Nutrient TMDL Support for Santa Clara River Watershed Lakes:

Lake Elizabeth, Munz Lake, and Lake Hughes

Task 1 Report Sections

Prepared for

USEPA Region 9

Prepared by

TETRA TECH

One Park Drive, Suite 200 • PO Box 14409
Research Triangle Park, NC 27709

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1 Introduction

The California Regional Water Quality Control Board, Los Angeles Region (Regional Board) is developing a total maximum daily load (TMDL) to attain the water quality standards for Nitrogen, Phosphorus, and algae in Lake Elizabeth, Munz Lake, and Lake Hughes (Figure 1-1) in the Santa Clara River Watershed (HUC 18070102). These lakes are referred to collectively as the Santa Clara River Watershed (SCR) lakes. The TMDL program is one of the primary frameworks for the nation to maintain and achieve healthy waterbodies, implemented pursuant to section 303(d) of the Clean Water Act (CWA). Total nitrogen, total phosphorus, and algae TMDLs will be addressed for each of the three lakes separately. Chlorophyll *a* is used as an indicator of algal density and a target of 20 micrograms per liter was established to protect beneficial uses for the LA Area Lakes TMDL (USEPA, 2012), which is also adopted here. The modeling pursuit for these three lakes will address site-specific nutrient loadings required to attain the chlorophyll *a* target for each lake. The purpose of this document is to provide report sections towards the development of a TMDL report; this document is not intended to represent a complete TMDL document.

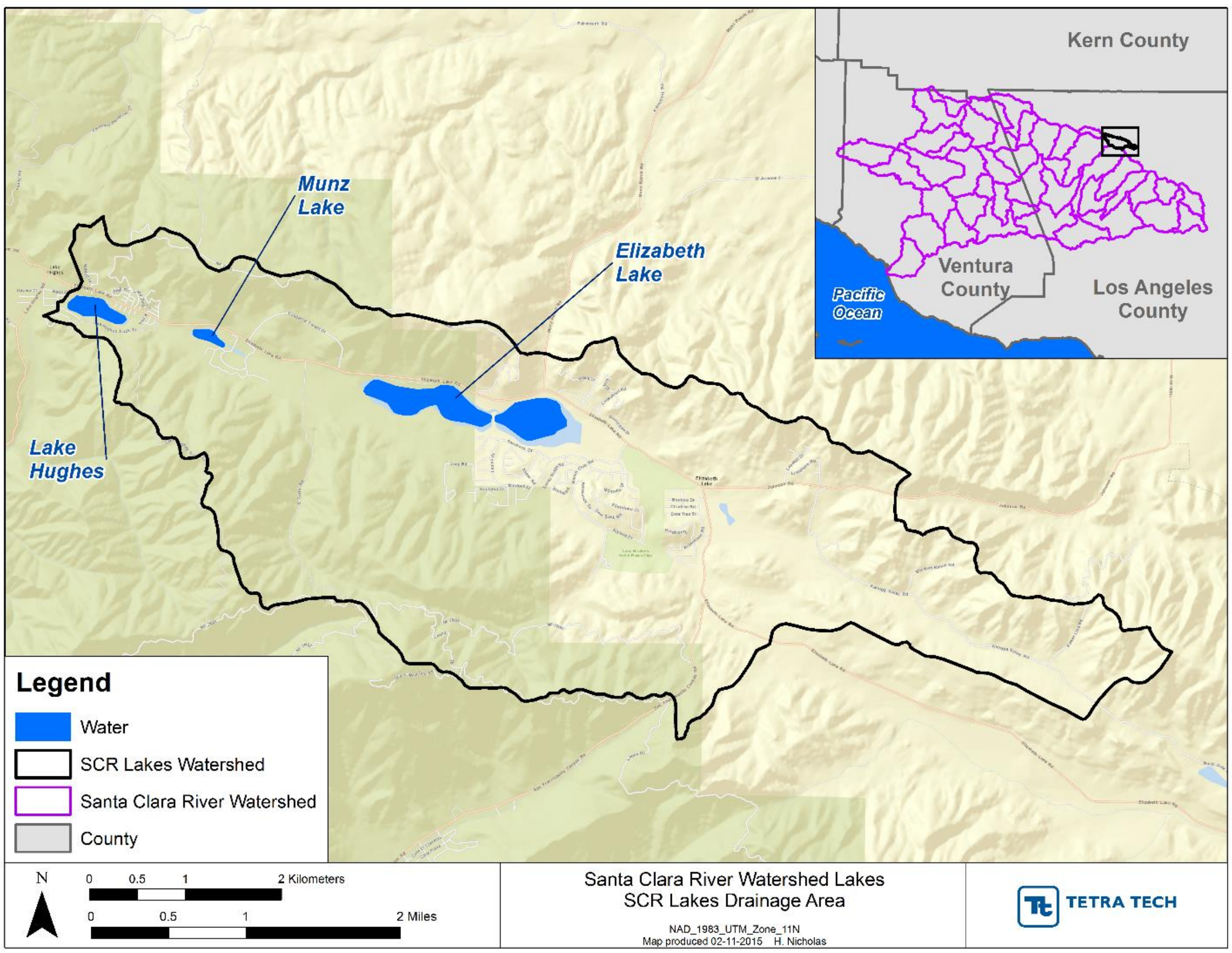

Figure 1-1. Location of Elizabeth, Munz, and Hughes Lakes and Watershed.

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2 Environmental Setting

The three lakes lie within the Santa Clara River watershed. The Santa Clara River, approximately one hundred miles long, is the largest river system in southern California and was selected by American Rivers as one of the nation's most endangered rivers in 2005. The river originates in the northern slope of the San Gabriel Mountains in Los Angeles County, traverses Ventura County and flows into the Pacific Ocean halfway between the cities of San Buenaventura and Oxnard. (LARWQCB, 2007) The SCR lakes, at the elevation of about 1,000 meters above mean sea level (MSL), are near the headwater of Lake Elizabeth Canyon Creek in the unincorporated community of Lake Hughes.

Each of the SCR Lakes – Lake Elizabeth, Munz Lake (also known as Lake Wendy), and Lake Hughes – are located along the San Andreas Fault at the northern edge of the Angeles National Forest. The watershed for these lakes represents a portion of the Lake Elizabeth hydrologic unit (HUC 1807010203 01), a semi-closed basin at the northern-most part of the Santa Clara River Watershed. From the fringe of the Mojave Desert, Lake Elizabeth Canyon Creek winds southwest through chaparral-studded hills for approximately 15 miles before reaching Castaic Lake, a 323,700 acre-foot capacity drinking water reservoir.

The SCR lakes were formed as sag ponds due to wet season precipitation and accumulation, and the drainage area to the three lakes includes only the eastern half of the HUC12. All three lakes have been known to dry up periodically. Local residents have reported that Lake Hughes, for example, has dried up completely at least four times since the 1960s (Chastang, 1993). During recent monitoring, Lake Hughes was observed to be dry on October 8, 2014.

The wet season for this area generally runs from January to March, during which time periodic flooding has occurred along these lakes. According to the National Hydrography Dataset Plus (NHDPlus) FlowLine coverage for California, every stream within the SCR Lakes Watershed is listed as intermittent. Intermittent streams also occur between each of the lakes (from Elizabeth westward to Hughes) during peak wet season periods, with overflow exiting Lake Hughes on the western side and leaving the basin to Castaic Canyon. Based on both LACRWQCB and resident observations, it is assumed that the lakes function as closed systems during the summer months and may also remain closed annually depending on precipitation.

About half of the drainage area for the three lakes was recently burnt in June 2013 due to the Powerhouse Fire which started south of the area in the Green Valley/San Francisquito Canyon area (Figure 2-1). Some 24 homes were destroyed in the fire, as well as 29 additional structures (Merl, 2013). About 20 separate fires have impacted this small watershed from 1915 to 2013 according to the Fire and Resource Assessment Program run by the California Department of Forestry and Fire Protection (CAL FIRE-FRAP, 2013). The largest events were the recent Powerhouse Fire (2013), the San Fran Fire which burned half of the drainage area for Lake Elizabeth (1989), and the Cherry Fire which burned the southern half of the watershed (1951) (CAL FIRE-FRAP, 2013). The vast majority of the watershed is undeveloped and supports native vegetation. The watershed lies within the Southern California Mountain Level III ecoregion, which is characterized by chaparral vegetation which is a native to the California area (USEPA, 2013). Chaparral landscapes are vulnerable to fires due to the presence of dense thickets and seasonal aridity (Hanes, 1971). If chaparral is not maintained, fuel buildup can increase vulnerability to wildfires. Dry conditions can also exacerbate vulnerability to wildfires.

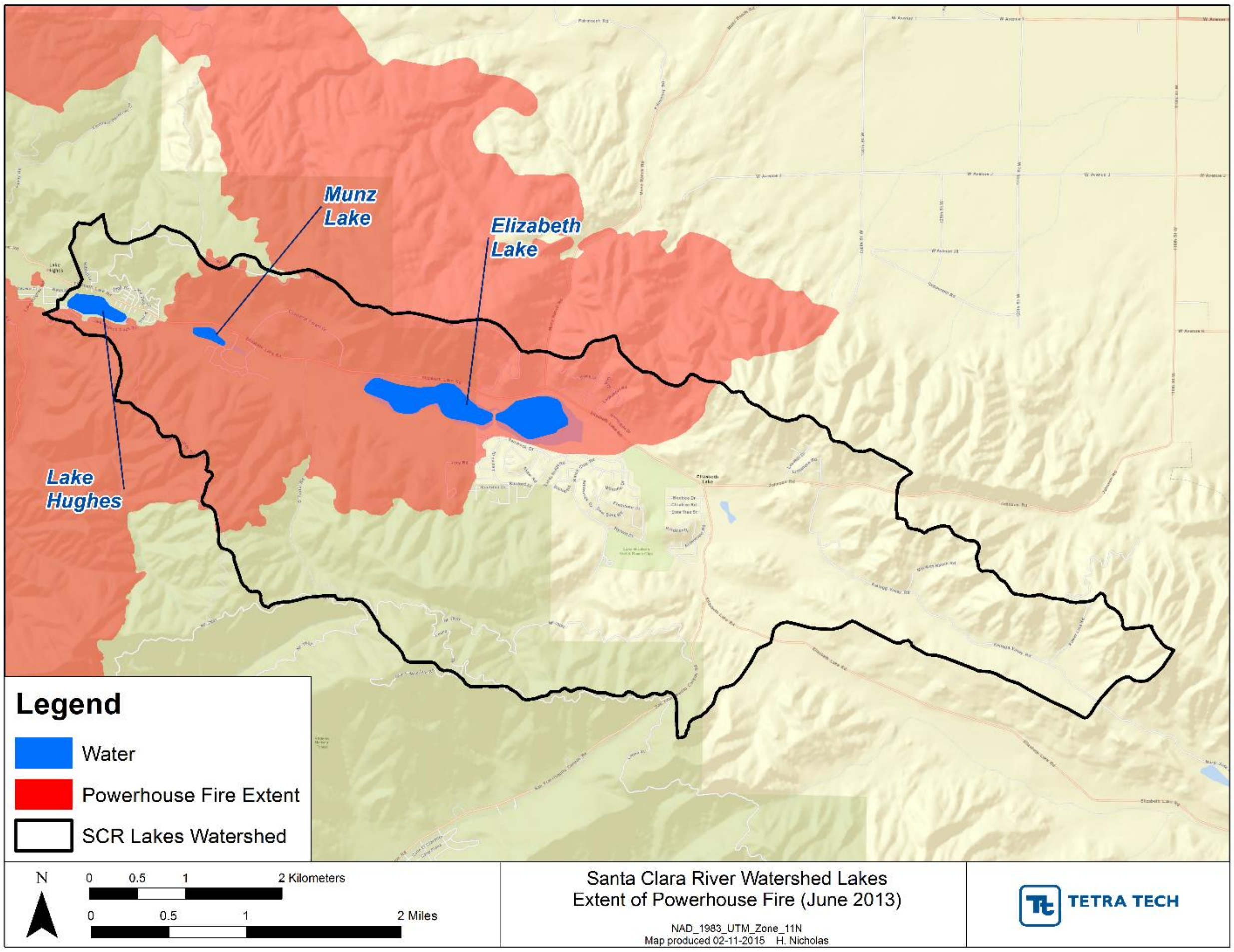

Figure 2-1. Extent of the Powerhouse Fire (June 2013) near Elizabeth, Munz, and Hughes Lakes.

Lake Elizabeth

Lake Elizabeth is surrounded by the unincorporated town of Lake Elizabeth. The lake is a 123.2-acre natural waterbody, approximately 3 miles wide oriented east-westerly. Lake depth varies seasonally, generally ranging from 6-15 feet along the lake perimeter and 18-20 feet near the lake center (Lund et al., 1994). The eastern half of the lake is private property, while the western shores are under the management of the US Forest Service (USFS) within the Angeles National Forest. The privately owned eastern portion of the lake has grassy areas and water tanks and is fenced in and posted as private property; however sections of fence have been damaged and could allow public access. USFS allows the access to Lake Elizabeth via trails and has a recreational area on the northwestern shore of the lake where a picnic area is located (LARWQCB, 2007).

The primary water source for Lake Elizabeth is rainfall and runoff from surrounding areas (CRWQCB, 2007). During the wet season, water can flow westward to Munz Lake, although this occurs infrequently. The CA Department of Fish and Wildlife also keeps Lake Elizabeth stocked with trout during wet years.

Munz Lake

Munz Lake is a privately owned, man-made lake which hosts The Painted Turtle, a camp for children with serious and/or terminal illnesses. The lake is about 6.5 acres in size, 5 feet deep at its average depth and irregularly shaped (LARWQCB, 2007). Water in the lake comes from rain and runoff, and overflow from Lake Elizabeth during the wet season (LARWQCB, 2007). Munz Lake discharges to Lake Hughes at its west end during overflow periods. The Painted Turtle camp refers to the waterbody as “Lake Wendy.”

Two groundwater wells exist near Munz Lake. According to recent conversations with the lake manager, the wells are not currently used to supplement the waterbody but rather to provide both irrigation water and potable water to the camp and nearby facilities. Past communications and sources indicate that the wells were once used to supplement water levels (S. Hada, LARWQCB, personal communication to H. Fisher, July 14, 2015; LARWQCB, 2006; CDWR, 1993). Lake activities are suspended at the Painted Turtle when water is too low, which occurred during the summer of 2014 when water depths averaged only 1-foot (personal communication with Painted Turtle Operations Director Allen McBroom).

Lake Hughes

Lake Hughes is surrounded by the incorporated community of the same name and has a surface area of 21.4 acres. Seasonal depth ranges similar to the other lakes, with an average of 3 feet deep along the perimeter and 18 feet in the center during the wet season. Lake Hughes is surrounded by private homes with direct backyard access to the lake on the north and southwestern shores, while the rest of the lake edges are vegetated. A sewer system was installed in 1990 around Lake Hughes to help address pollution associated with seeping septic tanks in the area (Chastang, 1993). Lake Hughes is fed partially by groundwater, rainfall and runoff, and infrequent overflow water from Munz and Lake Elizabeth. A bedrock sill prevents overflow water from leaving Lake Hughes except during severe flooding (CDWR, 1993).

2.1 Elevation, Storm Drain Networks, and TMDL Subwatershed Boundaries

The subject lakes reside in the western Antelope Valley in the foothills of the Sierra Pelona Mountains. Elevation in the drainage area for these lakes ranges from 971 to 1,391 meters (Figure 2-2). The sanitary sewer network for the unincorporated community of Lake Hughes, California includes a single non-county sewer-line which extends to the Munz Lake area (Figure 2-2) (LA County Department of Public Works, 2006) and transports sewage to the Lake Hughes Community Wastewater Treatment Plant. The Lake Hughes area and Painted Turtle Camp are serviced by this plant. No other data were available on sanitary sewers in the watershed. The community of Lake Elizabeth, California located along the eastern area of Lake Elizabeth, uses on-site wastewater treatment systems.

Limited data were available on stormwater systems in the watershed. Los Angeles County maintains one storm drain and six catch basins in the area of Lake Elizabeth, which are cleaned out annually. Other storm drains are likely to exist in the watershed. These storm drains likely follow the residential roads and coincide with the Lake Hughes sanitary sewer system.

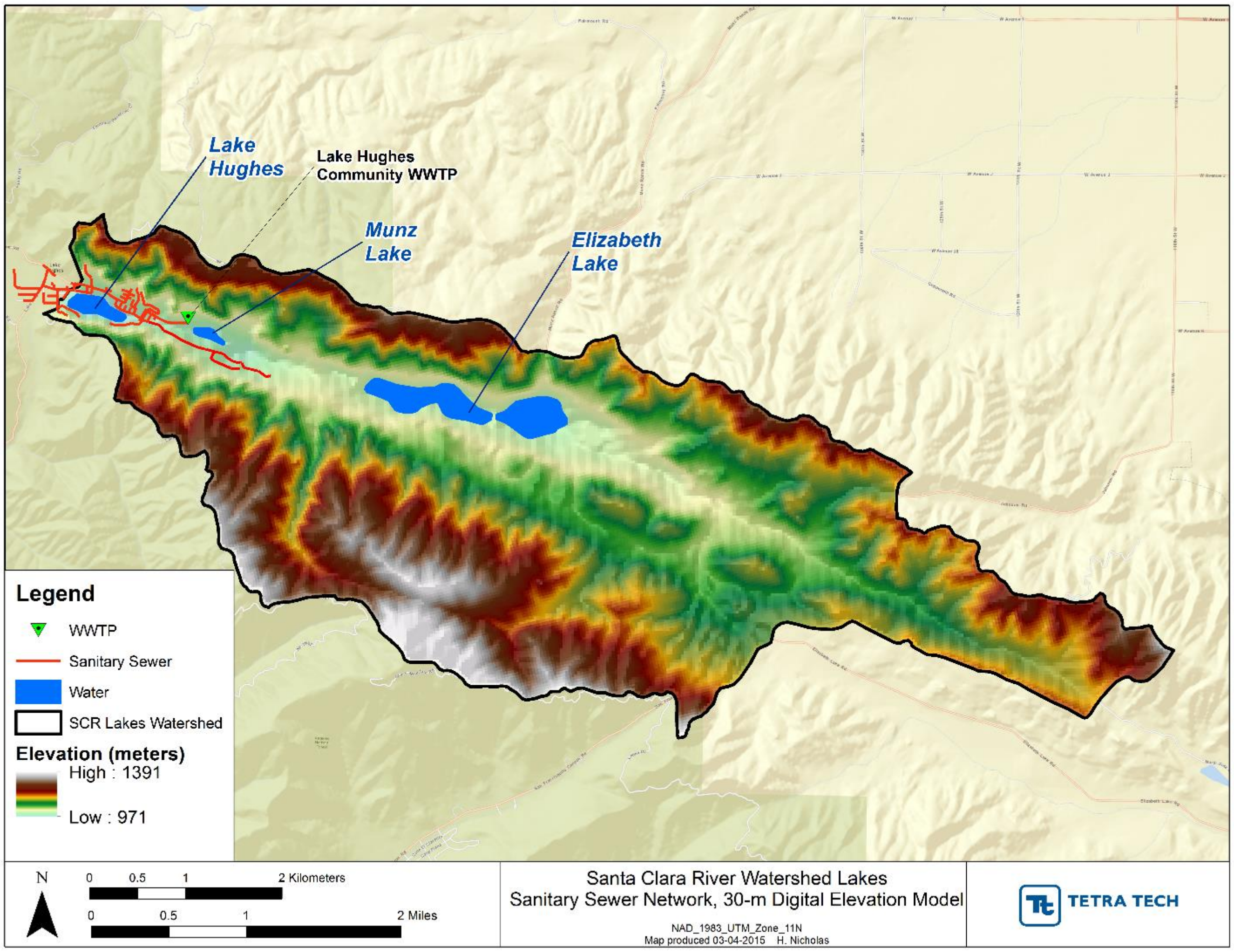

Figure 2-2. Elevation of Lake Hughes, Munz Lake, and Lake Elizabeth Area and Sanitary Sewer Network with WWTP labeled.

The respective drainage areas for each lake were delineated using ephemeral NHDPlusV2 Flowline data in tandem with a digital elevation model for the area. The separate upstream drainages for each lake are delineated in Figure 2-3. During extreme flooding events, the lakes are connected by overflow streams as they flow from east to west, however that is relatively rare (especially in recent years). The approximate non-nested drainage areas for each lake are: Lake Elizabeth is 7.61 square miles, Munz Lake is 2.34 square miles, and Lake Hughes is 0.77 square miles.

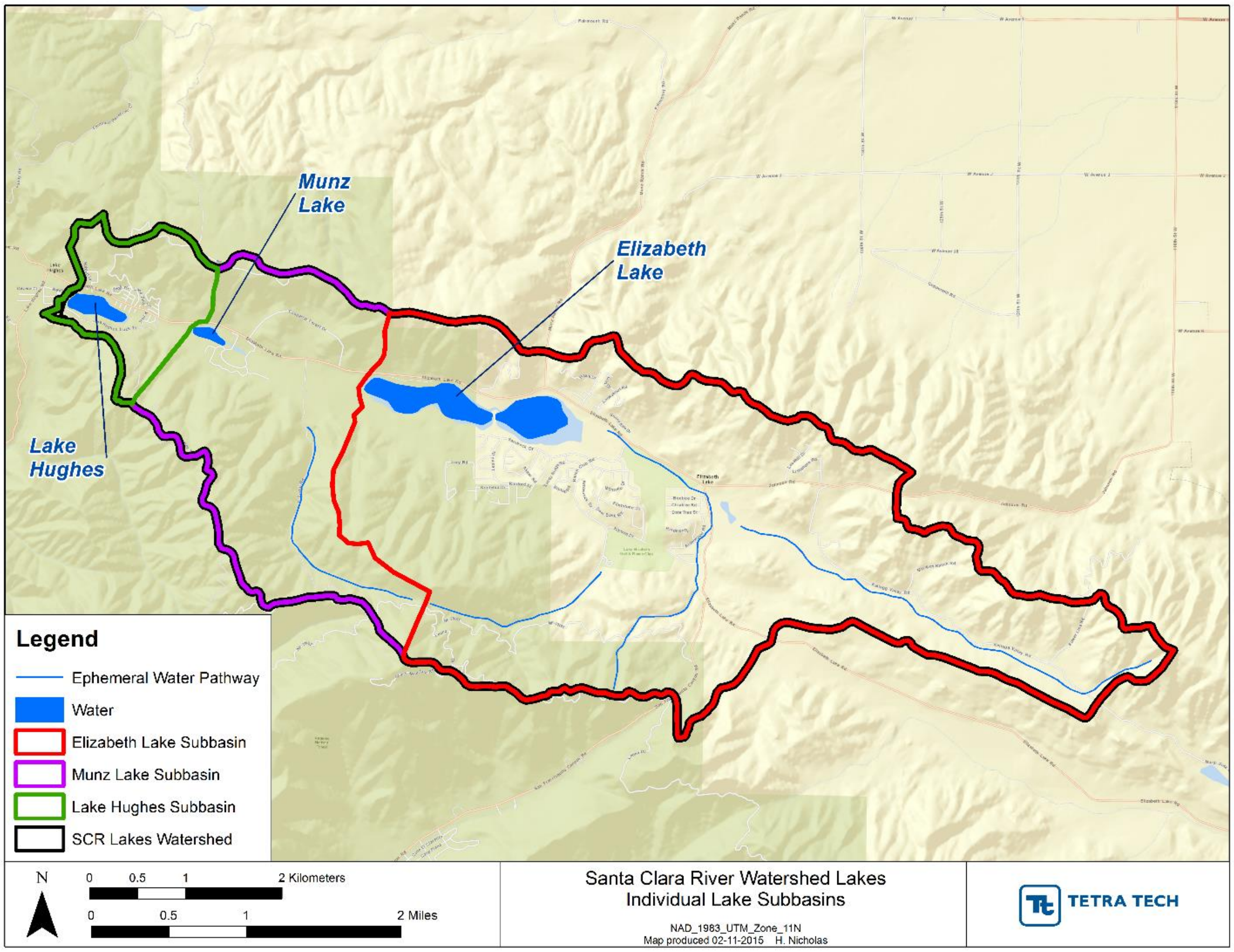

Figure 2-3. Separate Drainage Areas for Lake Hughes, Munz Lake, and Lake Elizabeth.

2.2 MS4 AND NON15 PERMITTEES

There are no non-MS4 NPDES dischargers in this basin. The unincorporated towns of Lake Hughes and Lake Elizabeth however are covered under the general MS4 permit for Los Angeles County (NPDES CAS004001) (Figure 2-4). Locations of storm inlets (catch basins) were approximated using field observations and information from the Los Angeles County Department of Public Works (LACDPW). The MS4 areas draining to the lakes were delineated using the catch basin locations, elevation data, and aerial imagery.

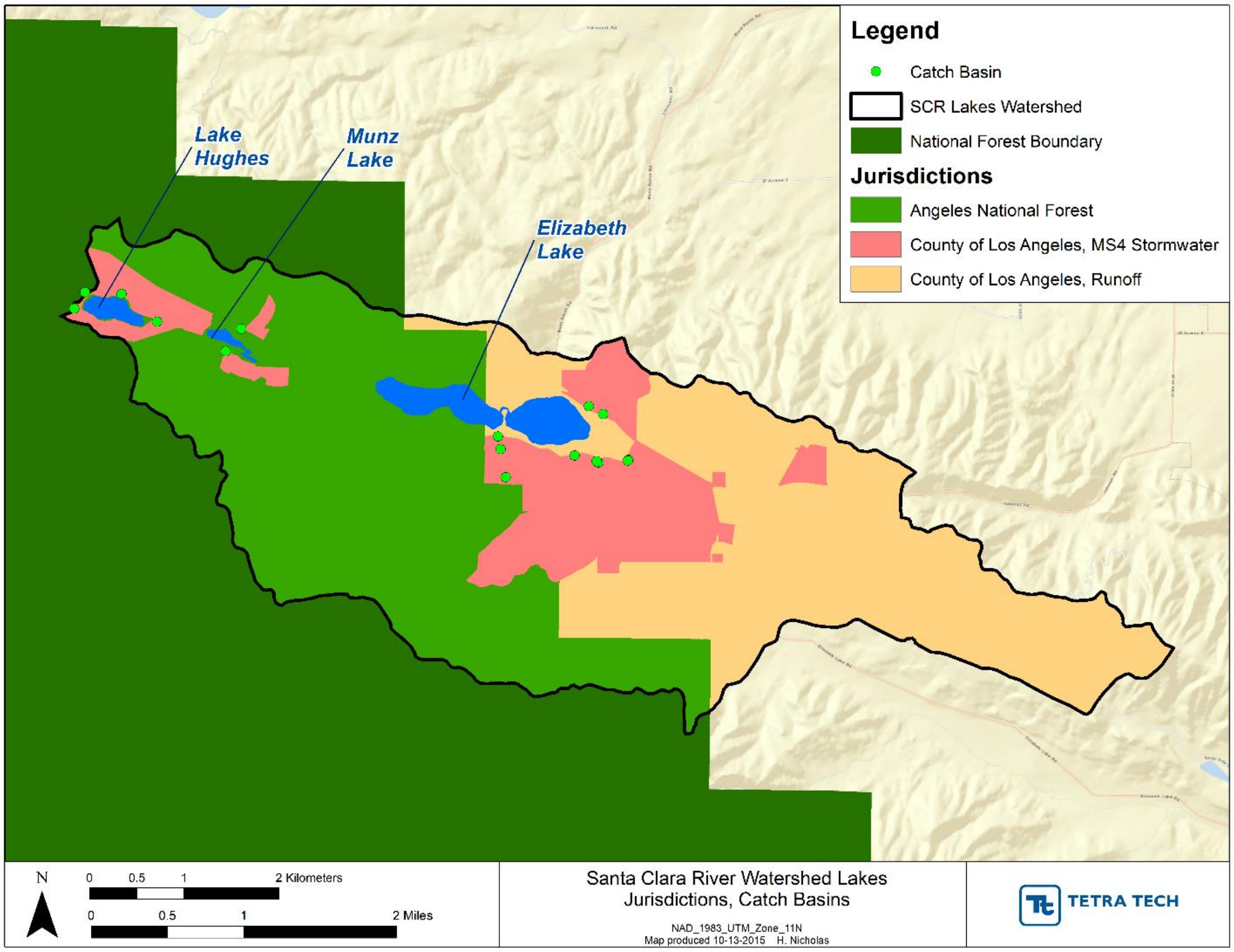

Figure 2-4. Jurisdictional boundaries across the SCR Lakes Watershed.

The Waste Discharge Requirements Program "Non Chapter 15 Program" (NON15) regulates point discharges not subject to the Federal Water Pollution Control Act. Two NON15 permittees are present in the SCR Lakes Watershed (Table 2-1). The Lake Hughes Community Wastewater Treatment Plant has reported monitoring data for the last several years; however, no monitoring data are available from the Lake Elizabeth Golf and Ranch Club. The lack of reporting from the Club has been tracked as a violation by the California Regional Water Board since at least 2005 (Violation Information: Claim No. 7007 2560 0001 7888 8670, File No. 03-059, Order No. 01-031, CI-8861, Series No. 064, Global ID WDR100001237). The Golf and Ranch Club went through foreclosure in 2010 and was sold in 2013 through a bank auction (Worden, 2013). No information is available on its current use, but it is assumed that the resort has not been operating for at least five years and is currently not under operation.

Table 2-1. NON15 Discharge Permittees in the Lake Hughes, Munz Lake, and Lake Elizabeth Drainage Area.

Waste Discharge Identification Number	Name	Location	Details
4B190134001	Lake Hughes Community Wastewater Treatment Plant	Next to Munz Lake	Serves Lake Hughes Community and Painted Turtle Camp, provides secondary treatment and on-site irrigation disposal. Designed for average dry weather flow 93,500 gpd. Baseline flow 0.04 MGD. Semi-annual groundwater monitoring and effluent testing of nitrite, nitrate, ammonia, total phosphorus.
4A197000064	Lake Elizabeth Golf and Ranch Club	Upstream of Lake Elizabeth	Not currently operating; Permit active as of 2005; Design flow 11,950 gpd, small commercial and multifamily residential subsurface sewage disposal system; Quarterly groundwater monitoring of nitrite, nitrate, ammonia, organic nitrogen

2.3 Land Uses and Soil Types

Several analyses, including wet-weather runoff and nutrient loading estimations, are linked to land use classifications in the SCR Lakes watershed. The AQUATERRA (2008) HSPF model generated for the entire Santa Clara River Watershed was used to estimate land use-based runoff volumes (Appendix A). A land use layer was created for the BATHTUB model which aligns with the HSPF model land uses and is similar to the layers used for the LA Lakes TMDL. The LA Lakes TMDL used the Southern California Association of Governments (SCAG 2005) land use data in tandem with analysis of current satellite imagery for areas that appeared to be misclassified. For the SCR lakes subbasins, SCAG 2008 was used to identify major land use and land cover across the watershed. Inspection of aerial imagery was used to correct some misclassified lands, largely around the Painted Turtle Camp. The SCAG 2008 land cover categorizes some 83 percent of the natural lands in the watershed as “vacant undifferentiated”, therefore those areas (and all natural lands) were re-classified using vegetation classes from the Landscape Fire and Resource Management Planning Tool (LANDFIRE, 2012).

The SCAG 2008 land use layer included 27 different classes which were aggregated into 5 new classes: natural lands (which LANDFIRE 2012 was used to differentiate), open water, low density development, roads, and waste water treatment plants (WWTPs). The LANDFIRE 2012 attribute of “EVT_ORDER” was used to classify land by its dominant physiognomic order which ranged from tree-dominated, to shrub-dominated, to herbaceous/non-vascular-dominated. The SCAG 2008 natural and vacant lands were reclassified based on LANDFIRE 2012 natural classes using raster calculations and inspection of aerial imagery. The results of this land use analysis are summarized in Figure 2-5, Table 2-2, Table 2-3, and Table 2-4.

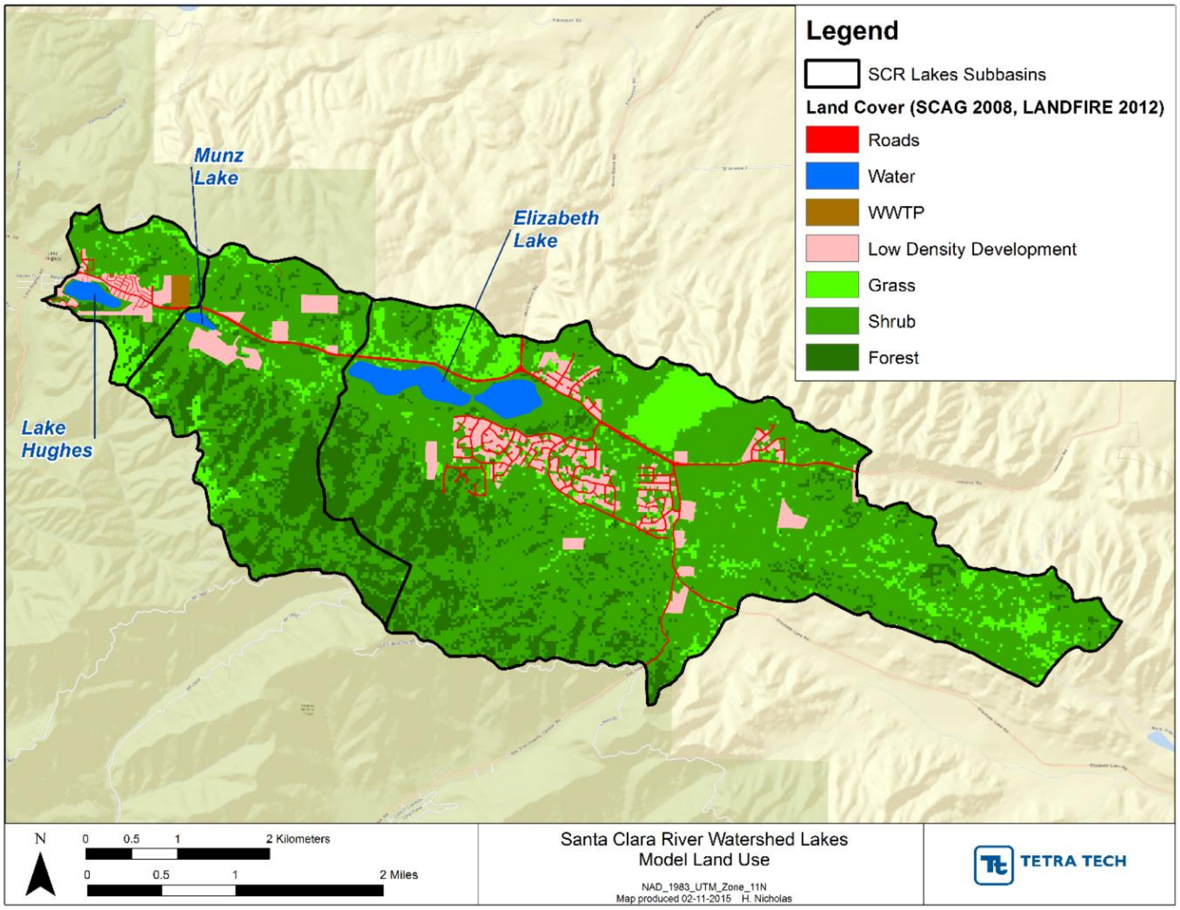

Figure 2-5. Land Use/Land Cover for SCR Lakes Watershed (SCAG 2008, LANDFIRE 2012).

Table 2-2. Land Use Areas (acres) by Jurisdictions for Lake Elizabeth Subbasin.

Land Use	Angeles National Forest	County of Los Angeles	MS4 Stormwater
Forest	478.68	131.88	60.13
Grass	56.22	398.18	50.88
LD Dev	11.80	36.66	218.18
Roads	17.30	22.56	101.70
Shrub	789.63	1888.29	453.02
Water	1.85	0.06	0.00

Table 2-3. Land Use Areas (acres) by Jurisdictions for Munz Lake Subbasin.

Land Use	Angeles National Forest	MS4 Stormwater
Forest	474.42	0.93
Grass	101.53	1.28
LD Dev	43.70	31.34
Roads	12.40	0.00
Shrub	809.40	15.26
Water	2.71	0.00

Table 2-4. Land Use Areas (acres) by Jurisdictions for Hughes Lake Subbasin.

Land Use	Angeles National Forest	MS4 Stormwater
Forest	31.55	11.10
Grass	56.88	5.70
LD Dev	5.88	58.24
Roads	0.34	16.82
Shrub	152.87	56.23
Water	0.98	0.00
WWTP	9.57	7.45

These three lakes fall directly along the San Andreas Fault, the zone of which is highlighted as a series of faults within the upper drainage area (Figure 2-6). The major geological units for the drainage area are Granodiorite, Sandstone, Mica Schist, Gneiss, and Alluvium (Ludington et al, 2007).

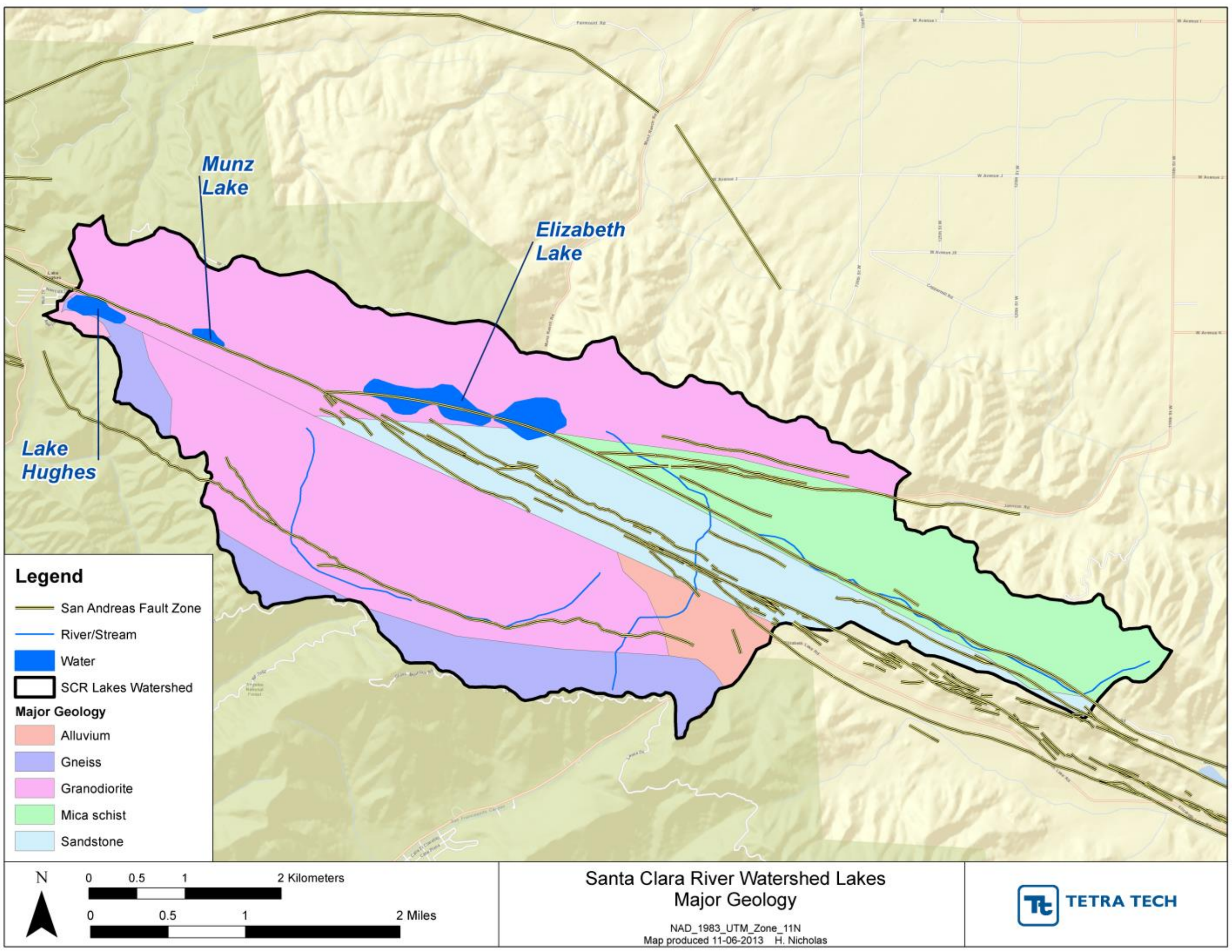

Figure 2-6. Major Geology and Faults for Lake Hughes, Munz Lake, and Lake Elizabeth Area

NRCS classifies soils into four hydrologic soil groups (HSGs) that describe the ability of the soil to infiltrate water, ranging from A (highest infiltration potential) to D (least infiltration potential). Twenty-five percent of the watershed area falls within each of the hydrologic soil groups according to the Soil Survey Geographic Database (SSURGO) (Figure 2-7). Note that the location of HSG Group A-soils between the lakes suggests an area of low runoff potential and high infiltration rate.

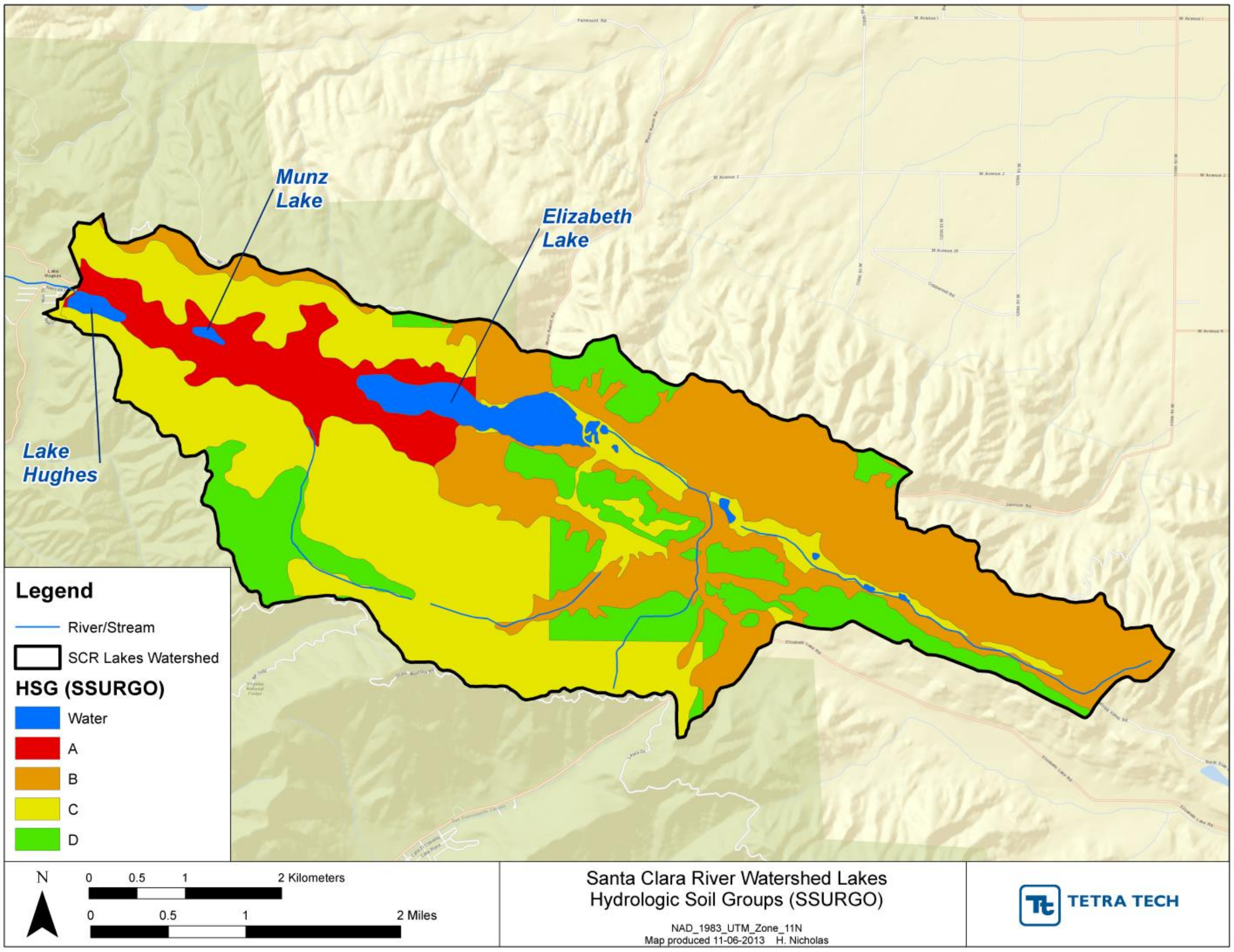

Figure 2-7. Hydrologic Soil Groups for Lake Hughes, Munz Lake, and Lake Elizabeth Area

3 Nutrient-Related Impairments

The three lakes addressed in this effort are Lake Elizabeth (#CAL4035100019990202155114), Munz Lake (#CAL4035100019990202154903), and Lake Hughes (#CAL4035100019990202154623), which are all on the current EPA 303(d) list for multiple impairments to beneficial uses. All three lakes are listed as impaired by eutrophication and trash (TMDLs for trash approved by EPA in 2008), while Lake Elizabeth is also listed for organic enrichment/low dissolved oxygen (DO) and pH, and Lake Hughes is also listed for algae, odor, and fish kills. These lakes have been included on the 303(d) listing for these impairments in 1996, 1998, 2002, 2006, and 2008-2010.

3.1 Beneficial Uses

California state water quality standards consist of the following elements: 1) beneficial uses, 2) narrative and/or numeric water quality objectives, and 3) an antidegradation policy. In California, beneficial uses are defined by the Regional Water Quality Control Boards (Regional Boards or RWQCB) in the Water Quality Control Plans (Basin Plans). Numeric and narrative objectives are specified in each region's Basin Plan, designed to be protective of the beneficial uses of each waterbody in the region. The LA RWQCB identified in the Basin Plan (LARWQCB, 1994) the beneficial uses for the various waterbodies in the SCR Lakes watershed (Table 3-1). Descriptions of these uses are listed in Appendix D.

Lake Elizabeth, Munz Lake, and Lake Hughes are hydraulically connected by intermittent channels and groundwater during the wet season (October through April) when precipitation is often sufficient to cause overflow. The chain of lakes ultimately discharge water downstream via Lake Elizabeth Canyon Creek to Castaic Lake. These downstream waterbodies are designated for multiple beneficial uses, including Municipal and Domestic Supply (MUN), Industrial Service Supply (IND), Industrial Process Supply (PROC), Agricultural Supply (AGR), Ground Water Recharge (GWR), and Freshwater Replenishment (FRSH).

The lakes are located in the Angeles National Forest, where many recreational activities occur, including boating, fishing on or along the lake shores, picnicking and hiking. These activities are supported by existing beneficial uses of Water Contact Recreation (REC-1) and Non-contact Water Recreation (REC-2) (LARWQCB, 1994). There are also private residences along the lake shores.

The thick growth of riparian plants, including species *Typha latifolia*, *Populus fremontii*, and *Chorizanthe parryi var. Fernandina* and communities such as Southern Willow Scrub and Valley Needlegrass grassland, provides suitable habitat for a variety of wildlife and support the beneficial uses of Warm Freshwater Habitat (WARM) and Wildlife Habitat (WILD) (Saint, Hanes and Lloyd, 1993). Wetlands associated with Lake Hughes also provide the wetland habitat beneficial use (WET).

Rare, Threatened, or Endangered Species (RARE) include those listed, or candidates for listing by the United States Fish and Wildlife Service (USFWS), California Department of Fish and Game (CDFG), and California Native Plant Society (CNPS). These species include, but are not limited to Nevin's barberry, short joint beavertail, Pierson's morning glory, alkali mariposa lily, California red-legged frog, southwestern pond turtle, California horned lizard, coast patchnosed snake, two-striped garter snake, merlin, prairie falcon, mountain plover, burrowing owl, California spotted owl, southwestern willow flycatcher, California condor, Mojave ground squirrel, and southern grasshopper mouse (CDFG, 2006). This beneficial use is assigned only for Lake Elizabeth.

Elevated nutrient levels are currently impairing the REC1, REC2, and WARM uses by stimulating excess algal growth (eutrophication), including formation of algal mats that impede recreational and drinking water use, contribute to oxygen depletion in bottom waters, and alter biology in ways that impair the

WARM aquatic life use and cause odor and aesthetic problems. At high enough nutrient concentrations, WILD and RARE uses could also be impaired.

Table 3-1. Beneficial Uses of the Lakes of Interest in the Santa Clara River Watershed

Waterbody	MUN	IND	PROC	AGR	GWR	FRSH	REC1	REC2	WARM	WILD	RARE	WET
Lake Elizabeth	P	P	P	P	P	P	E	E	E	E	E	
Lake Hughes	P	P	P	P	P	P	E	E	E	E		E[1]
Munz Lake	P[2]	P	P	P	E	P	E	E	E	E		

Key: Municipal and domestic water supply (MUN), industrial service supply (IND), industrial process supply (PROC), agricultural supply (AGR), ground water recharge (GWR), freshwater replenishment (FRSH), water contact recreation (REC1), non-contact water recreation (REC2), warm freshwater habitat (WARM), wildlife habitat (WILD), rare/threatened/endangered species (RARE), wetland habitat (WET), E = existing beneficial use, P = potential beneficial use,

[1] Waterbodies designated as WET may have wetlands habitat associated with only a portion of the waterbody. Any regulatory action would require a detailed analysis of the area.

[2] Designations will be considered for exemption at a later date under a Basin Plan amendment. No new effluent limitations will be placed in Waste Discharge Requirements as a result of these designations until the Regional Board adopts this amendment

3.2 NUMERIC TARGETS

The Basin Plan for the Los Angeles Region (LARWQCB, 1994) outlines the numeric water quality objectives and narrative criteria that apply to the SCR Lakes. The numeric objectives and quantitative measures associated with the narrative criteria together provide numeric targets for the TMDL. The following targets apply to the fish kills (ammonia and DO), algae, eutrophication, odor, and pH impairments (see Section 2 for additional details and Table 6-4 for a summary):

- Ammonia toxicity to aquatic life is caused primarily by the un-ionized form (NH_3), while most ammonia in water is present in the ionic form of ammonium (NH_4+). The Basin Plan expresses the chronic ammonia water quality objective as a function of pH and temperature because un-ionized ammonia (NH_3) is toxic to fish and other aquatic life. In order to assess compliance with the standard, pH, temperature, and ammonia must be determined at the same time. The toxicity of ammonia increases with increasing pH and temperature; therefore, ammonia water quality objectives depend on the site specific pH and temperature as well as the presence or absence of early life stages (ELS) of aquatic life. For the purpose of this report, pH and temperature samples at the surface of all three lakes (less than 0.5 meters of depth) were used to determine the median temperature (24.5 degrees Celsius) and 95th percentile pH (8.9), which were then used to calculate chronic water quality objectives. Based on Tables 3-1 through 3-4 of the Basin Plan (LARWQCB, 1994, as amended by Resolution Nos. 2002-001 and 2005-014), the targets for Lake Hughes are 1.56 mg-N/L for the one-hour Average Objective and 0.56 mg-N/L for the 30-day average objective. The four-day maximum average concentrations shall not exceed 2.5 times the 30-day average objective, or 1.41 mg-N/L. (The median temperature and 95th percentile pH values were calculated from the observed surface depth data and used in the calculation of ammonia water quality objectives. These are presented as example calculations since the actual target is the water quality objective which is dependent on pH and temperature. When assessing compliance refer to the water quality objective as expressed in the Basin Plan).

- The Basin Plan addresses excessive aquatic plant growth in the form of a narrative objective for biostimulatory substances (i.e., nutrients). Excess nutrient (e.g., nitrogen and phosphorous) concentrations in a waterbody can lead to nuisance effects such as algae, odors, and scum. The objective specifies, "waters shall not contain biostimulatory substances in concentrations that promote aquatic growth to the extent that such growth causes nuisance or adversely affects beneficial uses." The Regional Board has not adopted numeric water quality objectives for biostimulatory nutrients. However, the Regional Board has in the past, for the Machado Lake Nutrient TMDL and the Ventura River Algae TMDL, assigned numeric targets for biostimulatory nutrients and response indicators, such as chlorophyll *a* based on the California Nutrient Numeric Endpoints framework (Tetra Tech, 2006). The State Board is also in the process of developing a nutrient strategy and associated guidance on nutrient numeric endpoints; however, these are not yet finalized. As described in Tetra Tech (2006), summer (May to September) mean and annual mean chlorophyll *a* concentration of 20 µg/L are recommended as the maximum allowable level consistent with full support of contact recreational use and is also consistent with supporting warm water aquatic life. The mean chlorophyll *a* target must be met at half of the Secchi depth (to reflect average conditions over the photic zone) during the summer (May – September) and annual averaging periods.

- The Basin Plan states that "waters shall not contain taste or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible aquatic resources, cause nuisance, or adversely affect beneficial uses." A numeric target is not assigned to this narrative standard. Impairments related to odor are believed to be caused by anoxic conditions that promote release of odors from lake sediment; therefore, this narrative standard will be addressed by DO targets.

- The Basin Plan states "at a minimum the mean annual dissolved oxygen concentrations of all waters shall be greater than 7 mg/L, and no single determinations shall be less than 5.0 mg/L, except when natural conditions cause lesser concentrations." In addition, the Basin Plan states, "the dissolved oxygen content of all surface waters designated as WARM shall not be depressed below 5 mg/L as a result of waste discharges." Shallow, well-mixed lakes – such as Lake Elizabeth, Munz Lake, and Lake Hughes – must meet the DO target in the water column from the surface to 0.3 meters above the bottom of the lake.

- The Basin Plan states that "the pH of inland surface waters shall not be depressed below 6.5 or raised above 8.5 as a result of waste discharges. Ambient pH levels shall not be changed more than 0.5 units from natural conditions as a result of waste discharge." In lakes, deviations from the specified range of pH can occur as a result of excessive algal growth or from natural geochemical conditions. Shallow, well-mixed lakes – such as Lake Elizabeth, Munz Lake, and Lake Hughes – must meet the pH target in the water column from the surface to 0.3 meters above the bottom of the lake. The extent to which natural geologic conditions may contribute to pH excursions in these lakes is unknown; however, addressing eutrophication and meeting the chlorophyll *a* target described above would prevent significant contribution of algal growth to excursions of the pH target.

Numeric nitrogen and phosphorus targets, specific to Lake Elizabeth, Munz Lake, and Lake Hughes, are assigned to support the achievement of the narrative objective for nutrients and the chlorophyll a target described above. The numeric nutrient target concentrations are based on simulation of nutrient concentrations and chlorophyll *a* response with the Munz Lake BATHTUB model (see Sections 5 and 6). Based on the BATHTUB model for Munz Lake, the target nutrient concentrations consistent with achieving the mean chlorophyll *a* target within Lake Elizabeth, Munz Lake, and Lake Hughes are:

- 1.13 mg-N/L summer average (May – September) and annual average
- 0.113 mg-P/L summer average (May – September) and annual average

The targets applicable to the relevant impairments for Lake Elizabeth, Munz Lake, and Lake Hughes are summarized in Table 3-2, Table 3-3, and Table 3-4, respectively.

Table 3-2. Nutrient-Related Numeric Targets for Lake Elizabeth

Parameter	Numeric Target	Notes
Chlorophyll *a*	≤20 µg/L summer average (May – September) and annual average	
Dissolved Oxygen	≥7 mg/L minimum mean annual concentrations ≥5 mg/L single sample minimum	
pH	The pH of inland surface waters shall not be depressed below 6.5 or raised above 8.5 as a result of waste discharges. Ambient pH levels shall not be changed more than 0.5 units from natural conditions as a result of waste discharge.	
Total Nitrogen	≤1.13 mg-N/L summer average (May – September) and annual average	Based on simulation of allowable loads from the Munz Lake BATHTUB model
Total Phosphorous	≤0.113 mg-P/L summer average (May – September) and annual average	Based on simulation of allowable loads from the Munz Lake BATHTUB model

Table 3-3. Nutrient-Related Numeric Targets for Munz Lake

Parameter	Numeric Target	Notes
Chlorophyll *a*	≤20 µg/L summer average (May – September) and annual average	
Total Nitrogen	≤1.13 mg-N/L summer average (May – September) and annual average	Based on simulation of allowable loads from the BATHTUB model
Total Phosphorous	≤0.113 mg-P/L summer average (May – September) and annual average	Based on simulation of allowable loads from the BATHTUB model

Table 3-4. Nutrient-Related Numeric Targets for Lake Hughes

Parameter	Numeric Target	Notes
Ammonia[1]	≤1.56 mg-N/L acute (one-hour) ≤1.41 mg-N/L four-day average ≤0.56 mg-N/L chronic (30-day average)	Based on median temperature and 95th percentile pH
Chlorophyll *a*	≤20 µg/L summer average (May – September) and annual average	
Dissolved Oxygen	≥7 mg/L minimum mean annual concentrations ≥5 mg/L single sample minimum	
Total Nitrogen	≤1.13 mg-N/L summer average (May – September) and annual average	Based on simulation of allowable loads from the Munz Lake BATHTUB model
Total Phosphorous	≤0.113 mg-P/L summer average (May – September) and annual average	Based on simulation of allowable loads from the Munz Lake BATHTUB model

[1] The median temperature and 95th percentile pH values were calculated from the observed data and used in the calculation of the acute and chronic targets. These are presented as example calculations since the actual target varies with the values determined during sample collection.

3.3 SUMMARY OF MONITORING DATA

Monitoring data for SCR lakes were collected in the early 1990s and in 2014. This section summarizes the monitoring data relevant to the nutrient impairments. Additional details regarding monitoring are provided in Appendix E (Monitoring Data).

Water quality monitoring for the three SCR Lakes was conducted from 1992-1993 by the University of California, Riverside (Lund et al, 1994). This sampling effort occurred every few months from May 1992 until May 1993 and covered the following parameters: total Kjeldahl nitrogen (TKN), ammonia as N, nitrate as N, nitrite as N, dissolved orthophosphate as P, total phosphorus, pH, and total organic carbon (TOC). These samples were not analyzed for chlorophyll *a*.

In the 1992-1993 data for Lake Elizabeth, sampling depths ranged from 0 to 6.5 meters below the lake surface, although most samples were taken between 0 and 2.5 meters. All orthophosphate and total P samples exceeded the detection limit of 0.1 mg-P/L. Orthophosphate ranged from 0.3 to 0.4 mg-P/L, and total P ranged from 0.3 mg-P/L to 0.6 mg-P/L. Nine of the twenty nitrate samples and none of the nitrite samples exceeded the detection limit of 0.1 mg-N/L. Of the samples that did exceed the detection limit, nitrate ranged from 0.1 mg-N/L to 0.6 mg-N/L, with an average of 0.4 mg-N/L. TKN, which includes the organic and ammonia species of nitrogen, ranged from 0.9 mg-N/L to 6.6 mg-N/L, with an average of 3.8 mg-N/L and no samples below the detection limit (0.1 mg-N/L). For ammonium, 10 of the 20 samples exceeded the detection limit of 0.1 mg-N/L, and these samples ranged from 0.10 mg-N/L to 0.50 mg-N/L with an average of 0.27 mg-N/L. pH ranged from 8.3 to 9.5, and TOC ranged from 11.10 to 54.50 mg/L.

Nutrient concentrations were lower, overall, in Munz Lake during the 1992-1993 sampling period compared to the other two lakes. All samples were taken at the surface of the lake. Orthophosphate ranged from 0.2 mg-P/L to 0.3 mg-P/L, and total P ranged from 0.1 mg-P/L to 0.3 mg-P/L. Similar to Lake Elizabeth, nine of the twenty nitrate samples and none of the nitrite samples exceeded the detection limit of 0.1 mg-N/L. Of the samples that did exceed the detection limit, nitrate ranged from 0.1 mg-N/L to 0.3 mg-N/L, less than the average 1992-1993 nitrate concentration measured in Lake Elizabeth. Also lower than the Lake Elizabeth 1992-1993 average, TKN in Munz Lake ranged from 0.9 mg-N/L to 1.6 mg-N/L. Only 3 out of 20 samples exceeded the ammonium detection limit of 0.1 mg-N/L, all at 0.2 mg-N/L. pH ranged from 7.9 to 8.1, and TOC ranged from 4.1 to 11.5 mg/L.

Lake Hughes exhibited similar nutrient ranges compared to Munz Lake during the 1992-1993 sample period. Orthophosphate ranged from 0.1 mg-P/L to 0.3 mg-P/L, and total P ranged from 0.2 mg-P/L to 0.3 mg-P/L. Only 9 nitrite samples and 9 nitrate samples were recorded during this period, and all of these samples were below the detection limit of 0.1 mg-N/L. TKN ranged from 0.8 mg-N/L to 1.6 mg-N/L. None of the 8 ammonium samples exceeded the detection limit of 0.1 mg-N/L. pH ranged from 8.3 to 8.6, and TOC ranged from 7.9 mg/L to 45 mg/L.

The Painted Turtle Youth camp collected in-lake data (single sample analyzed by Morrison Well Maintenance, Lancaster, CA) following the Powerhouse Fire on August 6, 2013. Relevant observations for this TMDL included nitrate, which was below the reporting limit of 2 mg-N/L, and pH, which was 8.8.

ECORP Consulting collected data for Ridgetop Ranch Properties in Lake Elizabeth on July 2, 2014. Sampling locations included the eastern and western portions of the lake as well as a pond that existed between the two portions. Lake temperatures ranged from about 22 to 26 degrees Celsius. Excluding the value of 10.89 mg/L that was noted as uncertain, dissolved oxygen ranged from 6.97 to 7.93 mg/L. pH ranged from 8.8 to 9.7, and oxidation-reduction potential ranged from -81 ORPmV to 40 ORPmV. Salinity ranged from 3.6 ppt to 21.8 ppt. Excluding the value of 0 which was noted as uncertain, turbidity ranged from 132 NTU to 847 NTU. Conductivity ranged from 6,660 μS/cm to 34,800 μS/cm, and total dissolved solids ranged from 4,200 mg/L to 21,200 mg/L – indicating brackish conditions during this period when the lake level was low.

A more recent water quality sampling effort was conducted by the Los Angeles Regional Water Quality Control Board during the latter half of 2014. Two sampling dates during 2014 were analyzed for the following constituents: ammonia as N, chlorophyll-a, dissolved orthophosphate as P, nitrate as N, nitrite as N, total dissolved solids (TDS), total P, total suspended solids (TSS), pH, and conductivity. These samples generally revealed concentrations of total N and total P much higher than those reported in 1992-93.

The first sampling trip was conducted on July 8, 2014. Sampling occurred at all three lakes, although at Hughes and Elizabeth the sampling was conducted in less than one foot of water near the lake shore due to silty conditions. Hughes was sampled once, Munz was sampled twice, and Elizabeth was sampled twice. The second sampling trip was conducted on October 1, 2014 and October 8^{th}, 2014. Elizabeth and Hughes were each sampled once on the 1^{st}, and Elizabeth and Munz were both sampled once on the 8^{th}.

In Lake Elizabeth samples during 2014, orthophosphate ranged from 0.02 mg-P/L to 0.03 mg-P/L, and total phosphorus ranged from 1.2 to 2.7 mg-P/L. All nitrite samples were less than the detection limit of 0.01 mg-N/L, and nitrate ranged from 0.01 to 0.29 mg-N/L. TKN ranged from 31 to 82 mg-N/L. Ammonia samples ranged widely in concentration. At location LE 1 (northern shore, western portion) on July 8, 2014, the ammonia concentrations were 3.2 mg-N/L (average of two duplicates) while on the same day at LE 2 (northern shore, eastern portion) the ammonia concentration was below the detection limit of 0.02 mg-N/L. In October 2014, the ammonia concentrations were below the detection limit of 0.02 mg-N/L at both sampled locations of LE 1 and LE 3. All chlorophyll *a* samples were extremely high and well above the target of 20 µg/L, ranging from 264 µg/L to 698 µg/L. Conductivity ranged from 15,850 µS/cm to 31,800 µS/cm. TSS ranged from 69.7 to 179.3, and TDS ranged from 13,220 to 34,330 mg/L. pH ranged from 8.7 to 8.9.

Compared to both Lake Elizabeth and Lake Hughes, Munz Lake exhibited much lower total nitrogen, total phosphorus, and chlorophyll *a* concentrations, among other results, during the 2014 sampling. However, orthophosphate concentrations were similar to the other lakes, ranging from 0.02 mg-P/L to 0.03 mg-P/L. Total P at Munz Lake ranged from 0.06 mg-P/L to 0.07 mg-P/L, much lower than both Lake Elizabeth and Lake Hughes. All nitrite samples were less than the detection limit of 0.01 mg-N/L, and nitrate ranged from below the detection limit of 0.01 mg-N/L to 0.09 mg-N/L. TKN concentrations were much lower than those measured in the other two lakes, ranging from 1.1 mg-N/L to 1.5 mg-N/L. Ammonia ranged from 0.09 mg-N/L to 0.61 mg-N/L, lower than some locations at Lake Elizabeth and Lake Hughes during July. Chlorophyll *a* concentrations met the standard in July, measuring at about 9 µg/L, and exceeded the standard in October 2014, measuring 36 µg/L. Conductivity ranged from 747 to 1115 µS/cm. TSS ranged from 4.2 to 11.9, TDS ranged from 494 to 683 mg/L and pH ranged from 7.9 to 8.5.

At Lake Hughes in 2014, orthophosphate ranged from 0.01 mg-P/L to 0.04 mg-P/L, and total phosphorus ranged from 0.7 to 2.5 mg-P/L. All nitrite samples were less than the detection limit of 0.01 mg-N/L, and nitrate ranged from 0.17 to 0.65 mg-N/L. TKN ranged from 26 mg-N/L to 148 mg-N/L. Ammonia samples ranged from 2.4 mg-N/L in July 2014 to below the detection limit of 0.02 mg-N/L in October 2014. Similar to Lake Elizabeth, all chlorophyll *a* samples were well above the target, ranging from 173 µg/L to 494 µg/L. Conductivity ranged from 9,380 to 41,350 µS/cm. TSS ranged from 183 mg/L to 391 mg/L, TDS ranged from 9,555 mg/L to 50,040 mg/L, and pH ranged from 8.9 to 9.0.

The monitoring data (1992-1993, 2014) are documented in Appendix E along with maps of the 2014 monitoring locations.

4 Source Assessment

This section identifies and estimates existing nutrient loads and flows the potential sources of pollutants that discharge within the drainage area of these impaired lakes. In general, pollutants can enter surface waters from both point and nonpoint sources. Point sources include discharges from discrete human-engineered outfalls which are regulated through National Pollutant Discharge Elimination System (NPDES) permits, including MS4 areas within the watershed (Section 2.2). The SCR lakes watershed does not contain any non-MS4 NPDES permits. Non-NPDES wastewater sources include onsite wastewater systems and the NON15 permitted Lake Hughes Community Wastewater Treatment Plant (the Lake Elizabeth Golf and Ranch Club appears to have been closed since 2010). These wastewater sources are considered nonpoint sources because they discharge through the soil. Other nonpoint sources include agriculture, recreation and tourism (non-boating), and urban runoff/stormwater. Load estimates for recreation and tourism were not estimated and expected to be negligible considering that the current recreational uses are impaired.

The source assessment for the SCR Watershed Lakes includes external load and flow estimates from the surrounding watershed, groundwater, and atmosphere (Appendix A, Wet Weather Loading; Appendix B, Dry Weather Loading, Section B-1), wastewater treatment (Appendix B, Dry Weather Loading, Section B-2) and atmospheric deposition (Appendix C, Atmospheric Deposition).

Internal loading, which is the release of stored nutrients from bed sediments, also was considered in this source assessment. Elevated nutrient concentrations have been observed in all three lakes since the early 1990s (Section 3.3). Sources of nutrient loading during this time period might have included on-site wastewater treatment systems (OWTS), effluent from Wastewater Treatment Plants (WWTPs), stormwater runoff, and runoff from undeveloped areas. Sediments within all three lakes have likely accumulated nutrients from these sources over time. Nutrients stored in sediments can be released into the water column by multiple processes including anoxic conditions, wind perturbation, and the movement of fish and macroinvertebrates. Internal loading from bed sediments was considered a significant source of nutrients to Lake Elizabeth and Lake Hughes. Nutrient concentrations observed in 2014 in Lake Hughes and Lake Elizabeth indicate a severe increase in nutrient loading since the early 1990s that cannot be explained by external loading alone. It is hypothesized that conditions in the watershed following wildfires and firefighting, including the 2013 Powerhouse fire, contributed to the nutrients that have accumulated in the sediments. For example, it is understood that the fire retardant used by fire fighters during the 2013 Powerhouse fire was the commercial product Phos-Check, which contains 76-82 percent Monoammonium Phosphate and 8-12 percent Diammonium Phosphate, which are soluble forms of nitrogen and phosphorus and are frequently used as ingredients in commercial fertilizer (ILC Performance Products LP, 2011). Conclusive information was not available to explain the differences in nutrient concentrations between Munz Lake and the other two lakes. Potential reasons for these differences could include the lower surface area to depth ratio of Munz compared to the other two lakes as well as differences in cleanup efforts following recent wildfires.

As noted above, sediment stores of nutrients can be released into the water column through multiple mechanisms. Anoxic environments, often present at the sediment-water interface, increase the reduction and release of nutrients. Resuspension of sediment by wind mixing, and the movement of fish and macroinvertebrates, or bioturbation, can result in additional recycling from the sediment to the water column. Macrophyte decomposition is another source of internal loading. Intensive monitoring studies are typically required to accurately quantify internal nutrient loading. This level of information was not available for the lakes addressed by this TMDL. As explained in Section 5.2 and 5.3, internal loading for Lake Elizabeth and Lake Hughes was estimated by using the difference between the external load input and the total load input that resulted in a simulation of average observed concentrations in BATHTUB.

An explicit estimate of internal loading was not necessary for Munz Lake because it was possible to approximate the lake's observed nutrient concentrations using external loading estimates and the recommended range of model calibration factors (Section 5 provides more detail on calibration factors). Internal loading was simulated implicitly within BATHTUB, which is consistent with internal loading methods for the LA Lakes TMDLs (USEPA, 2012). Internal loading is implicitly accounted for in the model because the net sedimentation rates for nitrogen and phosphorus reflect the balance between settling and resuspension of nitrogen and phosphorus within the waterbody. Since BATHTUB is a steady-state model, it focuses on long-term average conditions rather than day-to-day variations in water quality. Internal nutrient loads from cycling processes may include sediment release and macrophyte decomposition. These processes are accounted for implicitly in the model through the calibration of the net sedimentation rates. These rates are estimated by BATHTUB based on empirical relationships derived from field data from many different lakes, including those in USEPA's National Eutrophication Survey and lakes operated by the Army Corps of Engineers.

Several conservative assumptions were incorporated into the existing load estimation to provide implicit Margins of Safety (MOS) for the TMDLs. For the Lake Hughes Community Wastewater Treatment Plant load estimates, the observed concentrations at the monitoring wells for the WWTP (downgradient to the spray irrigation field) were applied to simulated groundwater flows to estimate the nutrient loads delivered to Lake Hughes. Since the groundwater would travel further from these wells to the lake itself, the actual load delivered to Lake Hughes is expected to be lower than what is estimated. In addition, the estimated existing loads from OWTS are likely overestimated because dry conditions during the summer months are likely to result in less nutrient loading than the conditions assumed by Haith et al (1992). The wet weather loading estimates assume average loading across the HSPF modeling period (1996-2005) which includes several very wet years and might represent at least a slight overestimate of average annual loads. For dry weather loading from storm drains, the flow rates were based on a study of the greater Los Angeles area (USEPA, 2012) and likely reflect more dense development and, therefore, would likely be slightly higher than the actual loading from storm drains in the SCR lakes watershed. Internal loading estimates, as explained in Sections 5.2 and 5.3, were developed based on simulating the observed 2014 nutrient concentrations; considering that lake levels were observed to be low, the concentrations on which the internal load were based are likely to reflect conditions during dry years and, thus, a conservative assumption.

All existing loads to each lake are summarized in Table 4-1. These loads are specific to the direct drainage area of each lake and are not cumulative loads from the entire upstream drainage. Internal loading from lake bed sediments, as estimated, accounts for nearly 99 to 100 percent of the loading to Lake Elizabeth and Lake Hughes. In contrast, the majority of nutrient loading to Munz Lake is derived from either MS4 stormwater (45.5 percent TP loading; 35.9 TN loading) or other runoff (53.1 percent TP loading; 62.5 TN loading) and less than 2 percent of loading is derived from OWTS in the subbasin and atmospheric deposition combined.

Table 4-1. Summary of Average Annual Flows and Nutrient Loading to SCR Watershed Lakes.

Source/Jurisdiction		Input	Flow (ac-ft/yr)	Total Phosphorus (lb-P/yr) (percent of total load)	Total Nitrogen (lb-N/yr) (percent of total load)
Lake Elizabeth					
	County of Los Angeles	MS4 stormwater[1]	323	537 (0.07)	3,165 (0.07)
	County of Los Angeles	runoff	42	48 (0.01)	448 (0.01)
	Angeles National Forest	runoff	24	27 (<0.01)	239 (<0.01)
	On-site Wastewater	groundwater	38	160 (0.02)	961 (0.02)
	Atmospheric Deposition	deposition to lake surface	83	N/A	36 (<0.01)
	Internal Loading	lake sediment	N/A	760,000 (99.90)	42,470,000 (99.90)
	Total		509	760,773	42,474,848
Munz Lake					
	County of Los Angeles	MS4 stormwater[1]	18.6	33 (45.50)	184 (35.94)
	Angeles National Forest	runoff	28.6	38 (53.12)	320 (62.52)
	On-site Wastewater	groundwater	0.2	1 (1.38)	6 (1.17)
	Atmospheric Deposition	deposition to lake surface	4.4	N/A	2 (0.37)
	Total		560	72	512
Lake Hughes					
	County of Los Angeles	MS4 stormwater[1]	64.9	110 (0.20)	657 (0.01)
	Angeles National Forest	runoff	3.3	4 (0.01)	35 (<0.01)
	Lake Hughes Community Wastewater Treatment Facility (NON-15)	groundwater	8.8	1 (<0.01)	174 (<0.01)
	On-site Wastewater	groundwater	5.0	2 (<0.01)	14 (<0.01)
	Atmospheric Deposition	deposition to lake surface	14.4	N/A	6 (<0.01)
	Internal Loading	lake sediment	N/A	54,819 (99.79)	8,244,612 (99.99)
	Total		92	54,936	8,245,498

[1]This input includes effluent from storm drain systems during both wet and dry weather and, for the Lake Hughes drainage, includes MS4 loading from the Lake Hughes Community Wastewater Treatment Facility.

5 Linkage Analysis

The linkage analysis defines the connection between numeric targets and identified pollutant sources and may be described as the cause-and-effect relationship between the selected indicators, the associated numeric targets, and the identified sources. This provides the basis for estimating total assimilative capacity and any needed load reductions. To simulate the impacts of nutrient loading on the SCR lakes, the version of the BATHTUB lake water quality tool developed for U.S. EPA and the State Water Quality Board as part of California's nutrient numeric endpoints (NNE) development (Tetra Tech, 2006) was set up and calibrated for each hydraulically connected system. The BATHTUB Tool is a spreadsheet version of the US Army Corps of Engineers (USACE) BATHTUB model. The application of the BATHTUB Tool is described in detail in the LA Lakes TMDLs (USEPA, 2012). The SCR Lakes TMDLs were based on these methods unless otherwise stated. This section documents the lake-specific assumptions for the SCR Lakes linkage analysis.

BATHTUB is a steady-state model that calculates nutrient concentrations, chlorophyll *a* concentration (or algal density), turbidity, and hypolimnetic oxygen depletion based on nutrient loadings, hydrology, lake morphometry, and internal nutrient cycling processes. The empirical relationships used in BATHTUB were derived from field data from many different lakes, including those in USEPA's National Eutrophication Survey and lakes operated by the Army Corps of Engineers. BATHTUB uses a typical mass balance modeling approach that tracks the fate of external and internal nutrient loads between the water column, outflows, and sediments. External loads can be specified from various sources including stream inflows, nonpoint source runoff, atmospheric deposition, groundwater inflows, and point sources. Internal nutrient loads from cycling processes may include sediment release and macrophyte decomposition. The net sedimentation rates for nitrogen and phosphorus reflect the balance between settling and resuspension of nitrogen and phosphorus within the waterbody based on the model's empirical relationships. Internal loading from bed sediments is implicitly accounted for in the model based on the empirically-derived net sedimentation rates. If the empirical relationships underpredict internal loading, this loading can be directly specified (internal loading estimates are explained separately for each lake below). Since BATHTUB is a steady-state model, it focuses on the long-term central tendency of growing season conditions rather than day-to-day variations in water quality.

Target nutrient loads and resulting allocations are determined based on the secondary target – summer mean chlorophyll *a* concentration. The spreadsheet tool allows the user to specify a chlorophyll *a* target and predicts the probability that current conditions will exceed the target, as well as showing a matrix of allowable nitrogen and phosphorus loading combinations to meet the target. The user-defined chlorophyll *a* target can be input directly by the user, or can be calculated based on an allowable change in water transparency measured as Secchi depth. The LA Lakes Appendix A (Nutrient TMDL Development) describes additional details on the BATHTUB Tool and its use in determining allowable loads of nitrogen and phosphorus (USEPA, 2012).

In addition to loading rates of nitrogen and phosphorus, the BATHTUB Tool requires basic morphometric and flow data sufficient to establish depth and overflow rate for the simulation of summer season nutrient concentrations and chlorophyll *a*. The evaporation, precipitation, flow, and loading inputs also depend on the averaging period assumed. The averaging periods for the LA Lakes TMDLs were based on the turnover ratios (Walker, 1987). However, the assumption of the summer season averaging period would require the lakes to experience outflow during the growing season, and all available information on the lakes indicates that summer season outflow does not occur. Therefore, the annual averaging period was used for the BATHTUB model inputs.

Related to the seasonal hydrology of the lakes, the modeling required an assumption of the contributing drainage area. Data on flow between the lakes are not available. However, anecdotal evidence

(LARWQCB and resident observations) indicate that overflow from one lake to the next downstream lake occurs very infrequently. It was assumed that if loading from upstream lakes does occur, it is likely washed out during high precipitation events during the wet season, and this temporary loading has an insignificant effect on the lakes. Therefore, the loading estimates were based solely on the direct drainages areas to each lake.

The following sections describe the lake-specific assumptions and results from the linkage analysis for each of the SCR lakes. Munz Lake is considered first because it was used as a reference for the numeric nutrient targets for all three lakes.

5.1 Munz Lake

For the Munz Lake BATHTUB model, a surface area of 6.6 acres, an average depth of 5.5 feet, and a cumulative volume of 36 ac-ft. were assumed. Other model inputs included nutrient load estimates (Section 4). The BATHTUB Tool was calibrated to simulate the average concentrations observed across the two 2014 sampling events. Historic data from the 1990s are available; however they do not represent current conditions for the lake, and historic chlorophyll *a* observations were not available. BATHTUB is calibrated by adjusting calibration factors that act as multipliers on the empirically-derived model parameters. For nutrients, each net sedimentation rate (TN or TP) is multiplied by the calibration factor, and for chlorophyll *a*, the simulated concentration is multiplied by the calibration factor. The TN and TP calibration factors are selected from a range recommended by the model documentation (Walker, 1987). To predict the average observed total nitrogen across one-half the Secchi depth(1.33 mg-N/L), the calibration factor on the nitrogen sedimentation rate was set at 2.32 (recommended range is 0.3 to 3.0). To predict the average observed phosphorus concentrations across one-half the Secchi depth (0.065 mg-P/L), the calibration factor on the net phosphorus sedimentation rates would need to be set higher than the recommended maximum value of 2. The phosphorus calibration factor was set at 2, which resulted in a predicted concentration of 0.12 mg-P/L, which provides a conservative estimate of the required load reduction and is similar to how phosphorus concentrations in the northern Legg Lake system were simulated in USEPA (2012).

To simulate the average observed chlorophyll *a* concentration of 22.8 µg/L, the calibration factor on concentration was set to 0.535. If subsequent data are collected that will allow for full calibration of the BATHTUB model, then these TMDLs may be revisited. For now, this preliminary model is being used to determine the load reductions needed to attain the chlorophyll *a* target concentration, based on the best available information.

An explicit estimate of internal loading was not necessary for Munz Lake because it was possible to approximate the lake's observed concentrations using external loading estimates and the recommended range of model calibration factors. Internal loading was simulated implicitly within BATHTUB, which is consistent with internal loading methods for the LA Lakes TMDLs (USEPA, 2012). Internal loading is implicitly accounted for in the model because the net sedimentation rates for nitrogen and phosphorus reflect the balance between settling and resuspension of nitrogen and phosphorus within the waterbody. Since BATHTUB is a steady-state model, it focuses on long-term average conditions rather than day-to-day variations in water quality. Internal nutrient loads from cycling processes may include sediment release and macrophyte decomposition. These processes are accounted for implicitly in the model through the calibration of the net sedimentation rates. These rates are estimated by BATHTUB based on empirical relationships derived from field data from many different lakes, including those in USEPA's National Eutrophication Survey and lakes operated by the Army Corps of Engineers.

Based on the Munz Lake inflow concentrations, annual inflow volume, in-lake phosphorus concentrations, and approximate lake volume, an internal loading calculation of phosphorus would result in a negative number for this lake, indicating that settling is more dominant than resuspension, and internal loading of phosphorus is insignificant relative to other sources. Internal loading of nitrogen to Munz Lake was assumed to be insignificant compared to external loading sources because observed nitrogen concentrations were elevated but not considered extreme compared to the Lake Hughes and Lake Elizabeth conditions. Internal loading of nitrogen in lakes is typically insignificant relative to external loading.

5.2 Lake Elizabeth

Lake Elizabeth was assumed to have a surface area of 123 acres, an average depth of 16.4 feet, and a cumulative volume of 2020 ac-ft. Other model inputs included nutrient load estimates (Section 4). The three 2014 sampling events were used for the BATHTUB model set-up. Similar to Munz Lake, historic data from the 1990s are available, however they do not represent current conditions for the lake and historic Chlorophyll *a* observations were not available. All samples collected during the 2014 sampling were collected at less than one-half of the Secchi depth.

The Lake Elizabeth BATHTUB model could not be calibrated to the extremely high nutrient concentrations observed in 2014 because the calibration factors would need to be set well beyond their recommended ranges. However, the 2014 data indicated that Munz Lake was close to meeting the Chlorophyll *a* target of 20 µg/L (Munz Lake average was 22.8 µg/L). Therefore, Munz Lake was used as a reference for acceptable conditions in Lake Elizabeth, and the Munz Lake calibration factors were used for the Lake Elizabeth BATHTUB model. To predict the average observed total nitrogen and total phosphorus concentrations (64.0 mg-N/L and 1.93 mg-P/L, respectively), explicit estimates of internal load, entered as nutrient inflow inputs, were increased until simulated concentrations matched observed concentrations (21,235 US tons TN and 380 US tons TP). While this estimate of internal load is highly uncertain, no other simulation approaches were available that did not require the specification of a residence time, which is unknown for these lakes. The extremely eutrophic conditions in Lake Elizabeth prevented the use of BATHTUB for simulating algal response to nutrients. BATHTUB was developed based on a dataset of reservoirs with average summer chlorophyll *a* concentration ranging from 2 µg/L to 64 µg/L. During the July and October 2014 sampling, Lake Elizabeth exhibited chlorophyll *a* concentrations averaging 474 µg/L, more than seven times higher than this range. These extremely high chlorophyll *a* concentrations are likely caused by the excessive nutrient availability indicative of the observed nutrient concentrations.

In the absence of an algal response model specific to Lake Elizabeth, the Munz Lake numeric nutrient targets were applied to the Lake Elizabeth BATHTUB nutrient simulation to determine the load reductions needed for Lake Elizabeth. As explained further in Section 6.1, the Munz Lake numeric nutrient targets were based on achieving the chlorophyll *a* target of 20 µg/L. If subsequent data are collected that will allow for full calibration of the BATHTUB model, then these TMDLs may be revisited. For now, this preliminary model is being used to determine the load reductions needed to attain the chlorophyll *a* target concentration, based on the best available information.

5.3 Lake Hughes

Lake Hughes was assumed to have a surface area of 21.4 acres, an average depth of 9.8 feet, and a cumulative volume of 211 ac-ft. Other model inputs included nutrient load estimates (Section 4). The two 2014 sampling events were used for the BATHTUB model set-up. Similar to Munz Lake and Lake Elizabeth, historic data from the 1990s are available, however they do not represent current conditions for the lake and historic Chlorophyll *a* observations were not available. All samples collected during the 2014 sampling were collected at less than one-half of the Secchi depth.

Similar to Lake Elizabeth, the Lake Hughes BATHTUB model could not be calibrated to the extremely high nutrient concentrations observed in 2014 because the calibration factors would need to be set well beyond their recommended ranges. However, the 2014 data indicated that Munz Lake was close to meeting the Chlorophyll *a* target of 20 µg/L (Munz Lake average was 22.8 µg/L). Therefore, Munz Lake was used as a reference for acceptable conditions in Lake Hughes, and the Munz Lake calibration factors were used for the Lake Hughes BATHTUB model. To predict the average observed total nitrogen and total phosphorus concentrations (87.3 mg-N/L and 1.60 mg-P/L, respectively), explicit estimates of internal load, entered as nutrient inflow inputs, were increased until simulated concentrations matched observed concentrations (4,122 US tons TN and 27.4 US tons TP).

While this estimate of internal load is highly uncertain, no other simulation approaches were available that did not require the specification of a residence time, which is unknown for these lakes.

The extremely eutrophic conditions in Lake Elizabeth prevented the use of BATHTUB for simulating algal response to nutrients. BATHTUB was developed based on a dataset of reservoirs with average summer chlorophyll *a* concentration ranging from 2 µg/L to 64 µg/L. During the July and October 2014 sampling, Lake Hughes exhibited chlorophyll *a* concentrations averaging 333 µg/L, more than five times higher than this range. These extremely high chlorophyll *a* concentrations are likely caused by the extremely high nutrient availability indicative of the observed nutrient concentrations.

In the absence of an algal response model specific to Lake Elizabeth, the Munz Lake numeric nutrient targets were applied to the Lake Elizabeth BATHTUB nutrient simulation to determine the load reductions needed for Lake Elizabeth. As explained further in Section 6.1, the Munz Lake numeric nutrient targets were based on achieving the chlorophyll *a* target of 20 µg/L. If subsequent data are collected that will allow for full calibration of the BATHTUB model, then these TMDLs may be revisited. For now, this preliminary model is being used to determine the load reductions needed to attain the chlorophyll *a* target concentration, based on the best available information.

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6 TMDL Summary

A waterbody's loading capacity represents the maximum load of a pollutant that can be assimilated without violating water quality standards (40 CFR 130.2(f)). This is the maximum nutrient load consistent with meeting the numeric target of 20 µg/L of chlorophyll *a* as a summer average. The loading capacity can be further broken down into the wasteload allocations (WLA), load allocations (LA), and Margin of Safety (MOS) using the general TMDL equation:

$$TMDL = \sum WLA + LA + MOS$$

The following sections describe the approach and present the TMDL results for each impaired lake.

6.1 Munz Lake

In the BATHTUB model as applied here, algal growth is limited by both N and P concentrations, and there are multiple combinations of N and P load that are compatible with the chlorophyll *a* target. Following calibration of the BATHTUB Tool (Section5.1), the allowable loading combinations of nitrogen and phosphorus for Munz Lake were calculated using Visual Basic's GoalSeek function (Appendix A, Nutrient TMDL Development). The loading combination that achieved the target chlorophyll *a* concentration while also resulting in an in-lake ratio of total nitrogen concentration to total phosphorus concentration close to 10 was selected to match that typically observed in natural systems (Thomann and Mueller, 1987). The corresponding in-lake concentrations of nitrogen and phosphorus for Munz Lake were:

- 1.13 mg-N/L summer average (May – September) and annual average
- 0.113 mg-P/L summer average (May – September) and annual average

While both nutrient targets are consistent with recommendations in Tetra Tech (2006), the summer average is considered more protective and accounts for the summer season critical condition (Section 6.1.4). For Munz Lake, the loading capacities for total nitrogen and total phosphorus are 395 lb-N/yr and 63.9 lb-P/yr, respectively.

For total nitrogen, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 77 percent of the existing load of 512 lb-N/yr (Table 4-1). WLAs and LAs are developed assuming equal percent load reductions in all sources, and an implicit MOS is assumed based on conservative modelling assumptions. The resulting TMDL equation for total nitrogen is then:

395 lb-N/yr = 142 lb-N/yr + 253 lb-N/yr + 0 lb-N/yr

For total phosphorus, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 88 percent of the existing load of 72 lb-P/yr (Table 4-1). The resulting TMDL equation for total phosphorous is then:

63.9 lb-P/yr = 29.1 lb-P/yr + 34.8 lb-P/yr + 0 lb-P/yr

Allocations are assigned for this TMDL by requiring equal percentage reductions of all sources. Details associated with the WLAs, LAs, and MOS are presented in the following three sections.

As previously mentioned, in-lake concentrations of nitrogen and phosphorus have been determined for the lake based on simulation of allowable loads with the BATHTUB model. These in-lake concentrations are calculated from a complex set of equations that consider internal cycling processes (see LA Lakes TMDLs, Appendix A, Nutrient TMDL Development; USEPA, 2012) and, therefore, differ from concentrations associated with various inflows.

6.1.1 Wasteload Allocations

This TMDL establishes wasteload allocations (WLAs) for total phosphorus and total nitrogen for Munz Lake. The MS4 discharges (Figure 2-4) are the only sources of nutrient loading to Munz Lake that are assigned WLAs since no non-MS4 NPDES dischargers operate in the watershed. The WLA for this source to Munz Lake represents a 22.8 percent reduction in total nitrogen loading and an 11.7 percent reduction in total phosphorus loading (Table 6-1) from the existing loads (Table 4-1) and must be met as a one year average. The WLA applies at the point of discharge.

Table 6-1. Wasteload Allocations for Nutrient Loading to Munz Lake

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
County of Los Angeles	MS4 Stormwater	33.0	29.1	11.7%	184.1	142.1	22.8%

6.1.2 Load Allocations

Loads from land that do not drain to pipes or culverts prior to discharge to Munz Lake are assigned a load allocation. Loads from OWTS and atmospheric deposition are also assigned LAs. For Munz Lake, LAs represent an 11.7 percent reduction in total phosphorus loading, and a 22.8 percent reduction in total nitrogen loading (Table 6-2) from the existing loads (Table 4-1). LAs are provided for each responsible jurisdiction and input and must be met at the point of discharge.

Table 6-2. Load Allocations for Nutrient Loading to Munz Lake

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
Angeles National Forest	Runoff	38.48	33.96	11.7%	320.3	247.2	22.8%
On-site Wastewater	Groundwater	1.0	0.88	11.7%	6.0	4.6	22.8%
	Atmospheric deposition (to the lake surface)[1]	NA	NA		1.9	1.5	22.8%
Total		**39.5**	**34.8**	**11.7%**	**328.2**	**253.3**	**22.8%**

[2]Loads for atmospheric deposition are based on direct precipitation to the lake (calculated by the annual average precipitation multiplied by the surface area of the lake).

6.1.3 Margin of Safety

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. The MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. To account for the uncertainties concerning the relationship between nutrient loading and the resultant in-lake chlorophyll *a*, an implicit MOS is included in this TMDL based on conservative assumptions for the existing source loading estimates as described in Section 4.

6.1.4 Critical Conditions/Seasonality

TMDLs must include consideration of critical conditions and seasonal variation to ensure protection of the designated uses of the waterbody at all times. Critical conditions for nutrient impaired lakes typically occur during the warm summer months when water temperatures are elevated and algal growth rates are high. Elevated temperatures not only reduce the saturation levels of DO, but also increase the toxicity of ammonia and other chemicals in the water column. Excessive rates of algal growth may cause large swings in DO, elevated pH, odor, and aesthetic problems. Loading of nutrients to lakes during winter months are often biologically available to fuel algal growth in summer months. This nutrient TMDL accounts for summer season critical conditions by using the BATHTUB model to calculate possible annual loading rates consistent with meeting the summer chlorophyll *a* target concentration of 20 µg/L. Further, the model was developed primarily based on observations in 2014, when flows were low. The Munz Lake TMDL is expected to alleviate any pH and ammonia problems associated with excessive nutrient loading and eutrophication. This TMDL therefore protects for critical conditions.

6.1.5 Future Growth

The majority of the watershed is within the Angeles National Forest. It is not likely that the watershed will be developed and it is expected to remain as open space. No load allocation has been set aside for future growth, and it is unlikely that any dischargers will be permitted in the watershed.

If any sources currently assigned load allocations are later determined to be point sources requiring NPDES permits, those load allocations are to be treated as wasteload allocations for purposes of determining appropriate water quality-based effluent limitations pursuant to 40 CFR 122.44(d)(1).

6.2 LAKE ELIZABETH

As explained in Section 5.2, Munz Lake was used as a reference for acceptable conditions in Lake Elizabeth, therefore, the numeric nutrient targets developed for Munz Lake (Section 6.1) were selected as target nutrient concentrations consistent with achieving the mean chlorophyll *a* target within Lake Elizabeth. The corresponding in-lake concentrations of nitrogen and phosphorus for Lake Elizabeth are:

- 1.13 mg-N/L summer average (May – September) and annual average
- 0.113 mg-P/L summer average (May – September) and annual average

For Lake Elizabeth, the loading capacities for total nitrogen and total phosphorus are 14,929 lb-N/yr and 62,794 lb-P/yr, respectively.

For total nitrogen, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 0.04 percent of the existing load of 42,474,848 lb-N/yr (Table 4-1). WLAs and LAs are developed assuming equal percent load reductions in all sources, and an implicit MOS is assumed based on conservative assumptions. The resulting TMDL equation for total nitrogen is then:

14,929 lb-N/yr = 2,537 lb-N/yr + 12,392 lb-N/yr + 0 lb-N/yr

For total phosphorus, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 0.37 percent of the existing load of 760,773 lb-P/yr (Table 4-1). The resulting TMDL equation for total phosphorous is then:

2,794 lb-P/yr = 437 lb-P/yr + 2,358 lb-P/yr + 0 lb-P/yr

Allocations are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable Munz Lake inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L. Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets along with the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions. Details associated with the WLAs, LAs, and MOS are presented in the following three sections.

As previously mentioned, in-lake concentrations of nitrogen and phosphorus have been determined for the lake based on simulation of allowable loads with the BATHTUB model. These in-lake concentrations are calculated from a complex set of equations that consider internal cycling processes (see LA Lakes TMDL, Appendix A, Nutrient TMDL Development; USEPA, 2012) and, therefore, differ from concentrations associated with various inflows.

6.2.1 Wasteload Allocations

This TMDL establishes wasteload allocations (WLAs) for total phosphorus and total nitrogen for Lake Elizabeth. The MS4 discharges are the only sources of nutrient loading to Lake Elizabeth that are assigned WLAs since no non-MS4 NPDES dischargers operate in the watershed. The WLA for this source to Lake Elizabeth represents a 19.8 percent reduction in total nitrogen loading and an 18.7 percent reduction in total phosphorus loading (Table 6-3) from the existing loads (Table 4-1) and must be met as a one year average. The WLA applies at the point of discharge.

As indicated in Section 6.2, allocations, WLAs and LAs are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L (based on meeting the chlorophyll *a* targets in the Munz Lake model). Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets after the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions.

Table 6-3. Wasteload Allocations for Nutrient Loading to Lake Elizabeth

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
County of Los Angeles	MS4 Stormwater	536.9	436.7	18.7%	3,164.8	2536.8	19.8%

6.2.2 Load Allocations

Loads from land that does do not drain to pipes or culverts prior to discharge to Lake Elizabeth are assigned a load allocation. Loads from OWTS, internal loading, and atmospheric deposition are also assigned LAs. For external loads to Lake Elizabeth, total phosphorus LAs represent a 18.7 percent reduction in existing loading, and total nitrogen LAs represent a 19.8 percent reduction in existing loading (Table 6-4). For internal loads, LAs represent a 99.7 percent reduction in total phosphorus loading, and a 99.97 percent reduction in total nitrogen loading (Table 6-4) from the existing loads (Table 4-1). LAs are provided for each responsible jurisdiction and input and must be met at the point of discharge.

As indicated in Section 6.2, allocations, WLAs and LAs, are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L (based on meeting the chlorophyll *a* targets in the Munz Lake model). Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets after the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions.

Table 6-4. Load Allocations for Nutrient Loading to Lake Elizabeth

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
Angeles National Forest	Runoff	27.1	22.1	18.7%	238.8	191.4	19.8%
County of Los Angeles	Runoff	48.5	39.4	18.7%	447.9	359.0	19.8%
On-site Waste-water	Ground-water	160.0	130.1	18.7%	961.0	770.3	19.8%
Internal Loading	NA	760000.0	2,166.0	99.7%	42,470,000	11,042.2	99.97%
	Atmospheric deposition (to the lake surface)[1]	NA	NA	NA	36.00	28.9	19.8%
Total		**760,235.6**	**2,357.6**	**99.7%**	**42,471,683.6**	**12,391.8**	**99.97%**

[1]Loads for atmospheric deposition are based on direct precipitation to the lake (calculated by the annual average precipitation multiplied by the surface area of the lake).

6.2.3 Margin of Safety

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. The MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. To account for the uncertainties concerning the relationship between nutrient loading and the resultant in-lake chlorophyll *a*, an implicit MOS is included in this TMDL based on conservative assumptions for the existing source loading estimates as described in Section 4.

6.2.4 Critical Conditions/Seasonality

TMDLs must include consideration of critical conditions and seasonal variation to ensure protection of the designated uses of the waterbody at all times. Critical conditions for nutrient impaired lakes typically occur during the warm summer months when water temperatures are elevated and algal growth rates are high. Elevated temperatures not only reduce the saturation levels of DO, but also increase the toxicity of ammonia and other chemicals in the water column. Excessive rates of algal growth may cause large swings in DO, elevated pH, odor, and aesthetic problems. Loading of nutrients to lakes during winter months are often biologically available to fuel algal growth in summer months. This nutrient TMDL accounts for summer season critical conditions by using the BATHTUB model to calculate possible annual loading rates consistent with meeting the summer chlorophyll *a* target concentration of 20 µg/L in the reference waterbody of Munz Lake. The Lake Elizabeth TMDL is expected to alleviate any pH and ammonia problems associated with excessive nutrient loading and eutrophication. This TMDL therefore protects for critical conditions.

6.2.5 Future Growth

Development within the Lake Elizabeth watershed has occurred slowly over the past few decades. There is no indication that any additional dischargers will be permitted in the watershed in the future. No load allocation have been set aside for future growth.

If any sources currently assigned load allocations are later determined to be point sources requiring NPDES permits, those load allocations are to be treated as wasteload allocations for purposes of determining appropriate water quality-based effluent limitations pursuant to 40 CFR 122.44(d)(1).

6.3 LAKE HUGHES

As explained in Section 5.2, Munz Lake was used as a reference for acceptable conditions in Lake Hughes, therefore, the numeric nutrient targets developed for Munz Lake (Section 6.1) were selected as target nutrient concentrations consistent with achieving the mean chlorophyll *a* target within Lake Hughes. The corresponding in-lake concentrations of nitrogen and phosphorus for Lake Hughes are:

- 1.13 mg-N/L summer average (May – September) and annual average
- 0.113 mg-P/L summer average (May – September) and annual average

For Lake Hughes, the loading capacities for total nitrogen and total phosphorus are 1,669 lb-N/yr and 311 lb-P/yr, respectively.

For total nitrogen, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 0.02 percent of the existing load of 8,245,498 lb-N/yr (Table 4-1). WLAs and LAs are developed assuming equal percent load reductions in all sources, and an implicit MOS is assumed based on conservative assumptions. The resulting TMDL equation for total nitrogen is then:

1,669 lb-N/yr = 485 lb-N/yr + 1,184 lb-N/yr + 0 lb-N/yr

For total phosphorus, the allocatable load (divided among WLAs and LAs) is equal to the loading capacity and is 0.57 percent of the existing load of 54,936 lb-P/yr (Table 4-1). The resulting TMDL equation for total phosphorous is then:

311 lb-P/yr = 96 lb-P/yr + 215 lb-P/yr + 0 lb-P/yr

Allocations are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable Munz Lake inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L. Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets along with the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions. Details associated with the WLAs, LAs, and MOS are presented in the following three sections.

As previously mentioned, in-lake concentrations of nitrogen and phosphorus have been determined for the lake based on simulation of allowable loads with the BATHTUB model. These in-lake concentrations are calculated from a complex set of equations that consider internal cycling processes (see LA Lakes TMDL, Appendix A, Nutrient TMDL Development; USEPA, 2012) and, therefore, differ from concentrations associated with various inflows.

6.3.1 Wasteload Allocations

This TMDL establishes wasteload allocations (WLAs) for total phosphorus and total nitrogen for Lake Elizabeth. The MS4 discharges are the only sources of nutrient loading to Lake Hughes that are assigned WLAs since no non-MS4 NPDES dischargers operate in the watershed. The WLA for this source to Lake Hughes represents a 20.7 percent reduction in total nitrogen loading and a 3.2 percent reduction in total phosphorus loading (Table 6-5) from the existing loads (Table 4-1) and must be met as a one year average. The WLA applies at the point of discharge.

As indicated in Section 6.3, WLAs and LAs are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L (based on meeting the chlorophyll *a* targets in the Munz Lake model). Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets after the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions.

Table 6-5. Wasteload Allocations for Nutrient Loading to Lake Hughes

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
County of Los Angeles	MS4 Stormwater	110.10	106.6	3.2%	656.7	520.8	20.7%

6.3.2 Load Allocations

Loads from land that does do not drain to pipes or culverts prior to discharge to Lake Elizabeth are assigned a load allocation. Loads from OWTS and atmospheric deposition are also assigned LAs. For external loads to Lake Elizabeth, total phosphorus LAs represent a 3.2 percent reduction in existing loading, and total nitrogen LAs represent a 20.7 percent reduction in existing loading (Table 6-6). For internal loads, LAs represent a 99.6 percent reduction in total phosphorus loading, and a 99.99 percent reduction in total nitrogen loading (Table 6-6) from the existing loads (Table 4-1). LAs are provided for each responsible jurisdiction and input and must be met at the point of discharge.

As indicated in Section 6.3, WLAs and LAs are assigned for this TMDL by first requiring equal percentage reductions of all external sources that would meet the allowable inflow concentrations of 2.8 mg-N/L and 0.45 mg-P/L (based on meeting the chlorophyll *a* targets in the Munz Lake model). Then, the required reduction of the internal load is based on the load reduction necessary to meet the in-lake numeric nutrient targets after the required reductions in external load. Equal reductions for all sources were not appropriate because these would require the external sources to be reduced to loading rates or inflow concentrations significantly lower than background conditions.

Table 6-6. Load Allocations for Nutrient Loading to Lake Hughes

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red

Responsible Jurisdiction	Input	Total Phosphorus (lb-P/yr)			Total Nitrogen (lb-N/yr)		
		Existing	Allocation	% Red	Existing	Allocation	%Red
Angeles National Forest	Runoff	3.8	3.6	3.2%	34.8	27.6	20.7%
Lake Hughes Community Wastewater Treatment Facility (NON-15)	Groundwater	1.5	1.4	3.2%	174.3	138.2	20.7%
On-site Wastewater	Groundwater	2.0	1.9	3.2%	14.0	11.1	20.7%
Internal Loading	NA	54,819.0	197.3	99.6%	8,244,612.0	956.4	99.99%
	Atmospheric deposition (to the lake surface)[1]	NA	NA	NA	6.3	5.0	20.7%
Total		**54,826.2**	**204.3**	**99.6%**	**8,244,841.4**	**1,138.4**	**99.99%**

[1]Loads for atmospheric deposition are based on direct precipitation to the lake (calculated by the annual average precipitation multiplied by the surface area of the lake).

6.3.3 Margin of Safety

TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. The MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. To account for the uncertainties concerning the relationship between nutrient loading and the resultant in-lake chlorophyll *a*, an implicit MOS is included in this TMDL based on conservative assumptions for the existing source loading estimates as described in Section 4.

6.3.4 Critical Conditions/Seasonality

TMDLs must include consideration of critical conditions and seasonal variation to ensure protection of the designated uses of the waterbody at all times. Critical conditions for nutrient impaired lakes typically occur during the warm summer months when water temperatures are elevated and algal growth rates are high. Elevated temperatures not only reduce the saturation levels of DO, but also increase the toxicity of ammonia and other chemicals in the water column. Excessive rates of algal growth may cause large swings in DO, elevated pH, odor, and aesthetic problems. Loading of nutrients to lakes during winter months are often biologically available to fuel algal growth in summer months. This nutrient TMDL accounts for summer season critical conditions by using the BATHTUB model to calculate possible annual loading rates consistent with meeting the summer chlorophyll *a* target concentration of 20 µg/L. The Lake Hughes TMDL is expected to alleviate any pH and ammonia problems associated with excessive nutrient loading and eutrophication. This TMDL therefore protects for critical conditions.

6.3.5 Future Growth

The majority of the undeveloped land in the watershed is within the Angeles National Forest. It is not likely that the watershed will be developed and it is expected to remain as open space. No load allocation has been set aside for future growth, and it is unlikely that any dischargers will be permitted in the watershed.

If any sources currently assigned load allocations are later determined to be point sources requiring NPDES permits, those load allocations are to be treated as wasteload allocations for purposes of determining appropriate water quality-based effluent limitations pursuant to 40 CFR 122.44(d)(1).

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Appendix A. Estimation of Wet Weather Loading from Runoff

Estimation of watershed loading as a result of wet weather events is based on a calibrated hydrologic model created by AQUATERRA using the EPA Hydrologic Simulation Program FORTRAN (HSPF) (AQUA TERRA Consultants, 2008). This HSPF model simulates the entire Santa Clara River Watershed, and the model subbasin 209 corresponds to the Lake Elizabeth HUC12 in which the SCR lakes reside. The land use-based model output associated with subbasin 209 can be used to generate land use-based runoff estimates the SCR lakes.

In order to assess whether the output of this HSPF model can be appropriately extrapolated for this modeling exercise for Lake Hughes, Munz Lake, and Lake Elizabeth, an analysis of input variables was conducted. The hydrologic forcing variables supplied to the model are: precipitation and potential evapotranspiration and air temperature which varied across the entire SCR Watershed. Figure A-1 provides the names and locations of the meteorological stations applied to the model subbasin of interest. Given that the input locations for these meteorological forcing stations associated with model subbasin 209 are in close proximity to the lakes, the HSPF output was deemed to be appropriately representative of the SCR lakes model area.

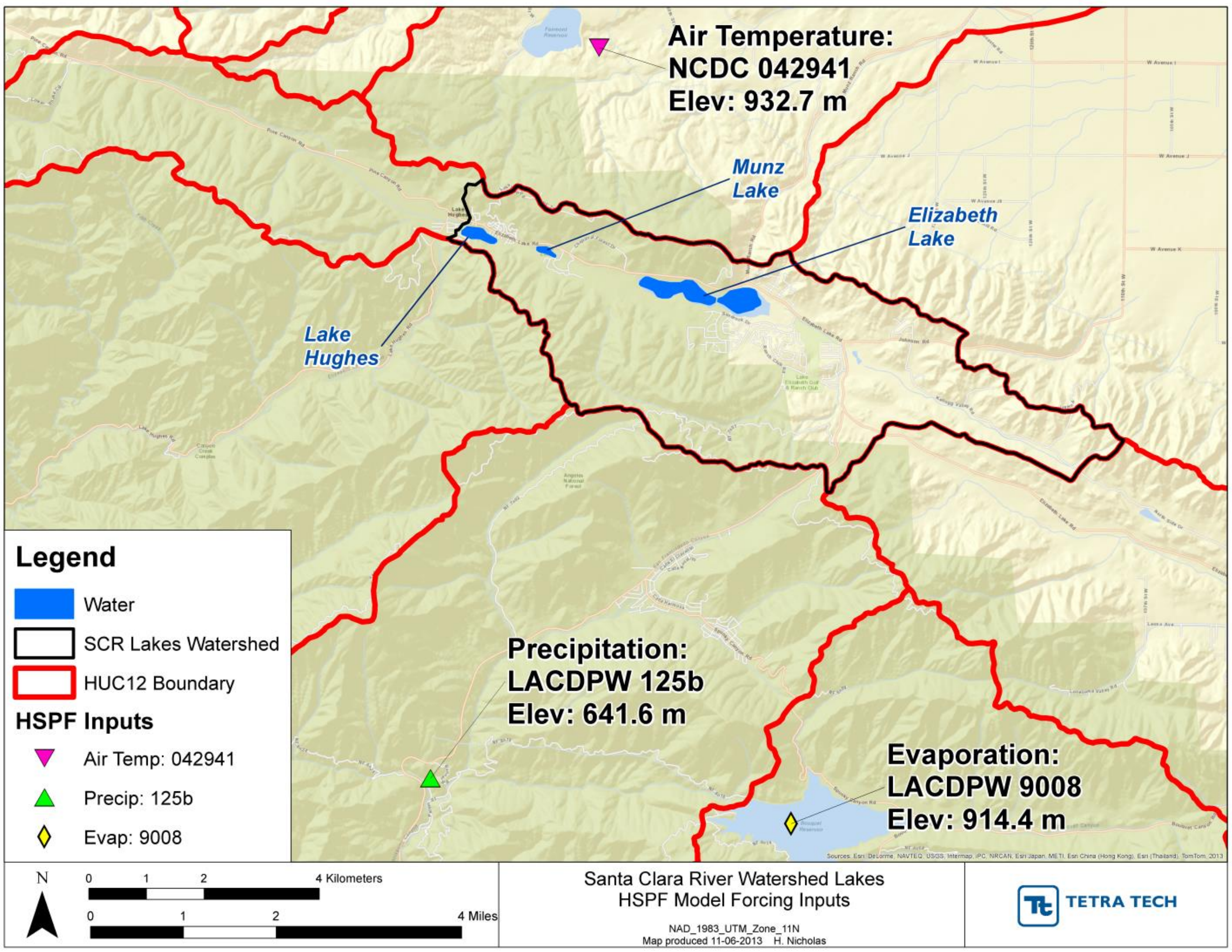

Figure A-1. HSPF Model Input Meteorological Forcing Inputs for Model Subbasin 209

A.1 ESTIMATION OF RUNOFF DEPTHS

In order to estimate flows by land use, the land use/land cover layer generated from the SCAG 2008 and LANDFIRE 2012 coverages were paired with the land uses in the AQUATERRA HSPF model. The relationship between SCAG, LANDFIRE, and the model land uses from the HSPF model are detailed in Table A-1. Each land use has an associated effective impervious area (EIA) which allows for the incorporation of both pervious and impervious lands. The EIA percentages were assigned to the land use categories based on values derived from the AQUATERRA HSPF model report, which bases their assumptions on the LACDPW 2006 Hydrology Manual and Standard Imperviousness Values and similarly selected literature.

Table A-1. Land Use Aggregation and HSPF Model Details

SCAG 2008 Aggregated Land Use Classes	LANDFIRE 2012 Natural Land Use Classes	HSPF Model Land Use Class	Effective Impervious Area (%)	EIA reference class
Water	N/A	N/A	0	None
Roads	N/A	Impervious	70	Major Roads
WWTP[1]	N/A	Agriculture	10	Low-density single family residential
Low Density Development	N/A	Low Density Development	20	Mobile home courts and subdivisions, low-density
Natural Landcover	Tree-dominated	Forest	0	Forest
	Shrub-dominated	Shrub	0	Shrubland
	Herbaceous/Non-vascular-dominated	Open/Grass	0	Vacant/undifferentiated grassland

[1] The waste water treatment plant parcel area will be treated as agriculture due to treated discharge application on-site.

Applying the HSPF land use classes allows for estimation of unit area flow by land use class for each lake subbasin and jurisdiction. Table A-2 provides average flows from each land use type (from HSPF model output) and the acreage of pervious area (PA) and impervious area (IA) of each land use type in each subbasin based on the EIAs from Table A-1.

Table A-2. Average Daily Flow Loading from Land Use Type to Each Lake

Land Use	Average Annual Runoff (in/yr)	Munz Lake		Lake Hughes		Lake Elizabeth	
		PA (acres)	IA (acres)	PA (acres)	IA (acres)	PA (acres)	IA (acres)
Forest	0.064	476.14	0.00	43.13	0.00	671.23	0.00
Shrub	0.079	827.68	0.00	215.73	0.00	3176.95	0.00
Grass	0.089	102.91	0.00	62.58	0.00	505.48	0.00
Agriculture (WWTP)	0.236	0.00	0.00	15.32	1.70	0.00	0.00
Low Density Development	0.829	60.16	15.04	51.30	12.82	213.32	53.33
Roads	0.936	3.72	8.68	5.15	12.02	42.47	99.09
Water	11.828	6.57	0.00	21.42	0.00	123.13	0.00

Although BATHTUB inputs are given on an annual and growing-season basis (May to September), the HSPF runoff rates for each land-use on the bimodal precipitation cycle that is present in this watershed (dry season is April to December, and wet season in January to March) is also provided. This seasonal runoff exploration was aggregated by land use (Figure A-2) as well as seasonally aggregated over time (Figure A-3).

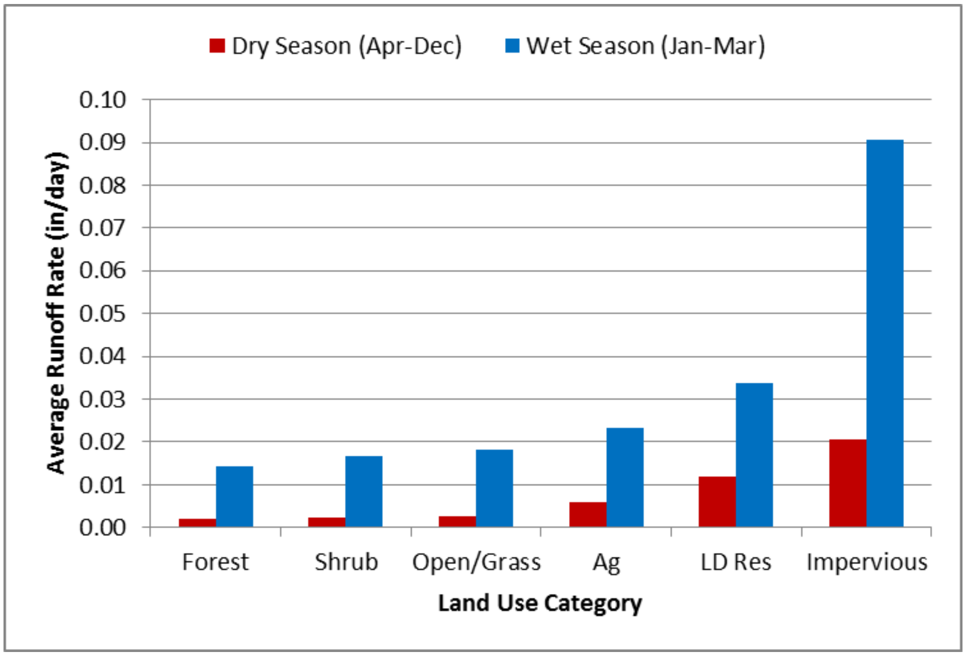

Figure A-2. Average Runoff Rate (in/yr) for each Land Use Category in SCR Lakes Watershed

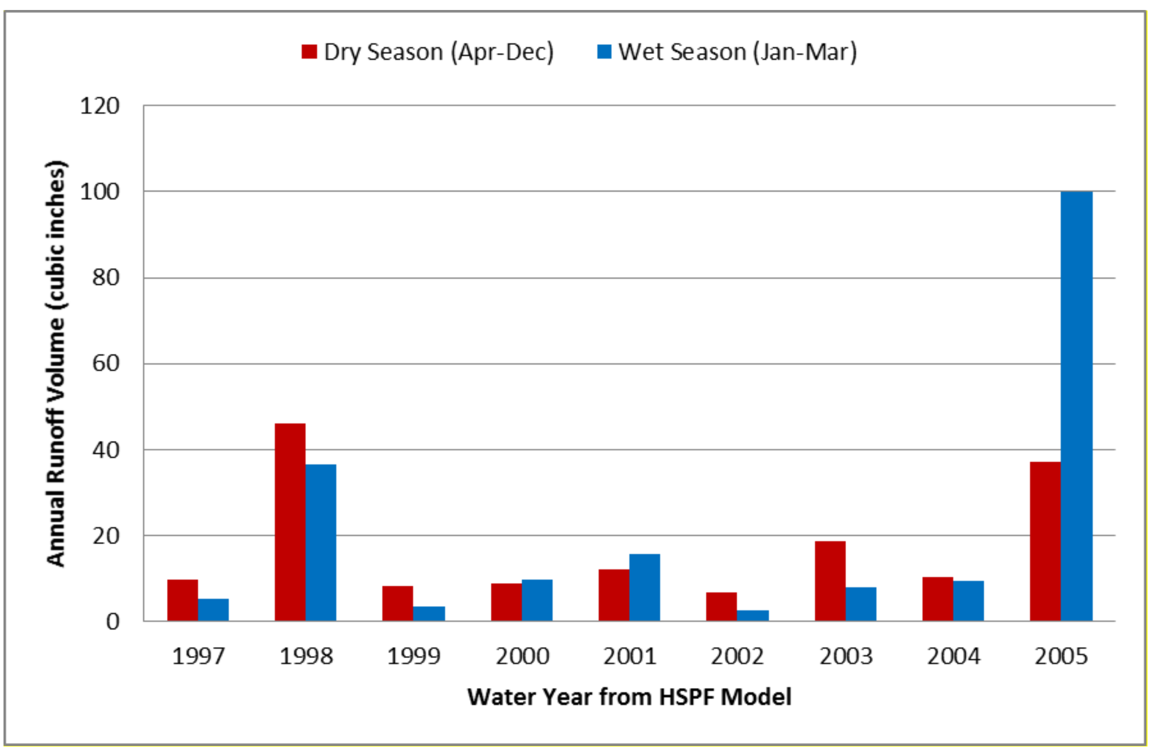

Figure A-3. Total Annual Runoff Volume (cubic inches/water year) for the SCR Lakes Watershed

A.2 Event Mean Concentrations

Event mean concentrations (EMCs) represent flow-weighted average concentrations of nutrients delivered during storm events. The HSPF model was used to simulate hydrology, and, therefore, nutrient loads must be estimated by multiplying runoff volumes by the pollutant EMCs from the LA Lakes TMDL (USEPA, 2012). Loading to each lake is estimated using EMC data for several monitoring years provided by SCCWRP (Ackerman and Schiff, 2003) and Los Angeles County Department of Public Works (LACDPW, 2000) for various land uses. EMCs from the LA Lakes TMDL were applied to the SCR Lakes model land uses, which were then multiplied by runoff depth and land area to estimate loads (Table A-3).

Table A-3. EMCs for Modeled Land Uses in the Los Angeles and San Gabriel LSPC Models (as applied in LA Lakes TMDL documentation)

Los Angeles Model Land Use	San Gabriel Model Land Use	SCR Lakes Model Land Use	Nitrogen EMC (mg/L)	Phosphorus EMC (mg/L)
Open	Evergreen Forest Land	Forest	3.2	0.11
Open	Shrub and Brush Rangeland	Shrub	3.2	0.11
Open	Herbaceous/Mixed Rangeland	Grass	3.2	0.11
Agriculture	Cropland/Pasture	WWTP	8.6	0.56
Residential	Residential	Low Density Development	4.51	0.73
Other Urban	Other Urban/Built Up	Roads	4.41	0.67
Water	Water	Water	0.00	0.00

A.3 Nutrient Loads

EMCs are applied to runoff depths for a corresponding land use and area to estimate pollutant loading to each impaired lake. For example, the average annual runoff depth for shrub lands in the Munz Lake watershed is 0.079 inches (Table A-4). There are 827.68 acres of shrub land present in the Munz Lake subbasin, with a subset of 809.40 acres from the Angeles National Forest jurisdiction (Table A-4). The nitrogen EMC for shrub is 3.2 mg/L.

The following calculation estimates the total nitrogen load delivered annually from this area:

$$\frac{3.2mg-N}{L}\cdot\frac{0.079in}{year}\cdot\frac{1ft}{12in}\cdot 803.40ac\cdot\frac{28.32L}{ft^3}\cdot\frac{43{,}560\,ft^2}{ac}\cdot\frac{1g}{1{,}000mg}\cdot\frac{1lb}{453.6g}=46.69lb-N$$

Table A-4, Table A-5, and Table A-6 summarize the total nitrogen and total phosphorus loads delivered to the lakes from each jurisdiction (summed for all land uses) and subbasin. Note that if a land use has both pervious and impervious area, loading rates are additive. The loads presented in the table are existing loads, not allocated loads. Note that annual and growing-season loading inputs was used in the BATHTUB model, for which the output is for the growing season as well.

Table A-4. Average Wet-Weather Nutrient Loads to Lake Elizabeth by Jurisdiction.

Jurisdiction	Annual Nitrogen (lb/yr)	Annual Phosphorus (lb/yr)	Growing Season Nitrogen (lb/yr)	Growing Season Phosphorus (lb/yr)
Angeles National Forest	238.76	27.2	24.71	2.13
County of Los Angeles	447.87	48.48	54.42	4.20
MS4 Stormwater	1606.24	225.25	118.04	16.20

Table A-5. Average Wet-Weather Nutrient Loads to Hughes Lake by Jurisdiction.

Jurisdiction	Annual Nitrogen (lb/yr)	Annual Phosphorus (lb/yr)	Growing Season Nitrogen (lb/yr)	Growing Season Phosphorus (lb/yr)
Angeles National Forest	34.85	3.77	5.04	0.37
MS4 Stormwater	365.08	51.79	29.17	3.73

Table A-6. Average Wet-Weather Nutrient Loads to Munz Lake by Jurisdiction.

Jurisdiction	Annual Nitrogen (lb/yr)	Annual Phosphorus (lb/yr)	Growing Season Nitrogen (lb/yr)	Growing Season Phosphorus (lb/yr)
Angeles National Forest	320.35	38.48	37.17	3.28
MS4 Stormwater	98.07	15.74	7.84	1.24

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Appendix B. Estimation of Loading during Dry Weather

The approach to dry weather loading estimates for SCR Lakes were based largely on the LA Lakes TMDLs methods as described in detail in USEPA (2012). Dry weather loading sources relevant to SCR Lakes were nutrient loads from storm drains, spray irrigation field effluent, and on-site wastewater treatment systems (OWTS). The specific assumptions and methods used for the SCR Lakes watershed are outlined in this appendix.

B.1 Nutrient Loads from Storm Drains

In USEPA (2012), total nitrogen and total phosphorus concentrations in dry weather runoff were estimated from the species monitored as 3 mg-N/L and 0.6 mg-P/L respectively for the Los Angeles area. During periods identified as dry weather in the vicinity of Los Angeles, USEPA (2012) estimated the areal flow rate (flow rate divided by contributing area) as 2.6 in/yr based on Ackerman and Stein (2005). These concentrations and flow rate were used to estimating the annual average dry weather flow rates as follows:

$$\frac{3.0mg-N}{L}\cdot\frac{2.6in}{yr}\cdot\frac{1ft}{12in}\cdot\frac{28.32L}{ft^3}\cdot\frac{43{,}560\,ft^2}{ac}\cdot\frac{1g}{1{,}000mg}\cdot\frac{1lb}{453.6g}=1.77lb-N/ac/yr$$

$$\frac{0.6mg-P}{L}\cdot\frac{2.6in}{yr}\cdot\frac{1ft}{12in}\cdot\frac{28.32L}{ft^3}\cdot\frac{43{,}560\,ft^2}{ac}\cdot\frac{1g}{1{,}000mg}\cdot\frac{1lb}{453.6g}=0.354lb-P/ac/yr$$

Using these assumptions, the estimated dry weather nutrient loads for SCR lakes are summarized in Table B-1.

Table B-1. Estimated Dry Weather Nutrient Loads and Flows to SCR Lakes from Storm Drains

Jurisdiction	Flow (ac-ft/yr)	Total Phosphorus (lb/yr)	Total Nitrogen (lb/yr)
Lake Elizabeth	191	312	1559
Munz Lake	11	17	86
Lake Hughes	36	59	292

B.2 Contributions from Other Dry Weather Inputs

The lakes do not currently receive artificial input from groundwater or potable water supplies, which leads to very low water levels during dry weather periods. Water used for irrigation around each lake has the potential to deliver pollutants via runoff into the lake. While this is mostly accounted for by estimating the dry weather loading from storm drains, a small amount of loading to Munz lake may result from irrigation vegetated areas outside the MS4 area. Other dry weather inputs include loading from groundwater, and source of this loading include the Lake Hughes Community WWTP spray irrigation effluent, on-site wastewater systems, natural background. The following sections document the assumptions and methods used to estimate the spray irrigation and on-site wastewater contributions. Natural background loading from groundwater was not explicitly estimated.

B.2.1 Nutrient Loads from Spray Irrigation Effluent

Although the WWTP does not record spray irrigation rates, it does sample water quality of the effluent and record influent flows to the plant. Due to several anomalies in the influent flow data that caused artificially high flows when blockage occurred in the pipes, the median influent rate was estimated rather than the average. It is assumed that the median influent rate would approximate the median effluent rate out of the WWTP onto the spray irrigation fields.

In order to capture the impact of flow and load from the Lake Hughes WWTP, spray irrigation was added to the loading environment. The original HSPF Model by AquaTerra was modified to simulate spray irrigation of treated effluent near the WWTP. In order to approximate the impact of the WWTP, the median influent flow rate of 25,515 gallons/day was applied to the HSPF model area as precipitation. The model output for interflow and groundwater flow associated with the grass landcover was used to estimate the subsurface flows associated with the WWTP spray irrigation field.

The average annual sum of interflow and groundwater flow from the irrigated grassland from the model from 1997-2004 is 19.59 inches/year. The irrigated area near the WWTP is approximately 5.42 acres according to aerial imagery, therefore the annual subsurface flow from the WWTP is 8.85 acre-feet/year. The loading rates applied to the spray irrigation subsurface flow are based on the average groundwater concentrations monitored downstream of the spray irrigation fields and reported by the WWTP (nitrogen concentration 7.24 mg/L, phosphorus concentration 0.06 mg/L). Table B-2 summarizes the estimated flow and nutrient loads from the Lake Hughes Community WWTP spray irrigation effluent, delivered via groundwater flow.

Table B-2. Estimated Groundwater Loads and Flows to Lake Hughes from the Lake Hughes Community WWTP

Jurisdiction	Flow (ac-ft/yr)	Total Phosphorus (lb/yr)	Total Nitrogen (lb/yr)
Lake Hughes	8.8	1.45	174.29

B.2.2 Nutrient Loads from On-Site Wastewater Treatment Systems

Nutrient loads from on-site wastewater systems (OWTS) were estimated using the methods in the Generalized Watershed Loading Functions (GWLF) model (Haith et al., 1992). Population served by OWTS use estimated using a combination of census data (U.S. Census Bureau, 2010), parcel data, aerial imagery, and OWTS counts from SWRCB (2002). Most of the occupied parcels within the Lake Hughes watershed are expected to be serviced by the Lake Hughes Community WWTP. Parcel counts and a review of aerial photographs provided an estimate of 12 OWTS within the Lake Hughes watershed. The SWRCB (2002) count of 110 appears to be including the WWTP service area, where OWTS are prohibited (LARWQCB, 1980), and, therefore, the parcel and aerial imagery estimates were considered more accurate. The system count of 12 was converted to population served using the average household size of 2.09 persons for the Lake Hughes and Munz Lake community (U.S. Census Bureau, 2010), resulting in a population of 25.

For Munz Lake, the OWTS count of 5 systems from SWRCB (2002) appears to be accurate based on a review of parcel data and aerial photographs. The system count of 5 was converted to population served using the average household size of 2.12 persons for the Lake Hughes and Munz Lake community (U.S. Census Bureau, 2010), resulting in a population of 11.

The SWRCB (2002) system counts appeared to underestimate the population served for Lake Elizabeth (127 systems and 272 persons served), and, therefore, the population was estimated using census data (U.S. Census Bureau, 2010) and verified using parcel data. Since no centralized wastewater treatment system is known to be operating in the Lake Elizabeth watershed, it was assumed that the entire population 1756 people was served by OWTS.

Using the approach from Haith et al., (1992), the OWTS were assumed to be functioning normally, and default values for per capita nutrient load and per capita vegetation uptake were applied since no other data on local OWTS loading were available. Although total phosphorus loading is not expected for non-failing systems during the summer season (May – September), the minimum total phosphorus loading for non-summer loading from normal systems was included as a conservative estimate. The proportion of spray irrigation flow reaching Lake Hughes (0.28) was used to provide an approximate proportion of OWTS loading and flow that would reach all three lakes. The resulting estimates of OWTS loading are summarized in Table B-3.

Table B-3. Estimated Dry Weather Nutrient Loads and Flows to SCR Lakes from OWTS

Jurisdiction	Flow (ac-ft/yr	Total Phosphorus (lb/yr)	Total Nitrogen (lb/yr)
Lake Elizabeth	38	160	961
Munz Lake	0.2	1	6
Lake Hughes	0.5	2	14

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Appendix C. Atmospheric Loading

Atmospheric deposition of nutrients directly to lake surfaces is considered a source of pollutant loading. This kind of atmospheric deposition may occur as either wet deposition (associated with precipitation) or dry deposition (associated with particulates). Consistent with load estimates for the LA Lakes TMDL development, atmospheric loading estimates were limited to nitrogen wet deposition for the SCR Lakes TMDLs. Nitrogen ry weather loading and phosphorus wet/dry deposition were not estimated as explained below.

Nitrogen Dry Deposition and Phosphorus Wet/Dry Deposition

Padgett and Sutula (2014) report measured wet and dry deposition of nitrogen and phosphorus from five sites in southern California in 2011 through 2013. At the time of the LA Lakes TMDLs development, data on dry deposition were not available and, therefore, dry deposition was not included in the loading estimates (USEPA, 2012). Phosphorus deposition was not included due to lack of data and the fact that phosphorus deposition is typically much lower than nitrogen deposition and assumed to be negligible for the lakes in question. The data in Padgett and Sutula (2014) were used to test whether the BATHTUB models were sensitive to the inclusion of dry nitrogen deposition and wet/dry phosphorus deposition. When these data were applied to the loading input in the Munz Lake BATHTUB model, the resulting in-lake concentrations increased by 0.4, 0.2, and 0.4 percent for TN, TP, and chlorophyll *a* respectively. It was determined that the inclusion of this additional loading would have a negligible effect on the model results. As more data are collected, the TMDLs may be ammended to reflect this addition deposition.

Nitrogen Wet Deposition

The National Atmospheric Deposition Program (NADP) monitors nitrate wet deposition at several locations in Southern California. In the LA Lakes TMDL, nitrate wet deposition was estimated using NADP interpolated isopleths to assign loads based on lake elevation. For the SCR lakes, a single NADP station was used (CA42, Tanbark Flat) because it is relatively close to the modeled lakes (some 50 miles southeast within the Angeles National Forest), and has an elevation of 853 meters while the lakes have an average elevation of approximately 970 meters.

NADP Station CA42 data was used to estimate annual precipitation-weighted nitrate concentrations for the impaired lakes as paired with precipitation data from LADPW 125b used previously in this report. Loading estimates were made for the time period in which the HSPF model was run (1996-2005) (Table C-1).

Table C-1. Annual nitrate deposition details for all SCR Lakes, 1996-2005.

Year	Annual Precipitation-Weighted Nitrate Deposition (mg-NO3/L) from NADP CA42	Annual Precipitation (in) from LADPW 125b
1996	0.48	8.41
1997	0.89	5.74
1998	0.92	17.02
1999	1.33	3.83
2000	0.80	6.83
2001	0.71	6.66
2002	0.62	3.70
2003	0.73	6.48
2004	0.58	8.24
2005	0.39	13.92

The annual direct deposition load (Table C-2) to a water surface depends on amount of precipitation, the lake surface area, and the precipitation-weighted nitrate concentration measured for that year. For example, the nitrogen load deposited to the surface of Munz Lake in 2005 may be estimated as follows:

1) Convert the units of the precipitation-weight nitrate concentration for 2005 from NO3 to N.

$$\frac{0.39\ mg - NO_3}{L} \cdot \frac{1\ mmol\ NO_3}{62\ mg\ NO_3} \cdot \frac{1\ mmol\ N}{1\ mmol\ NO_3} \cdot \frac{14\ mg\ N}{1\ mmol\ N} = \frac{0.087\ mg\ N}{L}$$

2) Estimate the volume of precipitation to the lake surface in 2005.

$$13.92\ in\ \cdot 6.57\ ac\ \cdot \frac{1\ ft}{12\ in} = 7.62\ ac - ft$$

3) Multiply the concentration of volume to calculate load.

$$\frac{0.087\ mg\ N}{L} \cdot 7.62\ ac - ft\ \cdot \frac{43{,}560\ ft^2}{1\ ac} \cdot \frac{28.32\ L}{1\ ft^3} \cdot \frac{1\ g}{1000\ mg} \cdot \frac{1\ lb}{453.6\ g} = 1.8\ lb - N$$

Table C-2. Annual nitrogen load (lbs) from atmospheric deposition to impaired lakes, 1996-2005. Surface area is in parentheses.

Year	Elizabeth Lake (123.13 ac)	Munz Lake (6.57 ac)	Hughes Lake (21.42 ac)
1996	25.6	1.4	4.5
1997	32.0	1.7	5.6
1998	98.1	5.2	17.1
1999	32.2	1.7	5.6
2000	34.5	1.8	6.0
2001	29.6	1.6	5.1
2002	14.4	0.8	2.5
2003	29.7	1.6	5.2
2004	30.2	1.6	5.3
2005	33.9	1.8	5.9
Average	36.0	1.9	6.3

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Appendix D. Definitions of Beneficial Uses

The Water Quality Control Plan for the Los Angeles Region (LARWQCB, 1994) defines nine beneficial uses for the lakes addressed by this report:

MUN – Municipal and Domestic Supply. Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

IND – Industrial Service Supply: Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.

PROC – Industrial Process Supply: Uses of water for industrial activities that depend primarily on water quality.

AGR – Agricultural Supply. Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

GWR – Ground Water Recharge. Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

FRSH – Freshwater replenishment. Uses of water for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).

REC1 – Water Contact Recreation. 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, waterskiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

REC2 – Non-contact Water Recreation. 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.

WARM – Warm Freshwater Habitat. 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.

WILD – Wildlife Habitat. 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 – Rare, Threatened, or Endangered Species. 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.

WET – Wetland Habitat. Uses of water that support wetland ecosystems, including, but not limited to, preservation or enhancement of wetland habitats, vegetation, fish, shellfish, or wildlife, and other unique wetland functions which enhance water quality, such as providing flood and erosion control, streambank stabilization, and filtration and purification of naturally occurring contaminants.

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Appendix E. Monitoring Data for SCR Lakes

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Table E-1. Munz Lake monitoring data collected by LARWQCB in 1990 and 1997

Location	Sampling Date	Sampling Time	TKN	NH4 -N	NO2 -N	NO3 -N	PO4	pH	Temperature	DO	Specific Conductance
			mg/L	mg/L	mg/L	mg/L	mg/L	pH units	Degrees C	mg/L	mS/cm
Munz Lake campground	9/6/1990					<0.2		8.15	26.60	4.60	<0.02
Munz Lake campground	4/10/1997	904	0.70	0.20	<0.03	<0.2	0.07	7.80			0.99

Table E-2. Hughes Lake monitoring data collected by LARWQCB in 1990 and 1997

Location	Sampling Date	Sampling Time	TKN	NH4 -N	NO2 -N	NO3 -N	PO4	pH	Temperature	DO	Specific Conductance
			mg/L	mg/L	mg/L	mg/L	mg/L	pH units	Degrees C	mg/L	mS/cm
Lake Hughes, South Shore (LHSS)	9/6/1990					<0.2		9.15	32.10	3.20	0.02
Lake Hughes, end of Trail A Road (LHTA)	4/10/1997	920	1.30	0.40	<0.03	<0.2	0.07	8.30			1.38

Table E-3. Elizabeth Lake monitoring data collected by LARWQCB in 1990 and 1997

Location	Sampling Date	Sampling Time	TKN	NH4 -N	NO2 -N	NO3 -N	PO4	pH	Temperature	DO	Specific Conductance
			mg/L	mg/L	mg/L	mg/L	mg/L	pH units	Degrees C	mg/L	mS/cm
Elizabeth Lake, East End (ELEE)	9/6/1990					<0.2		9.30	23.50	6.00	0.02
Elizabeth Lake, West End (ELWE)	9/6/1990					<0.2		9.25	22.30	5.00	0.01
Elizabeth Lake, at Boat Ramp (ELBR)	4/10/1997	840	1.60	0.50	<0.03	0.30	0.35	8.50			1.68

Table E-4. Elizabeth Lake 1992-1993 monitoring data for nutrients.

Date	Station ID	Depth (m)	TKN (mg/L)	NH4-N (mg/L)	NO2-N (mg/L)	NO3-N (mg/L)	PO4-P (mg/L)	Total P (mg/L)	pH	TOC (mg/L)
9/30/1992	U A	0	-	0.1	<0.1	0.1	0.3	-	9.5	51.9
9/30/1992	U B	1.5	5.5	<0.1	<0.1	<0.1	0.3	0.4	9.5	47.8
9/30/1992	U A1	0	5.4	<0.1	<0.1	<0.1	0.3	0.4	9.2	47
9/30/1992	U B1	1.5	5.5	<0.1	<0.1	<0.1	0.3	0.4	9.2	40.9
9/30/1992	U A2	0	5.7	<0.1	<0.1	<0.1	0.3	0.4	9.2	50.4
9/30/1992	U B2	1.5	5.6	<0.1	<0.1	<0.1	0.3	0.4	9.2	45.9
9/30/1992	U A3	0	4.7	0.1	<0.1	<0.1	0.3	<0.1	9.2	46.9
9/30/1992	U B3	1.5	-	<0.1	<0.1	<0.1	0.3	-	9.2	46.5
11/11/1992	U A1	0	6.6	<0.1	<0.1	<0.1	0.3	0.5	9.1	54.5
11/11/1992	U A2	0	6.5	<0.1	<0.1	<0.1	0.3	0.6	9.1	51.6
11/11/1992	U A3	0	6.1	<0.1	<0.1	<0.1	0.3	0.5	9.1	52.2
1/25/1993	U A	0	3.1	0.4	<0.1	0.4	0.3	0.3	8.7	17.9
1/25/1993	U B	2	2.9	0.4	<0.1	0.4	0.4	0.3	8.8	17.7
3/3/1993	U A	0	1.7	0.5	<0.1	0.6	0.4	0.3	8.3	13.6
3/3/1993	U B	2.5	2.3	0.4	<0.1	0.6	0.4	0.4	8.4	13
3/3/1993	U C	5.5	2.7	0.4	<0.1	0.6	0.4	0.4	8.4	13.2
5/17/1993	U A	0	1.1	<0.1	<0.1	0.3	0.4	0.4	8.3	11.5
5/17/1993	U B	2.5	1	0.1	<0.1	0.3	0.4	0.3	8.4	11.4
5/17/1993	U C	4.5	0.9	0.1	<0.1	0.3	0.3	0.3	8.4	11.1
5/17/1993	U D	6.5	1	0.2	<0.1	0.4	0.4	0.3	8.3	11.4

Table E-5. Munz Lake 1992-1993 monitoring data for nutrients.

Date	Station ID	Depth (m)	TKN (mg/L)	NH4-N (mg/L)	NO2-N (mg/L)	NO3-N (mg/L)	PO4-P (mg/L)	Total P (mg/L)	pH	TOC (mg/L)
8/24/1992	Y A1	0	1.5	<0.1	<0.1	<0.1	<0.1	<0.1	8.1	11.5
8/24/1992	Y A2	0	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	8.1	9.5
8/24/1992	Y A3	0	1.3	<0.1	<0.1	<0.1	<0.1	<0.1	8	10.3
11/11/1992	Y A1	0	1.3	<0.1	<0.1	<0.1	<0.1	0.1	8	5.9
11/11/1992	Y A2	0	1.1	<0.1	<0.1	<0.1	<0.1	0.1	8	6.3
11/11/1992	Y A3	0	1.4	<0.1	<0.1	<0.1	<0.1	0.1	8	6.7
1/25/1993	Y A1	0	0.9	0.2	<0.1	0.3	0.3	0.3	8	4.1
1/25/1993	Y A2	0	0.9	0.2	<0.1	0.3	0.3	0.3	7.9	4.4
1/25/1993	Y A3	0	0.9	0.2	<0.1	0.3	0.3	0.3	8	4.1
3/3/1993	Y A1	0	1.3	<0.1	<0.1	0.1	0.2	0.3	7.9	5.7
3/3/1993	Y A2	0	1.6	<0.1	<0.1	0.1	0.2	0.3	7.9	5.8
3/3/1993	Y A3	0	1.3	<0.1	<0.1	0.1	0.2	0.2	7.9	8.6
5/6/1993	Y A1	0	1.2	<0.1	<0.1	<0.1	<0.1	0.1	8.1	7.7
5/6/1993	Y A2	0	1	<0.1	<0.1	<0.1	<0.1	0.1	8.1	7.7
5/6/1993	Y A3	0	1.1	<0.1	<0.1	<0.1	<0.1	0.1	8.1	7.3

Table E-6. Lake Hughes 1992-1993 monitoring data for nutrients.

Date	Station ID	Depth (m)	TKN (mg/L)	NH4-N (mg/L)	NO2-N (mg/L)	NO3-N (mg/L)	PO4-P (mg/L)	Total P (mg/L)	pH	TOC (mg/L)
5/17/1992	W A	0	0.8	<0.1	<0.1	<0.1	0.2	0.2	8.3	9.3
5/17/1992	W B	1.5	0.8	<0.1	<0.1	<0.1	0.2	0.2	8.3	9.6
5/17/1992	W C	2.5	0.8	<0.1	<0.1	<0.1	0.2	0.2	8.4	9.3
5/17/1992	W D	3.5	0.8	<0.1	<0.1	<0.1	0.3	0.2	8.4	9.3
11/11/1992	W A	0		NA	<0.1	NA	NA		8.4	45
1/25/1993	W A1	0	1.6	<0.1	<0.1	<0.1	0.1	0.3	8.5	9.6
1/25/1993	W A2	0							8.6	
3/3/1993	W A	0	1.3	<0.1	<0.1	<0.1	0.2	0.3	8.3	8.1
3/3/1993	W B	1.5	1.4	<0.1	<0.1	<0.1	0.2	0.3	8.3	8
3/3/1993	W C	2.5	1.2	<0.1	<0.1	<0.1	0.2	0.2	8.3	7.9

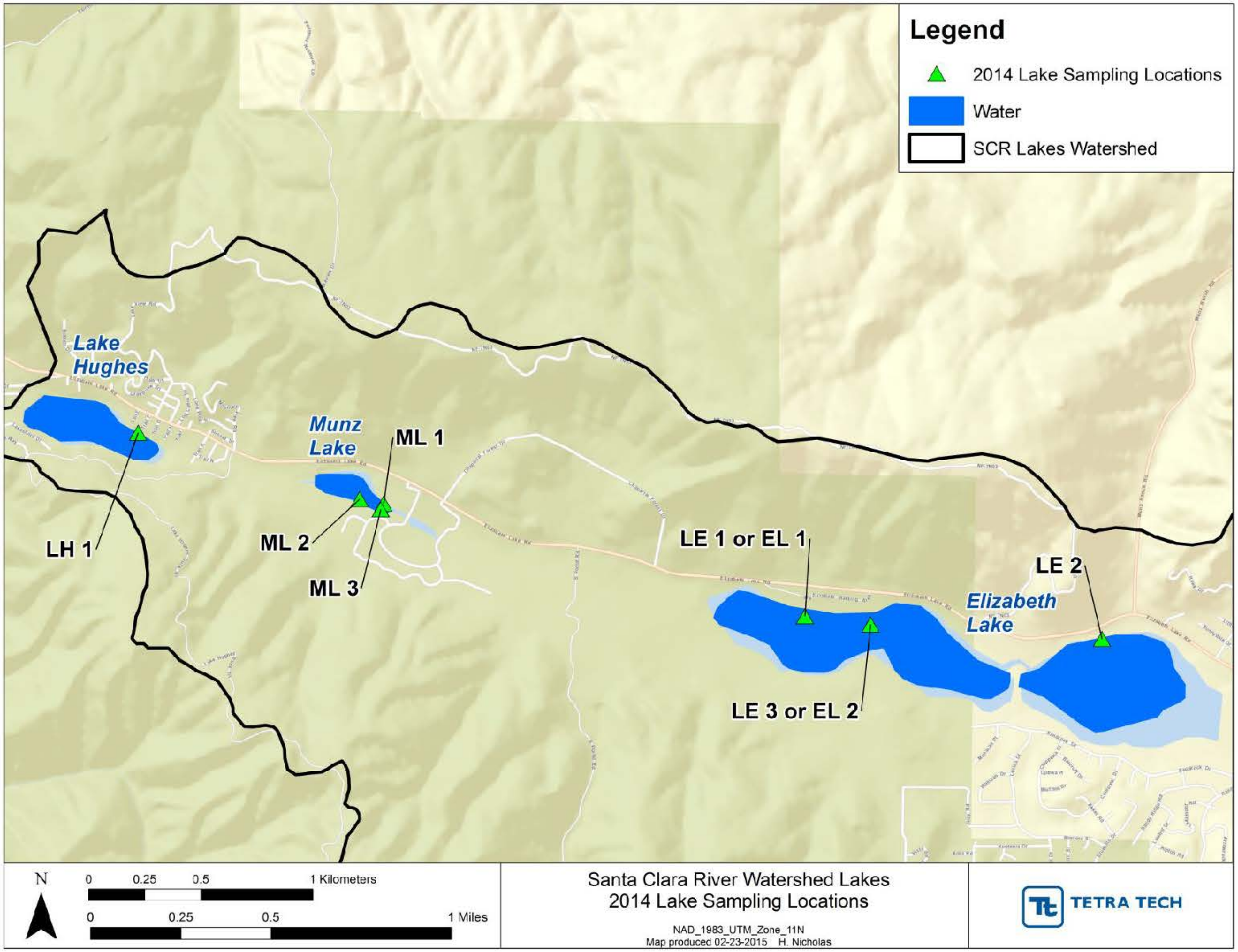

Figure E-1. 2014 Lake Sampling Locations

Table E-7. Lake Elizabeth 2014 monitoring data for nutrients.

Location	Replicate	Sampling Date	Sampling Time	NH3-N	Chla	Conductivity	PO4-P	NO3-N	NO2-N	pH	TKN	TDS	TP	TSS
				mg/L	mg/m3	µS/cm	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L
LE 1		7/8/2014	1:40 PM								31.40			
LE 1	R1	7/8/2014	1:40 PM	3.12	514.90	16090	0.02	0.16	<0.01	8.70 H		13230	1.19	75.50
LE 1	R2	7/8/2014	1:40 PM	3.26		15610				8.70 H		13210	1.21	79.30
LE 2		7/8/2014	2:30 PM								81.90			
LE 2	R1	7/8/2014	2:30 PM	<0.02	407.50	31800	0.03	0.10	<0.01	8.90 H		34330	2.19	158.10
LE 2	R2	7/8/2014	2:30 PM				0.03		<0.01					
EL 1		10/1/2014	12:45 PM								62.60			
EL 1	R1	10/1/2014	12:45 PM	<0.02	264.00	29	0.02	0.02 J	<0.01	8.90		29620	1.37	69.70
EL 1	R2	10/1/2014	12:45 PM	<0.02			0.02	<0.01 SL	<0.01	8.90		29320	1.38	
EL 2		10/8/2014	2:50 PM								72.20			
EL 2	R1	10/8/2014	2:50 PM	<0.02	698.00	30300	0.03	0.29	<0.01	8.80 H		30200	2.72	179.30
EL 2	R2	10/8/2014	2:50 PM	<0.02								30340		

J: Analyte was detected at a concentration below the RL and above the MDL, reported value is estimated.
SL: Analyte results for R1 and/or R2 were lower than 10 times the MDL, therefore RPD acceptance limits do not apply.
H: Sample received and/or analyzed past the recommended holding time.

Table E-8. Munz Lake 2014 monitoring data for nutrients.

Location	Replicate	Sampling Date	Sampling Time	NH3-N	Chla	Conductivity	PO4-P	NO3-N	NO2-N	pH	TKN	TDS	TP	TSS
				mg/L	mg/m3	µS/cm	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L
ML 1		7/8/2014	11:40 AM								1.62			
ML 1	R1	7/8/2014	11:40 AM	0.08	8.50	982	0.02	0.09	<0.01	8.90 H		640	0.07	3.10
ML 1	R2	7/8/2014	11:40 AM	0.11 SL		977	0.02		<0.01	8.90 H		630	0.06	
ML 2		7/8/2014	12:00 PM								1.29			
ML 2	R1	7/8/2014	12:00 PM	0.07	10.40	1386	0.03	0.08	<0.01	7.80 H		780	0.08	5.20
ML 2	R2	7/8/2014	12:00 PM					0.07						
ML 3		10/8/2014	11:25 AM								1.10			
ML 3	R1	10/8/2014	11:25 AM	0.61	36.20	746	0.03	<0.01	<0.01	7.90 H		494	0.06	11.90
ML 3	R2	10/8/2014	11:25 AM			748	0.03	<0.01	<0.01	7.90 H			0.07	

SL: Analyte results for R1 and/or R2 were lower than 10 times the MDL, therefore RPD acceptance limits do not apply.
H: Sample received and/or analyzed past the recommended holding time.

Table E-9. Lake Hughes 2014 monitoring data for nutrients.

Location	Replicate	Sampling Date	Sampling Time	NH3-N	Chla	Conductivity	PO4-P	NO3-N	NO2-N	pH	TKN	TDS	TP	TSS
				mg/L	mg/m3	µS/cm	mg/L	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	mg/L
LH 1		7/8/2014	1:00 PM								25.80			
LH 1	R1	7/8/2014	1:00 PM	2.40	172.50	9350	0.01	0.17	<0.01	9.10 [H]		9580	0.64	192.00
LH 1	R2	7/8/2014	1:00 PM	2.36		9410	0.02		<0.01	8.90 [H]		9530	0.68	174.30
LH 1		10/1/2014	12:15 PM								148.00			
LH 1	R1	10/1/2014	12:15 PM	<0.02	494.00	42	0.04	0.65	<0.01	8.90		50040	2.53	384.40
LH 1	R2	10/1/2014	12:15 PM			41								396.70

H: Sample received and/or analyzed past the recommended holding time.

Table E-10. Lake Elizabeth July 2014 monitoring data by ECORP Consulting.

Location	Sampling Date	Temperature	pH	Conductivity	Salinity	Dissolved Oxygen	Turbidity	TDS	Oxidation-Reduction Potential
		°C	pH units	mS/cm	ppt	mg/L	NTU	g/L	ORPmV
Elizabeth Lake - East Lake	7/2/2014	26.35	8.82	34.8	21.8	10.89 [A]	667	21.2	-81
Pond between East and West Lake (North)	7/2/2014	21.67	9.68	6.66	3.6	7.93	847	4.2	0
Pond between East and West Lake (South)	7/2/2014	23.91	8.99	21.5	12.9	6.97	0 [B]	13.3	-4
Elizabeth Lake - West Lake	7/2/2014	24.5	8.86	17.6	10.4	7.54	132	10.9	40

A: DO meter unstable during monitoring, reading likely inaccurate.
B: Turbidity result is likely >1000 NTU. Turbidity meter unstable during high turbidity situations, fluctuating between either 0 NTU or 1000 NTU (maximum).

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