commercial/Industrial Total		0.1	1.1	9.8	54	0.8	4.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	1.1	3.6	0.0	0.0
Forest	Forest	0.1	0.6	0.2	1.5	0.0	0.3
Agriculture	Irrigated Agriculture	0.3	1.3	0.9	4.8	0.0	0.3
	Non-irrigated Agriculture	0.0	0.0	0.7	3.4	0.0	0.0
	Orchard, Vineyard, and Nursery	12	120	2.7	11	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.1	0.0	0.0
Agriculture Total		13	121	9.3	43	0.1	0.3
Open Space	Open and Recreation	0.0	0.0	0.1	0.3	0.0	0.0
	Chaparral, Scrub	8.5	77	9.6	85	5.3	49
	Grassland, Herbaceous	4.9	26	2.9	17	1.4	8.3
Open Space Total		13	104	13	102	6.7	57
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.4	0.4	3.0	0.0	0.1
Total Land Use-based Load		33	287	53	368	11	86

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Average At-Source Land Use-based TN Loads (lb/month) for September (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	5.1	45	15	93	2.5	21
	High Density	0.1	0.7	39	44	0.2	0.4
	Transitional	0.0	0.0	6.5	7.9	0.0	0.1
Residential Total		5.2	45	60	145	2.7	22
Commercial/Industrial	Commercial, Institutional	0.2	0.4	9.6	11	0.7	2.7
	Horse Ranches	0.0	0.0	1.8	17	0.0	0.0
	Industrial	0.1	0.5	6.4	13	0.8	2.4
Commercial/Industrial Total		0.3	0.8	18	41	1.5	5.1
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	1.1	2.5	0.0	0.0
Forest	Forest	0.0	0.4	0.1	1.2	0.0	0.3
Agriculture	Irrigated Agriculture	0.3	0.9	1.6	3.4	0.1	0.3
	Non-irrigated Agriculture	0.0	0.0	2.8	2.5	0.0	0.0
	Orchard, Vineyard, and Nursery	8.1	90	4.0	7.3	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		8.5	91	10	30	0.1	0.3
Open Space	Open and Recreation	0.0	0.0	0.2	0.2	0.0	0.0
	Chaparral, Scrub	5.0	61	6.5	68	3.4	40
	Grassland, Herbaceous	1.6	17	1.7	13	0.7	6.5
Open Space Total		6.7	78	8.4	82	4.1	47
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.3	0.2	2.3	0.0	0.1
Total Land Use-based Load		21	215	96	286	8.4	74

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for October (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	82	36	107	75	30	17
	High Density	2.1	0.5	336	36	1.9	0.3
	Transitional	0.0	0.0	50	7.9	0.2	0.1
Residential Total		84	36	494	119	32	18
Commercial/Industrial	Commercial, Institutional	1.7	0.3	84	9.2	11	2.0
	Horse Ranches	0.0	0.0	28	15	0.0	0.0
	Industrial	1.3	0.4	51	11	17	1.5
Commercial/Industrial Total		3.0	0.7	162	35	28	3.6
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	14	2.6	0.1	0.0
Forest	Forest	0.4	0.3	0.6	1.0	0.2	0.2
Agriculture	Irrigated Agriculture	74	6.9	200	21	10	1.1
	Non-irrigated Agriculture	0.0	0.0	13	2.1	0.0	0.0
	Orchard, Vineyard, and Nursery	186	77	537	52	0.4	0.0
	Dairy, Livestock	0.0	0.0	2.3	0.3	0.0	0.0
Agriculture Total		260	84	780	90	11	1.2
Open Space	Open and Recreation	0.0	0.0	1.6	0.2	0.2	0.0
	Chaparral, Scrub	36	51	38	57	19	34
	Grassland, Herbaceous	38	16	16	12	9.2	5.9
Open Space Total		74	67	55	69	29	40
CALTRANS	CALTRANS (within each jurisdiction)	0.8	0.2	1.4	2.0	0.1	0.1
Total Land Use-based Load		422	188	1,479	303	100	62

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for November (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	47	54	97	86	11	19
	High Density	1.1	0.9	253	40	1.0	0.3
	Transitional	0.0	0.0	45	17	0.1	0.2
Residential Total		48	55	395	143	12	19
Commercial/Industrial	Commercial, Institutional	1.3	0.5	65	10	3.5	2.2
	Horse Ranches	0.0	0.0	31	35	0.0	0.0
	Industrial	1.0	0.8	42	15	3.2	2.0
Commercial/Industrial Total		2.3	1.3	138	60	6.7	4.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	12	6.2	0.1	0.0
Forest	Forest	0.6	0.8	0.8	1.2	0.2	0.3
Agriculture	Irrigated Agriculture	25	18	68	41	0.8	1.0
	Non-irrigated Agriculture	0.0	0.0	12	4.0	0.0	0.0
	Orchard, Vineyard, and Nursery	101	128	212	172	0.1	0.1
	Dairy, Livestock	0.0	0.0	0.8	0.7	0.0	0.0
Agriculture Total		125	146	324	253	1.0	1.1
Open Space	Open and Recreation	0.0	0.0	1.3	0.4	0.2	0.0
	Chaparral, Scrub	56	82	49	72	23	40
	Grassland, Herbaceous	56	63	17	19	9.2	12
Open Space Total		112	145	67	92	32	52
CALTRANS	CALTRANS (within each jurisdiction)	0.4	0.5	1.7	2.6	0.1	0.1
Total Land Use-based Load		288	348	906	522	52	77

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TN Loads (lb/month) for December (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	2,172	92	3,757	111	212	19
	High Density	42	1.6	2,772	51	11	0.4
	Transitional	0.9	0.0	1,183	31	7.2	0.2
Residential Total		2,214	94	7,712	193	230	20
Commercial/Industrial	Commercial, Institutional	18	0.8	564	14	39	3.1
	Horse Ranches	0.0	0.0	2,253	63	0.0	0.0
	Industrial	30	1.5	509	20	36	3.5
Commercial/Industrial Total		48	2.3	3,326	97	75	6.6
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	1.7	0.0	453	12	2.7	0.1
Forest	Forest	87	1.5	98	1.6	15	0.3
Agriculture	Irrigated Agriculture	1,338	86	3,104	184	68	2.9
	Non-irrigated Agriculture	0.0	0.0	603	6.4	4.7	0.0
	Orchard, Vineyard, and Nursery	5,191	361	18,263	802	7.7	0.4
	Dairy, Livestock	0.0	0.0	34	1.8	0.0	0.0
Agriculture Total		6,529	447	24,256	1,057	80	3.3
Open Space	Open and Recreation	1.8	0.0	31	0.7	2.1	0.0
	Chaparral, Scrub	2,344	132	3,184	98	865	52
	Grassland, Herbaceous	1,809	132	1,054	29	611	18
Open Space Total		4,155	263	4,269	127	1,477	69
CALTRANS	CALTRANS (within each jurisdiction)	35	1.0	140	3.7	2.8	0.1
Total Land Use-based Load		12,982	808	37,904	1,427	1,869	99

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Average At-Source Land Use-based TP Loads (lb/month) for January (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	9,467	40	11,422	77	413	6.4
	High Density	171	0.8	6,597	45	15	0.2
	Transitional	5.3	0.0	2,644	12	14	0.1
Residential Total		9,644	41	20,663	134	442	6.7
Commercial/Industrial	Commercial, Institutional	45	0.4	1,074	12	40	1.3
	Horse Ranches	0.0	0.0	643	33	0.0	0.0
	Industrial	174	0.7	980	12	41	1.3
Commercial/Industrial Total		219	1.1	2,696	57	81	2.6
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	5.8	0.0	1,116	4.3	4.1	0.0
Forest	Forest	503	2.3	412	2.2	80	0.4
Agriculture	Irrigated Agriculture	1,017	24	1,937	63	12	1.4
	Non-irrigated Agriculture	0.0	0.0	1,243	6.1	4.4	0.0
	Orchard, Vineyard, and Nursery	6,156	155	18,951	450	1.8	0.1
	Dairy, Livestock	0.0	0.0	9.2	1.8	0.0	0.0
Agriculture Total		7,173	179	22,140	521	18	1.5
Open Space	Open and Recreation	1.4	0.0	40	0.2	2.7	0.0
	Chaparral, Scrub	5,258	20	12,868	60	1,451	8.9
	Grassland, Herbaceous	2,114	6.6	4,831	22	3,506	16
Open Space Total		7,373	27	17,738	83	4,960	24
CALTRANS	CALTRANS (within each jurisdiction)	220	0.5	560	2.6	13	0.1
Total Land Use-based Load		25,138	251	65,326	804	5,597	36

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Average At-Source Land Use-based TP Loads (lb/month) for February (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	4,172	44	4,986	90	299	4.5
	High Density	76	0.8	2,874	55	8.0	0.2
	Transitional	1.9	0.0	1,002	14	6.4	0.1
Residential Total		4,250	45	8,862	159	314	4.8
Commercial/Industrial	Commercial, Institutional	13	0.4	358	15	24	0.8
	Horse Ranches	0.0	0.0	644	43	0.0	0.0
	Industrial	62	0.8	361	13	30	0.4
Commercial/Industrial Total		75	1.2	1,363	71	54	1.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	1.9	0.0	394	5.1	1.3	0.0
Forest	Forest	273	2.9	248	2.8	42	0.5
Agriculture	Irrigated Agriculture	542	26	1,166	62	15	1.1
	Non-irrigated Agriculture	0.0	0.0	912	6.6	2.0	0.0
	Orchard, Vineyard, and Nursery	3,277	176	9,864	571	1.2	0.1
	Dairy, Livestock	0.0	0.0	21	1.3	0.0	0.0
Agriculture Total		3,818	202	11,962	641	18	1.2
Open Space	Open and Recreation	0.6	0.0	17	0.3	1.1	0.0
	Chaparral, Scrub	2,476	25	6,894	75	854	9.1
	Grassland, Herbaceous	841	7.7	2,198	26	1,681	17
Open Space Total		3,317	33	9,109	101	2,536	26
CALTRANS	CALTRANS (within each jurisdiction)	95	0.6	221	3.0	7.0	0.0
Total Land Use-based Load		11,832	284	32,160	982	2,972	34

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for March (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	708	62	601	133	32	12
	High Density	11	1.2	347	78	0.8	0.3
	Transitional	0.3	0.0	109	17	0.5	0.1
Residential Total		719	64	1,057	229	33	12
Commercial/Industrial	Commercial, Institutional	2.0	0.6	61	21	3.1	1.8
	Horse Ranches	0.0	0.0	70	48	0.0	0.0
	Industrial	10	1.0	54	18	4.2	1.3
Commercial/Industrial Total		12	1.6	185	87	7.3	3.1
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.2	0.0	40	6.1	0.1	0.0
Forest	Forest	4.7	2.9	4.8	3.9	1.0	0.7
Agriculture	Irrigated Agriculture	64	14	125	34	0.9	0.3
	Non-irrigated Agriculture	0.0	0.0	15	8.9	0.1	0.0
	Orchard, Vineyard, and Nursery	376	124	1,041	326	0.2	0.0
	Dairy, Livestock	0.0	0.0	1.3	0.8	0.0	0.0
Agriculture Total		440	138	1,183	370	1.2	0.4
Open Space	Open and Recreation	0.0	0.0	1.3	0.4	0.1	0.0
	Chaparral, Scrub	66	27	148	100	23	16
	Grassland, Herbaceous	40	8.0	57	34	47	22
Open Space Total		106	35	206	134	70	38
CALTRANS	CALTRANS (within each jurisdiction)	13	0.7	25	4.0	0.8	0.1
Total Land Use-based Load		1,295	241	2,701	834	113	55

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for April (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	481	29	406	53	25	5.9
	High Density	7.7	0.5	259	29	0.7	0.2
	Transitional	0.2	0.0	96	9.0	0.5	0.1
Residential Total		489	29	762	91	26	6.2
Commercial/Industrial	Commercial, Institutional	1.2	0.3	40	7.9	3.6	1.0
	Horse Ranches	0.0	0.0	45	23	0.0	0.0
	Industrial	6.8	0.5	41	7.9	6.1	1.1
Commercial/Industrial Total		8.0	0.7	125	39	9.7	2.1
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.2	0.0	45	3.1	0.1	0.0
Forest	Forest	2.5	0.9	2.4	1.2	0.5	0.2
Agriculture	Irrigated Agriculture	37	4.5	69	9.3	0.9	0.1
	Non-irrigated Agriculture	0.0	0.0	11	3.6	0.1	0.0
	Orchard, Vineyard, and Nursery	174	53	435	74	0.1	0.0
	Dairy, Livestock	0.0	0.0	0.7	0.1	0.0	0.0
Agriculture Total		211	58	515	87	1.1	0.1
Open Space	Open and Recreation	0.0	0.0	1.3	0.2	0.1	0.0
	Chaparral, Scrub	50	9.7	106	35	16	6.1
	Grassland, Herbaceous	40	3.3	62	14	51	8.6
Open Space Total		90	13	169	49	67	15
CALTRANS	CALTRANS (within each jurisdiction)	11	0.3	25	1.6	0.6	0.0
Total Land Use-based Load		812	102	1,645	271	105	23

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for May (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	13	23	16	43	2.2	5.1
	High Density	0.1	0.4	28	23	0.1	0.1
	Transitional	0.0	0.0	5.9	5.0	0.0	0.0
Residential Total		13	24	49	71	2.4	5.2
Commercial/Industrial	Commercial, Institutional	0.2	0.2	8.3	6.2	0.7	0.7
	Horse Ranches	0.0	0.0	5.9	12	0.0	0.0
	Industrial	0.1	0.3	5.1	5.8	0.9	0.5
Commercial/Industrial Total		0.3	0.5	19	24	1.5	1.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	1.5	1.7	0.0	0.0
Forest	Forest	0.2	0.7	0.2	0.9	0.0	0.2
Agriculture	Irrigated Agriculture	1.7	1.0	4.3	2.4	0.0	0.1
	Non-irrigated Agriculture	0.0	0.0	1.8	2.2	0.0	0.0
	Orchard, Vineyard, and Nursery	11	35	19	11	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.1	0.0	0.0	0.0
Agriculture Total		12	36	25	16	0.1	0.1
Open Space	Open and Recreation	0.0	0.0	0.2	0.1	0.0	0.0
	Chaparral, Scrub	1.9	6.5	7.4	27	1.5	4.7
	Grassland, Herbaceous	0.7	1.9	3.6	9.4	2.1	6.0
Open Space Total		2.6	8.4	11	36	3.5	11
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.2	0.2	1.2	0.0	0.0
Total Land Use-based Load		28	70	107	150	7.6	17

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for June (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.0	15	0.0	27	0.0	4.2
	High Density	0.0	0.2	0.0	13	0.0	0.1
	Transitional	0.0	0.0	0.0	2.3	0.0	0.0
Residential Total		0.0	15	0.0	42	0.0	4.3
Commercial/Industrial	Commercial, Institutional	0.0	0.1	0.0	3.5	0.0	0.5
	Horse Ranches	0.0	0.0	0.0	5.1	0.0	0.0
	Industrial	0.0	0.2	0.0	3.4	0.0	0.4
Commercial/Industrial Total		0	0	0	12	0	1
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.8	0.0	0.0
Forest	Forest	0.0	0.3	0.0	0.5	0.0	0.1
Agriculture	Irrigated Agriculture	0.0	0.6	0.0	1.5	0.0	0.1
	Non-irrigated Agriculture	0.0	0.0	0.0	1.2	0.0	0.0
	Orchard, Vineyard, and Nursery	0.0	27	0.0	3.7	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	27	0.0	6.4	0.0	0.1
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	3.0	0.0	15	0.0	2.9
	Grassland, Herbaceous	0.0	0.8	0.0	5.0	0.0	3.0
Open Space Total		0.0	3.8	0.0	20	0.0	5.9
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.1	0.0	0.6	0.0	0.0
Total Land Use-based Load		0.0	47	0.0	82	0.0	11

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for July (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	10	8.0	7.7	15	0.7	2.8
	High Density	0.0	0.1	13	7.4	0.0	0.0
	Transitional	0.0	0.0	4.7	1.2	0.0	0.0
Residential Total		10	8.1	26	24	0.7	2.9
Commercial/Industrial	Commercial, Institutional	0.1	0.1	4.0	1.9	0.1	0.3
	Horse Ranches	0.0	0.0	0.7	2.6	0.0	0.0
	Industrial	0.1	0.1	3.8	2.0	0.1	0.2
Commercial/Industrial Total		0.2	0.1	8.5	6.5	0.2	0.6
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	2.8	0.4	0.0	0.0
Forest	Forest	0.0	0.1	0.0	0.3	0.0	0.1
Agriculture	Irrigated Agriculture	1.4	0.2	3.8	0.7	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.7	0.6	0.0	0.0
	Orchard, Vineyard, and Nursery	6.3	16	25	1.7	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	0.0	0.0	0.0	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.1	0.0	0.0	0.0
	Chaparral, Scrub	0.3	1.4	1.6	8.2	0.2	1.7
	Grassland, Herbaceous	0.1	0.4	2.4	2.7	1.2	1.5
Open Space Total		0.4	1.8	4.1	11	1.4	3.2
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	2.1	0.4	0.0	0.0
Total Land Use-based Load		19	26	73	45	2.3	6.8

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for August (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.7	6.0	1.8	12	0.5	2.3
	High Density	0.0	0.1	2.6	5.7	0.0	0.0
	Transitional	0.0	0.0	0.5	1.1	0.0	0.0
Residential Total		0.8	6.0	4.8	19	0.5	2.4
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.8	1.4	0.1	0.3
	Horse Ranches	0.0	0.0	0.5	2.3	0.0	0.0
	Industrial	0.0	0.1	0.5	1.6	0.2	0.2
Commercial/Industrial Total		0.0	0.1	1.8	5.4	0.3	0.5
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.2	0.4	0.0	0.0
Forest	Forest	0.0	0.1	0.0	0.2	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.2	0.1	0.5	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.1	0.5	0.0	0.0
	Orchard, Vineyard, and Nursery	1.3	12	0.4	1.1	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		1.3	12	0.6	2.2	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.2	1.1	0.9	6.7	0.2	1.3
	Grassland, Herbaceous	0.1	0.3	0.4	2.3	0.2	1.2
Open Space Total		0.2	1.4	1.4	9.1	0.5	2.5
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.3	0.0	0.0
Total Land Use-based Load		2.3	20	8.9	36	1.2	5.4

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for September (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	1.0	4.5	3.6	9.3	0.8	2.6
	High Density	0.0	0.1	14	4.4	0.1	0.1
	Transitional	0.0	0.0	2.5	0.8	0.0	0.0
Residential Total		1.0	4.5	20	15	0.8	2.7
Commercial/Industrial	Commercial, Institutional	0.1	0.0	4.0	1.1	0.4	0.5
	Horse Ranches	0.0	0.0	0.3	1.7	0.0	0.0
	Industrial	0.0	0.0	2.4	1.3	0.5	0.7
Commercial/Industrial Total		0.1	0.1	6.7	4.1	0.8	1.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.4	0.3	0.0	0.0
Forest	Forest	0.0	0.1	0.0	0.2	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.1	0.2	0.3	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	1.0	0.4	0.0	0.0
	Orchard, Vineyard, and Nursery	0.9	9.0	0.8	0.7	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.9	9.1	2.0	1.5	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.1	0.0	0.0	0.0
	Chaparral, Scrub	0.1	0.8	0.9	5.3	0.2	1.2
	Grassland, Herbaceous	0.0	0.2	0.4	1.8	0.1	1.0
Open Space Total		0.1	1.0	1.3	7.1	0.4	2.2
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.2	0.0	0.0
Total Land Use-based Load		2.2	15	30	28	2.1	6.1

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for October (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	49	3.6	19	7.5	6.6	1.7
	High Density	1.2	0.1	52	3.6	0.3	0.0
	Transitional	0.0	0.0	9.5	0.8	0.0	0.0
Residential Total		50	3.6	80	12	7.0	1.8
Commercial/Industrial	Commercial, Institutional	0.3	0.0	16	0.9	2.7	0.2
	Horse Ranches	0.0	0.0	3.1	1.5	0.0	0.0
	Industrial	0.7	0.0	9.7	1.1	4.4	0.2
Commercial/Industrial Total		1.0	0.1	29	3.5	7.1	0.4
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	2.4	0.3	0.0	0.0
Forest	Forest	0.1	0.1	0.1	0.1	0.0	0.0
Agriculture	Irrigated Agriculture	13	0.7	29	2.1	1.2	0.1
	Non-irrigated Agriculture	0.0	0.0	3.0	0.3	0.0	0.0
	Orchard, Vineyard, and Nursery	29	7.7	84	5.2	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.2	0.0	0.0	0.0
Agriculture Total		42	8.4	116	7.6	1.2	0.1
Open Space	Open and Recreation	0.0	0.0	0.3	0.0	0.0	0.0
	Chaparral, Scrub	1.6	0.7	5.4	4.4	1.8	0.9
	Grassland, Herbaceous	0.8	0.2	3.2	1.6	2.1	0.9
Open Space Total		2.4	0.8	8.9	6.1	3.9	1.8
CALTRANS	CALTRANS (within each jurisdiction)	0.5	0.0	0.3	0.2	0.0	0.0
Total Land Use-based Load		96	13	237	30	19	4.1

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for November (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	8.4	5.4	20	8.6	2.6	2.1
	High Density	0.2	0.1	68	4.0	0.3	0.0
	Transitional	0.0	0.0	11	1.7	0.0	0.0
Residential Total		8.7	5.5	100	14	3.0	2.1
Commercial/Industrial	Commercial, Institutional	0.4	0.0	21	1.0	1.3	0.3
	Horse Ranches	0.0	0.0	3.8	3.5	0.0	0.0
	Industrial	0.2	0.1	12	1.5	1.6	0.4
Commercial/Industrial Total		0.6	0.1	37	6.0	2.9	0.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	2.8	0.6	0.0	0.0
Forest	Forest	0.1	0.1	0.1	0.2	0.0	0.0
Agriculture	Irrigated Agriculture	3.2	1.8	8.7	4.1	0.1	0.1
	Non-irrigated Agriculture	0.0	0.0	3.3	0.6	0.0	0.0
	Orchard, Vineyard, and Nursery	13	13	31	17	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.1	0.1	0.0	0.0
Agriculture Total		16	15	43	22	0.1	0.1
Open Space	Open and Recreation	0.0	0.0	0.4	0.0	0.1	0.0
	Chaparral, Scrub	1.5	1.5	6.1	5.9	1.2	1.4
	Grassland, Herbaceous	0.7	0.6	3.2	2.7	1.7	1.7
Open Space Total		2.2	2.0	9.7	8.6	2.9	3.1
CALTRANS	CALTRANS (within each jurisdiction)	0.1	0.1	0.2	0.3	0.0	0.0
Total Land Use-based Load		28	22	192	52	9.0	6.1

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average At-Source Land Use-based TP Loads (lb/month) for December (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	16,261	9.2	24,467	11	802	2.8
	High Density	282	0.2	14,323	5.1	38	0.1
	Transitional	9.2	0.0	6,136	3.1	33	0.0
Residential Total		16,553	9.4	44,925	19	873	2.9
Commercial/Industrial	Commercial, Institutional	88	0.1	2,766	1.4	107	0.7
	Horse Ranches	0.0	0.0	1,142	6.3	0.0	0.0
	Industrial	310	0.2	2,620	2.0	73	1.2
Commercial/Industrial Total		397	0.2	6,528	9.7	180	1.9
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	5.8	0.0	2,269	1.2	8.5	0.0
Forest	Forest	1,467	0.2	1,472	0.2	234	0.1
Agriculture	Irrigated Agriculture	1,505	8.6	2,826	18	15	0.3
	Non-irrigated Agriculture	0.0	0.0	3,296	1.0	13	0.0
	Orchard, Vineyard, and Nursery	8,899	36	28,858	80	2.9	0.0
	Dairy, Livestock	0.0	0.0	6.5	0.2	0.0	0.0
Agriculture Total		10,405	45	34,987	100	31	0.4
Open Space	Open and Recreation	4.8	0.0	92	0.1	6.5	0.0
	Chaparral, Scrub	14,458	2.6	44,041	8.1	4,424	1.7
	Grassland, Herbaceous	4,879	1.1	15,645	4.0	10,190	2.6
Open Space Total		19,343	3.7	59,778	12	14,621	4.3
CALTRANS	CALTRANS (within each jurisdiction)	376	0.1	1,234	0.4	22	0.0
Total Land Use-based Load		48,546	58	151,193	143	15,968	9.6

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TN Loads (lb/month) for January (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	2,697	304	3,761	437	199	44
	High Density	53	5.8	2,265	261	11	1.3
	Transitional	1.2	0.1	1,081	67	5.2	0.5
Residential Total		2,751	310	7,108	764	215	46
Commercial/Industrial	Commercial, Institutional	23	2.9	470	76	33	7.1
	Horse Ranches	0.0	0.0	1,243	136	0.0	0.0
	Industrial	40	5.5	443	73	30	6.0
Commercial/Industrial Total		62	8.3	2,156	285	63	13
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	2.4	0.1	411	27	1.8	0.1
Forest	Forest	145	11	114	8.6	21	1.8
Agriculture	Irrigated Agriculture	1,543	180	2,764	395	68	14
	Non-irrigated Agriculture	0.0	0.0	548	24	2.8	0.1
	Orchard, Vineyard, and Nursery	6,610	1,168	21,225	3,116	3.8	0.2
	Dairy, Livestock	0.0	0.0	51	12	0.0	0.0
Agriculture Total		8,152	1,348	25,831	3,683	75	14
Open Space	Open and Recreation	2.3	0.1	25	1.4	1.5	0.1
	Chaparral, Scrub	3,655	767	4,015	507	1,283	275
	Grassland, Herbaceous	2,495	595	979	84	650	60
Open Space Total		6,152	1,362	5,019	593	1,935	334
CALTRANS	CALTRANS (within each jurisdiction)	43	4.0	115	14	3.0	0.4
Total Land Use-based Load		17,162	3,033	39,397	5,230	2,292	408

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Average Delivered Land Use-based TN Loads (lb/month) for February (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	3,129	330	4,271	509	395	32
	High Density	59	6.3	2,782	313	14	1.4
	Transitional	1.5	0.1	1,172	78	7.5	0.4
Residential Total		3,190	336	8,225	900	417	34
Commercial/Industrial	Commercial, Institutional	22	3.1	583	92	60	5.6
	Horse Ranches	0.0	0.0	1,571	173	0.0	0.0
	Industrial	43	6.2	501	79	70	3.1
Commercial/Industrial Total		65	9.4	2,654	344	130	8.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	2.5	0.2	443	31	1.8	0.1
Forest	Forest	167	14	138	11	25	2.1
Agriculture	Irrigated Agriculture	1,431	197	2,732	394	112	11
	Non-irrigated Agriculture	0.0	0.0	660	25	2.3	0.1
	Orchard, Vineyard, and Nursery	6,742	1,323	21,421	3,966	3.5	0.2
	Dairy, Livestock	0.0	0.0	85	8.3	0.0	0.0
Agriculture Total		8,173	1,521	26,468	4,566	118	11
Open Space	Open and Recreation	2.1	0.1	27	1.6	1.6	0.1
	Chaparral, Scrub	4,080	973	4,766	652	1,595	360
	Grassland, Herbaceous	2,638	705	1,112	99	834	63
Open Space Total		6,721	1,678	5,905	752	2,431	423
CALTRANS	CALTRANS (within each jurisdiction)	55	4.8	140	16	6.2	0.4
Total Land Use-based Load		18,206	3,550	42,265	6,436	3,104	477

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Average Delivered Land Use-based TN Loads (lb/month) for March (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	662	463	795	749	69	91
	High Density	12	8.7	531	444	2.4	2.5
	Transitional	0.3	0.1	207	96	1.0	0.8
Residential Total		674	472	1,533	1,289	73	95
Commercial/Industrial	Commercial, Institutional	4.7	4.4	132	128	10	13
	Horse Ranches	0.0	0.0	266	199	0.0	0.0
	Industrial	8.7	7.7	109	109	9.6	12
Commercial/Industrial Total		13	12	507	436	20	25
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.4	0.2	75	37	0.3	0.1
Forest	Forest	13	15	12	15	2.5	3.2
Agriculture	Irrigated Agriculture	236	100	433	214	6.8	3.1
	Non-irrigated Agriculture	0.0	0.0	43	35	0.3	0.1
	Orchard, Vineyard, and Nursery	1,151	919	3,539	2,249	0.6	0.1
	Dairy, Livestock	0.0	0.0	7.7	4.9	0.0	0.0
Agriculture Total		1,387	1,019	4,288	2,702	7.6	3.3
Open Space	Open and Recreation	0.3	0.1	4.1	2.0	0.3	0.1
	Chaparral, Scrub	799	1,096	633	845	338	491
	Grassland, Herbaceous	587	691	128	131	86	89
Open Space Total		0.0	0.0	0.0	0.0	0.0	0.0
CALTRANS	CALTRANS (within each jurisdiction)	10	5.6	26	22	1.0	0.9
Total Land Use-based Load		3,471	3,296	6,927	5,264	526	704

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Average Delivered Land Use-based TN Loads (lb/month) for April (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	443	210	428	298	46	44
	High Density	7.4	3.8	345	164	1.7	1.0
	Transitional	0.2	0.1	158	51	0.7	0.4
Residential Total		450	214	932	513	48	45
Commercial/Industrial	Commercial, Institutional	2.8	1.9	81	49	9.0	6.3
	Horse Ranches	0.0	0.0	162	93	0.0	0.0
	Industrial	5.6	3.4	70	47	12	5.3
Commercial/Industrial Total		8.5	5.4	313	189	21	12
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.3	0.1	63	19	0.2	0.1
Forest	Forest	4.9	4.5	4.5	4.7	1.0	1.1
Agriculture	Irrigated Agriculture	137	33	213	52	6.6	0.9
	Non-irrigated Agriculture	0.0	0.0	25	14	0.2	0.1
	Orchard, Vineyard, and Nursery	549	394	1,282	491	0.4	0.1
	Dairy, Livestock	0.0	0.0	3.5	0.7	0.0	0.0
Agriculture Total		685	427	1,686	650	7.2	1.0
Open Space	Open and Recreation	0.2	0.1	3.3	1.1	0.3	0.1
	Chaparral, Scrub	322	389	256	293	126	172
	Grassland, Herbaceous	315	284	82	53	57	34
Open Space Total		637	673	341	347	183	206
CALTRANS	CALTRANS (within each jurisdiction)	8.3	2.4	18	8.8	0.6	0.4
Total Land Use-based Load		1,790	1,322	3,190	1,633	260	265

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Average Delivered Land Use-based TN Loads (lb/month) for May (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	2.0	8.4	1.6	6.8	3.7	15
	High Density	0.0	0.1	1.3	3.5	0.1	0.2
	Transitional	0.0	0.0	0.4	0.6	0.0	0.1
Residential Total		2.0	8.6	3.3	11	3.8	15
Commercial/Industrial	Commercial, Institutional	0.0	0.1	0.5	1.2	0.7	2.0
	Horse Ranches	0.0	0.0	0.4	0.8	0.0	0.0
	Industrial	0.0	0.1	0.4	1.0	0.4	0.8
Commercial/Industrial Total		0.0	0.2	1.2	3.0	1.1	2.8
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.2	0.3	0.0	0.0
Forest	Forest	0.0	0.2	0.0	0.1	0.0	0.1
Agriculture	Irrigated Agriculture	0.5	0.3	0.5	0.3	0.3	0.6
	Non-irrigated Agriculture	0.0	0.0	0.1	0.2	0.0	0.0
	Orchard, Vineyard, and Nursery	3.0	12	2.6	2.0	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		3.5	12	3.5	3.3	0.3	0.6
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	2.4	13	1.6	9.0	1.8	8.9
	Grassland, Herbaceous	1.9	7.6	0.3	1.1	1.0	3.6
Open Space Total		4.3	21	1.9	10	2.8	13
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.1	0.0	0.1	0.1	0.2
Total Land Use-based Load		10.0	42	9.8	27	8.0	31

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TN Loads (lb/month) for June (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.0	5.3	0.0	4.3	0.0	13
	High Density	0.0	0.1	0.0	2.0	0.0	0.2
	Transitional	0.0	0.0	0.0	0.3	0.0	0.1
Residential Total		0.0	5.4	0.0	6.6	0.0	13
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.0	0.7	0.0	1.8
	Horse Ranches	0.0	0.0	0.0	0.4	0.0	0.0
	Industrial	0.0	0.1	0.0	0.6	0.0	0.6
Commercial/Industrial Total		0	0	0	2	0	2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.1	0.0	0.0
Forest	Forest	0.0	0.1	0.0	0.1	0.0	0.1
Agriculture	Irrigated Agriculture	0.0	0.2	0.0	0.2	0.0	0.5
	Non-irrigated Agriculture	0.0	0.0	0.0	0.1	0.0	0.0
	Orchard, Vineyard, and Nursery	0.0	9.3	0.0	0.6	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	9.4	0.0	1.2	0.0	0.5
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	6.7	0.0	5.1	0.0	6.1
	Grassland, Herbaceous	0.0	3.0	0.0	0.6	0.0	2.5
Open Space Total		0.0	9.7	0.0	5.7	0.0	8.5
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.1	0.0	0.2
Total Land Use-based Load		0.0	25	0.0	15	0.0	25

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Average Delivered Land Use-based TN Loads (lb/month) for July (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.9	3.0	0.9	2.5	0.8	9.6
	High Density	0.0	0.0	2.6	1.1	0.0	0.1
	Transitional	0.0	0.0	0.3	0.2	0.0	0.0
Residential Total		0.9	3.0	3.9	3.7	0.9	9.7
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.9	0.4	0.1	1.3
	Horse Ranches	0.0	0.0	0.0	0.2	0.0	0.0
	Industrial	0.0	0.0	0.6	0.3	0.0	0.4
Commercial/Industrial Total		0.0	0.1	1.5	0.9	0.2	1.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.2	0.1	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.2	0.1	0.3	0.1	0.0	0.4
	Non-irrigated Agriculture	0.0	0.0	0.1	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.9	5.5	1.7	0.3	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	0.0	0.0	0.0	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.3	3.6	0.3	2.9	0.3	3.8
	Grassland, Herbaceous	0.2	1.2	0.1	0.3	0.2	1.5
Open Space Total		0.0	0.0	0.0	0.0	0.0	0.0
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.1
Total Land Use-based Load		2.4	14	8.1	8.5	1.6	17

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Average Delivered Land Use-based TN Loads (lb/month) for August (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.2	2.2	0.2	1.9	1.1	8.0
	High Density	0.0	0.0	0.1	0.9	0.0	0.1
	Transitional	0.0	0.0	0.0	0.1	0.0	0.0
Residential Total		0.3	2.3	0.4	2.9	1.1	8.1
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.0	0.3	0.2	1.0
	Horse Ranches	0.0	0.0	0.0	0.2	0.0	0.0
	Industrial	0.0	0.0	0.0	0.3	0.1	0.3
Commercial/Industrial Total		0.0	0.0	0.1	0.7	0.2	1.4
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.1	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.1	0.0	0.1	0.0	0.3
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.4	4.3	0.1	0.2	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.5	4.3	0.1	0.5	0.0	0.3
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.3	2.8	0.2	2.3	0.4	3.0
	Grassland, Herbaceous	0.2	0.9	0.0	0.3	0.2	1.2
Open Space Total		0.5	3.7	0.3	2.6	0.6	4.2
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.1
Total Land Use-based Load		1.2	10	0.9	6.7	2.0	14

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Average Delivered Land Use-based TN Loads (lb/month) for September (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.2	1.7	0.2	1.5	0.9	7.6
	High Density	0.0	0.0	0.5	0.7	0.0	0.1
	Transitional	0.0	0.0	0.1	0.1	0.0	0.0
Residential Total		0.2	1.7	0.8	2.3	1.0	7.8
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.2	0.2	0.2	1.1
	Horse Ranches	0.0	0.0	0.0	0.1	0.0	0.0
	Industrial	0.0	0.0	0.1	0.2	0.1	0.4
Commercial/Industrial Total		0.0	0.0	0.3	0.6	0.4	1.5
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.0	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.0	0.0	0.0	0.1	0.3
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.3	3.2	0.1	0.2	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.3	3.2	0.2	0.4	0.1	0.3
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.2	2.2	0.2	1.9	0.3	2.7
	Grassland, Herbaceous	0.1	0.6	0.0	0.2	0.1	1.0
Open Space Total		0.2	2.8	0.2	2.1	0.4	3.7
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.1
Total Land Use-based Load		0.7	7.8	1.5	5.2	1.8	13

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TN Loads (lb/month) for October (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	61	27	62	44	27	15
	High Density	1.6	0.4	190	20	1.5	0.2
	Transitional	0.0	0.0	30	4.4	0.1	0.1
Residential Total		63	27	281	68	29	15
Commercial/Industrial	Commercial, Institutional	1.2	0.2	52	5.7	9.6	1.7
	Horse Ranches	0.0	0.0	11	6.4	0.0	0.0
	Industrial	1.0	0.3	33	6.6	15	1.4
Commercial/Industrial Total		2.2	0.5	97	19	25	3.1
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	8.7	1.5	0.0	0.0
Forest	Forest	0.3	0.3	0.4	0.6	0.2	0.1
Agriculture	Irrigated Agriculture	56	5.2	104	11	9.9	1.1
	Non-irrigated Agriculture	0.0	0.0	8.1	1.3	0.0	0.0
	Orchard, Vineyard, and Nursery	140	58	348	33	0.1	0.0
	Dairy, Livestock	0.0	0.0	1.5	0.2	0.0	0.0
Agriculture Total		196	63	473	52	10	1.1
Open Space	Open and Recreation	0.0	0.0	0.9	0.1	0.1	0.0
	Chaparral, Scrub	27	38	25	38	15	25
	Grassland, Herbaceous	28	12	8.3	6.5	6.0	3.8
Open Space Total		55	50	34	45	21	29
CALTRANS	CALTRANS (within each jurisdiction)	0.6	0.2	0.8	1.1	0.1	0.1
Total Land Use-based Load		317	140	883	180	85	49

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TN Loads (lb/month) for November (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	35	41	56	50	9.5	16
	High Density	0.8	0.7	143	22	0.7	0.2
	Transitional	0.0	0.0	27	9.8	0.1	0.1
Residential Total		36	41	225	82	10	17
Commercial/Industrial	Commercial, Institutional	1.0	0.3	41	6.4	2.7	1.9
	Horse Ranches	0.0	0.0	12	14	0.0	0.0
	Industrial	0.7	0.6	27	8.8	2.8	1.7
Commercial/Industrial Total		1.7	1.0	81	29	5.5	3.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	7.4	3.7	0.0	0.0
Forest	Forest	0.5	0.6	0.5	0.7	0.1	0.2
Agriculture	Irrigated Agriculture	19	13	35	23	0.7	1.0
	Non-irrigated Agriculture	0.0	0.0	7.4	2.4	0.0	0.0
	Orchard, Vineyard, and Nursery	75	96	138	115	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.5	0.4	0.0	0.0
Agriculture Total		94	109	194	155	0.8	1.0
Open Space	Open and Recreation	0.0	0.0	0.7	0.2	0.1	0.0
	Chaparral, Scrub	41	61	32	49	17	30
	Grassland, Herbaceous	42	47	9.1	10	5.5	7.4
Open Space Total		83	108	42	59	23	38
CALTRANS	CALTRANS (within each jurisdiction)	0.3	0.4	0.9	1.4	0.0	0.1
Total Land Use-based Load		215	260	537	317	39	59

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Average Delivered Land Use-based TN Loads (lb/month) for December (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	1,628	69	2,114	64	159	16
	High Density	31	1.2	1,546	29	7.8	0.3
	Transitional	0.7	0.0	682	18	3.3	0.1
Residential Total		1,660	70	4,342	111	170	17
Commercial/Industrial	Commercial, Institutional	13	0.6	349	8.6	29	2.6
	Horse Ranches	0.0	0.0	853	25	0.0	0.0
	Industrial	22	1.1	306	12	32	3.1
Commercial/Industrial Total		35	1.7	1,508	45	61	5.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	1.3	0.0	273	7.2	1.2	0.0
Forest	Forest	66	1.1	59	1.0	9.5	0.2
Agriculture	Irrigated Agriculture	1,013	65	1,683	100	63	2.7
	Non-irrigated Agriculture	0.0	0.0	339	3.7	2.5	0.0
	Orchard, Vineyard, and Nursery	3,905	271	12,308	535	2.7	0.1
	Dairy, Livestock	0.0	0.0	19	1.1	0.0	0.0
Agriculture Total		4,918	336	15,202	664	69	2.9
Open Space	Open and Recreation	1.4	0.0	17	0.4	1.1	0.0
	Chaparral, Scrub	1,749	98	1,967	66	615	38
	Grassland, Herbaceous	1,346	98	524	15	324	10
Open Space Total		3,096	196	2,508	81	940	49
CALTRANS	CALTRANS (within each jurisdiction)	26	0.7	75	2.0	2.3	0.1
Total Land Use-based Load		9,737	605	23,055	887	1,243	74

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Average Delivered Land Use-based TP Loads (lb/month) for January (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	9,038	38	10,330	70	369	5.8
	High Density	163	0.7	5,969	41	14	0.2
	Transitional	5.0	0.0	2,375	11	8.9	0.1
Residential Total		9,206	39	18,675	121	392	6.0
Commercial/Industrial	Commercial, Institutional	43	0.4	988	11	28	1.1
	Horse Ranches	0.0	0.0	556	29	0.0	0.0
	Industrial	165	0.7	883	11	37	1.3
Commercial/Industrial Total		208	1.1	2,427	51	65	2.4
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	5.5	0.0	1,025	4.0	2.3	0.0
Forest	Forest	481	2.2	370	1.9	71	0.3
Agriculture	Irrigated Agriculture	972	23	1,725	56	11	1.4
	Non-irrigated Agriculture	0.0	0.0	1,124	5.5	2.9	0.0
	Orchard, Vineyard, and Nursery	5,880	148	17,822	423	0.9	0.0
	Dairy, Livestock	0.0	0.0	8.4	1.6	0.0	0.0
Agriculture Total		6,852	171	20,680	486	14	1.5
Open Space	Open and Recreation	1.4	0.0	35	0.2	1.9	0.0
	Chaparral, Scrub	5,013	19	11,690	55	1,268	7.9
	Grassland, Herbaceous	2,014	6.3	4,245	19	2,456	11
Open Space Total		7,029	26	15,970	74	3,727	19
CALTRANS	CALTRANS (within each jurisdiction)	209	0.5	507	2.3	12	0.0
Total Land Use-based Load		23,991	240	59,654	741	4,282	29

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Average Delivered Land Use-based TP Loads (lb/month) for February (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	3,983	42	4,510	82	278	3.8
	High Density	72	0.8	2,603	50	7.4	0.2
	Transitional	1.8	0.0	903	12	4.5	0.1
Residential Total		4,058	43	8,016	144	290	4.1
Commercial/Industrial	Commercial, Institutional	12	0.4	330	14	20	0.7
	Horse Ranches	0.0	0.0	557	37	0.0	0.0
	Industrial	59	0.8	327	12	28	0.4
Commercial/Industrial Total		71	1.2	1,215	63	48	1.0
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	1.8	0.0	362	4.7	0.8	0.0
Forest	Forest	261	2.7	220	2.5	36	0.4
Agriculture	Irrigated Agriculture	518	25	1,038	55	15	1.1
	Non-irrigated Agriculture	0.0	0.0	829	5.9	1.4	0.0
	Orchard, Vineyard, and Nursery	3,130	168	9,273	537	0.6	0.0
	Dairy, Livestock	0.0	0.0	19	1.2	0.0	0.0
Agriculture Total		3,647	193	11,159	599	16	1.1
Open Space	Open and Recreation	0.6	0.0	15	0.3	0.8	0.0
	Chaparral, Scrub	2,360	24	6,238	67	753	7.8
	Grassland, Herbaceous	801	7.4	1,935	23	1,211	12
Open Space Total		3,162	31	8,187	90	1,965	20
CALTRANS	CALTRANS (within each jurisdiction)	91	0.6	201	2.7	6.7	0.0
Total Land Use-based Load		11,292	271	29,361	906	2,362	26

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Average Delivered Land Use-based TP Loads (lb/month) for March (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	676	60	545	121	29	11
	High Density	11	1.1	315	71	0.8	0.3
	Transitional	0.3	0.0	99	16	0.3	0.1
Residential Total		687	61	958	207	30	11
Commercial/Industrial	Commercial, Institutional	1.9	0.6	56	19	2.5	1.5
	Horse Ranches	0.0	0.0	60	42	0.0	0.0
	Industrial	9.8	1.0	50	17	3.9	1.3
Commercial/Industrial Total		12	1.6	166	77	6.5	2.9
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.2	0.0	37	5.6	0.1	0.0
Forest	Forest	4.5	2.8	4.3	3.4	0.9	0.6
Agriculture	Irrigated Agriculture	61	13	111	31	0.9	0.3
	Non-irrigated Agriculture	0.0	0.0	13	8.0	0.1	0.0
	Orchard, Vineyard, and Nursery	359	119	979	307	0.1	0.0
	Dairy, Livestock	0.0	0.0	1.2	0.7	0.0	0.0
Agriculture Total		420	132	1,105	346	1.0	0.4
Open Space	Open and Recreation	0.0	0.0	1.1	0.3	0.1	0.0
	Chaparral, Scrub	63	25	135	91	20	15
	Grassland, Herbaceous	39	7.6	50	30	36	16
Open Space Total		101	33	186	121	57	31
CALTRANS	CALTRANS (within each jurisdiction)	12	0.7	23	3.6	0.7	0.1
Total Land Use-based Load		1,236	230	2,479	764	96	46

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Average Delivered Land Use-based TP Loads (lb/month) for April (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	459	28	368	48	23	5.5
	High Density	7.3	0.5	236	26	0.7	0.1
	Transitional	0.2	0.0	87	8.1	0.3	0.0
Residential Total		467	28	690	82	24	5.7
Commercial/Industrial	Commercial, Institutional	1.1	0.2	37	7.3	3.3	1.0
	Horse Ranches	0.0	0.0	38	20	0.0	0.0
	Industrial	6.4	0.4	37	7.2	5.8	1.0
Commercial/Industrial Total		7.6	0.7	113	35	9.1	2.0
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.2	0.0	42	2.8	0.1	0.0
Forest	Forest	2.4	0.9	2.2	1.1	0.4	0.2
Agriculture	Irrigated Agriculture	35	4.3	60	8.0	0.8	0.1
	Non-irrigated Agriculture	0.0	0.0	9.7	3.3	0.0	0.0
	Orchard, Vineyard, and Nursery	166	51	407	69	0.1	0.0
	Dairy, Livestock	0.0	0.0	0.6	0.1	0.0	0.0
Agriculture Total		202	55	478	80	1.0	0.1
Open Space	Open and Recreation	0.0	0.0	1.2	0.2	0.1	0.0
	Chaparral, Scrub	48	9.2	97	32	14	5.4
	Grassland, Herbaceous	38	3.1	54	12	38	6.3
Open Space Total		86	12	153	44	53	12
CALTRANS	CALTRANS (within each jurisdiction)	10	0.3	23	1.5	0.6	0.0
Total Land Use-based Load		775	98	1,500	247	88	20

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Average Delivered Land Use-based TP Loads (lb/month) for May (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	1.0	1.9	0.6	1.5	0.8	1.8
	High Density	0.0	0.0	0.9	0.8	0.0	0.0
	Transitional	0.0	0.0	0.2	0.2	0.0	0.0
Residential Total		1.1	1.9	1.7	2.5	0.9	1.8
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.3	0.2	0.3	0.2
	Horse Ranches	0.0	0.0	0.1	0.2	0.0	0.0
	Industrial	0.0	0.0	0.2	0.2	0.3	0.1
Commercial/Industrial Total		0.0	0.0	0.7	0.7	0.6	0.4
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.1	0.1	0.0	0.0
Forest	Forest	0.0	0.1	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.2	0.1	0.2	0.1	0.0	0.1
	Non-irrigated Agriculture	0.0	0.0	0.1	0.1	0.0	0.0
	Orchard, Vineyard, and Nursery	0.8	2.4	1.0	0.7	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		1.0	2.5	1.3	0.8	0.0	0.1
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.2	0.6	0.3	1.2	0.3	0.9
	Grassland, Herbaceous	0.1	0.1	0.1	0.3	0.2	0.7
Open Space Total		0.2	0.8	0.4	1.5	0.5	1.6
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.0
Total Land Use-based Load		2.3	5.3	4.1	5.6	2.0	3.9

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TP Loads (lb/month) for June (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.0	1.2	0.0	1.0	0.0	1.6
	High Density	0.0	0.0	0.0	0.4	0.0	0.0
	Transitional	0.0	0.0	0.0	0.1	0.0	0.0
Residential Total		0.0	1.2	0.0	1.5	0.0	1.6
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.0	0.1	0.0	0.2
	Horse Ranches	0.0	0.0	0.0	0.1	0.0	0.0
	Industrial	0.0	0.0	0.0	0.1	0.0	0.1
Commercial/Industrial Total		0	0	0	0	0	0
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.0	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.1	0.0	0.1	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.0	1.8	0.0	0.2	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	1.8	0.0	0.3	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	0.3	0.0	0.7	0.0	0.6
	Grassland, Herbaceous	0.0	0.1	0.0	0.2	0.0	0.5
Open Space Total		0.0	0.3	0.0	0.8	0.0	1.1
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.0
Total Land Use-based Load		0.0	3.4	0.0	3.1	0.0	3.1

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Average Delivered Land Use-based TP Loads (lb/month) for July (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.9	0.6	0.4	0.6	0.1	1.1
	High Density	0.0	0.0	0.4	0.2	0.0	0.0
	Transitional	0.0	0.0	0.1	0.0	0.0	0.0
Residential Total		0.9	0.6	0.9	0.8	0.1	1.2
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.2	0.1	0.0	0.1
	Horse Ranches	0.0	0.0	0.0	0.1	0.0	0.0
	Industrial	0.0	0.0	0.2	0.1	0.0	0.1
Commercial/Industrial Total		0.0	0.0	0.3	0.2	0.0	0.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.1	0.0	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.1	0.0	0.2	0.0	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.5	1.0	1.5	0.1	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.0	0.0	0.0	0.0	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	0.1	0.1	0.4	0.0	0.4
	Grassland, Herbaceous	0.0	0.0	0.1	0.1	0.1	0.3
Open Space Total		0.0	0.2	0.1	0.5	0.1	0.7
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.0
Total Land Use-based Load		1.6	1.9	3.2	1.7	0.3	2.1

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O’Neill.

Average Delivered Land Use-based TP Loads (lb/month) for August (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.1	0.5	0.1	0.4	0.2	0.9
	High Density	0.0	0.0	0.1	0.2	0.0	0.0
	Transitional	0.0	0.0	0.0	0.0	0.0	0.0
Residential Total		0.1	0.5	0.2	0.7	0.2	1.0
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.0	0.1	0.1	0.1
	Horse Ranches	0.0	0.0	0.0	0.0	0.0	0.0
	Industrial	0.0	0.0	0.0	0.1	0.1	0.1
Commercial/Industrial Total		0.0	0.0	0.1	0.2	0.1	0.2
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.0	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.1	0.8	0.0	0.1	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.1	0.8	0.0	0.1	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	0.1	0.0	0.3	0.1	0.3
	Grassland, Herbaceous	0.0	0.0	0.0	0.1	0.0	0.2
Open Space Total		0.0	0.1	0.1	0.4	0.1	0.5
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.0
Total Land Use-based Load		0.2	1.4	0.3	1.3	0.4	1.7

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TP Loads (lb/month) for September (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	0.1	0.4	0.1	0.3	0.4	1.2
	High Density	0.0	0.0	0.4	0.1	0.0	0.0
	Transitional	0.0	0.0	0.1	0.0	0.0	0.0
Residential Total		0.1	0.4	0.6	0.5	0.4	1.2
Commercial/Industrial	Commercial, Institutional	0.0	0.0	0.2	0.0	0.1	0.3
	Horse Ranches	0.0	0.0	0.0	0.0	0.0	0.0
	Industrial	0.0	0.0	0.1	0.0	0.2	0.2
Commercial/Industrial Total		0.0	0.0	0.3	0.1	0.3	0.5
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	0.0	0.0	0.0	0.0
Forest	Forest	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	Irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Non-irrigated Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
	Orchard, Vineyard, and Nursery	0.1	0.6	0.0	0.0	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture Total		0.1	0.6	0.1	0.1	0.0	0.0
Open Space	Open and Recreation	0.0	0.0	0.0	0.0	0.0	0.0
	Chaparral, Scrub	0.0	0.1	0.0	0.2	0.1	0.3
	Grassland, Herbaceous	0.0	0.0	0.0	0.1	0.0	0.2
Open Space Total		0.0	0.1	0.0	0.3	0.1	0.5
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.0	0.0	0.0	0.0
Total Land Use-based Load		0.2	1.1	1.1	1.0	0.8	2.2

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TP Loads (lb/month) for October (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	46	3.4	17	6.8	6.5	1.7
	High Density	1.1	0.1	47	3.2	0.3	0.0
	Transitional	0.0	0.0	8.7	0.7	0.0	0.0
Residential Total		47	3.5	73	11	6.8	1.7
Commercial/Industrial	Commercial, Institutional	0.3	0.0	15	0.8	2.6	0.2
	Horse Ranches	0.0	0.0	2.7	1.3	0.0	0.0
	Industrial	0.6	0.0	9.0	1.0	4.3	0.2
Commercial/Industrial Total		1.0	0.1	26	3.2	6.8	0.3
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	2.2	0.2	0.0	0.0
Forest	Forest	0.1	0.1	0.1	0.1	0.0	0.0
Agriculture	Irrigated Agriculture	12	0.7	25	1.8	1.1	0.1
	Non-irrigated Agriculture	0.0	0.0	2.7	0.3	0.0	0.0
	Orchard, Vineyard, and Nursery	28	7.4	78	4.8	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.2	0.0	0.0	0.0
Agriculture Total		40	8.0	106	6.9	1.2	0.1
Open Space	Open and Recreation	0.0	0.0	0.2	0.0	0.0	0.0
	Chaparral, Scrub	1.5	0.6	4.9	4.0	1.7	0.9
	Grassland, Herbaceous	0.7	0.2	2.9	1.4	1.6	0.6
Open Space Total		2.3	0.8	8.0	5.5	3.4	1.5
CALTRANS	CALTRANS (within each jurisdiction)	0.5	0.0	0.3	0.2	0.0	0.0
Total Land Use-based Load		91	12	216	27	18	3.7

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TP Loads (lb/month) for November (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	8.1	5.2	18	7.8	2.6	2.0
	High Density	0.2	0.1	62	3.6	0.3	0.0
	Transitional	0.0	0.0	10	1.5	0.0	0.0
Residential Total		8.3	5.3	91	13	2.9	2.1
Commercial/Industrial	Commercial, Institutional	0.4	0.0	19	1.0	1.2	0.3
	Horse Ranches	0.0	0.0	3.3	3.0	0.0	0.0
	Industrial	0.2	0.1	11	1.3	1.5	0.4
Commercial/Industrial Total		0.5	0.1	34	5.3	2.8	0.7
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	0.0	0.0	2.6	0.6	0.0	0.0
Forest	Forest	0.1	0.1	0.1	0.2	0.0	0.0
Agriculture	Irrigated Agriculture	3.0	1.7	7.5	3.5	0.1	0.1
	Non-irrigated Agriculture	0.0	0.0	3.0	0.6	0.0	0.0
	Orchard, Vineyard, and Nursery	12	12	29	16	0.0	0.0
	Dairy, Livestock	0.0	0.0	0.1	0.1	0.0	0.0
Agriculture Total		15	14	39	20	0.1	0.1
Open Space	Open and Recreation	0.0	0.0	0.3	0.0	0.0	0.0
	Chaparral, Scrub	1.4	1.4	5.5	5.3	1.1	1.2
	Grassland, Herbaceous	0.7	0.5	2.9	2.4	1.3	1.3
Open Space Total		2.1	1.9	8.7	7.8	2.4	2.6
CALTRANS	CALTRANS (within each jurisdiction)	0.0	0.0	0.2	0.2	0.0	0.0
Total Land Use-based Load		27	21	176	47	8.2	5.5

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Delivered Land Use-based TP Loads (lb/month) for December (2003-2010)

Aggregate Land Use	Land Use Category	Jurisdiction					
		San Diego Co.		Riverside Co.		Federal Lands	
		Wet	Dry	Wet	Dry	Wet	Dry
Residential	Low Density	15,524	8.8	22,096	10	692	2.7
	High Density	268	0.2	12,950	4.6	35	0.1
	Transitional	8.8	0.0	5,524	2.8	21	0.0
Residential Total		15,801	8.9	40,570	18	748	2.8
Commercial/Industrial	Commercial, Institutional	83	0.1	2,547	1.3	76	0.7
	Horse Ranches	0.0	0.0	989	5.4	0.0	0.0
	Industrial	295	0.1	2,369	1.8	66	1.1
Commercial/Industrial Total		378	0.2	5,904	8.5	142	1.8
Local Roads	Roads (non-CALTRANS)	0.0	0.0	0.0	0.0	0.0	0.0
Parks and recreation	Parks and recreation	5.5	0.0	2,082	1.1	4.9	0.0
Forest	Forest	1,401	0.2	1,310	0.2	200	0.0
Agriculture	Irrigated Agriculture	1,438	8.2	2,510	16	13	0.3
	Non-irrigated Agriculture	0.0	0.0	2,980	0.9	8.7	0.0
	Orchard, Vineyard, and Nursery	8,501	34	27,123	75	1.4	0.0
	Dairy, Livestock	0.0	0.0	5.9	0.2	0.0	0.0
Agriculture Total		9,939	43	32,619	92	23	0.3
Open Space	Open and Recreation	4.6	0.0	81	0.1	4.7	0.0
	Chaparral, Scrub	13,779	2.5	39,770	7.3	3,747	1.5
	Grassland, Herbaceous	4,648	1.0	13,693	3.5	6,840	2.0
Open Space Total		18,432	3.6	53,544	11	10,592	3.5
CALTRANS	CALTRANS (within each jurisdiction)	358	0.1	1,117	0.3	21	0.0
Total Land Use-based Load		46,315	56	137,147	130	11,731	8.5

Notes: Winter days are classified as October 1-April 30 and summer days are classified as May 1-September 30. Wet days are defined as days with ≥ 0.1 inch of rainfall observed on that day or on any of the three previous days, and dry days are defined as days with < 0.1 inch of rainfall observed on that day or on any of the three previous days. Tabulation includes surface and subsurface flows from the portion of the watershed not intercepted by Diamond Valley, Skinner, Vail, and Lake O'Neill.

Average Source and Delivered to Estuary Non-Land Use-based TN Loads by Month (lb; 2003-2010)

Month	CWRMA releases		Upstream Reservoirs		Lake O'Neill		Lower SMR aquifer discharge		Local groundwater to Estuary	
	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered	TN-source	TN-delivered
1	506	374	913	24	418	365	4,167	3,859	21	21
2	332	245	751	22	595	673	7,314	7,361	1	1
3	475	351	755	23	795	861	8,214	8,988	0	0
4	475	351	652	17	760	665	7,482	6,547	0	0
5	472	16	60	0	124	12	5,348	508	0	0
6	576	20	34	0	70	7	1,880	179	207	207
7	507	17	435	1	84	8	647	61	207	207
8	378	13	542	1	33	3	0	0	207	207
9	377	13	166	0	64	6	5	1	207	207
10	384	284	544	13	630	551	1	1	207	207
11	318	235	667	16	134	117	0	0	207	207
12	235	173	279	7	573	502	502	439	207	207
Total	*5,035*	*2,092*	*5,798*	*125*	*4,280*	*3,770*	*35,559*	*27,945*	*1,471*	*1,471*

Average Source and Delivered to Estuary Non-Land Use-based TP Loads by Month (lb; 2003-2010)

Month	CWRMA releases		Upstream Reservoirs		Lake O'Neill		Lower SMR aquifer discharge		Local groundwater to Estuary	
	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered	TP-source	TP-delivered
1	506	374	913	24	418	365	4,167	3,859	21	21
2	332	245	751	22	595	673	7,314	7,361	1	1
3	475	351	755	23	795	861	8,214	8,988	0	0
4	475	351	652	17	760	665	7,482	6,547	0	0
5	472	16	60	0	124	12	5,348	508	0	0
6	576	20	34	0	70	7	1,880	179	207	207
7	507	17	435	1	84	8	647	61	207	207
8	378	13	542	1	33	3	0	0	207	207
9	377	13	166	0	64	6	5	1	207	207
10	384	284	544	13	630	551	1	1	207	207
11	318	235	667	16	134	117	0	0	207	207
12	235	173	279	7	573	502	502	439	207	207
Total	*5,035*	*2,092*	*5,798*	*125*	*4,280*	*3,770*	*35,559*	*27,945*	*1,471*	*1,471*

APPENDIX 4: SCC-PAC HISTORICAL ANALYSIS OF SANTA MARGARITA RIVER ESTUARY TIDAL INLET CLOSURE

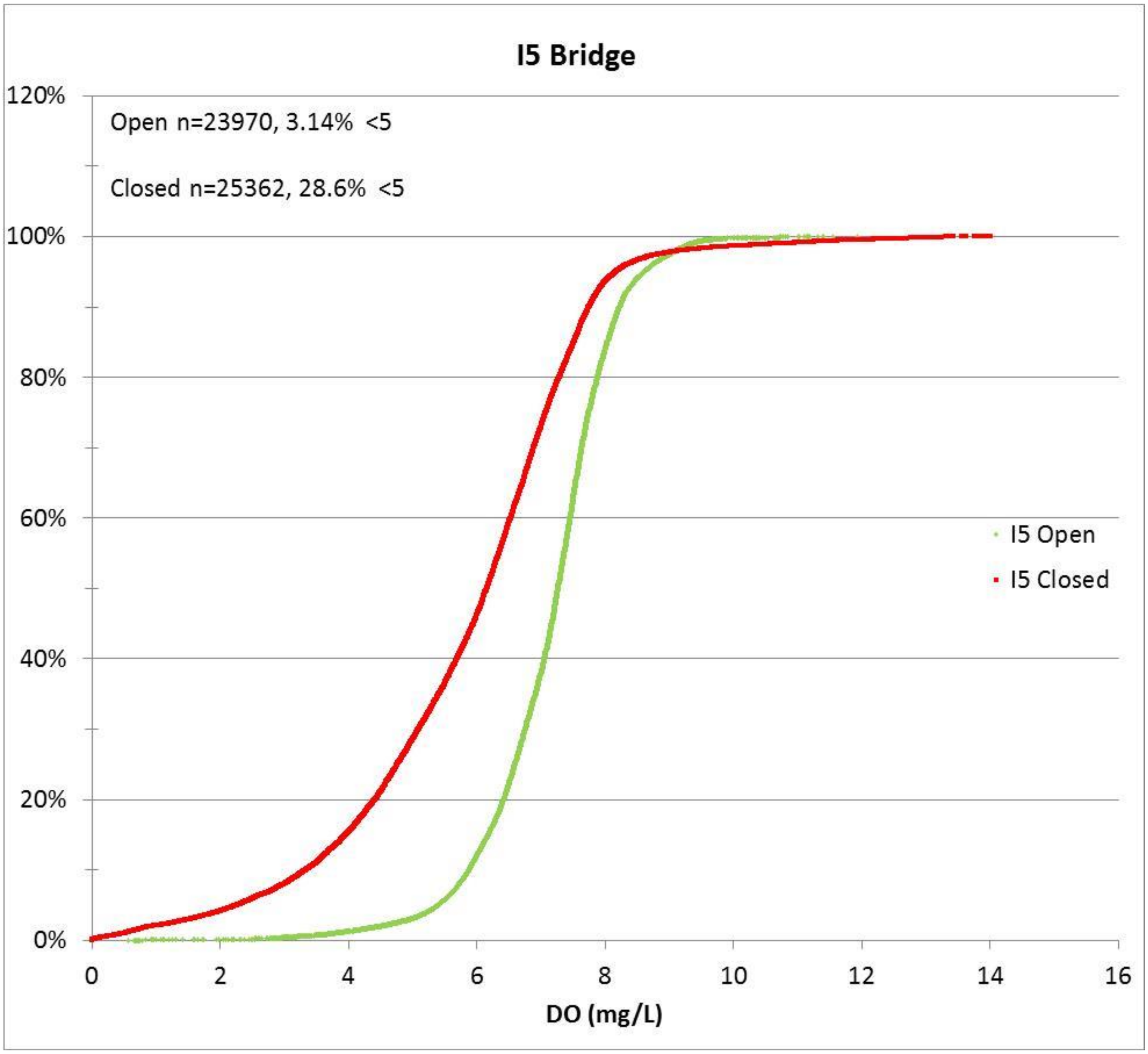
Santa Margarita Estuary Dissolved Oxygen (DO) Evaluation

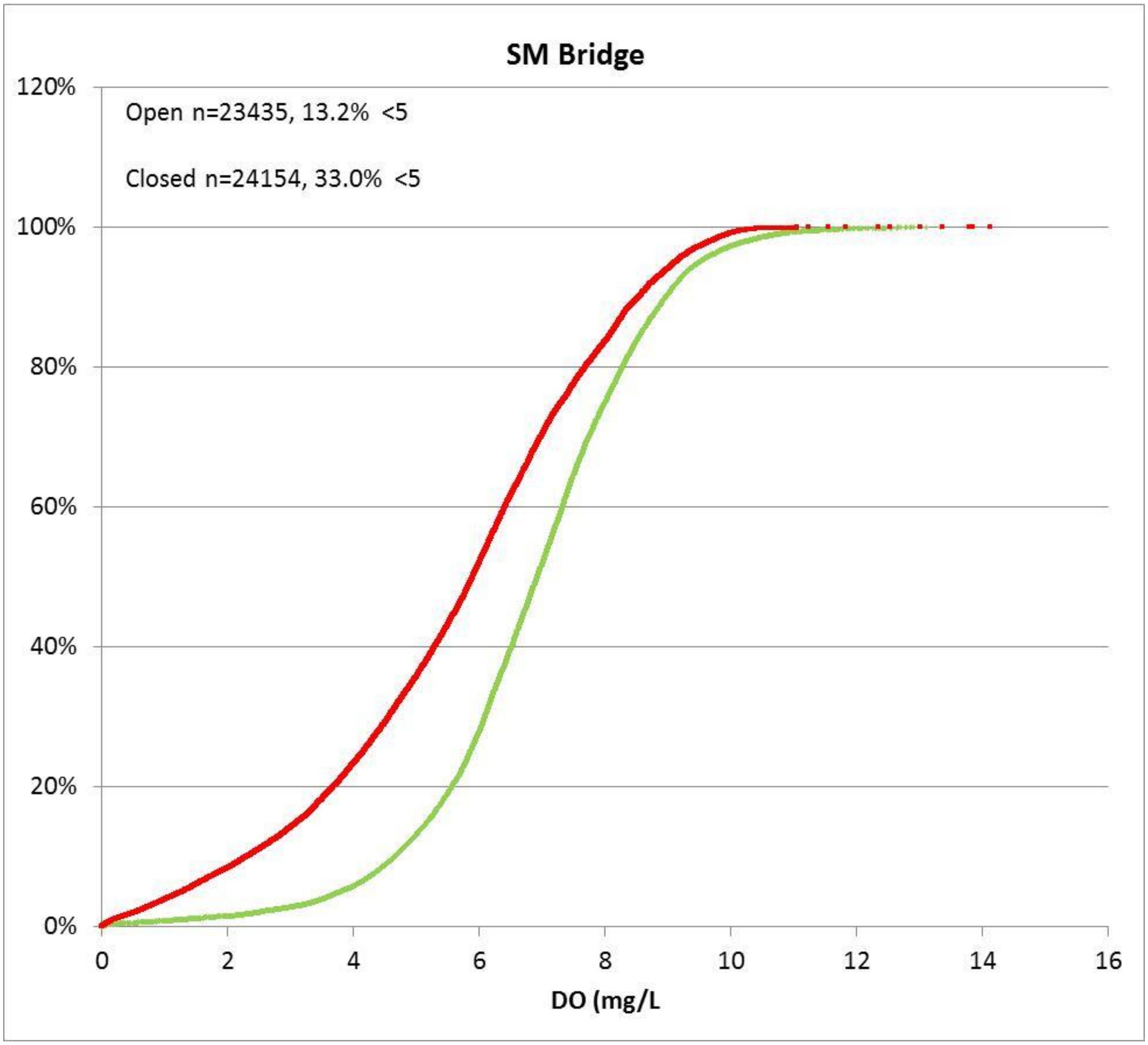
Chuck Katz, SSC Pacific

Goal: Evaluate dissolved oxygen data data Collected by between September 2014 and February 2016 during open and closed mouth conditions using recently collected data.

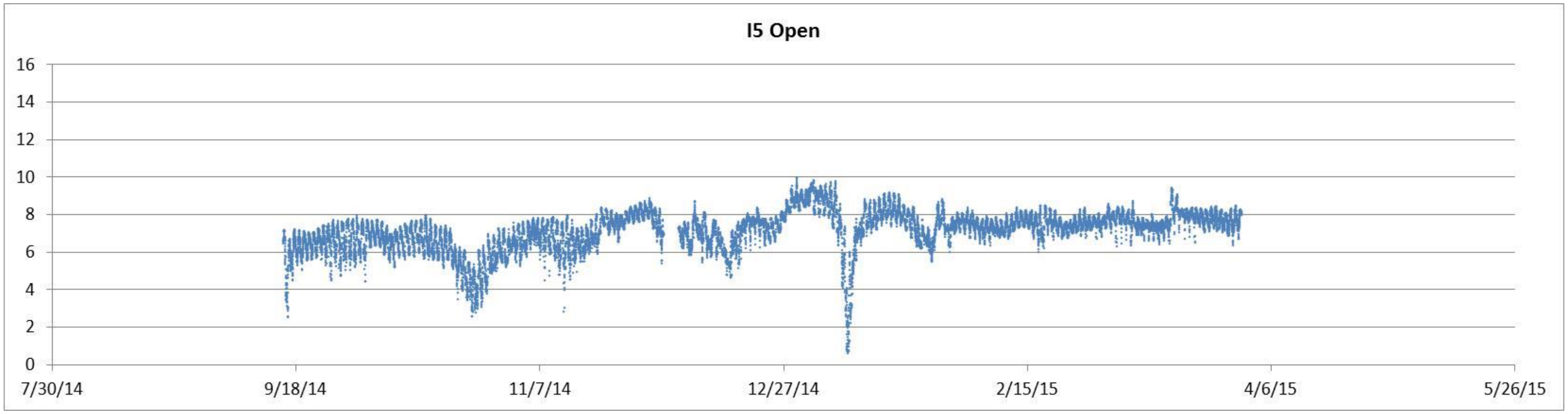
- The data used in the evaluation are provisional and subject to modification.
- The evaluation used data from buoys located at the Interstate 5 Bridge (I5) and Stuart Mesa Bridge (SMB) between September 2014 and February 2016.
- The data collection rate was every 15 minutes.
- Some missing data records include times when calibrations were conducted, when buoys were removed during first large storm of 2015 (safety concerns), and a couple of sensor failures.
- Some data were compromised from fouling and/or times when there was exceptional low flow in and around the sensor cages. The final dataset used represents our best efforts at adjusting values between calibration periods when we thought a correction for the fouling was appropriate. Some remaining very low and zero values are questionable and may represent fouling or data affected by zero flow around the sensor and may need to be adjusted further. The I5 sensor system was not affected as much by fouling issues.
- Open and closed conditions were based on level logger data measured at I5 and SMB. Closed conditions showed daily level changes of less than 5 cm.
- Data from the two open periods were combined into one set.
- Used the following dates/times for the I5 Dataset:
    - Open 9/15/2014 12:15 - 3/30/2015 23:45 and 12/23/2015 0:00 - 2/17/2016 23:45
    - Closed 4/1/2015 0:00 - 12/21/2015 23:45
- Used the following dates/times for the SMB Dataset:
    - Open 9/11/2014 14:15 - 3/30/2015 23:45 and 12/23/2015 0:00 - 2/17/2016 23:45
    - Closed 4/1/2015 0:00 - 12/21/2015 23:45
- The data were sorted on DO (mg/L) values in ascending order before calculating the percentile value.
- **RESULTS**

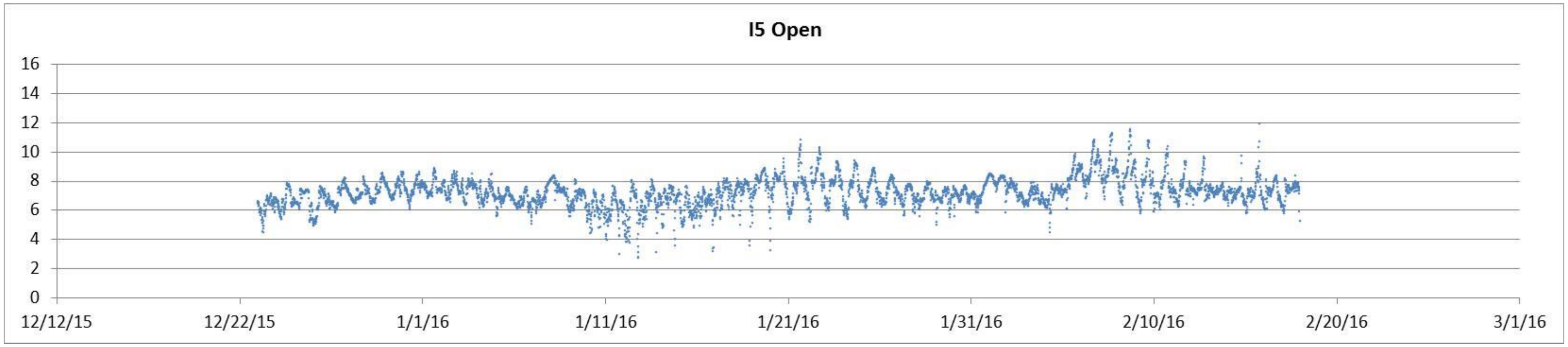
	OPEN		**CLOSED**	
I5	Count = 23,970	3.14% < 5 mg/L	Count = 25,362	28.6% < 5 mg/L
SMB	Count = 23,435	13.2% < 5 mg/L	Count = 24,154	33.0% < 5 mg/L

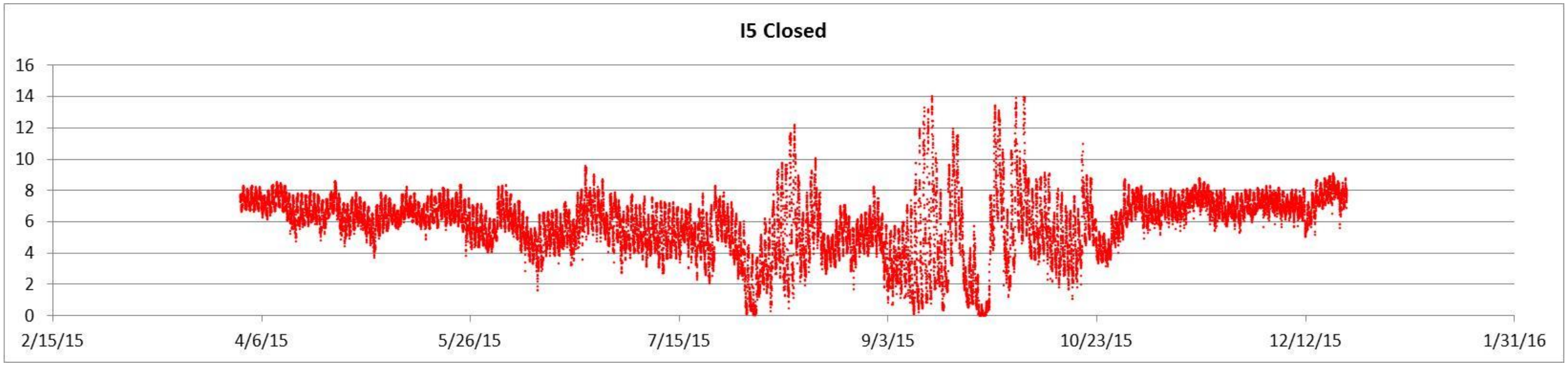

I5 Bridge
120%
100%
80%
60%
40%
20%
0%
Open n=23970, 3.14% <5
Closed n=25362, 28.6% <5
I5 Open
I5 Closed
0
2
4
6
8
10
12
14
16
DO (mg/L)


SM Bridge
Open n=23435, 13.2% <5
Closed n=24154, 33.0% <5
120%
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
12
14
16
DO (mg/L

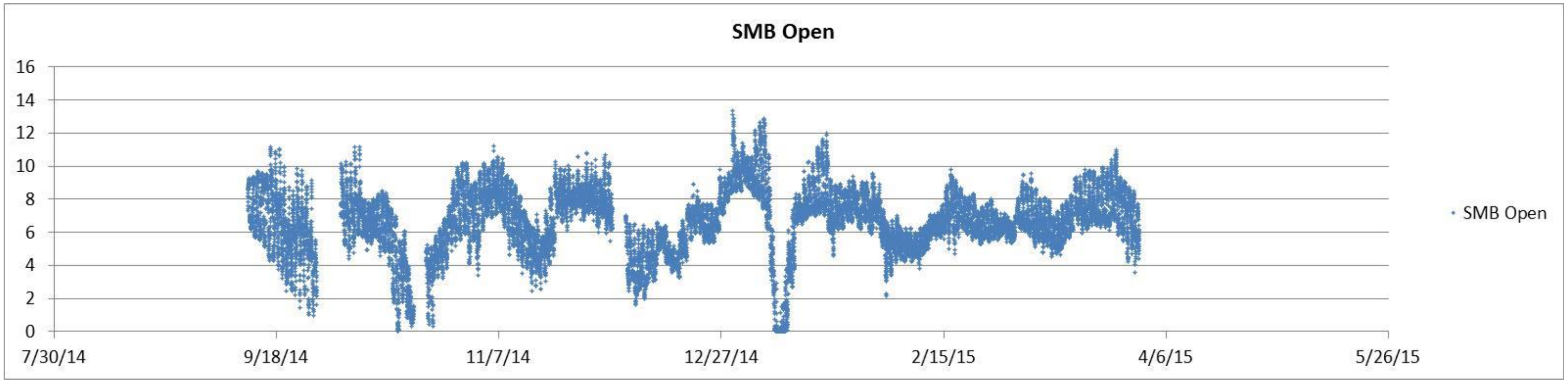
Dissolved oxygen over time at I5.

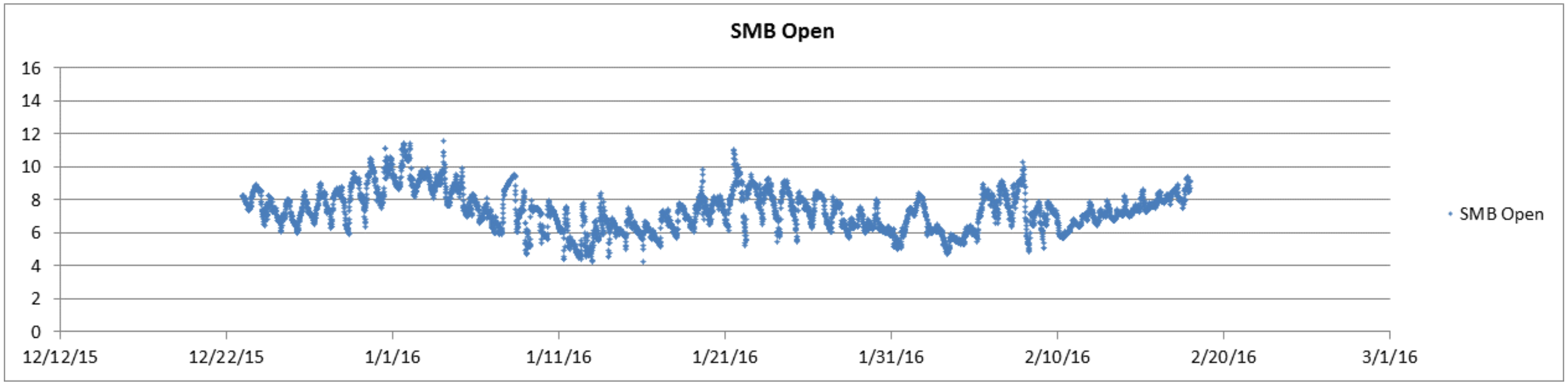


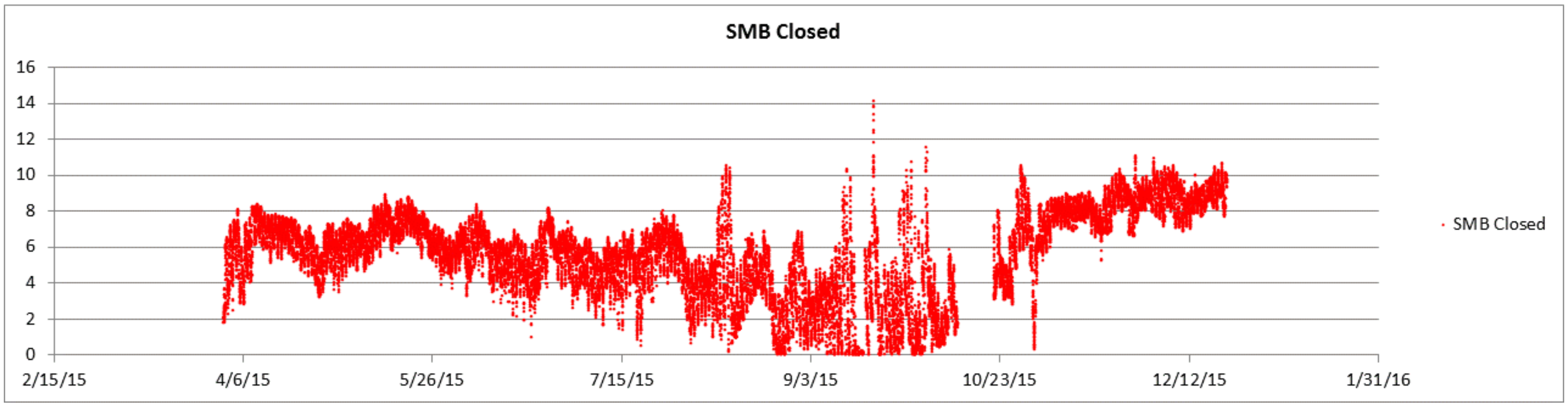




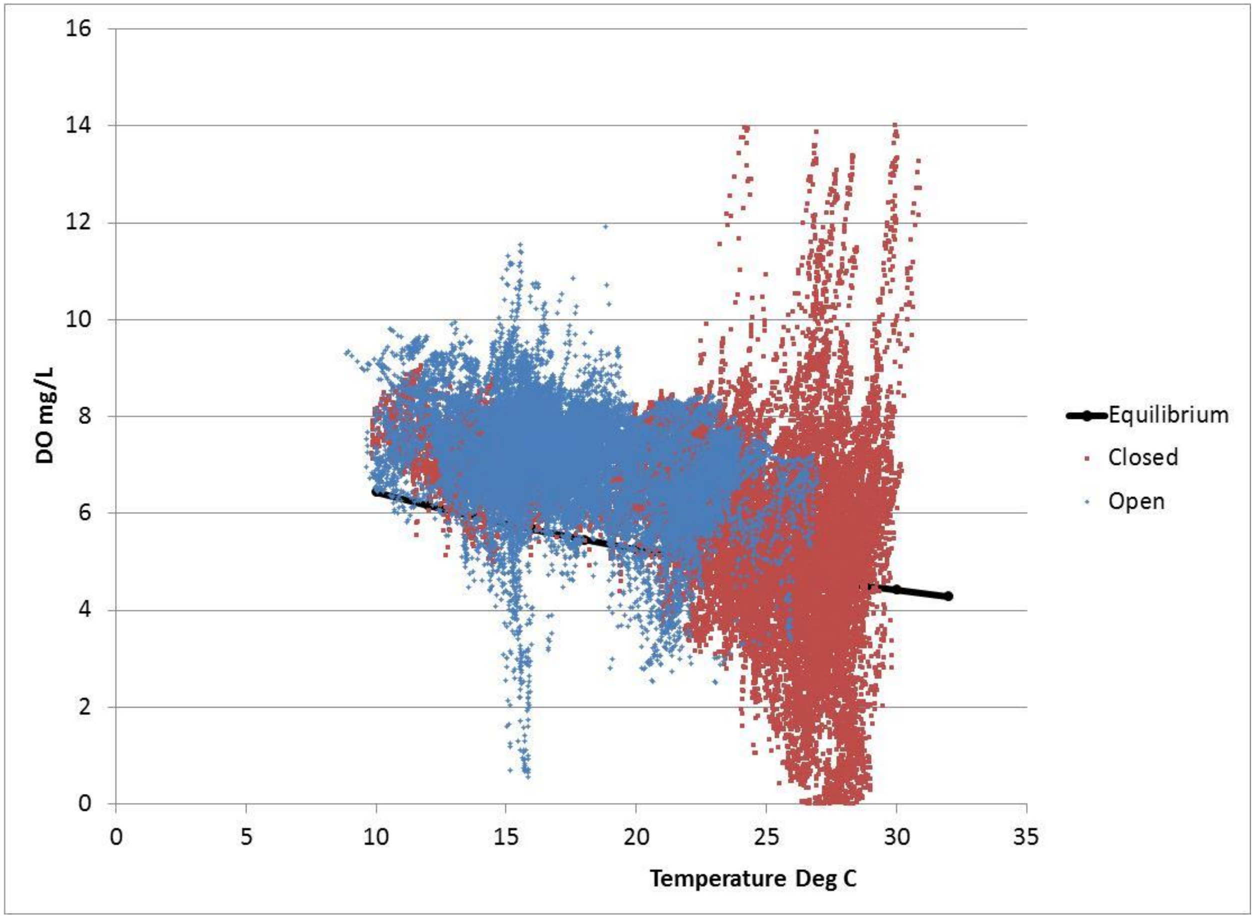
Dissolved oxygen over time at SMB.







Temperature vs. DO at I5. Shows changes are due to both physical (equilibrium) and biological effects.


16
14
12
10
8
6
4
2
0
DO mg/L
0
5
10
15
20
25
30
35
Temperature Deg C
Equilibrium
Closed
Open