Total Maximum Daily Load for Total Phosphorus to Address Cyanobacteria Blooms

in

Pinto Lake

Santa Cruz County, California

Pinto Lake
October 2016
Photo: P. Osmolovsky

GAVIN NEWSOM
GOVERNOR

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Draft TMDL Report
for Public Review

March 2020

California Environmental Protection Agency
State Water Resources Control Board

Prepared by
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DRAFT TOTAL MAXIMUM DAILY LOADS REPORT ADDRESSING CYANOBACTERIA BLOOMS IN PINTO LAKE

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Draft Total Maximum Daily Load for Total Phosphorus Addressing Cyanobacteria Blooms in Pinto Lake

APPROVALS (PENDING)

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The TMDL project documents are also available online at:
http://www.waterboards.ca.gov/centralcoast/water_issues/programs/tmdl/docs/pinto_lake/index.shtml

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GLOSSARY OF TERMS AND ACRONYMS

> “The difference between the *almost right* word and the *right* word is really a large matter.” ➔ Mark Twain

Reference Table for Acronyms and Terms Used in this TMDL Report

(the hyperlinks will take you to a webpage with more information about the acronym or the term)

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.
antidegradation	Antidegradation policies are provisions of federal and state law that require that wherever the existing quality of water is better than the quality of water established by water quality objectives, such existing water quality shall be maintained unless otherwise provided by the provisions of the state antidegradation policy (see Basin Plan Section II.A.).
background levels background conditions	Background levels refer to the chemical, physical, and biological conditions in a medium (e.g., water, soil) that would exist without human-caused changes in the watershed. Background levels (also referred to as “background conditions”) result from natural geomorphological processes such as weathering or dissolution.
Basin Plan	Water Quality Control Plan for the Central Coastal Basin.
biostimulation	As used herein, “biostimulation” refers to a state of excess growth of algae due to anthropogenic nutrient inputs into an aquatic system. Biostimulation is characterized by a number of other factors in addition to nitrogen and phosphorus inputs; for example, dissolved oxygen levels, chlorophyll *a*, sunlight availability, and pH[A,B].
beneficial uses	Legally designated uses of waters of the state that may be protected against water quality degradation including, but not limited to, drinking water supply, agricultural supply, aquatic habitat.
blue-green algae	See cyanobacteria. Blue-green algae, which are more correctly known as cyanobacteria, are frequently found in freshwater systems, however, they are not algae but microorganisms that possess characteristics of algae (chlorophyll *a* and oxygenic photosynthesis).
catchment (catchment area)	A catchment area is an area from which surface runoff is carried away by a single drainage system (source: European Environment Agency glossary).
CDFW	California Department of Fish and Wildlife
COLD	Cold Freshwater Habitat – Uses of surface waters that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife including invertebrates.
cyanobacteria	Any of the various photosynthetic bacteria of the phylum Cyanobacteria that are generally blue-green in color and are widespread in marine and freshwater environments, with some species capable of nitrogen fixation. Also called blue-green alga, blue-green bacterium (American Heritage® Dictionary of the English Language).
degradation	In the context of state and federal antidegradation policies, “degradation” refers to a deterioration of existing levels of good water quality. The State Water Resources Control Board states that “the term ‘degradation’ refers to impacts on water quality even if beneficial uses are not unreasonably affected.”
ephemeral stream	An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

Reference Table for Acronyms and Terms Used in this TMDL Report

(the hyperlinks will take you to a webpage with more information about the acronym or the term)

epilimnion	The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly uniform (constant) temperature. The layer is readily mixed by wind action.
groundwater basin	A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom. Lateral boundaries are features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. Bottom boundaries would include rock or sediments of very low permeability if no aquifers occur below those sediments within the basin (source: California Department of Water Resources)
GWR	Groundwater Recharge –Uses of surface waters for natural or artificial recharge of groundwater for purposes of future extraction and maintenance of water quality.
Harmful algal blooms (HABs)	Harmful Algal Blooms (often abbreviated HABs) are overgrowths of algae in water. Some produce dangerous toxins but even nontoxic blooms hurt the environment and local economies. Nutrient pollution from human activities makes HABs more severe and frequent (USEPA). Freshwater cyanobacterial blooms can produce highly potent cyanotoxins and are known as cyanobacterial HABs (cyanoHABs).
high quality water	High quality water is defined by the State Water Resources Control Board as those waters which “contain levels of water quality constituents or characteristics that are better than the established water quality objectives.” And further states that “High quality waters are determined based on specific properties or characteristics. Therefore, waters can be of high quality for some constituents or beneficial uses, but not for others.”
HUC	Hydrologic unit code
Hydrography	Hydrography is the science the measures and describes the physical features of bodies of water.
Hydrology	Hydrology is the scientific study of the movement, distribution, and quality of water on Earth and other planets.
hypolimnion	The lowest layer in a thermally stratified lake or reservoir. This layer consists of colder, denser water, has a constant temperature, and no mixing occurs.
impairment impaired water	The U.S. Environmental Protection Agency defines “impaired waters” as waters that are too polluted or otherwise degraded to meet water quality standards.
Intermittent stream	An intermittent stream has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow.
load allocation	The load allocation is the portion of the receiving water's loading capacity attributed to (1) nonpoint sources of pollution, and (2) natural background sources [CFR §130.2(f)].
loading capacity assimilative capacity	The loading capacity (also called assimilative capacity) is the greatest amount of a pollutant that a waterbody can assimilate and still meet water quality standards [CFR §130.2(f)]
MS4	Municipal separate storm sewer systems

Reference Table for Acronyms and Terms Used in this TMDL Report

(the hyperlinks will take you to a webpage with more information about the acronym or the term)

MUN	Municipal and Domestic Supply – Uses of water for community, military, or individual water supply systems, including but not limited to drinking water supply.
mean annual flow	Mean annual flow means the average flow of a stream (measured in cubic feet per second), from measurements or estimates, over the course of a year.
mean annual precipitation	Mean annual precipitation is the average precipitation for a year (usually calendar) based on the whole period of record or for a selected period (usually 30 year period such as 1981-2010).
microcystins	Toxins produced by cyanobacteria. These toxins are cyclic heptapeptides with seven amino acids. Microcystins are named for the various amino acids on the peptide structure. (Reference: USEPA Drinking Water Treatability Database). Microcystins are the toxins produced by some freshwater cyanobacteria upon their death, including those in the genera *Microcystis*, and *Anabena*.
Microcystis	A genera of freshwater cyanobacteria which can be found in harmful algal blooms. *Microcystis aeruginosa* is a particular species of the Microcystis that is poisonous and may become abundant and troublesome in lakes where much organic matter is present (Merriam-Webster). *Microcystis* is the species that produces the toxin microcystin upon its death.
NHDplus	National hydrography dataset plus
nuisance	State law defines nuisance, as anything that Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property; affects an entire community, neighborhood, or considerable number of persons; and is a result of the treatment or disposal of waste (see Porter Cologne Water Quality Control Act § 13050(m).
NO_3 or NO_3-N	nitrate or nitrate as nitrogen
nonpoint source	Nonpoint source (NPS) pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources from movement of water and soil across the landscape. As the runoff moves, it picks up and carries away natural and manmade pollutants from the landscape, finally depositing them into receiving waters.
NPDES	National pollutant discharge elimination system
OWTS	Onsite wastewater treatment systems
perennial stream	A perennial stream has flowing water year-round during a typical year. The water table is located above the stream bed for most of the year. Groundwater is the primary source of water for stream flow. Runoff from rainfall is a supplemental source of water for stream flow.
point source	Point sources of pollution refer to discrete conveyances, such as pipes or man-made ditches that discharge pollutants into waters of the United States. This includes not only discharges from municipal wastewater treatment plants and industrial facilities, but also collected storm drainage from larger urban areas, certain animal feedlots and fish farms, some types of ships, tank trucks, offshore oil platforms, and collected runoff from many construction sites.
pollution	State law defines pollution as *"an alteration of the quality of the waters of the state by waste to a degree which unreasonable affects the waters for beneficial uses"* (see Porter Cologne Water Quality Control Act § 13050(*l*). Pollution is defined in federal regulation as *"the manmade or man induced alteration of the chemical, physical, biological, and radiological integrity of the water."*

Reference Table for Acronyms and Terms Used in this TMDL Report (the hyperlinks will take you to a webpage with more information about the acronym or the term)	
receiving water	A receiving water is a stream, river, lake, ocean, or other surface or groundwaters into which treated or untreated wastewater is discharged.
river basin	A river basin is the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta.
STEPL	Spreadsheet tool for estimating pollutant load
thermocline	The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. Also called the metalimnion.
threatened waterbody	A threatened waterbody is any waterbody that currently attains water quality standards, but for which existing and readily available data and information on adverse declining trends indicate that water quality standards will likely be exceeded by the time the next list of impaired or threatened waterbodies is required to be submitted to EPA.
TMDL	Total maximum daily load
USEPA	United States Environmental Protection Agency
WARM	Warm Freshwater Habitat – Uses of surface waters that support water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife including invertebrates.
Waste load allocation	The waste load allocation is the portion of a receiving water's loading capacity that is allocated to NPDES-permitted point sources of pollution.
waterbodies	From the perspective of federal law, waterbodies are geographically defined portion of navigable waters, waters of the contiguous zone, and ocean waters under the jurisdiction of the United States, including segments of rivers, streams, lakes, wetlands, coastal waters and ocean waters.
watershed	A watershed is the land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds (“subwatersheds”) that ultimately combine at a common point.
waters of the state	“Waters of the state” means any surface water or groundwater, including saline waters, within the boundaries of the state” [Water Code Section 13050(e)].
WBD	Watershed boundary dataset
wetland	Wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

[A] See: U.S. Fish and Wildlife Service, 2011. 5-Year Review, Summary and Evaluation: *Rorippa gambellii* [*Nasturtieum gambelli*] (Gambel’s watercress). September 2011, Ventura Fish and Wildlife Office.

[B] The term “eutrophication” has often been considered to be synonymous or interchangeable with the term “biostimulation.” California central coast researchers have noted that the word “eutrophication” is problematic because it lacks scientific specificity. These researchers recommend that the regional water quality control boards not use the word (see Rollins, Los Huertos, Krone-Davis, and Ritz, 2012, Algae Biomonitoring and Assessment for Streams and Rivers of California’s Central Coast).

Report Summary / Executive Summary

PENDING

1 INTRODUCTION

The purpose of this report is to present information, data, and recommendations supporting development of total maximum daily loads (TMDLs) and an associated strategy for improving water quality in Pinto Lake, Santa Cruz County. Simply put, a TMDL report is a written plan that describes how an impaired waterbody will achieve water quality standards. For example, the California Water Plan describes TMDLs as *"action plans…to improve water quality."* The following introductory sections (Sections 1.1 through 1.6) provide a brief regulatory, environmental, and scientific context for the materials that follow in the report.

1.1 Federal Clean Water Act

> *"The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." ➔ Clean Water Act §101(a)*

TMDLs are a requirement of the federal Clean Water Act. The Clean Water Act establishes the basic structure for regulating discharges of pollutants into waters of the United States and for regulating water quality standards for surface waters. Federal regulations[1] implementing the TMDL-related portions of the Clean Water Act include Title 40 Code of Federal Regulations (CFR) Part 130 (Water Quality Planning and Management), and 40 CFR Part 131 (Water Quality Standards).

Section 303(d) of the Clean Water Act requires every state to evaluate its waterbodies, and maintain a list of waters that are considered "impaired"[2] either because the water exceeds water quality standards or does not achieve its designated use. For each impaired water on the Central Coast's portion of the Clean Water Act section 303(d) List, the Central Coast Water Board must develop and implement a plan to reduce pollutants so that the waterbody is no longer impaired and can be de-listed. Section 303(d) of the Clean Water Act states:

> *"Each State shall establish for the waters identified in paragraph (1)(A) of this subsection, and in accordance with the priority ranking, the total maximum daily load, for those pollutants which the Administrator identifies under section 1314(a)(2) of this title as suitable for such calculation. Such load shall be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality."*

The State of California complies with this requirement by periodically assessing the conditions of the rivers, lakes and bays and identifying them as "impaired" if they do not meet water quality standards. These waters, and the pollutant or condition causing the impairment, are placed on the 303(d) List of impaired waters, referred to hereafter as the "303(d) List."

In addition to creating a list of waterbodies not meeting water quality standards, the Clean Water Act mandates each state to develop TMDLs for each waterbody listed. Simply put, TMDLs projects are strategies or plans to address and rectify impaired waters identified on the 303(d) List.

The Central Coast Water Board is the agency responsible for developing TMDLs and programs of implementation for waterbodies identified as not meeting water quality objectives pursuant to Clean Water Act section 303(d) and in accordance with the Porter-Cologne Water Quality Control Act §13242.

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[1] Regulations explain the technical, operational, and legal details necessary to implement laws passed by Congress. Laws written by Congress (in this case the Clean Water Act) provide the authority for USEPA to write regulations.

[2] The U.S. Environmental Protection Agency defines "impaired waters" as waters that are too polluted or otherwise degraded to meet water quality standards.

1.2 California's Porter-Cologne Water Quality Control Act

California's TMDL program is charged with creating plans that consider all sources and causes of water pollution and water quality degradation, and allocating responsibility for corrective measures which result in attainment of water quality standards[3].

In California, the State Water Resources Control Board (State Water Board) has interpreted state law (Porter-Cologne Water Quality Control Act, California Water Code Section 13000 et. seq.) to require that implementation be addressed when TMDLs are incorporated into Basin Plans (water quality control plans)[4].

The Porter-Cologne Water Quality Control Act (Porter-Cologne) requires each regional water quality control board to formulate and adopt water quality control plans for all areas within its region. It also requires that a program of implementation be developed that describes how water quality standards will be attained[5]. Text Box 1-1 presents the required elements of a "program of implementation."

Accordingly, TMDLs can be developed as a component of the program of implementation – thus triggering the need to describe the regulatory, non-regulatory, and/or voluntary actions needed to achieve water quality objectives (aka, an "implementation strategy or plan").

Text Box 1-1. Required elements of a "program of implementation" pursuant to Porter-Cologne.

> Porter-Cologne §13242
>
> The **program of implementation** for achieving water quality objectives shall include, but not be limited to:
> (a) A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private.
> (b) A time schedule for the actions to be taken.
> (c) A description of surveillance to be undertaken to determine compliance with objectives.
>
> *(emphasis added by Central Coast Water Board staff)*

Worth noting is that a TMDL differs from other pollution control management measures because the TMDL requires that loads from *all* pollution sources within a watershed be allocated. Other pollution control measures generally focus on one, or a few identifiable sources.

1.3 California Impaired Waters Policy

On June 16, 2005, the State Water Board adopted the Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options (State Water Board Resolution 2005-0050), hereafter referred to as the Impaired Waters Policy.

The overarching intent and objectives of the Impaired Waters Policy are articulated in Text Box 1-2.

Text Box 1-2. Intent and objectives of the Impaired Waters Policy.

> "*Where waters are not meeting their beneficial uses from anthropogenic sources of pollutants, the Water Boards will use the Total Maximum Daily Load (TMDL) program to craft an implementation plan to ensure that the waters meet all applicable standards as soon as is practicable.*"
>
> ➔ *Water Quality Control Policy for Addressing Impaired Waters: Regulatory Structure and Options, June 2005 (aka, the "Impaired Waters Policy")*

The Impaired Waters Policy articulates a number of ways the Regional Boards can address impaired waters through the state's TMDL program. The policy states that the Regional Boards have independent

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[3] State of California, S.B. 469 TMDL Guidance: A Process for Addressing Impaired Waters in California, June 2005. Approved by Resolution 2005-0050.

[4] State Water Resources Control Board, TMDL program webpage (accessed October 2016).

[5] Porter-Cologne Water Quality Control Act §13242.

discretion, broad flexibility, numerous options, and some legal constraints that apply when determining how to address impaired waters.

Generally speaking, if failure to attain water quality standards is due to natural causes, the appropriate regulatory response is to correct the standards for that waterbody. In contrast, if a waterbody is impaired because of controllable human activities, a TMDL is required, and an associated implementation plan must be developed using existing regulatory tools to correct the water quality impairment.

1.4 Environmental Impacts of Harmful Cyanobacteria Blooms

> *"[Cyanobacteria] have survived every mass extinction. While we are unlikely to defeat a 3.5-billion-year-old organism, we may be able to come to some sort of comfortable draw."*
>
> ➔ Robert Ketley, Water Quality Program Manager (retired), City of Watsonville

The California Water Quality Monitoring Council has described the nature and environmental impacts of cyanobacteria blooms, as follows. At the base of the food chain in fresh, brackish, and marine systems are photosynthetic cyanobacteria and algae. Both single-celled microscopic and larger multicellular forms exist. Cyanobacteria and algae are naturally present in most freshwater and marine aquatic ecosystems, and perform many roles that are vital for ecosystem health.

However, under certain conditions, including light and temperature levels, levels of nutrients, and lack of water turbulence, cyanobacteria and some algae can quickly multiply into a harmful algal bloom. According to the U.S. Environmental Protection Agency (USEPA), nutrient enrichment from fertilizers, urban sources, and stormwater runoff is a key factor in occurrences of cyanobacteria blooms[6]. Some cyanobacteria and harmful algae can produce toxic chemicals, including cyanotoxins, domoic acid, and other algal toxins. Cyanobacteria and harmful algal blooms can thus have negative impacts on the environment, people, pets, wildlife, or livestock, as well as the economy. Figure 1-1 illustrates a cyanobacteria bloom at Pinto Lake.

Figure 1-1. Pinto Lake, cyanobacteria bloom (photo credit: Shanta Keeling, October 2016).

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[6] U.S. Environmental Protection Agency webpage, "The Science of Harmful Algal Blooms", https://www.usgs.gov/news/science-harmful-algae-blooms accessed October 2016.

The most researched group of freshwater harmful algal blooms is blue-green algae, more correctly known as cyanobacteria. Some freshwater cyanobacteria blooms produce potent cyanotoxins. According to the U.S. Environmental Protection Agency, these cyanotoxins can cause human health problems ranging from a mild skin rash, to vomiting and nausea, to serious illness. Respiratory paralysis leading to death in wildlife and pets can also be a consequence of cyanotoxins.

High biomass blooms, whether of toxic or nontoxic species, can harm aquatic ecosystems by leading to very low oxygen levels in the water column (hypoxia), resulting in higher mortality rates in local fish, shellfish, invertebrate, and plant populations. The blooms may also affect benthic flora and fauna due to decreased light penetration. Toxic blooms from some cyanobacteria genera may lead to inhibition of other phytoplankton and suppression of zooplankton grazing, leading to reduced growth and reproductive rates, and changes in community structure and composition.

In addition to the production of toxins, cyanobacteria have often been associated in drinking water with taste and odor problems. Dying and lysing cells release their contents (toxins) into the water and are subject to rapid putrefaction of the material. Blooms produce a variety of odor and taste compounds which are not toxic but are a nuisance to the public.

Currently, there reportedly have been no confirmations of human deaths in the United States from exposure to cyanotoxins, however many people have become ill from exposure, and acute human poisoning is a distinct risk (Dr. Wayne Carmichael of the Wright State University-Department of Biological Sciences, as reported in NBC News, 2009).

Worth noting is that TMDL development intended to address cyanobacteria blooms in Pinto Lake is consistent with the Central Coast Water Board's highest identified priorities. Text Box 1-3 presents the Central Coast Water Board's two highest priority areas[7] (listed in priority order).

Text Box 1-3. Central Coast Water Board's top two priorities (see board meeting staff reports from (July 2012, October 2013, January 2016, and March 2016).

1) "Preventing and Correcting Threats to Human Health"
2) "Preventing and Correcting Degradation of Aquatic Habitat"
   "Including requirements for aquatic habitat protection in Total Maximum Daily Load Orders"

1.5 Description of the Water Quality Problem at Pinto Lake

> *"Every fall, Pinto Lake's microcystin levels spike way beyond what's considered dangerous for humans and animals."*
>
> ➔ from: *Evotis*, a monthly online publication of the University of California Davis One Health Institute

Pinto Lake is a shallow, 103-acre hypereutrophic lake located within the Lower Pajaro River watershed in Santa Cruz County. The lake is bordered by two public parks and private lands. Outside of the public parks, land use in the lake's approximately 1,400 acre catchment is characterized by agricultural and ranch land, with some suburban and rural residential areas and businesses including stables, kennels, and a composting facility.

Previous researchers have assessed and described the nature of the water quality problem at Pinto Lake (Ketley et al., 2013, CSUMB and Resource Conservation District of Santa Cruz County, 2013, and Stanfield, 2013). Due to human activities in the Pinto Lake watershed, the lake ecosystem has become degraded. In the historical past, removal of native vegetation promoted increased erosion and allowed nutrient-rich sediment to enter the lake. Fertilizer applications and other human activities have increased loading of nutrients to the lake. As a result, beginning in the 1970s Pinto

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[7] See Staff Report (agenda item 3) for the July 11, 2012 Water Board meeting.

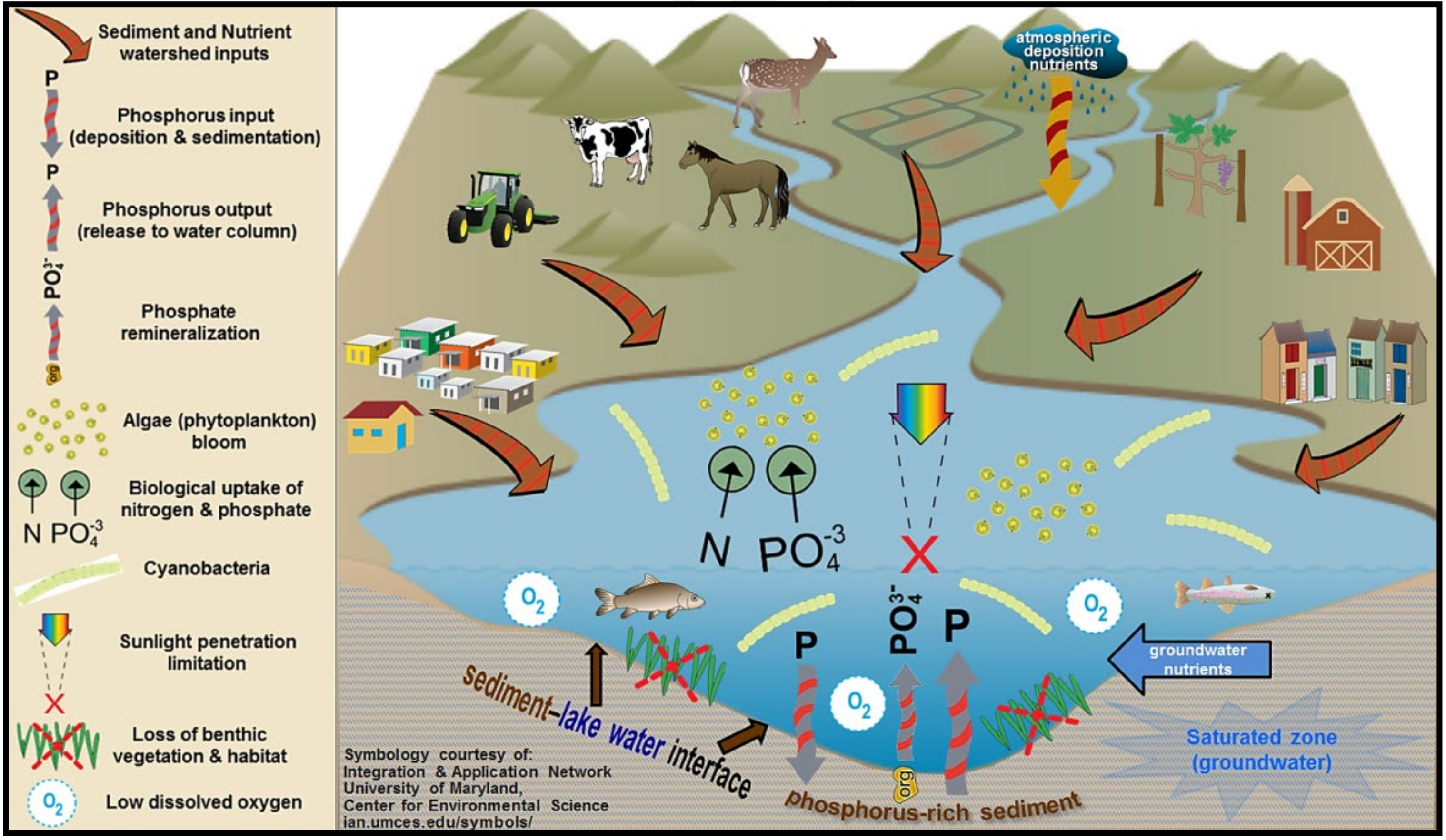
Lake has experienced seasonal and persistent cyanobacteria algal blooms. These blooms adversely affect the lake’s aquatic ecosystem and recreational uses.

> *Interviews with Pinto Lake watershed residents and Santa Cruz County community members have described Pinto Lake shifting from a largely swimmable recreational resource in the late 1960s to early 1970s to the current cyanobacteria-dominated lake we see today, suggesting that the blooms began to be a problem sometime in the late 70s- early 80s. Knowledgeable lakeside residents mentioned draining of the lake in the 1960s (in an attempt to eradicate carp) and conversion of apple orchards to berry crops as potentially significant changes in the lake and its watershed.*
>
> ➔ from: California State University, Monterey Bay (CSUMB) and Resource Conservation District of Santa Cruz County, *Pinto Lake Watershed: Implementation Strategies for Restoring Water Quality in Pinto Lake*. March 2013.

As a result of these water quality problems, Pinto Lake is listed on the Clean Water Act section 303(d) List of impaired waterbodies due to impairments associated with harmful algal blooms. This type of water quality impairment is a biological response to excessive loading of nutrients to the lake. While nutrients - specifically nitrogen and phosphorus – are essential for plant growth and are naturally present and ubiquitous in the environment, they are considered pollutants when they occur at levels which have adverse impacts on water quality (see Figure 1-2).

According to the 2010 Clean Water Act section 303(d) List, water quality impairments in Pinto Lake include unacceptable amounts of cyanobacteria microcystins (i.e., algal toxins), low dissolved oxygen, and scum/floating material. In the past, Pinto Lake was not subject to episodic and intense cyanobacteria algal blooms based on interviews with long-term lakeside residents, knowledgeable locals, or inferred from sediment core data (CSUMB and Resource Conservation District of Santa Cruz County, 2013).

Figure 1-2. Conceptual illustration of nutrient inputs and associated cyanobacteria blooms in Pinto Lake.



Episodic algal blooms in Pinto Lake, resulting from nutrient-driven biostimulation[8] constitute a potential health risk and public nuisance to humans, to their pets, and to wildlife. The majority of freshwater harmful algal blooms (HABs) reported in the United States and worldwide are due to one group of algae, cyanobacteria (CyanoHABs, or blue-green algae).

University of California-Santa Cruz researchers report that Pinto Lake is one of the most toxic lakes ever recorded in the scientific literature based on episodic high levels of algal cyanotoxins[9].

An illustration of an algae bloom in Pinto Lake is presented in Figure 1-3, Figure 1-4, and Figure 1-5.

Figure 1-3. Cyanobacteria bloom in Pinto Lake (photo submitted by City of Watsonville staff).

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[8] As used herein, "biostimulation" refers to a state of excess growth of aquatic vegetation due to anthropogenic nutrient inputs into an aquatic system. Biostimulation is characterized by a number of other factors in addition to nitrogen and phosphorus inputs; for example, dissolved oxygen levels, chlorophyll *a*, sunlight availability, and pH.

[9] The National Wildlife Federation reported that Pinto Lake "contains some of the most toxic water in the nation."

Figure 1-4. Cyanobacteria bloom at Pinto Lake boat dock, September 2015 (photo credit: Robert Ketley).

Figure 1-5. Cyanobacteria bloom at Pinto Lake fishing pier, October 2015 (photo credit: Robert Ketley).

The office of California Assembly Member Luis A. Alejo recently described the water quality-related problems associated with Pinto Lake:

> *Freshwater blue green algae toxins caused the deaths of over 31 endangered southern sea otters in Monterey Bay. In 2012 a blue green algal bloom at Pinto Lake, just 4 miles from the Monterey Bay, resulted in the death of countless waterfowl. "The birds were convulsing on the ground and flying into buildings and cars all across town" states Robert Ketley, Water Quality Program Manager for Watsonville.*
>
> ➔ Press Release dated February 12, 2015 from California Assembly Member Luis A. Alejo

Cyanobacteria blooms and associated poor water quality have adversely affected a number of beneficial uses of Pinto Lake. Figure 1-6 illustrates some of the various environmental and health-related risks associated with cyanobacteria blooms at Pinto Lake.

According to the USEPA, these cyanotoxins can cause human health problems ranging from a mild skin rash, to vomiting and nausea, to serious illness. Respiratory paralysis leading to death in wildlife and pets can also be a consequence of cyanotoxins. These effects are not theoretical; The World Health Organization (WHO, 1999) and other agencies have reported on worldwide animal poisonings and adverse human health effects.

> *"The carcasses of about 120 elk were discovered Aug. 27 on a ranch near Mora (New Mexico). After tissue and water samples were analyzed by laboratories in five states, investigators determined that the cause of the deaths most likely was a toxin produced by blue-green algae."*
>
> ➔ from: New Mexico Department of Game and Fish in *"New Mexico Wildlife"* (Vol. 57, No.3 – Winter 2014)

The California Department of Public Health and various County Health Departments have documented cases of dog die-offs throughout the state and the nation due to cyanotoxins. Dogs can die when their owners allow them to swim or wade in waterbodies with algal blooms. Dogs are also attracted to fermenting mats of cyanobacteria near shorelines of waterbodies (Carmichael, 2011). Dogs reportedly die due to ingestion associated with licking algae and associated toxins from their coats.

> *"In mammals, including humans, chronic exposure can lead to increased risk of cancer, while acute exposure can give you jaundice-like conditions, and at high enough concentrations can cause death," said Dr. Kudela. "We can be exposed to the toxins through drinking water, consumption of algae, and even through breathing in toxins that become aerosolized."*
>
> ➔ Dr. Raphael Kudela, professor of Ocean Sciences, University of California, Santa Cruz quoted in Evotis, a monthly online publication of the UC Davis One Health Institute

Also noteworthy, cyanotoxins originating from freshwater sources, such as coastal lakes and streams, have been implicated in the deaths of southern sea otters in Monterey Bay (Miller et al., 2010). Waters carrying the cyanotoxins from Pinto Lake can drain to Monterey Bay via drainage to the Pajaro River and its tributaries. It should be noted that there are many possible source areas contributing cyanotoxins to Monterey Bay areas watersheds, and Pinto Lake should not be singled out as the sole source.

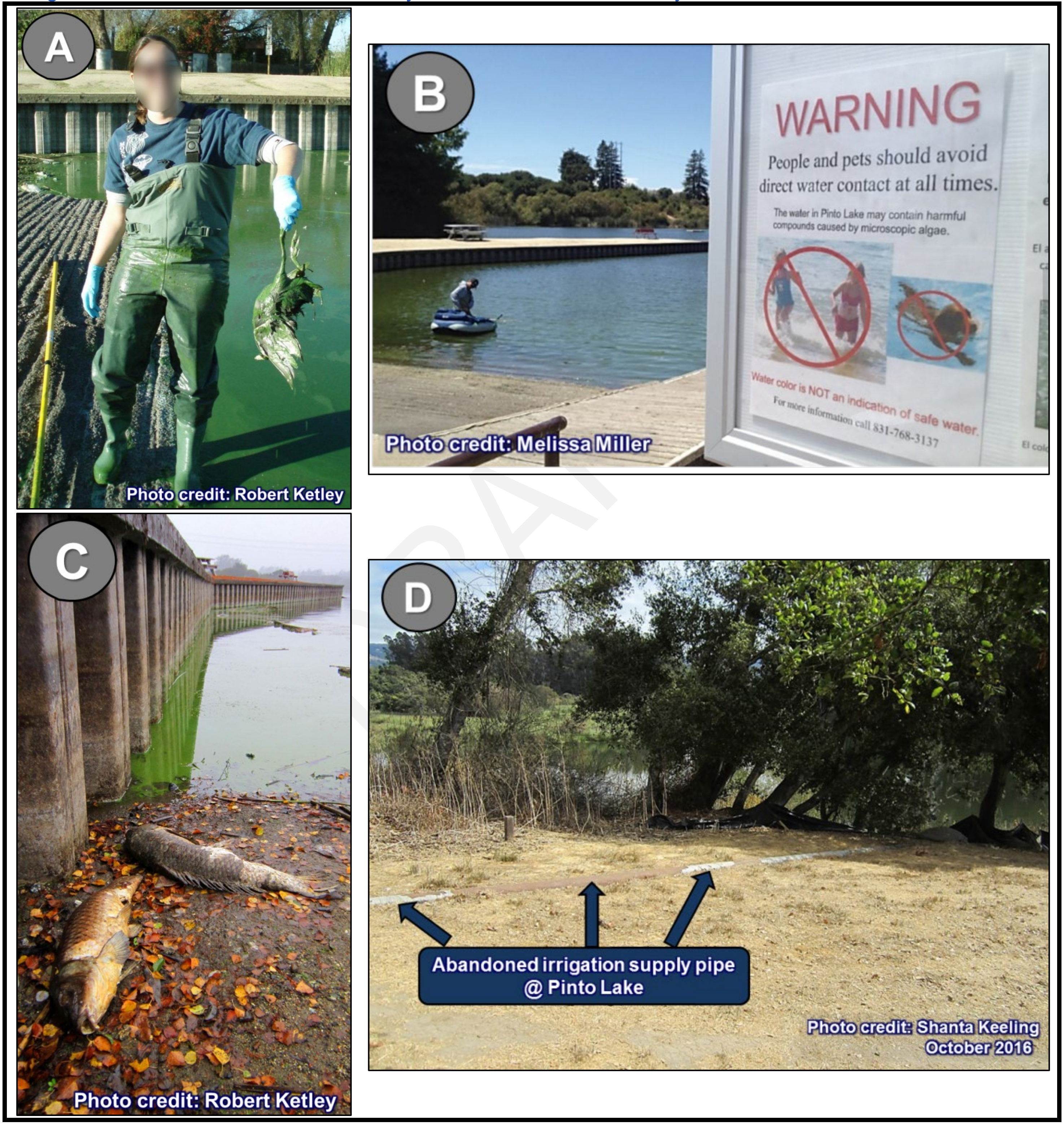
> *"As we started doing the post-mortem examinations on some of these otters, we could see that the livers were very swollen and had areas of hemorrhage," said Dr. Miller, a veterinarian and wildlife pathologist for the California Department of Fish and Wildlife Marine Wildlife Veterinary Care and Research Center. "In some cases, even if the animal had just died, we would lift the liver out of the abdomen to take a closer look and it would literally fall apart in our hands."*
>
> ➔ Dr. Melissa Miller, quoted in *Evotis*, a monthly online publication of the UC Davis One Health Institute

To date, we are unaware of any medically confirmed cases of human illness associated with cyanotoxins at Pinto Lake, and the reporting we have received on human health impacts is circumstantial. Irrespective of medical confirmation, medical professionals and the scientific literature confirm that the risk is real. It is possible some illnesses go unreported, or that connections between illnesses and cyanobacteria blooms are not apparent to people. City of Watsonville staff has reported anecdotal cases of people contracting skin rashes, upset stomach, burning eyes, or flu-like symptoms associated with contact with cyanobacteria blooms in Pinto Lake.

Also significant, cyanobacteria blooms have adversely affected the agricultural uses of Pinto Lake waters. Farmers around the lake reportedly had to abandon use of the lake water as an irrigation source due to concerns about the cyanotoxins found in the water (see Figure 1-6 (D)).

> "*Pinto Lake used to be an irrigation source for food crops. Growers were forced to abandon the use of lake water and drill wells to tap into a deep aquifer because of threats to food and worker safety posed by the (cyanobacteria) toxins.*"
>
> ➔ letter from California Legislature Assemblymen Luis Alejo and Mark Stone, and State Senator William Monning to State Water Resources Control Board Chair Felicia Marcus, dated October 4, 2013
>
> *Parenthetical clarification added by Central Coast Water Board staff.*

Figure 1-6. Some adverse impacts to Pinto Lake by cyanobacteria blooms. (A) cyanotoxins can damage the livers of birds and other animals. In 2011, many coots, as well as some grebes and cormorants, were killed at Pinto Lake. (B) Public health warning sign posted at Pinto Lake, advising visitors of health risks of harmful cyanobacteria blooms. (C) Cyanobacteria blooms can reduce the amount of dissolved oxygen in the lake, making it difficult for fish to survive. (D) Growers had to abandon use of lake waters as an irrigation source due to concerns about cyanotoxins associated with cyanobacteria blooms.



1.6 A Note on Spatial Datasets & Scientific Certainty

Central Coast Regional Water Quality Control Board (Central Coast Water Board) staff endeavored to use the best available spatial datasets from reputable scientific and public agency sources to render and assess physical, hydrologic, and biologic conditions in the Pinto Lake catchment. Spatial data of these types are used routinely in TMDL development and watershed studies nationwide. Where appropriate, staff endeavored to clearly label spatial data and literature-derived values as estimates in this project report, and identify source data and any assumptions.

It is important to recognize that the nature of public agency data and digital spatial data provide snapshots of conditions at the time the data was compiled, or are regionally-scaled and are not intended to always faithfully and accurately render all local, real-time, or site-specific conditions. When reviewing TMDLs, the USEPA will recognize these types of datasets as estimates, approximations, and scoping assessments. As appropriate, closer assessments of site specific conditions and higher resolution information about localized pollution problems would be conducted during TMDL implementation.

Also noteworthy is that while science is one cornerstone of the TMDL program, a search for full scientific certainty and a resolution of all uncertainties is not contemplated or required in TMDLs adopted in accordance with the Clean Water Act, and pursuant to USEPA guidance. Staff endeavored to identify uncertainties in the TMDL, and reduce uncertainties where possible on the basis of available data. It should be recognized that from the water quality risk management perspective, scientific certainty is balanced by decision makers against the necessities of addressing risk management. Conceptually, this issue is articulated by reporting from the U.S. National Research Council as shown below:

Text Box 1-4. Scientific certainty and TMDLs as articualted by the U.S. National Research Council, National Academy of Sciences.

> *“**Scientific uncertainty is a reality within all water quality programs, including the TMDL program that cannot be entirely eliminated.** The states and EPA should move forward with decision-making and implementation of the TMDL program in the face of this uncertainty while making substantial efforts to reduce uncertainty. Securing designated uses is limited not only by a focus on administrative rather than water quality outcomes in the TMDL process, but also by unreasonable expectations for predictive certainty among regulators, affected sources, and stakeholders… Although science should be one cornerstone of the program, an unwarranted search for scientific certainty is detrimental to the water quality management needs of the nation. Recognition of uncertainty and creative ways to make decisions under such uncertainty should be built into water quality management policy.”*
>
> ➔ National Academy of Sciences – National Research Council (2001)
>
> Report issued pursuant to a request from the U.S. Congress to assess the scientific basis of the TMDL program: National Research Council, 2001. “Assessing the TMDL Approach to Water Quality Management – Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction, Water Science and Technology Board”
>
> *(Emphasis not added – emphasis as published in the original National Research Council report)*

It is important for the Central Coast Water Board to endeavor to be transparent about the processes for vetting information used to guide TMDL development. The science of harmful algal blooms and nutrient pollution is a large and complex field of study. Thus, for this TMDL project it is not possible for staff to review and vet all information pertaining to the science of cyanobacteria blooms.

Much of the information we compiled is from subject matter experts and local resource professionals specifically for this TMDL project. Other information compiled is from a variety of sources including peer-reviewed scientific articles, government reports, private consulting scientists, and individuals with local knowledge concerning Pinto Lake. We made professional judgements about the scientific confidence and weight to place on various information sources. While there is no ironclad, universal rule about how much scientific confidence one should place on a given source[10], Figure 1-7 illustrates conceptually how scientific confidence associated with different sources of information might vary.

Figure 1-7. Illustration of how scientific confidence associated with different sources might vary.

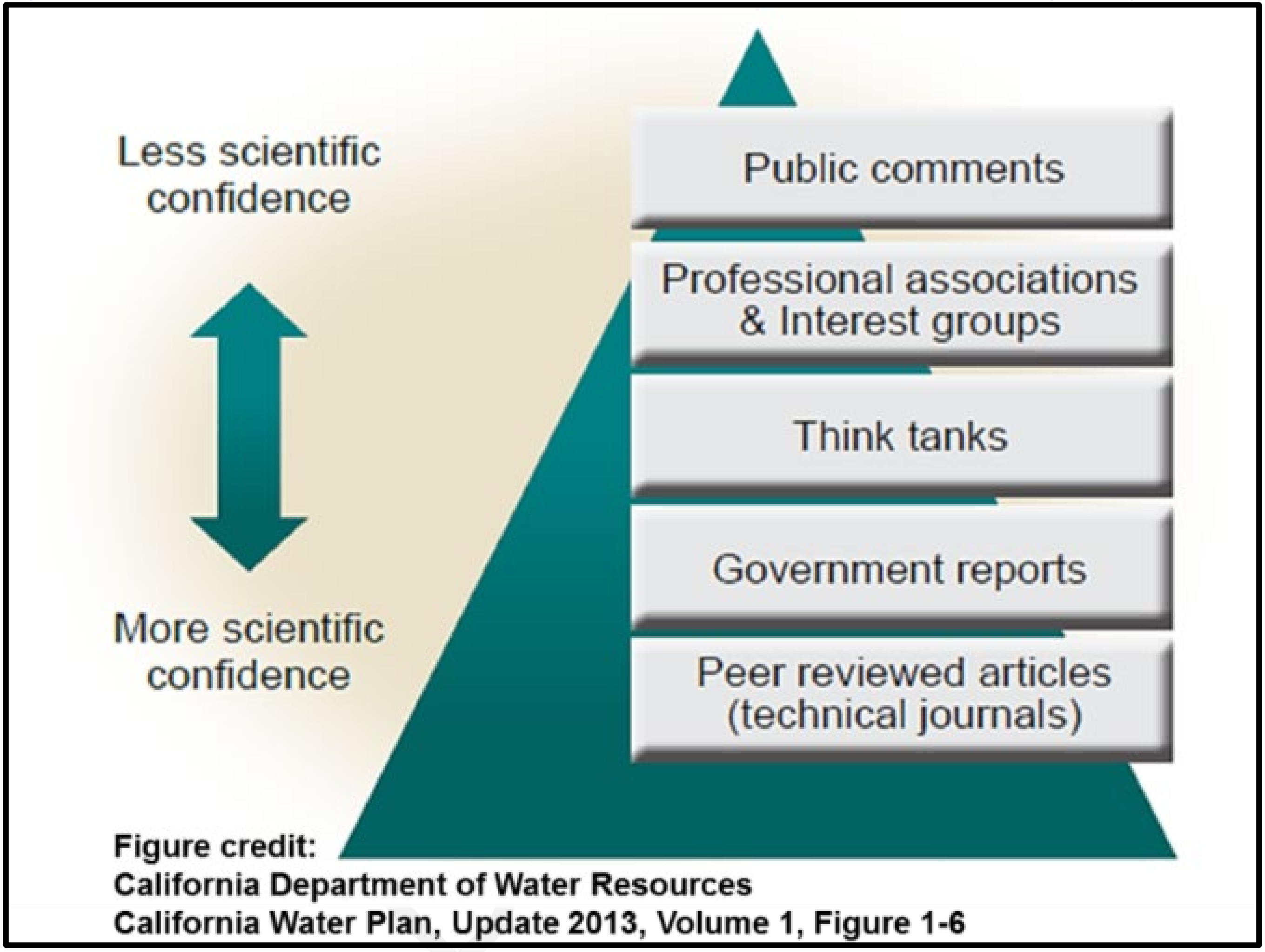


Figure credit:
California Department of Water Resources
California Water Plan, Update 2013, Volume 1, Figure 1-6

2 LAKE CATCHMENT SETTING

2.1 TMDL Project Area

> *"Healthy lakes enhance our quality of life. We use lakes for drinking water, energy production, food, and recreation. Fish, birds, and other wildlife rely on them for habitat and survival."*
>
> ➔ U.S. Environmental Protection Agency, National Lakes Assessment 2012

This section of the report highlights the areas targeted by this TMDL. This TMDL project includes Pinto Lake (see Figure 2-1 and Figure 2-2) and surrounding areas that drain to the lake. Based on GIS spatial analysis, Pinto Lake drains a 1,400-acre catchment of Santa Cruz County, north of the City of Watsonville. Plainly speaking, this is the geographic area for which watershed improvement activities and monitoring will need to occur to improve environmental quality at the lake.

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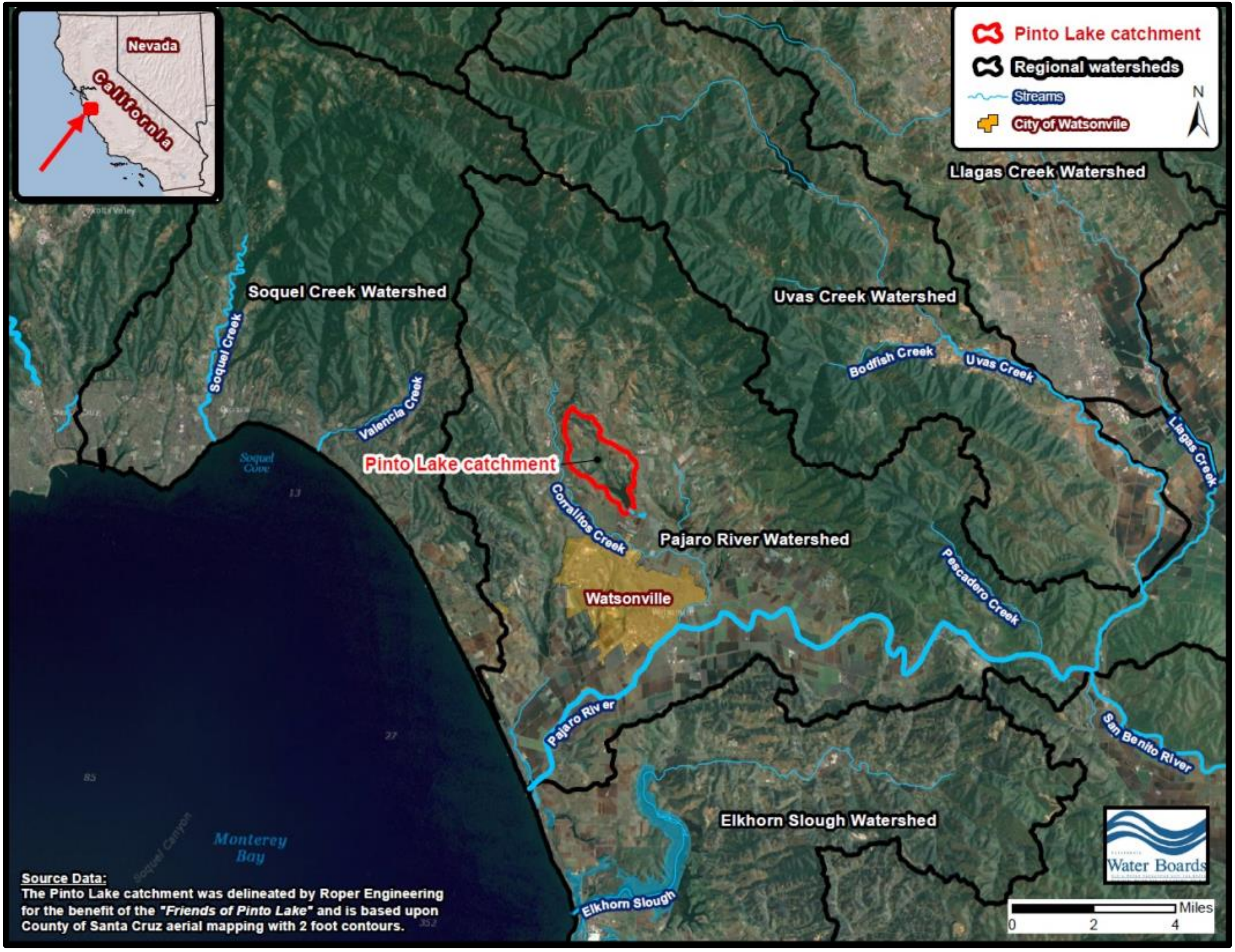
[10] For example, public comments that use verifiable peer-reviewed scientific report(s) and data for support might be given greater weight than might be given to public comments consisting of unsubstantiated assertion and opinion.

Figure 2-1. Pinto Lake, August 2013.

Pinto Lake, August 2013
Picture credit: Stephanie Salomonsen
followthehighlinehome.com

Figure 2-2. Location map, Pinto Lake catchment, Santa Cruz County, California.



Source Data:
The Pinto Lake catchment was delineated by Roper Engineering for the benefit of the *"Friends of Pinto Lake"* and is based upon County of Santa Cruz aerial mapping with 2 foot contours.

Pinto Lake is a natural, perennial lake that has existed for at least 8,000 years as a result of a tectonically-driven local topographic depression (Plater et al., 2006). The lake is an important recreational and aesthetic resource for the public, and historically has provided high quality habitat for aquatic species and wildlife.

Elevations in the Pinto Lake catchment range from 112 feet above mean sea level (MSL) at the City of Watsonville's Pinto Lake Park located at the southeastern margin of the lake, to 513 feet above MSL in the northwestern, upland reaches of the lake catchment. According to Plater et al. (2006), lake bathymetry is generally in the range of 2 to 6 meters (about $6^1/_2$ feet to 20 feet); maximum depths range to about 8 meters (~25 feet) in the central part of the lake.

Delineation of watershed drainage boundaries is a necessary part of TMDL development. Drainage boundaries of the conterminous United States are delineated based on the Watershed Boundary Dataset[11], which contain digital hydrologic unit boundary layers organized based on Hydrologic Unit Codes. Hydrologic Unit Codes (HUCs) were developed by the United States Geological Survey to identify all the drainage basins of the United States.

Noteworthy is that watersheds range in all sizes depending on how the drainage area of interest is spatially defined, if drainage areas are nested, and on the nature and focus of a particular hydrologic study. Watersheds can be characterized by a hierarchy as presented in Table 2-1.

Table 2-1. Watershed hierarchy (basins, subbasins, watersheds, subwatersheds, catchments). The Pinto Lake catchment is a small (<1,500 acres) drainage area nested within the much larger Pajaro River basin.

Hydrologic Unit	**Approx. Drainage Area (square miles, unless otherwise noted)**	**Example(s)**	**Spatial Data Reference or Delineation Methodology**
basin	≥ 1,000	Pajaro River basin	Watershed Boundary Dataset HUC-8 shapefiles
subbasin	> 250 to < 1,000	San Benito River subbasin	2 or 3 HUC-10s [A] *(spatial dissolve)*
watershed	~ 100 to ~ 250	Llagas Creek watershed Uvas Creek watershed	Watershed Boundary Dataset HUC-10 shapefiles
subwatershed	> 10 to < 100	Salsipuedes Creek subwatershed Corrilitos Creek subwatershed	Watershed Boundary Dataset HUC-12 shapefiles
catchment	~ 1 to < 10	**Pinto Lake catchment** *(a catchment nested within the Salsipuedes Creek subwatershed)*	Roper Engineering Autocad® linework based on County of Santa Cruz aerial mapping with two-foot contours
subcatchment	< 1,000 acres	Todos Santos Creek subcatchment Amesti Creek subcatchment *(subcatchments nested within the Pinto Lake catchment)*	Delineation using ArcMap® 10.1 spatial analyst hydrology tool

This watershed hierarchy is based on adaptation from two sources: 1) Jonathan Brant, PhD, and Gerald J. Kauffman, MPA, PE (2011) Water Resources and Environmental Depth Reference Manual for the Civil Professional Engineer Exam, and 2) the Watershed Boundary Dataset (National Hydrography Dataset user guide accessed November 2016.

[A] This is approximately equivalent to "Hydrologic Area" in the CalWater 2.2 watershed convention.

Roper Engineering, a civil engineering and surveying firm in Watsonville, generously provided us Autocad® digital linework for the Pinto Lake catchment (refer back to Figure 2-2). Roper Engineering

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[11] The Watershed Boundary Dataset (WBD) is developed by federal agencies and national associations. WBD contains watershed boundaries that define the areal extent of surface water drainage to a downstream outlet. WBD watershed boundaries are determined solely upon science-based principles, not favoring any administrative boundaries.

produced the catchment delineation for the benefit of *Friends of Pinto Lake*. The Autocad® linework is based upon County of Santa Cruz aerial mapping with two-foot contours.

We provide additional detail and information about the physical and environmental setting of the lake catchment in report Sections 2.2 through 2.14.

2.2 Land Use & Land Cover

Land use conditions play an important role in pollutant fate and transport in any given watershed, thus evaluating land use and land cover is an important part of TMDL development.

At the time of this TMDL report preparation, we relied on the most current land cover data available, namely the Department of Conservation’s 2014 Farmland Mapping and Monitoring Program dataset. The Farmland Mapping and Monitoring Program maps are periodically updated with the use of aerial photographs, a computer mapping system, public review, and field reconnaissance. Table 2-2 presents the Farmland Mapping and Monitoring Program land use and land cover categories as defined by the Department of Conservation.

Table 2-2. Land use and land cover categories used in this TMDL report and as defined by the California Department of Conservation's Farmland Mapping and Monitoring Program.

Land Use / Land Cover	**Description (with alphabetic code) as defined by Farmland Mapping and Monitoring Program** [A]
Farmland	*The aggregate category "Farmland" used in this TMDL report includes several categories defined by the Farmland Mapping and Monitoring Program, as shown below:* Prime Farmland (P): Irrigated land with the best combination of physical and chemical features able to sustain long-term production of agricultural crops. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for production of irrigated crops at some time during the four years prior to the mapping date. Farmland of Statewide Importance (S): Irrigated land similar to Prime Farmland that has a good combination of physical and chemical characteristics for the production of agricultural crops. This land has minor shortcomings, such as greater slopes or less ability to store soil moisture than Prime Farmland. Land must have been used for production of irrigated crops at some time during the four years prior to the mapping date. Unique Farmland (U): Lesser quality soils used for the production of the state's leading agricultural crops. This land is usually irrigated, but may include non-irrigated orchards or vineyards as found in some climatic zones in California. Land must have been cropped at some time during the four years prior to the mapping date.
Urban and Built-up Land	Urban and Built-Up Land (D)**:** Urban and Built-Up land is occupied by structures with a building density of at least 1 unit to 1.5 acres, or approximately 6 structures to a 10-acre parcel. Common examples include residential, industrial, commercial, institutional facilities, cemeteries, airports, golf courses, sanitary landfills, sewage treatment, and water control structures.
Grazing Land *Note: this only refers to lands that have the potential for livestock grazing. It does not imply active livestock grazing is currently taking place on these lands.*	Grazing Land (G)**:** Land on which the existing vegetation is suited to the grazing of livestock. This category is used only in California and was developed in cooperation with the California Cattlemen's Association, University of California Cooperative Extension, and other groups interested in the extent of grazing activities. The minimum mapping unit for Grazing Land is 40 acres.
Other Land (Woodland, Undeveloped, or Restricted)	Other Land (X)**:** Land which does not meet the criteria of any other category. Typical uses include low-density rural development, heavily forested land, mined land, or government land with restrictions on use.
Open Water	Water (W)**:** Water areas with an extent of at least 40 acres.

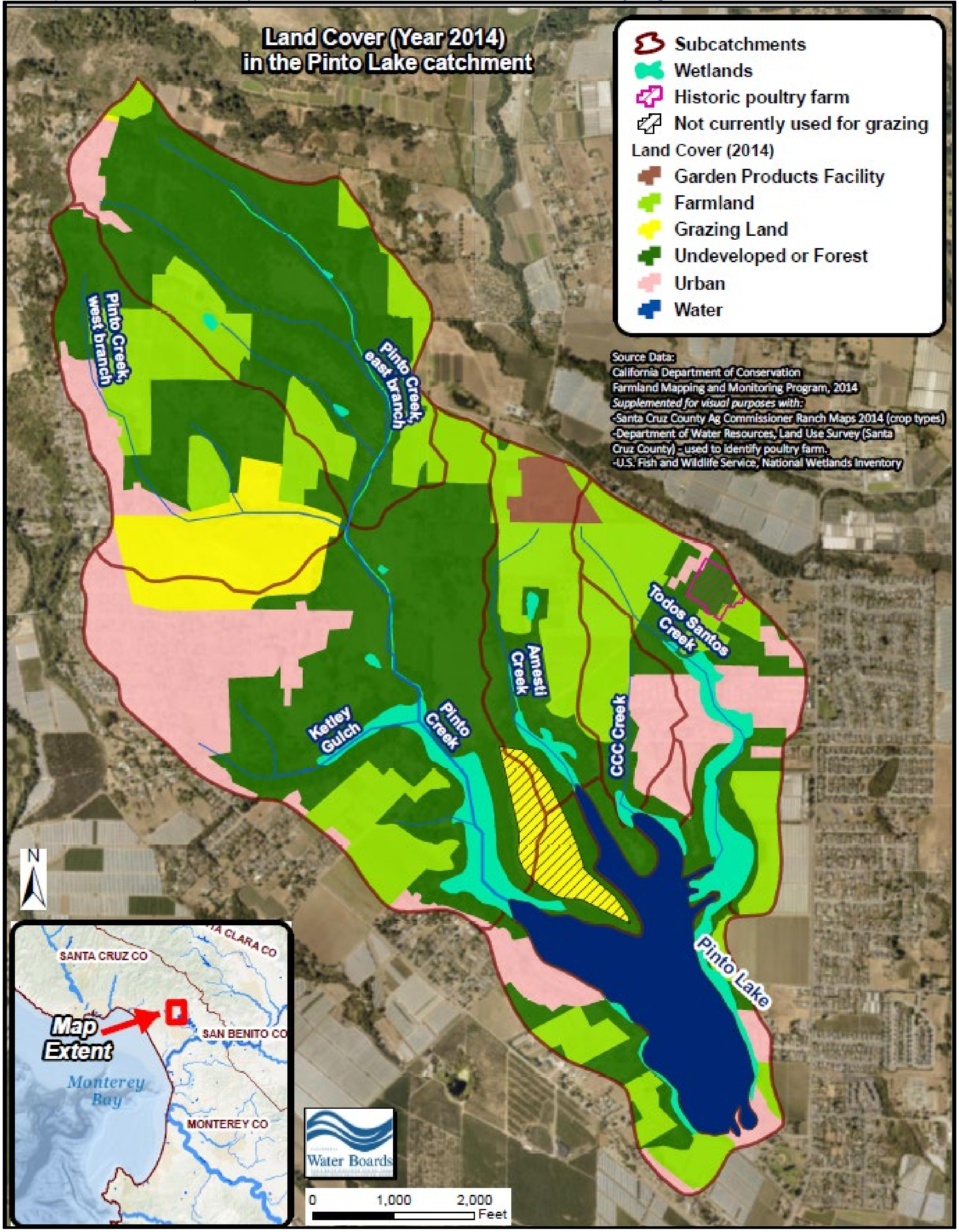
[A] *Land use-Land cover dataset: California Department of Conservation Farmland Mapping and Monitoring Program (2014)*

Figure 2-3 illustrates land use and land cover in the Pinto Lake catchment based on Farmland Mapping and Monitoring Program (FMMP) data. Farmland, urban/built-up areas, undeveloped lands, and woodlands are the primary land use/land cover categories in the lake catchment. There are about 80 acres of wetlands around the lake and around some tributary creeks.

Additionally, the catchment contains a composting facility and reportedly a poultry farm according to 1997 vintage crop map data from the Department of Water Resources. It is unclear if this poultry farm is still in operation; local resource professional we spoke to have not seen any poultry operations in the lake catchment in recent times.

Stakeholders have also reported in some areas of the lake catchment there are significant amounts of livestock (e.g. horse, cattle). These animals are reportedly concentrated in the rural residential areas of the northern Pinto Creek Mainstem subcatchment, and the southern Pinto Creek East Branch subcatchment (refer to Figure 2-3 from map reference). During field reconnaissance in April 2017, we observed a herd of ~20 grazing cattle off Pioneer Road in the Pinto Lake mainstem subcatchment.

Figure 2-3. Land use and land cover in the Pinto Lake catchment (FMMP - year 2014) annontated with crop information (2014) available from the Santa Cruz County Ag Commissioners office.



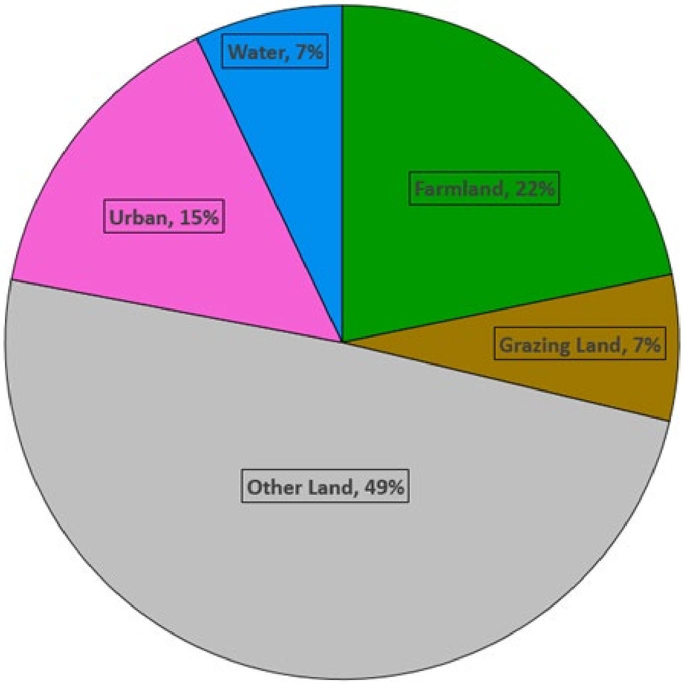
Source Data:
California Department of Conservation
Farmland Mapping and Monitoring Program, 2014
Supplemented for visual purposes with:
-Santa Cruz County Ag Commissioner Ranch Maps 2014 (crop types)
-Department of Water Resources, Land Use Survey (Santa Cruz County) - used to identify poultry farm.
-U.S. Fish and Wildlife Service, National Wetlands Inventory

Table 2-3 tabulates the distribution of land cover in the Pinto Lake catchment. Just under half of the catchment is comprised of woodlands and undeveloped areas. Farmlands comprise just under a quarter of the land use and urban lands make up about 15% of the catchment.

According to crop data from the Santa Cruz County Agricultural Commissioner, in 2014 the primary crops produced in Pinto Lake catchment included bush berries (e.g., strawberries, blackberries, raspberries, blueberries), nursery/greenhouse products (e.g., outdoor plants and flowers), and rotational crops. In 2014, there were also a few dozen acres in the catchment producing grape and orchard products (e.g., apples, lemon, wine grapes, etc.). Water Board records, accessed January 2017, indicate that 14 growers in the catchment are enrolled in the Irrigated Lands Agricultural Order.

Table 2-4 presents the distribution of land cover at a higher spatial resolution; the table tabulates land cover estimates for all the subcatchments nested within the Pinto Lake catchment.

Table 2-3. Tabulation of estimated land use and land cover in the Pinto Lake catchment (FMMP - year 2014).

Pinto catchment Land Cover (Year 2014)[A]	**U.S. Acres**	**Catchment Land Cover Pie Chart**
Urban and Built-Up Land	218.8	
Farmland	319.2	
Grazing Land	102.8	
Other Land (Woodland, Undeveloped, or Restricted) *In the Pinto Lake catchment this land use classification also includes a composting facility of about 15 acres, a 7 acre poultry farm (reported from legacy land use data and which may no longer be in operation), and about 80 acres of wetlands.*	722.2	
Open Water	104.2	
Total	1,467.1	

[A] Source: Calif. Dept. of Conservation, Farmland Mapping and Monitoring Program (2014)

Table 2-4. Estimated land cover (FMMP - year 2014)[A] tabulated by subcatchments (units = U.S. acres).

Subcatchment Name[A]	**Urban & Built Up**	**Grazing Lands**	**Other Land: Woodland, Undeveloped, or Restricted**	**Farmland**	**Open Water**	**Total**
Amesti Creek subcatchment	0	3.4	58.6	47.3	0	109
CCC Creek subcatchment	15.6	0	12.6	23.2	0	51
Lakeside areas *(includes Pinto Lake)*	34.0	14.8	59.7	33.5	104.2	246
Pinto Creek Mainstem subcatchment	97.7	26.4	245.0	46.4	0	415
Pinto Creek, East Branch subcatchment	10.8	0.3	204.4	59.5	0	275

Subcatchment Name[A]	Urban & Built Up	Grazing Lands	Other Land: Woodland, Undeveloped, or Restricted	Farmland	Open Water	Total
Pinto Creek, West Branch subcatchment	22.3	57.9	74.1	51.8	0	207
Todos Santos Creek subcatchment	38.3	0	67.8	56.7	0	163

[A] – Refer to Figure 2-11 on page 30 and Table 2-6 on page 30 to view subcatchment location and information.

Additional land cover classification is available from the National Land Cover Dataset (NLCD). Here we present NLCD maps and data for the Pinto Lake catchment for visualization and informational purposes[12]. NLCD provides higher resolution information on certain types of land cover, for example residential and urban land cover. Table 2-5 presents detailed descriptions of NLCD land classification categories

According to NLCD, residential and developed areas in the Pinto Lake catchment overwhelmingly are comprised of open space. Developed open space is defined as areas comprised mostly of lawn grasses and vegetation and less than 20 percent constructed materials and impervious surface. There are about 100 acres of low intensity developed areas in the catchment, and a few areas of medium intensity (35 acres) and high intensity (11 acres) developed areas in the catchment.

Table 2-5. Land use and land cover categories used in this TMDL report and as defined by the National Land Cover Dataset (2011).

Code, Land Cover	Description as defined by National Land Cover Dataset[A]
11 Open Water	All areas of open water, generally with less than 25% cover or vegetation or soil
21 Developed Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units,
22 Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
23 Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
24 Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.
42 Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
43 Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
52 Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted

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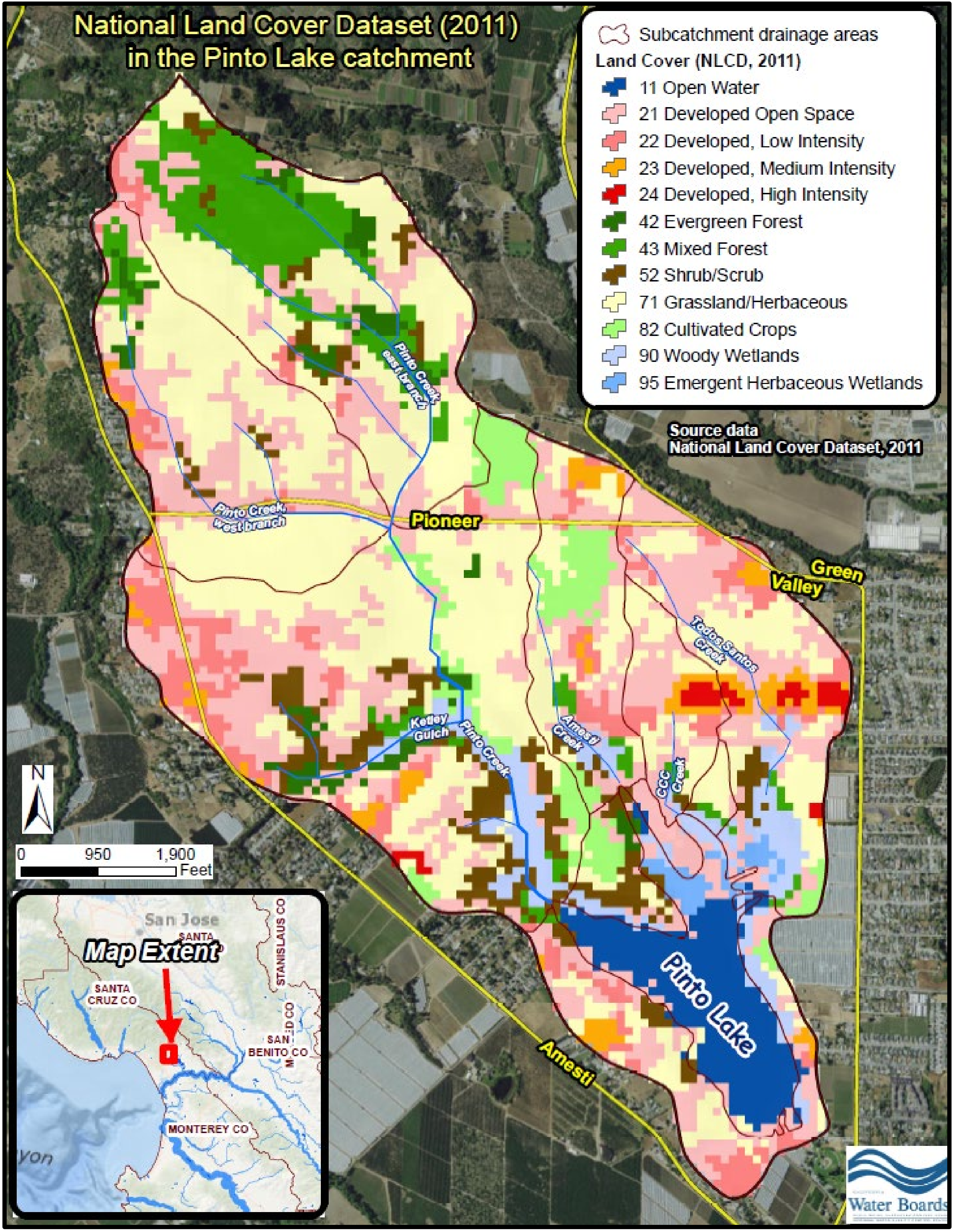
[12] The NLCD digital spatial data provide snapshots of conditions at the time the data was compiled. The land cover reported in this dataset should not be assumed to be identical to the Farmland Mapping and Monitoring program, as the two programs are of different vintage, have different goals, and use different metrics and methodologies to assess and report land cover. .

Code, Land Cover	Description as defined by National Land Cover Dataset [A]
	from environmental conditions.
71 Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
82 Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class al
90 Woody Wetlands	Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
95 Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

[A] *National Land Cover Dataset (2011)*

Figure 2-4. National Land Cover Dataset (NLCD, 2011) for the Pinto Lake catchment.



Land cover data compiled in this section plays a central role in assessment of sources of pollution to Pinto Lake. Source assessment is addressed in detail in Section **6**.

2.3 Hydrography

Hydrography is the physical description and measurement of surface waterbodies[13]. Assessing the hydrography of any given watershed or catchment is an important step in evaluating the magnitude and nature of pollutant transport and loading in waterbodies, thus it is relevant to conduct a review of hydrographic data for this report.

The Water Cycle

Before outlining the hydrography of the lake and creek tributaries, it is worth highlighting key information concerning the water cycle, also known as the "hydrologic cycle".

> *"Groundwater, surface waters…it's all connected!"* ➔ *Bindu Bhakta, Michigan State University Extension*

It is important to recognize that surface water, groundwater, and atmospheric water are all interconnected through the water cycle. Figure 2-5 illustrates how water falls on the landscape as precipitation, moves across the landscape as runoff, percolates into the subsurface as groundwater, and evaporates from surface waterbodies and from land back into the atmosphere in a continuous and constant cycle. Thus, the words "surface water", "groundwater", and "atmospheric water" are human constructs that simply describe where water is *at that moment in time*. From the water molecule's perspective, it is all one single resource – water.

Figure 2-5. The water cycle from a watershed perspective.

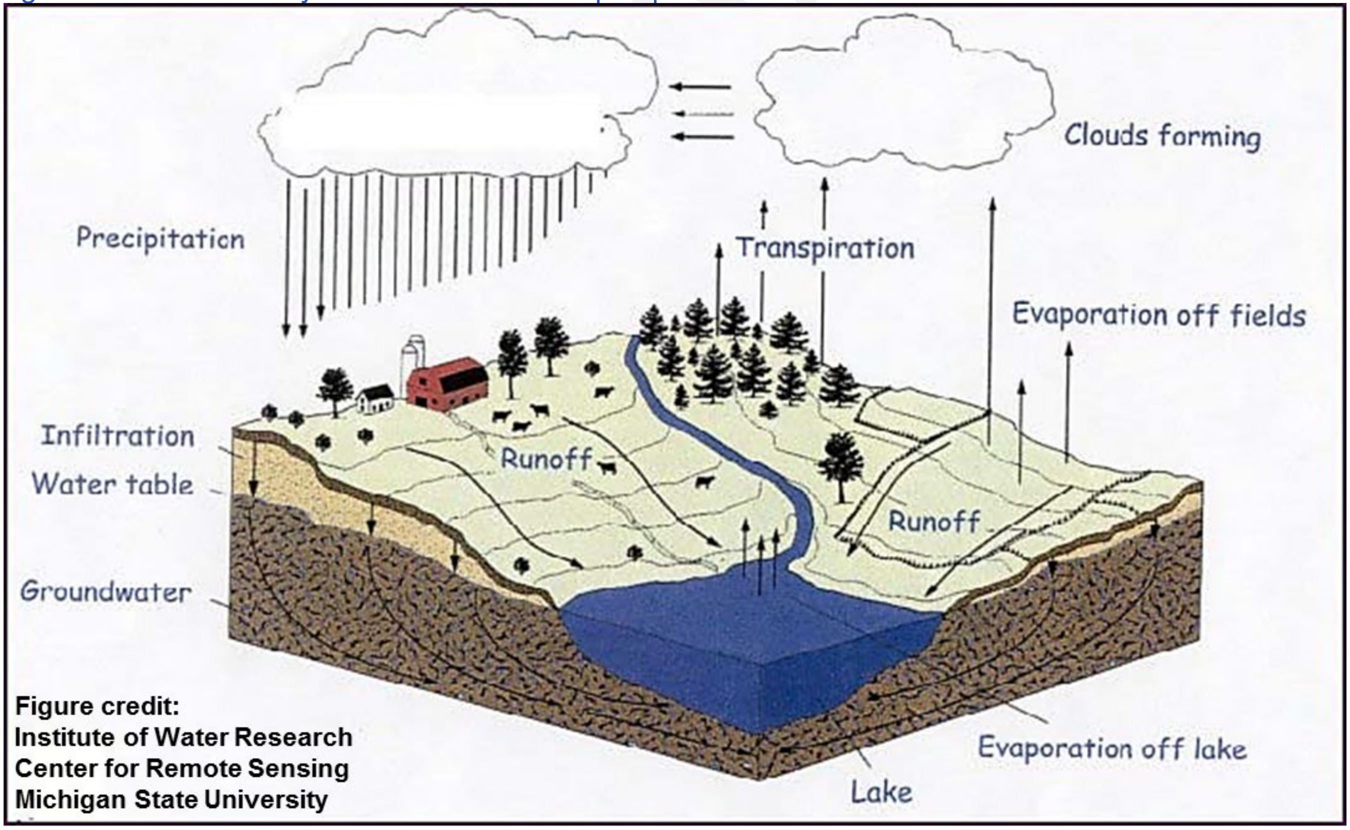


Figure credit:
Institute of Water Research
Center for Remote Sensing
Michigan State University

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[13] As defined by National Oceanic and Atmospheric Administration – webpage, accessed November 2016. Online linkage: http://oceanservice.noaa.gov/facts/hydrography.html

Lake Hydrography

Previous researchers have described the hydrography of Pinto Lake [Ketley et al. (2013), CSUMB and Resource Conservation District of Santa Cruz County (2013), and Stanfield (2013)], and we rely to a great extent on those sources here. Pinto Lake is a shallow, hypereutrophic lake with a surface area of just over 100 acres, located within the Lower Pajaro River watershed in Santa Cruz County. Lake hydrology (currents, waves, circulation) and lake chemistry are, to some extent, driven by temperature, stream flows, and seasonal conditions as illustrated in Figure 2-6 and Figure 2-7, and as detailed in additional detail below.

Many people may visualize a lake as a uniform mass of water that is evenly mixed from top to bottom and from side to side, as in a bathtub. In fact, in any given lake, seasonal differences in temperature and the mixing effects of wind can influence lake hydrology, lake chemistry, and lake water stratification. At Pinto Lake, tributary stream flows, air temperature, water temperature, heat transfer, and wind can seasonally affect lake hydrology, and nutrient concentrations at various lake depths, as further outlined below.

Winter and spring months bring in higher volume flows from the surrounding tributaries due to increased rainfall and runoff within the watershed. Data collected between 2009-2011 (Stanfield, 2013) show that lake surface water in winter months is typically cool with an average temperature of less than 14°C and the water column tends to be well-mixed.

In spring and summer months, increased air temperature and solar radiation raise surface water temperatures significantly, averaging around 22°C. During these months, deeper waters near the lake bottom remain much cooler, generally around 13°C. This difference in water temperatures during summer months creates a seasonal thermocline[14], causing the lake to be stratified into two distinct thermal layers (the upper, warmer epilimnion, and the lower, colder, hypolimnion) – refer to Figure 2-6(A) and Figure 2-7(A). This stratification reduces the amount of mixing of the deeper nutrient-rich waters below the thermocline.

Eventually the seasonal thermocline disappears as the lake warms up in the autumn, which leads again to the mixing of the two layers. This mixing results in additional nutrients being distributed throughout the entire water column [Ketley et al. (2013), CSUMB and Resource Conservation District of Santa Cruz County (2013)] – refer to Figure 2-6(B) and Figure 2-7(B).

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[14] A thermocline is a transition layer between warmer water at a lake surface, and the cooler deep water below.

Figure 2-6. Conceptual illustration of Pinto Lake hydrography: (A) lake waters are stratified by thermal and density contasts in the spring and summer; and (B) lake waters are mixed in the autumn and winter due to homogenization of water temperatures and water density.

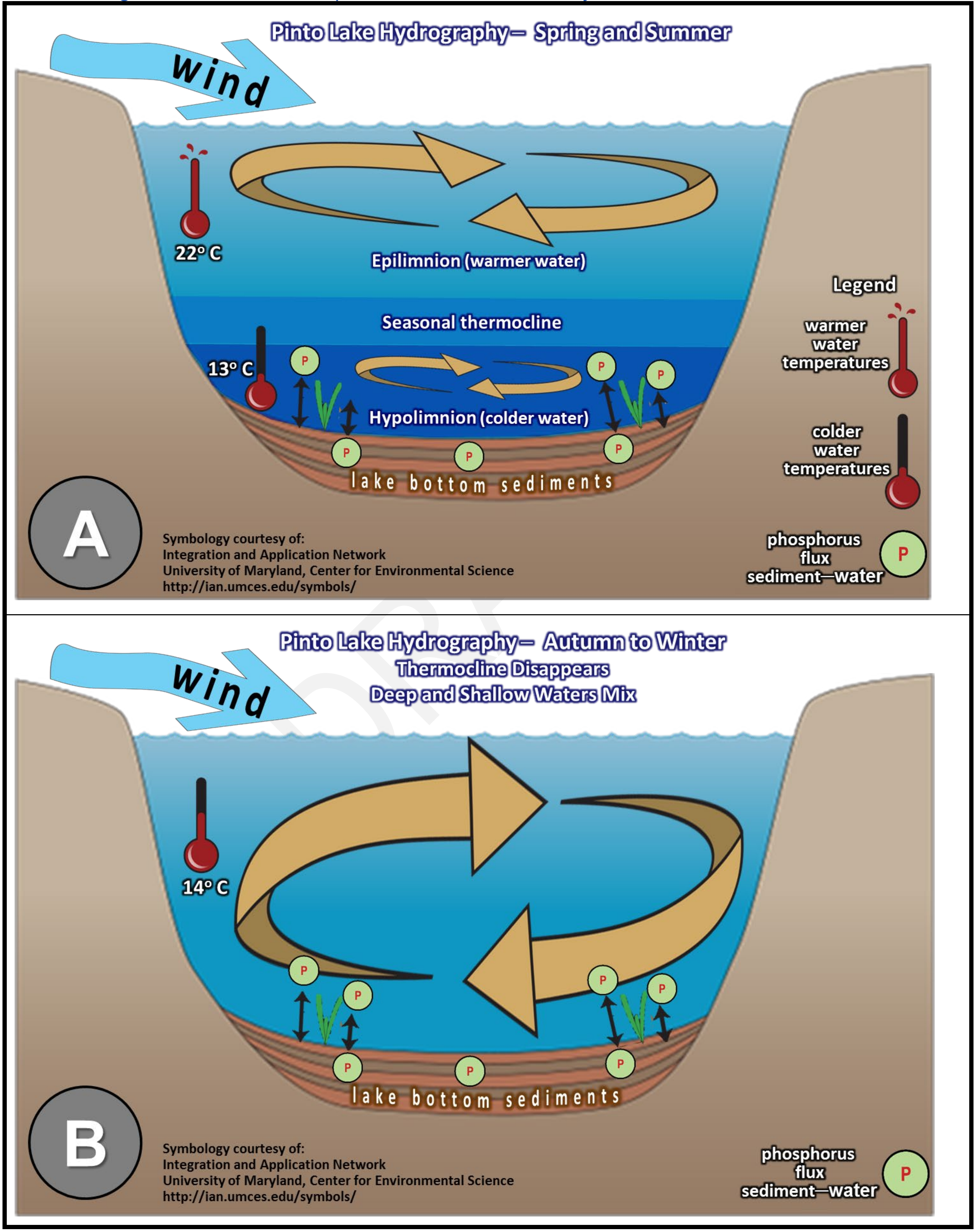
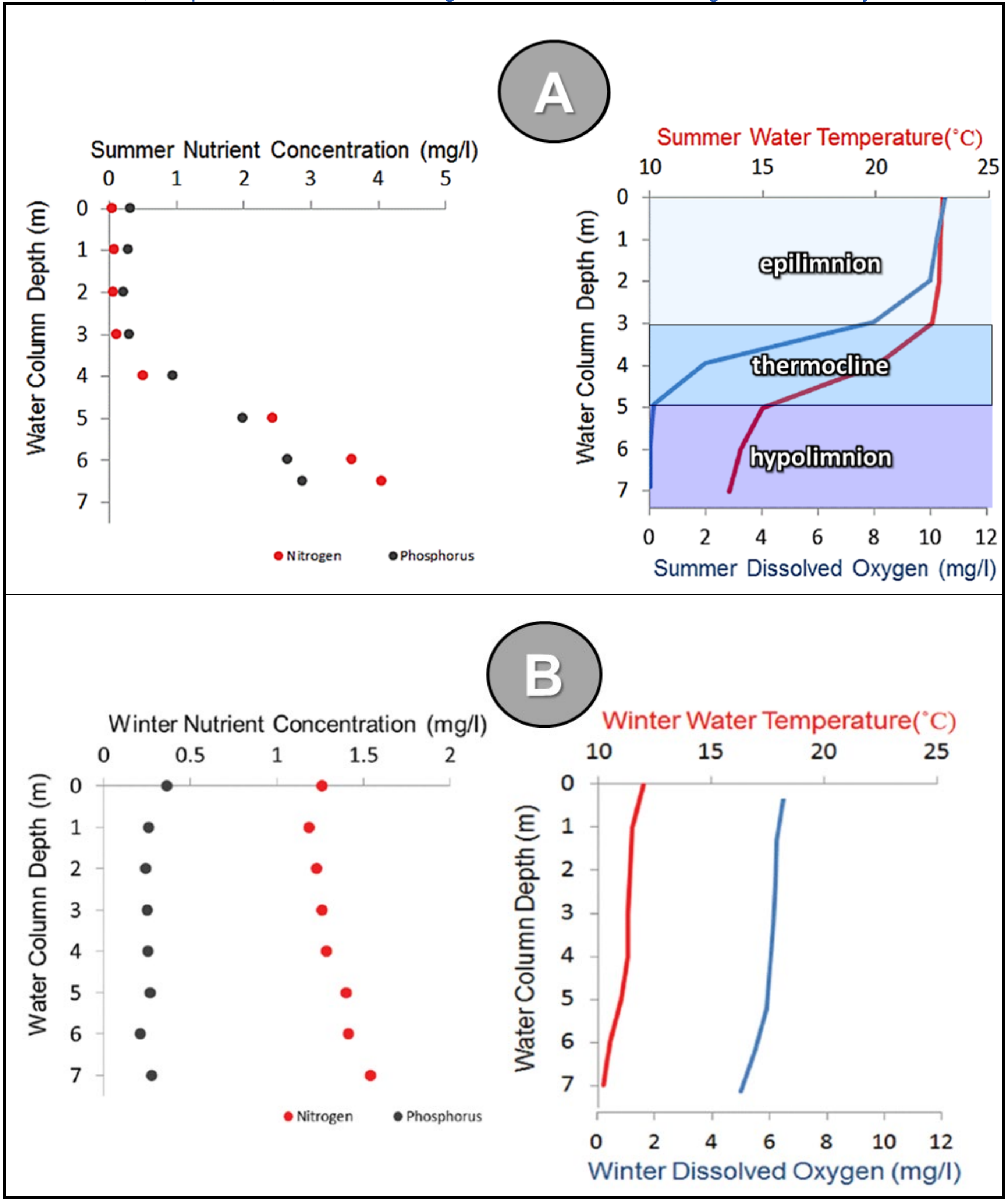


Figure 2-7. Figure from CSUMB and Resource Conservation District of Santa Cruz County, 2013. (A) Summer nutrient concentrations, temperature, and dissolved oxgen illustrating thermal stratification of lake waters and nutrient-enrichment of deep waters (hypolimnion); and (B) Winter nutrient concentrations, temperature, and dissolved oxgen in Pinto Lake, illustrating a well mixed system.



Another relevant aspect of local hydrography is lake water–groundwater interactions. Almost all lakes interact with groundwater (U.S. Geological Survey, 1998). Groundwater data in the vicinity of Pinto Lake suggest a long-term trend of a southeast to south shallow groundwater flow trend. These observations suggest that shallow groundwater flows towards – and potentially into – Pinto Lake generally from the north and northwest. At the south end of Pinto Lake, groundwater appears to be flowing away from the lake towards the southeast (i.e., towards the central axis of the Pajaro Valley groundwater basin). We provide additional information on lake water–groundwater interaction in report Section 2.10.

With regard to regional surface water drainage, Pinto Lake waters can seasonally or episodically drain via a ditch and tributary creeks to the Pajaro River and then ultimately to Monterey Bay (see Figure 2-8). More explicitly, lake waters drain through a grated pipe at the south end of the lake within city park property. Drainage occurs only when lake levels are high enough to spill into the pipe. This pipe conveys lake water underground traversing about 1,000 feet beneath a parking lot south of the lake, underneath Green Valley Road, and then discharges to a ditch on the south side of Green Valley Road (see Figure 2-9). This ditch is informally called “Little Pinto Creek” by City of Watsonville staff. Water in Little Pinto Creek can flow downstream to Salsipuedes Creek, from there to the Pajaro River, and ultimately may periodically flow into the Pajaro River estuary and coastal waters of Monterey Bay.

Figure 2-8. Pinto Lake regional surface drainage. Lake waters periodically drain via ditch (“Little Pinto Creek”) and tributary streams to the Pajaro River and Monterey Bay.

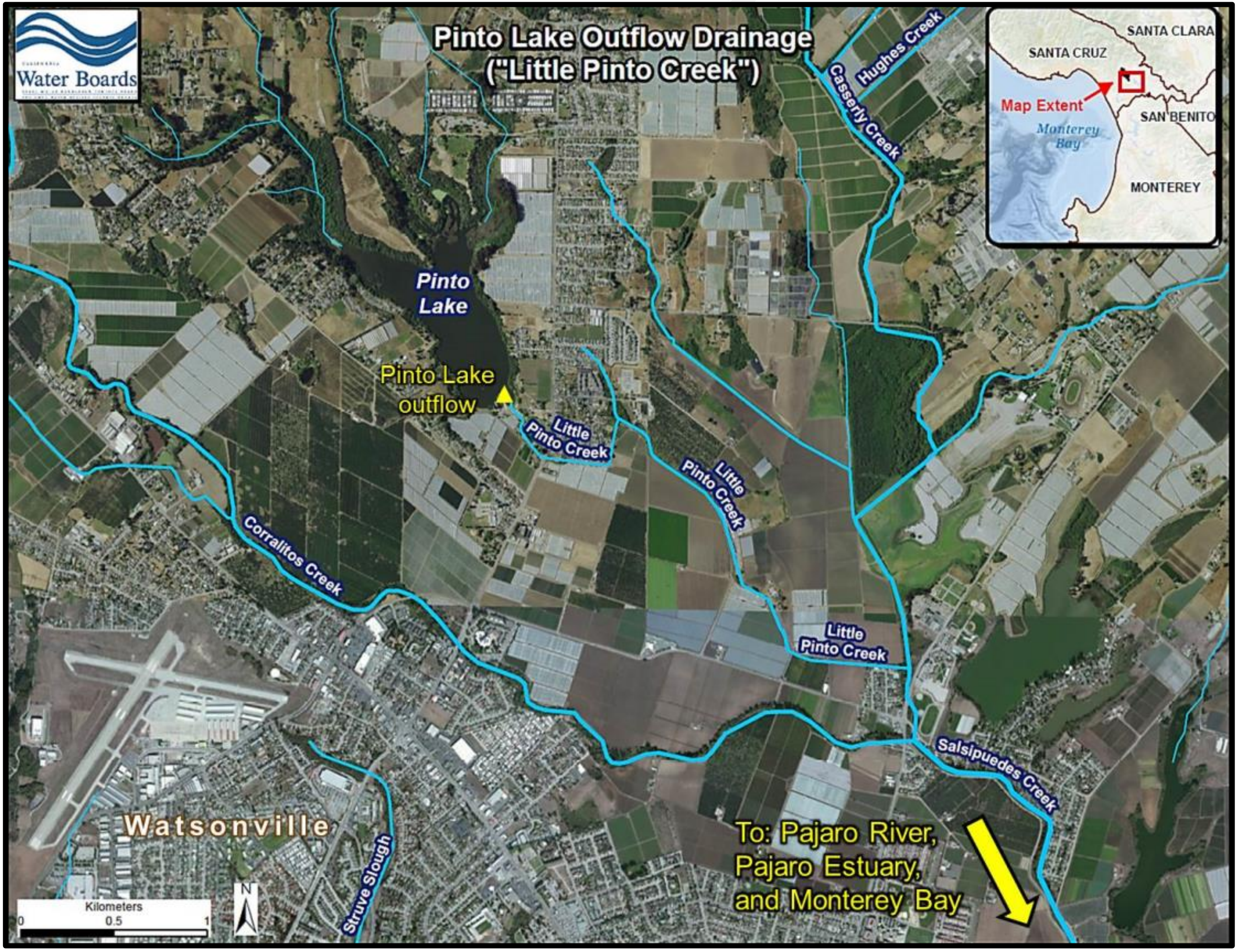
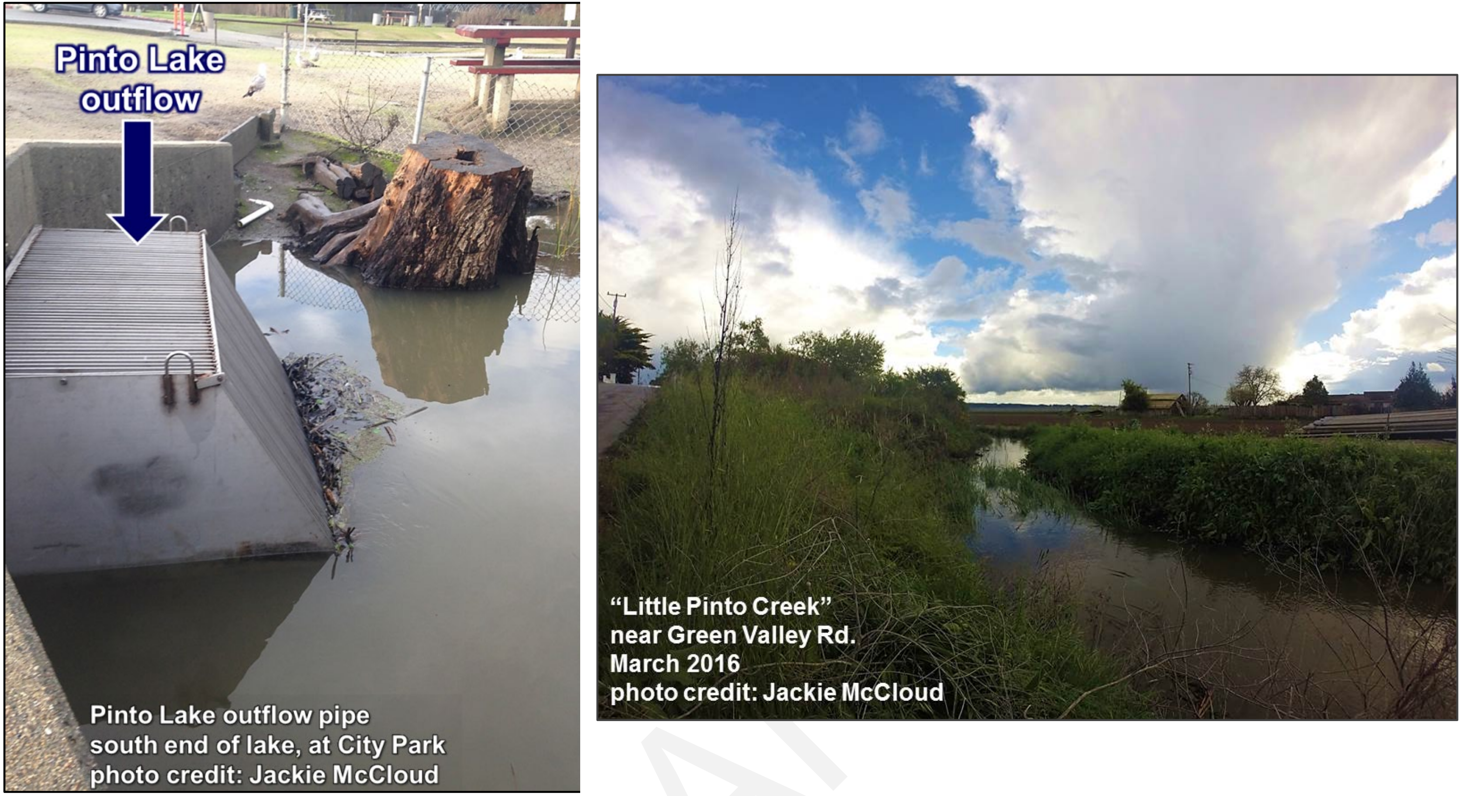


Figure 2-9, Pinto Lake surface water conveyance features for lake water drainage. An aerial map view of these conveyance features was shown previously in Figure 2-8.



Hydrography of Creek Tributaries

The entire drainage area of the Pinto Lake catchment encompasses over 1,400 acres with a network of creeks draining to Pinto Lake. Figure 2-10 presents a generalized illustration of the hydrography of the Pinto Lake catchment. We used the ArcMap™ 10.1 spatial analyst hydrology tool extension to delineate the stream network shown in Figure 2-10.

The main lake tributary is Pinto Creek, a third order stream based on the [Strahler stream classification convention]. Pinto Creek drains the northern and western areas of the Pinto Lake catchment. A number of other informally named creeks[15] drain parts of the central and eastern margins of the lake catchment.

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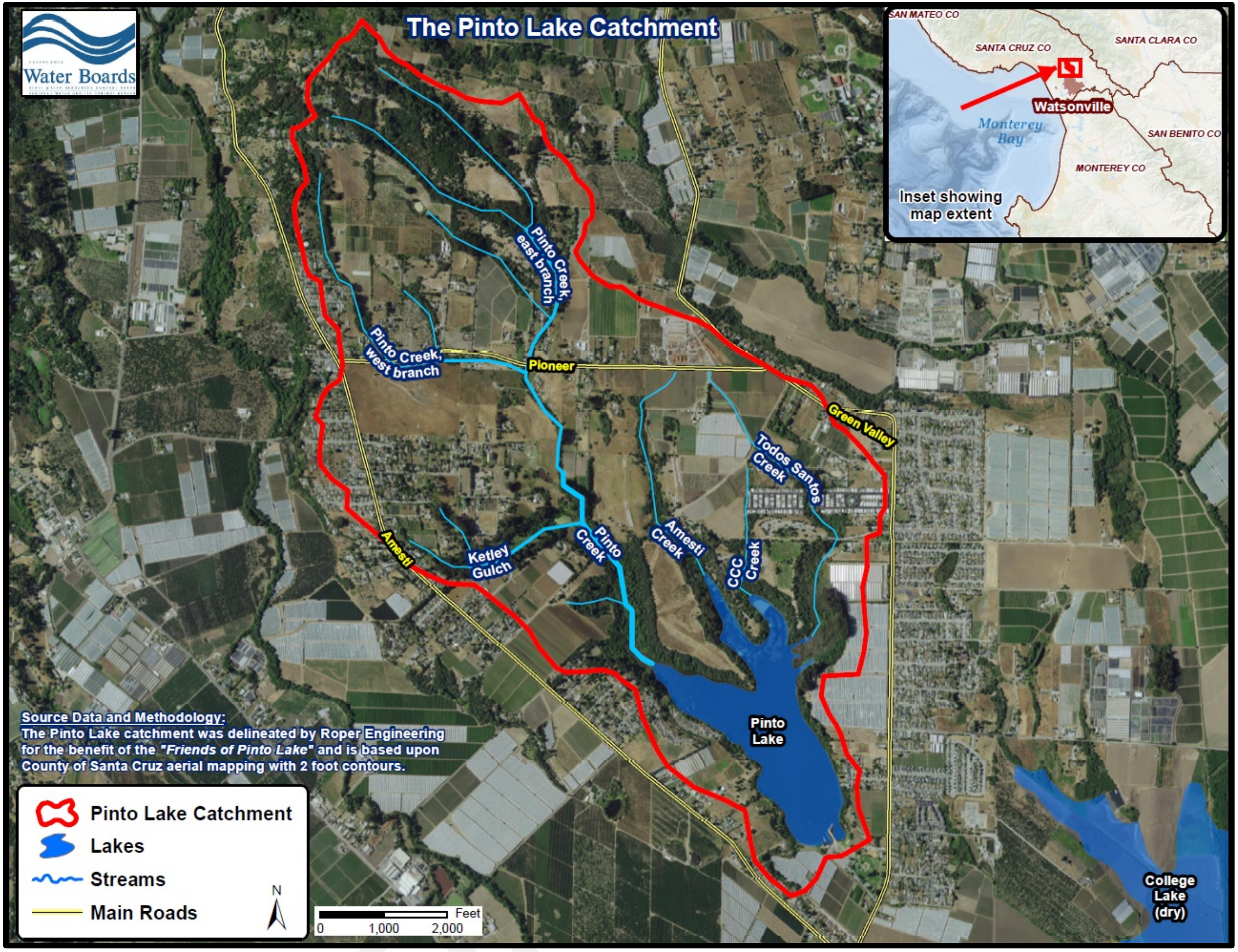
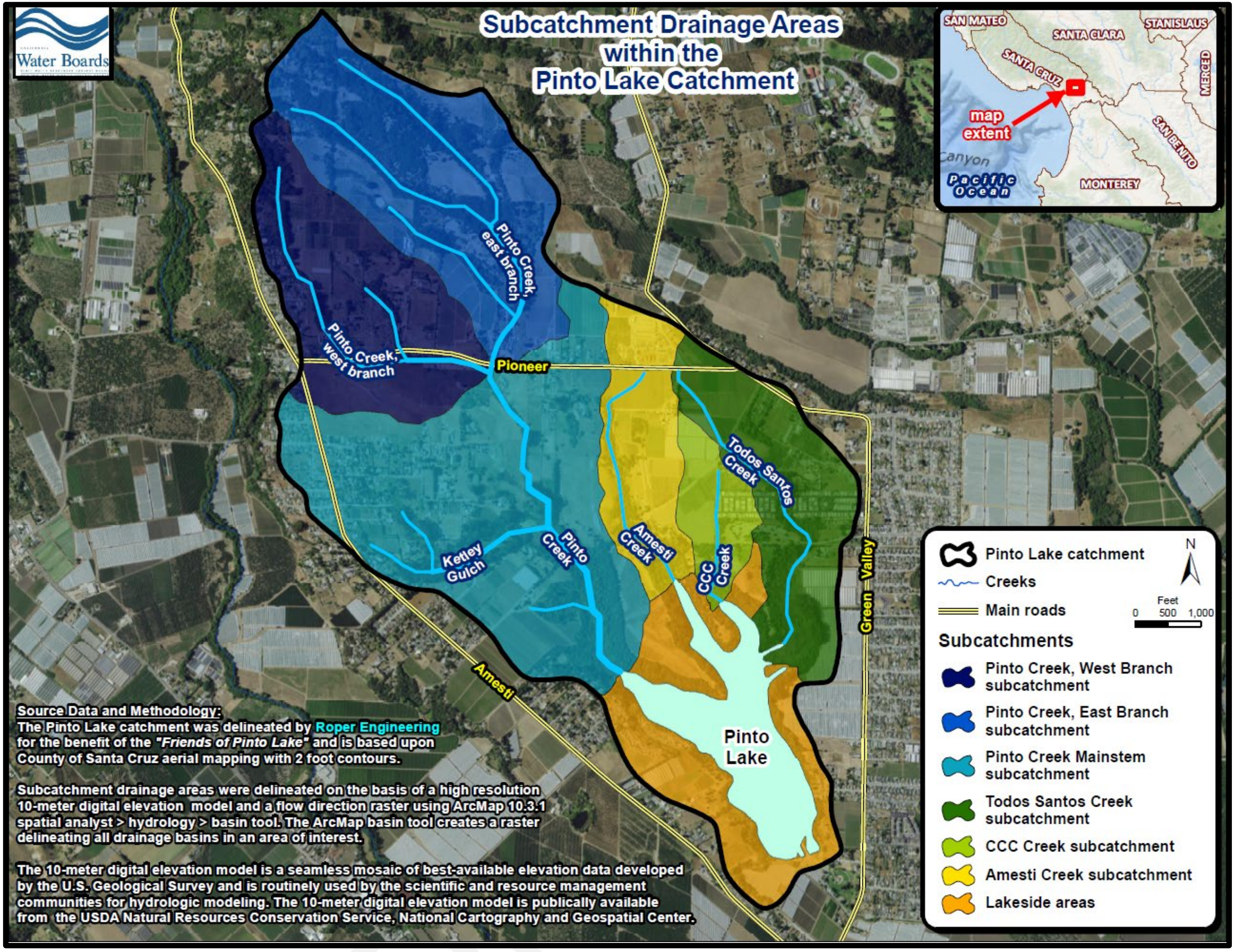
[15] The informal tributary creek names are used by local researchers and stakeholders working in the lake catchment and were provided to Central Coast Water Board staff by City of Watsonville staff.

Figure 2-10. Generalized hydrography of Pinto Lake catchment.



The tributary creeks each drain specific areas of land within the Pinto Lake catchment. Figure 2-11 illustrates these subcatchment–scale drainage areas. A *Lakeside Area* is also shown, indicating areas that drain directly to the lake – i.e., areas that do not drain to one of the identified tributary creeks. Table 2-6 presents a tabulation of the individual subcatchment drainage area sizes.

Figure 2-11. Subcatchment–scale drainage areas within the Pinto Lake catchment.



Source Data and Methodology:
The Pinto Lake catchment was delineated by Roper Engineering for the benefit of the *"Friends of Pinto Lake"* and is based upon County of Santa Cruz aerial mapping with 2 foot contours.

Subcatchment drainage areas were delineated on the basis of a high resolution 10-meter digital elevation model and a flow direction raster using ArcMap 10.3.1 spatial analyst > hydrology > basin tool. The ArcMap basin tool creates a raster delineating all drainage basins in an area of interest.

The 10-meter digital elevation model is a seamless mosaic of best-available elevation data developed by the U.S. Geological Survey and is routinely used by the scientific and resource management communities for hydrologic modeling. The 10-meter digital elevation model is publically available from the USDA Natural Resources Conservation Service, National Cartography and Geospatial Center.

Table 2-6. Tabulation of subcatchment drainage areas sizes.

Subcatchment	Drainage Area^{A} (acres)	Drainage Area^{A} (square miles)
Pinto Creek, mainstem subcatchment	415	0.65
Pinto Creek, east branch subcatchment	275	0.43
Pinto Creek, west branch subcatchment	207	0.32
Amesti Creek subcatchment	109	0.17
CCC Creek subcatchment	51	0.08
Todos Santos Creek subcatchment	163	0.25
Lakeside Areas	142	0.22

[A] Methodology: 30-meter digital elevation model and a flow direction raster used in conjunction with the Esri® ArcMap 10.3.1™ spatial analyst tool.

In years past, local resource professionals reportedly assumed that Pinto Creek was the most significant tributary to Pinto Lake, and that significant flows from other lake tributaries were largely absent (Ketley, et al., 2013). Recent field observations and sampling have revealed significant flows from other tributaries during periods of precipitation (Ketley, et al., 2013) – see Figure 2-12. Stakeholders reported that a better understanding of flow and pollutant loading from the various tributary subcatchments would be beneficial (also from Ketley, et al., 2013). Flow information can be important in any given watershed study, and can be useful in estimating pollutant transport, load, and fate.

Figure 2-12. Pinto Lake creek tributaries: (A) Amesti Creek during rainfall-runoff event; and (B) CCC Creek during rainfall runoff event. (Photos courtesy of Jackie McCloud, City of Watsonville).

Our review of local hydrography includes estimates of subcatchment runoff and tributary creek flows. Accordingly, Table 2-7 presents an outline of known or estimated hydrologic conditions associated with the tributary creeks of Pinto Lake. At the time of this report, measured flow data for the tributary creeks were not available. We thus estimated mean annual runoff and flow[16] in Table 2-7 based on a State Water Resources Control Board-recognized Rainfall-Runoff method[17]. This method involves some assumptions about runoff and land cover characteristics, and thus our runoff/flow estimates are only approximations, subject to significant uncertainty.

Table 2-7. Hydrologic conditions of tributary creeks of Pinto Lake. Due to uncertainties, flow estimates are shown to two significant figures.

Stream Reach	**Strahler Stream Order**	**Estimated mean annual rainfall[a]**	**Drainage area (acres) [b]**	**Estimated runoff coefficient[c]**	**Estimated average annual runoff[d] (acre-ft./year)**	**Estimated mean annual flow[d] (cubic ft./sec.)**	**Flow Regime[e]**
Pinto Creek	3rd order	2.09 ft. (25.1 inches)	897	0.45	840	1.2	Intermittent (source: NHDplus)

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[16] Mean annual flow means the average flow of a stream (measured in cubic feet per second), from measurements or estimates, over the course of a year.

[17] See: State Water Resources Control Board Methods to Estimate Streamflow and Water Availability, May 1, 2002. Rainfall runoff methods use rainfall data and land cover characteristics to calculate runoff for a particular watershed or catchment.

Stream Reach	Strahler Stream Order	Estimated mean annual rainfall[a]	Drainage area (acres) [b]	Estimated runoff coefficient[c]	Estimated average annual runoff[d] (acre-ft./year)	Estimated mean annual flow[d] (cubic ft./sec.)	Flow Regime[e]
Pinto Creek, east branch	2nd order	2.2 ft. (26.4 inches)	275	0.45	270	0.4	Presumed ephemeral to intermittent (source: Ketley, et al., 2013)
Pinto Creek, west branch	1st order	2.2 ft. (26.4 inches)	207	0.45	200	0.3	Presumed ephemeral to intermittent (source: Ketley, et al., 2013)
Amesti Creek	1st order	2.09 ft. (25.1 inches)	109	0.45	100	0.1	Presumed ephemeral to intermittent (source: Ketley, et al., 2013)
CCC Creek	1st order	2.09 ft. (25.1 inches)	51	0.45	50	0.1	Presumed ephemeral to intermittent (source: Ketley, et al., 2013)
Todos Santos Creek	1st order	2.09 ft. (25.1 inches)	163	0.45	150	0.2	Presumed ephemeral to intermittent (source: Ketley, et al., 2013)

[a] See rainfall estimates from Table 2-15 on page 55.

[b] See drainage area estimates from Table 2-15 on page 55. The "Pinto Creek" drainage area includes drainage areas from the upstream tributary branches: east branch Pinto Creek and west branch Pinto Creek.

[c] Estimated from runoff coefficients in the Caltrans Highway Design Manual (1995), as reported by the State Water Board.

[d] Estimated by the State Water Board-recognized Rainfall-Runoff Method, expressed as Q = cIA, where Q is estimated average runoff (acre-feet per year), c is the estimated runoff coefficient, I is the average annual precipitation (feet), and A is the drainage area (acres).

[e] An **intermittent stream** has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow. An **ephemeral stream** has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

2.4 Wetlands

Wetlands are an important feature of the landscape. Wetlands can function like natural sponges, absorbing excess nutrients, sediment, and other pollutants before they reach rivers, lakes, and other waterbodies[18]. It can thus be relevant to characterize the nature and extent of wetlands in any given watershed study.

Also worth noting, in the southern Pinto Lake catchment and particularly in areas proximal to the lake, wetlands constitute a significant portion of the observed land cover (see Figure 2-13), and therefore land cover analysis should take into account the nature and extent of local wetlands. Geospatial data for the

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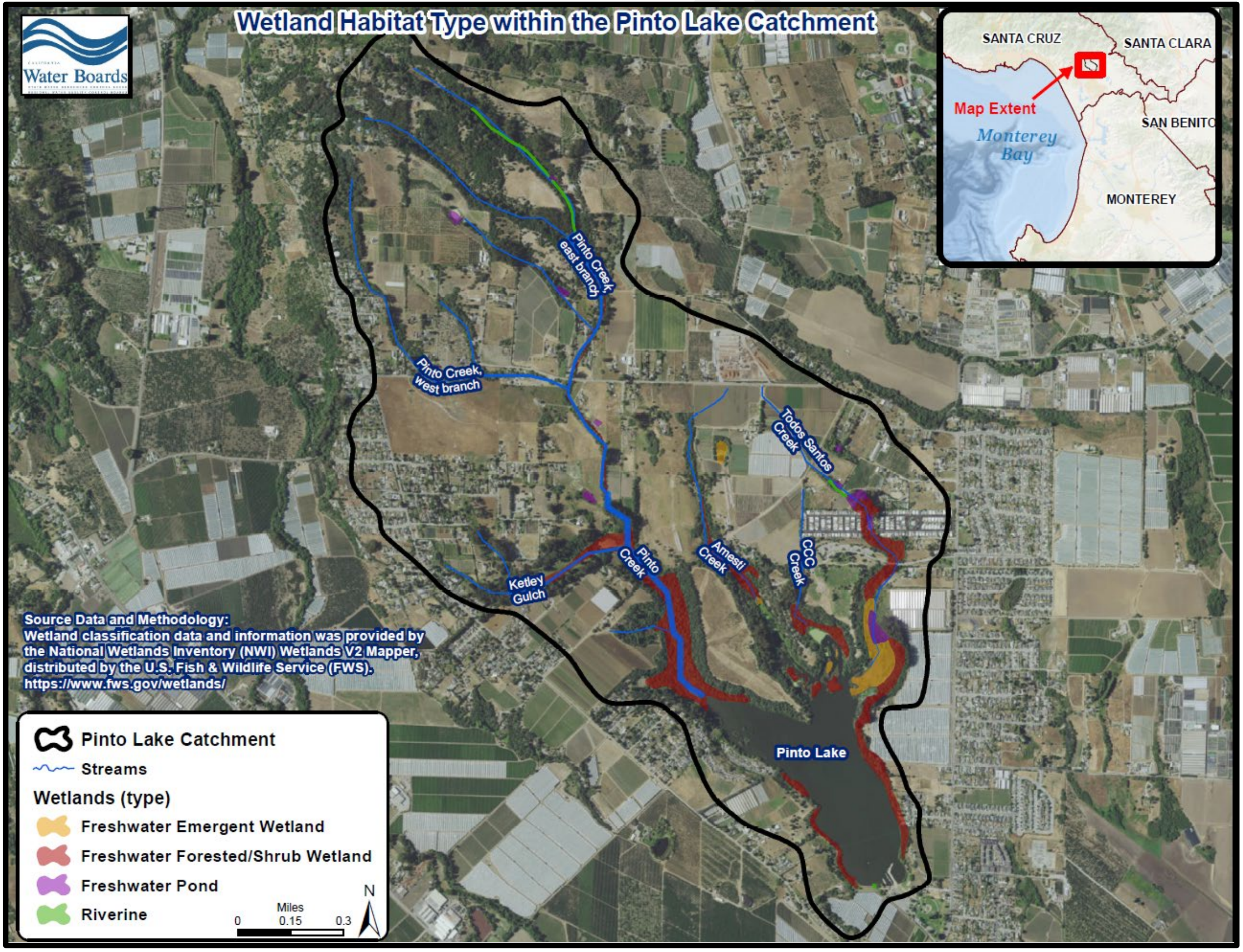
[18] U.S. Environmental Protection Agency, 2004. Wetlands Overview factsheet.EPA 843-F-04-011a.

location, areal extent, and type of wetlands are available from the U.S. Fish and Wildlife Service's National Wetland Inventory dataset[19].

According to the U.S. Environmental Protection Agency, wetlands are among the most productive ecosystems in the world and can provide numerous benefits such as protecting and improving water quality, storing floodwaters, and maintaining surface water flows during dry periods[20]. Plant roots and microorganisms in a wetland may absorb nutrients that are dissolved in water and originating from fertilizer applications, septic systems, manure, and wastewater. Other pollutants bind to soil particles in the wetland. Frequently, this filtration process may remove much of the water's nutrient and pollutant load before the water flows out of the wetland[21].

Consequently, it is important to recognize that healthy, functioning wetlands in the Pinto Lake catchment may provide important environmental benefits, including but not limited to water quality protection. Indeed, a local resource professional informed us that the extensive wetlands around lower Pinto Creek likely act to filter pollutants, therefore reducing sediment and nutrient loads to the lake from Pinto Creek (oral communication, October 4, 2016, Jackie McCloud, City of Watsonville, Environmental Projects Manager).

Figure 2-13. Wetland habitat types in the Pinto Lake catchment.



Wetland Habitat Type within the Pinto Lake Catchment

Source Data and Methodology:
Wetland classification data and information was provided by the National Wetlands Inventory (NWI) Wetlands V2 Mapper, distributed by the U.S. Fish & Wildlife Service (FWS).
https://www.fws.gov/wetlands/

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[19] National Wetlands Inventory, online linkage: https://www.fws.gov/wetlands/nwi/index.html.

[20] U.S. Environmental Protection Agency wetlands webpage, https://www.epa.gov/wetlands/why-are-wetlands-important accessed November 2016.

[21] U.S. Environmental Protection Agency, 2002. Functions and Values of Wetlands factsheet.EPA 843-F-01-002c.

Table 2-8 tabulates the extent and nature of various types of wetlands in the Pinto Lake catchment.

Table 2-8. Wetland type and acerage in the Pinto Lake catchment including summaries of classification descriptions from the National Wetlands Inventory provided by the U.S. Fish & Wildlife Service.

Wetland type[A]	**Total area (acres)**	**Description**[B]
Freshwater emergent wetland	9.3	In this wetland class, emergent plants—i.e., erect, rooted, herbaceous hydrophytes, excluding mosses and lichens—are the tallest life form with at least 30% areal coverage. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.
Freshwater forested/shrub wetland	64.2	In Forested wetlands, trees are the dominant life form—i.e., the tallest life form with at least 30 percent areal coverage. Trees are defined as woody plants at least 6 m (20 ft) in height.
Freshwater pond	5.9	A Palustrine System wetland. This category was developed to group the vegetated wetlands traditionally called by such names as marsh, swamp, bog, fen, and prairie, which are found throughout the U.S. It also includes the small, shallow, permanent or intermittent water bodies often called ponds.
Riverine wetland	1.4	The Riverine System includes all wetlands contained within a channel. A channel is an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water.

[A] Source: U.S. Fish and Wildlife Service, National Wetlands Inventory available at: https://www.fws.gov/wetlands/Data/Wetland-Codes.html. The National Wetlands Inventory dataset represent the extent, approximate location, and type of wetlands in the United States and its Territories. Metadata available at: https://www.fws.gov/wetlands/data/metadata/FWS_Wetlands.xml.

[B] Source: Classification of Wetlands and Deepwater Habitats of the United States, Federal Geographic Data Committee, August 2013, FGDC-STD-004-2013.

There are about 80 acres of wetlands in the catchment, with the vast majority of wetlands occurring proximal to the lake in the southern portions of the catchment. The most common type of wetland in the catchment are forested-shrub wetlands (aka, “woody wetlands”), comprising about 80% of all wetland land cover in the catchment. Woody wetlands are a nontidal wetland dominated by trees, shrubs, and other woody type vegetation. The water regime for the woody wetlands around Pinto Lake area is generally characterized by temporary and seasonal flooding, with only a small portion having semipermanent flooded conditions with access to surface waters during the growing season (in most years).

Freshwater emergent wetlands are the next most common wetland in the Pinto Lake catchment (accounting for approximately 11% of total wetland areas). These wetlands are characterized by herbaceous vegetation, typically perennials, which are persistent through most of the growing season. Freshwater emergent wetlands are seasonally flooded especially during the early parts of the growing season. However, it should be noted that according to the National Wetlands Inventory dataset, a portion of the emergent wetlands surrounding Pinto Lake have been hydrologically altered and are affected by “ditching” (hydrologic modification by ditches).

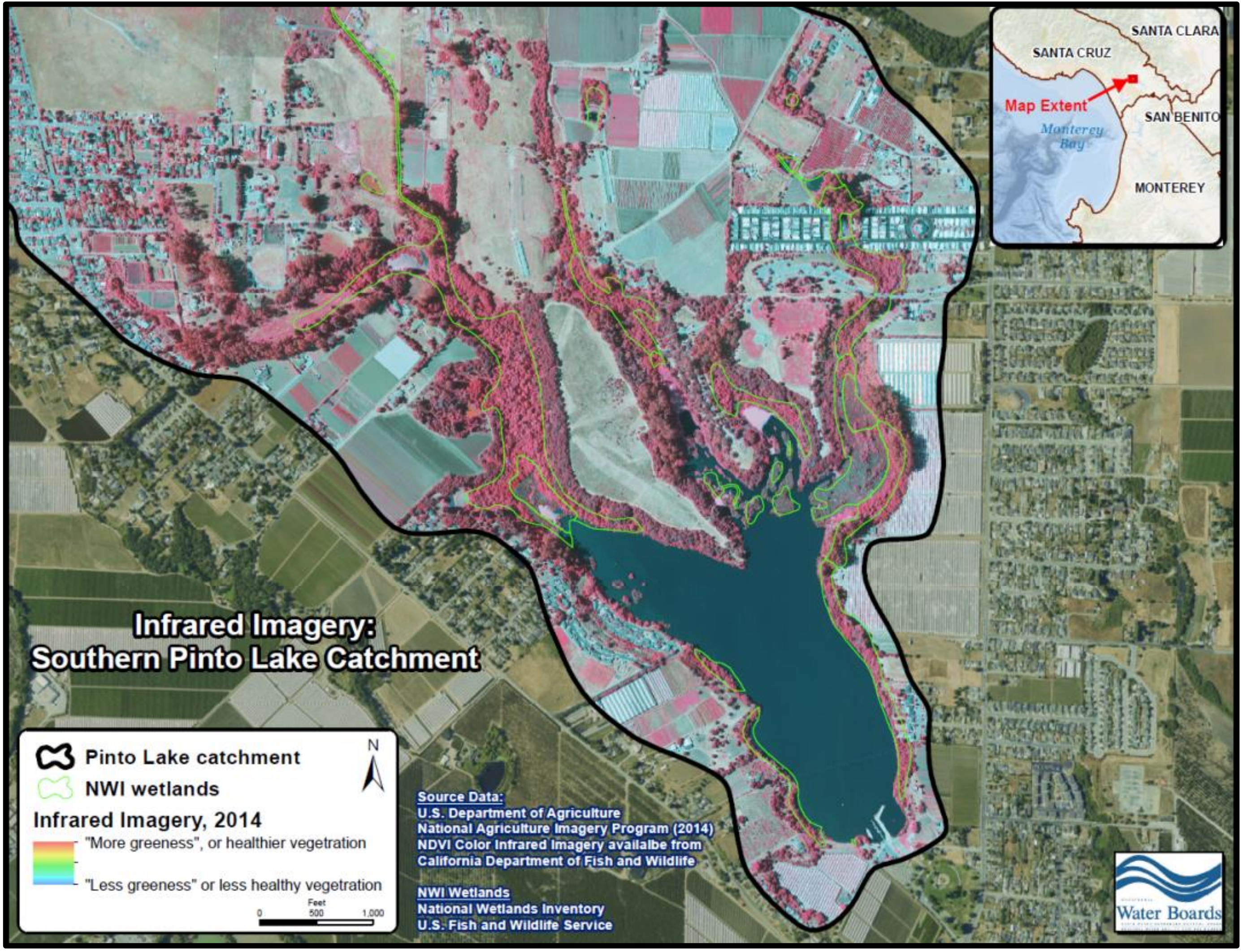
Freshwater ponds and riverine wetlands are the least common types of wetlands in the Pinto Lake catchment accounting for only a few acres of the catchment (refer back to Table 2-8).

Other methods are available to staff to assess the spatial distribution of wetlands and other types of vegetative cover. One such methodology is infrared spectral analysis. Infrared imagery is available from the National Agricultural Imagery Program, a program that collects and processes infrared aerial photography. Infrared analysis in aerial imagery is based on the fact that most objects exhibit a negligible infrared reflectance, but actively growing plants exhibit a high infrared reflectance and stressed plants (either from disease or drought) exhibits a reduction in their infrared reflectance. Thus, infrared imagery can highlight areas of denser, healthy green vegetation. This vegetation can include riparian vegetation, wetlands (areas of shallow groundwater), as well as areas of healthy irrigated cropland and lawns.

Figure 2-14 illustrates variations in vegetative density, and “greenness” in the southern part of the Pinto Lake catchment. The infrared imagery clearly highlights that the northside of Pinto Lake is characterized by substantial amounts of wetlands, indicating dense, green vegetative ground cover as well as the presence of shallow groundwater.

A related observation is that the infrared analyses highlight that substantial areas of shallow groundwater occur at the north end of Pinto Lake, indicative of a north-to-south shallow groundwater flow regime (refer to report Section 2.10 for more detailed information and assessment of shallow groundwater flow).

Figure 2-14. Infrared spectral image (year 2014) of the southern Pinto Lake catchment, illustrating variations in vegetative density.



Source Data:
U.S. Department of Agriculture
National Agriculture Imagery Program (2014)
NDVI Color Infrared Imagery availalbe from
California Department of Fish and Wildlife

NWI Wetlands
National Wetlands Inventory
U.S. Fish and Wildlife Service

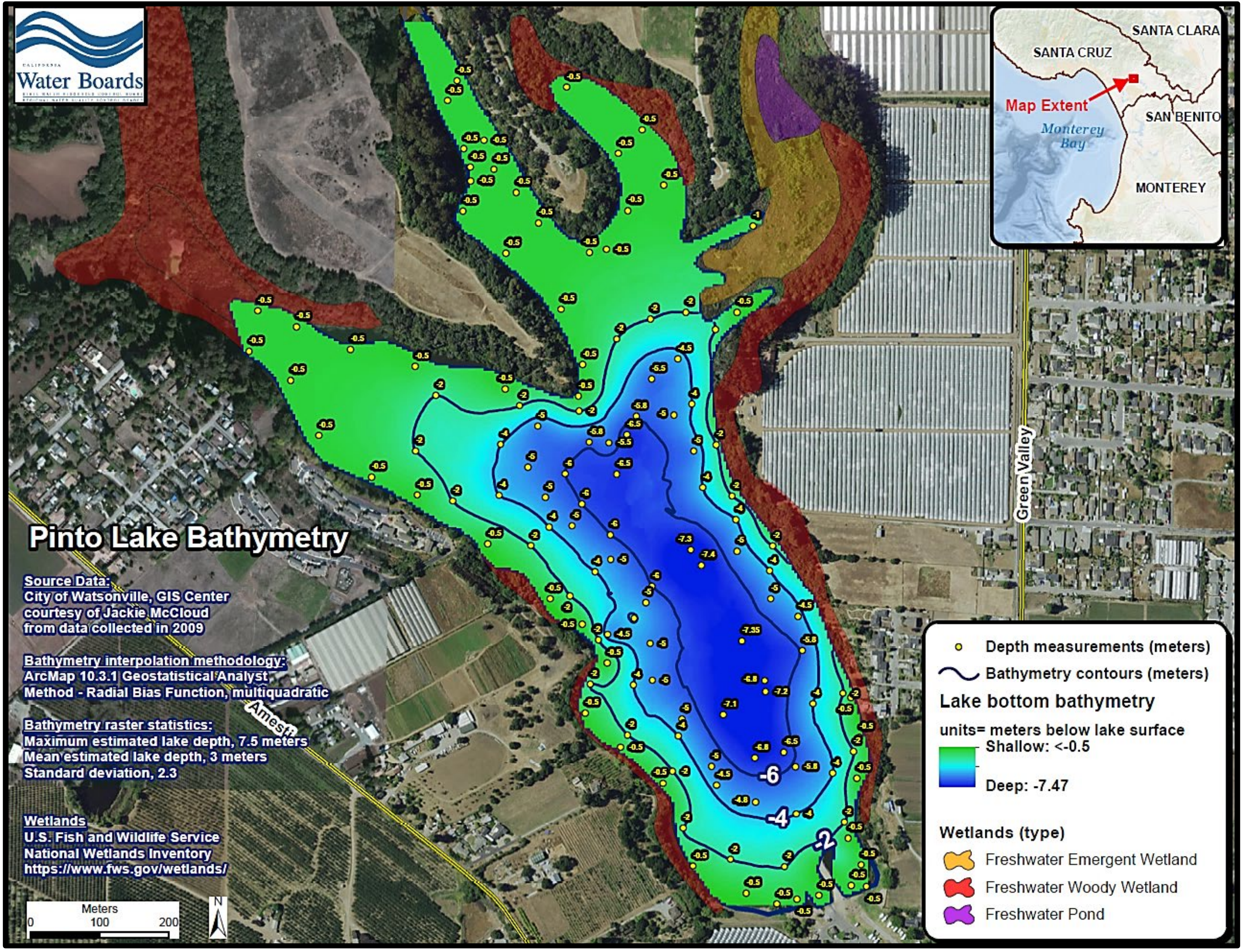
2.5 Lake Bathymetry & Morphology

Lake bathymetry is relevant to assess in this TMDL report because lake morphology attributes, such as lake depth, lake volume, and surface area are necessary user input values for the California BATHTUB Lake Model Tool. Bathymetry refers to the depth and shapes of underwater terrain. In the same way that topographic maps represent the three-dimensional relief of land features, bathymetric maps illustrate land that lies underwater.

Figure 2-15 and Figure 2-16 illustrate the bathymetry of Pinto Lake based on depth measurements collected in 2009 and provided to us by City of Watsonville staff.

For purposes of lake bathymetry and volumetric calculations, the areal extent of the lake was limited to areas that the California Department of Water Resources' land cover dataset classify as "lake", which generally includes areas of open water. In contrast, areas defined as wetlands by land cover datasets were not included in lake bathymetry and volumetric calculations[22].

Figure 2-15. Bathymetry of Pinto Lake.



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[22] According to the Federal Geographic Data Committee, the emergent vegetation adjacent to rivers and lakes is often referred to as "the shore zone" or the "zone of emergent vegetation", and is generally considered **separately** from the river or lake (see Federal Geographic Data Committee *Classification of Wetlands and Deepwater Habitats* report, FGDC-STD-004-2013). Emphasis added by Central Coast Water Board staff.

Figure 2-16. Low angle (oblique) aerial views and corresponding 3-dimentional bathymetric modles of Pinto Lake (image credit: P. Osmolovsky, Central Coast Water Board).

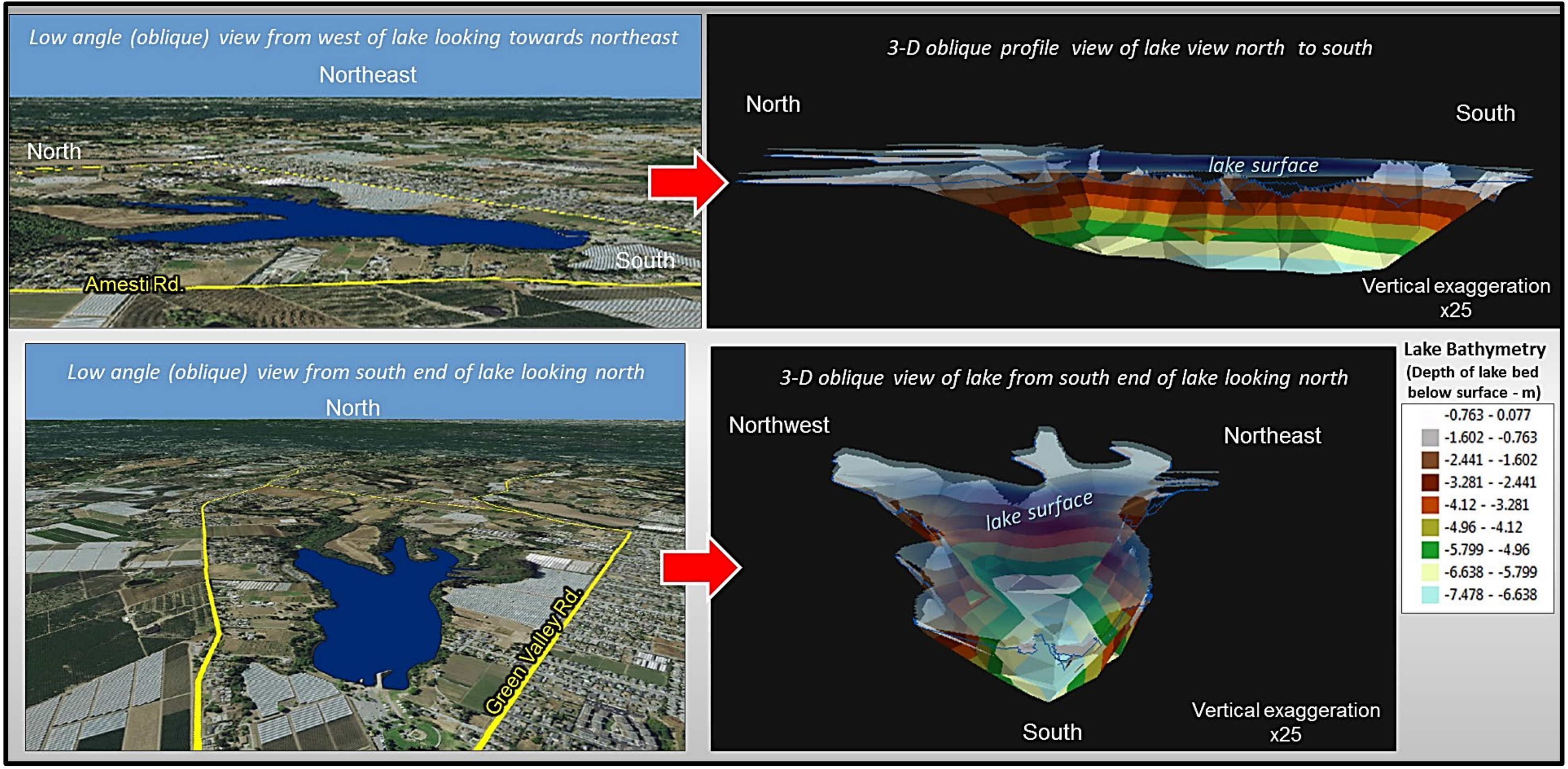
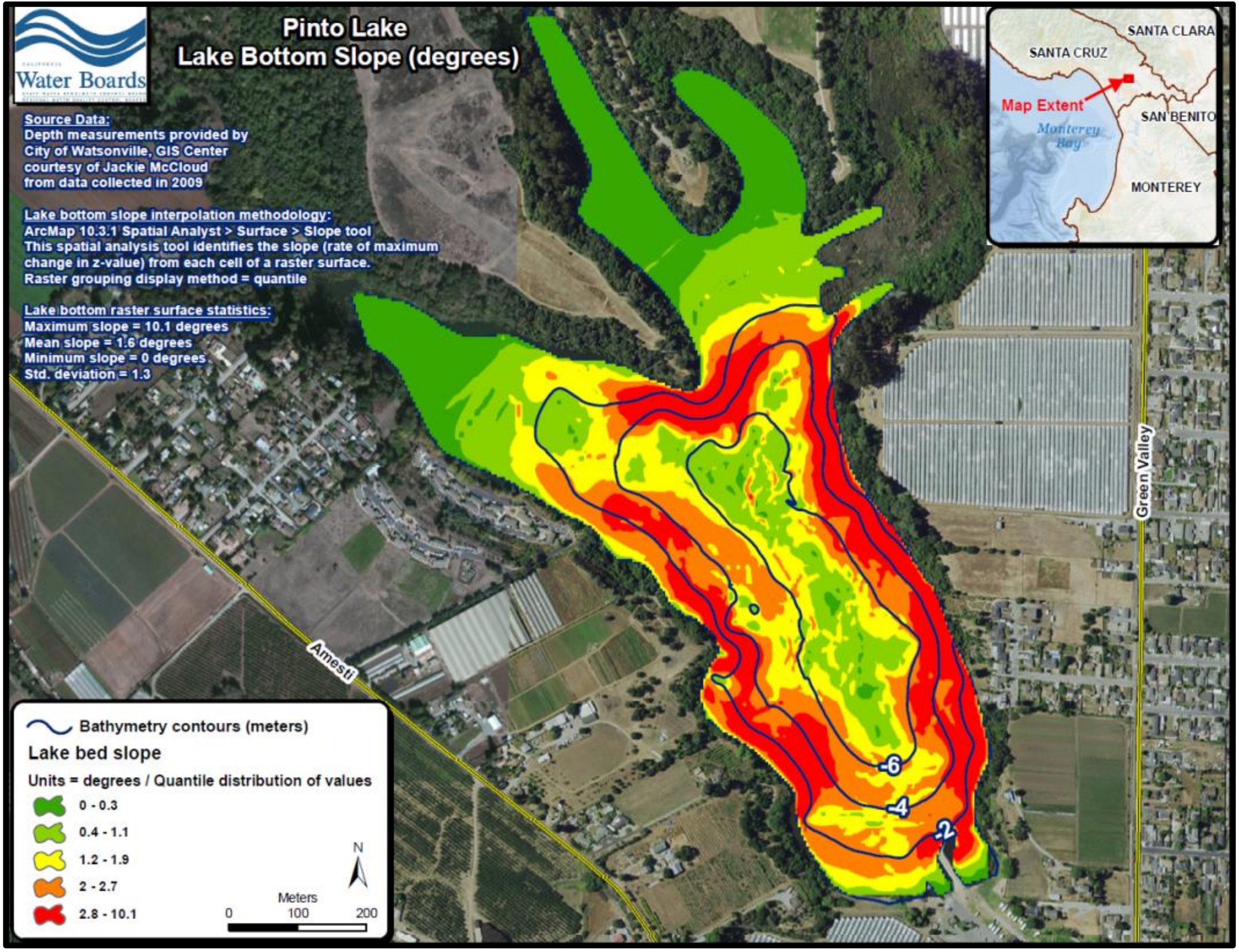


Figure 2-17 presents the morphology of the lakebed in terms of slope (degrees of inclination). The steep-sided lake margins, and the elongated north-northwest/south-southeast trending trough of the lakebed are consistent with the lake's geologic genesis as a tectonically driven sag pond[23] associated with the Zayente Fault zone.

Figure 2-17. Pinto Lake, lake bottom slope (units = degrees).



Source Data:
Depth measurements provided by City of Watsonville, GIS Center courtesy of Jackie McCloud from data collected in 2009

Lake bottom slope interpolation methodology:
ArcMap 10.3.1 Spatial Analyst > Surface > Slope tool
This spatial analysis tool identifies the slope (rate of maximum change in z-value) from each cell of a raster surface.
Raster grouping display method = quantile

Lake bottom raster surface statistics:
Maximum slope = 10.1 degrees
Mean slope = 1.6 degrees
Minimum slope = 0 degrees
Std. deviation = 1.3

We calculated geometric and volumetric attributes of the lake using the depth measurements in conjunction with the Esri® ArcGIS™ 10.3.1 3D Analyst tool. Table 2-9 tabulates these lake attributes. Worth noting is that mean lake depth estimated here (3 meters) comports reasonably well with a mean lake depth estimate reported in the scientific literature (3.75 meters, see Blanco and Los Huertos, 2014).

Table 2-9. Volumetric and bathymetric attributes of Pinto Lake.

Waterbody	Lake surface area^A (acres)	Mean lake depth^B (meters)	Maximum lake depth (meters)	Volume of lake water^C (cubic meters)	Volume of lake water^C (acre-feet)
Pinto Lake	103.8	3	~ 7.5	1,248,736	1,012

^{A} Source: California Department of Water Resources, Farmland Mapping and Monitoring Program (FMMP) geospatial dataset, 2012. We relied on the FMMP land cover attribute "open water" to defined the areal extent of Pinto Lake.

^{B} Source: Geospatial raster data, derived from interpolated lake depth measurements collected in 2009 and provided to us by City of Watsonville staff. Refer to Figure 2-15 on page 36.

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[23] "Sag ponds" are defined in the Environmental Engineering Dictionary as "a small body of water occupying an enclosed depression or sag where recent fault movement has impounded drainage."

[C] Volumetric calculation methodology: ArcMap™ 3D Spatial Analyst > Surface Volume tool. This tool calculates the area and volume between a surface (e.g. a lake bathymetry raster surface) and a reference plane (e.g., a lake surface datum).

2.6 Human Population & Demographics

In any given TMDL report, there can be both practical and policy-related reasons to consider the human demographics of a watershed. Thus, this section of the report presents information on population, demographics, and socioeconomic factors in and around the Pinto Lake catchment.

Environmental Justice refers to federal and state policies that promote the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. The basic concept behind the term "environmental justice" is that all people – regardless of their race, color, nation, origin, or income – are able to enjoy equally high levels of environmental protection.

Text Box 2-1. Central Coast Water Board's Environmental Justice program.

> *“At the Central Coast Water Board, Environmental Justice (EJ) shapes our priorities, frames our projects, and informs our actions. It embraces the idea that every community, regardless of its size and economic standing, deserves access to safe water.”*
>
> *“The Water Board’s EJ Program goals include: Integrating EJ considerations into the development, adoption, implementation, and enforcement of Board decisions, regulations, and policies.”*
>
> ➔ Central Coast Water Board Environmental Justice webpage

Accordingly, consistent with the state Environmental Justice program, here we present some aspects of human demographics in the Pinto Lake catchment in this section of the report.

It is worth noting that Pinto Lake is an important recreational and aesthetic resource for the socio-economically disadvantaged nearby community of Watsonville.

Text Box 2-2. Pinto Lake is a resource for economically disadvanted Watonsonville families.

> *“The Pinto Lake watershed has two parks located on the lake which serve over 100,000 visitors per year. Many of the visitors are young families from Watsonville’s disadvantaged community.”*
>
> ➔ *City of Watsonville, Public Works and Utilities Department,* Memorandum *dated Dec. 10, 2013 and entitled “Application for $750,000 in Clean Water Act 319H Grant Funds for Pinto Lake”*

The City of Watsonville is a designated Disadvantaged Community[24] pursuant to Senate Bill 535. Practically speaking, this means the community is characterized by higher levels of poverty, lower household incomes, higher unemployment and other adverse economic indicators relative to other parts of the state.

Further, the City of Watsonville is disproportionately impacted by multiple sources of pollution relative to other areas of the state, according to information from the California Environmental Protection Agency. Watsonville is in the bottom fifth (83rd percentile) of the state’s population for communities that are most impacted by economic disadvantage, coupled with disproportionate environmental burden of multiple pollution sources (refer to Figure 2-18).

Therefore, TMDL development with the goal of reducing environmental pollution at Pinto Lake is consistent with the Central Coast Water Board’s objective of integrating environmental justice considerations into our activities and decisions (refer back to Text Box 2-1).

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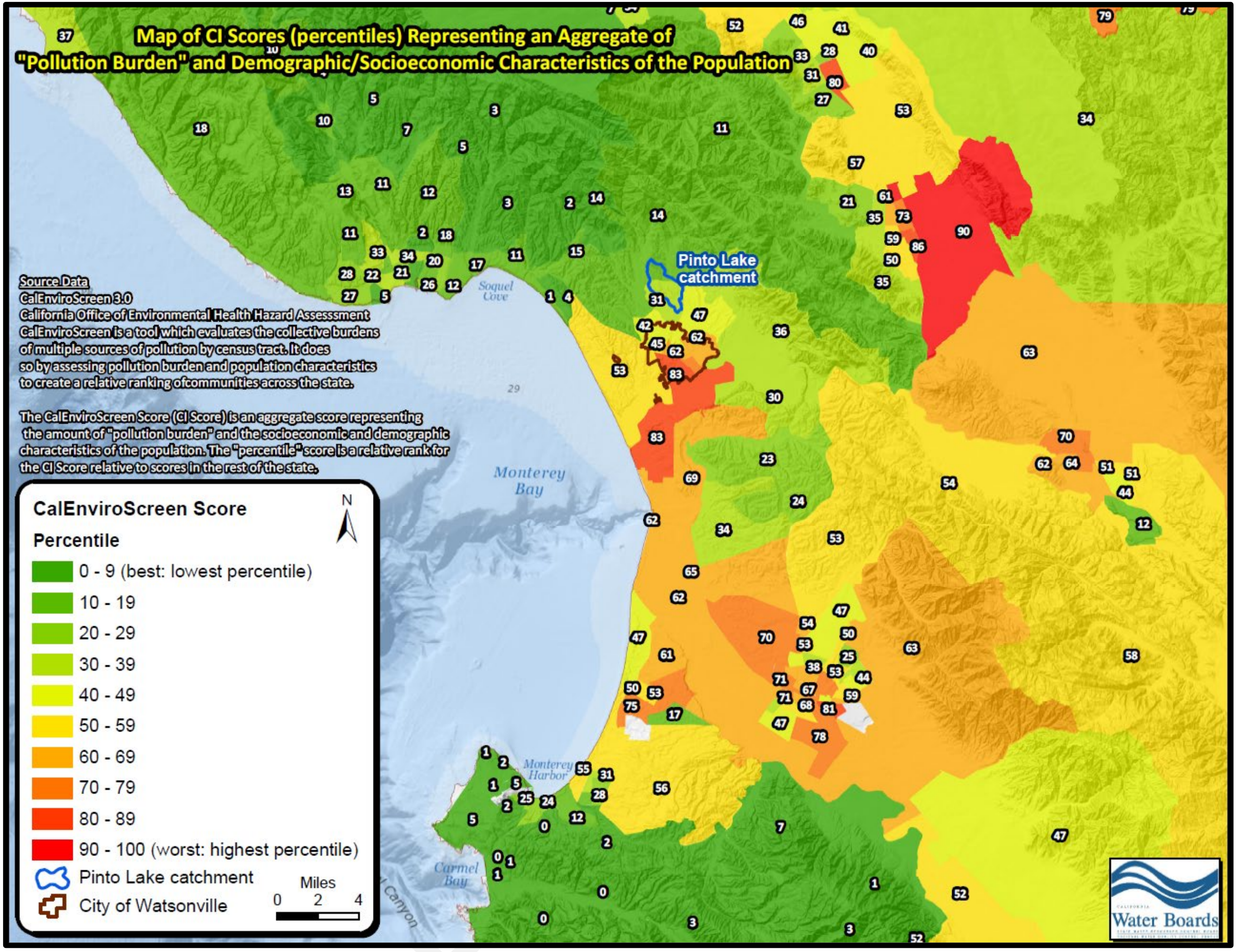
[24] A disadvantaged community is defined by the California Environmental Protection Agency for the purpose of SB 535. They are communities with annual household median household incomes that are less than 80 percent of the statewide annual median household income. However, this definition is subject to modification and review, as the state develops ways to better identify disadvantage communities pursuant to SB 535.

Figure 2-18. Map showing CalEnviroScreen scores (percentiles) for the human population of the Monterey Bay area. CalEnviroScreen scores are a screening methodology to help identify communities that are disproportionately burdened by multiple sources of pollution.



Source Data
CalEnviroScreen 3.0
California Office of Environmental Health Hazard Assesssment
CalEnviroScreen is a tool which evaluates the collective burdens of multiple sources of pollution by census tract. It does so by assessing pollution burden and population characteristics to create a relative ranking ofcommunities across the state.

The CalEnviroScreen Score (CI Score) is an aggregate score representing the amount of "pollution burden" and the socioeconomic and demographic characteristics of the population. The "percentile" score is a relative rank for the CI Score relative to scores in the rest of the state.

Population and housing estimates of any given watershed can be important to consider, as residential areas, septic systems, and urban stormwater can all be sources of pollution. In some watershed studies, census data on population and housing units[25] can be evaluated in efforts to estimate the number of septic systems in the watershed or catchment. To estimate the number of housing units located within the Pinto Lake catchment, staff analyzed census blocks which geographically overlaid the Pinto Lake catchment using Esri® ArcMap™ 10.3.1 spatial analysis software. Figure 2-19 illustrates three main block groups geographically covering the Pinto Lake catchment. The block groups are labeled here as A, B, and C.

We estimate that the human population living within the Pinto Lake catchment is 2,025 people, with an average of 3.2 people per housing unit, according to 2010 Census Bureau data. The number of housing units in the catchment is approximately 630 (see Table 2-10).

---

[25] The U.S. Census Bureau defines a *housing unit* as “a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters.”

Figure 2-19. Census blocks and reported number of housing units in the Pinto Lake catchment and the immediate vicinity (source data: U.S. Census Bureau, 2010).

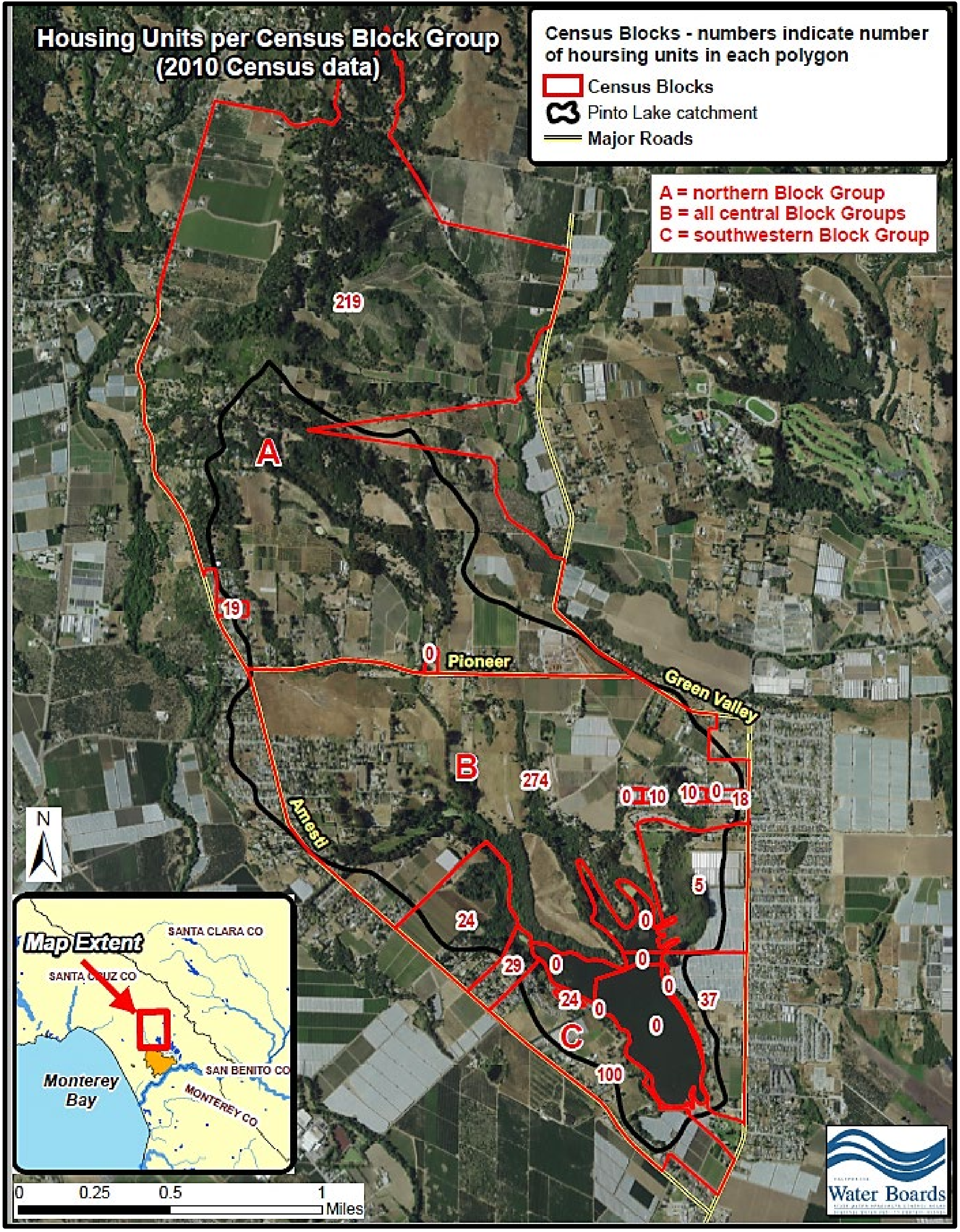


Table 2-10. Estimate of population in the Pinto Lake catchment based on Census 2010 block group data.

Census Block Group[1]	Housing Units	Total Population
A[2] (northern block group)	110	320
B[3] (southern block group)	460	1,503
C[4] (southwestern block group)	60	202
Pinto Lake catchment total	630	2,025

[1] These letter values are arbitrary values associated with US Census Bureau Block groups (i.e., Block, Block Group, Census Tract, County, State). Please see Table 2-11 for the full text of the block groups.

[2] Half of census block "A" falls outside the catchment, and half the land classified as "residential" in the census block by the National Land Cover Dataset (2011) also falls outside the Pinto Lake catchment. Therefore, the census estimates for housing and population for this block group were reduced by half in this table (e.g. 219/2 = 110).

[3] The majority of census block "B" is within the catchment, so the entire block group number is reported.

[4] Approximately 60% of this block group is within the catchment, therefore 60% of the total number of housing units and population is reported for this block group are shown in this table (e.g. 100*.6=60).

Table 2-11. Tabulation of how we grouped U.S. Census Bureau blocks, block groups, census tracts for purposes of population esimates previously shown in Figure 2-19 and Table 2-10.

We Grouped Three Areas of Census Blocks in Our Population Analysis (see Figure 2-19)	**Census Bureau Designated Block groups**
A	Block 1053, Block Group 1, Census Tract 1224, Santa Cruz County, CA
B	Block 1054, Block Group 1, Census Tract 1224, Santa Cruz County, California
	Block 1016, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1000, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1014, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 2010, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2007, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2002, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2009, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2001, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 1015, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1010, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1001, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1005, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1002, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 1058, Block Group 1, Census Tract 1224, Santa Cruz County, California
	Block 2004, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2003, Block Group 2, Census Tract 1231, Santa Cruz County,

	California
	Block 1004, Block Group 1, Census Tract 1231, Santa Cruz County, California
	Block 2008, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2011, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2005, Block Group 2, Census Tract 1231, Santa Cruz County, California
	Block 2006, Block Group 2, Census Tract 1231, Santa Cruz County, California
C	Block 1003, Block Group 1, Census Tract 1231, Santa Cruz County, California

In any given watershed, septic systems can locally be a source of nitrogen and phosphorus to groundwater and surface water resources. Accordingly, it can be important to consider septic systems as a source category in TMDL development. We estimated the number of households on septic systems in the Pinto Lake catchment using the aforementioned census information in conjunction with local knowledge provided by resource professionals (see Figure 2-20).

Based on communication with Mr. John Ricker, County of Santa Cruz Water Resources Division Director, most residential areas on the east side of Pinto Lake along Green Valley Road are sewered, although there are a few older homes not hooked up to the sewer, particularly north of the trailer park in the Todos Santos subcatchment. In contrast, residential areas on the west side of Pinto Lake, along Amesti Road, and areas north of Pioneer Road use septic systems.

Figure 2-20. Estimated number of households on septic systems in the Pinto Lake catchment.

Report Section **6** addresses septic systems as a source of nutrients to the lake in further detail.

2.7 Geomorphology

Geomorphology[26] is the study of landforms, their processes, form, and sediments at the surface of the Earth. In any given watershed study, geomorphology can be relevant to consider because landform morphology can frequently be related to processes like erosion and sedimentation. Frequently, nutrient

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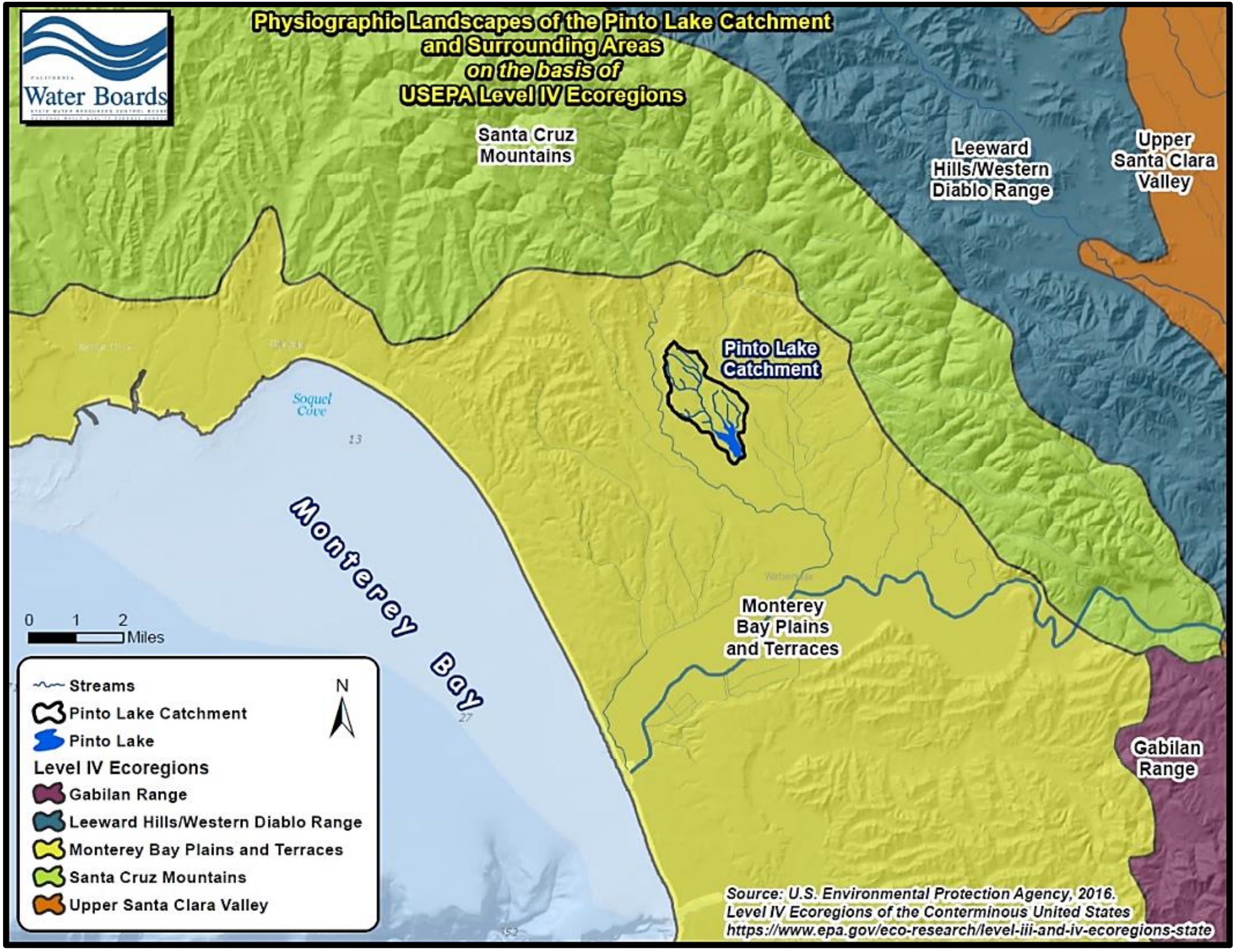
[26] As defined by the British Society for Geomorphology.

pollution, particularly phosphorus pollution, is associated with the transport and deposition of sediment. Here, we outline the available published information concerning Pinto Lake catchment geomorphology.

Figure 2-21 illustrates generalized geomorphic landscape provinces of Monterey Bay area.

Pinto Lake occurs in the Monterey Bay Plans and Terraces subecoregion of central California. According to the U.S. Forest Service[27], the landscapes of this subecoregion are characterized by alluvial plains (mostly gently sloping to nearly level floodplain), stream terraces, and alluvial fans, and also dissected Quaternary nonmarine deposits on the Watsonville Plain. Fluvial erosion and deposition are the main geomorphic processes. The soils are mostly Fluventic, Fluvaquentic, and Pachic Haploxerolls and Typic and Chromic Pelloxererts on floodplains. They are Entic, Typic, and Pachic Haploxerolls, Ultic Palexerolls, and Typic Natrixeralfs on stream terraces and old alluvial fans. Xeric Argialbolls, Pachic Argixerolls, and Mollic Palexeralfs are the main soils on marine terraces.

Figure 2-21. Physiographic landscapes of the Monterey Bay area on the basis of Level IV ecoregions.



Source: U.S. Environmental Protection Agency, 2016. Level IV Ecoregions of the Conterminous United States https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-state

Figure 2-22 broadly illustrates the distribution of lowlands and uplands in the Pinto Lake catchment, based on variations in slope as derived from a 30 meter digital elevation model.

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[27] U.S. Forest Service, archived webpage, accessed November 2016. Online linkage: http://web.archive.org/web/20071109050210/http://www.fs.fed.us/r5/projects/ecoregions/261ah.htm

Figure 2-22. Map showing lowlands and uplands in the Pinto Lake catchment on the basis of variations in land slope (degrees).

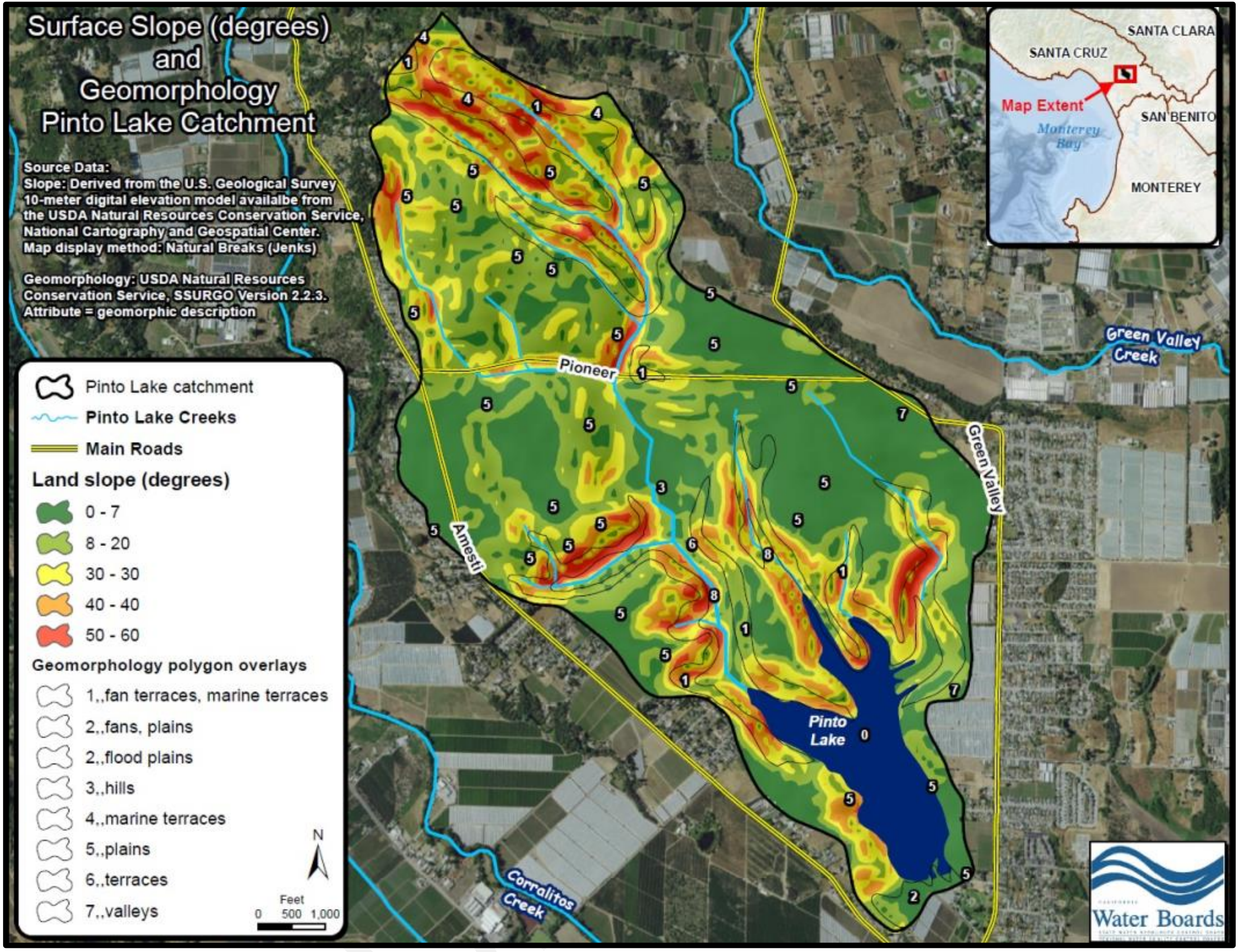
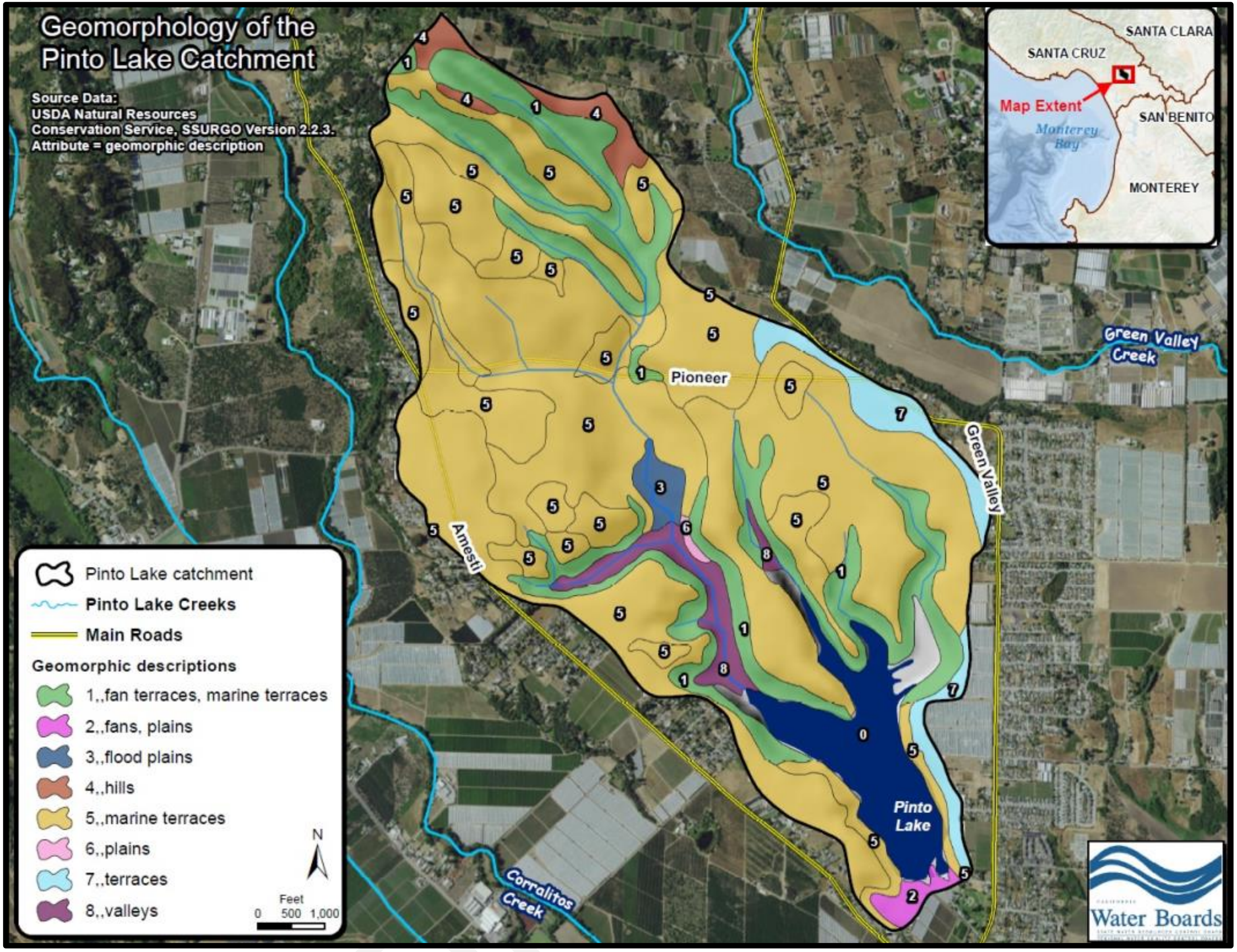


Figure 2-23 illustrates geomorphic descriptions of landscapes of the Pinto Lake catchment. The lake itself is located in a small valley between two sides of a marine terrace deposit. This valley was formed as a consequence of geologically recent movement on the Zayente Fault (oral communication, Robert Ketley, City of Watsonville). Soils in the Pinto Lake catchment tend to be medium to heavy-textured that can retard the penetration of water. Terraces in the Pinto Lake catchment are highly vulnerable to erosion, especially gully erosion (Plater, et al., 2006).

Figure 2-23. Geomorphology of the Pinto Lake catchment.



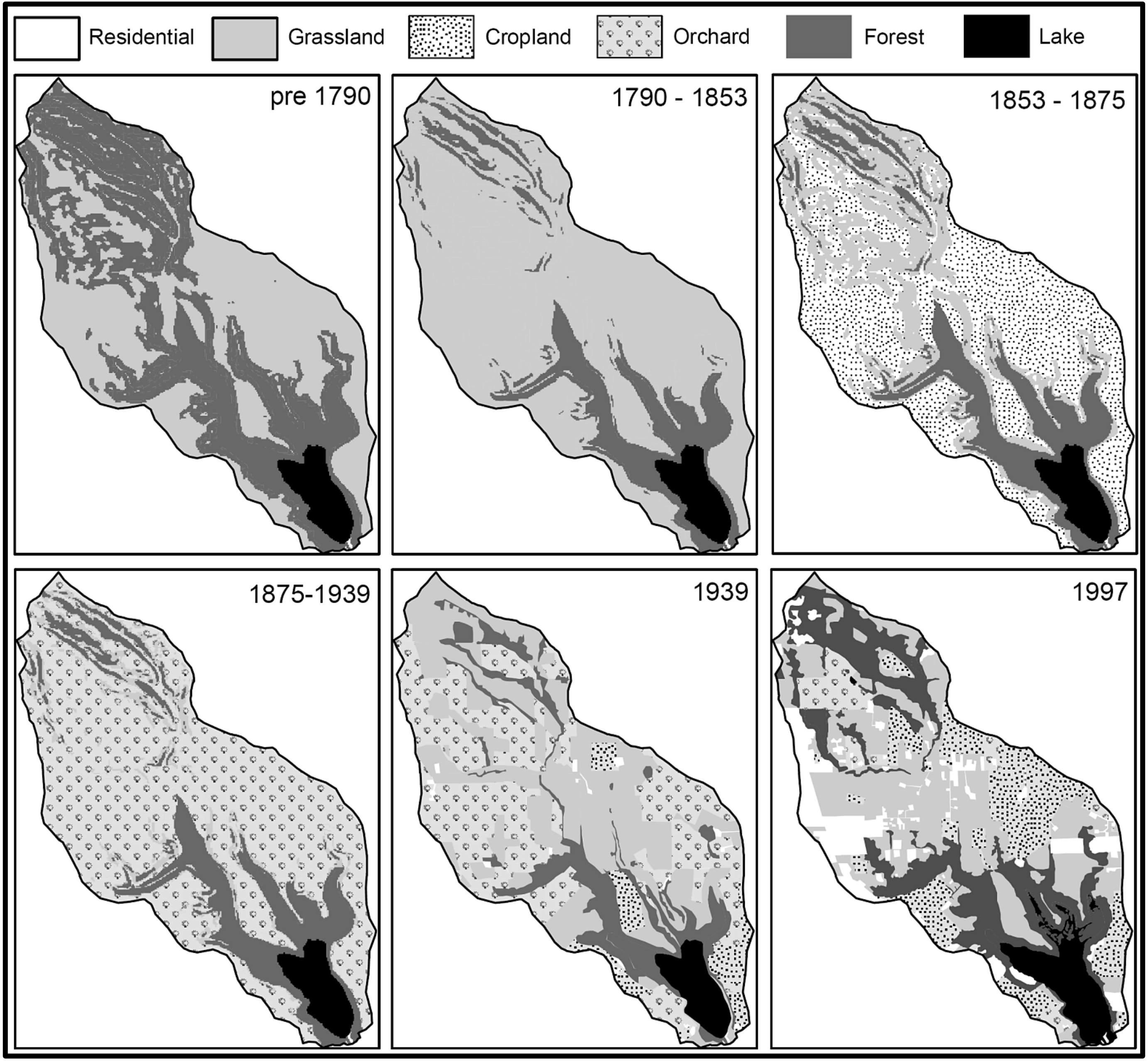
Geomorphic processes include sedimentation and erosion. Researchers and local resource professionals report that natural and human-induced sedimentation and erosion are important environmental processes in the Pinto Lake catchment (Plater et al., 2006 and Boyle et al., 2011, and personal communication January 2017, Dr. John C. Holz, limnologist at HAB Aquatic Solutions, LLC). Thus, it is relevant to highlight some key aspects of sedimentation and erosion in the lake catchment.

Boyle et al. (2011) reported their findings on the sedimentary record at Pinto Lake. According to these researchers, prior to European settlement of California, the sediment accumulation rate in Pinto Lake averaged 2 millimeters per year. Worth noting is that the landscapes of pre-19th century coastal California were largely unaffected by early nomadic aboriginals who lived by fishing and exploiting seasonal resources (Plater et al., 2006). In contrast, the sedimentary record post-1790 indicates the lake sediment has become more mineral rich and has been accumulating at a rate of 19 mm per year (Boyle et al., 2011).

Measured as mass flux, the sedimentary record indicates the sediment yield rate in the lake catchment was less than 200 tons per year prior to 1800. Beginning in the mid-19th century and into modern times, sediment yield estimates in the catchment range between 800 to 1,100 tons per year (Boyle et al., 2011).

Consequently, in the Pinto Lake catchment, modifications to the landscape are a prevailing factor in sedimentation and erosion rates, as reported in peer-reviewed scientific literature (Plater et al., 2006 and Boyle et al., 2011). Figure 2-24 presents estimates of changes in land cover in the Pinto Lake catchment since 1790. The most significant historical land disturbance was redwood deforestation between 1844 and 1860 (Plater et al., 2006). Historical and recent changes in sedimentation rate at the lake are attributed to deforestation and land use practices that have occurred in the 19th and 20th centuries.

Figure 2-24. Distribution of major land cover classes through time in the Pinto Lake catchment (figure courtesy of Dr. John F. Boyle, Department of Environmental Sciences, University of Liverpool, UK). Land cover classes are derived from high quality aerial photographs (after 1938), and from historical information about land use in the Pajaro Valley (prior to 1938).



Given the nature of landscape morphology and soils in the Pinto Lake catchment, local resource professionals consider sediment control to be an important watershed management tool (personal communication Lisa Lurie, Resource Conservation District of Santa Cruz County, and Jackie McCloud, Environmental Project Manager, City of Watsonville).

2.8 Nutrient Ecoregions & Reference Conditions

Researchers, lake managers, and regulators frequently take nutrient ecoregions and reference conditions into consideration during the development of any given nutrient TMDL. Reference conditions can be used to assess what levels of nutrient-related parameters might be expected to be attainable in lake waters.

Worth noting is that reference conditions are not necessarily pristine lakes, or those undisturbed by humans.

> *"Ideally, reference conditions associated with nutrient-related variables such as phosphorus, nitrogen, and chlorophyll a are concentrations representative of lake conditions in the absence of anthropogenic disturbances and pollution. However, because it can be argued that most, if not all, lakes have been impacted by human activity to some degree, reference conditions realistically represent the least impacted conditions or what is considered to be the most attainable conditions."*
>
> ➔ U.S. Environmental Protection Agency, Nutrient Criteria Technical Guidance Manual, Lakes and Reservoirs, First Edition, EPA-822-B00-001, April 2000.

Since reference conditions are not uniform across the nation or across any given state due to natural variability, the USEPA has designated nutrient ecoregions that denote areas with ecosystems that are generally similar. The intent of classifying nutrient ecoregions is to identify groups of lakes that could generally be expected to exist in similar environmental conditions.

The Pinto Lake catchment is located largely in ecoregion III-6 – Southern and Central California Chaparral and Oak Woodlands[28] (see Figure 2-25). The primary distinguishing characteristic of this ecoregion is its Mediterranean climate of hot dry summers and cool moist winters, and associated vegetative cover comprising mainly chaparral and oak woodlands; grasslands occur in some lower elevations and patches of pine are found at higher elevations. Most of the California Chaparral and Oak Woodlands ecoregion consists of open low mountains or foothills, but there are areas of irregular plains in the south and near the border of the adjacent Central California Valley ecoregion.

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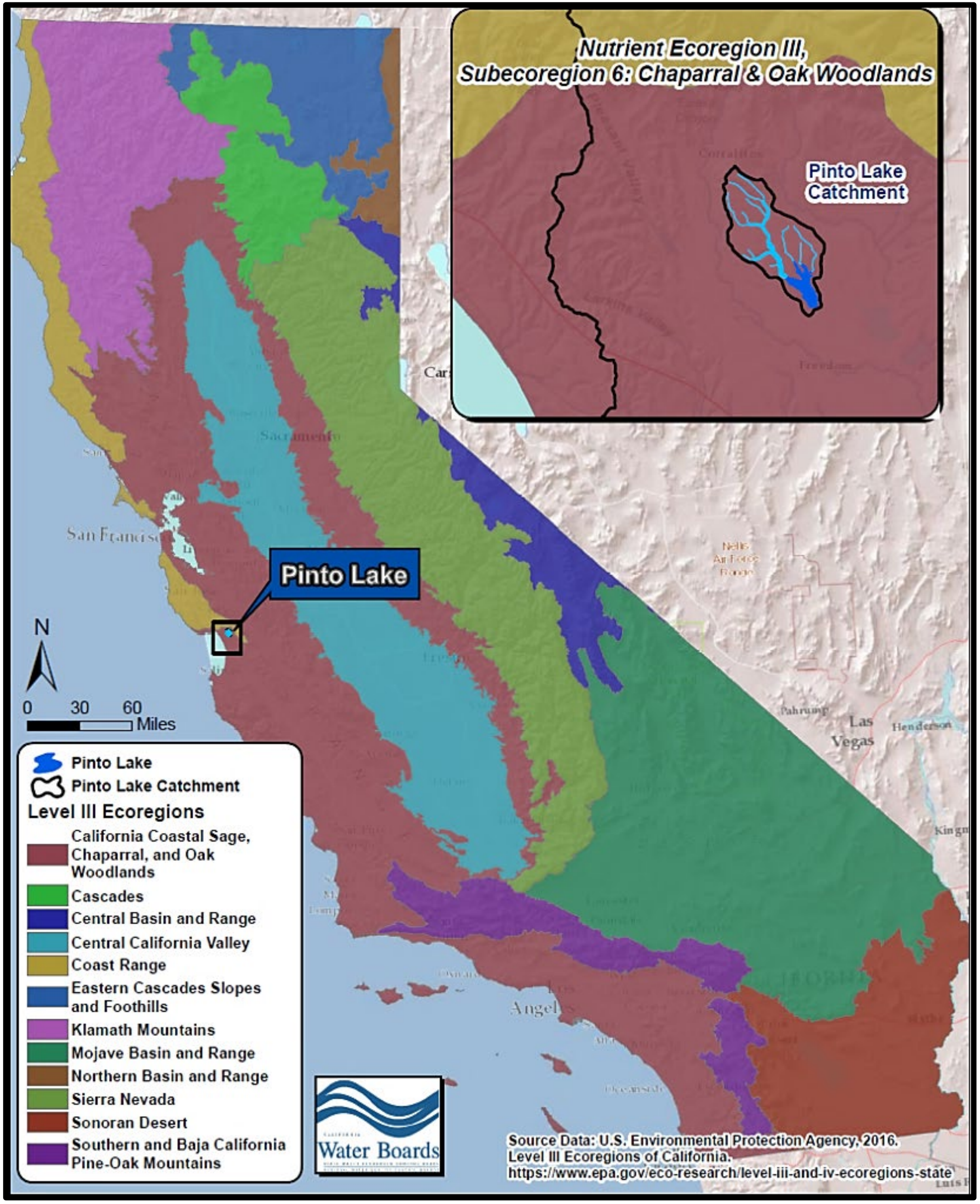
[28] Also referred to throughout this report more concisely as "Nutrient subecoregion 6".

Figure 2-25. California Level III nutrient ecoregions. The Pinto Lake catchment is in Ecoregion III-6, California Chaparral and Oak Woodlands.



Source Data: U.S. Environmental Protection Agency, 2016. Level III Ecoregions of California. https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-state

Ecoregional natural variation illustrates that a single, uniform numeric nutrient water quality target is not appropriate at the national or state-level scale. At the larger geographic scales, natural ambient nutrient concentrations and associated biostimulatory risks in surface waters are highly variable due to variations in vegetation, hydrology, climate, geology and other natural factors. As such, it is important to consider natural variability of nutrient concentrations locally at smaller geographic scales (e.g., ecoregional or watershed scales).

USEPA Ecoregional Nutrient Numeric Criteria

In 2001, the U.S. Environmental Protection Agency published ambient numeric criteria to support the development of state nutrient criteria in lakes and reservoirs of nutrient ecoregions III (USEPA, 2001).

The intent of the document is to provide benchmark nutrient criteria to help states and lake managers assess the risk of nutrient enrichment in lakes.

> *"This document presents EPA's nutrient criteria for Lakes and Reservoirs in Nutrient Ecoregion III. These criteria provide EPA's recommendations to States and authorized Tribes for use in establishing their water quality standards consistent with section 303(c) of the Clean Water Act (CWA). EPA's recommended section 304(a) criteria are not laws or regulations; they are guidance that States and Tribes may use as a starting point in creating their own water quality standards"*
>
> ➔ from: Ambient Water Quality Criteria Recommendations – Lakes and Reservoirs in Nutrient Ecoregion III, USEPA December 2001.

Table 2-12 presents the U.S. Environmental Protection Agency's numeric criteria intended to be representative of reference conditions (i.e., relatively unimpacted conditions) for lakes in the southern and central California oak and chaparral ecoregion.

Table 2-12. Reference conditions for ecoregion III-6 lakes and reservoirs (southern and central California chaparral and oak woodlands).

Parameter	**25th Percentiles based on all seasons data for the decade**
Total nitrogen (TN) – mg/L	0.51
Total phosphorous (TP) – mg/L	0.172[a]
Chlorophyll *a* – µg/L	24.6
Secchi – meters (secchi is a measure of water transparency)	1.9[b]

a – U.S. Environmental Protection Agency states that this value appears inordinately high and may either be a statistical anomaly or reflect a unique condition. In any case, further regional investigation is indicated to determine the sources, i.e., measurement error, notational error, statistical anomaly, naturally enriched conditions, or cultural impacts. However, also worth noting is that the Central Coast Ambient Monitoring Program emphasizes the fact that naturally high background levels of phosphorus are generally found in some parts of the California central coast region.

b - A 25th percentile for a season is best derived with data from a minimum of 4 lakes/season. However, this table provides 25th percentiles that were derived with fewer than 4 lakes/season in order to retain all information for all seasons. In calculating the 25th percentile for a season with fewer than 4 lake medians, the statistical program automatically used the minimum value within the fewer-than-4 population. If fewer than 4 lakes were used in developing a seasonal quartile and or all-seasons median, the entry is flagged.

It should be re-emphasized that the above ecoregional criteria are not regulatory standards, and the U.S. Environmental Protection Agency in fact considers them "starting points" developed based on data available at the time. The agency has recognized that States need to evaluate these values critically, and assess the need to develop nutrient targets appropriate to different geographic scales and at higher spatial resolution.

National Aquatic Resources Survey of Lakes (2012)

It can be informative to compare the existing quality of Pinto Lake waters to lake waters from around ecoregion III-6. Chemistry of lake waters at the ecoregional scale across the nation is available from the United States Environmental Protection Agency.

The U.S. Environmental Protection Agency's National Lake Assessment provides water quality information from the nation's lakes. Data from lakes collected in subecoregion III-6 allow for comparison between Pinto Lake waters, and waters from other California lakes in relatively comparable ecosystems.

Figure 2-26. Map showing lake sample locations for USEPA National Lake Assessment (2012), for lakes located in nutrient subecoregion III-6 (southern and central California chaparral and oak woodlands).

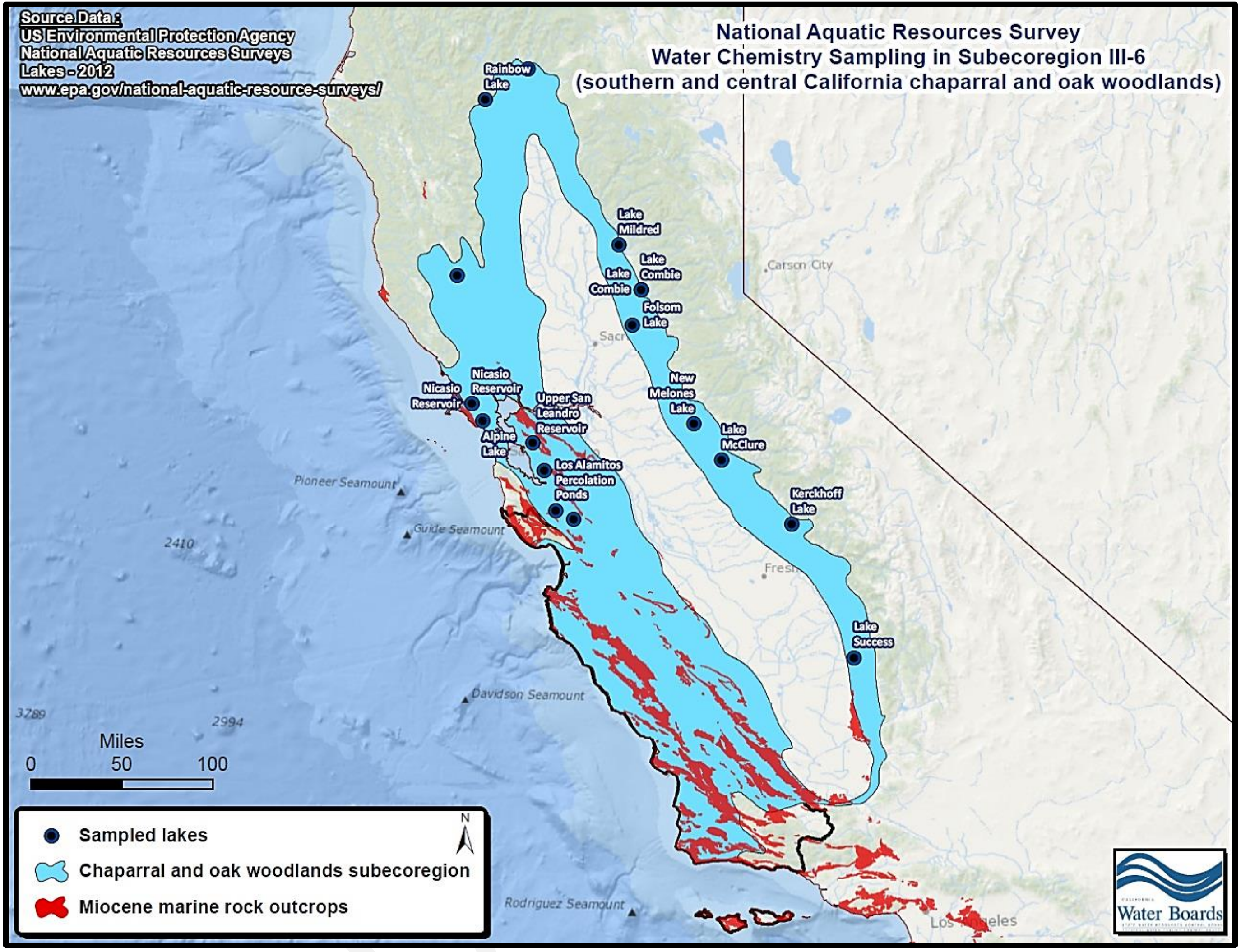


Table 2-13 presents numerical summaries of water quality in ecoregion III-6 sampled lakes available from the U.S. Environmental Protection Agency 2012 National Lakes Assessment. Phosphorus concentrations in these lakes typically are lower than observed in Pinto Lake waters (see report Section 4). It should be noted that most of the ecoregion III-6 lakes sampled in the 2012 National Lakes Assessment did not occur in areas draining Miocene marine rocks (refer back to Figure 2-26). Outcropping Miocene rocks can have elevated phosphorus content and may locally contribute higher levels of phosphorus to California's central coast surface waterbodies (LVMWD 2012, Domagalski, 2013).

Table 2-13. Numerical summaries of water quality data from 2012 National Lakes Assessment, for sampled lakes of subecoregion III-6.

Sampled Lakes [A]	Parameter [B, C]	Dates Sampled	Arithmetic Mean	Min	25th %	50th % (median)	75th %	90th %	Max	No. of Samples
Lakes of subecoregion III-6 sampled for the 2012 National Lakes Assessment	Nitrate+nitrite as N	May 2012- Sept. 2012	0.0098	0.002	0.005	0.005	0.0054	0.018	0.057	18
	Total ammonia as N	May 2012- Sept. 2012	0.015	0.0024	0.006	0.013	0.019	0.03	0.047	18

Sampled Lakes[A]	Parameter[B, C]	Dates Sampled	Arithmetic Mean	Min	25th %	50th % (median)	75th %	90th %	Max	No. of Samples
	Total nitrogen as N	May 2012-Sept. 2012	0.28	0.064	0.12	0.17	0.41	0.52	0.78	18
	Total phosphorus as P	May 2012-Sept. 2012	0.018	0.0041	0.006	0.014	0.03	0.034	0.04	18
	pH	May 2012-Sept. 2012	7.7	6.3	7.4	7.8	8.1	8.6	9.3	18
	Chlorophyll *a* – *(littoral-lake shore)*	May 2012-Sept. 2012	6.8	0.6	1.7	4	6.8	14	39	18

[A] Refer back to Figure 2-26.
[B] Units: all parameters reported in mg/L except chlorophyll *a* = micrograms/L and pH = – [log H+].
[C] Water quality data sources: U.S. Environmental Protection Agency, National Lakes Assessment (2012).

2.9 Climate & Atmospheric Deposition

Central Coast Water Board staff conducted a review of climatic data for this progress report. Precipitation is often considered in the development of TMDLs. Precipitation is directly related to a number of watershed hydrologic functions, such as surface runoff, groundwater recharge, and water table elevations.

The Pinto Lake catchment, and California's central coast are characterized by a Mediterranean–type climate, with the vast majority of precipitation falling between November and April (see Table 2-14).

Table 2-14. Precipitation records in the vicinity of Pinto Lake.

Station	Elevation (ft.)	Climatic Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Watsonville Waterworks[A] **(1938-2013)**	95	Average Precipitation (inches)	4.52	3.89	3.02	1.52	0.49	0.14	0.04	0.05	0.30	0.99	2.39	4.18	**21.52**
Corralitos (COR)[B]	450	Average Precipitation (inches)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**27.05**

A: Western U.S. COOP weather station (Source: NOAA Western Regional Climate Center).
B: California Department of Forestry weather station – data published in the California Natural Resources Agency CERES database.
C: Located in Soquel Creek watershed of Santa Cruz mountains, northwest of the Pinto Lake catchment.
NR = not reported

Mean annual precipitation[29] estimates for the Pinto Lake catchment are available via the Parameter-elevation Regressions on Independent Slopes Model (PRISM)[30]. PRISM is a climate mapping system

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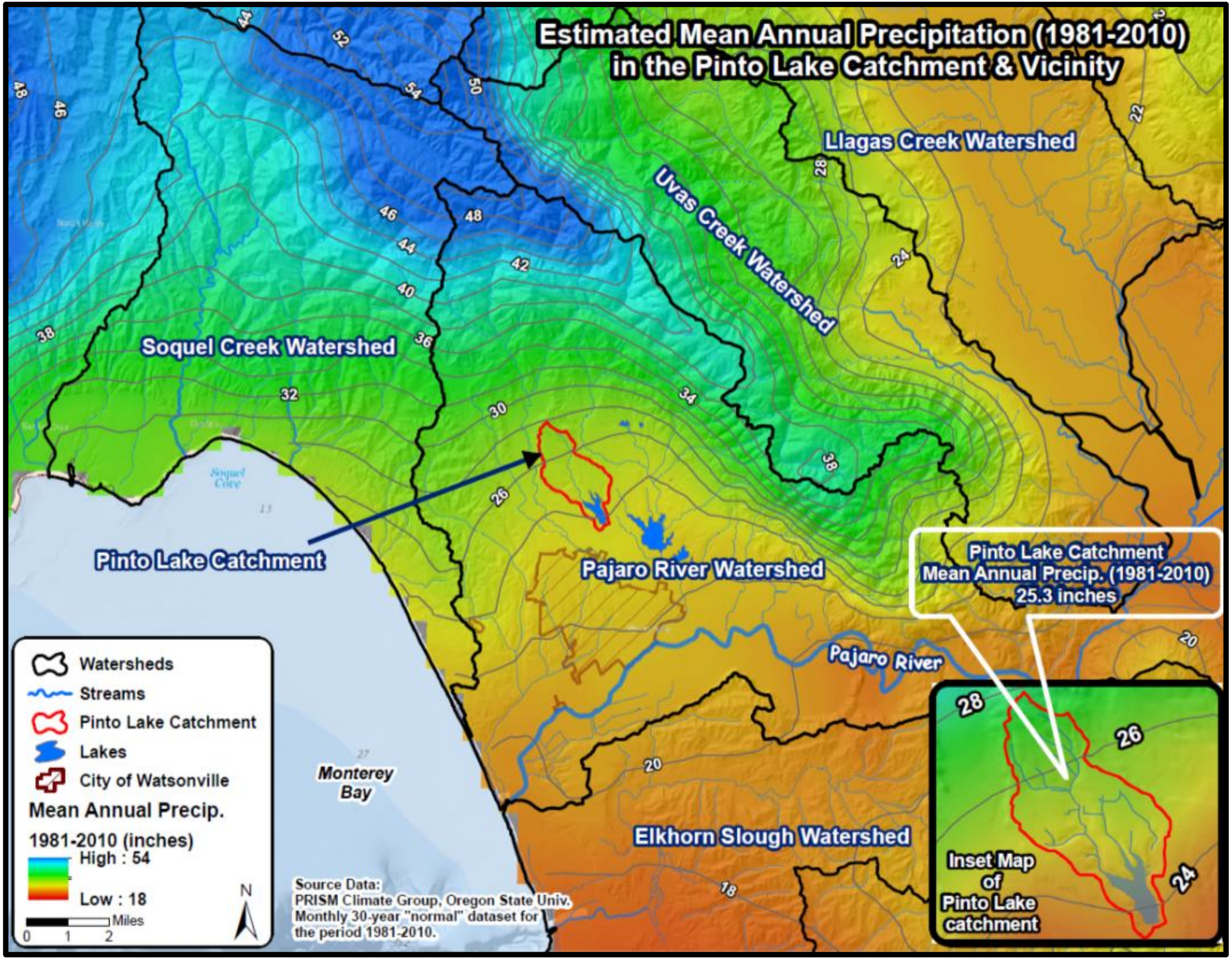
[29] Mean annual precipitation is the average precipitation for a year (usually calendar) based on the whole period of record or for a selected period (usually 30 year period such as 1981-2010).

[30] The PRISM dataset was developed by researchers at Oregon State University, and uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of climatic parameters. The dataset

that accounts for orographic climatic effects and is widely used in watershed studies and TMDL projects to make projections of precipitation into rural or mountainous areas where rain gage data is often absent, or sparse.

An isohyetal map for estimated mean annual precipitation (1981-2010) in the Pinto Lake catchment and vicinity is presented in Figure 2-27. Estimated mean annual precipitation within the Pinto Lake catchment is summarized in Text Box 2-3.

Figure 2-27 . Estimated mean annual precipitation for the 30 year period of 1981-2010 in the Pinto Lake catchment and vicinity.



Estimated Mean Annual Precipitation (1981-2010) in the Pinto Lake Catchment & Vicinity

Pinto Lake Catchment Mean Annual Precip. (1981-2010) 25.3 inches

Source Data: PRISM Climate Group, Oregon State Univ. Monthly 30-year "normal" dataset for the period 1981-2010.

Text Box 2-3. Estimated mean annual rainfall (1981-2010) in the Pinto Lake catchment.

> Based on the PRISM data, estimated mean annual precipitation within the Pinto Lake catchment for the period 1981-2010 was **25.3 inches per year**.

Spatial variation in rainfall within the Pinto Lake catchment is not substantial due to the small size of the catchment. Nonetheless, the PRISM precipitation dataset allows for high-resolution assessment of spatial variation in rainfall, and thus Table 2-15 presents estimated mean annual precipitation for specific areas within the Pinto Lake catchment.

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incorporates a digital elevation model, and expert knowledge of climatic variation, including rain shadows, coastal effects, and orographic effects.

Table 2-15. Spatial variation in mean annual rainfall in the Pinto Lake catchment (1981-2010).

Area	**Estimated mean annual precipitation (inches)**	**Source Data**
Pinto Lake	23.9	PRISM dataset, Oregon State University
Southern tributary creek subcatchments *(Pinto Creek mainstem, Amesti Creek, CCC Creek, and Todos Santos Creek)*	25.1	PRISM dataset, Oregon State University
Northern upland areas *(east and west branches subcatchments of Pinto Creek)*	26.4	PRISM dataset, Oregon State University

It should be reiterated that the PRISM model represents average precipitation conditions over a 30-year period. As of summer 2015, California has been experiencing extreme drought conditions for several years. Consequently, solutions and timeframes for water quality improvements and monitoring aimed at achieving pollutant load reductions in Pinto Lake may need to consider assumptions about water quality conditions under extreme drought conditions.

Other climatic parameters may be considered during TMDL development. Atmospheric deposition of nitrogen and phosphorus is often considered in watershed assessments of nutrient pollution. Deposition of nutrients by rainfall can locally be a significant source of loading to surface waters in any given watershed. Because nitrogen can exist as a gaseous phase (while phosphorus cannot), nitrogen is more prone to atmospheric transport and deposition. Phosphorus associated with fine-grained airborne particulate matter can also exist in the atmosphere (USEPA, 1999a). Additionally, atmospheric deposition of nitrogen compounds is generally most prevalent downwind of large urban areas, near point sources of combustion (like coal burning power plants), or in mixed urban/agricultural areas characterized by substantial vehicular combustion contributions to local air quality (Westbrook and Edinger-Marshall, 2014).

Figure 2-28 presents estimated total nitrogen atmospheric deposition for the year 2002 in the Monterey Bay region and vicinity based on a deposition model developed by the University of California-Riverside Center for Conservation Biology[31]. Based on summary statistics of the California statewide nitrogen deposition raster data, the 25th percentile of data values is 2.5 kilogram (kg) of nitrogen per hectare (Ha)[32] and the median value is 3.7 kg/hectare.

These values (2.5 to 3.7 kg/Ha) presumably could represent a plausible range for lightly-impacted or natural ambient atmospheric deposition conditions in California. The estimated atmospheric deposition of nitrogen at Pinto Lake is 9 kg/Ha, which is higher than the aforementioned ambient condition, suggesting a human contribution to nitrogen atmospheric deposition at the lake. However, note that atmospheric nitrogen deposition at Pinto Lake is lower than in highly developed areas of southern California such as the Los Angeles Basin and the Santa Ana Basin, which generally can range to above 20 kg/Ha of nitrogen annually based on the raster data.

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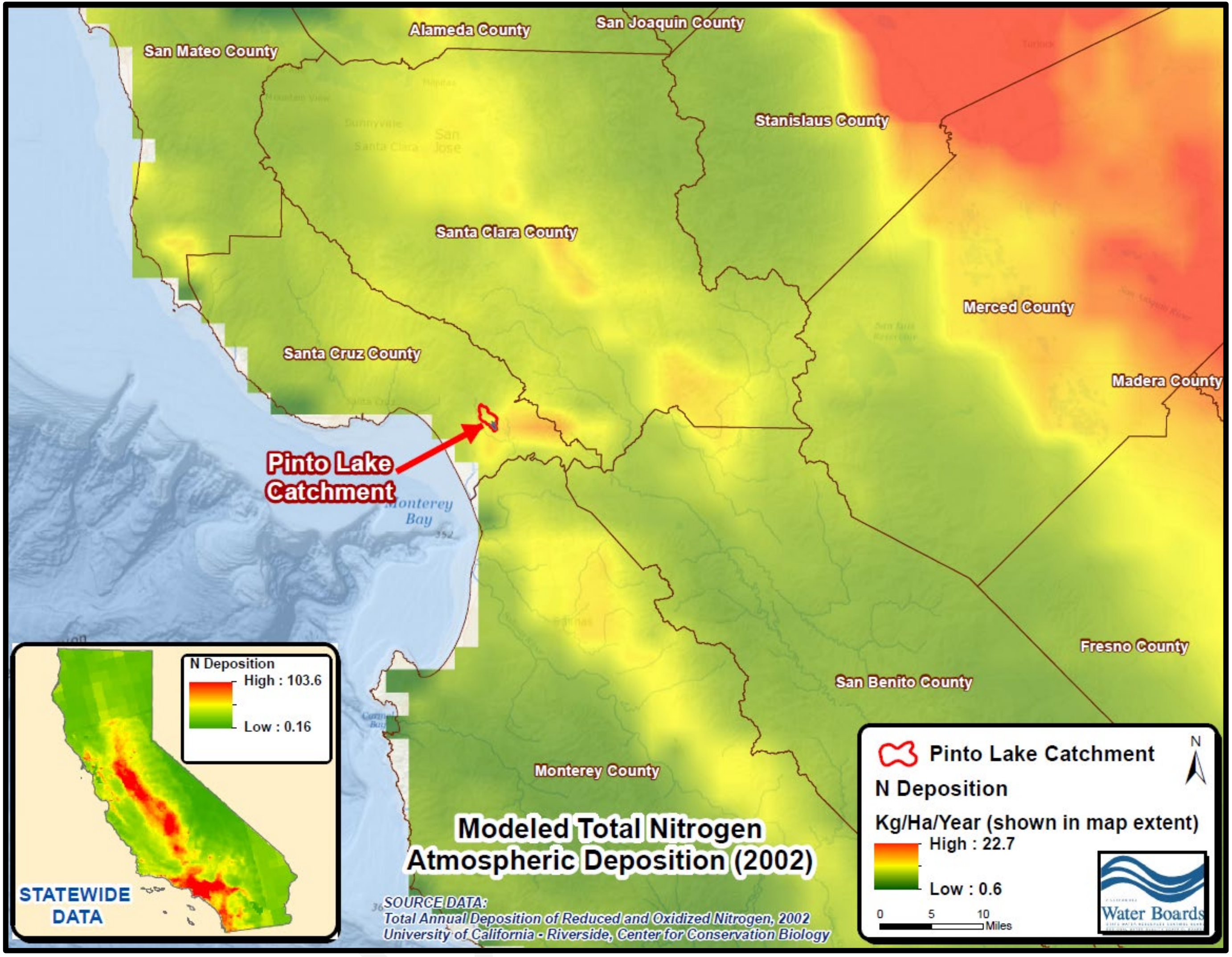
[31] Tonnesen, G., Z. Wang, M. Omary, and C. J. Chien. 2007. University of California-Riverside. Assessment of Nitrogen Deposition: Modeling and Habitat Assessment. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-032.

[32] One hectare is equal to 2.47 acres.

Figure 2-28. Estimated atmospheric deposition of nitrogen as N (units=kg/Ha/year) in the Monterey Bay region and vicinity.



Based on the University of California-Riverside atmospheric deposition model, atmospheric deposition of total nitrogen on Pinto Lake and annual atmospheric nitrogen loading to the lake can be estimated as shown in Text Box 2-4.

Text Box 2-4. Estimated annual atmospheric deposition of total nitrogen to Pinto Lake.

The estimated average annual direct atmospheric deposition of total nitrogen on Pinto Lake is:

9.0 kilograms total nitrogen (N) per hectare per year

Based on spatial geometry calculation in Esri® ArcMap™ 10.3.1, the areal size of Pinto Lake is 42 hectares. Therefore, estimated average annual atmospheric nitrogen (N) load to the lake is:

378 kilograms (833 pounds) of N per year

Atmospheric phosphorus can be found in organic and inorganic dust particles. A general atmospheric deposition rate for total phosphorus has been estimated as 0.6 kg of phosphorus/Ha/year (USEPA 1994, as reported in San Diego Regional Water Quality Control Board, 2006). Accordingly, atmospheric deposition of phosphorus at Pinto Lake, and annual atmospheric phosphorus loading at the lake can be estimated as shown in Text Box 2-5.

Text Box 2-5. Estimated annual atmospheric deposition of phosphorus to Pinto Lake.

The estimated average annual direct atmospheric deposition of phosphorus on Pinto Lake is:

0.6 kilograms phosphorus (P) per hectare per year

Based on spatial geometry calculation in Esri® ArcMap™ 10.3.1, the areal size of Pinto Lake is 42 hectares. Therefore, estimated average annual atmospheric phosphorus (P) load to the lake is:

25 kilograms (55 pounds) of P per year

2.10 Groundwater

Groundwater can be important to consider in TMDL development, and thus we conducted a cursory review of groundwater data for this progress report. Notably, Pinto Lake researchers have previously recognized groundwater as a potential and perhaps important source of nutrient loading to Pinto Lake (Ketley et al., 2013).

TMDLs do not directly address pollution of groundwater. However, TMDL reports can and do consider groundwater-surface water interactions. Groundwaters and surface waters are not closed systems that act independently from each other. Indeed, groundwater inflow to surface waters can be a source of nutrients or salts to any given surface waterbody. The physical interconnectedness of surface waters and groundwater is widely recognized by scientific agencies, researchers, and resource professionals, as highlighted below:

"Traditionally, management of water resources has focused on surface water or ground water as separate entities….Nearly all surface-water features (streams, lakes reservoirs, wetlands, and estuaries) interact with groundwater. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of ground water can degrade surface water. Thus, effective land and water management requires a clear understanding of the linkages between ground water and surface water as it applies to any given hydrologic setting."

➔ U.S. Geological Survey, 1998. Circular 1139: "Groundwater and Surface Water – A Single Resource."

"Although surface water and groundwater appear to be two distinct sources of water, they are not. Surface water and groundwater are basically one singular source of water connected physically in the hydrologic cycle...Effective management requires consideration of both water sources as one resource."

➔ California Department of Water Resources: Relationship between Groundwater and Surface Water (webpage, 2012)

"The popular misconception in U.S. western culture appears to be that groundwater and surface water are two separate sources of water. This bimodal legal approach to managing what is one resource – water – has not resulted in rational water management in California…whether the water is above the land surface or below the land surface, it is the same water. Labeling it "groundwater" or "surface water" is a human construct that represents where the water is at that moment in time. They are not different sources."

➔ Carl Hauge, retired Chief Hydrologist for the California Department of Water Resources, in Groundwater Resources Association of California, web seminar entitled *"No Surface Water = No Groundwater"*, October 2015.

"Surface water and ground water are increasingly viewed as a single resource within linked reservoirs. The movement of water from streams to aquifers and from aquifers to streams influences both the quantity and quality of available water within both reservoirs."

➔ C. Ruehl, A. Fisher, C. Hatch, M. Los Huertos, G. Stemler, and C. Shennan (2006), *Differential gauging and tracer tests resolve seepage fluxes in a strongly-losing stream.* Journal of Hydrology, volume 330, pp. 235-248.

"Groundwater and surface water are intimately connected and should be thought of as a single resource."

➔ Ken Bradbury, State Geologist, Director of Wisconsin Geological & Natural History Survey, in *"Water as One Resource"*, American Geoscience's Institute Critical Issues Webinar Series, July 13, 2015.

> *"…groundwater and surface water are closely interconnected and need to be thought of as one hydrologic system."*
>
> ➔ Tetra Tech, Inc., in *"TMDL Model Evaluation and Research Needs"*, Contract 68-C-04-007, EPA/600/R-05/149, November 2005.

> *"Groundwater-dependent ecosystems (GDEs) are at risk globally due to unsustainable levels of groundwater extraction, especially in arid and semi-arid regions…Over-extraction of groundwater stores can create several problems. These include loss of discharge from groundwater to wetlands, springs and streams/rivers, which results in loss of ecosystem structure and function and the associated loss of ecosystem services…"*
>
> ➔ "Groundwater-dependent ecosystems: recent insights from satellite and field-based studies" (Eamus et al., 2015, Hydrology and Earth System Sciences, 19, pp. 4229-4256.

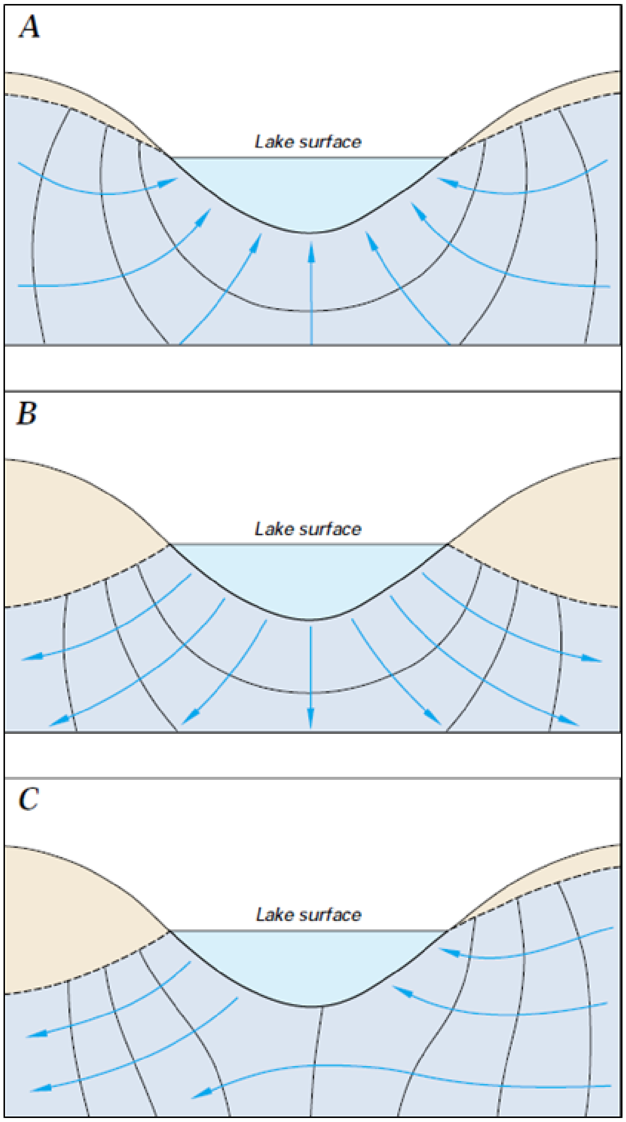
> *"It's a myth that groundwater is separate from surface water and also a myth that it's difficult to legally integrate the two….California's groundwater and surface water are often closely interconnected and sometimes managed jointly."*
>
> ➔ Buzz Thompson, Professor of Natural Resources Law, Stanford University Law School, quoted in *Managing California's Groundwater*, by Gary Pitzer in Western Water January/February 2014, *and* from Public Policy Institute of California, *California Water Myths*, www.ppic.org.

The U.S. Geological Survey has published a clear and concise description about the nature of hydrologic interactions between lakes and groundwater, as highlighted below:

> *"Lakes interact with groundwater in three basic ways: some receive groundwater inflow throughout their entire bed; some have seepage loss to ground water throughout their entire bed; but perhaps most lakes receive groundwater inflow through part of their bed and have seepage loss to ground water through other parts."*
>
> ➔ U.S. Geological Survey, 1998. Circular 1139: "Groundwater and Surface Water – A Single Resource."

Figure 2-29 conceptually illustrates the nature of these hydrologic interactions between lakes and groundwater.

Figure 2-29. Lakes are intimately connected to the groundwater system.



(A) Lake that receives groundwater inflow.

(B) Lake that loses water as seepage to groundwater.

(C) Lake that *receives* groundwater inflow through parts of the lake bed, and *loses* water to seepage to groundwater through other parts of the lake bed.

Figure credits: U.S. Geological Survey Circular 1139 (1998)

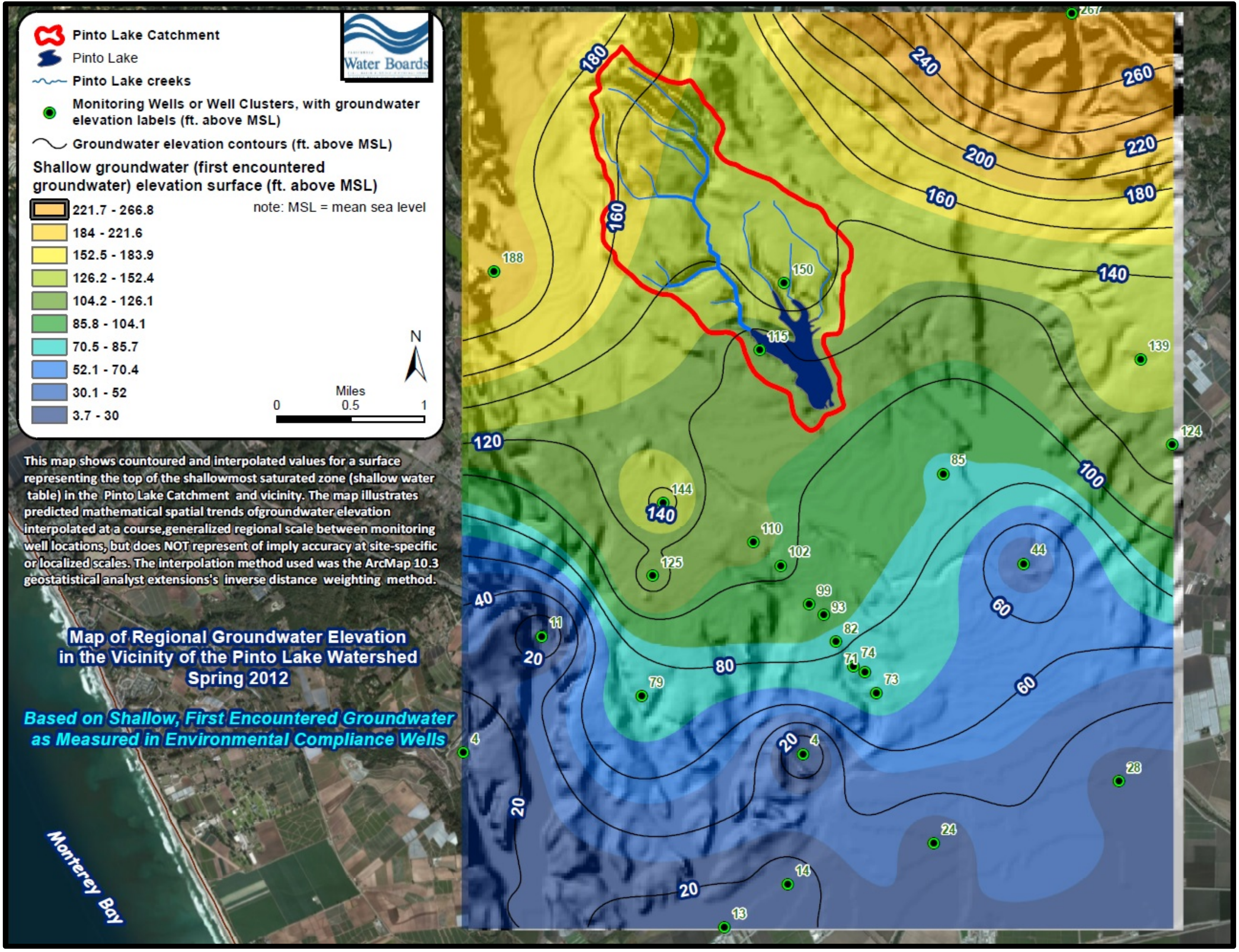
The potential interaction between Pinto Lake and shallow groundwater can be inferred by examining groundwater elevations from wells which tap shallow groundwater. Local groundwater elevations can provide a good starting point for understanding how groundwater interacts with the lake. One of the most reliable sources of information on shallow groundwater is available from environmental compliance well information found in the State Water Board's GeoTracker database. Environmental compliance wells are generally constructed to monitor conditions in first-encountered groundwater, rather than in deeper drinking water supply and irrigation supply aquifers. Therefore, these environmental compliance wells can provide insight into groundwater elevation and hydraulic gradient in the water table of the shallow saturated zone.

Additionally, California State University-Monterey Bay graduate student researchers Scott Blanco and Erin Stanfield provided us limited amounts of shallow groundwater elevation data in areas immediately surrounding Pinto Lake.

All groundwater flows along a hydraulic gradient, which is to say groundwater flows from areas of high hydraulic head (e.g., higher water level elevation) to areas of low head (e.g., low groundwater elevations). Using well construction details and water depth information available from GeoTracker and

California State University researchers, we constructed a shallow groundwater elevation map (Spring 2012) for the Pinto Lake catchment and vicinity (see Figure 2-30) and a shallow groundwater flow direction map (see Figure 2-31).

Figure 2-30. Map of groundwater elevation Spring 2012, Pinto Lake catchment and vicinity, on the basis of shallow, first-encountered groundwater reported in monitoring well data.



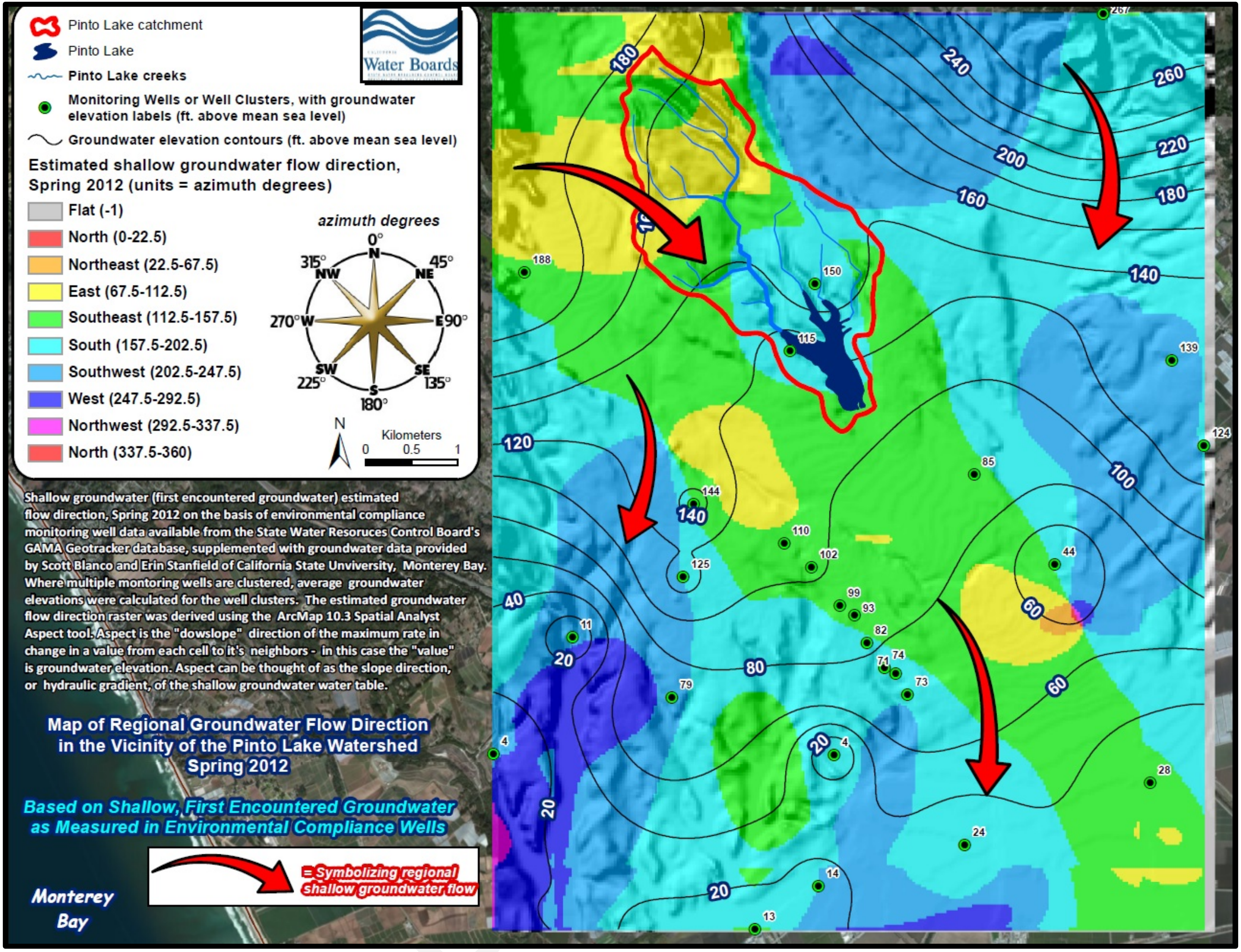
This map shows countoured and interpolated values for a surface representing the top of the shallowmost saturated zone (shallow water table) in the Pinto Lake Catchment and vicinity. The map illustrates predicted mathematical spatial trends ofgroundwater elevation interpolated at a course,generalized regional scale between monitoring well locations, but does NOT represent of imply accuracy at site-specific or localized scales. The interpolation method used was the ArcMap 10.3 geostatistical analyst extensions's inverse distance weighting method.

Map of Regional Groundwater Elevation
in the Vicinity of the Pinto Lake Watershed
Spring 2012

Based on Shallow, First Encountered Groundwater
as Measured in Environmental Compliance Wells

In Spring 2012, shallow groundwater underlying the Pinto Lake catchment and vicinity generally appears to flow in a southeast to south azimuthal direction (see Figure 2-31). Cursory review of groundwater data from previous years suggested a similar, long-term trend of a southeast to south shallow groundwater flow trend in the Pinto Lake catchment. These observations suggest that shallow groundwater flows towards – and potentially into – Pinto Lake generally from the north and northwest. At the south end of Pinto Lake, groundwater appears to be flowing away from the lake towards the southeast (i.e., towards the central axis of the Pajaro Valley groundwater basin). According to the U.S. Geological Survey, this type of shallow groundwater–lake interactions is a common hydrogeologic setting for many lakes (for example, refer back to Figure 2-29, type “C” groundwater– lake interaction on page 59). Specifically, the lake apparently gains groundwater across part of the lakebed, and the lake loses groundwater across other parts of the lakebed.

Figure 2-31. Map of shallow groundwater flow direction Spring 2012, Pinto Lake catchment and vicinity.



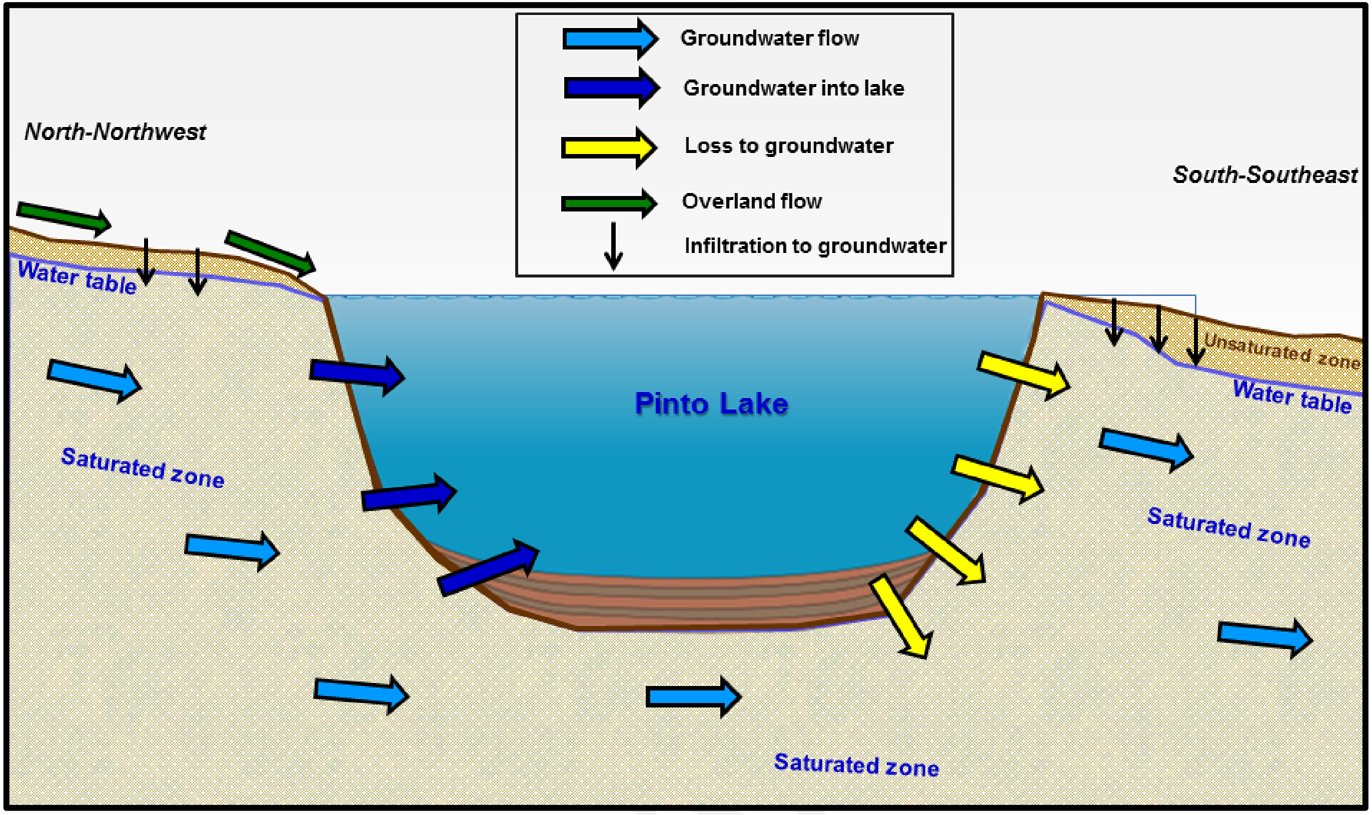
Shallow groundwater (first encountered groundwater) estimated flow direction, Spring 2012 on the basis of environmental compliance monitoring well data available from the State Water Resoruces Control Board's GAMA Geotracker database, supplemented with groundwater data provided by Scott Blanco and Erin Stanfield of California State Unviversity, Monterey Bay. Where multiple montoring wells are clustered, average groundwater elevations were calculated for the well clusters. The estimated groundwater flow direction raster was derived using the ArcMap 10.3 Spatial Analyst Aspect tool. Aspect is the "dowslope" direction of the maximum rate in change in a value from each cell to it's neighbors - in this case the "value" is groundwater elevation. Aspect can be thought of as the slope direction, or hydraulic gradient, of the shallow groundwater water table.

Map of Regional Groundwater Flow Direction in the Vicinity of the Pinto Lake Watershed Spring 2012

Based on Shallow, First Encountered Groundwater as Measured in Environmental Compliance Wells

Based on the observed groundwater elevation data, we believe that towards the northern side of the lake groundwater flows into the lake for much of the year while the southern parts of the lake typically lose lake water to groundwater (refer to Figure 2-32). Undoubtedly, there are transitional areas across the lakebed, where there is groundwater inflow parts of the year or seasonally, and lake water is lost to groundwater other parts of the year.

Figure 2-32. Conceptual understanding of generalized groundwater interaction with Pinto Lake.



It is worth nothing that a composite groundwater map for groundwater elevation observations from the fall of 2010, published by the Pacific Institute, also indicates a hydraulic gradient (groundwater flow) towards the southeast and south in the vicinity of Pinto Lake (Pacific Institute, undated report). Hydraulic gradients shown on composite groundwater maps are not necessarily directly comparable to our estimates of hydraulic gradient of first-encountered, shallow groundwater – however, the Pacific Institute reporting does add some measure of confidence to our estimate of groundwater hydraulic gradient in the Pinto Lake catchment.

It should be noted that our estimates of hydraulic gradients (flow direction) for shallow groundwater discussed above are only an approximation of subsurface, shallow groundwater conditions. The hydraulic gradient illustrated in Figure 2-30 and Figure 2-31 represents a mathematical spatial trend of groundwater elevations interpolated at a coarse, regional scale between observations from a limited number of monitoring sites, but does not represent or imply accuracy at localized, site-specific scales. Site-specific groundwater hydraulic gradients (flow directions) may vary due to factors such as groundwater pumping, artificial recharge, and local hydrogeologic conditions.

Estimated nitrate as N concentrations in shallow, recently-recharged groundwater are available from the U.S. Geological Survey. Figure 2-33 illustrates estimated nitrate as nitrogen concentration in project area shallow, recently-recharged groundwater in the Pajaro Valley and vicinity (data source: U.S. Geological Survey GWAVA model[33]). Shallow, recently recharged groundwater is defined by the U.S. Geological Survey in the GWAVA dataset as groundwaters less than 5 meters below ground surface. Table 2-16 presents numerical summaries of the predicted nitrate concentrations in shallow groundwater hydraulically upgradient of Pinto Lake. These shallow groundwaters are predicted to have relatively low average nitrate as N concentrations (3.65 mg/L mean and 1.36 mg/L median), with a range of predicted nitrate as N concentrations of 0.05 to 13.47 mg/L.

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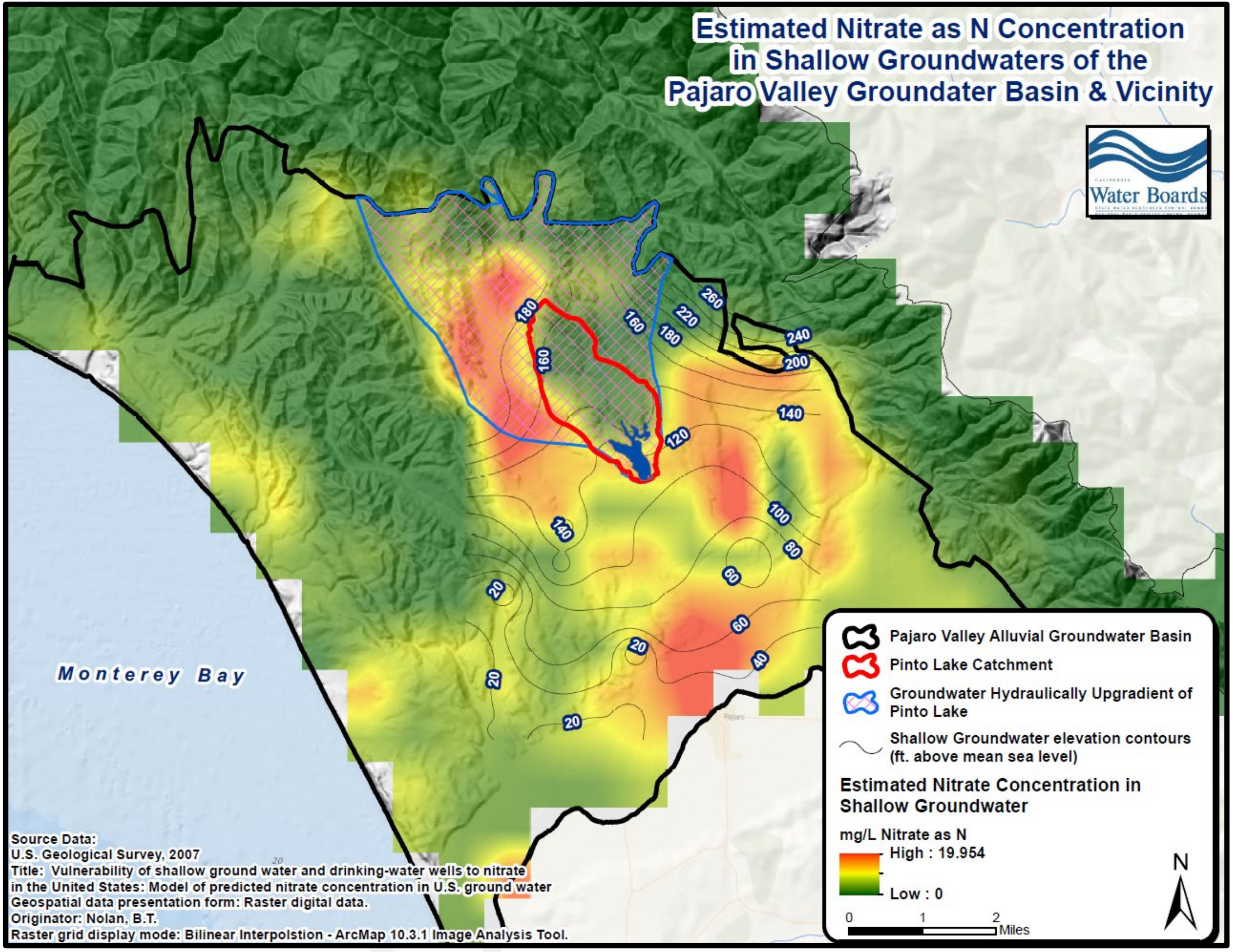
[33] The GWAVA dataset represents predicted nitrate concentration in shallow, recently recharged groundwater in the conterminous United States, and was generated by a national nonlinear regression model based on 14 input parameters.

Figure 2-33. Map illustrating estimated nitrate as N concentrations in shallow groundwater of the Pajaro Valley groundwater basin, and shallow groundwater hydraulically upgradient from Pinto Lake.



Source Data:
U.S. Geological Survey, 2007
Title: Vulnerability of shallow ground water and drinking-water wells to nitrate in the United States: Model of predicted nitrate concentration in U.S. ground water
Geospatial data presentation form: Raster digital data.
Originator: Nolan, B.T.
Raster grid display mode: Bilinear Interpolstion - ArcMap 10.3.1 Image Analysis Tool.

Table 2-16. Summary statistics for predicted nitrate concentrations (mg/L as N) in shallow, recently-recharged groundwater upgradient of Pinto Lake (refer back to Figure 2-33 for illustration of upgradient groundwater area).

Groundwater Model	Groundwater Body	Arithmetic Mean	Minimum	50% (median)	Maximum	Standard Deviation
GWAVA-S[A]	Shallow groundwater upgradient of Pinto Lake	3.65	0.05	1.36	13.47	4.07

[A] U.S. Geological Survey, 2007. Vulnerability of shallow ground water and drinking-water wells to nitrate in the United States: Model of predicted nitrate concentration in shallow, recently recharged groundwater The GWAVA-S model predicts nitrate concentrations of shallow (typically less than five meters below ground surface), recently recharged groundwater, based on the work of Nolan and Hitt (2006).

2.11 Geology

Geology can have a significant influence on natural, background concentrations of nutrients and other inorganic constituents in surface waters. The linkage between geologic conditions and surface water chemistry has long been recognized (for example, U.S. Geological Survey, 1910 and U.S. Geological

Survey, 1985). Stein and Kyonga-Yoon (2007) reported that catchment geology was the most influential environmental factor on water quality variability from undeveloped stream reaches in lightly-disturbed, natural areas located in Ventura, Los Angeles, and Orange counties, California. Stein and Kyonga-Yoon (2007) concluded that catchments underlain by sedimentary rock had higher stream flow concentrations of metals, nutrients, and total suspended solids, as compared to areas underlain by igneous rock.

Additionally, the Utah Geological Survey hypothesized that organic-rich marine sedimentary rocks in the Cedar Valley of southern Utah may locally contribute to elevated nitrate observed in groundwater (Utah Geological Survey, 2001). Nitrogen found in the organic material of these rock strata are presumed by the Utah Geological Survey researchers to be capable of oxidizing to nitrate and may subsequently leach to groundwater.

Further, the Las Virgenes Municipal Water District (LVMWD, 2012) recently reported that high background levels of biostimulatory substances (nitrogen and phosphate) in the Malibu Creek Watershed appear to be associated with exposures of the Monterey/Modelo Formation. Also worth noting, Domagalski (2013) states that knowledge about natural and geologic sources of phosphorus in watersheds are important for developing nutrient management strategies.

Consequently, in evaluating the effect of anthropogenic activities on nutrient loading to waterbodies in a TMDL project, it is important to also consider the potential impact on nutrient water quality which might result from local geology.

Central Coast Water Board staff conducted a brief and cursory review of geologic data for this report. Figure 2-34 presents an illustration of the geology of the Pinto Lake catchment and vicinity. Riparian creek corridors in the lake catchment are characterized by fine-grained Holocene[34] alluvium[35], while surficial geologic materials located outside the riparian corridors and in the uplands of the lake catchment are characterized by older, late Pleistocene[36] alluvium. At this time, we do not have analytical data for the phosphorus content of this alluvium.

A map of surficial geologic materials, derived from soils mapping programs, is presented in Figure 2-35.

Phosphorus-prone geologic materials may be associated with Upper Tertiary (Miocene) mudstones of the Santa Cruz mountains (geologic unit number 500, as illustrated on Figure 2-34). Whether or not detrital materials from these Miocene mudstones were ever deposited in the Pinto Lake catchment is uncertain. There is currently no direct surface water hydrologic connection between the lake catchment and Miocene strata of the Santa Cruz mountains. It is possible that historical hydrologic connectivity existed between the lake catchment and the Miocene strata of the Santa Cruz mountains during flood stages, or due to migrations and changes in depositional patterns and stream networks in the recent geologic past.

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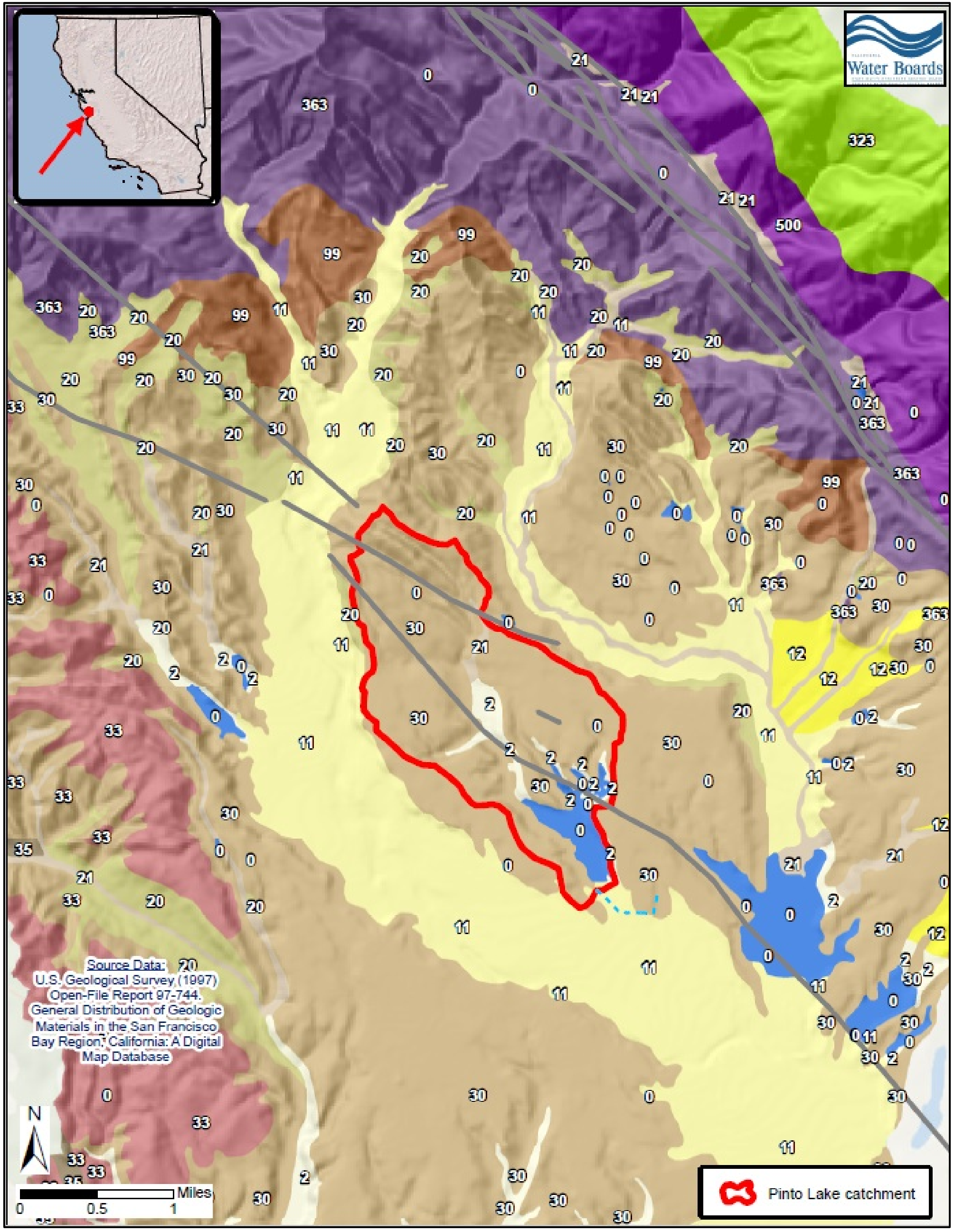
[34] The Holocene is a geologic epoch which began 11,700 years ago at the end of the Pleistocene epoch and includes the present day. Thus, Holocene geologic materials include sediments and detrital matter that are currently being deposited on the land surface by air and water, as well as materials that have been deposited in the very recent geologic past.

[35] Sedimentary material deposited by rivers and streams is commonly referred to as alluvium, or alluvial deposits.

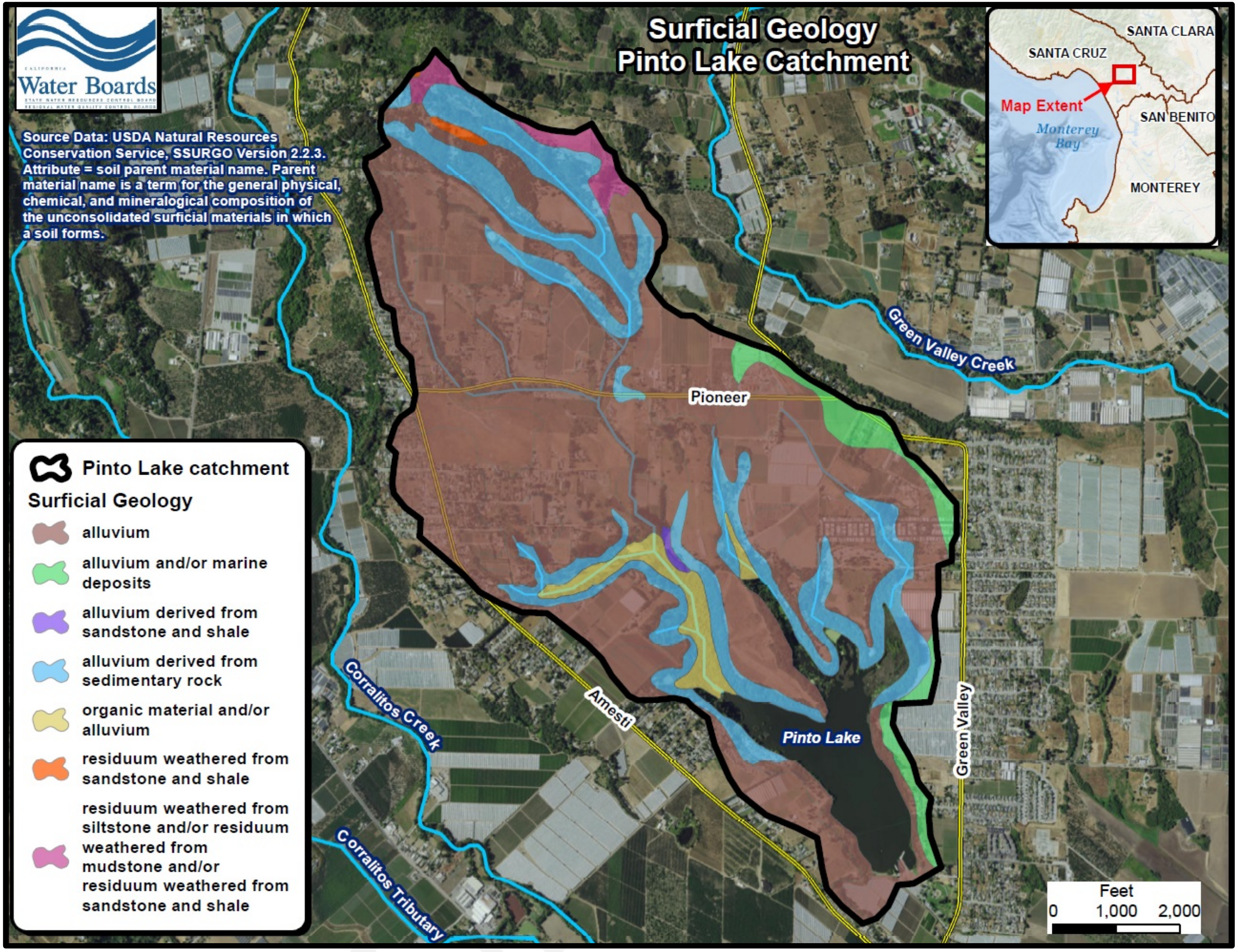
[36] The Pleistocene epoch is a relatively young geologic era which lasted from about 2.6 million years ago to 11,700 years ago.

Figure 2-34. Map of geologic units in the Pinto Lake catchment and vicinity.



Source Data:
U.S. Geological Survey (1997)
Open-File Report 97-744.
General Distribution of Geologic
Materials in the San Francisco
Bay Region, California: A Digital
Map Database

Figure 2-35. Map of surficial geology in the Pinto Lake catchment.



Estimates of the average percentage of phosphorus and nitrogen in soils of the Pinto Lake catchment can be derived using geochemical data published by the U.S. Geological Survey (2014). This geochemical dataset compiles estimates of the percentage of lithologic phosphorus (phosphorus pentoxide) and of lithologic nitrogen in surface or near-surface geologic materials in the conterminous United States. Consequently, we derived phosphorus and nitrogen estimates for the Monterey Bay region and for Pinto Lake catchment as follows.

Figure 2-36 and Figure 2-37 present maps of average percent phosphorus and average percent nitrogen respectively, in surface and near surface geologic materials of the Monterey Bay region.

Table 2-17 presents the estimated average phosphorus and nitrogen (%) in surficial geologic materials of the Pinto Lake catchment.

Figure 2-36. Map of percentage of phosphorus pentoxide (P_2O_5) in surface and near-surface geologic materials of the Monterey Bay region.

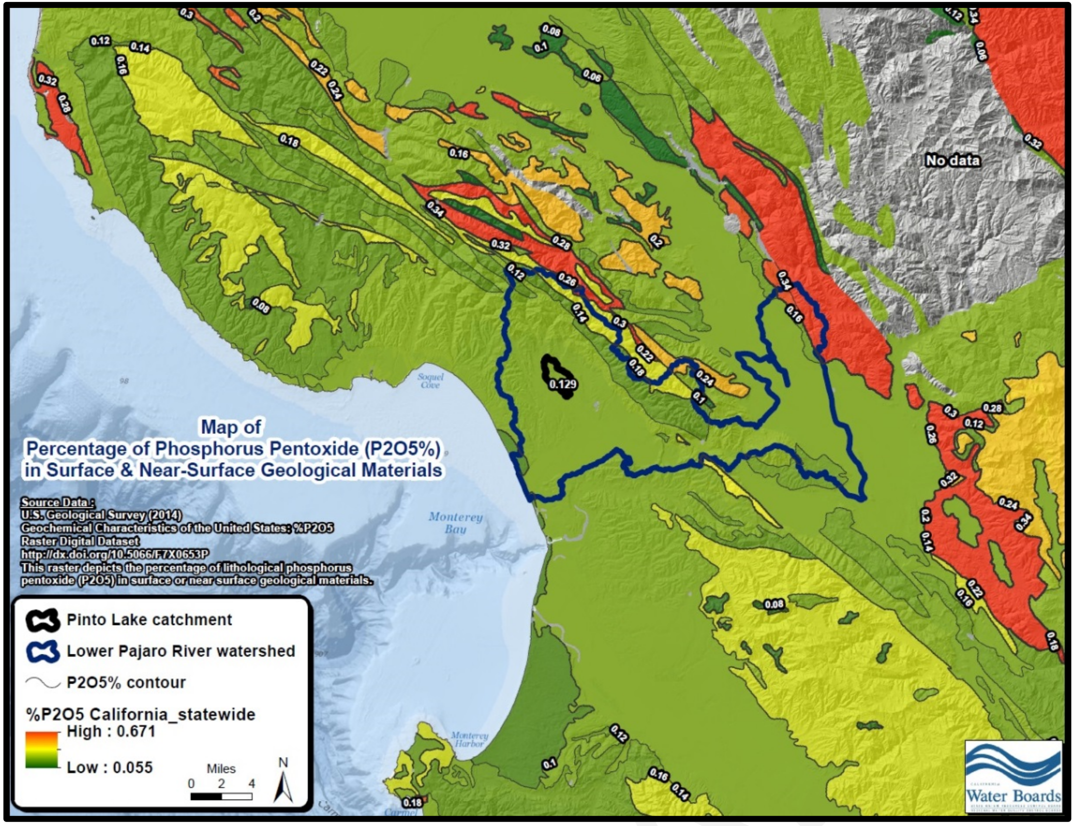


Figure 2-37. Map of estimated percentage of nitrogen (N) in surface and near-surface geologic materials of the Monterey Bay region.

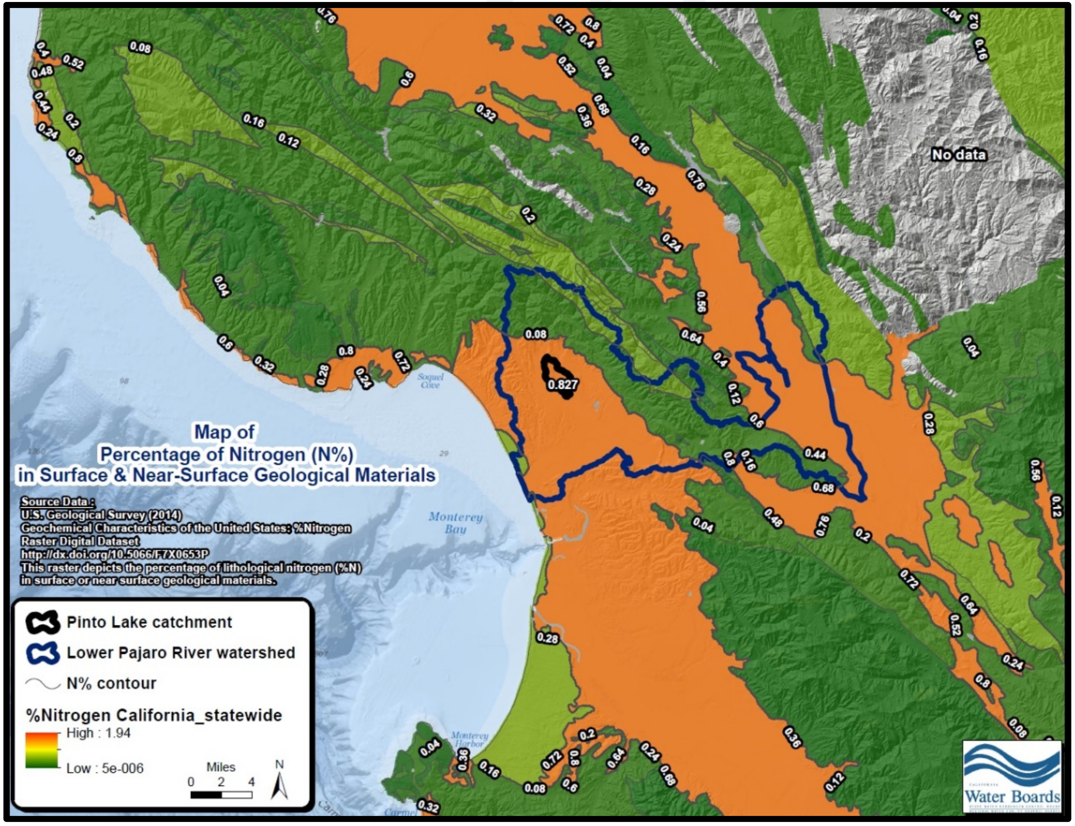


Table 2-17. Estimated average percent phosphorus and nitrogen in surface and near-surface geologic materials of the Pinto Lake catchment. These estimates are derived from the maps previously shown in Figure 2-36 and Figure 2-37

	Average percent phosphorus (estimated) [A]	**Average percent nitrogen (estimated)** [A]
Surface and near-surface geologic materials of the Pinto Lake catchment	0.06% [B]	0.83%

[A] Source data: Olson, J.R. and Hawkins, C.P., 2014, Geochemical Characteristics of the Conterminous United States: U.S. Geological Survey data release

[B] Molecular P_2O_5 can be converted to elemental phosphorus (P) by multiplying P_2O_5 by 0.4364.

Based on the available data, there is no direct evidence of phosphorus-enriched rocks and geologic materials occurring in that currently drain towards the Pinto Lake catchment. It is important to recognize that hydrologic drainage patterns can change over the course of centuries and millennia so it is possible that at one time in the recent geologic past, areas containing phosphatic rocks in the Santa Cruz Mountains drained towards the Pinto Lake catchment.

2.12 Soils

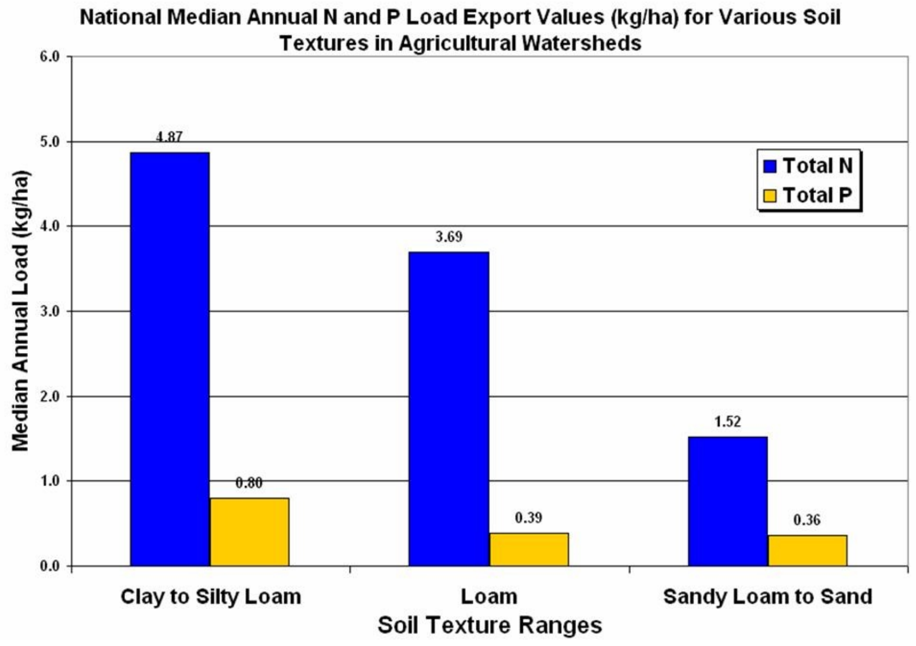
> *"Phosphorus is largely retained in soil by a process called adsorption.* ***Soils have a limited capacity to store phosphorus****, and once the capacity of soil to adsorb phosphorus is exceeded,* ***the excess will dissolve and move more freely with water*** *either directly to a stream or downward to an aquifer. Surface-water runoff from rainstorms or excess irrigation is the primary way that phosphorus or soil containing phosphorus is transported to streams in most watersheds."*
>
> ➔ U.S. Geological Survey, National Water Quality Assessment Program (2012), Fact Sheet 2012-3004. emphasis added by Central Coast Water Board staff

In general, harmful algal bloom problems in lakes nationwide are due to phosphorus. There are a few nitrogen-limited lakes in the nation, but most lake management programs across the United States focus on phosphorus control (personal communication January 2017, Dr. John C. Holz, limnologist at HAB Aquatic Solutions, LLC). As such, it is necessary to consider the fate and transport of phosphorus in watersheds in the context of soils and sediments. Transport and fate of phosphorus in watersheds is associated with soil geochemistry and sediment transport. Soils have physical and hydrologic characteristics, which may have a significant influence on the transport and fate of phosphorus and nitrogen.

Watershed researchers and TMDL projects often assess soil characteristics in conjunction with other physical watershed parameters to estimate the risk and magnitude of nutrient loading to waterbodies (Mitsova-Boneva and Wang, 2008; McMahon and Roessler, 2002; Kellog et al., 2006).

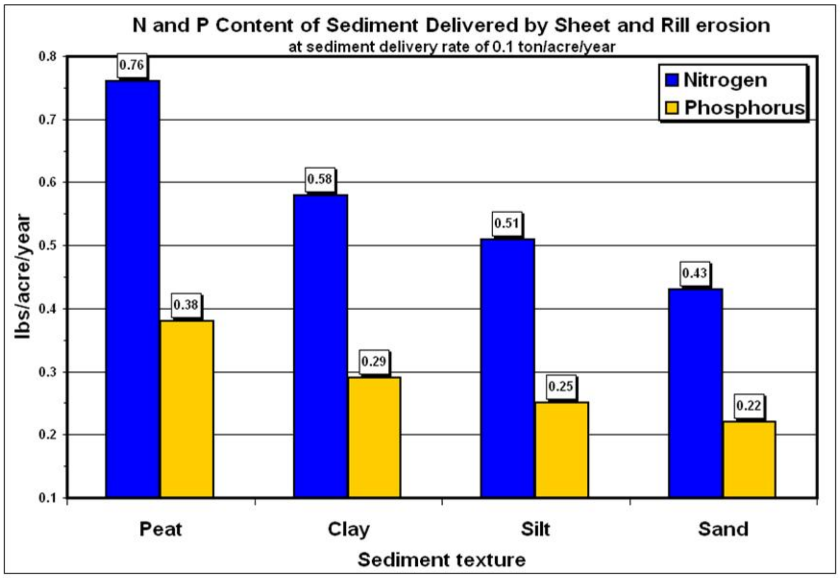
The relationship between nutrient export (loads) and soil texture is illustrated in Figure 2-38 and Figure 2-39. Generally, fine-textured soils with lower capacity for infiltration of precipitation/water are more prone to runoff and are consequently typically associated with a higher risk of phosphorus and nitrogen loads to surface waters.

Figure 2-38. Median annual total nitrogen and total phosphorus (N and P) export for various soil textures.



Data Source: Measured Annual Nutrient loads from Agricultural Environments" (MANAGE) database - US. Dept. of Agriculture

Figure 2-39. Nitrogen and phosphorus (N and P) content of sediment delivered by sheet and rill erosion.



Data source: Derived from AGNPS equations in Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson, 1987. AGNPS, Agricultural –Non-Point-Source Pollution Model; A Large Watershed Analysis Tool. U.S. Department of Agriculture – Agriculture Res. Serv., Conservation Resource Report 35 – and reported in *"Pollutants Controlled Calculation And Documentation For Section 319 Watersheds Training Manual, Michigan Department of Environmental Quality.*

Sediments and soils of the Pinto Lake catchment are generally expected to have relatively high phosphorus content compared to most ambient background soil conditions in California, and are higher in phosphorus relative to most soils sampled within the conterminous United States. Table 2-18 presents statistical summaries of phosphorus concentrations in soils in the United States.

Table 2-18. Statistical summaries of phosphorus concentrations soils in the conterminous United States; in the Oak and Chaparral Ecoregion of central California; and in the Pinto Lake catchment. Units = mg/kg.

Soil Dataset	**Mean**	**Min.**	**10th %**	**25th %**	**50th % (median)**	**75th %**	**90th %**	**Max.**	**Number of Samples**
Natural background concentrations of phosphorus in California soils (Kearney Soil Dataset)[A]									
Composite of all California Samples	412	13	73	199	360	555	776	1,210	50
Composite of California Oak & Chaparral Ecoregion Samples	421	82	195	309	378	487	602	1,210	17
U.S. Geological Survey National Soil Dataset –phosphorus concentrations in soil horizon A [B]									
Composite of All United States Samples (0-50cm)	626	trace	170	330	550	800	1,140	7,650	4857
Composite of All California Oak & Chaparral Ecoregion Samples (0-40cm)	664	170	240	340	530	910	1,090	2,210	41
Pinto Lake Sediment Core Data –phosphorus concentrations [C]									
Composite of all samples	1,278	491	600	711	1237	1,792	2,010	2,346	16
Pinto Creek (0-20cm)	633	491	504	523	600	710	789	842	4
Pinto Lake Abyss (0-20cm)	1,785	1,641	1,671	1,717	1,755	1,823	1,924	1,991	4
Pinto Lake Point (0-20cm)	1,968	1,631	1,702	1,809	1,948	2,108	2,251	2,346	4
Todos Santos (0-20cm)	725	708	709	711	717	731	748	759	4

[A] Kearney Foundation of Soil Science, Division of Agriculture and Natural Resources, University of California, 1996. Special Report: Background Concentrations of Trace and Major Elements in California Soil.

[B] U.S. Geological Survey, 2013. Data Series 801: Geochemical and Mineralogical Data for Soils of the Conterminous United States.

[C] City of Watsonville, Pinto Lake sediment core samples – unpublished data October 2014.

We compiled available data for sediment and soil phosphorus concentration for the Pinto Lake catchment and for the Monterey Bay region. These spatial data and analytical data are presented in Figure 2-40 through Figure 2-42 and in Table 2-19.

Figure 2-40. Pinto Lake sediment core sampling locations. (City of Watsonville, unpublished data, October 2014).

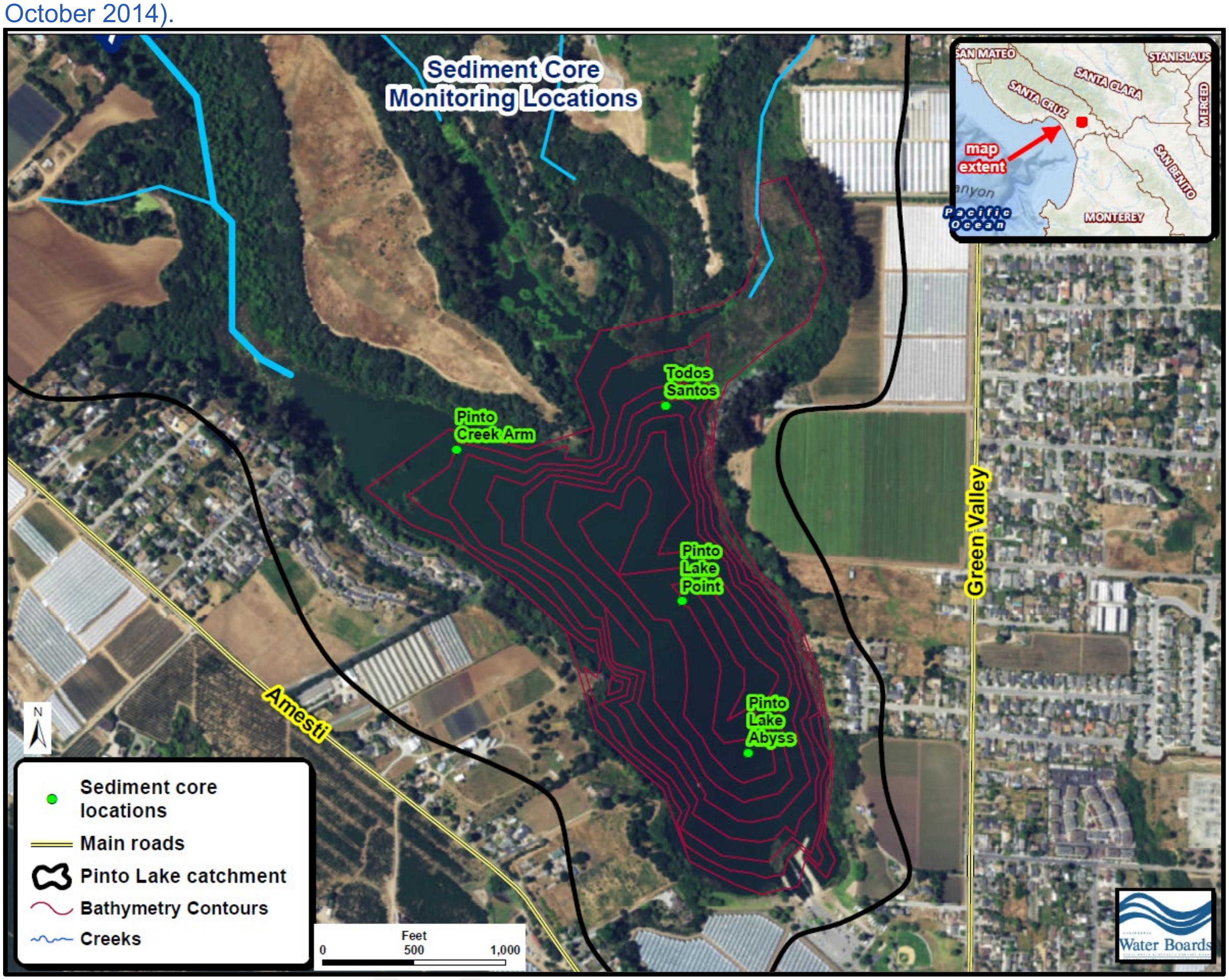
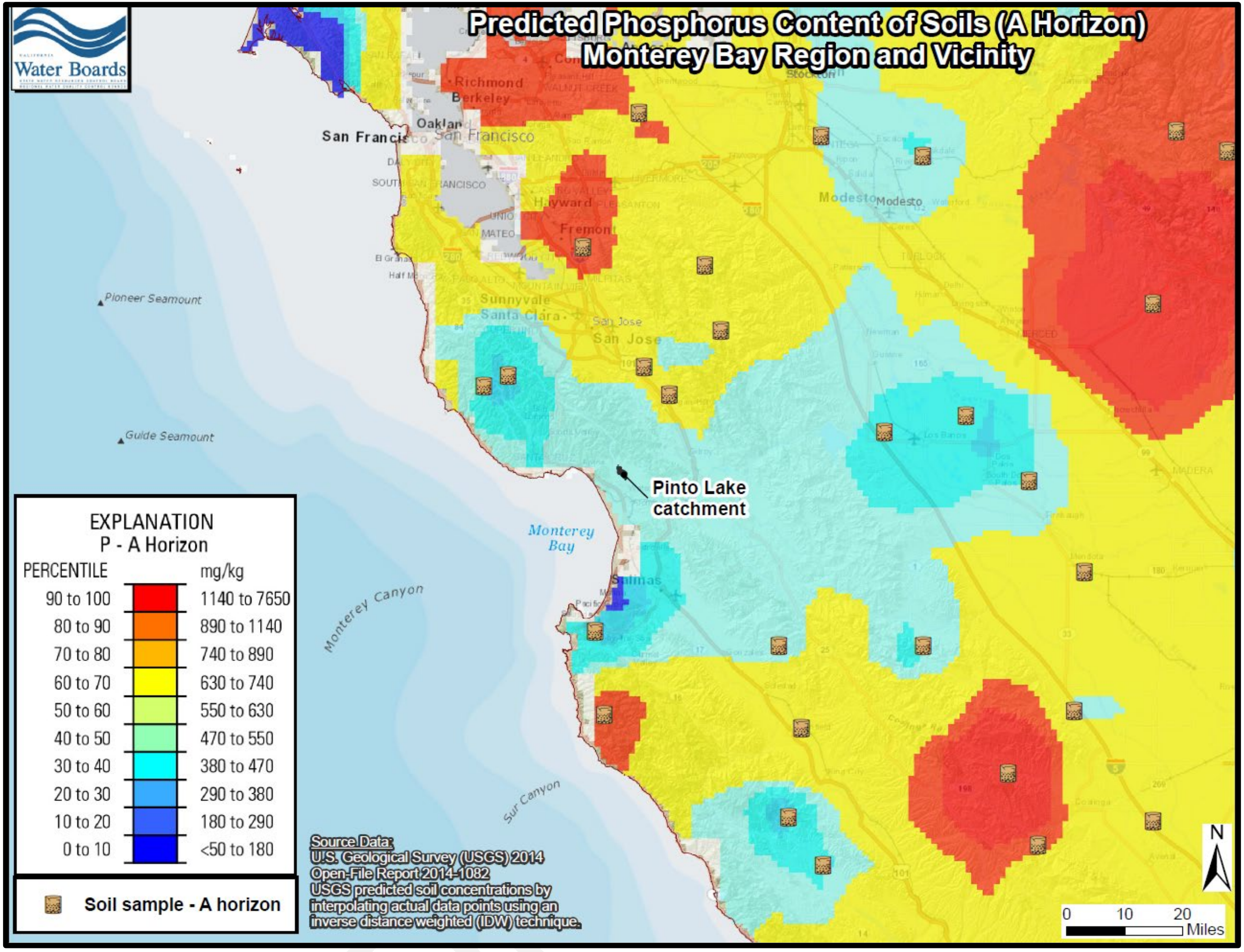
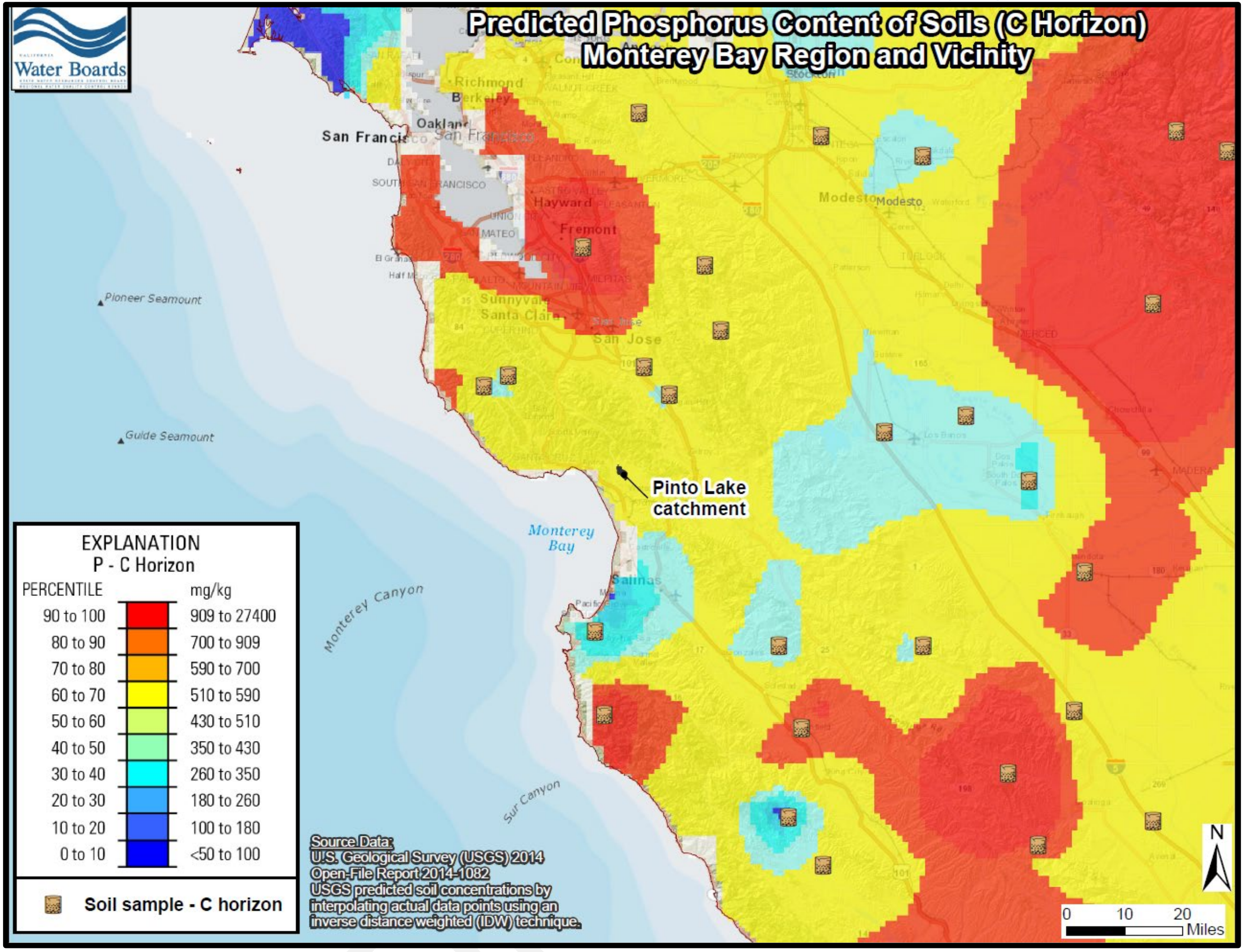


Figure 2-41. Estimated phosphorus content in A horizon soils of the Monterey Bay region and vicinity.



Source Data:
U.S. Geological Survey (USGS) 2014
Open-File Report 2014-1082
USGS predicted soil concentrations by interpolating actual data points using an inverse distance weighted (IDW) technique.

Figure 2-42. Estimated phosphorus content in C horizon soils of the Monterey Bay region and vicinity



Source Data:
U.S. Geological Survey (USGS) 2014
Open-File Report 2014-1082
USGS predicted soil concentrations by interpolating actual data points using an inverse distance weighted (IDW) technique.

Table 2-19. Phosphorus data reported for sediment cores in the Pinto Lake catchment.

	Total Phosphorus	Soluble and labile P				Non-labile P			Fraction labile / non-labile P	
		Forms of phosphorus relatively available to plants				Insoluble or slowly soluble forms of phosphorus (relatively unavailable to plants)				
Sample ID (cm)	Total Phosphorus (mg/kg)	Loosely Bound Phosphorus (mg/kg)	Organic Phosphorus (mg/kg)	Iron Bound Phosphorus (mg/kg)	**Total (mg/kg)**	Aluminum Bound Phosphorus (mg/kg)	Calcium Bound Phosphorus (mg/kg)	Total (mg/kg)	% labile P	% non-labile P
Pinto Creek Arm 0-5	491	<2.00	98.8	27.3	127.1	246	118	364	26%	74%
Pinto Creek Arm 6-10	534	<2.00	65.3	42.9	109.2	338	87.0	425	20%	80%

	Total Phosphorus	Soluble and labile P				Non-labile P			Fraction labile / non-labile P	
		Forms of phosphorus relatively available to plants				Insoluble or slowly soluble forms of phosphorus (relatively unavailable to plants)				
Pinto Creek Arm 11-15	666	<2.00	74.0	32.8	107.8	469	89.8	559	16%	84%
Pinto Creek Arm 16-20	842	<2.00	65.2	42.9	109.1	661	72.2	733	13%	87%
Todos Santos 0-5	759	<2.00	116	127	244.0	452	64.3	516	32%	68%
Todos Santos 6-10	721	<2.00	99.4	63.9	164.3	497	61.1	558	23%	
Todos Santos 11-15	708	<2.00	106	44.9	151.9	488	69.6	558	21%	
Todos Santos 16-20	712	<2.00	81.1	101	183.1	459	71.6	531	26%	

Figure 2-43 illustrates a box and whisker plot[37] of phosphorus concentrations in soils. Box and whisker plots are a graphical way of representing data dispersion. In this box plot, soils are grouped into three categories: 1) soil samples representing ambient, natural background conditions in California Ecoregion III-6[38]; 2) soils samples representing all observed soil conditions in sampling conducted by the U.S. Geological Survey in California Ecoregion III-6; and 3) sediment samples collected in the Pinto Lake catchment. In general, the box plots illustrate that phosphorus is higher in sediments from Pinto Lake catchment than phosphorus concentrations found more typically in sediment samples collected from across California Ecoregion III-6." The data suggests that the Pinto Lake catchment locally has soils and sediment that are relatively high in phosphorus.

It should be noted that adsorbed phosphorus exists in soil in several phases; phosphorus may be bound to iron oxides, calcium oxides, and/or aluminum oxides. In general, calcium and aluminum bound phosphorus is insoluble. Iron bound phosphorus can be soluble depending on redox geochemical

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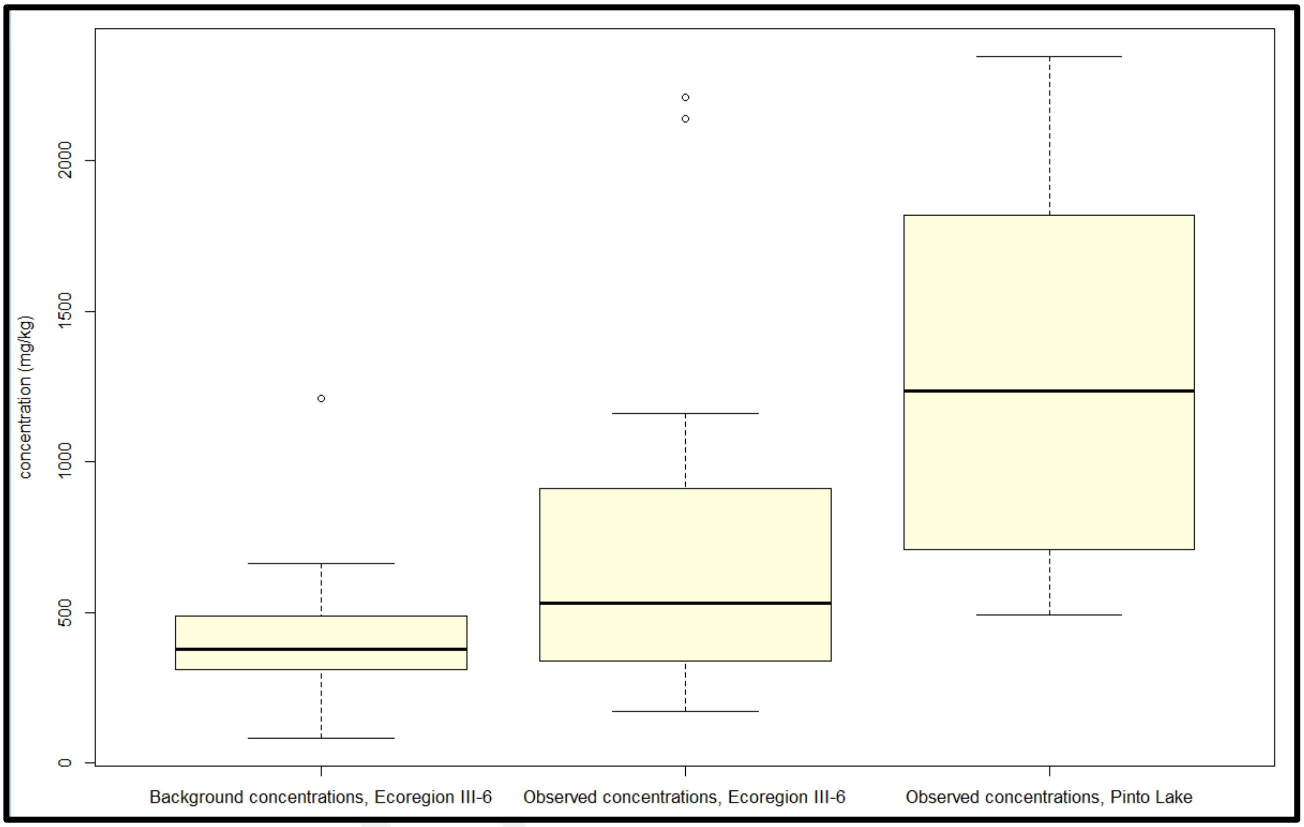
[37] Statistical distributions can be represented as box plots. For more information on the nature and utility of box plots please refer to: http://en.wikipedia.org/wiki/Box_plot.

[38] Ecoregions are geographic areas with ecosystems that are generally similar physically, biologically, and climatologically. Ecoregion III-6 is a USEPA designation that refers to chaparral and oak woodland ecosystems of southern and central California, including much of the central coast region as well as chaparral and oak woodland ecosystems of the Sierra Nevada foothills. In this case, staff also included the Santa Cruz mountains geographically in our analysis; these mountains are technically in a different ecoregion, but were included here due to their proximity with the Pinto Lake catchment.

conditions in the soil, and is therefore the adsorbed phase of phosphorus most at risk of becoming mobile in water. According to Dr. John C. Holz, limnologist at HAB Aquatic Solutions, LLC, iron bound phosphorus in the Pinto Lake catchment is relatively high compared to other watersheds he is aware of (oral communication, January 2017).

Figure 2-43. Box plot illustrating phosphorus concentration variation in soils of USEPA Ecoregion III-6 (central California oak and chaparral ecoregion) as compared to phosphorus concentrations in the Pinto Lake catchment sediments. Summary statistics for information in this boxplot were previously presented in Table 2-18.



Soil data for the Pinto Lake catchment are available from the U.S. Department of Agriculture National Resources Conservation Service's Soil Survey Geographic (SSURGO) database. Soils attributes available in the SSURGO database include many soil attributes that can be important in farming, resource management, erosion, land management, and water quality. It should be noted that many SSURGO soil attributes are based on county-level and regional soil survey mapping, and thus site-specific and localized soil variation can be expected.

Various soil attributes that might be assessed in the context of TMDL development, or in the context of resource protection, land management, and water quality, are presented in Figure 2-44 through Figure 2-50. In general, the SSURGO data indicate that large parts of the Pinto Lake catchment have soils with slow infiltration rates and which are relatively susceptible to erosion. If merited, a closer evaluation of soil attributes could occur as TMDL development progresses.

Also worth noting, some areas in and around the Pinto Lake catchment are characterized by shallow (~two feet below ground surface) clay hardpan layers (see Figure 2-50). These subsurface conditions can cause perched groundwater horizons and horizontal flow of shallow perched groundwater (personal communication Richard Casale, District Conservationist, U.S. Dept. of Agriculture Natural Resources Conservation Service, July 22, 2014). This type of shallow groundwater lateral flow therefore has the potential to result in hydraulic communication locally with surface waterbodies.

Figure 2-44. Map of soil units in the Pinto Lake catchment.

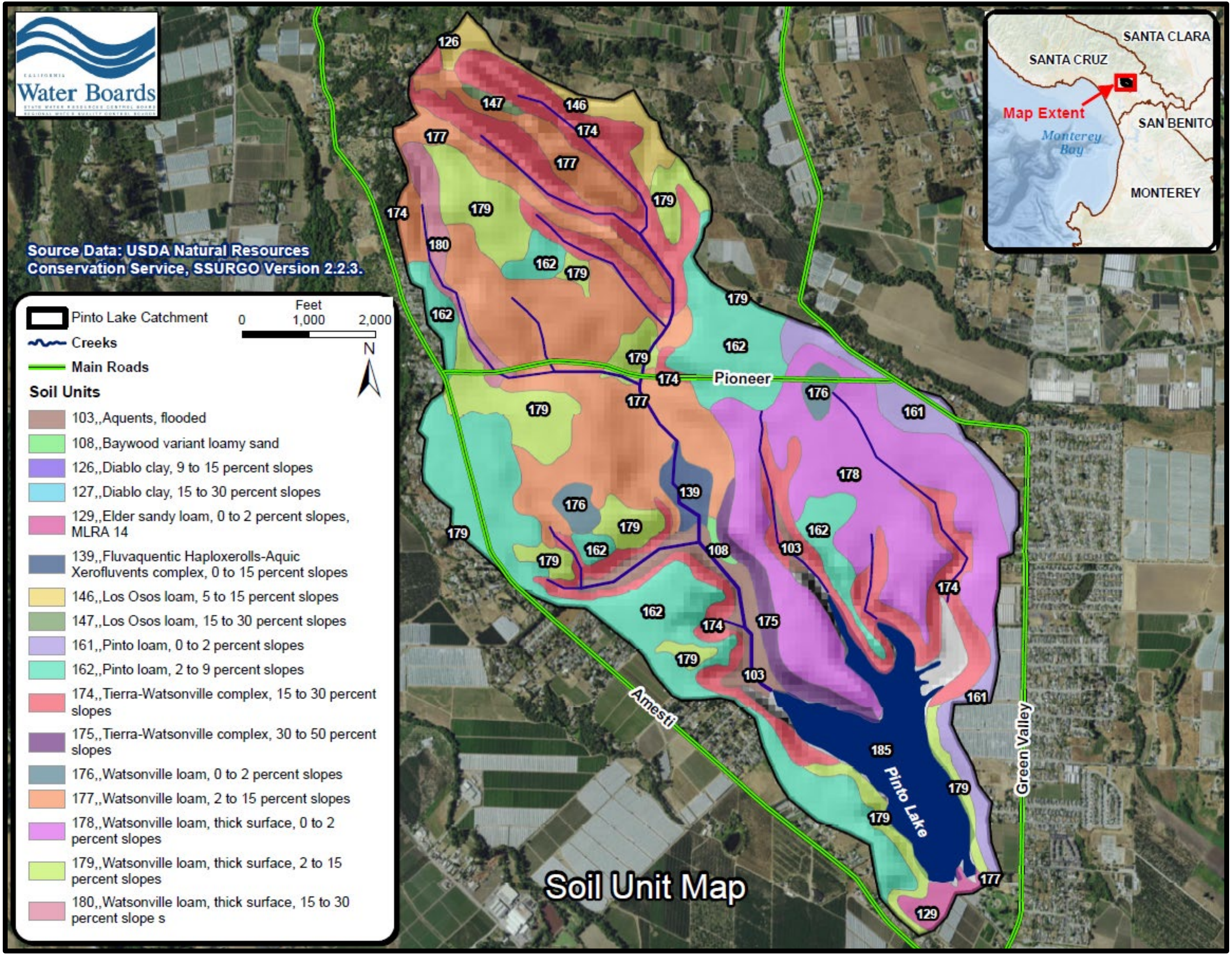
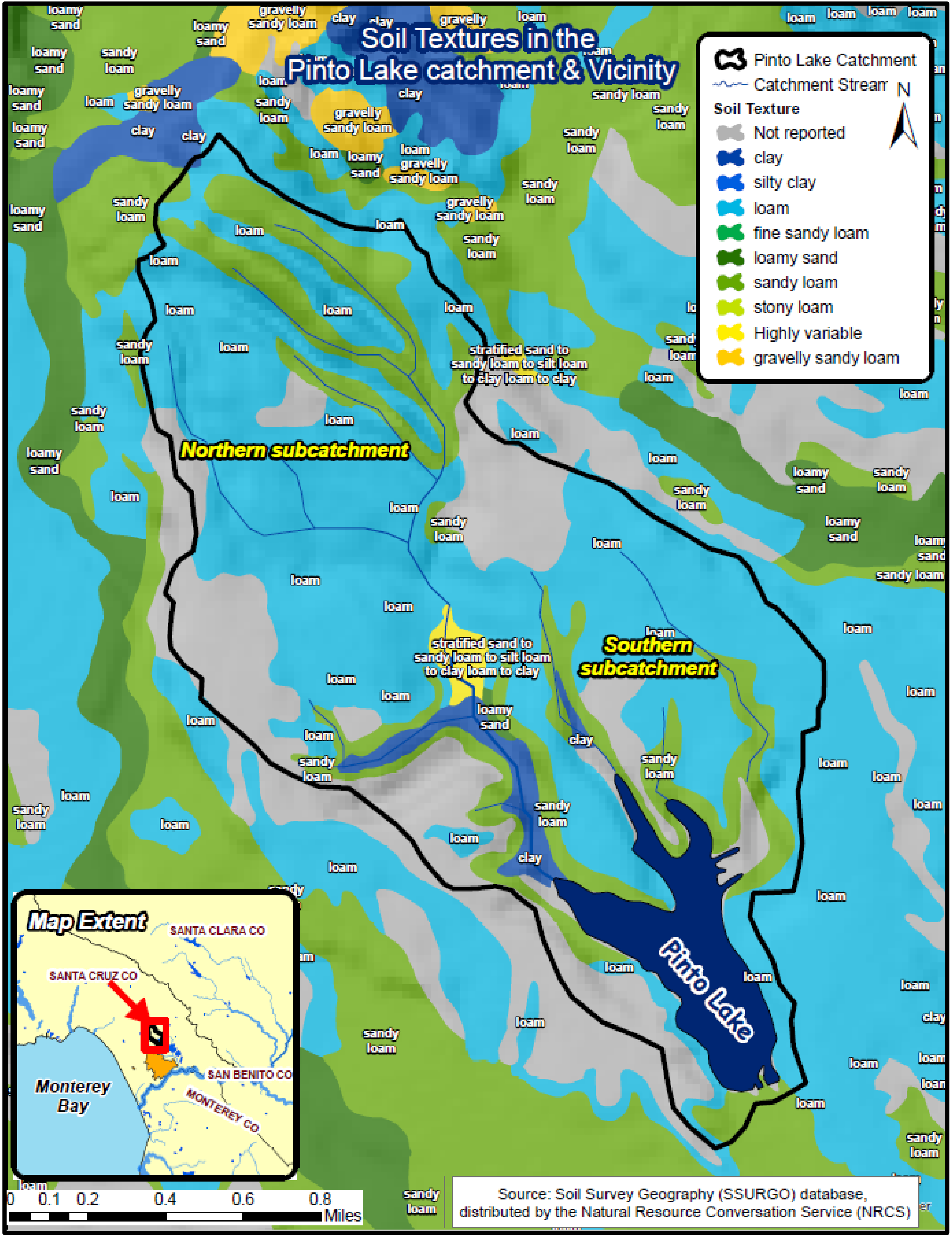
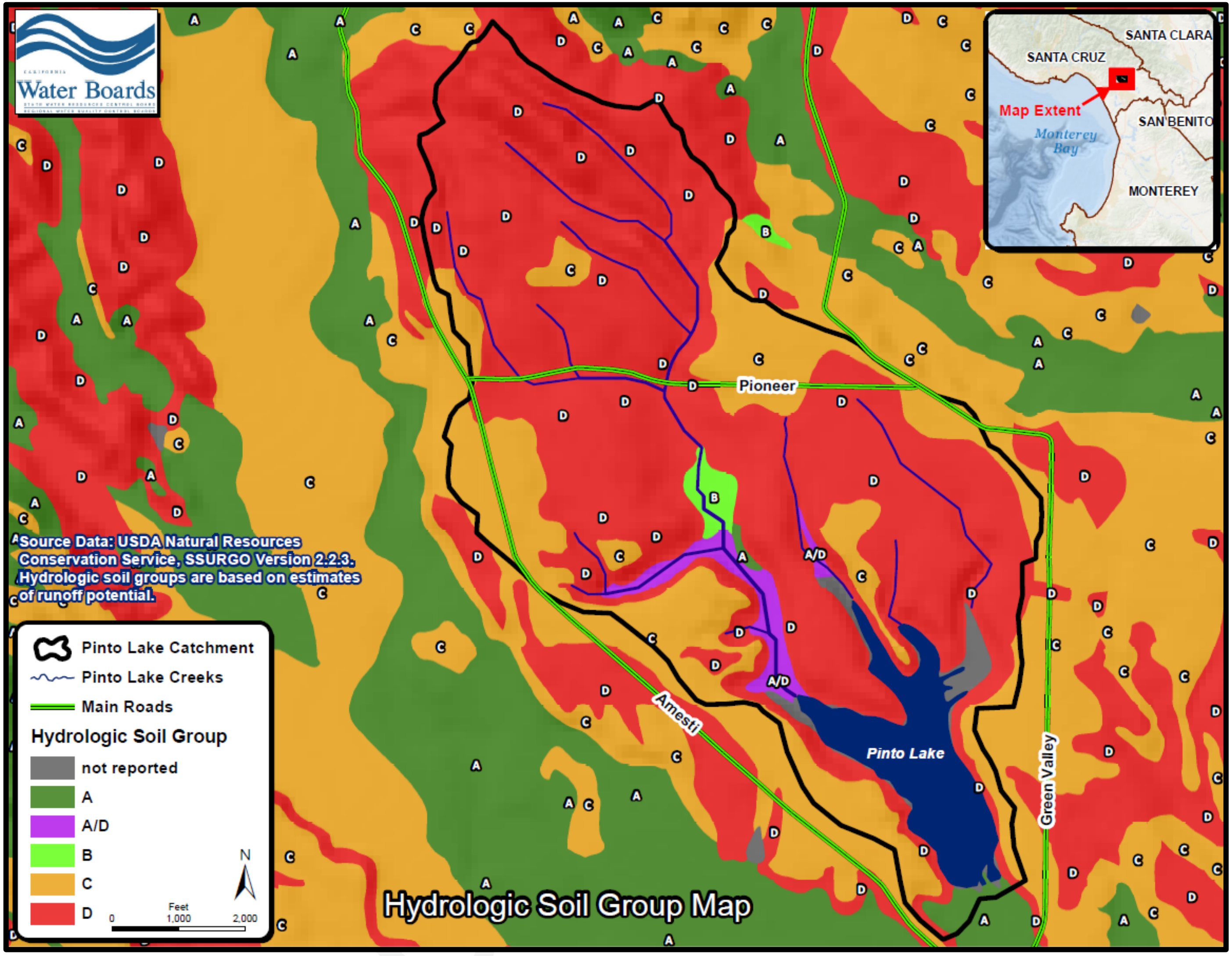


Figure 2-45. Soil textures in the Pinto Lake catchment and vicinity.



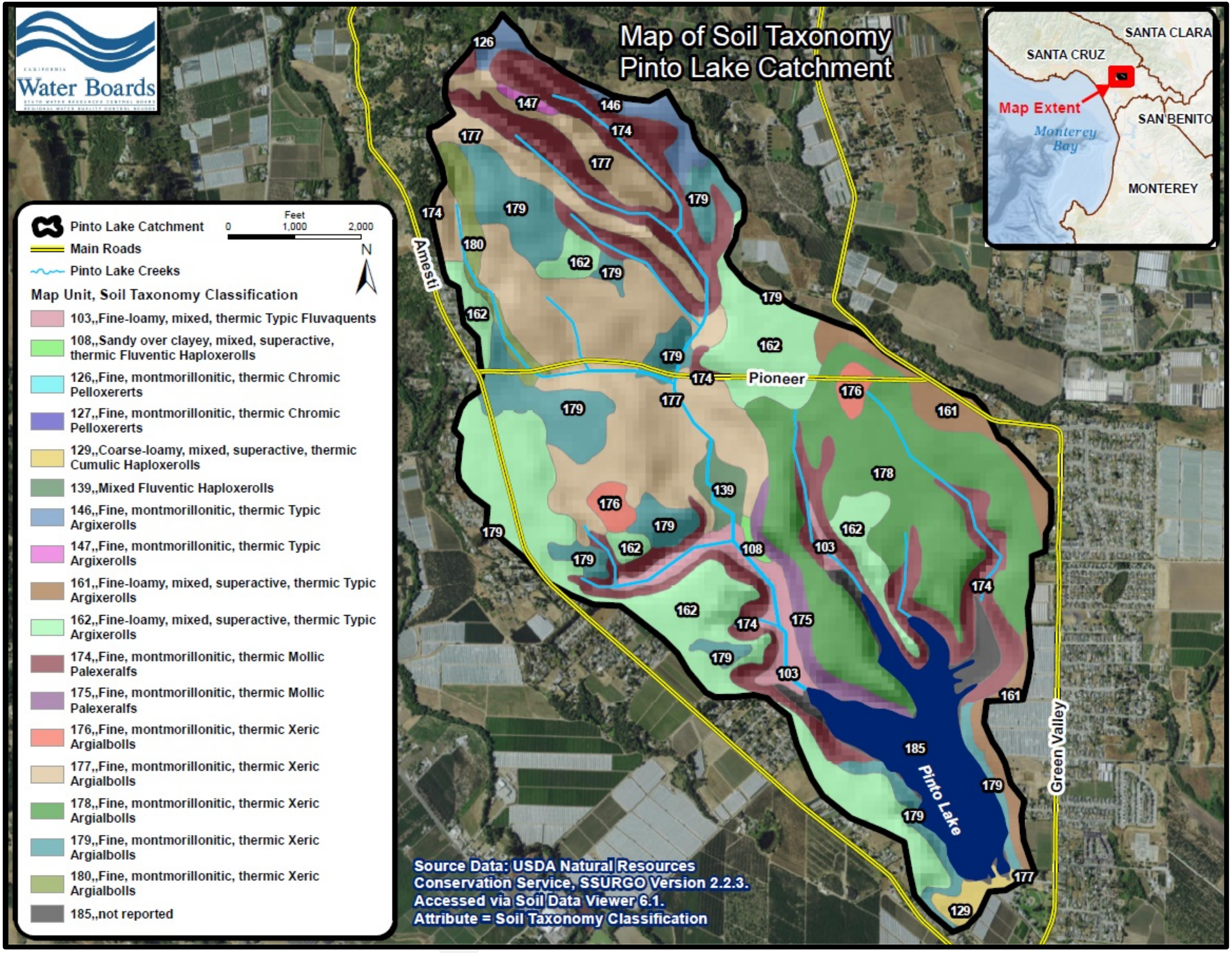
Source: Soil Survey Geography (SSURGO) database, distributed by the Natural Resource Conversation Service (NRCS)

Figure 2-46. Hydrologic soils groups (HSGs) in the Pinto Lake catchment and vicinity, with tabular description of HSGs.



Hydrologic Soil Group Descriptions	
A	Well drained to excessively drained sands or gravelly sands.
B	Moderately well drained or well drained soils having moderately fine to moderately course texture.
C	Soils having a slow infiltration rate when thoroughly wet; moderately fine or fine texture.
D	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays, soils which have a high water table, soils that have a claypan or clay layer near the surface, and soils that overlie a shallow, nearly impervious surface.
A/D	If a soil is assigned a dual hydrologic group, the first letter is for drained areas and the second is for undrained areas.

Figure 2-47. Map showing soil taxonomic classifications in the Pinto Lake catchment.



Source Data: USDA Natural Resources Conservation Service, SSURGO Version 2.2.3. Accessed via Soil Data Viewer 6.1. Attribute = Soil Taxonomy Classification

Figure 2-48. Map of soil erodibility (K factor) in the Pinto Lake catchment and vicinity.

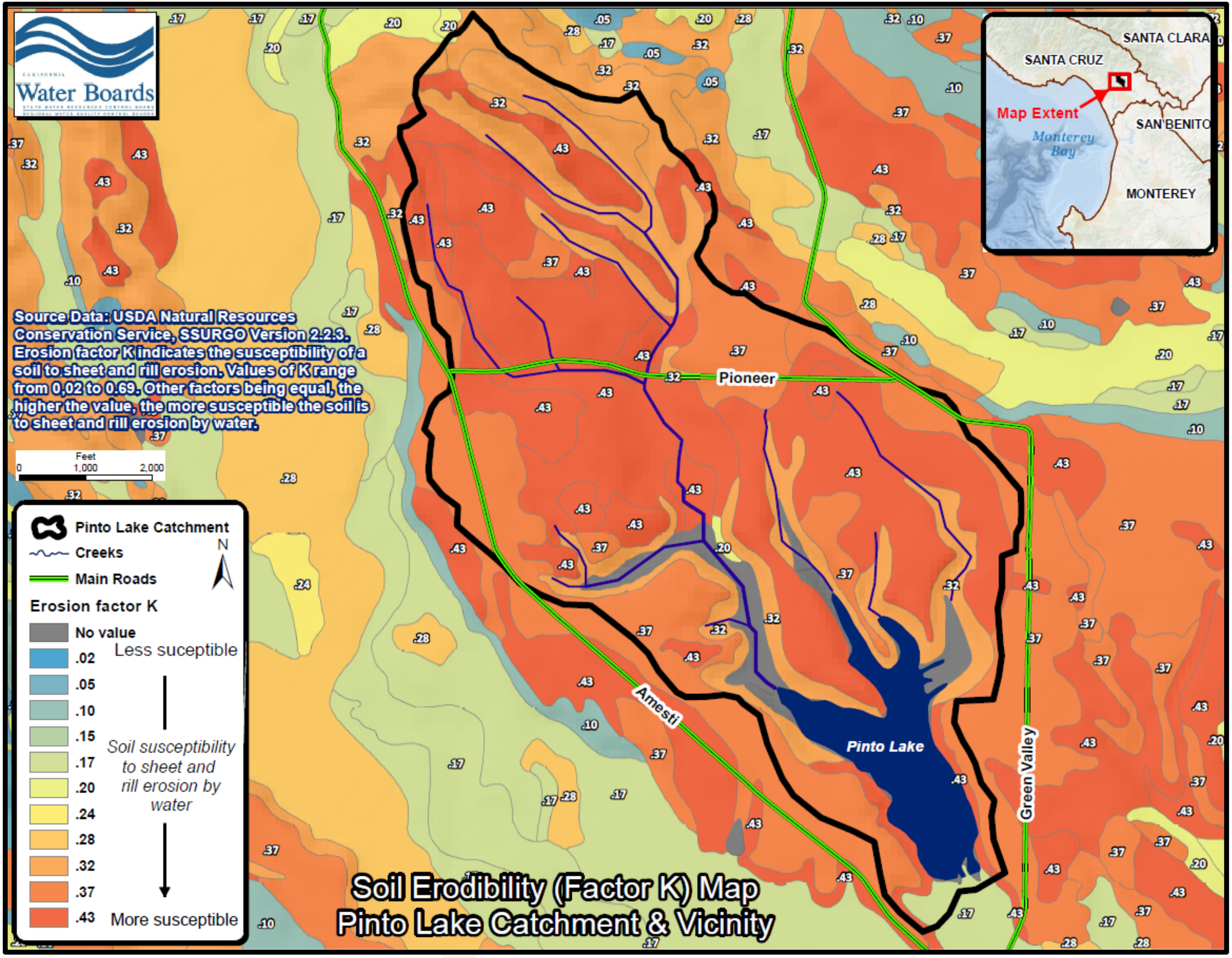


Figure 2-49. Map of soil cation exchange capacity, Pinto Lake catchment and vicinity.

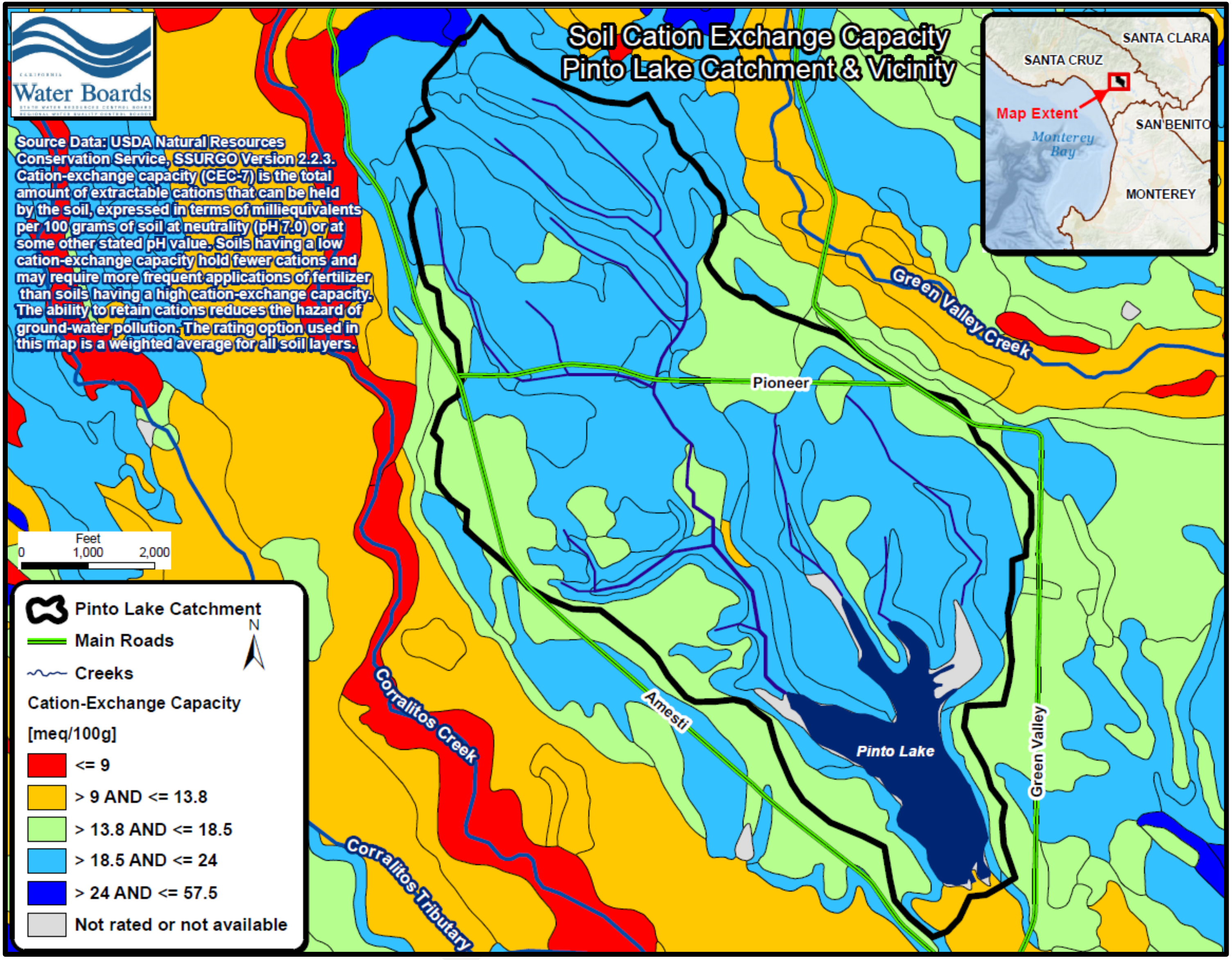
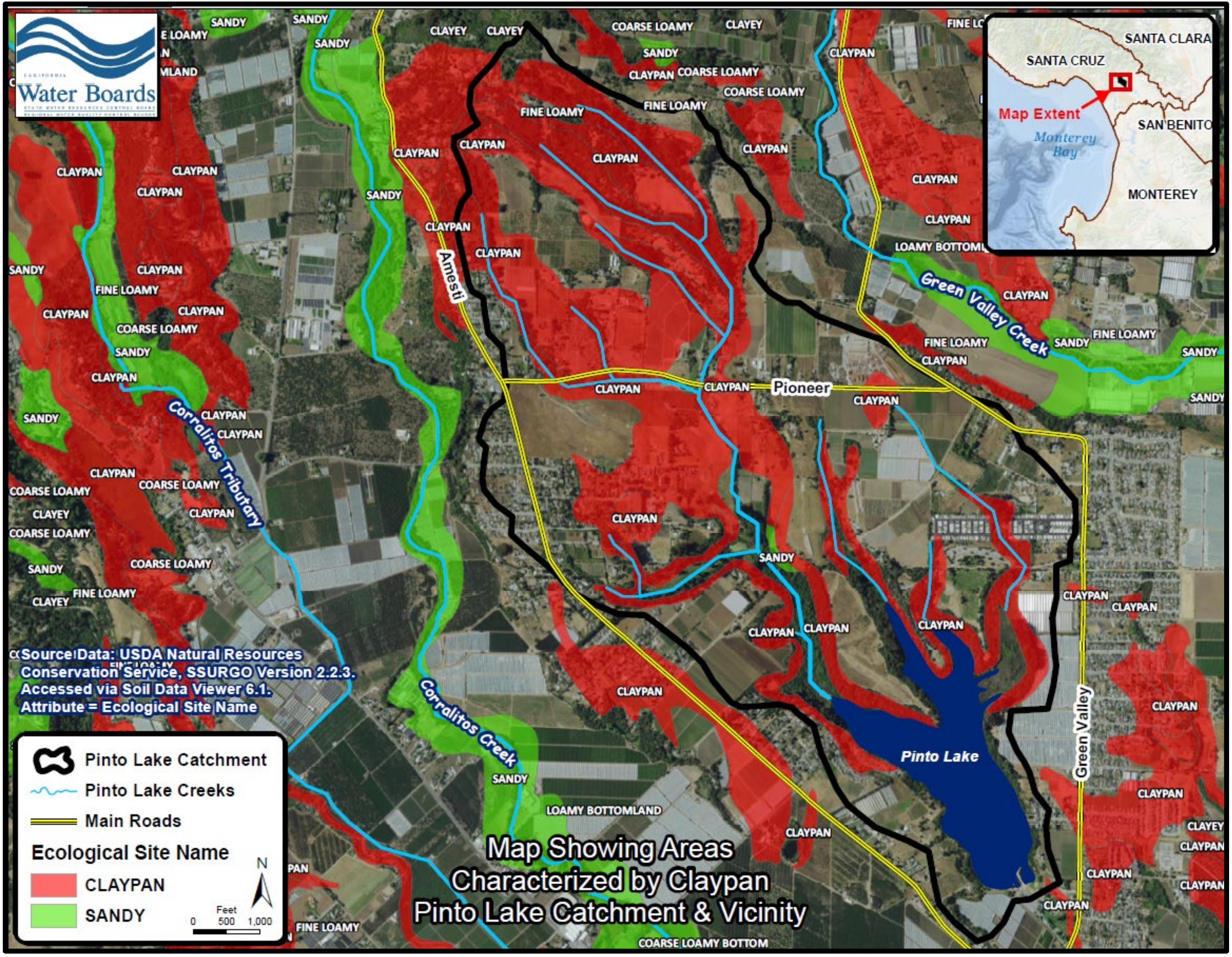


Figure 2-50. Map highlighting areas characterized by shallow clay hard pan layers in the Pinto Lake catchment and vicinity.



Source Data: USDA Natural Resources Conservation Service, SSURGO Version 2.2.3. Accessed via Soil Data Viewer 6.1. Attribute = Ecological Site Name

Thus, in the development of nutrient TMDLs it can be important to evaluate ambient concentrations of nutrients in soils. Soil nutrients can be a contributing source to nutrients in stream waters. Furthermore, the spreadsheet pollutant source estimation tool used in this TMDL project requires user-inputs for soil nutrients concentrations (refer to Section **6.1**).

We estimated soil nitrogen content in the Pinto Lake catchment, by assuming it was similar in nature to regional average soil nitrogen within the larger Pajaro River basin. Recall that the Pinto Lake catchment is a drainage area within the larger Pajaro River basin. Predictive models and data on soil nitrogen are available from the International Geosphere-Biosphere Programme Data and Information Services (IGBP-DIS)[39] – see Figure 2-51, Table 2-20, and also from soil nitrogen data compiled by Post and Mann

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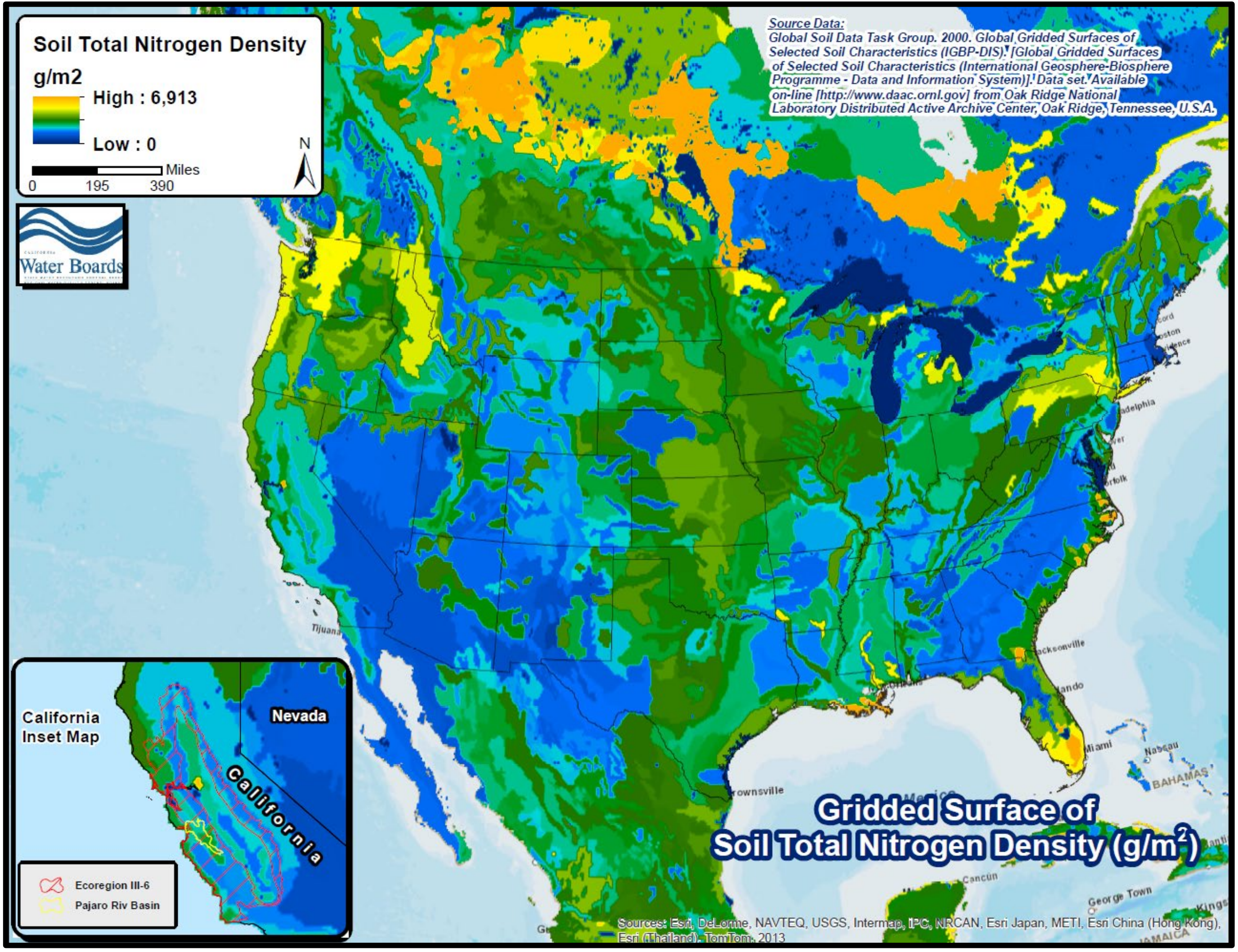
[39] The IGBP-DIS Global Gridded Surfaces of Selected Soil Characteristics data set contains data surfaces for total nitrogen density. The data surface was generated by the SoilData System, which was developed by the Global Soil Data Task of the IGBP-DIS. The SoilData System uses a statistical bootstrapping approach to link the pedon records in the Global Pedon Database to the Food and Agriculture Organization of the United Nations/United Nations Educational, Scientific and Cultural Organization (FAO/UNESCO) Digital Soil Map of the World. Available from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC).

(1990) – see Table 2-21. These data can be used to infer a plausible average soil nitrogen content that could be expected in the Pajaro River basin.

Numerical summaries and box plots of the grid cell values from the IGBP-DIS gridded surface[40] indicate that the median soil total nitrogen density (g/m^2) for the Pajaro River basin is quite similar to the median soil total nitrogen density for the conterminous United States (see Table 2-20). It should be noted that a cursory review of quantile-comparison plots of the IGDP-DIS data indicates the gridded cell values are highly non-normally distributed, and thus the *median* (rather than the arithmetic mean) grid cell value is a better measure of the central tendency or "average" of the grid cell values for soil total nitrogen density.

Figure 2-51. Gridded surface of estimated soil total nitrogen density (g/m^2),from the IGBP-DIS dataset.



Source Data: Global Soil Data Task Group. 2000. Global Gridded Surfaces of Selected Soil Characteristics (IGBP-DIS). [Global Gridded Surfaces of Selected Soil Characteristics (International Geosphere-Biosphere Programme - Data and Information System)]. Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, IPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

Table 2-20. Soil total nitrogen density statistics: Grid cell value statistics from the IGBP-DIS gridded surface shown previously in Figure 2-51 clipped to various geographic regions. Units = g/m^2.

Region	Mean	Standard Deviation	Min	25th %	50th % (median)	75th %	Max	Number of Grid Cell Values
Calif. Oak & Chaparral Ecoregion ^{A}	1,138	223	938	947	980	1,270	1,859	1,135
California (State-wide)	1,024	403	494	516	1,097	1,163	3,284	5,948

---

[40] A gridded surface is a way of representing a surficial feature of the earth digitally. In GIS analysis, a gridded surface is stored as raster data. Raster data is a rectangular matrix of cells, represented in rows and columns. Each cell represents a defined square area on the earth's surface and holds a value that is static across the entire cell.

Pajaro River basin	1,330	165	947	1,245	1,245	1,483	1,483	50
Conterminous USA	1,234	486	287	808	1,238	1,557	5,404	116,509

[A] See U.S. Environmental Protection Agency Level III and IV ecoregions of the continental United States online linage: http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm

Staff used the observed soil nitrogen analytical field data (Post and Mann, 1990) in conjunction with modelled soil nitrogen grids (IGBP-DIS) to infer a plausible average soil nitrogen concentration in the Pajaro River basin. Table 2-21 present box plots and numerical summaries of observed soil nitrogen concentration (%) based on soil data reported by Post and Mann, 1990.

Noteworthy, is that the median soil nitrogen concentration value for the entire dataset (i.e., the composite of all vegetation-land cover categories) is 0.068% (see Table 2-21). Also, recall as previously noted, that the median (50th percentile) soil total nitrogen density (g/m^2) in the Pajaro Basin is approximately equal to median soil total nitrogen density for the conterminous United States on the basis of IGBP-DIS gridded surface models (refer back to Table 2-20).

Thus, the median soil nitrogen concentration expected in the Pajaro River basin comports reasonably well with a median expected soil nitrogen concentration for the conterminous United States. Therefore, a plausible median soil nitrogen content on a percentage basis (%) for the Pajaro River basin can be assumed to be equal to the median soil nitrogen concentration derived from the Post and Mann (1990) data in Table 2-21, which is 0.068 % nitrogen.

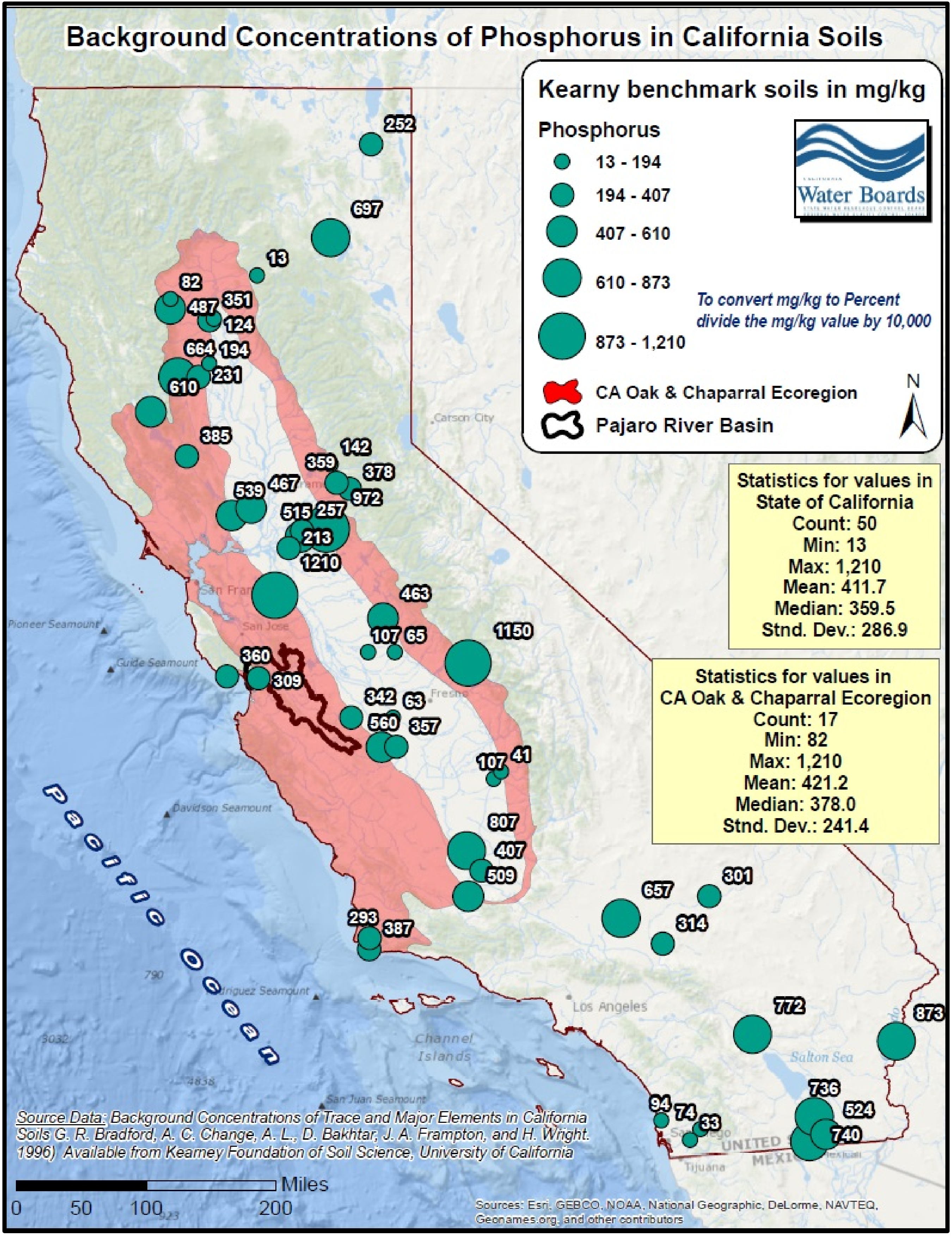
Table 2-21. Numerical summaries of United States observed soil total nitrogen (units = %) for select vegetative land cover systems on the basis of data used in Post and Mann, 1990[A].

Vegetation-Land Cover	Mean	Standard Deviation	Min	25th %	50th % (median)	75th %	Max	Number of Samples
cultivated	0.203694	0.565534	0.004	0.042	0.07	0.12675	3.67	654
fields	0.080465	0.064178	0.019	0.033	0.051	0.112	0.255	43
native prairie	0.142215	0.134856	0.008	0.068	0.101	0.1695	1.088	191
orchards	0.054706	0.061158	0.013	0.024	0.032	0.066	0.266	17
pasture	0.103363	0.126064	0.005	0.038	0.068	0.125	1.422	383
range	0.111329	0.096355	0.011	0.05025	0.0905	0.13475	0.581	82
trees	0.106121	0.155925	0.007	0.032	0.051	0.115	1.67	497
Numerical summary for composite of entire dataset	0.142525	0.355064	0.004	0.039	0.068	0.126	3.67	1869

[A] Post, W.M. and L.K. Mann. 1990. *Changes in Soil Organic Carbon and Nitrogen as a Result of Cultivation*, in A.F. Bowman, editor, *Soils and the Greenhouse Effect*, John Wiley and Sons. The authors assembled and analyzed a database of soil organic carbon and nitrogen information from a broad range of soil types from over 1100 profiles and representing major agricultural soils in the United States, using data compiled by the U.S. Dept. of Agriculture Soil Conservation Service National Soils Analytical Laboratory.

Data on ambient soil concentrations of phosphorus in California soils is available from the University of California–Kearney Foundation of Soil Science (Kearney Foundation, 1996). Figure 2-52 illustrates background concentrations of phosphorus in California soils based on Kearney benchmark soils selected from throughout the state (Kerney Foundation, 1996). The median soil phosphorus content in benchmark soils from within the California Oak and Chaparral Subecoregion is 378 mg/kg (0.038 weight percent) – thus, this value may constitute a plausible average ambient background soil phosphorus content for the Pajaro River basin (for a discussion of nutrient ecoregions refer back to Section 2.8).

Figure 2-52. Background concentrations of phosphorus in California soils.



Source Data: Background Concentrations of Trace and Major Elements in California Soils G. R. Bradford, A. C. Change, A. L., D. Bakhtar, J. A. Frampton, and H. Wright. 1996) Available from Kearney Foundation of Soil Science, University of California

Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors

Knowledge of average phosphorus and nitrogen concentrations in soil can be useful in any given watershed study or TMDL. Text Box 2-6 presents our estimates for average watershed phosphorus and nitrogen content of soils in the Pinto Lake catchment.

Text Box 2-6. Estimated average concentration of soil nitrogen (%) and soil phosphorus (%) in soils of the Pinto Lake catchment.

Based on the aforementioned information, estimated average soil nutrient content (%) in the Pinto Lake catchment can be summarized as follows:

Average soil phosphorus (mobile-P + labile organic P) content (%) in the Pinto Lake catchment[1]:

0.01%

Average sediment phosphorus content in lake bed sediments of Pinto Lake[2]:

0.03%

Average soil nitrogen content (%) in the Pinto Lake catchment[3]:

0.07%

[1] We derived this value by averaging the mobile-P (mobile-P = iron bound P and loosely sorbed P) and labile organic P soil phosphorus analyses from Pinto Creek and Todos Santos creeks (refer back to Table 2-18) and using appropriate unit conversion factors, (mg/kg ➔ weight percent). See Tetra Tech (2016) for a description of mobile-P and labile organic P. Pete – you can omit this if you are going to describe this elsewhere in the text.

[2] This value is derived by taking the average mobile-P (mobile-P = iron bound P and loosely sorbed P) and labile organic P sediment phosphorus content observed from "Pinto Lake abyss" samples; these samples correspond to the central portion of the lake (refer back to Table 2-18) and using appropriate unit conversion factors, (mg/kg ➔ weight percent).

[3] This estimate is derived from information provided in Table 2-21 and accompanying narrative text.

2.13 Fish & Wildlife

> *"Every fall, Pinto Lake's microcystin levels spike way beyond what's considered dangerous for humans and animals."*
>
> ➔ from: *Evotis*, a monthly online publication of the University of California Davis One Health Institute

In any given watershed assessment, it can be important to consider available information on aquatic ecosystems and wildlife. This type of information is also important for TMDL programmatic activities that must comply with the California Environmental Quality Act (CEQA)[41]. *(add citation here to the Attachment containing your CEQA checklist report).*

Nutrient water quality plays an important role in fish and wildlife habitat. Nutrients and algae are present naturally in all aquatic ecosystems. However, problems can occur when too much nitrogen and phosphorus is loaded to a waterbody.

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[41] Pursuant to Public Resources Code Section 21080.5, the Natural Resources Agency has approved the Regional Water Quality Control Boards' basin planning process as a "certified regulatory program" that adequately satisfies the CEQA (Public Resources Code, Section 21000 et seq.) requirements for preparing environmental documents (14 California Code of Regulations [CCR] §15251(g); 23 CCR § 3782).

Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. Nitrogen and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water.

But when too much nitrogen and phosphorus enter the environment - usually from a wide range of human activities - the air and water can become polluted… Too much nitrogen and phosphorus in the water causes algae to grow faster than ecosystems can handle. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive. Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish.

➔ from: U.S. Environmental Protection Agency

A number of the designated aquatic habitat and wildlife beneficial uses for Pinto Lake (refer to Section 3.2 and Table 3-2) could potentially be adversely affected by higher than natural nutrient levels, cyanobacteria blooms, and associated water quality stressors, such as dissolved oxygen imbalances. These types of water quality stressors can affect the entire aquatic food web, from algae and other microscopic organisms, through benthic macroinvertebrates (principally aquatic insect larvae), through fish, to the mammals and birds at the top of the food web.

It is worth noting that Pinto Lake is an important recreational and aesthetic resource for the public, and historically has provided high quality habitat for aquatic species and wildlife.

"The Pinto Lake watershed has two parks located on the lake which serve over 100,000 visitors per year. Many of the visitors are young families from Watsonville's disadvantaged community. The lake's location on the Pacific flight path has made it a popular bird watching location. In recent years, the lake has been a nesting site for a pair of bald eagles. The lake used to be a very popular fishing location. Unfortunately, trout plants at the lake were suspended in 2013, when analysis showed high levels of cyanotoxins in the fish."

➔ *City of Watsonville, Public Works and Utilities Department, Memorandum dated Dec. 10, 2013 and entitled "Application for $750,000 in Clean Water Act 319H Grant Funds for Pinto Lake"*

In Pinto Lake, these environmental risks are not theoretical. City of Watsonville staff report that fish and wildlife habitat have been degraded in Pinto Lake due to nutrient pollution and associated harmful algal blooms.

"Toxic algal blooms (in Pinto Lake) ***have caused fish and bird deaths at the lake*** *and represent a public health issue for members of the public who participate in water-based recreational activities such as boating and fishing."*

➔ City of Watsonville Public Works and Utilities Department (2015), memorandum to City Manager Pro Tempore, dated March 12, 2015

(parenthetical clarification and emphasis added by Central Coast Water Board staff)

"Pinto's cyanobacteria blooms have been ***implicated in fish kills***, ***bird deaths*** *and the death of several southern sea otters in Monterey Bay."*

➔ from: California State University, Monterey Bay and Resource Conservation District of Santa Cruz County, *Pinto Lake Watershed: Implementation Strategies for Restoring Water Quality in Pinto Lake*. March 2013.

(emphasis added by Central Coast Water Board staff)

"CB (cyanobacteria) have the potential to produce a range of toxins, including alkaloid (anatoxin, cylindrospermopsin, saxitoxin) and peptide toxins (microcystin, BMAA) (Cox et al., 2005). Additionally, the sheer effect of large accumulations of cyanobacterial cells can lead to aesthetic impact (scums and odor), exclusion of more palatable green algae and diatoms, pH and ***dissolved oxygen fluctuations leading to fish kills****, as well as increased TOC which can exacerbate internal loading processes."*

➔ from: Scott Blanco (2014), *Thermocline Stability-Induced Control of Freshwater Cyanobacterial Bloom: Hypereutrophic Mediterranean-Climate Pinto Lake (Watsonville, CA).* USDA-WRI Watershed Management

Internship Report. Advisors: Marc Los Huertos (CSU-Monterey Bay), Aparna Sreenivasan (CSU-Monterey Bay), Robert Ketley (City of Watsonville)
(parenthetical clarification and emphasis added by Central Coast Water Board staff)

Figure 2-53. Cyanobacteria blooms are reportedly implicated in fish kills and wildlife deaths at Pinto Lake (photo credit: Robert Ketley, City of Watsonville).

Cyanobacteria blooms reduce the amount of dissolved oxygen in the lake, which makes it difficult for fish to survive.
Photo by Robert Ketley

Worth noting is that algae and cyanobacteria are a natural part of freshwater ecosystems, and episodic algae blooms are sometimes a natural phenomenon. However, the intensity and frequency of harmful cyanobacteria blooms in Pinto Lake have been increasing since the 1970s or early 1980s according to local resource professionals, researchers, and local residents, suggesting that human influences are contributing to the changes in water quality:

> *"Interviews with Pinto Lake watershed residents and Santa Cruz County community members have described Pinto Lake shifting from a largely swimmable recreational resource in the late 1960s to early 1970s to the current cyanobacteria-dominated lake we see today, suggesting that the blooms began to be a problem sometime in the late 70s- early 80s…"*
>
> ➔ from: California State University, Monterey Bay and Resource Conservation District of Santa Cruz County,. *Pinto Lake Watershed: Implementation Strategies for Restoring Water Quality in Pinto Lake*. March 2013.

> *"Algal blooms have persisted in the lake for decades, but only recently have toxin concentrations risen to alarming levels."*
>
> ➔ from: The Bay Nature Institute, January 2, 2014, *"The Rise of Cyanobacteria at Pinto Lake",* by Patricia Walden

With regard to animal life in the Pinto Lake catchment, fish are the most noticeable components of aquatic ecosystems, and their declines signals ecosystem deterioration. Alternatively, healthy fish assemblages signal clean and healthy waters (Moyle, 2002).

According to the California Department of Fish and Wildlife, the decline of California's fishes, and of other aquatic organisms, will continue and many extinctions will occur unless the widespread nature of the problem is addressed in a systematic effort to protect aquatic habitat in all watersheds of the state (Moyle et al., 1995).

One way to begin to assess freshwater aquatic habitat of the Pinto Lake catchment is to review regional information and the spatial distribution of California's zoogeographic provinces – see Figure 2-54. The Pinto Lake catchment – part of the larger Pajaro River basin – is located in the Monterey Bay zoogeographic subprovince. This subprovince is composed of the three major rivers that flow into Monterey Bay: the San Lorenzo River, the Pajaro River, and the Salinas River.

Historically, the Monterey Bay subprovince and the Pajaro River had an array of freshwater native fish species characteristic of the Central Valley subprovince (Sacramento sucker, California roach, hitch, Sacramento blackfish, Sacramento pikeminnow, speckled dace, thicktail chub, Sacramento perch, tule perch, and riffle sculpin), as well as saltwater dispersant fishes including the Pacific Lamprey, threespine stickleback, prickly sculpin, and steelhead (Moyle, 2002).

The similarity of the freshwater fish fauna of the Monterey Bay subprovince and the Pajaro River to fauna of the Central Valley zoogeographic province is likely due to hydrologic connectivity between the subprovince and the Central Valley sometime during the middle or late Pleistocene epoch, between 12 thousand to 50 thousand years ago[42] (Moyle, 2002).

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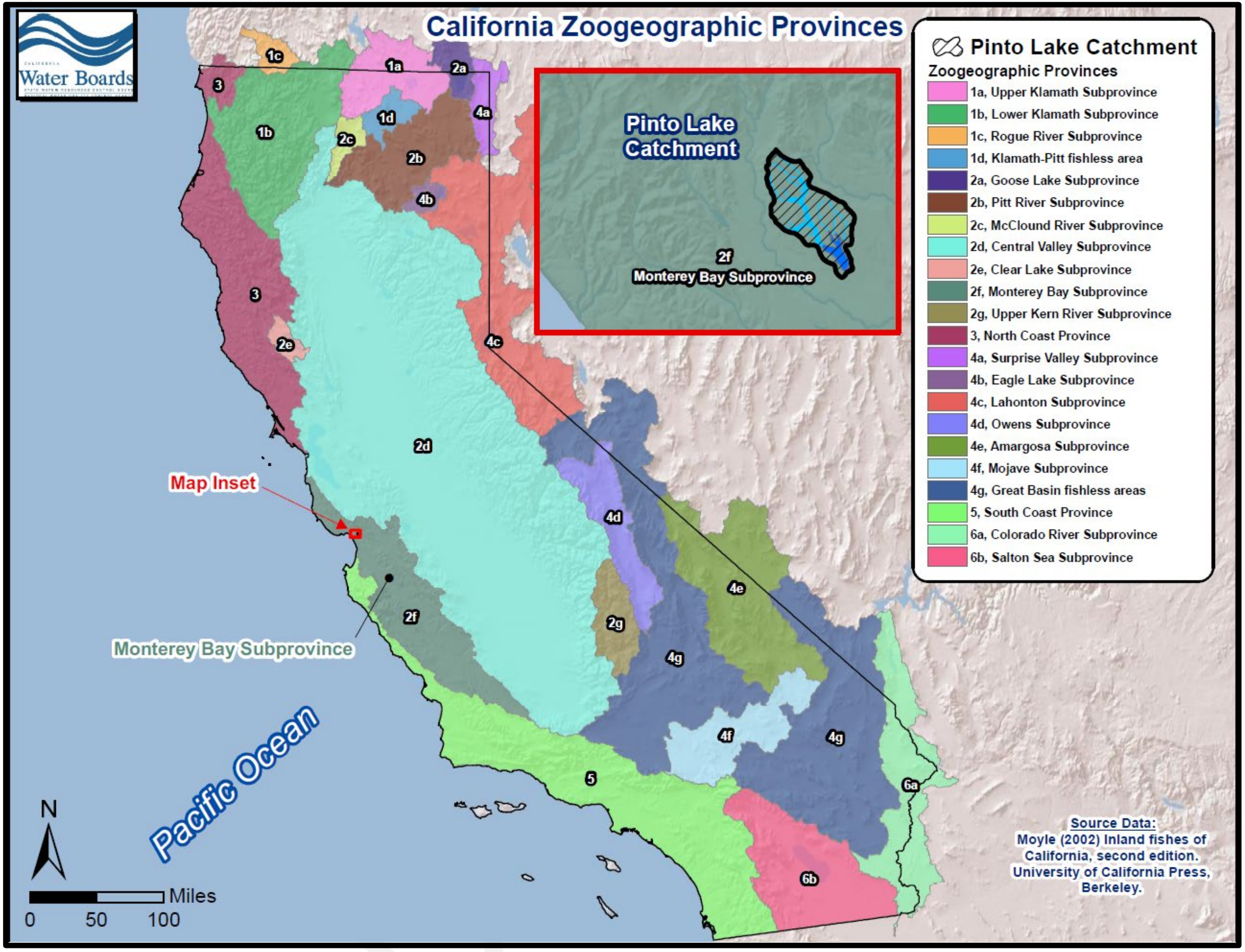
[42] Geologic evidence suggests that upper Coyote Creek (which now flows to the San Francisco Bay) has episodically changed course in the past, sometimes flowing into Llagas Creek, a Pajaro River tributary – thus providing a plausible hydrologic connection for lowland fishes of the Central Valley zoogeographic subprovince to have migrated into the Pajaro River Basin (Banner, 1907 as reported in Moyle, 2002).

Figure 2-54. Zoogeographic provinces of California.



Source Data: Moyle (2002) Inland fishes of California, second edition. University of California Press, Berkeley.

Current Fish Assemblage

According to sport fishing publications and local residents, the current fish assemblage of Pinto Lake consists of non-native introduced or planted species. These include common carp, largemouth bass, crappie, bluegill, and rainbow trout[43] (Fish Sniffer magazine, 2013). These non-native sport fish are reportedly stocked in the lake by the California Department of Fish and Wildlife.

Native Fish of the Salsipuedes Creek & Corrillitos Creek Subwatersheds

Figure 2-55 illustrates the current, best-known ranges for native inland fish species in the watershed drainages associated with Pinto Lake. These estimates of native fish distributions are subject to uncertainties and some assumptions, and are based on the best professional judgment of fisheries biologists at the University of California-Davis[44].

According to UC Davis California Fish Website, some of these species are generally not known to occupy lake habitat; for example, the anadromous Pacific lamprey's inland habitat is apparently limited to freshwater streams, and the white sturgeon's habitat is typically limited to estuaries and river systems.

Native fish assemblages have apparently largely disappeared from Pinto Lake (Rosales, 2011, and personal communication, Robert Ketley-City of Watsonville 2011). There is however, anecdotal reporting

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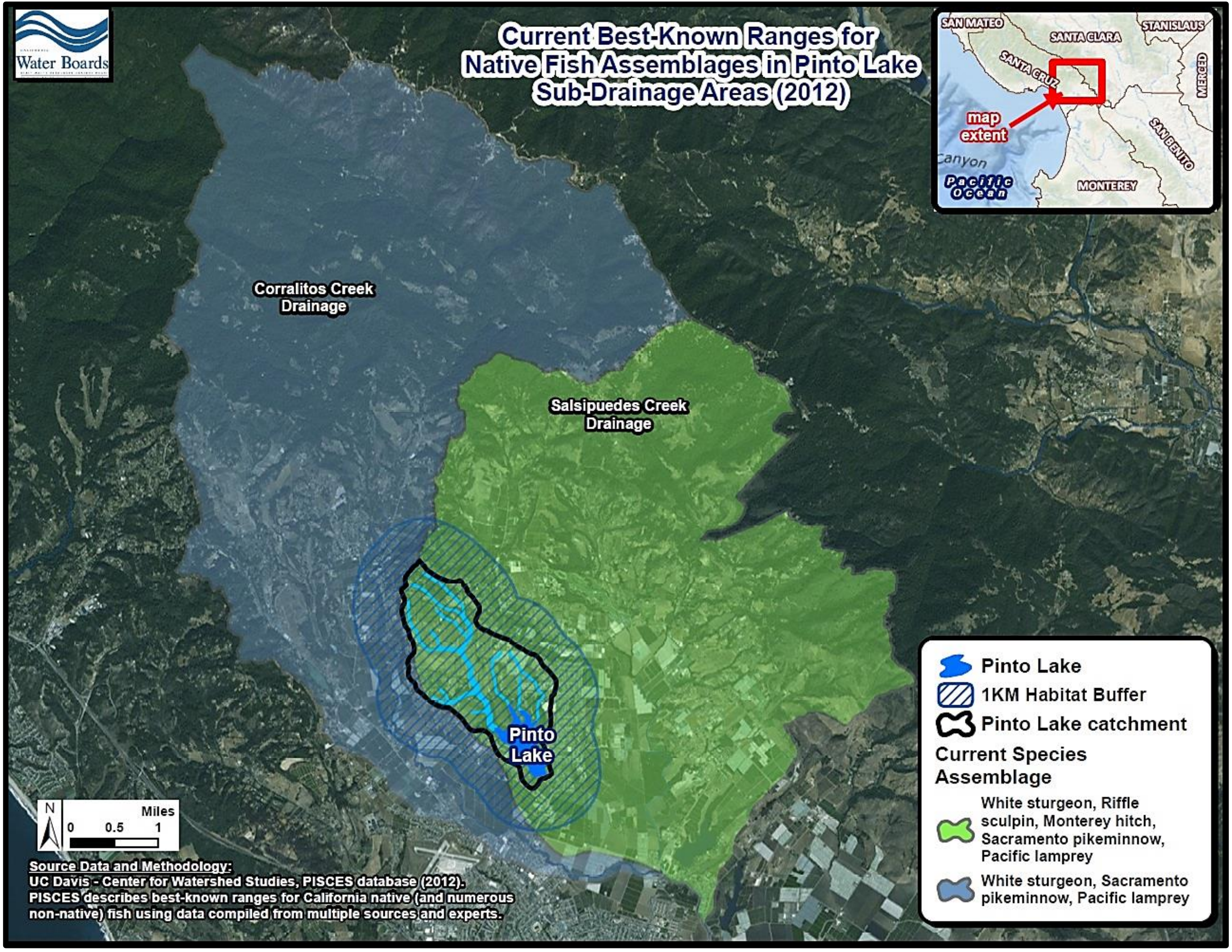
[43] Reportedly, trout are episodically planted by the Department of Fish and Wildlife in late winter or spring for sport fishing.

[44] Source data: University of California, Davis – Center for Watershed Sciences, PISCES species occurrence database. PISCES is a database that standardizes, maps, and analyzes the distribution of fish species in California based on watershed units.

of a rare observation of a native Sacramento pikeminnow in the lake (personal communication, Robert Ketley- City of Watsonville). In addition, there is reporting that native sacramento sucker, sacramento pikeminnow, and hitch have been observed (Rosales, 2011) in nearby College Lake, located 1 mile southeast of Pinto Lake, thus suggesting these native fish species are associated currently with lake habitat in this part of Santa Cruz County.

Figure 2-55. Current best known ranges for native inland fish species in the Pinto Lake vicinity (Salsipuedes and Corrilitos creeks subwatersheds).



Source Data and Methodology:
UC Davis - Center for Watershed Studies, PISCES database (2012).
PISCES describes best-known ranges for California native (and numerous non-native) fish using data compiled from multiple sources and experts.

Special Status Species in the Pinto Lake Catchment

Pursuant to California Public Resources Code §21159, the Regional Water Quality Control Boards are required to perform a programmatic-level environmental analysis for purposes of complying with the California Environmental Quality Act. Part of this environmental analysis includes assessing whether or not a programmatic action by the Regional Water Quality Control Boards would have a substantial adverse impact on biological resources, including sensitive or special status species in the area affected by the programmatic action.

Accordingly, it is necessary for us to compile information on sensitive, rare, or special status species in the Pinto Lake catchment.

"Special status species" is a broad term used to refer to all the animal taxa tracked by the California Department of Fish and Wildlife's California Natural Diversity Database. The list is sometimes referred to as the list of "species at risk" or the "special animals" list. To be included on the "special status species" list, the animal or plant taxa must meet certain conditions indicating the species is rare, threatened, endangered, declining in population, sensitive, or otherwise meeting some level of conservation concern.

Table 2-22 presents a compilation of special status species known to occur in the Pinto Lake catchment, based on information available from the California Department of Fish and Wildlife. It should be noted that the California Natural Diversity Database is a "positive detection" database. Practically speaking, this means that records of sensitive species only exist in the database where these species were observed. Geographic areas in the database that have no records simply mean there is limited information there, or that no organized surveys have taken place there. One cannot conclude that there is less biological diversity in these places, simply due to lack of information.

Table 2-22. Special status species that are known to occur within the Pinto Lake catchment. This information was compiled from the California Department of Fish and Wildlife's California (CDFW) Natural Diversity Database and from the publications/lists of special animals on the CDFW's Threatened and Endangered Species and the Species of Special Concern webpages (accessed December 2016). Plants and animals shown in this table are reported to occur in Pinto Lake and or areas draining to Pinto Lake.

Species	Common Name	State Rank	Federal Legal Status	California Legal Status	Other Status
Lavinia exilicauda harengus	Monterey hitch	S2S4	None	None	CDFW:SSC
Lavinia symmetricus subditus	Monterey roach	S2S3	None	None	CDFW:SSC
Entosphenus tridentatus	Pacific lamprey	S4	None	None	AFS:VU BLM:S CDFW:SSC USFS:S
Cottus gulosus	riffle sculpin	S3S4	None	None	CDFW:SSC
Hysterocarpus traskii traskii	Sacramento tule perch	S2S3	None	None	NA
Acipenser transmontanus	white sturgeon	S2	None	None	AFS:EN CDFW:SSC IUCN:LC
Emys marmorata	western pond turtle	S3	None	None	BLM:S CDFW:SSC IUCN:VU USFS:S
Holocarpha macradenia	Santa Cruz tarplant	S1	Threatened	Endangered	NA
Monolopia gracilens	woodland woollythreads	S2S3	None	None	NA

STATE RANKING

The *state rank* (S-rank) refers to the overall imperilment status within California's state boundaries. State ranks represent a letter and number score that reflects a combination of Rarity, Threat, and Trend factors, with weighting being heavier on Rarity than the other two.

S1 = **Critically Imperiled** - Critically imperiled in the state because of extreme rarity (often 5 or fewer populations) or because of factor(s) such as very steep declines making it especially vulnerable to extirpation from the state.

S2 = **Imperiled** - Imperiled in the state because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the state.

S3 = **Vulnerable** - Vulnerable in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation from the state.

S4 = **Apparently Secure** - Uncommon but not rare in the state; some cause for long-term concern due to declines or other factors.

S5 = **Secure** - Common, widespread, and abundant in the state.

OTHER STATUS: CODE ABBREVIATIONS

AFS:VU - American Fisheries Society - Vulnerable
BLM:S - Bureau of Land Management – Sensitive
CDFW:SSC - California Department of Fish & Wildlife - Species of Special Concern
IUCN:LC - The International Union for Conservation of Nature - Least Concern
IUCN:VU - The International Union for Conservation of Nature - Vulnerable
USFS:S – U.S. Forest Service – Sensitive

2.14 Coastal Receiving Waters & Downstream Impacts

The purpose of this section is to consider and outline downstream water quality impacts associated with cyanotoxin blooms in Pinto Lake. In coastal watersheds, excess nutrients and cyanotoxins in freshwater inland streams and lakes can ultimately end up in coastal marine receiving waters (lagoons, estuaries, bays) where the nutrient concentrations, toxins, and pollutant loads may degrade the coastal marine water resource. Excessive nutrient inputs from human activities upstream of coastal waterbodies, even hundreds of miles inland, can degrade the health of coastal ecosystems, especially estuaries[45].

Furthermore, federal water quality regulations require that water quality standards for lakes and streams must take into consideration and be protective of *downstream* water quality, such as coastal waters. Thus, watershed improvement activities and water quality goals in any given coastal watershed should take into account minimizing downstream impacts to downstream estuaries, lagoons, and coastal marine waters.

> *"In designating uses of a water body and the appropriate criteria for those uses, the State* ***shall take into consideration*** *the water quality standards of* ***downstream waters*** *and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of* ***downstream waters****."*
>
> ➔ *Code of Federal Regulations, 40 C.F.R. 131.10(b)*
>
> *emphasis added by Central Coast Water Board staff*

The Monterey Bay watersheds, which include the Pinto Lake catchment, the Salsipuedes Creek subwatershed, and the Pajaro River watershed are noteworthy, in part, for being an area of California that can drain directly to estuaries and ecologically sensitive coastal bay receiving waters (see Figure 2-56). Coastal estuaries, lagoons, and bays are ecologically sensitive areas that are especially prone to pollution loading from land activities and freshwater stream inputs. Pinto Lake waters can seasonally or episodically drain via a ditch and tributary creeks to the Pajaro River and then ultimately to Monterey Bay (refer Figure 2-56) when the Pajaro River Estuary is open to ocean waters. As such, the Pajaro River-Watsonville Slough Estuary and Monterey Bay coastal waters represent the coastal confluence receiving waters for Pinto Lake drainage.

It is important to recognize that some of these downstream receiving waters are managed as sensitive ecological areas and accordingly have been designated as National Marine Protection Areas – specifically, the Monterey Bay National Marine Sanctuary (see Figure 2-56). The Monterey Bay National Marine Sanctuary has legally established goals and conservation objectives[46]. The Monterey Bay National Marine Sanctuary was established and is managed in part to sustain, conserve, and restore the protected area's natural biodiversity, populations, habitats, fisheries, and ecosystems. Also worth noting, the California Coastal Commission has identified the Pajaro River and Watsonville Slough coastal area as Critical Coastal Areas (CCA)[47] – see Figure 2-56. CCAs are an administrative, non-regulatory designation for coastal waterbodies that need protection from polluted runoff.

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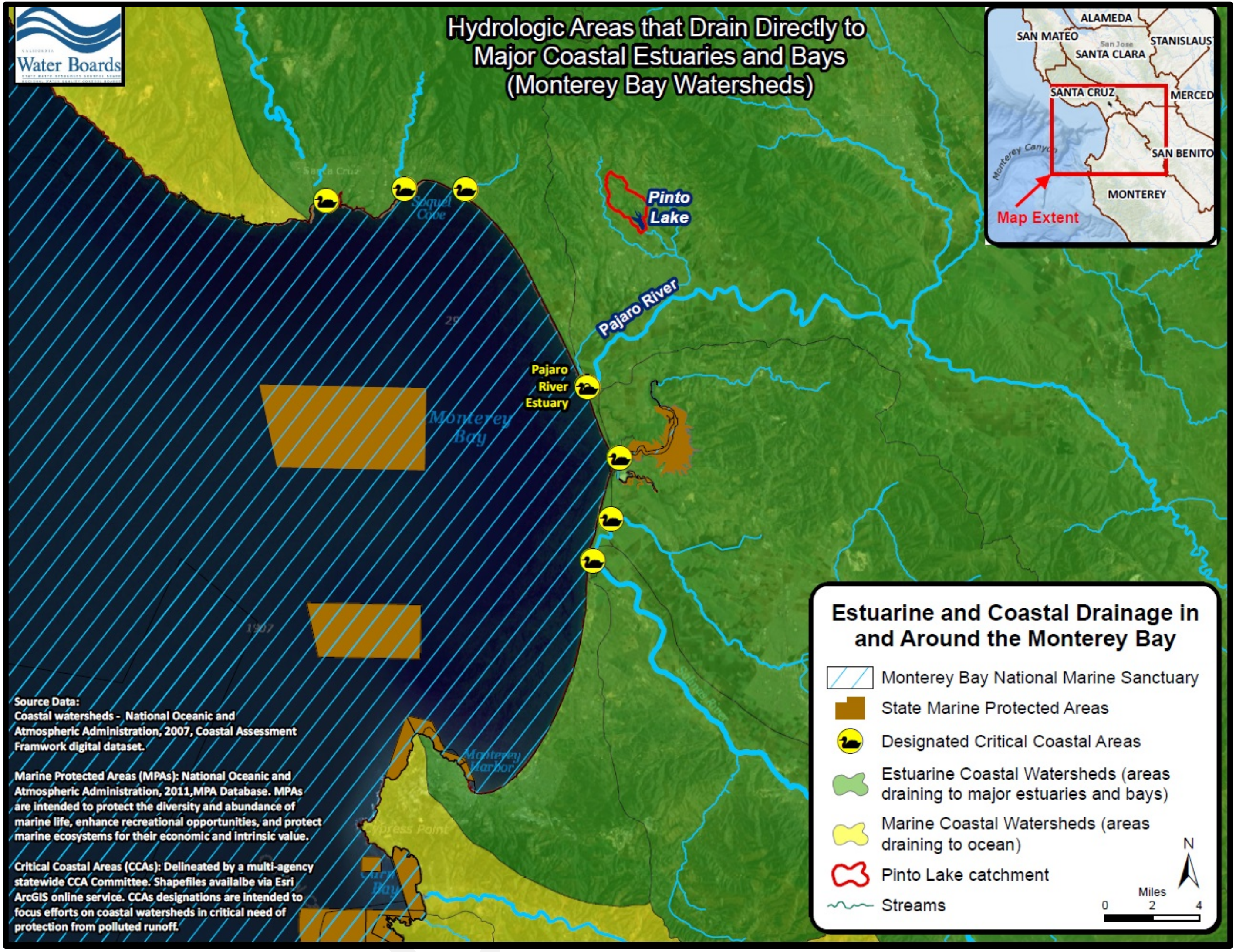
[45] National Oceanic and Atmospheric Administration, "State of the Coast" webpage. Online linkage: http://stateofthecoast.noaa.gov/hypoxia/welcome.html

[46] See National Oceanic and Atmospheric Administration – National Marine Protected Areas website. Online linkage: http://marineprotectedareas.noaa.gov/

[47] Pursuant to the federal Coastal Zone Act Reauthorization Amendments of 1990, the state's Critical Coastal Areas (CCA) Program is a program to foster collaboration among local stakeholders and government agencies, to better coordinate resources and focus efforts on coastal waters in critical need of protection from polluted runoff.

Figure 2-56. Map of hydrologic areas of the Monterey Bay area which drain directly to major coastal estuaries and bays.



Source Data:
Coastal watersheds - National Oceanic and Atmospheric Administration, 2007, Coastal Assessment Framwork digital dataset.

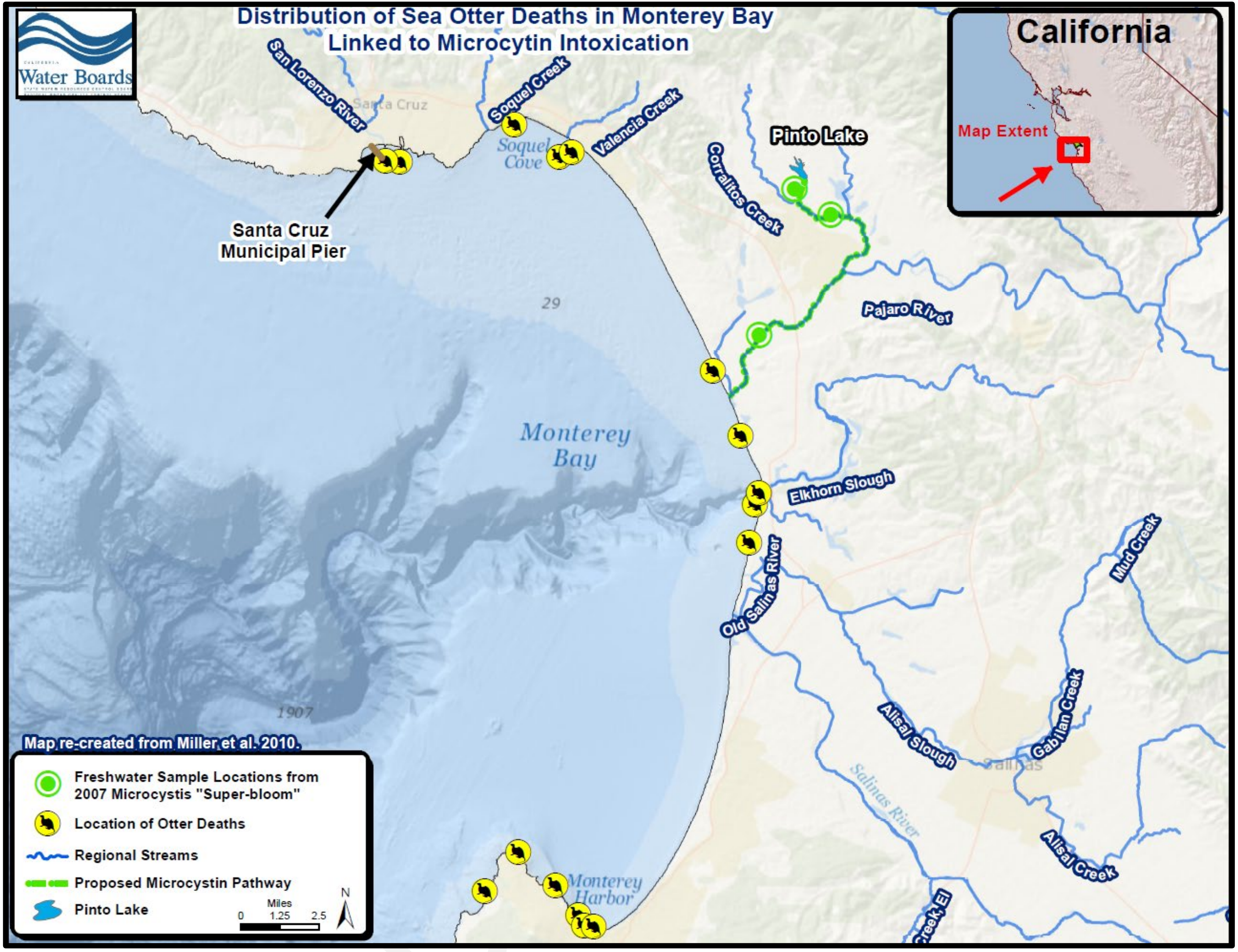
Marine Protected Areas (MPAs): National Oceanic and Atmospheric Administration, 2011,MPA Database. MPAs are intended to protect the diversity and abundance of marine life, enhance recreational opportunities, and protect marine ecosystems for their economic and intrinsic value.

Critical Coastal Areas (CCAs): Delineated by a multi-agency statewide CCA Committee. Shapefiles availalbe via Esri ArcGIS online service. CCAs designations are intended to focus efforts on coastal watersheds in critical need of protection from polluted runoff.

Adverse impacts to marine coastal environments by pollution originating from inland watersheds of the Pajaro valley are not theoretical. The deaths of multiple threatened southern sea otters in Monterey Bay in 2007 ultimately provided the first documentation of microcystin poisoning in a marine mammal (Miller et al., 2010), thus further highlighting the importance of recognizing that pollution from freshwater inland sources can adversely impact coastal marine waterbodies. Figure 2-57 highlights to locations of sea other deaths based on reporting by Miller et al., 2010.

The unsuspected cause of death of the otters spurred an environmental investigation to determine how a freshwater-derived toxin (specifically microcystin) was able to transfer up the marine food web. Miller et al. (2010) theorized the bioaccumulation of microcystins in marine invertebrates as the likely vector for the introduction of freshwater-derived toxins into the otter’s diets.

Figure 2-57. Distribution of sea otter deaths and *Microcystis* freshwater sampling locations in Monterey Bay watersheds (map re-created from Miller et al., 2010).



The ability of potential invertebrate food items (i.e. shellfish such as clams, mussels, oysters, etc.) to accumulate and concentrate microcystin toxin at levels that could cause detrimental health impacts to both human and animals is not yet fully understood (Gibble et al., 2016). However, results from Miller et al. (2010) provide compelling evidence implicating the land-sea flow of microcystin with tropic transfer through marine invertebrates as the most likely pathway of exposure to this biotoxin. A later study from San Francisco and Tomales Bays examined the uptake of microcystin toxin by common bivalve species (mussels and oysters) and further demonstrated the accumulation and retention capabilities of this particular cyanotoxin (Gibble et al., 2016). Data from this study showed detectable levels of microcystins for up to eight weeks after 24 hours of exposure to both particulate and dissolved microcystin (Gibble et al., 2016). Results from this study highlight potential implications for human health on a global scale based on the consumption of commercially important and popular aquaculture species such as oysters and mussels. Furthermore, because microcystin is a freshwater toxin, it is not frequently monitored in marine environments where aquaculture operations exist, therefore increasing the likelihood of contaminated shellfish, destined for public consumption, potentially going unnoticed (Gibble et al., 2016, Miller et al., 2010).

Despite the confirmation of the presence of microcystin in the coastal environment, and the determination of the poisoning of multiple animals, the source of the toxin in the marine environment is not entirely clear (Gibble and Kudela, 2014). Miller et al. (2010) identified Pinto Lake as a potential "hotspot" source of the toxin and described the linkage pathway for the transfer into Monterey Bay. However, the distribution of the effected otters was widespread, suggesting other, perhaps less obvious sources could be contributing toxins to the coastal ocean environment (Gibble and Kudela, 2014). Data collected between 1999 and 2008 showed multiple cases of otters dying due to microcystin intoxication to be clustered near river mouths, coastal ponds, embayments and harbors (refer back to Figure 2-57) (Miller et al., 2010).

A follow up study (survey years 2011-2013) shows microcystins are present and persistent in at least four major river basins (Big Basin, Pajaro River, Salinas River, and Carmel River) that drain into Monterey Bay (Gibble and Kudela, 2014). The potential negative impacts to humans and wildlife are elevated due to the capacity of these toxins to accumulate, biomagnify, and persist in food webs (Gibble and Kudela, 2014, Miller et al., 2010). This exemplifies the necessity to track, monitor, and mitigate the occurrence of cyanobacterial blooms in fresh, estuarine, and marine waters alike. Despite the negative health risks to humans and wildlife, microcystins are not routinely monitored by federal, state, or local management agencies (Gibble and Kudela, 2014). This makes it difficult to determine baseline or background levels of "naturally occurring" levels of cyanobacteria and microcystin concentrations in these diverse aquatic environments.

Further complications arise due to the extensive distribution and presence of various concentrations of microcystins throughout the year in each of the major watersheds in the Monterey Bay area. The number of ecosystems impacted (e.g. freshwater, estuarine, and marine) makes managing environmental impacts at the land-sea interface difficult at best (Gibble and Kudela, 2014).

It's important to note, however, that Pinto Lake is not the sole perpetrator of cyanotoxins into the seas. "I never want people to think that all of the otters died because of Pinto Lake," said Dr. Miller. "Because that's absolutely not true."

➔ From: "Evotis", a monthly online publication of the University of California One Health Institute, quoting Dr. Melissa Miller, wildlife pathologist, UC Davis Wildlife Health Center

The sea otter deaths in Monterey Bay are an illustration of how cyanotoxins produced in a freshwater environment can affect receiving waters and demonstrates the important role of fluvial systems as conduits to transport intact toxins from inland waters to downstream marine environments (Fetscher et al., 2015).

Wrapping up, the scientific literature reports adverse environmental effects to marine coastal waters of Monterey Bay by pollution originating in freshwater inland sources, thus demonstrating that watershed improvement activities should recognize and take into account downstream impacts to coastal waters.

3 WATER QUALITY STANDARDS

TMDLs are requirements pursuant to the federal Clean Water Act. The broad objective of the federal Clean Water Act is to "restore and maintain the chemical, physical and biological integrity of the Nation's waters[48]." Water quality standards are provisions of state and federal law intended to implement the federal Clean Water Act. The purpose of water quality standards is to protect human health and to ensure that all state water resources can be utilized to their full potential. TMDL projects are a step towards ensuring that waterbodies achieve their designated water quality standards.

Accordingly, pursuant to state and federal law, California's water quality standards consist of the following:

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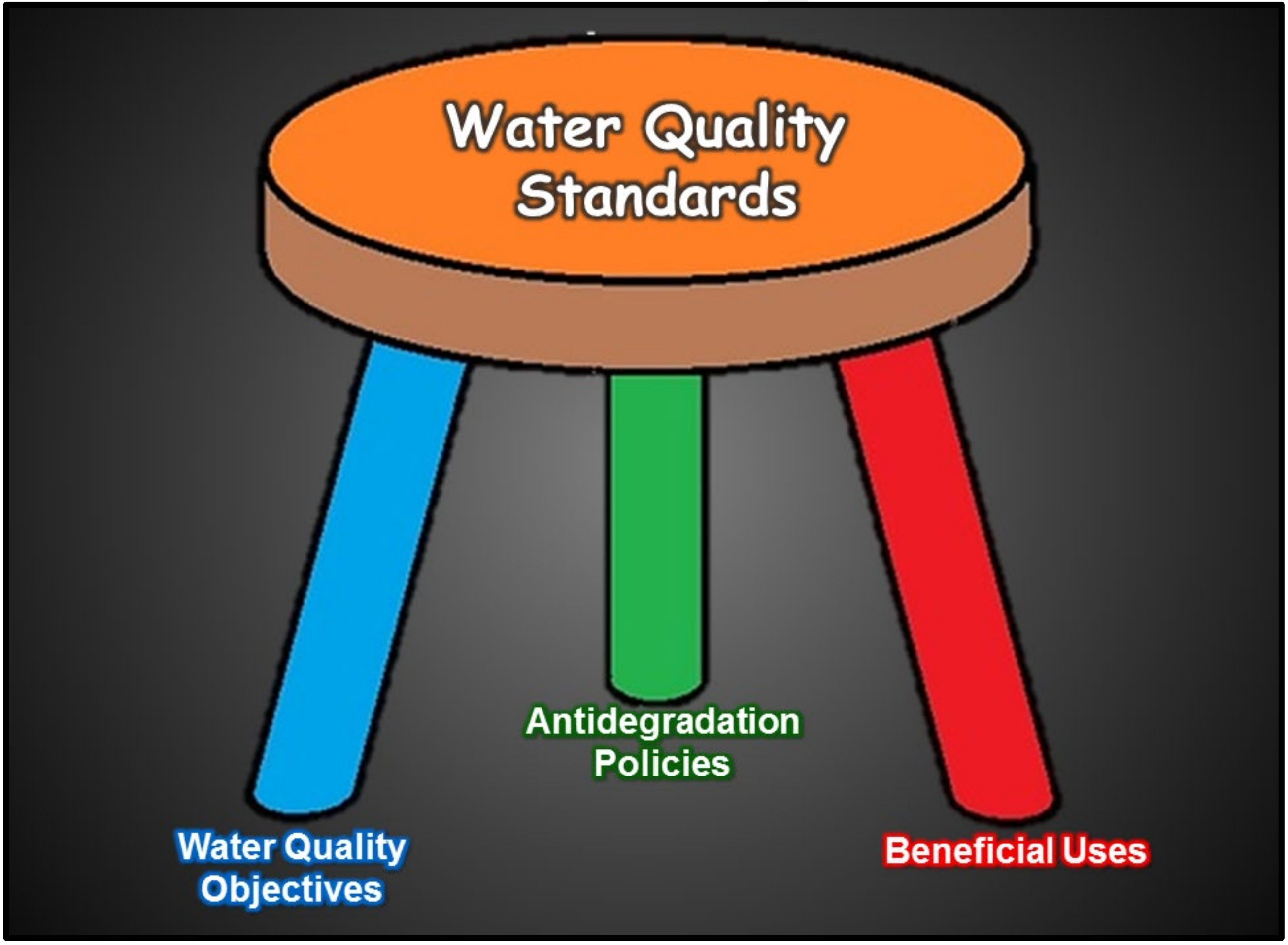
[48] Federal Water Pollution Control Act (33 U.S.C. 1251 et seq.) Title 1, Section 101(a)

- Beneficial uses[49], which refer to legally-designated uses of waters of the state that may be protected against water quality degradation (e.g., drinking water supply, recreation, aquatic habitat, agricultural supply, etc.)
- Water quality objectives[50], which refer to limits or levels (numeric or narrative) of water quality constituents or characteristics that provide for the reasonable protection of beneficial uses of waters of the state.
- Antidegradation policies, which are implemented to maintain and protect existing water quality, and high quality waters.

Therefore, beneficial uses, water quality objectives, and antidegradation policies are mutually supporting and collectively constitute water quality standards[51] (see Figure 3-1). Beneficial uses, relevant water quality objectives, and antidegradation requirements that pertain to this TMDL are presented below in Section 3.1, Section 3.2, and Section 3.3 respectively.

Figure 3-1. California's water quality standards consist of beneficial uses, water quality objectives, and antidegradation policies and TMDLs are action plans to assist the states in implementing their water quality standards.



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[49] ""Beneficial uses" is a term used in California's regulatory scheme, and it is equivalent to the federal Clean Water Act regulatory term "designated uses".

[50] "Water quality criteria" is a term in the federal Clean Water Act regulatory scheme. The equivalent California term under state regulation is "water quality objectives."

[51] See 40 CFR Ch. 1 §131

3.1 Beneficial Uses

Beneficial uses specify management objectives and expectations for how each waterbody may be used. These uses include drinking water supply, agricultural supply, recreation, and protection of aquatic habitat, among others.

California's water quality standards designate beneficial uses for each waterbody and the scientific criteria to support that use. The Central Coast Water Board is required under both State and Federal Law to protect and regulate beneficial uses of waters of the state.

The Water Quality Control Plan for the Central Coastal Basin (Basin Plan) identifies beneficial uses for waterbodies of California's central coast region. Table 3-1 presents beneficial uses for Pinto Lake.

Table 3-1. Central Coast Basin Plan (March 2016 edition) designated beneficial uses for Pinto Lake.

Waterbody	MUN	AGR	GWR	REC-1	REC-2	WILD	WARM	SPWN	COMM
Pinto Lake	X	X	X	X	X	X	X	X	X

MUN: Municipal and domestic water supply
AGR: Agricultural supply
GWR: Ground water recharge
REC-1: Water contact recreation
REC-2: Non-contact water recreation
WILD: Wildlife habitat
WARM: Warm fresh water habitat
SPWN: Spawning, reproduction, and/or early development of fish
COMM: Commercial and sport fishing development

Beneficial uses apply to both current and potential beneficial uses of the waters of the state[52]. Beneficial uses are regarded as existing whether the waterbody is perennial or ephemeral, or the flow is intermittent or continuous[53].

Presented below are narrative descriptions of the designated beneficial uses of Pinto Lake waters that are most likely to be potentially at risk of impairment by cyanotoxins, nutrients, and nutrient-related parameters.

3.1.1 Water Recreation (REC-1 and REC-2)

Pinto Lake is designated for water recreational uses. Section 2 of the Basin Plan defines these beneficial uses as follows:

> *REC-1: Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.*
>
> *REC-2: Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.*

Pinto Lake is a valuable recreational and aesthetic resource for local residents and visitors. Historically, the lake was a swimmable recreational resource, and to this day supports numerous non-water contact recreational opportunities such as boating, fishing, hiking, picnicking, and aesthetic enjoyment.

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[52] Chapter 2.I. Water Quality Control Plan for the Central Coastal Basin (2016)

[53] *Ibid*

> *"Interviews with Pinto Lake watershed residents and Santa Cruz County community members have described Pinto Lake shifting from a largely swimmable recreational resource in the late 1960s to early 1970s to the current cyanobacteria-dominated lake we see today, suggesting that the blooms began to be a problem sometime in the late 70s- early 80s…"*
>
> ➔ from: California State University, Monterey Bay and Resource Conservation District of Santa Cruz County. *Pinto Lake Watershed: Implementation Strategies for Restoring Water Quality in Pinto Lake*. March 2013.

The Basin Plan contains water quality objectives protective of water recreational beneficial uses. Those water quality objectives most relevant to nutrient pollution[54] and cyanobacteria blooms are highlighted in report Section 3.2 and in Table 3-2.

Worth noting is that the Basin Plan also contains a narrative toxicity water quality objective relevant to nutrient pollution and cyanobacteria blooms at Pinto Lake, as follows.

> ***General toxicity objective for all inland surface waters, enclosed bays, and estuaries***
> *"All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, toxicity bioassays of appropriate duration, or other appropriate methods as specified by the Regional Board."*

Because illnesses are considered detrimental physiological responses in humans, the narrative toxicity objective applies to cyanotoxins. Possible health effects of exposure to cyanotoxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects including poisoning (refer back to Section 1.4).

3.1.2 Aquatic Habitat, Wildlife Habitat, & Sport Fishing (WARM, SPWN, WILD, COMM)

Pinto Lake is designated for freshwater aquatic habitat beneficial uses. Section 2 of the Basin Plan defines these beneficial uses as follows:

> *WARM: Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.*
>
> *SPWN: Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.*
>
> *WILD: Uses of water that support terrestrial ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.*
>
> *COMM: Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.*

The Basin Plan contains water quality objectives protective of these aquatic habitat, sport fishing, and wildlife beneficial uses. Those water quality objectives most relevant to nutrient pollution[55] and cyanobacteria blooms are highlighted in report Section 3.2 and in Table 3-2.

Worth noting is that the Basin Plan also contains two narrative water quality objectives relevant to nutrient pollution and cyanobacteria blooms at Pinto Lake, and are as follows.

The biostimulatory substances objective is a narrative water quality objective that states:

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[54] Nutrients, such as nitrate, do not by themselves necessarily directly impair aquatic habitat beneficial uses. Rather, they cause indirect impacts by promoting algal growth and low dissolved oxygen that impair aquatic habitat uses.

[55] *Ibid*.

> ***Biostimulatory substances objective for all inland surface waters, enclosed bays, and estuaries***
> *"Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses."*

Since excess loading of nutrients in Pinto Lake can contribute to harmful cyanobacteria blooms, and related disruptions of the natural balance of dissolved oxygen and ecosystems of the lake, the biostimulatory substances narrative objective applies to the aforementioned aquatic habitat beneficial uses.

The general toxicity objective is a narrative water quality objective previously noted in **Error! Reference source not found.**. Since cyanotoxins are known to cause "detrimental physiological responses" in wildlife resulting from contact and ingestion, the toxicity narrative water quality objective applies to the current or potential aquatic habitat and wildlife habitat beneficial uses of Pinto Lake.

3.1.3 Municipal & Domestic Water Supply (MUN)

Pinto Lake is designated for municipal and domestic water supply beneficial uses. Section 2 of the Basin Plan defines this beneficial use as follows:

> *MUN: Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply. According to State Board Resolution No. 88- 63, "Sources of Drinking Water Policy" all surface waters are considered suitable, or potentially suitable, for municipal or domestic water supply except where:*
>
> *TDS exceeds 3000 mg/l (5000 uS/cm electrical conductivity);*
> *Contamination exists, that cannot reasonably be treated for domestic use;*
> *The source is not sufficient to supply an average sustained yield of 200 gallons per day;*
> *The water is in collection or treatment systems of municipal or industrial wastewaters, process waters, mining wastewaters, or storm water runoff; and*
> *The water is in systems for conveying or holding agricultural drainage waters.*

The Basin Plan contains water quality objectives protective of municipal and domestic water supply beneficial uses. Those water quality objectives most relevant to nutrient pollution and cyanobacteria blooms are highlighted in report Section 3.2 and in Table 3-2.

As mentioned previously in **Error! Reference source not found.**, the Basin Plan contains a narrative water quality objective relevant to nutrient pollution and cyanobacteria blooms at Pinto Lake. Since cyanotoxins are known to cause "detrimental physiological responses" in humans resulting from contact and ingestion, the toxicity narrative water quality objective applies to the current or potential municipal and domestic water supply beneficial uses of Pinto Lake.

3.1.4 Agricultural Supply (AGR)

Pinto Lake waters are designated for agricultural supply beneficial uses. Section 2 of the Basin Plan defines this beneficial use as follows:

> *AGR: Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing (see Basin Plan, Chapter 2, Section II).*

Cyanotoxin water quality can affect the agricultural supply beneficial uses of Pinto Lake waters, as articulated below, and as evidenced in Figure 3-2.

> ***"Pinto Lake used to be an irrigation source for food crops.*** *Growers were forced to* ***abandon*** *the use of lake water and drill wells to tap into a deep aquifer because of threats to food and worker safety posed by the (cyanobacteria)* ***toxins****."*
>
> ➔ letter from California Legislature Assemblymen Luis Alejo and Mark Stone, and State Senator William Monning to State Water Resources Control Board Chair Felicia Marcus, dated October 4, 2013
>
> *Emphasis and parenthetical clarification added by Central Coast Water Board staff.*

Figure 3-2. According to reporting from local resource professionals and residents, growers had to abandon use of cyanotoxin-prone Pinto Lake waters as an irrigation supply source due to concerns with worker safety and food safety.

Thus, in this context, the water quality objective that is most applicable for the support of agricultural supply uses in Pinto Lake is the Basin Plan's general toxicity water quality objective for all inland surface water, enclosed bays, and estuaries[56] (**Error! Reference source not found.**.). Since cyanotoxins are known to cause "detrimental physiological responses" in humans resulting from contact and ingestion, the toxicity narrative water quality objective applies to the agricultural supply beneficial uses of the lake, specifically as it pertains to worker safety and food safety.

3.2 Water Quality Objectives

Water quality objectives[50] refer to limits or levels of water quality constituents or characteristics that provide for the reasonable protection of beneficial uses of waters of the state. Water quality objectives can be numeric (e.g., the maximum pollutant concentration levels permitted in a waterbody) or they can be narrative (e.g., an objective that describes the desired conditions of a waterbody, such as being "free from" certain negative environmental conditions).

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[56] Basin Plan (2016) Chapter 3 Section II.A,2.a.

Since narrative water quality objectives do not have a specific numeric threshold associated with them, the Central Coast Water Board uses scientifically-defensible numeric criteria or numeric guidelines to interpret narrative water quality objectives. Text Box 3-1 and Text Box 3-2 highlight guidance from federal and state agencies concerning the selection of numeric targets to interpret narrative water quality objectives.

Text Box 3-1. Quantitative interpretations of narrative water quality objectives (USEPA guidance).

> *"In situations where applicable water quality standards are expressed in narrative terms or where 303(d) listings were prompted primarily by beneficial use or antidegradation concerns,* ***it is necessary to develop a quantitative interpretation of narrative standards*****.*
>
> *➔ U.S. Environmental Protection Agency (2000b)*
>
> emphasis added by Central Coast Water Board staff

Text Box 3-2. Quantitative interpretations of narrative water quality objectives (State Water Board Office of Chief Counsel guidance).

> *"For waterbodies listed because of failure to meet a narrative water quality objective,* ***the numeric target will be a quantitative interpretation of the narrative objective*****. For example, if a waterbody fails to achieve a narrative objective for settleable solids, the TMDL could include targets for annual mass sediment loading." ➔ State Water Resources Control Board, Office of Chief Counsel (1999)*
>
> emphasis added by Central Coast Water Board staff

The Basin Plan contains both numeric and narrative water quality objectives that apply to cyanobacteria, nutrients, toxicity, algae, and nutrient-related parameters. These water quality objectives are established to protect beneficial uses and are compiled in Table 3-2.

Table 3-2. Compilation of Basin Plan water quality objectives and numeric thresholds for nutrients and nutrient-related parameters.

Constituent / Parameter	Water Quality Objective	Numeric Thresholds or Guideline Values *(“not to exceed” values, unless otherwise noted)*	Primary Beneficial Use(s) Protected
Cyanotoxin (microcystin)	Basin Plan Toxicity narrative water quality objective[A]	0.8 µg/L *Office of Environmental Health Hazard Assessment Public Health Action Level for microcystin and Human Recreational Uses (May 2012)*	REC-1 (water contact recreation) REC-1 (non-contact water recreation) AGR (agricultural supply – irrigation water) *The Office of Environmental Health Hazard Assessment Public Health Action Level numeric guideline values are not specifically intended for irrigation water. However, the guidelines are applicable to incidental human ingestion of water, and it has been reported that lake waters have been abandoned by growers as an irrigation source due to concerns about worker safety posed by cyanotoxins[C]. We thus conclude it is reasonable at this time to apply the guidelines to support AGR beneficial uses of lake waters.*
	Basin Plan Toxicity narrative water quality objective[A]	0.3 µg/L *U.S. Environmental Protection Agency Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins (June 2015)*	MUN (municipal and domestic water supply)

Constituent / Parameter	**Water Quality Objective**	**Numeric Thresholds or Guideline Values** *(“not to exceed” values, unless otherwise noted)*	**Primary Beneficial Use(s) Protected**
	Basin Plan Toxicity narrative water quality objective[A]	0.9 µg/L *Office of Environmental Health Hazard Assessment Action Level for microcystin and Subchronic Water Intake, Cattle (dairy)* 2 µg/L *Office of Environmental Health Hazard Assessment Action Level for microcystin and Subchronic Water Intake, Dog* 3 µg/L *Office of Environmental Health Hazard Assessment Action Level for microcystin Subchronic Water Intake, Cattle (beef)*	AGR (agricultural supply - livestock watering) WILD (wildlife habitat) *Scientifically-based numeric water quality criteria to protect wildlife from toxicity associated with microcystin are not available at this time. We conclude it is reasonable to apply the Office of Health Hazard Assessment Action Level for cattle (dairy) of 0.9 µg/L for the protection of mammalian and avian wildlife at the lake, until more data is available.*
Biostimulatory Substances (phosphorus and nitrogen)	Basin Plan Biostimulatory substances Narrative water quality objective[B]	0.172 mg/L Total Phosphorus *U.S. Environmental Protection Agency* Ambient Water Quality Criteria Recommendations, *Lakes and Reservoirs in Nutrient Ecoregion III (December 2001, EPA-822-B-01-008). This is not a regulatory criterion, but is published for use as a guideline and assessment tool.*	Adverse impacts to beneficial uses or public nuisances resulting from cyanobacteria blooms, i.e., REC-1, REC-2, WILD, WARM.
	Basin Plan Biostimulatory substances Narrative water quality objective[B]	0.51 mg/L Total Nitrogen *U.S. Environmental Protection Agency Ambient Water Quality Criteria Recommendations, Lakes and Reservoirs in Nutrient Ecoregion III (December 2001, EPA-822-B-01-008). This is not a regulatory criterion, but is published for use as a guideline and assessment tool.*	Adverse impacts to beneficial uses or public nuisances resulting from cyanobacteria blooms, i.e., REC-1, REC-2, WILD, WARM.

Constituent / Parameter	**Water Quality Objective**	**Numeric Thresholds or Guideline Values** *(“not to exceed” values, unless otherwise noted)*	**Primary Beneficial Use(s) Protected**
Biostimulatory Substances (chlorophyll *a*)	Biostimulatory substances Narrative water quality objective[B]	15 µg/L *Oregon Administrative Rules (2000), Nuisance Phytoplankton Growth This is a criterion used by the State of Oregon for nuisance phytoplankton growth in lakes and rivers, and is used by the California’s Central Coast Ambient Monitoring Program.as a screening threshold*[D].	Adverse impacts to beneficial uses or public nuisances resulting from cyanobacteria blooms, i.e., REC-1, REC-2, WILD, WARM
Ammonia as N (thresholds for both un-ionized ammonia and total ammonia) *un-ionized ammonia is the molecule NH3 (reported as N)* *total ammonia is ammonia plus ionized ammonium (NH3 as N) + (NH4 as N)*	Basin Plan numeric water quality objective	0.025 mg/L Un-ionized ammonia	Freshwater aquatic habitat (WARM, SPWN) General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries *(toxicity objective)*
	Basin Plan Toxicity narrative water quality objective[A]	Total ammonia 4.4 mg/L (at pH 7.8 and 23° C) [E] - summer/fall 12 mg/L (at pH 7.5 and 17° C) [F] - winter/spring Chronic 30 day rolling average *U.S. Environmental Protection Agency Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater, chronic 30 day (April 2013)*	Freshwater aquatic habitat (WARM, SPWN) *The U.S. Environmental Protection Agency reports that the criteria are pH and temperature dependent. Table 5b (Oncorhynchus species absent) in “Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater (EPA, 2013)” provide the temperature and pH-dependent values of the chronic criteria magnitude.*
	Basin Plan Toxicity narrative water quality objective[A]	Total ammonia 30 mg/L *U.S. Environmental Protection Agency Health Advisory (2012) EPA-822-S-12-001*	MUN (Municipal/Domestic Supply) *The ammonia health advisory is a non-regulatory water quality guideline at which non-cancer adverse health effects are not anticipated to occur over specific exposure duration.*
Nitrate as N	Basin Plan numeric water quality objective	10 mg/L	MUN, GWR (Municipal/Domestic Supply; Groundwater Recharge)

Constituent / Parameter	Water Quality Objective	Numeric Thresholds or Guideline Values *("not to exceed" values, unless otherwise noted)*	Primary Beneficial Use(s) Protected
Includes Nitrate plus Nitrite as N	Basin Plan numeric water quality objectives (Table 3-3 in Basin Plan)	5 – 30 mg/L *California Agricultural Extension Service guidelines*	AGR (Agricultural Supply – irrigation water) *"Severe" problems for sensitive crops at greater than 30 mg/L* *"Increasing problems" for sensitive crops at 5 to 30 mg/L*
	Basin Plan numeric water quality objective (Table 3-4 in Basin Plan)	100 mg/L *National Academy of Sciences-National Academy of Engineers guidelines*	AGR (Agricultural Supply - livestock watering)
Nitrite (NO2–N)	Basin Plan numeric water quality objective (Table 3-4 in Basin Plan)	10 mg/L *National Academy of Sciences-National Academy of Engineers guidelines*	AGR (Agricultural Supply - livestock watering)
Dissolved Oxygen	General Inland Surface Waters numeric objectives	Median dissolved oxygen values should not fall below 85% saturation.	General Water Quality Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries.
	Basin Plan numeric water quality objective WARM, SPWN	Dissolved Oxygen shall not be depressed below 5.0 mg/L (WARM) Dissolved Oxygen shall not be depressed below 7.0 mg/L (SPWN)	WARM (warm freshwater habitat) SPWN (fish spawning)
	Basin Plan numeric water quality objective AGR	Dissolved Oxygen shall not be depressed below 2.0 mg/L	AGR (Agricultural Supply)
pH	General Inland Surface Waters numeric objective	pH value shall not be depressed below 7.0 or raised above 8.5.	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries.
	Basin Plan numeric water quality objective MUN, AGR, REC-1, REC-2	The pH value shall neither be depressed below 6.5 nor raised above 8.3.	MUN, AGR, REC-1, REC-1 (Municipal/Domestic Supply, Agricultural Supply, Water Recreation)
	Basin Plan numeric water quality objective WARM	pH value shall not be depressed below 7.0 or raised above 8.5	WARM (Warm freshwater habitat)

[A] *The Basin Plan toxicity narrative objective states: "All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life…" (Toxicity Objective, Basin Plan, Chapter 3).*

Constituent / Parameter	Water Quality Objective	Numeric Thresholds or Guideline Values *("not to exceed" values, unless otherwise noted)*	Primary Beneficial Use(s) Protected

[B] The Basin Plan biostimulatory substances narrative objective states: "Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses." (Biostimulatory Substances Objective, Basin Plan, Chapter 3).

[C] "Pinto Lake used to be an irrigation source for food crops. ***Growers were forced to abandon the use of lake water*** *and drill wells to tap into a deep aquifer because of threats to food and* ***worker safety posed by the (cyanobacteria) toxins****." ➔ Quote from letter written by California Legislature Assemblymen Luis Alejo and Mark Stone, and State Senator William Monning to State Water Resources Control Board Chair Felicia Marcus, dated October 4, 2013. (Emphasis and parenthetical clarification added by Central Coast Water Board staff.)*

[D] Worcester, K., Paradies D.M., and Adams, M. 2010. Interpreting Narrative Objectives for Biostimulatory Substances for California Central Coast Waters. Central Coast Ambient Monitoring Program, California Central Coast Water Board, Technical Report.

[E] Based on Table 5b of "Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater (EPA, 2013)" total ammonia guideline of 4.4 mg/L would be reasonably consistent with Pinto Lake water temperature and pH conditions in summer and early fall. Available water quality data indicate that median water temperature and pH conditions in the lake from July 1 to October 31 are 22.6º C and 7.8 respectively.

[F] Based on Table 5b of "Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater (EPA, 2013)" total ammonia guideline of 12mg/L would be reasonably consistent with Pinto Lake water temperature and pH conditions in late fall, winter, and spring. Available water quality data indicate that median water temperature and pH conditions in the lake from November 1 to June 30 are 16.8º C and 7.5 respectively.

3.3 Antidegradation Policy

Antidegradation is a component of water quality standards. Worth noting here is that the goals of the federal Clean Water Act are not limited to restoring *polluted* waters back to an acceptable state, as highlighted below.

> *“The objective of this Act is to restore and **maintain** the chemical, physical, and biological integrity of the Nation’s waters.”*
>
> ➔ Clean Water Act §101(a) *(emphasis added by Central Coast Water Board staff)*

The U.S. Environmental Agency states that the TMDL process must reflect antidegradation policy:

> *“The TMDL/WLA/LA process distributes the allowable pollutant loadings to a water body. Such allocations also consider the contribution to pollutant loadings from nonpoint sources. This process must reflect applicable State water quality standards including the **antidegradation policy**.”*
>
> ➔ U.S. Environmental Protection Agency (2012), Water Quality Standards Handbook, Chapter 4: Antidegradation. EPA-823-B-12-002. *(emphasis added by Central Coast Water Board staff)*

Simply put, the guiding principle of antidegradation is to maintain and protect existing high quality waters:

> ***Antidegradation***
> *“Purpose: To prevent deterioration of existing levels of good water quality.”*
>
> ➔ U.S. Environmental Protection Agency, Watershed Academy Webinar, “Introduction to the Clean Water Act”

Indeed, the Central Coast Water Board has consistently recognized the importance of antidegradation, which is articulated as *preventing* a deterioration of existing good water quality:

> *Central Coast Water Board’s highest priorities (these are in priority order):*
>
> 1. ***Preventing** and Correcting Threats to Human Health*
> 2. ***Preventing** and Correcting Degradation of Aquatic Habitat*
> 3. ***Preventing** Degradation of Hydrologic Processes*
> 4. ***Preventing**/Reversing Seawater Intrusion*
> 5. ***Preventing** Further Degradation of Groundwater Basins from Salts*
>
> ➔ source: Central Coast Water Board staff reports of July 2012, October 2013, January 2016, and March 2016 *(emphasis added by Central Coast Water Board staff).*

According to the U.S. Environmental Protection Agency, an antidegradation policy is one of the minimum elements required to be included in a state’s water quality standards[57]. Antidegradation policies are consistent with the intent and goals of the federal Clean Water Act, especially the clause shown above that speaks to “restoring and *maintaining* chemical, physical, and biological integrity of the Nation’s waters”[58, 59] (emphasis added).

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[57] U.S. Environmental Protection Agency, *“Questions & Answers on: Antidegradation”* EPA/811/1985.5, Office of Water Regulations and Standards, August 1985.

[58] *Ibid*

[59] Federal Water Pollution Control Act (Clean Water Act), Sec. 101(a).

> *"Designated uses and water quality criteria are the primary tools states and authorized tribes use to achieve the objectives and goals of the Clean Water Act, and* ***antidegradation requirements*** *complement these tools* ***by providing a framework for maintaining existing uses, for protecting waters that are of a higher quality than necessary to support the Clean Water Act goals,*** *and for protecting waters identified by states and authorized tribes as Outstanding National Resource Waters (ONRWs)."*
>
> ➔ U.S. Environmental Protection Agency (*emphasis added by Central Coast Water Board staff)*

State Water Resources Control Board Resolution No. 68-16 articulates California's antidegradation policy. This state policy articulates that existing good quality waters must be maintained, but it does not constitute a "zero-discharge" standard, and does not unconditionally require that existing water quality be maintained everywhere and at all times[60]. Under the policy, some "limited degradation"[61] of existing water quality can be allowed when it can be justified and it is reasonable to do so.

> *"Whenever the* ***existing quality of water is better than the quality established in policies*** *as of the date on which such policies become effective,* ***such existing high quality will be maintained*** *until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."*
>
> ➔ State Water Resources Control Board Resolution No. 68-16.
>
> (emphasis added by Central Coast Water Board staff)

These federal and state policies ensure that antidegradation is implemented as a stand-alone water quality objective on its own merit:

> *"The State Board has adopted Resolution No. 68-16, the "Statement of Policy with Respect to Maintaining High Quality Waters in California" as part of state policy for water quality control. Resolution No. 68-16 has also been adopted, as a general* ***water quality objective****, in all sixteen regional water quality control plans."*
>
> ➔ State Water Resources Control Board Water Quality Order No. 86-17.
>
> (*emphasis added by Central Coast Water Board staff)*

Accordingly, Section 3.2 of the Basin Plan, states that wherever the existing quality of water is better than the quality of water established in the Basin Plan as objectives, **such existing quality shall be maintained** unless otherwise provided by provisions of the state antidegradation policy.

Without antidegradation safeguards, incremental or continual deterioration of existing high quality waters could be allowed (see Figure 3-3). The state recognizes that allowing activities which result in incremental degradation of high quality waters (even if the activity is not severe enough to cause water quality standards violations) over time may cause a waterbody to no longer have any remaining assimilative capacity and thus beneficial uses of the waters would be at risk of impairment.

The U.S. Environmental Protection Agency has also issued detailed guidelines for implementation of federal antidegradation regulations for surface waters (40 CFR 131.12). The State Water Board has interpreted Resolution No. 68-16 (i.e., the state antidegradation policy) to incorporate the federal antidegradation policy to ensure consistency. It is important to note that federal policy only applies to surface waters, while state policy applies to both surface and ground waters.

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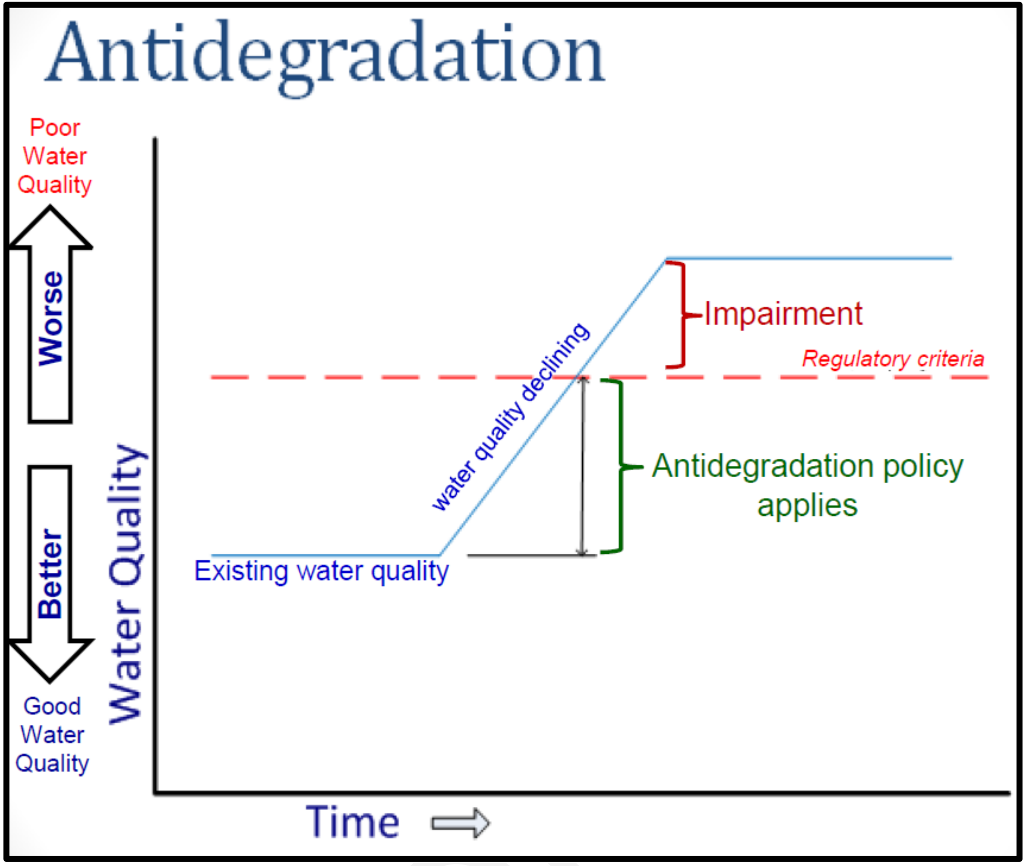
[60] See State Water Quality Resources Control Board Water Quality Order No. 86-8.

[61] *Ibid*

Figure 3-3. An illustration of the intent of antidegradation policy: to prevent the incremental deterioration of existing good quality waters. If further degradation of existing good quality waters is to be allowed it must be justified in accordance with state policy (figure adapted from State Water Board, Division of Water Quality).



For purposes of the antidegradation policy, “high quality waters” are defined on a pollutant-by-pollutant basis. From the perspective of water quality management, it is simply not enough to improve impaired waters – protection of existing high quality waters and prevention of any further water quality degradation is a high priority goal of the Central Coast Water Board[62]. Therefore, TMDL implementation efforts are justified in considering improved protection of high quality waters and addressing antidegradation concerns, as well as focusing on improving impaired waterbodies.

Worth noting is that the U.S. Environmental Protection Agency recognizes the validity of using TMDLs as a tool for implementing antidegradation goals:

> *Identifying opportunities to protect waters that are not yet impaired: TMDLs are typically written for restoring impaired waters; however, states can prepare TMDLs geared towards maintaining a “better than water quality standard” condition for a given waterbody-pollutant combination, and they can be a useful tool for high quality waters.*
>
> ➔ U.S. Environmental Protection Agency, 2014a. Opportunities to Protect Drinking Water Sources and Advance Watershed Goals Through the Clean Water Act: A Toolkit for State, Interstate, Tribal and Federal Water Program Managers. November 2014.

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[62] The Central Coast Water Board considers *preventing* impairment of waterbodies to be as important a priority as *correcting* impairments of waterbodies (see the staff report for agenda item 3, July 11, 2012 Central Coast Water Board meeting).

Similarly, the U.S. Environmental Protection Agency makes clear that TMDLs can serve as planning tools not only for *restoring* water quality, but also for *protecting* and *maintaining* water quality consistent with the goals of antidegradation policies:

> *"A TMDL serves as a planning tool and potential starting point for restoration or* ***protection*** *activities with the ultimate goal of attaining or* ***maintaining*** *water quality standards." (emphasis added by Central Coast Water Board staff)*
>
> ➔ U.S. Environmental Protection Agency, Implementing Clean Water Action Section 303(d): Impaired Waters and Total Maximum Daily Loads (TMDLs) – webpage accessed April 2016 https://www.epa.gov/tmdl
> *(emphasis added by Central Coast Water Board staff).*

3.4 California Clean Water Act Section 303(d) Listing Policy

Water quality standards, such as those discussed previously, play a central role in federally-mandated statewide assessments of impaired waterbodies. The Central Coast Water Board periodically assesses water quality monitoring data for surface waters to determine if they contain pollutants at levels that exceed water quality standards.

In accordance with the Water Quality Control Policy for developing California's Clean Water Act (CWA) section 303(d) List (State Water Board, 2015) – hereafter referred to as the California Listing Policy – waterbody and pollutants that exceed water quality standards are placed on the state's 303(d) List of impaired waters.

It is important to note that TMDLs are established in accordance with the *Porter-Cologne Act's basin planning process* independently of the State Water Board's approval of the C*lean Water Act section 303(d) List.* Thus, while TMDLs can and do rely on the California Listing Policy for guidance is assessing water quality, there is no legal requirement to do so[63]. Water pollution, contamination, nuisance, and degradation of waterbodies have their own meanings under state law[64] and state policy[65].

> *"A plain reading of the Listing Policy clearly shows that it is an independent biennial process that pertains to the water boards' development of the Clean Water Act section 303(d) list, and not the development of a TMDL….Nowhere does the Porter-Cologne Act or the Clean Water Act specify or provide that a water board is precluded from regulating the state's waters by developing a TMDL, until after the water is so degraded that it must be identified on the section 303(d) List."*
>
> ➔ *Matthew J. Goldman, Deputy Attorney General, California Department of Justice, Respondents' Opposition Brief, Case No. 34-2015-80002177, Superior Court of California*

> *"The Listing Policy applies only to the placement of a water segment on the section 303(d) list…the Listing Policy itself states it applies '****only*** *to the* ***listing process*** *methodology used to comply with section 303(d)'." (emphasis added by court)*
>
> ➔ *Superior Court of California, County of Sacramento - Court Ruling on Case No. 34-2015-80002177, January 17, 2017, Pyrethroid Working Group v. California Central Coast Regional Water Quality Control Board.*

However, waterbodies identified as degraded or polluted during the TMDL process must meet the criteria for "impairment" pursuant to the California Listing Policy if they are to be included in *subsequent* statewide Clean Water Act section 303(d) Lists.

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[63] California Department of Justice, Respondents' Opposition Brief (July 26, 2016),, Case No. 34-2015-80002177, Superior Court of California, County of Sacramento.

[64] Porter-Cologne Water Quality Control Act, §13050.

[65] State Water Resources Control Board, Resolution No. 68-16, as supplemented by guidance published by State Water Resources Control Board entitled "Questions and Answers – Resolution No. 68-16" dated February16, 1995.

The California Listing Policy also defines the minimum number of measured exceedances needed to place a water segment on the 303(d) List for toxicants (Listing Policy, Table 3.1) and for conventional or other pollutants (California Listing Policy, Table 3.2). These exceedance criteria can serve as guidance in identifying water quality problems during TMDL development.

With regard to the water quality constituents addressed in this TMDL, it is important to note that nutrients are considered toxicants[66] in accordance with the California Listing Policy, while low dissolved oxygen, chlorophyll *a* and pH, are conventional pollutants.

3.4.1 Clean Water Act Section 303(d) Impairments (Year 2014)

Listing a waterbody as impaired under federal law in California is governed by the Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) Listing Policy. The State and Regional Water Boards assess water quality data for California's waters every few years to determine if they contain pollutants at levels that exceed protective water quality criteria and standards. This periodic assessment is required under section 303(d) of the federal Clean Water Act. The last section 303(d) assessment in the central coast region was approved by the Central Coast Regional Board at the December 9, 2016 Board Hearing. The central coast 303(d) List was combined with approved 303(d) List's from other Regional Water Boards to create California's 2014-2016 303(d) List. The USEPA subsequently approved California's 2014- 2016 303(d) List on April 6, 2018. The previous section 303(d) assessment conducted in the central coast region was approved by USEPA in 2010.

Table 3-3 outlines the impairments identified in Pinto Lake in the 2014- 2016 303(d) assessment. Note that were few changes between the 2010 303(d) List and the 2014-2016 303(d) List. The only changes made between the two versions of the List were changing the pollutant name from "total ammonia" to "ammonia" and adding a listing for DDT.

Table 3-3. Clean Water Act section 303(d) impairments at Pinto Lake (year 2014[1]).

Waterbody Name	Waterbody Identifier	USGS Watershed Cataloging Unit*	Pollutant	Pollutant Category	Final Listing Decision
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Ammonia	Nutrients	List on 303(d) List (TMDL required list)
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Chlorophyll *a*	Nutrients	List on 303(d) List (TMDL required list)
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Cyanobacteria hepatotoxic microcystins	Miscellaneous	List on 303(d) List (TMDL required list)

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[66] See Section 7 Definitions-Toxicants in *Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List*, State Water Board (2004).

Waterbody Name	Waterbody Identifier	USGS Watershed Cataloging Unit*	Pollutant	Pollutant Category	Final Listing Decision
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	DDT (Dichlorodiphenyl-trichloroethane)	Miscellaneous	List on 303(d) List (TMDL required list)
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Low Dissolved Oxygen	Nutrients	Do Not Delist from the 303(d) List (TMDL required list)
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Scum/Foam-unnatural	Nuisance	List on 303(d) List (TMDL required list)
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	pH	Miscellaneous	List on 303(d) List (TMDL required list)

1 – Note that while the most recent 303(d) assessment is called the 2014-2016 version, this assessment includes data submitted up to 2010.

4 WATER QUALITY DATA ANALYSIS

4.1 Water Quality Data Sources and Monitoring Sites

Surface water quality data (i.e., data from the lake, from tributary creeks, and from diches) used in this report were kindly made available to Central Coast Water Board staff from the following sources:

1. City of Watsonville water quality data.
2. County of Santa Cruz water quality data.
3. Water quality data collected by researchers from University of California, Santa Cruz.
4. Water quality data collected by researchers from California State University, Monterey Bay.

Key stakeholders that assisted in contributing surface water quality data included Dr. Raphael Kudela and his team of researchers from the University of California–Santa Cruz; Mr. John Ricker of the County of Santa Cruz; Mr. Robert Ketley and Ms. Jackie McCloud of the City of Watsonville; Mr. Scott Blanco and Ms. Erin Stanfield affiliated with California State University–Monterey Bay.

Figure 4-1 illustrates the surface water quality monitoring locations in the Pinto Lake catchment. Surface water quality data summaries are compiled in Sections 4.2 through 4.6.

Groundwater quality data (i.e., data from shallow groundwater[67] and springs) used in this report were obtained from the following sources:

1. U.S. Geological Survey's National Water Information System (NWIS).
2. State Water Board's GeoTracker database.
3. U.S. Geological Survey's National Uranium Resource Evaluation (NURE) Hydrogeochemical Reconnaissance dataset.

Report Section 4.8 presents maps and data summaries for groundwater quality data used in report.

Where appropriate, Central Coast Water Board staff conducted additional data quality control and data filtering on the water quality data. This quality control included:

1) Filtering the data to extract only grab samples and field measurements (thus excluding field blanks and duplicates);

2) Converting nutrient data reported in compound molecular reporting conventions to the elemental reporting convention (e.g., converting nitrate molecular (NO_3) concentration values to nitrate as elemental nitrogen (N) values);

3) Quantifying censored data[68] by substituting imputed values[69, 70];

4) Where appropriate, combining water quality data from monitoring sites which were in close proximity to each other (<200 meters), in the same surface waterbody, and when there was no compelling reason to treat them, for TMDL purposes, as individual, discrete monitoring sites[71]; consistent with guidance published in the *California Listing Policy* (State Water Board, 2015);

5) If there were more than one sample collected on the same day, from the same sampling location, we averaged those samples: and

6) For microcystin data, multiple layers of analyses were performed due to the large number of non-detect values in the dataset and the fact that four different laboratory methods were used to determine the concentration of microcystin; all with different detection limits.

    a) Imputed values were derived for all non-detectable, less than values, or zero values[72].

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[67] In an attempt to report groundwater data that reasonably could be expected to be representative of shallow groundwater, we filtered groundwater data on the basis of well construction information. If and where well construction information was available, we included in our final dataset only private domestic drinking water wells, or wells that were constructed to a depth less than 200 feet below ground surface. These well were presumed to be representative or influenced by shallower groundwaters. Wells identified as irrigation or municipal supply wells or wells constructed to a depth of greater than 200 feet below ground surface were excluded from our final dataset, as these types of wells would generally be expected to be influenced or representative of deeper groundwater aquifers (i.e., groundwaters that have not recently been in hydraulic communication with surface waters such as lakes, creeks, or ditches).

[68] Censored data are non-quantified measurements of constituents that are reported as less than a detection limit or reporting limit, because the sample constituent exists in a concentration lower than can reliably be detected and reported by the laboratory.

[69] An imputed value is the implicit or estimated value of an item for which an actual or "true" value is not available or not known.

[70] Many substitution methods exist to account for censored data. In many water quality studies, censored data is often simply substituted with zero or with one-half the detection limit. These simple substitution schemes can introduce bias into resulting statistics of the dataset. In this report, we substituted imputed values for the censored data using a *Regression on Order Statistics* (ROS) technique for analyzing any censored data. The ROS technique for analyzing censored data is available via the State Water Board's RP calculator tool. According to the State Water Board's RP calculator user's guide, the ROS technique for analyzing censored data is a robust and unbiased method for imputing censored data.

[71] The California Listing Policy Section 6.1.5.2 states: *"Samples collected within 200 meters of each other should be considered samples from the same station or location."* It should be recognized that TMDLs are watershed studies which endeavor to identify waterbody impairments at the stream reach scale. Typically, a monitoring program consisting of high-resolution, fine-scale monitoring – such as discrete monitoring locations upgradient and downgradient of a pipe or culvert – is more appropriate for field-scale or implementation studies.

[72] We accomplished this using the State Water Board's RP calculator using the less than detection limit. RP calculator uses a Regression on Order Statistics (ROS) technique for analyzing any censored data (71% of the microcystin sampling events at Pinto Lake were non-detects, or "left-censored" data).

b) If the data was censored indicating that the result was greater than 10, for example, the number entered in the dataset was 10 as we could not determine how high the value was (the number 10 is provided as an arbitrary numeric example).
c) If the data was interval censored, where the concentration was > 0.5 < 3, for example, we determined a random number (using MS Excel function =RANDBETWEEN) between this lower and upper limit for our data analysis and inputted that value into the dataset. Only a handful of results from the available data were interval censored.

We also needed to convert some water quality data to appropriate and consistent reporting conventions. Water quality data using different analytical reporting conventions can result in confusion, and even scientists and regulators have to practice diligence to avoid mixing-up and conflating nitrate concentrations which are reported in different conventions. Mixing up and conflating analytical nitrate reporting conventions can result in apples-to-oranges comparisons.

Nitrate concentration values are commonly reported as either molecular nitrate (NO_3), or as nitrate as elemental nitrogen (i.e., NO_3-N or nitrate as N). Note that the maximum contaminant level (MCL) in drinking water as molecular nitrate (NO_3) is 45 mg/L, whereas this MCL when reported as elemental nitrogen (NO_3-N) is 10 mg/L. While these two nitrate numeric values would appear to represent different concentrations, these concentration values are in fact equivalent to each other − the only difference being whether or not the molecular weight of the oxygen atoms in the nitrate molecule is included in the analytical reporting.

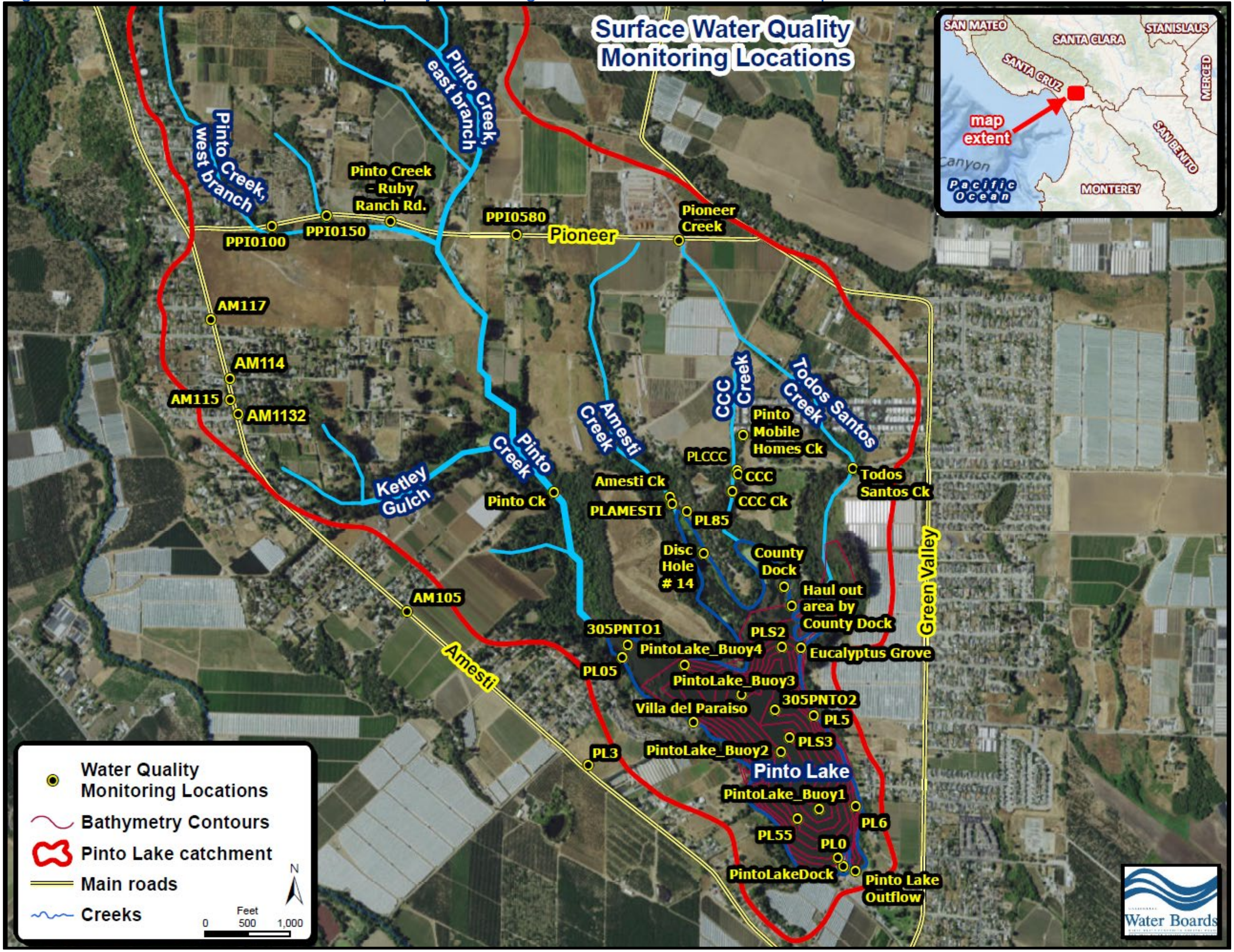
National and USEPA water quality standards, water quality modeling tools, most scientific literature, and most TMDLs use the elemental nitrogen reporting convention (i.e., written as either nitrate as nitrogen; NO_3-N; or nitrate as N). Likewise, this TMDL Report uses the elemental nitrogen convention (i.e., nitrate as N).

It should be noted that effective January 1, 2016 the State Water Board will require nitrate laboratory results to be expressed as nitrate as nitrogen. As a result, the maximum contaminant level for nitrate in drinking water is now expressed as “10 mg/L (as nitrogen)” instead of “45 mg/L (as nitrate)”; and thus the convention to report nitrate as molecular NO_3 (i.e., nitrate as NO_3) is no longer appropriate.

Similarly, in this progress report ammonia is reported as elemental nitrogen (e.g., un-ionized ammonia as nitrogen – NH_3-N), and phosphate is reported as elemental phosphorus (e.g., orthophosphate as phosphorus – PO_4-P).

Also worth noting, is that most nitrogen analytical measurements include and report nitrate (NO_3) plus nitrite (NO_2), but because concentrations of nitrite (NO_2) are typically insignificant relative to nitrate, this mixture is simply called “nitrate” in this TMDL report, and in most regulatory contexts.

Figure 4-1. Pinto Lake catchment water quality monitoring locations used in this TMDL report.



4.2 Statistical Summary of Surface Water Quality Data

The intent of this section of the report is to present numerical summaries of surface water quality data compiled for this TMDL project.

Statistical summaries of surface waters (lake water, creeks, ditches) in the Pinto Lake catchment are presented in Table 4-1 through Table 4-9. The locations of the sampling sites used in the numerical summaries are shown in Figure 4-2. Selected constituents are presented spatially in Figure 4-3 and Figure 4-4.

Statistical summaries are a way of organizing data and providing ways to assess trends, variation, and dispersion in water quality. Using these data and statistical summaries we assess water quality spatial variation, seasonality, and temporal variation in subsequent sections of this report.

Figure 4-2. Surface water monitoring locations in the Pinto Lake catchment and vicinity.

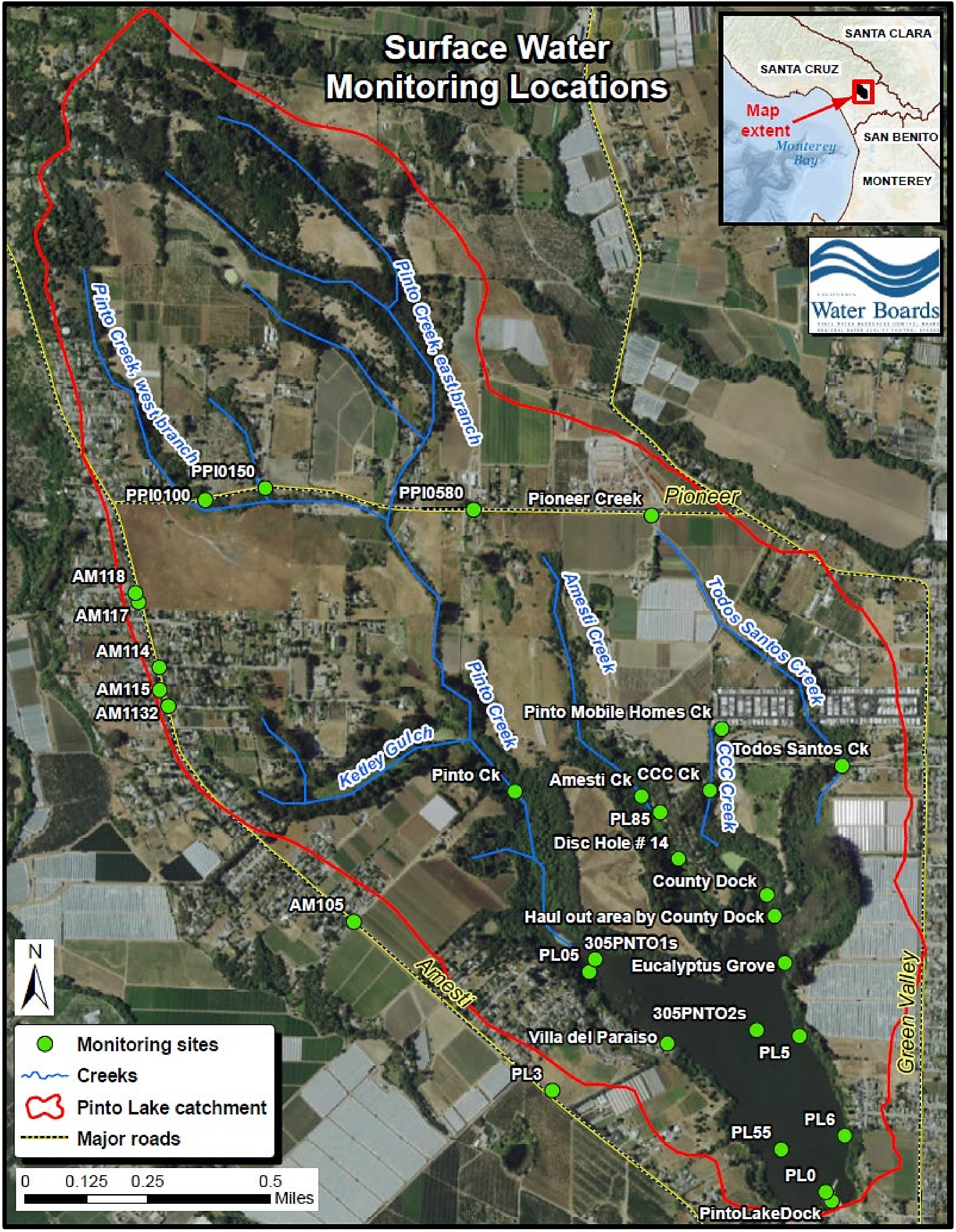


Table 4-1. Summary statistics for nitrate as N (units=mg/L) and exceedances of the drinking water standard in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
Pinto Lake	**All sites**	793	10/5/2000	4/27/2016	0.20	0.00	0.015	0.07	0.30	7.92	0	0%
	305PNTO1b	12	6/10/2005	5/22/2006	0.19	0.0021	0.005	0.02	0.47	0.65	0	0%
	305PNTO1m	12	6/10/2005	5/22/2006	0.20	0.0003	0.007	0.02	0.47	0.65	0	0%
	305PNTO1s	12	6/10/2005	5/22/2006	0.20	0.0015	0.007	0.02	0.47	0.69	0	0%
	305PNTO2b	12	6/10/2005	5/22/2006	0.17	0.0009	0.008	0.01	0.39	0.60	0	0%
	305PNTO2m	12	6/10/2005	5/22/2006	0.20	0.0002	0.011	0.02	0.44	0.69	0	0%
	305PNTO2s	12	6/10/2005	5/22/2006	0.20	0.0016	0.004	0.02	0.47	0.69	0	0%
	305PNTO3b	12	6/10/2005	5/22/2006	0.19	0.0012	0.007	0.02	0.45	0.70	0	0%
	305PNTO3m	12	6/10/2005	5/22/2006	0.20	0.0032	0.008	0.02	0.47	0.69	0	0%
	County Dock	10	8/1/2013	3/19/2015	0.17	0.0009	0.018	0.14	0.32	0.42	0	0%
	Disc Hole # 14	3	8/1/2013	3/19/2015	0.13	0.0023	0.083	0.16	0.19	0.22	0	0%
	Haul out area by County Dock	7	12/16/2013	7/1/2014	0.21	0.0038	0.100	0.25	0.32	0.35	0	0%
	PintoLakeDock	390	6/10/2005	4/26/2015	0.21	0.0000	0.023	0.07	0.39	1.12	0	0%
	PintoLake_Buoy1	40	4/1/2011	4/27/2016	0.13	0.0010	0.017	0.08	0.22	0.60	0	0%
	PintoLake_Buoy1b	1	4/27/2016	4/27/2016	0.20	0.2000	0.200	0.20	0.20	0.20	0	0%
	PintoLake_Buoy1m	1	4/27/2016	4/27/2016	0.20	0.2000	0.200	0.20	0.20	0.20	0	0%
	PintoLake_Buoy2b	39	4/1/2011	4/2/2012	0.11	0.0010	0.008	0.05	0.13	0.82	0	0%
	PintoLake_Buoy2m	38	4/1/2011	4/2/2012	0.13	0.0022	0.016	0.07	0.22	0.70	0	0%
	PintoLake_Buoy2s	39	4/1/2011	4/2/2012	0.33	0.0000	0.016	0.08	0.23	7.92	0	0%
	PintoLake_Buoy3	39	4/1/2011	4/2/2012	0.12	0.0010	0.011	0.06	0.22	0.45	0	0%
	PintoLake_Buoy4	40	4/1/2011	4/27/2016	0.13	0.0020	0.015	0.07	0.21	0.63	0	0%
	PintoLake_Buoy4b	1	4/27/2016	4/27/2016	0.14	0.1399	0.140	0.14	0.14	0.14	0	0%
	PintoLake_Buoy4m	1	4/27/2016	4/27/2016	0.20	0.2000	0.200	0.20	0.20	0.20	0	0%
	PL0	23	5/7/1992	4/20/2005	0.30	0.0027	0.045	0.16	0.42	1.48	0	0%
	PL05	2	10/5/2000	4/20/2005	0.22	0.0500	0.133	0.22	0.30	0.38	0	0%
	PL3	3	12/6/2000	4/20/2005	0.25	0.1400	0.160	0.18	0.31	0.43	0	0%
	PL5	1	4/20/2005	4/20/2005	0.28	0.2800	0.280	0.28	0.28	0.28	0	0%
	PL55	1	4/20/2005	4/20/2005	0.42	0.4200	0.420	0.42	0.42	0.42	0	0%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
	PL6	1	4/20/2005	4/20/2005	0.41	0.4100	0.410	0.41	0.41	0.41	0	0%
	PLS2b	1	4/27/2016	4/27/2016	0.01	0.0093	0.01	0.01	0.01	0.01	0	0%
	PLS2m	1	4/27/2016	4/27/2016	0.10	0.1000	0.10	0.10	0.10	0.10	0	0%
	PLS2s	1	4/27/2016	4/27/2016	0.20	0.2000	0.20	0.20	0.20	0.20	0	0%
	PLS3b	1	4/27/2016	4/27/2016	0.10	0.1000	0.10	0.10	0.10	0.10	0	0%
	PLS3m	1	4/27/2016	4/27/2016	0.20	0.2000	0.20	0.20	0.20	0.20	0	0%
	PLS3s	1	4/27/2016	4/27/2016	0.20	0.2000	0.20	0.20	0.20	0.20	0	0%
	Villa del Paraiso	11	12/16/2013	3/19/2015	0.28	0.0018	0.021	0.24	0.43	0.78	0	0%
Pinto Lake Outflow	Pinto Lake Outflow	1	2/9/2015	2/9/2015	1.20	1.20	1.20	1.20	1.20	1.20	0	0%
Amesti Creek	**All sites**	22	12/16/2012	1/19/2016	1.432	0.0200	0.042	0.186	1.94	8.40	0	0%
	Amesti Creek	17	12/16/2012	4/1/2014	0.77	0.0200	0.038	0.12	1.37	4.97	0	0%
	PLAMESTI	5	1/12/2015	1/19/2016	3.69	0.1000	1.970	3.76	4.23	8.40	0	0%
CCC Creek	**All sites**	44	2/11/2013	1/19/2016	7.27	0.0770	3.775	4.32	5.62	26.05	7	16%
	CCC	1	4/7/2015	4/7/2015	8.00	8.00	8.00	8.00	8.00	8.00	0	0%
	CCC Creek	41	2/11/2013	4/1/2014	7.32	0.0770	3.760	4.28	5.07	26.05	7	17%
	PLCCC	2	1/5/2016	1/19/2016	5.77	5.265	5.516	5.77	6.02	6.27	0	0%
Pinto Creek	**All sites**	9	2/1/2012	4/7/2015	1.15	0.0328	0.092	0.41	1.39	4.20	0	0%
	Pinto Creek	6	2/1/2012	4/1/2014	0.53	0.0328	0.079	0.25	0.99	1.39	0	0%
	Pinto Creek – Ruby Ranch Rd.	3	1/12/2015	4/7/2015	2.40	0.2000	1.500	2.80	3.50	4.20	0	0%
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	3	2/8/2013	4/1/2014	2.91	0.3195	1.885	3.45	4.20	4.96	0	0%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	0.82	0.8200	0.820	0.82	0.82	0.82	0	0%
Todos Santos Creek	Todos Santos Creek	27	12/24/2012	4/7/2015	1.55	0.0953	0.227	0.85	2.37	5.49	0	0%
Ditch	**All sites**	20	5/6/1993	12/23/2014	3.31	0.0050	0.879	2.37	4.38	14.51	1	5%
	AM105	3	3/3/2009	3/21/2012	1.04	0.6440	0.801	0.96	1.24	1.53	0	0%
	AM1132	7	5/6/1993	3/21/2012	1.49	0.0050	0.275	0.51	1.25	6.85	0	0%
	AM114	2	3/21/2012	12/23/2014	9.16	3.8120	6.487	9.16	11.84	14.51	1	50%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 10mg/L (MUN Standard)	% Exceeding 10 mg/L
	AM115	2	3/3/2009	3/21/2012	4.88	4.2300	4.554	4.88	5.20	5.53	0	0%
	AM117	1	3/21/2012	3/21/2012	8.87	8.8660	8.866	8.87	8.87	8.87	0	0%
	PL85	1	12/23/2014	12/23/2014	2.53	2.5300	2.530	2.53	2.53	2.53	0	0%
	PPI0100	2	3/21/2012	12/23/2014	3.88	2.995	3.439	3.88	4.33	4.77	0	0%
	PPI0150	1	12/23/2014	12/23/2014	2.20	2.2000	2.200	2.20	2.20	2.20	0	0%
	PPI0580	1	12/23/2014	12/23/2014	3.31	3.3100	3.310	3.31	3.31	3.31	0	0%

Table 4-2. Summary statistics for total nitrogen as N (units=mg/L) and exceedances of a generic lake criteria in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceed 0.51 mg/L[1]	% Exceed 0.51 mg/L
Pinto Lake	PintoLakeDock	222	4/18/2010	5/31/2014	1.87	0.65	1.08	1.60	2.30	12.87	222	100%
Amesti Creek	Amesti Ck	11	12/16/2012	3/11/2013	1.40	0.01	0.59	0.88	1.48	6.10	9	82%
CCC Creek	CCC Creek	30	2/11/2013	2/19/2014	6.58	0.09	3.32	3.97	5.08	28.91	29	97%
Pinto Creek	Pinto Ck	2	3/19/2012	12/16/2012	0.39	0.06	0.23	0.39	0.56	0.73	1	50%
Unnamed tributary to CCC Creek	Pinto Mobile Homes Ck	1	2/8/2013	2/8/2013	4.29	4.29	4.29	4.29	4.29	4.29	1	100%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	1.26	1.26	1.26	1.26	1.26	1.26	1	100%
Todos Santos Creek	Todos Santos Ck	16	12/24/2012	2/19/2014	2.54	0.26	0.63	2.10	4.04	6.42	12	75%

1 - A concentration of 0.51 mg/L nitrogen represents a U.S. Environmental Protection Agency screening threshold we use here for informational purposes but should not be considered a TMDL numeric target. (see: *U.S. Environmental Protection Agency Ambient Water Quality Criteria Recommendations, Lakes and Reservoirs in Nutrient Ecoregion III (December 2001, EPA-822-B-01-008). This is not a regulatory criterion, but is published for use as a guideline and assessment tool.*

Table 4-3. Summary statistics for un-ionized ammonia as N (units=mg/L) and exceedances of Basin Plan standard in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.025mg/L (Basin Plan Standard)	% Exceeding 0.025 mg/L
Pinto Lake	**All sites**	235	6/10/2005	4/27/2016	0.671	0.001	0.018	0.120	0.859	12.766	160	68%
	305PNTO1b	12	6/10/2005	5/22/2006	0.554	0.030	0.148	0.330	0.968	1.570	12	100%
	305PNTO1m	12	6/10/2005	5/22/2006	0.529	0.030	0.089	0.220	0.913	1.780	12	100%
	305PNTO1s	12	6/10/2005	5/22/2006	0.510	0.009	0.080	0.245	0.824	1.840	9	75%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.025mg/L (Basin Plan Standard)	% Exceeding 0.025 mg/L
	305PNTO2b	12	6/10/2005	5/22/2006	3.112	0.360	0.968	1.605	4.580	9.570	12	100%
	305PNTO2m	12	6/10/2005	5/22/2006	0.611	0.200	0.308	0.360	0.861	1.860	12	100%
	305PNTO2s	12	6/10/2005	5/22/2006	0.477	0.007	0.066	0.240	0.790	1.580	9	75%
	305PNTO3b	12	6/10/2005	5/22/2006	0.542	0.020	0.112	0.300	0.918	1.810	10	83%
	305PNTO3m	12	6/10/2005	5/22/2006	0.486	0.012	0.075	0.210	0.716	1.850	10	83%
	County Dock	10	8/1/2013	3/19/2015	0.822	0.006	0.015	0.040	0.861	4.977	5	50%
	Disc Hole #14	2	8/1/2013	3/19/2015	0.012	0.003	0.007	0.012	0.016	0.021	0	0%
	Haul out area by County Dock	7	12/16/2013	7/1/2014	2.057	0.001	0.050	0.768	1.588	10.355	5	71%
	PintoLake_Buoy1b	1	4/27/2016	4/27/2016	0.009	0.009	0.009	0.009	0.009	0.009	0	0%
	PintoLake_Buoy1m	1	4/27/2016	4/27/2016	0.037	0.037	0.037	0.037	0.037	0.037	1	100%
	PintoLake_Buoy1	1	4/27/2016	4/27/2016	0.053	0.053	0.053	0.053	0.053	0.053	1	100%
	PintoLake_Buoy4b	1	4/27/2016	4/27/2016	1.80	1.80	1.80	1.80	1.80	1.80	1	100%
	PintoLake_Buoy4m	1	4/27/2016	4/27/2016	0.148	0.148	0.148	0.148	0.148	0.148	1	100%
	PintoLake_Buoy4	1	4/27/2016	4/27/2016	0.106	0.106	0.106	0.106	0.106	0.106	1	100%
	Pinto Lake Dock	98	6/10/2005	3/19/2015	0.323	0.001	0.011	0.028	0.288	4.482	50	51%
	PLS2b	1	4/27/2016	4/27/2016	2.20	2.20	2.20	2.20	2.20	2.20	1	100%
	PLS2m	1	4/27/2016	4/27/2016	0.015	0.015	0.015	0.015	0.015	0.015	0	0%
	PLS2s	1	4/27/2016	4/27/2016	0.075	0.075	0.075	0.075	0.075	0.075	1	100%
	PLS3b	1	4/27/2016	4/27/2016	0.50	0.50	0.50	0.50	0.50	0.50	1	100%
	PLS3m	1	4/27/2016	4/27/2016	0.024	0.024	0.024	0.024	0.024	0.024	0	0%
	PLS3s	1	4/27/2016	4/27/2016	0.004	0.004	0.004	0.004	0.004	0.004	0	0%
	Villa del Paraiso	10	12/16/2013	3/19/2015	1.661	0.004	0.019	0.152	0.955	12.766	6	60%
Pinto Lake Outflow	Pinto Lake Outflow	1	2/9/2015	2/9/2015	0.30	0.30	0.30	0.30	0.30	0.30	1	100%
Amesti Creek	**All sites**	21	2/16/2012	1/19/2016	0.057	0.017	0.028	0.040	0.080	0.200	17	81%
	Amesti Creek	17	12/16/2012	4/1/2014	0.050	0.017	0.028	0.040	0.060	0.125	14	82%
	PLAMESTI	4	2/9/2016	1/19/2016	0.086	0.022	0.031	0.061	0.116	0.20	3	75%
CCC Creek	**All sites**	44	2/11/2013	1/19/2016	0.046	0.005	0.020	0.031	0.051	0.406	29	66%
	CCC Ck	41	2/11/2013	4/1/2014	0.046	0.005	0.020	0.030	0.049	0.406	26	63%
	CCC	1	4/7/2015	4/7/2015	0.031	0.031	0.031	0.031	0.031	0.031	1	100%
	PLCCC	2	1/5/2016	1/19/2016	0.07	0.07	0.07	0.07	0.07	0.07	2	100%
Pinto Creek	**All sites**	8	2/1/2012	4/7/2015	0.089	0.057	0.060	0.076	0.113	0.154	8	100%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.025mg/L (Basin Plan Standard)	% Exceeding 0.025 mg/L
	Pinto Ck	6	2/1/2012	4/1/2014	0.089	0.057	0.062	0.076	0.104	0.154	6	100%
	Pinto Creek–Ruby Ranch Rd.	2	2/9/2015	4/7/2015	0.09	0.06	0.075	0.09	0.105	0.12	2	100%
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	3	2/8/2013	4/1/2014	0.127	0.032	0.053	0.073	0.174	0.275	3	100%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	0.040	0.040	0.040	0.040	0.040	0.040	1	100%
Todos Santos Creek	Todos Santos Creek	27	12/24/2012	4/7/2015	0.183	0.001	0.040	0.060	0.108	2.009	25	93%
Ditch	**All sites**	5	12/23/2014	12/23/2014	0.035	0.006	0.015	0.028	0.047	0.077	3	60%
	AM114	1	12/23/2014	12/23/2014	0.077	0.077	0.077	0.077	0.077	0.077	1	100%
	PL85	1	12/23/2014	12/23/2014	0.028	0.028	0.028	0.028	0.028	0.028	1	100%
	PPI0100	1	12/23/2014	12/23/2014	0.015	0.015	0.015	0.015	0.015	0.015	0	0%
	PPI0150	1	12/23/2014	12/23/2014	0.047	0.047	0.047	0.047	0.047	0.047	1	100%
	PPI0580	1	12/23/2014	12/23/2014	0.006	0.006	0.006	0.006	0.006	0.006	0	0%

Table 4-4. Summary statistics for dissolved oxygen (units=mg/L) and exceedances of Basin Plan standards in waterbodies in Pinto Lake.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	Max	No. below 5.0 mg/L	% below 5.0 mg/L	No. below 7.0 mg/L	% below 7.0 mg/L
Pinto Lake	**All sites**	278	6/10/2005	7/19/2014	8.08	0.01	22.88	70	25%	120	43%
	305PNTO1b	12	6/10/2005	5/22/2006	4.43	1.87	8.26	9	75%	11	92%
	305PNTO1m	12	6/10/2005	5/22/2006	6.25	2.57	13.50	6	50%	9	75%
	305PNTO1s	12	6/10/2005	5/22/2006	6.66	3.28	14.00	4	33%	9	75%
	305PNTO2b	12	6/10/2005	5/22/2006	1.23	0.01	4.87	12	100%	12	100%
	305PNTO2m	12	6/10/2005	5/22/2006	2.97	0.17	6.59	10	83%	12	100%
	305PNTO2s	12	6/10/2005	5/22/2006	7.91	3.11	19.20	4	33%	7	58%
	305PNTO3b	12	6/10/2005	5/22/2006	5.39	0.70	9.61	6	50%	9	75%
	305PNTO3m	12	6/10/2005	5/22/2006	7.25	3.28	15.30	2	17%	7	58%
	Pinto Lake Dock	96	6/10/2005	6/25/2014	8.93	2.66	20.52	10	10%	31	32%
	PL5	86	1/18/2012	7/19/2014	10.28	0.68	22.88	7	8%	13	15%

Table 4-5. Summary statistics for dissolved oxygen saturation (units=%) in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Min	Median Saturation (%)	Max	No. below 85% Saturation[1]	% below 85% Saturation
Pinto Lake	**All sites**	145	5/15/2009	7/19/2014	6.4	100.0	270.6	44	30%
	Pinto Lake Dock	59	5/15/2009	4/1/2014	44.0	99.0	211.0	22	37%
	PL5	86	1/18/2012	7/19/2014	6.4	101.85	270.6	22	26%

Table 4-6. Summary statistics for total phosphorous as P (units=mg/L) and exceedances of a generic lake criteria for phosphate water quality criteria in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.172 mg/L[1]	% Exceeding 0.172 mg/L
Pinto Lake	**All sites**	327	4/18/2010	10/29/2016	0.163	0.002	0.034	0.114	0.207	1.60	110	34%
	PintoLake_Buoy1b	1	4/27/2016	4/27/2016	0.450	0.450	0.450	0.450	0.450	0.450	1	100%
	PintoLake_Buoy1m	1	4/27/2016	4/27/2016	0.430	0.430	0.430	0.430	0.430	0.430	1	100%
	PintoLake_Buoy1s	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PintoLake_Buoy4b	1	4/27/2016	4/27/2016	1.300	1.300	1.300	1.300	1.300	1.300	1	100%
	PintoLake_Buoy4m	1	4/27/2016	4/27/2016	0.450	0.450	0.450	0.450	0.450	0.450	1	100%
	PintoLake_Buoy4s	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PLS2b	1	4/27/2016	4/27/2016	1.600	1.600	1.600	1.600	1.600	1.600	1	100%
	PLS2m	1	4/27/2016	4/27/2016	0.480	0.480	0.480	0.480	0.480	0.480	1	100%
	PLS2s	1	4/27/2016	4/27/2016	0.410	0.410	0.410	0.410	0.410	0.410	1	100%
	PLS3b	1	4/27/2016	4/27/2016	0.530	0.530	0.530	0.530	0.530	0.530	1	100%
	PLS3m	1	4/27/2016	4/27/2016	0.430	0.430	0.430	0.430	0.430	0.430	1	100%
	PLS3s	1	4/27/2016	4/27/2016	0.410	0.410	0.410	0.410	0.410	0.410	1	100%
	County Dock	10	8/1/2013	3/19/2015	0.038	0.006	0.018	0.023	0.028	0.154	0	0%
	Disc Hole #14	3	8/1/2013	3/19/2015	0.263	0.027	0.120	0.214	0.381	0.549	2	67%
	Haulout area by County Dock	7	12/16/2013	7/1/2014	0.040	0.007	0.010	0.031	0.046	0.125	0	0%
	Pinto Lake Dock	284	4/18/2010	4/26/2015	0.154	0.002	0.042	0.118	0.200	1.36	94	33%
	Villa del Paraiso	11	12/16/2013	3/19/2015	0.071	0.008	0.016	0.022	0.064	0.279	2	18%
Amesti Creek	**All sites**	23			0.612	0.000	0.411	0.448	0.649	2.050	22	96%
	Amesti Creek	18	2/11/2012	4/8/2013	0.486	0.393	0.408	0.434	0.490	0.760	18	100%
	PLAMESTI	5	2/6/2014	1/19/2016	1.064	0.000	0.670	1.200	1.400	2.050	4	80%
CCC Creek	**All sites**	36	2/11/2013	1/19/2016	0.500	0.067	0.141	0.196	0.248	7.045	20	56%
	CCC	2	2/6/2014	4/7/2015	0.540	0.400	0.470	0.540	0.610	0.680	2	100%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.172 mg/L[1]	% Exceeding 0.172 mg/L
	CCC Creek	32	2/11/2013	1/2/2014	0.402	0.067	0.135	0.173	0.229	7.045	16	50%
	PLCCC	2	1/5/2016	1/19/2016	2.025	1.900	1.963	2.025	2.088	2.150	2	100%
Pinto Creek	**All sites**	7	2/1/2012	4/7/2015	0.238	0.033	0.060	0.185	0.381	0.570	4	57%
	Pinto Creek-Ruby Ranch Rd.	2	1/12/2015	4/7/2015	0.485	0.400	0.443	0.485	0.528	0.570	2	100%
	Pinto Creek	5	2/1/2012	12/16/2012	0.140	0.033	0.055	0.064	0.185	0.362	2	40%
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	1	2/8/2013	2/8/2013	0.073	0.073	0.073	0.073	0.073	0.073	0	0%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	0.110	0.110	0.110	0.110	0.110	0.110	0	0%
Todos Santos Creek	Todos Santos Creek	23	12/24/2012	4/7/2015	0.219	0.059	0.077	0.102	0.247	1.020	8	35%
Ditch	**All sites**	14	3/3/2009	12/23/2014	0.11	0.01	0.03	0.09	0.12	0.63	1	7%
	AM105	2	3/3/2009	3/21/2012	0.100	0.094	0.096	0.098	0.099	0.101	0	0%
	AM1132	1	3/21/2012	3/21/2012	0.019	0.019	0.019	0.019	0.019	0.019	0	0%
	AM114	2	3/21/2014	12/23/2014	0.048	0.017	0.032	0.048	0.064	0.080	0	0%
	AM115	2	3/3/2009	3/21/2012	0.089	0.031	0.060	0.089	0.118	0.147	0	0%
	AM117	1	3/21/2012	3/21/2012	0.024	0.024	0.024	0.024	0.024	0.024	0	0%
	PL85	1	12/23/2014	12/23/2014	0.630	0.630	0.630	0.630	0.630	0.630	1	100%
	PPI0100	2	3/21/2012	12/23/2014	0.074	0.028	0.051	0.074	0.097	0.120	0	0%
	PPI0150	1	12/23/2014	12/23/2014	0.130	0.130	0.130	0.130	0.130	0.130	0	0%
	PPI0580	1	12/23/2014	12/23/2014	0.115	0.115	0.115	0.115	0.115	0.115	0	0%
	PPIO100	1	3/21/2012	3/21/2012								

1 - A concentration of 0.172 mg/L phosphate as P represents …….?.

Table 4-7. Summary statistics for orthophosphate as P (units=mg/L) and exceedances of a generic lake criteria for orthophosphate water quality criteria in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.06 mg/L[1]	% Exceeding 0.06 mg/L
Pinto Lake	**All sites**	482	6/10/2005	4/27/2016	0.205	0.0004	0.070	0.130	0.236	2.732	381	79%
	305PNTO1b	12	6/10/2005	5/22/2006	0.109	0.022	0.075	0.114	0.147	0.190	9	75%
	305PNTO1m	12	6/10/2005	5/22/2006	0.116	0.021	0.078	0.118	0.145	0.212	10	83%
	305PNTO1s	12	6/10/2005	5/22/2006	0.123	0.026	0.060	0.120	0.153	0.305	8	67%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.06 mg/L[1]	% Exceeding 0.06 mg/L
	305PNTO2b	12	6/10/2005	5/22/2006	0.488	0.040	0.120	0.325	0.858	1.335	11	92%
	305PNTO2m	12	6/10/2005	5/22/2006	0.133	0.030	0.103	0.129	0.143	0.290	10	83%
	305PNTO2s	12	6/10/2005	5/22/2006	0.108	0.015	0.073	0.115	0.140	0.200	9	75%
	305PNTO3b	12	6/10/2005	5/22/2006	0.108	0.012	0.078	0.105	0.148	0.190	10	83%
	305PNTO3m	12	6/10/2005	5/22/2006	0.107	0.020	0.070	0.130	0.131	0.200	10	83%
	PintoLake_Buoy1	40	4/1/2011	4/27/2016	0.141	0.015	0.070	0.109	0.195	0.400	32	80%
	PintoLake_Buoy1b	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PintoLake_Buoy1m	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PintoLake_Buoy2b	39	4/1/2011	4/2/2012	0.632	0.0004	0.152	0.476	1.054	2.732	32	82%
	PintoLake_Buoy2m	39	4/1/2011	4/2/2012	0.230	0.017	0.086	0.239	0.348	0.490	33	85%
	PintoLake_Buoy2s	39	4/1/2011	4/2/2012	0.133	0.006	0.070	0.112	0.199	0.327	31	79%
	PintoLake_Buoy3	39	4/1/2011	4/2/2012	0.170	0.011	0.066	0.131	0.239	0.860	31	79%
	PintoLake_Buoy4	40	4/1/2011	4/27/2016	0.157	0.005	0.072	0.122	0.246	0.456	33	83%
	PintoLake_Buoy4b	1	4/27/2016	4/27/2016	0.700	0.700	0.700	0.700	0.700	0.700	1	100%
	PintoLake_Buoy4m	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PLS2b	1	4/27/2016	4/27/2016	0.800	0.800	0.800	0.800	0.800	0.800	1	100%
	PLS2m	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PLS2s	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PLS3b	1	4/27/2016	4/27/2016	0.500	0.500	0.500	0.500	0.500	0.500	1	100%
	PLS3m	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PLS3s	1	4/27/2016	4/27/2016	0.400	0.400	0.400	0.400	0.400	0.400	1	100%
	PintoLakeDock	140	6/10/2005	12/9/2014	0.150	0.008	0.060	0.110	0.200	1.400	102	73%
Amesti Creek	**All sites**	19	12/16/2012	4/7/2015	0.404	0.320	0.352	0.374	0.437	0.620	19	100%
	Amesti Creek	17	12/16/2012	4/1/2014	0.388	0.320	0.351	0.368	0.412	0.516	17	100%
	PLAMESTI	2	2/6/2014	4/7/2015	0.535	0.450	0.493	0.535	0.578	0.620	2	100%
CCC Creek	**All sites**	36	2/11/2013	4/7/2015	0.102	0.020	0.060	0.075	0.184	0.569	26	72%
	CCC	2	2/6/2014	4/7/2015	0.240	0.220	0.230	0.240	0.256	0.260	2	100%
	CCC Creek	34	2/11/2013	4/1/2014	0.094	0.020	0.059	0.074	0.095	0.569	24	71%
Pinto Creek	**All sites**	7	2/1/2012	4/7/2015	0.135	0.010	0.026	0.076	0.197	0.410	4	57%
	Pinto Creek	6	2/1/2012	4/1/2014	0.124	0.010	0.026	0.052	0.165	0.410	3	50%
	Pinto Creek-Ruby Ranch Rd.	1	4/7/2015	4/7/2015	0.200	0.200	0.200	0.200	0.200	0.200	1	100%

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.06 mg/L[1]	% Exceeding 0.06 mg/L
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	3	2/8/2013	4/1/2014	0.314	0.021	0.121	0.221	0.461	0.701	2	67%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	0.024	0.024	0.024	0.024	0.024	0.024	0	0%
Todos Santos Creek	Todos Santos Creek	27	12/24/2012	4/7/2015	0.128	0.010	0.026	0.079	0.164	0.494	15	56%

1 - A concentration of 0.06 mg/L orthophosphate represents the 75% percentile of all orthophosphate lake water quality criteria reported by states to the U.S. Environmental Protection Agency. As of July 2015, there were 8 different lake orthophosphate water quality criteria reported for lakes in various states. The 75th percentile is a statistical threshold which represents that 75% of all reported lake criteria values were *lower* than 0.06 mg/L, and 25% of reported lake criteria were *higher* than 0.06 mg/L. This value is a screening threshold for informational purposes but should not be considered a TMDL numeric target.

Table 4-8. Summary statistics for chlorophyll *a* (units=µg/L) and exceedances of 15 µg/L and of a generic lake criterion (35 µg/L) in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceed 15 µg/L[1]	% Exceed 15 µg/L	No. Exceed 35 µg/L[2]	% Exceed 35 µg/L
Pinto Lake	**All sites**	306	6/10/2005	6/19/2015	242.26	0.47	11.04	26.89	75.00	15,183.00	210	69%	133	43%
	305PNTO1s	12	6/10/2005	5/22/2006	65.92	2.00	13.50	23.50	39.25	490.00	8	67%	4	33%
	305PNTO2s	12	6/10/2005	5/22/2006	83.33	2.00	7.50	44.50	69.25	604.00	8	67%	7	58%
	Pinto Lake Dock	282	6/10/2005	6/19/2015	256.53	0.47	11.27	26.60	76.97	15,183.00	194	69%	122	43%
Amesti Creek	Amesti Creek	11	1/20/2013	4/8/2013	1.36	0.03	0.18	1.02	2.38	3.40	0	0%	0	0%
CCC Creek	CCC Creek	34	2/11/2013	1/8/2014	1.58	0.001	0.06	0.14	0.31	34.90	1	3%	0	0%
Pinto Creek	Pinto Creek	2	2/1/2012	2/11/2012	1.90	1.73	1.81	1.90	1.98	2.06	0	0%	0	0%
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	1	2/8/2013	2/8/2013	0.92	0.92	0.92	0.92	0.92	0.92	0	0%	0	0%
Pioneer Creek	Pioneer Creek	1	2/8/2013	2/8/2013	1.03	1.03	1.03	1.03	1.03	1.03	0	0%	0	0%
Todos Santos Creek	Todos Santos Creek	20	1/20/2013	2/7/2014	10.50	0.01	0.09	0.65	7.28	66.44	5	25%	2	10%

1 - Fifteen µg/L chlorophyll *a* represents a condition for which the Central Coast Water Board will designate water bodies as impaired for aquatic life use, Worcester, K, et al., 2010.

2 - A concentration of 35 µg/L chlorophyll *a* represents the 75th percentile of all chlorophyll *a* lake water quality criteria reported by states to the U.S. Environmental Protection Agency. As of July 2015, there were 281 different lake phosphate water quality criteria reported for lakes in various states. The 75th percentile is a statistical threshold which represents that 75% of all reported lake criteria values were *lower* than 35 µg/L and 25% of reported lake criteria were *higher* than 35 µg/L. This value is a screening threshold for informational purposes but should not be considered a TMDL numeric target.

Table 4-9. Summary statistics for microcystin (units=µg/L or ppb) and exceedances of 0.8 µg/L criteria in waterbodies in the Pinto Lake catchment.

Waterbody	Monitoring Site ID	No. of Samples	Temporal Representation		Arithmetic Mean	Min	25%	50% (median)	75%	Max	No. Exceeding 0.8µg/L[1]	% Exceeding 0.8 µg/L
Pinto Lake	**All sites**	671	4/3/2013	9/29/2016	7.63	ND	ND	0.033	0.525	1193	148	22%
	County Dock	41	5/6/2013	9/29/2016	1.003	ND	ND	ND	ND	20.00	5	12%
	Disc Hole #14	30	5/6/2013	9/23/2016	0.121	ND	ND	ND	ND	0.625	0	0%
	Eucalyptus Grove	25	4/3/2013	9/24/2013	0.694	ND	ND	ND	ND	10.00	6	24%
	Haulout area by County Dock	32	9/10/2013	9/29/2016	2.289	ND	ND	ND	1.000	20.00	11	34%
	Pinto Lake Dock	485	9/28/2006	10/26/2016	10.112	ND	ND	0.0335	0.630	1193.00	110	23%
	Villa del Paraiso	58	4/3/2013	9/29/2016	1.390	ND	ND	ND	1.000	20.00	16	28%

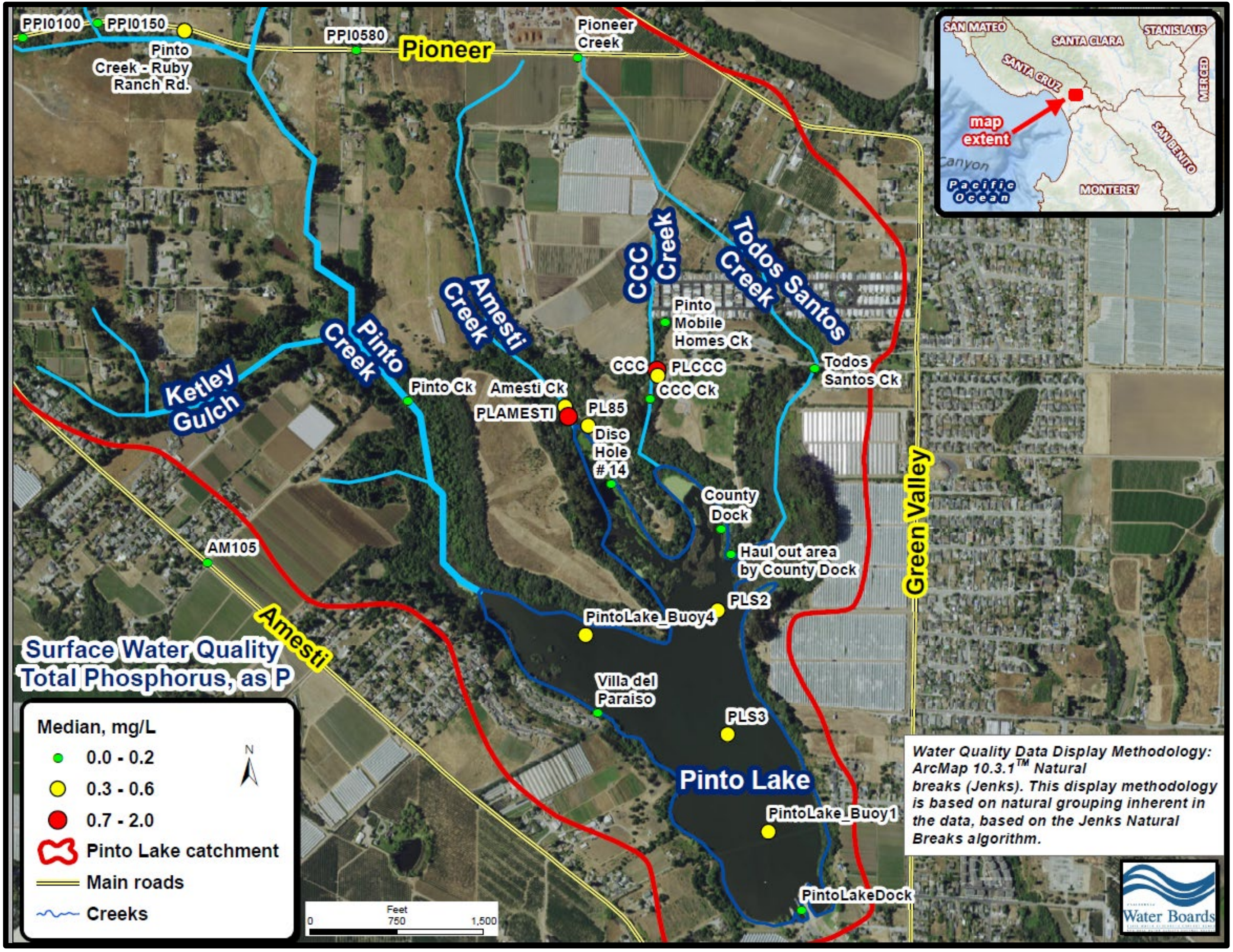
1 – The State of California Office of Environmental Health Hazard Assessment (OEHHA) has a published peer-reviewed public health action-level guideline for microcystins in recreational waters of 0.8 µg/L (2012).

4.3 Surface Water Quality Spatial Trends

The purpose of this section is to provide some observations and graphical illustrations of spatial variation in water quality in the Pinto Lake catchment. Simply put, how does water quality vary geographically across the watershed? Figure 4-3 through Figure 4-9 present bubble maps[73] illustrating the spatial distribution of the various water quality constituents in surface waters based on available data. These figures show the median values (except for microcystin, which shows arithmetic mean) for the given constituent where the data was collected. These maps provide a visual illustration of the spatial distribution of the surface water quality data collected. Note that lake samples used here are samples taken at the lake surface only. Depth profile water quality samples are discussed separately in report Section 4.6.

Several simple observations can be noted from these maps; namely that of all the tributary creeks, nutrient concentrations in Pinto Creek tend to be relatively low, that chlorophyll *a* concentrations in the lake tend to exceed guideline threshold values for water quality (see Figures 4-8 and 4-19), and that microcystin concentrations tend to be highest at the south end of the lake near the dock (see Figures 4-9 and 4-21).

Figure 4-3. Total phosphorus concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm.

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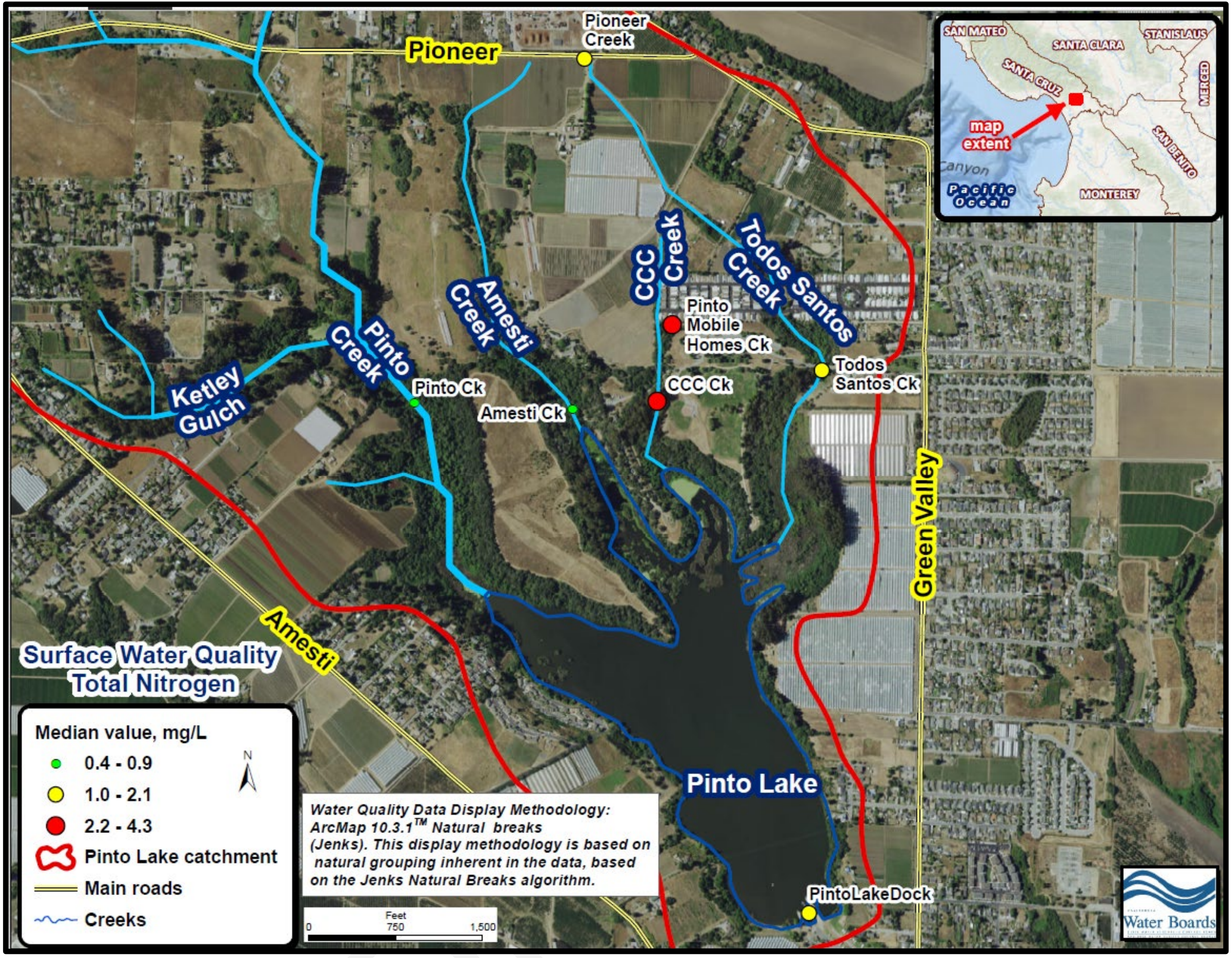
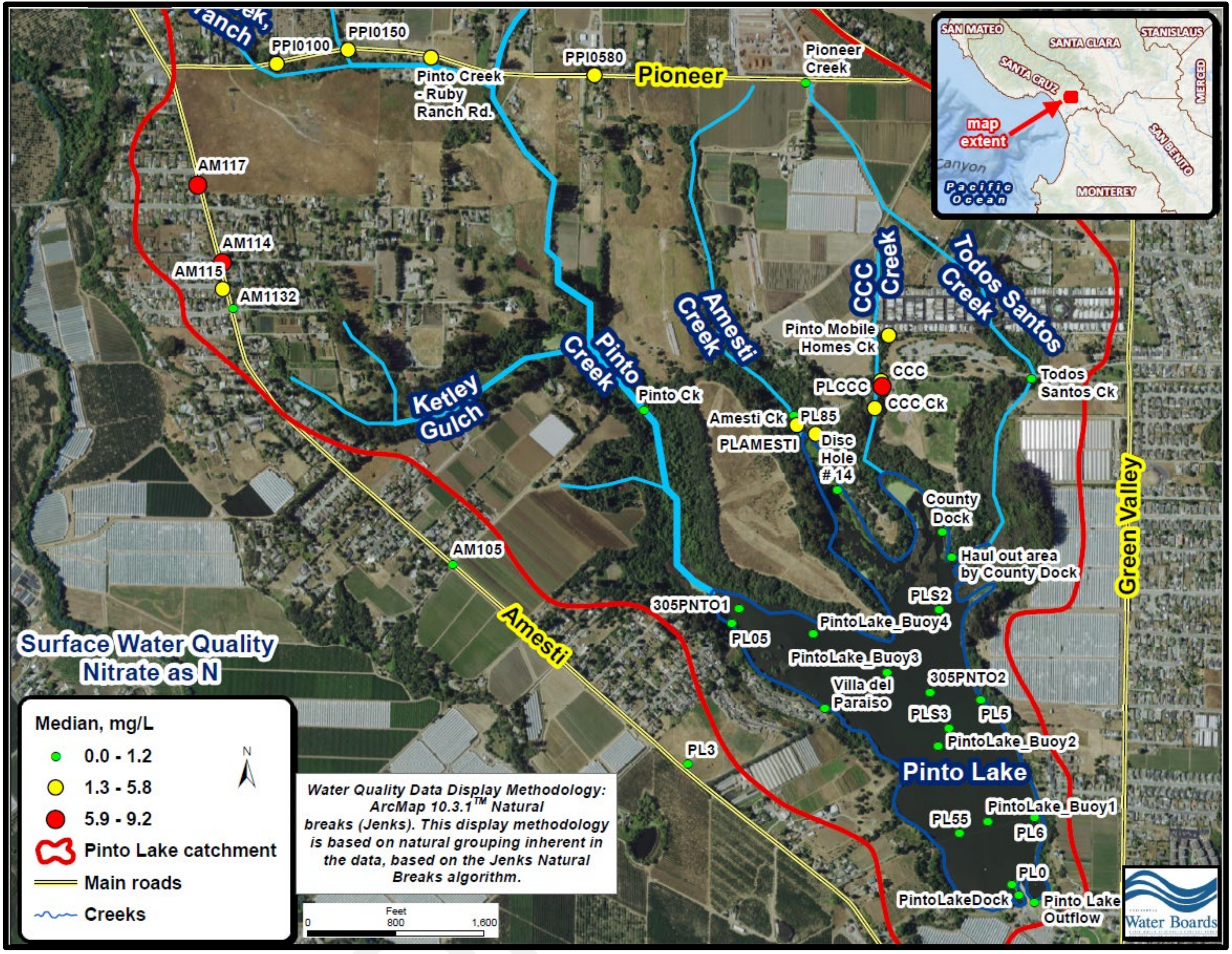
[73] A bubble map is a way of showing a representative value, such as an average value, of the aggregate of data collected at a site, and thus the map can show broad trends and variations in representative values spatially from discrete sampling sites.

Figure 4-4.Total nitrogen concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm.

Figure 4-5.Nitrate as N concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm.

Figure 4-6.Un-ionized ammonia concentrations in the Pinto Lake catchment.

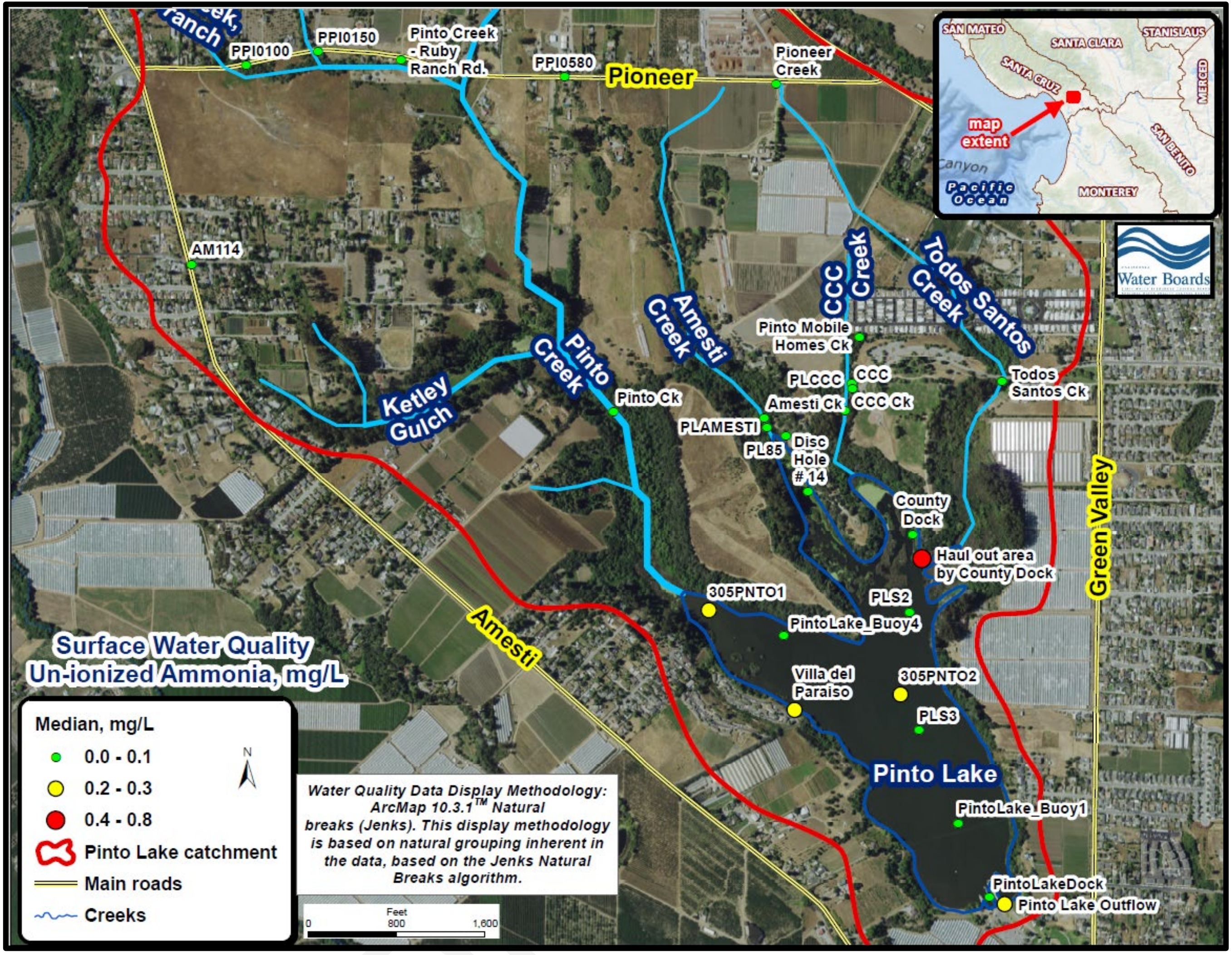
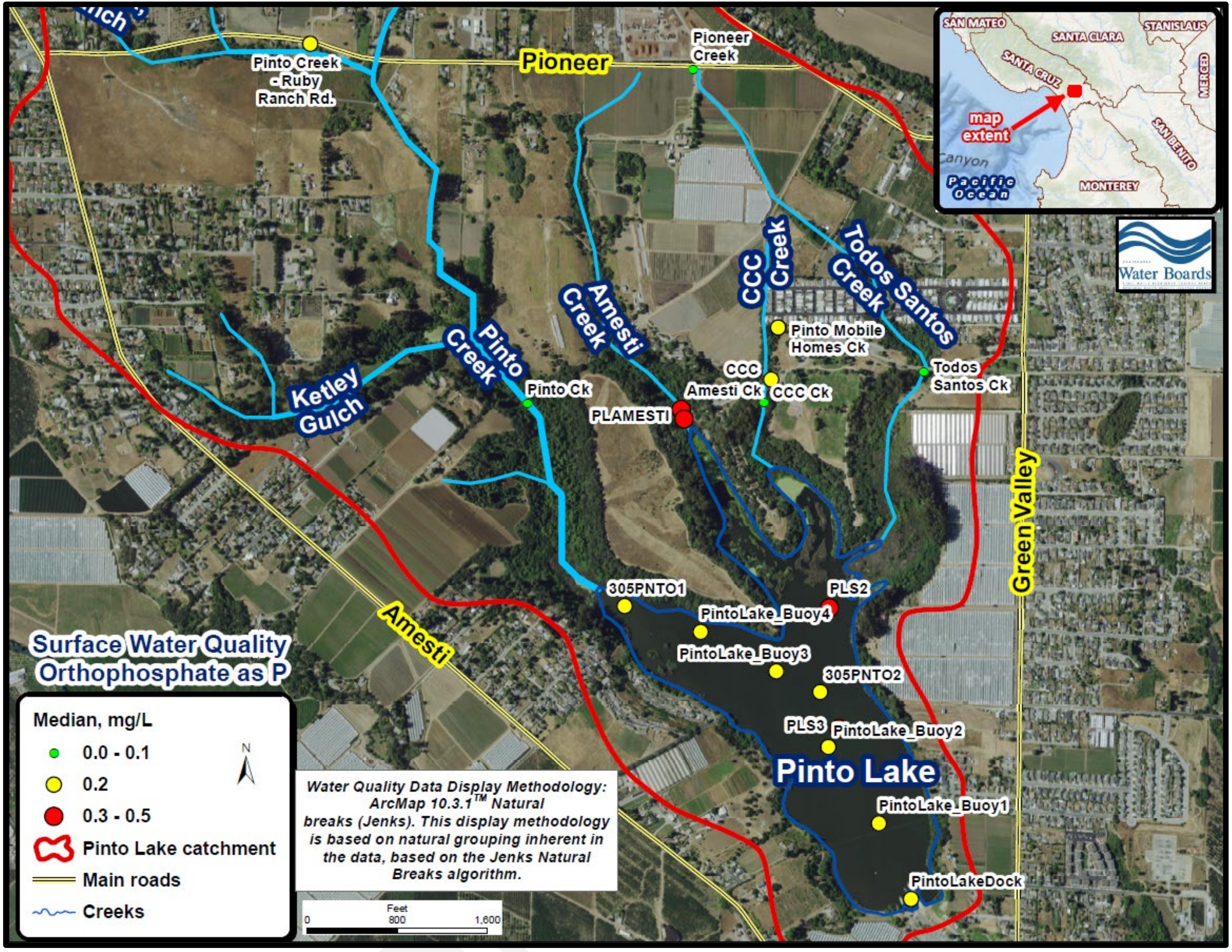
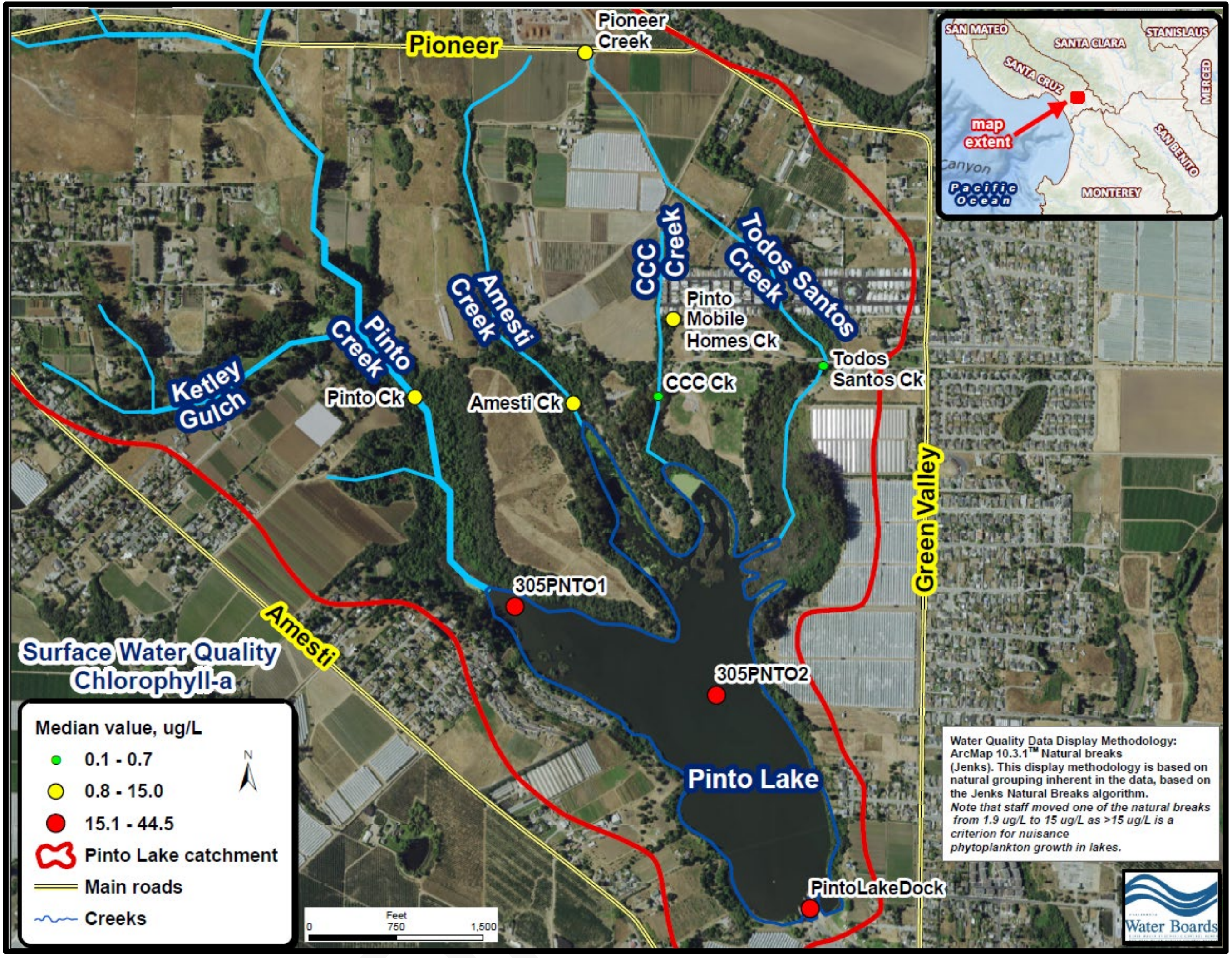


Figure 4-7.Orthophosphate as P concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm.

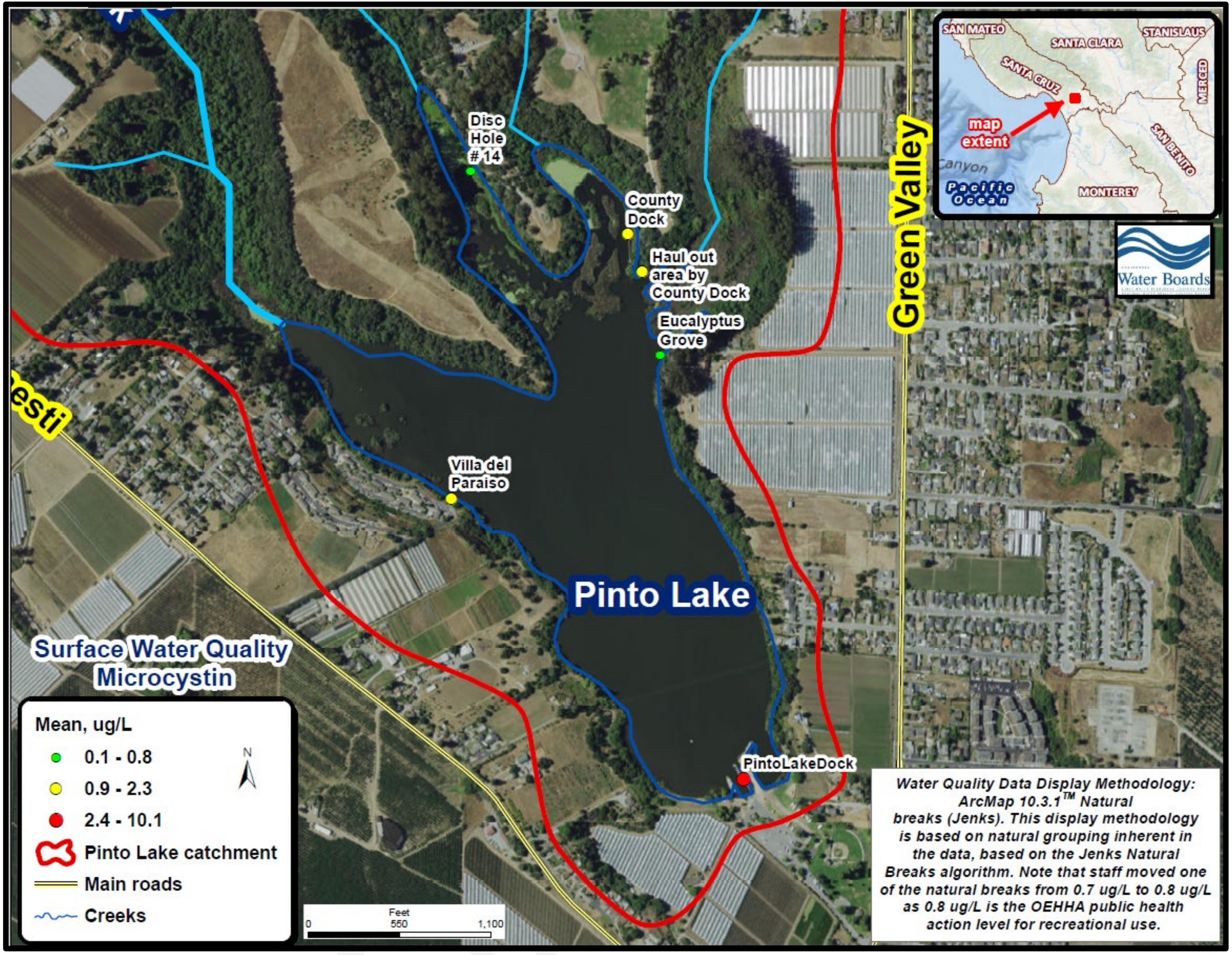
Figure 4-8.Chlorophyll *a* concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm.

Note that staff moved one of the natural breaks from 1.9 ug/L to 15 ug/L as >15 ug/L is a criterion for nuisance phytoplankton growth in lakes.

Figure 4-9.Microcystin concentrations in the Pinto Lake catchment.



Water Quality Data Display Methodology: ArcMap 10.3.1™ Natural breaks (Jenks). This display methodology is based on natural grouping inherent in the data, based on the Jenks Natural Breaks algorithm. Note that staff moved one of the natural breaks from 0.7 ug/L to 0.8 ug/L as 0.8 ug/L is the OEHHA public health action level for recreational use.

Another way of illustrating spatial variation is using statistical box plots[74]. Box plots are a common way of displaying the comparative distribution and dispersion of data (in this case, water quality data) at various sampling sites. Figures 4-10 through 4-21 represent statistical distributions (box and whisker plots) of the various water quality constituents in surface waters based on available data at monitoring sites throughout the Pinto Lake catchment. Note that occasionally on some box and whisker plot figures, a few monitoring sites have insufficient data to construct a proper box and whiskers. The data representing these sites may lack "whiskers" or other box plot components. However, we include these in the box and whisker figures in this report for completeness. Water quality samples reported in these box plot figures were taken at the surface, unless otherwise noted with a letter qualifier "b," "m," or "s" at the end of the monitoring site names (corresponding to various depth categories: near lake **b**ottom, **m**id-water column, and **s**hallow/**s**urface sample depths - respectively).

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[74] For those unfamiliar with the nature and utility of box plots please refer to: http://en.wikipedia.org/wiki/Box_plot

Figure 4-10. Box and whiskers plots, total phopshorus water quality data for all surface water quality monitoring sites within the Pinto Lake catchment, ordered alphabetically. Some of the highest measured concentrations were recorded for tributary monitoring sites located in Amesti Creek (e.g. PLAMESTI), and CCC Creek (e.g. PLCCC). The maximum concentration recorded was 7.045 mg/L at CCC Ck.

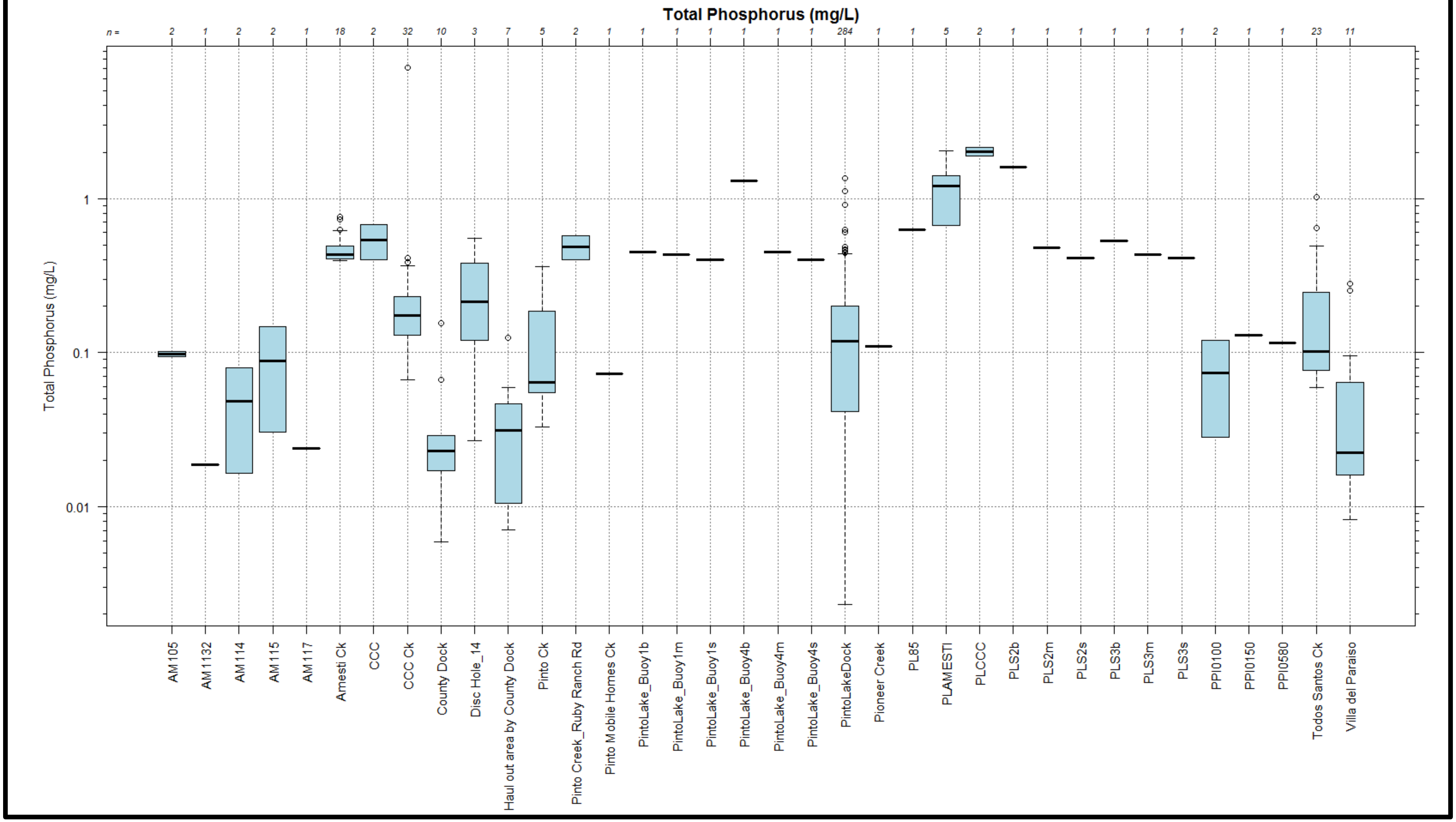
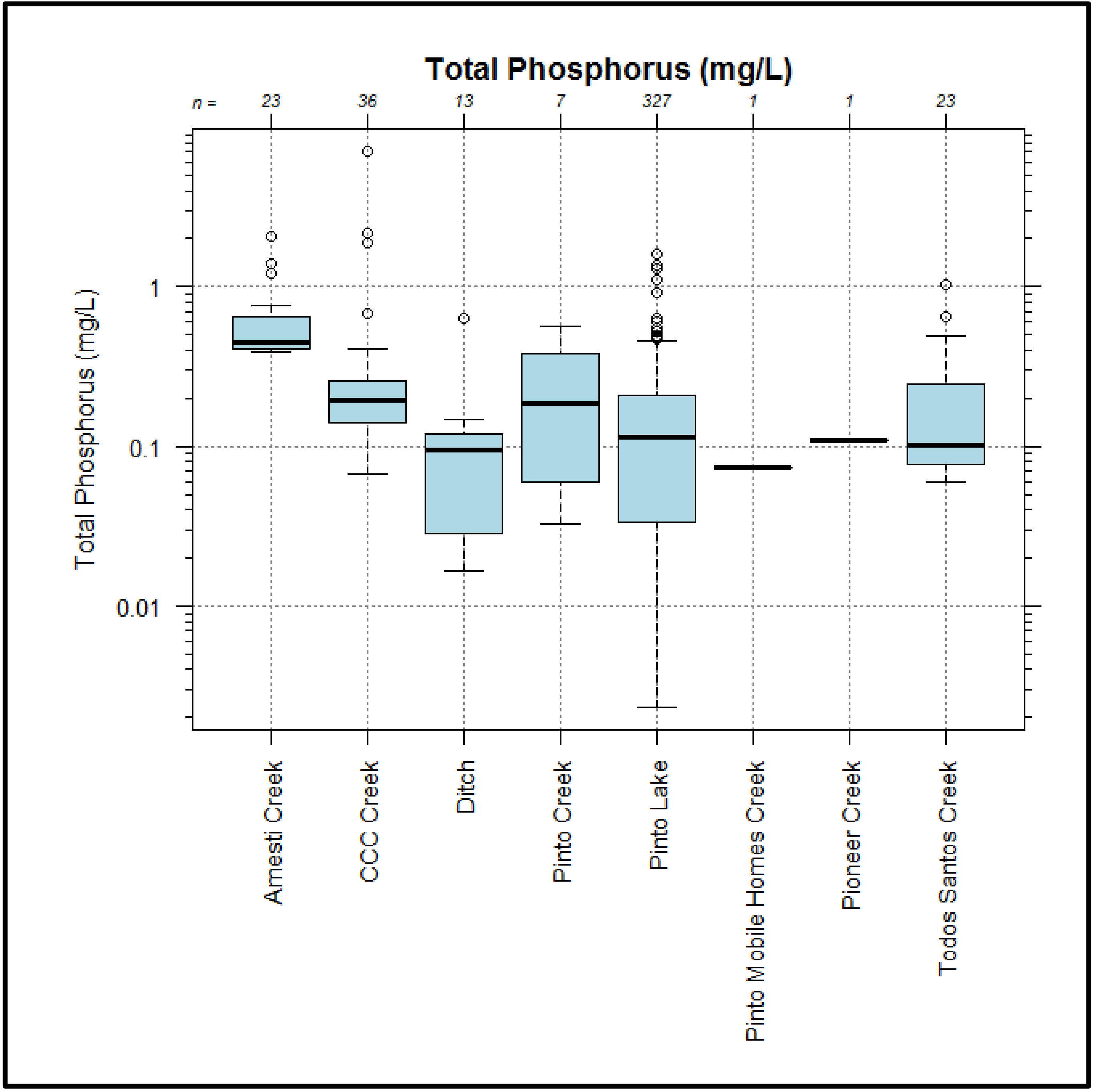
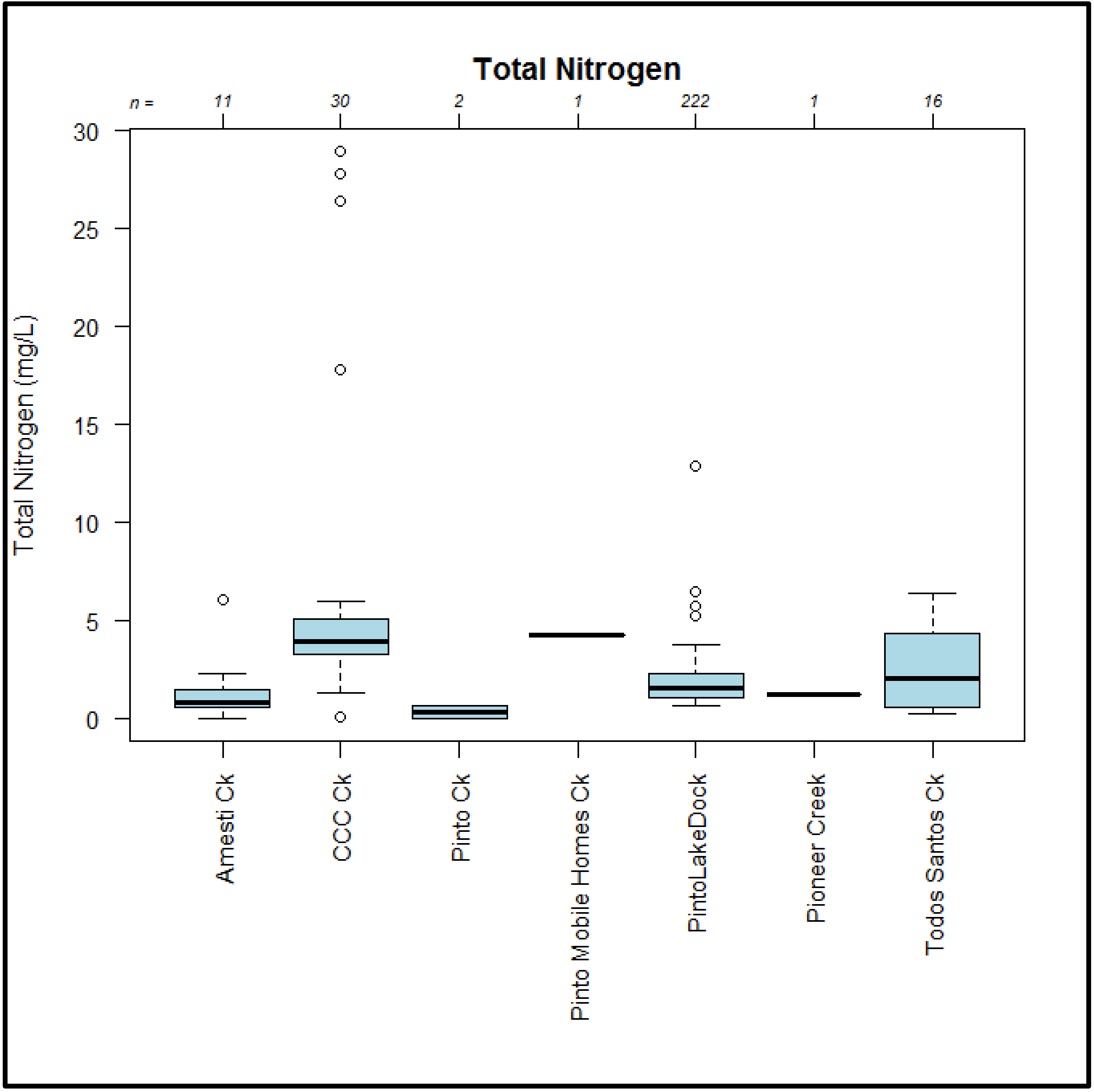


Figure 4-11. Box and whiskers plots, total phosporus water quality data, aggregated by creek, ditch or Pinto Lake. Tributaries Amesti Creek, CCC Creek and Pinto Creek had the highest average (and median) total phosphorous concentrations of all waterbody/surface water types sampled.



Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-12. Box and whiskers plot, total nitrogen water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically. The sites with the highest average (and median) concentrations of total nitrogen are CCC Ck followed by Todos Santos Ck.



Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-13. Box and whiskers plot, nitrate as N water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically. For reference, the nitrate as N water quality standard for drinking water is 10 mg/L.

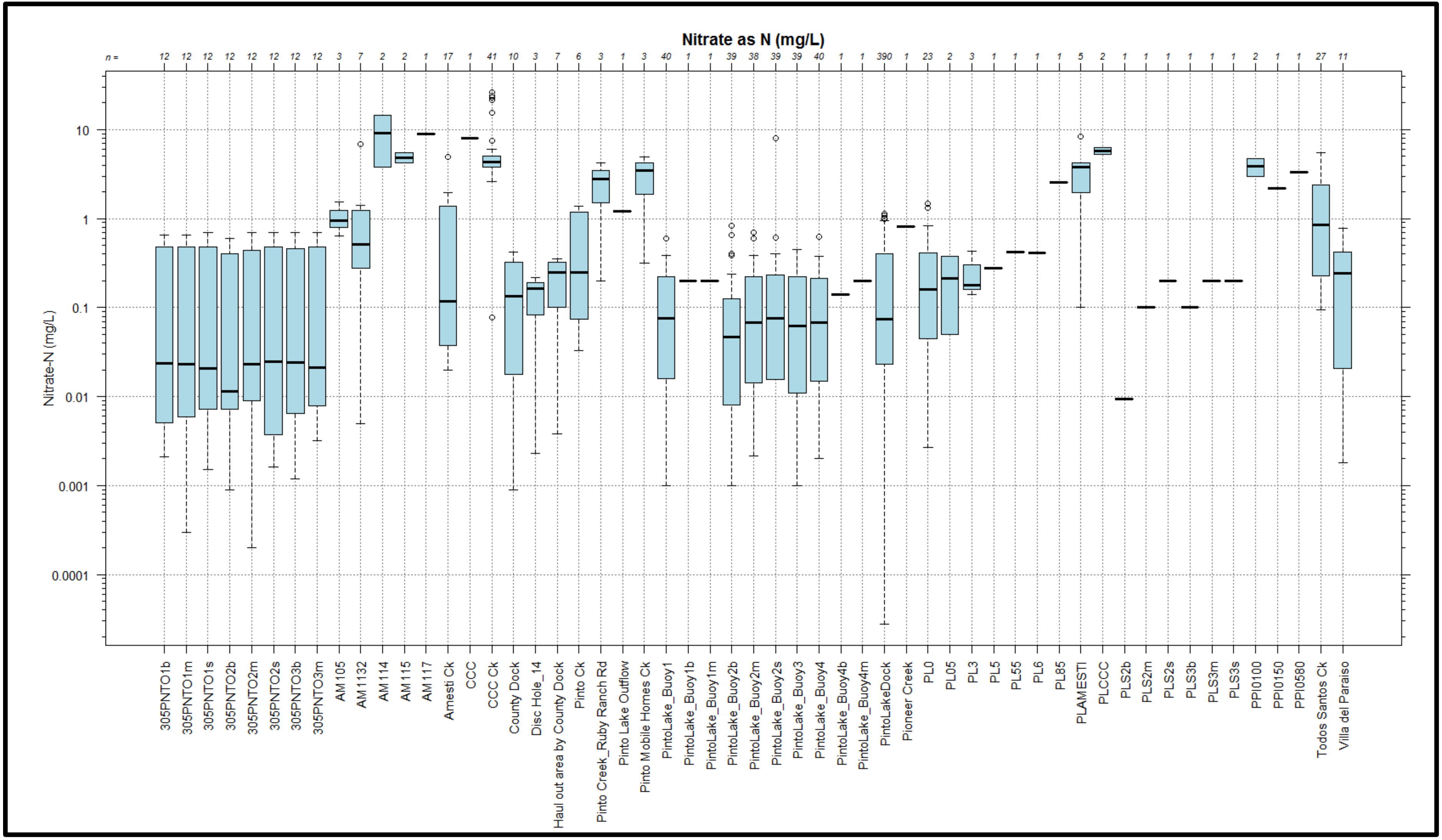
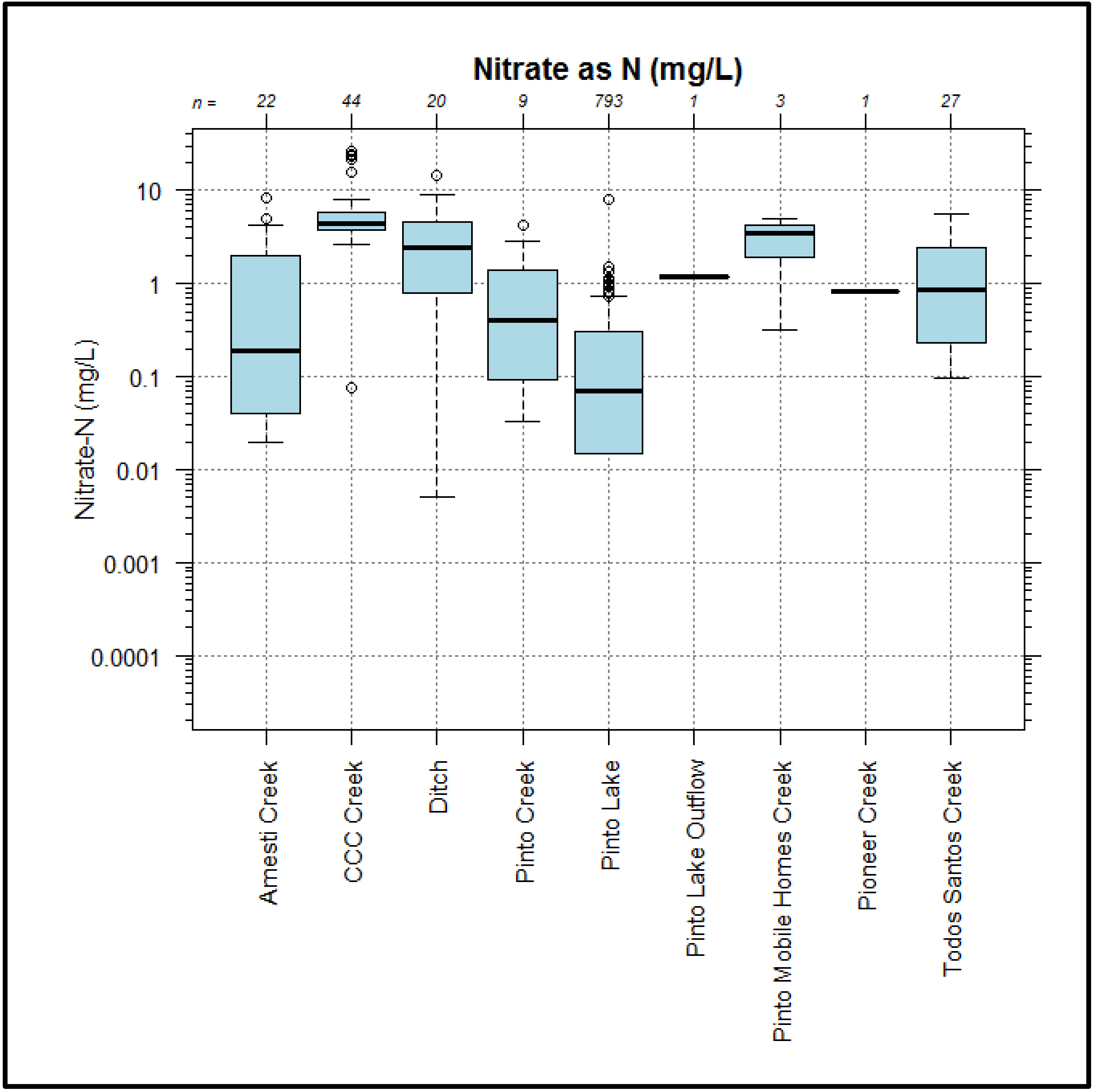


Figure 4-14. Box and whiskers plot, nitrate as N water quality data, aggregated by creek, ditch or Pinto Lake. For reference, the nitrate as N water quality standard for drinking water is 10 mg/L.



Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-15. Box and whiskers plot, un-ionized ammonia water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically.

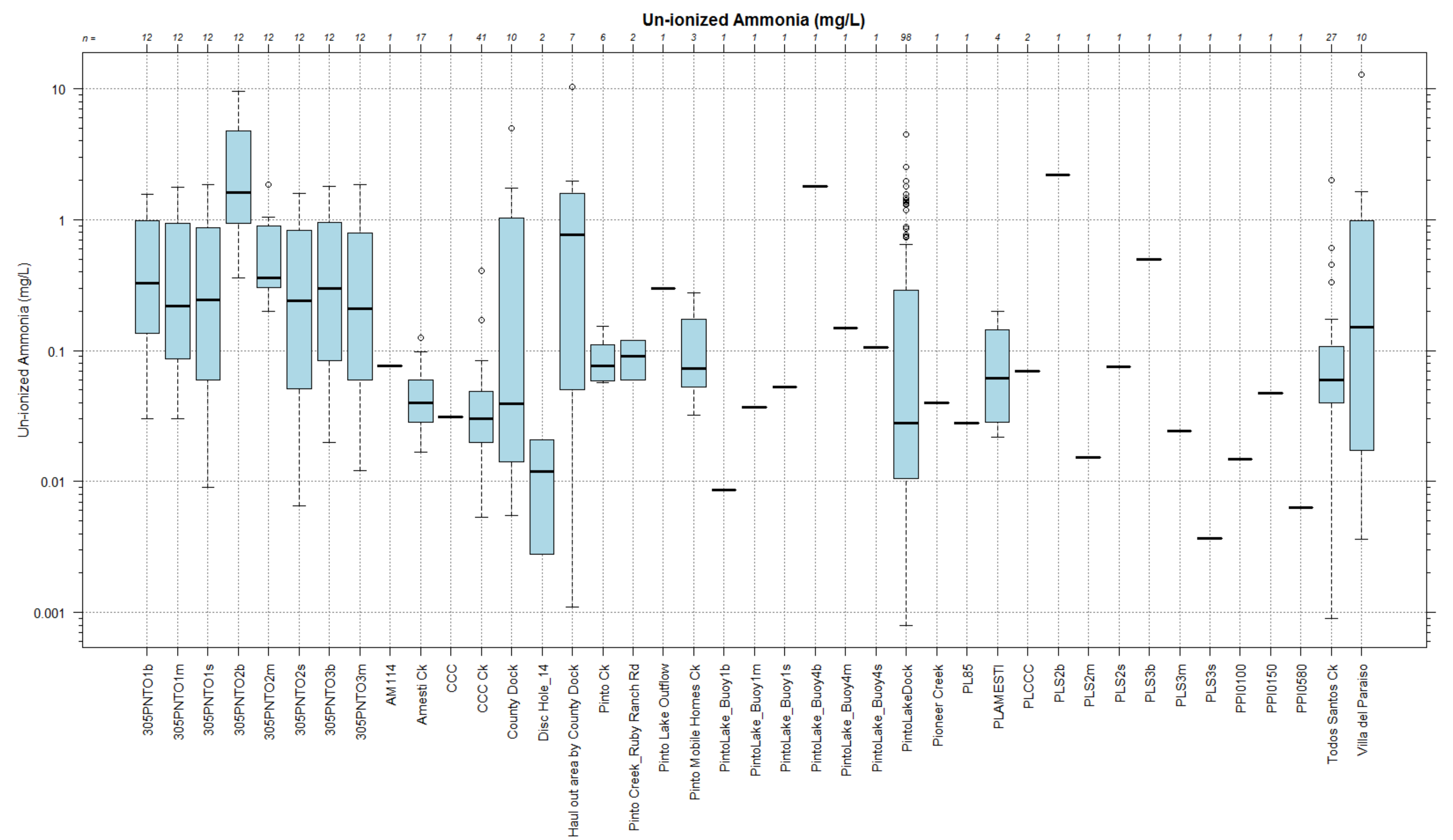
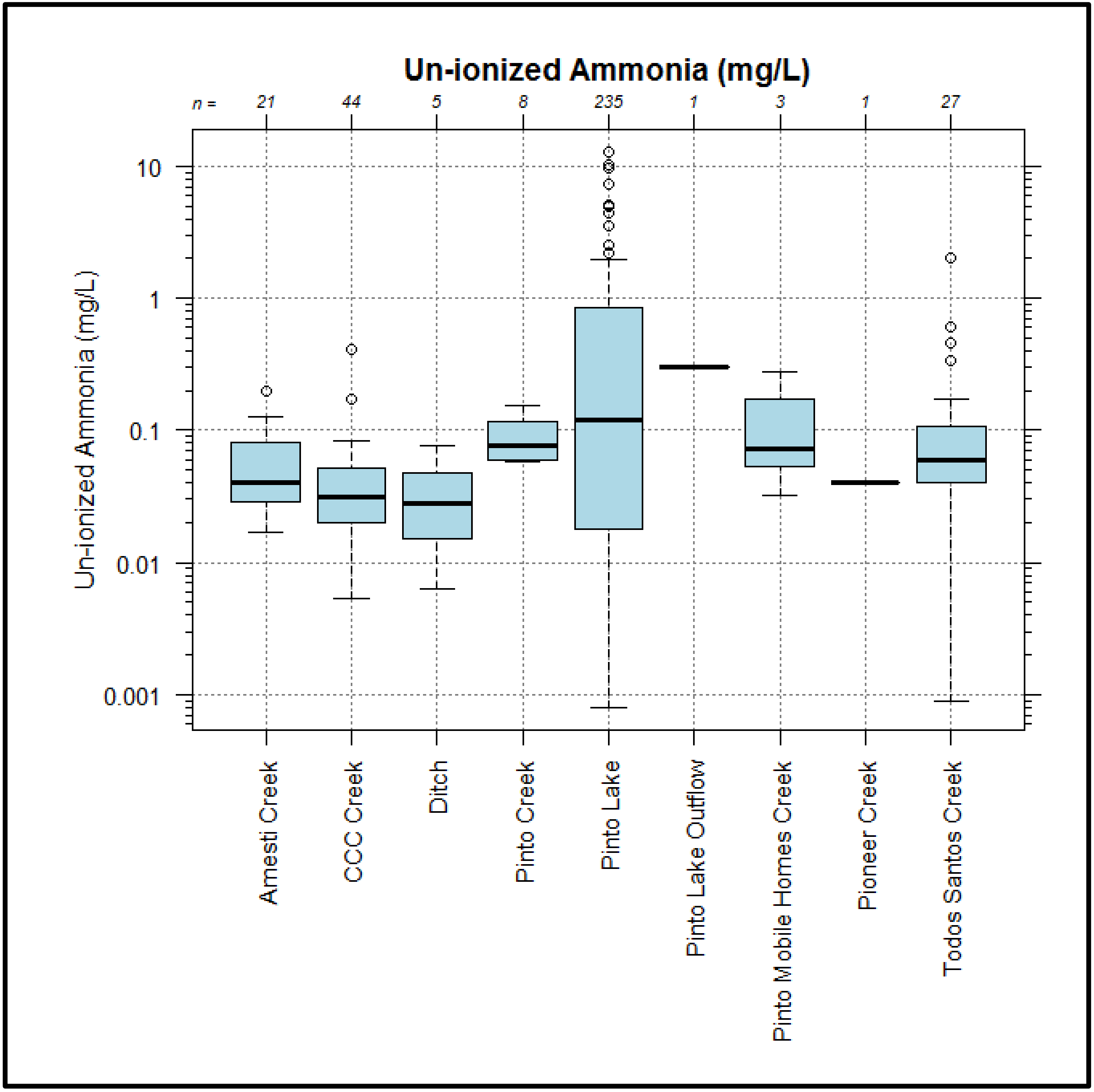


Figure 4-16. Box and whiskers plot, un-ionized ammonia water quality data, aggregated by creek, ditch or Pinto Lake.



Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-17. Box and whiskers plot, orthophosphate as P water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically. For reference, the orthophosphate as P guideline concentration of 0.06 mg/L represents the 75% percentile of all orthophosphate lake water quality criteria reported by states to the U.S. Environmental Protection Agency.

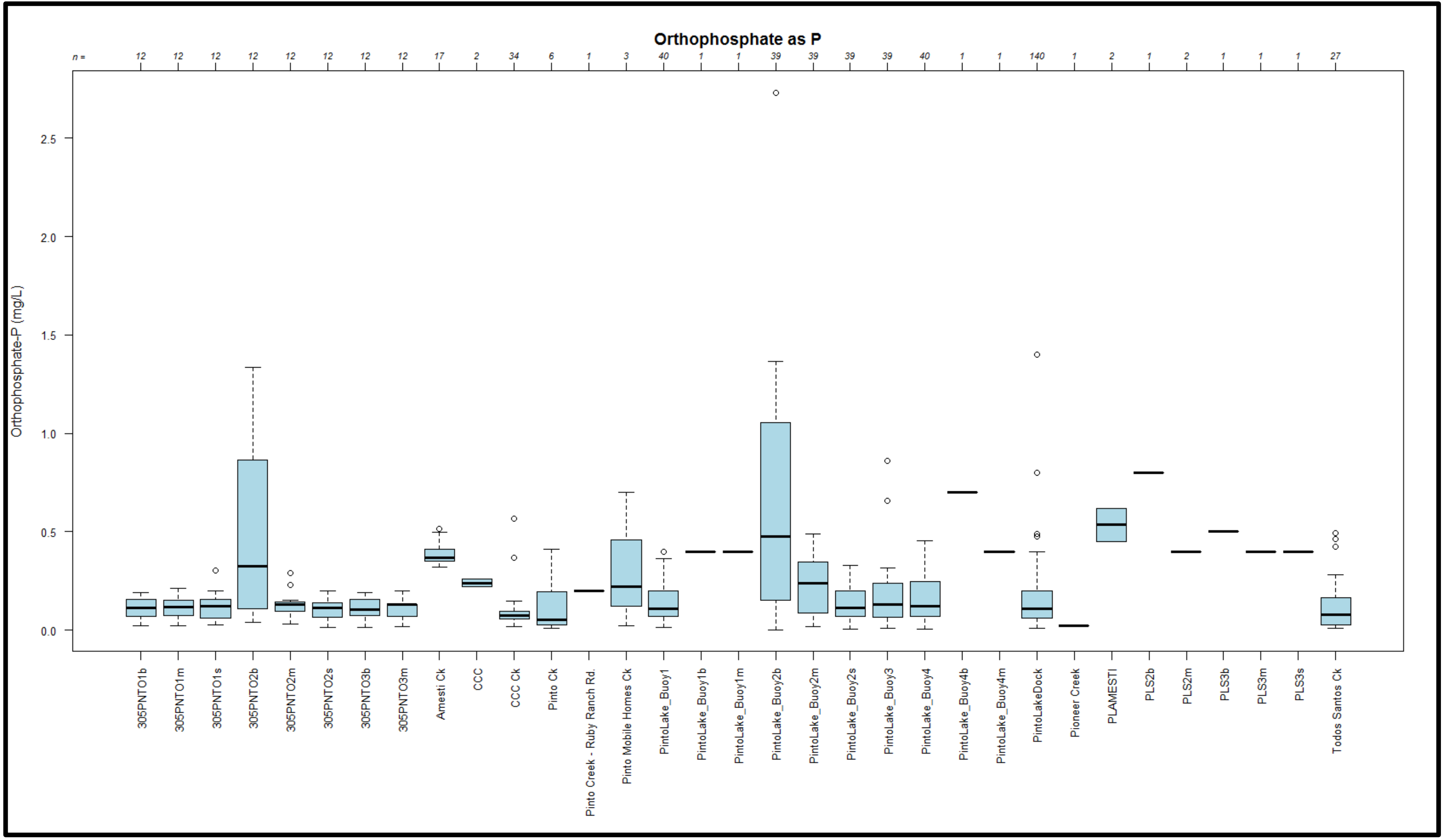
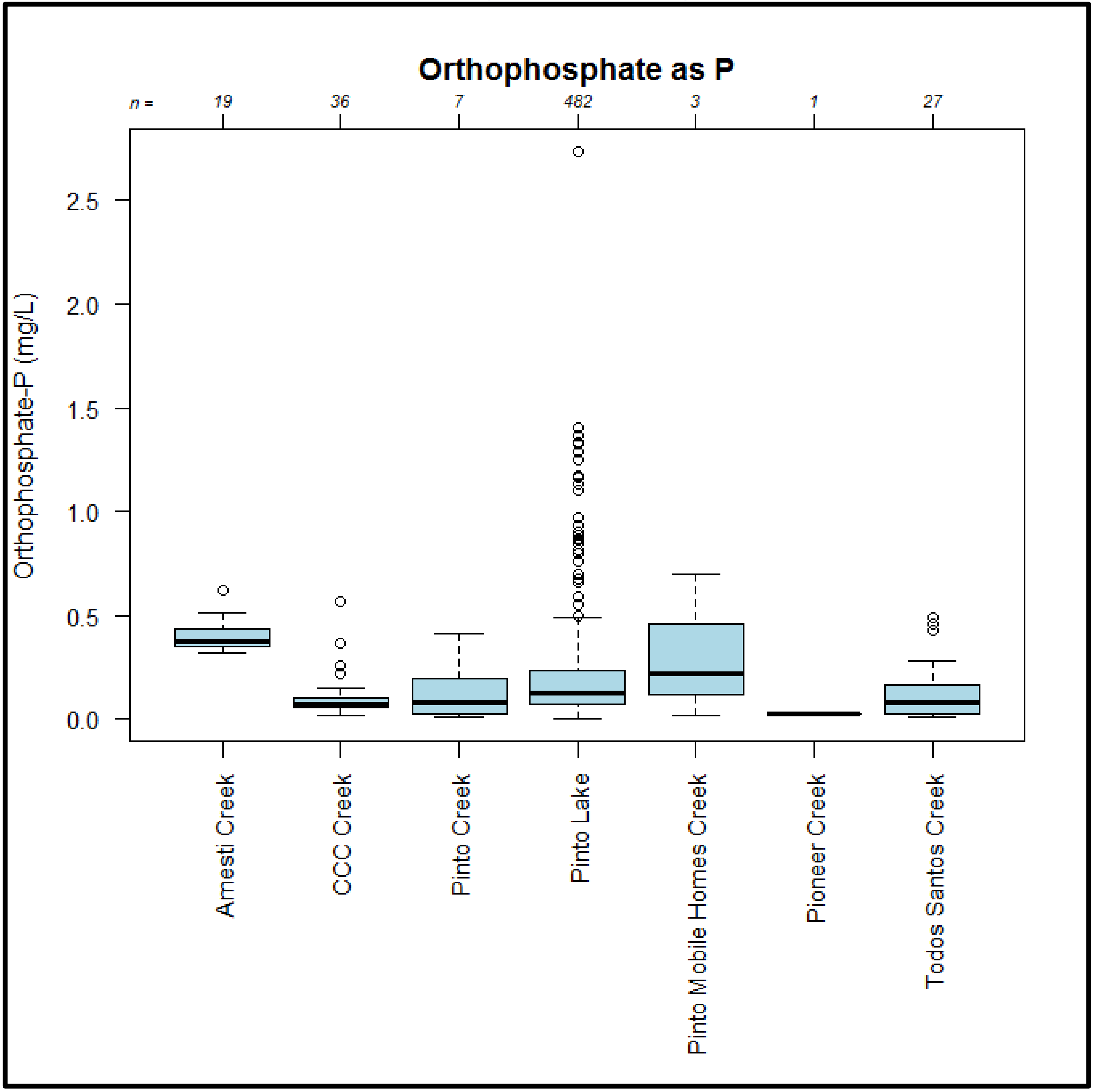
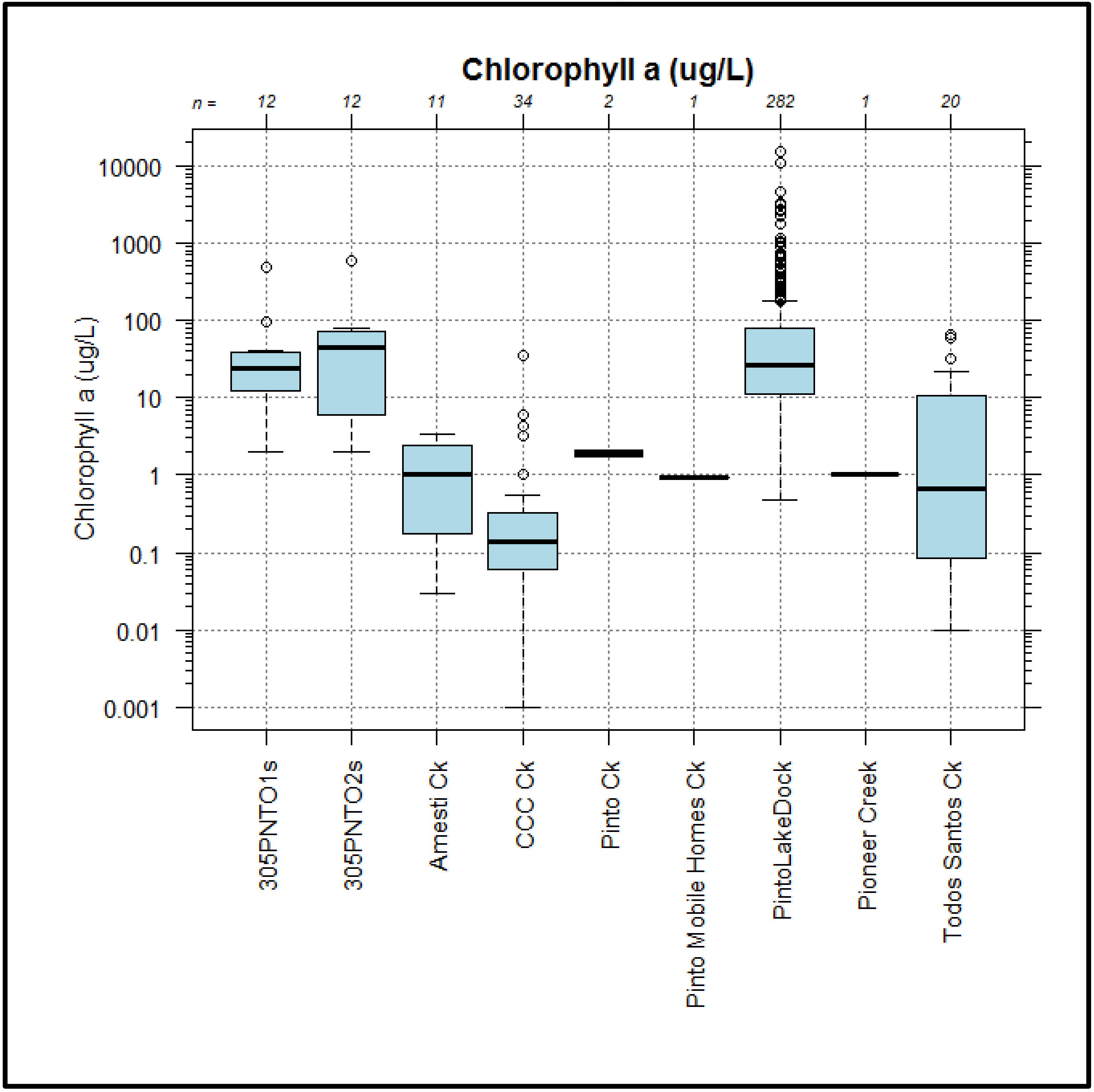


Figure 4-18. Box and whiskers plot, orthophosphate as P water quality data aggregated by creek or Pinto Lake. For reference, the orthophosphate as P guideline is 0.06 mg/L.



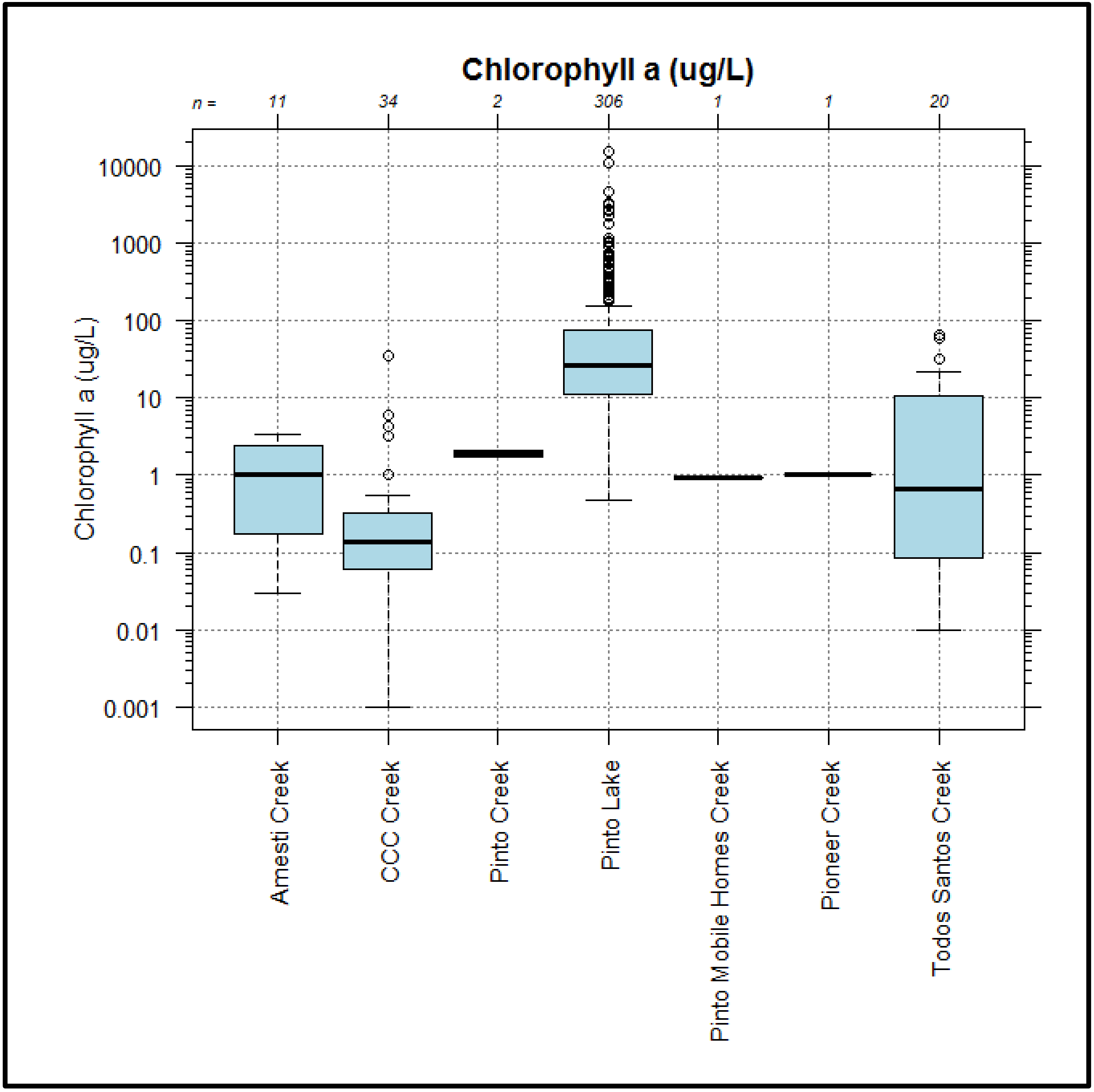
Note that "Pinto Mobile Homes Creek" is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-19. Box and whiskers plot, chlorophyll *a* water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically.



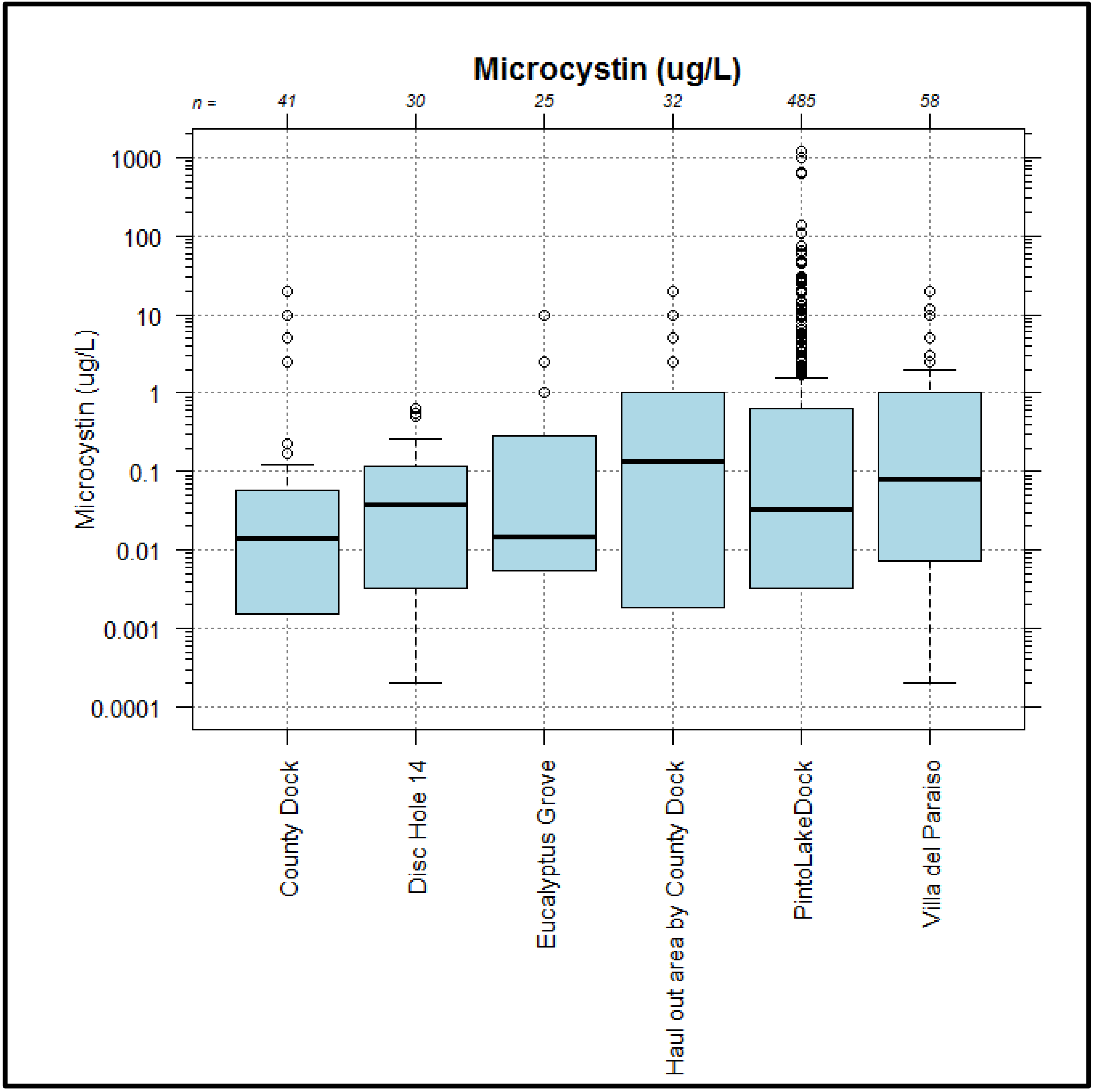
Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-20. Box and whiskers plot, chlorophyll *a* water quality data for aggregated by creek or Pinto Lake.



Note that “Pinto Mobile Homes Creek” is an informal name used for an unnamed tributary of CCC Creek. The sampling site is located approximately 125 feet due east of CCC Creek. See Figure 4-1 for more details.

Figure 4-21. Box and whiskers plot, microcystin water quality data for all surface water quality sampling sites within the Pinto Lake catchment, ordered alphabetically.



4.4 Surface Water Quality Temporal Trends

Temporal trends in the TMDL context refer to water quality variation over time. In any given watershed study, it is common to assess water quality response over time.

Figure 4-13 and Figure 4-14 illustrate time series plots of total phosphorus concentrations and chlorophyll *a* concentrations at the Pinto Lake dock. The total phosphorus data indicate there is a long-term seasonal periodicity to the phosphorus concentrations; concentrations often spiking in the fall, and becoming lower in the winter and spring. This periodicity may be related to seasonal changes in lake water mixing (refer to report Sections 2.3 and 4.6). Researchers observe this type of periodicity in phosphorus concentrations in algae-enriched lakes nationwide (Pinto Lake technical advisory committee meeting presentation January 2017 by Dr. John Holz, lake limnologist with HAB Aquatic Solutions, LLC).

In addition, we performed Kendall's tau[75] nonparametric correlation tests using R[76] on the available water quality data. Kendall's tau is a correlation coefficient calculated and used to determine if there is a statistically significant relationship between two variables.

The results of the Kendall's tau tests are annotated on Figure 4-13 and Figure 4-14, and further tabulated in Table 4-10 through Table 4-16.

Worth noting is that most monitored sites indicate an increasing trend in microcystin concentrations, although statistical significance varies between sites (refer to Table 4-16). A statistically significant correlation tests indicates that pollutant concentrations at a monitoring site have a positive (increasing) trend over the periods of record. Practically speaking, statistical significance means that there is a very low probability that the observed trend (increasing or decreasing) of a pollutant over time at a monitoring site could result from random chance. Thus, based on the available data, we can say that microcystin concentrations are trending higher in a few areas (Villa del Paraiso, haul out area by County Dock), but in other areas of the lake there are no statistically significant trends in microcystin concentrations over the period of record.

It is important to note that statistical significance does not provide evidence for a causal relationship between two variables. Statistical significance is simply a measure of the mathematical association between two variables. Evidence for causation must come from knowledge of watershed processes, not just from mathematical relationships (Hesel and Hirsch, 2002).

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[75] As described by the U.S. Geological Survey (U.S. Geological Survey, 2002b), the Kendall's tau test statistic is a nonparametric measure of the monotonic correlation between the variables. By convention, Kendall's tau correlation coefficients are considered statistically significant when probabilities (p-values) are less than 0.05.

[76] R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Figure 4-13. Temporal variations in total phosphorus concentrations at the Pinto Lake dock, April 2010 to April 2015. The data indicate there is a long term seasonal periodicity to the phosphorus concentrations; concentations often spiking in the fall, and becoming lower in the winter and spring.

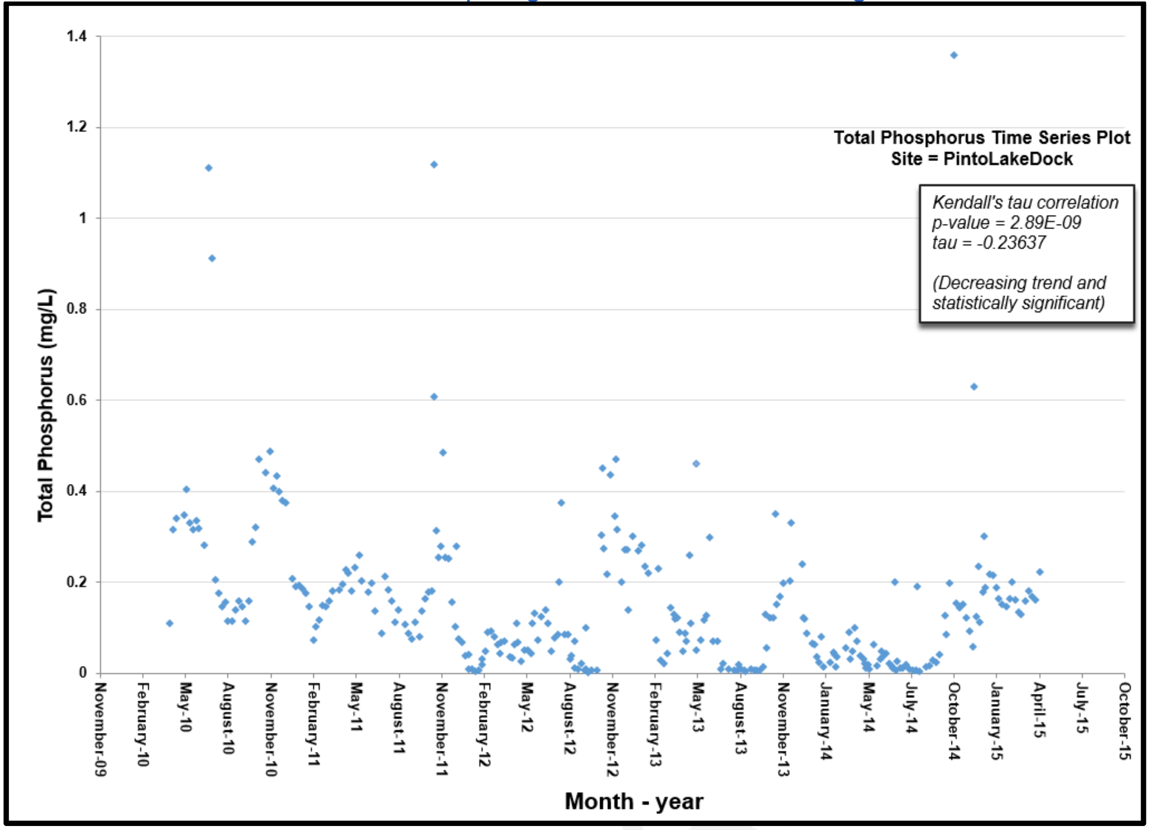


Figure 4-14. Temporal variations in total chlorophyll *a* concentrations at the Pinto Lake dock, June 2005 to June 2015.

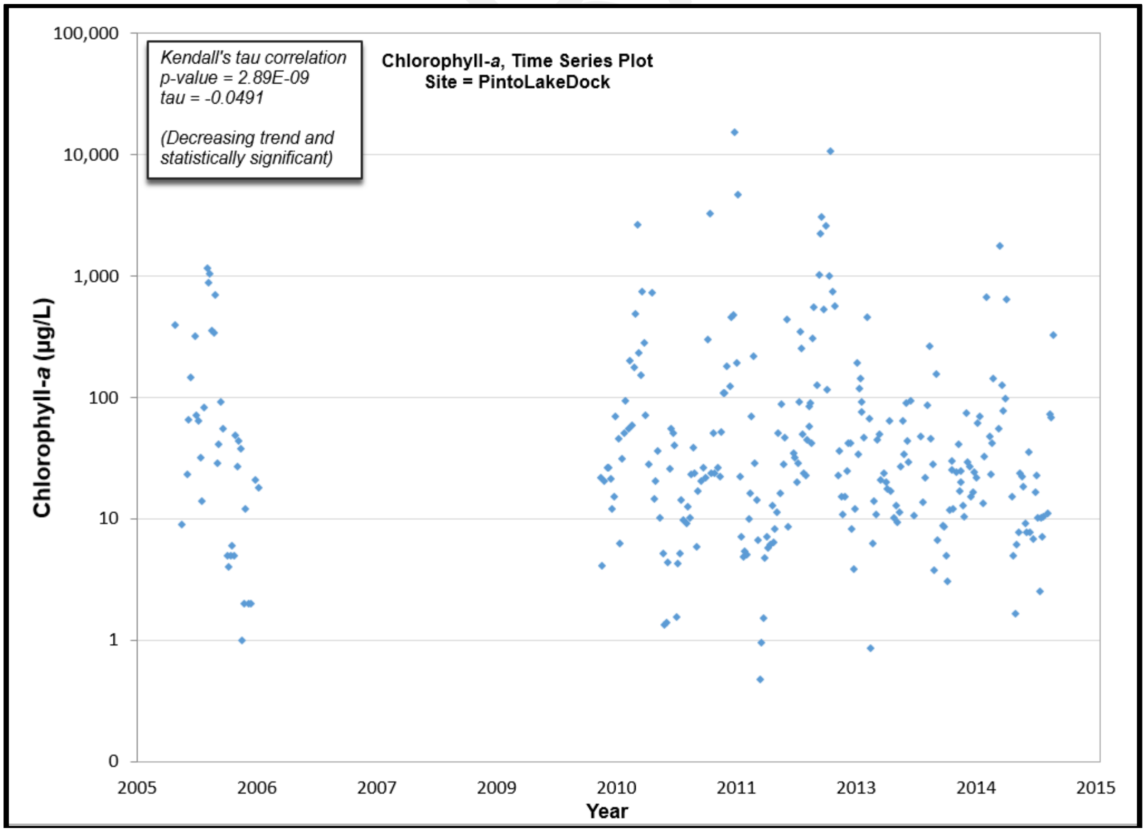


Table 4-10. Tabular summary of nitrate as N concentrations temporal trends and significance at monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
305PNTO1b	Pinto Lake	12	6/10/2005-5/22/2006	0.272727	2.50E-01	Increasing Trend and Not Statistically Significant
305PNTO1m	Pinto Lake	12	6/10/2005-5/22/2006	0.272727	2.50E-01	Increasing Trend and Not Statistically Significant
305PNTO1s	Pinto Lake	12	6/10/2005-5/22/2006	0.30303	1.97E-01	Increasing Trend and Not Statistically Significant
305PNTO2b	Pinto Lake	12	6/10/2005-5/22/2006	0.212121	3.81E-01	Increasing Trend and Not Statistically Significant
305PNTO2m	Pinto Lake	12	6/10/2005-5/22/2006	0.198479	3.72E-01	Increasing Trend and Not Statistically Significant
305PNTO2s	Pinto Lake	12	6/10/2005-5/22/2006	0.393939	8.63E-02	Increasing Trend and Not Statistically Significant
305PNTO3b	Pinto Lake	12	6/10/2005-5/22/2006	0.30303	1.97E-01	Increasing Trend and Not Statistically Significant
305PNTO3m	Pinto Lake	12	6/10/2005-5/22/2006	0.30303	1.97E-01	Increasing Trend and Not Statistically Significant
AM105	Ditch	3	3/3/2009, 3/18/2009, 3/21/2012	-	-	Inconclusive due to inadequate sample size
AM1132	Ditch	7	5/6/1993-11/10/1994, 3/21/2012 No Samples 1995-2011	0.333333	3.81E-01	Increasing Trend and Not Statistically Significant
Amesti Ck	Amesti Creek	17	12/16/2012-4/1/2014	-0.35294	5.18E-02	Decreasing Trend and Statistically Significant
CCC Ck	CCC Creek	41	2/11/2013-4/1/2014	-0.24664	2.33E-02	Decreasing Trend and Statistically Significant
County Dock	Pinto Lake	10	8/1/2013-3/19/2015	-0.2	4.84E-01	Decreasing Trend and Not Statistically Significant
Disc Hole_14	Pinto Lake	3	8/1/2013, 12/31/2014, 3/19/2015	-	-	Inconclusive due to inadequate sample size
Haul out area by County Dock	Pinto Lake	7	12/16/2013-7/1/2014	-0.42857	2.39E-01	Decreasing Trend and Not Statistically Significant
Pinto Ck	Pinto Creek	6	2/1/2012-4/1/2014 No Samples 2013	0.066667	1.00E+00	Increasing Trend and Not Statistically Significant
Pinto Creek_Ruby Ranch Rd	Pinto Creek	3	1/12/2015, 2/9/2015, 4/7/2015	-	-	Inconclusive due to inadequate sample size

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
Pinto Mobile Homes Ck	Unnamed tributary to CCC Creek	3	2/8/2013, 2/7/2014, 4/1/2014	-	-	Inconclusive due to inadequate sample size
PintoLake_Buoy1	Pinto Lake	40	4/1/2011-4/2/2012, 4/27/2016	0.111754	3.11E-01	Increasing Trend and Not Statistically Significant
PintoLake_Buoy2b	Pinto Lake	39	4/1/2011-4/2/2012	0.067797	5.45E-01	Increasing Trend and Not Statistically Significant
PintoLake_Buoy2m	Pinto Lake	38	4/1/2011-4/2/2012	0.157895	1.68E-01	Increasing Trend and Not Statistically Significant
PintoLake_Buoy2s	Pinto Lake	39	4/1/2011-4/2/2012	0.196212	7.93E-02	Increasing Trend and Not Statistically Significant
PintoLake_Buoy3	Pinto Lake	39	4/1/2011-4/2/2012	0.151454	1.75E-01	Increasing Trend and Not Statistically Significant
PintoLake_Buoy4	Pinto Lake	40	4/1/2011-4/2/2012, 4/27/2016	0.242775	2.76E-02	Increasing Trend and Statistically Significant
PintoLakeDock	Pinto Lake	390	6/10/2005-5/22/2006, 5/15/2009-4/26/2015 No Samples 2007-2008	0.160313	2.29E-06	Increasing Trend and Statistically Significant
PL0	Pinto Lake	23	5/7/1992-2/16/1995, 11/18/1999, 9/7/2000-4/20/2005 No Samples 1996-1998, 2002, 2004. One sample in 1999, 2001, and 2005.			Inconclusive due to inadequate temporal variation
PL3	Pinto Lake	3	12/6/2000, 1/17/2001, 4/20/2005	-	-	Inconclusive due to inadequate sample size
PLAMESTI	Amesti Creek	5	1/12/2015-1/19/2016	-	-	Inconclusive due to inadequate sample size
Todos Santos Ck	Todos Santos Creek	27	12/24/2012-4/7/2015	-0.24536	7.29E-02	Decreasing Trend and Not Statistically Significant
Villa del Paraiso	Pinto Lake	11	12/16/2013-3/19/2015	0.054545	8.79E-01	Increasing Trend and Not Statistically Significant

Table 4-11. Tabular summary of orthophosphate as P concentrations temporal trends and significance at monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
305PNTO1b	Pinto Lake	12	6/10/2005-5/22/2006	-0.03077	0.890403	Decreasing Trend and Not Statistically Significant

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
305PNTO1m	Pinto Lake	12	6/10/2005-5/22/2006	-0.10687	0.630417	Decreasing Trend and Not Statistically Significant
305PNTO1s	Pinto Lake	12	6/10/2005-5/22/2006	-0.06253	0.781511	Decreasing Trend and Not Statistically Significant
305PNTO2b	Pinto Lake	12	6/10/2005-5/22/2006	-0.63636	0.003182	Decreasing Trend and Statistically Significant
305PNTO2m	Pinto Lake	12	6/10/2005-5/22/2006	0.093796	0.677392	Increasing Trend and Not Statistically Significant
305PNTO2s	Pinto Lake	12	6/10/2005-5/22/2006	0.108556	0.628244	Increasing Trend and Not Statistically Significant
305PNTO3b	Pinto Lake	12	6/10/2005-5/22/2006	0.137409	0.536174	Increasing Trend and Not Statistically Significant
305PNTO3m	Pinto Lake	12	6/10/2005-5/22/2006	-0.06253	0.781511	Decreasing Trend and Not Statistically Significant
Amesti Ck	Amesti Creek	17	12/16/2012-4/1/2014	-0.31735	0.076264	Decreasing Trend and Not Statistically Significant
CCC Ck	CCC Creek	34	2/11/2013-4/1/2014	0.180357	0.134238	Increasing Trend and Not Statistically Significant
Pinto Ck	Pinto Creek	6	2/1/2012-12/16/2012, 4/1/2014 No Samples 2013	0.2	0.719444	Increasing Trend and Not Statistically Significant
Pinto Mobile Homes Ck	Unnamed tributary to CCC Creek	3	2/8/2013, 2/7/2014, 4/1/2014	-	-	Inconclusive due to inadequate sample size
PintoLake_Buoy1	Pinto Lake	40	4/1/2011-4/2/2012, 4/27/2016 No Samples 2013-2015	-0.34146	0.001938	Decreasing Trend and Statistically Significant
PintoLake_Buoy2b	Pinto Lake	39	4/1/2011-4/2/2012	-0.16745	0.133583	Decreasing Trend and Not Statistically Significant
PintoLake_Buoy2m	Pinto Lake	39	4/1/2011-4/2/2012	-0.31714	0.004161	Decreasing Trend and Statistically Significant
PintoLake_Buoy2s	Pinto Lake	39	4/1/2011-4/2/2012	-0.33919	0.002391	Decreasing Trend and Not Statistically Significant
PintoLake_Buoy3	Pinto Lake	39	4/1/2011-4/2/2012	-0.36622	0.001043	Decreasing Trend and Statistically Significant

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
PintoLake_Buoy4	Pinto Lake	40	4/1/2011-4/2/2012, 4/27/2016 No Samples 2013-2015	-0.18345	0.095671	Decreasing Trend and Not Statistically Significant
PintoLakeDock	Pinto Lake	140	6/10/2005-5/22/2006, 5/15/2009-12/9/2014 No Samples 2007-2008	-0.13247	0.021159	Decreasing Trend and Statistically Significant
Todos Santos Ck	Todos Santos Creek	27	12/24/2012-4/7/2015	0.133903	0.340955	Increasing Trend and Not Statistically Significant

Table 4-12. Tabular summary of total phosphorus concentrations temporal trends and significance at several monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
Amesti Ck	Amesti Creek	18	2/11/2012-4/8/2013	-0.15738	3.63E-01	Decreasing Trend and Not Statistically Significant
CCC Ck	CCC Creek	32	2/11/2013-1/2/2014	-0.41129	7.44E-04	Decreasing Trend and Statistically Significant
County Dock	Pinto Lake	10	8/1/2013-3/19/2015	-0.46667	7.26E-02	Decreasing Trend and Not Statistically Significant
Disc Hole_14	Pinto Lake	3	8/1/2013-3/19/2015	-	-	Inconclusive due to inadequate sample size
Haul out area by County Dock	Pinto Lake	7	12/16/2013-7/1/2014	-0.52381	1.36E-01	Decreasing Trend and Not Statistically Significant
Pinto Ck	Pinto Creek	5	2/1/2012-12/16/2012	-0.2	8.17E-01	Decreasing Trend and Not Statistically Significant
PintoLakeDock	Pinto Lake	284	4/18/2010-10/29/2016	-0.23637	2.89E-09	Decreasing Trend and Statistically Significant
PLAMESTI	Amesti Creek	5	2/6/2014-1/19/2016	-	-	Inconclusive due to inadequate sample size
Todos Santos Ck	Todos Santos Creek	23	12/24/2012-4/7/2015	0.356436	1.74E-02	Increasing Trend and Statistically Significant
Villa del Paraiso	Pinto Lake	11	12/16/2013-3/19/2015	0.127273	6.48E-01	Increasing Trend and Not Statistically Significant

Table 4-13. Tabular summary of total nitrogen concentrations temporal trends and significance at several monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
Amesti Ck	Amesti Creek	11	12/16/2012-3/11/2013	-0.49091	0.040532	Decreasing Trend and Statistically Significant
CCC Ck	CCC Creek	30	2/11/2013-2/19/2014	-0.13563	0.30359	Decreasing Trend and Not Statistically Significant
PintoLakeDock	Pinto Lake	222	4/18/2010-5/31/2014	0.109652	0.015253	Increasing Trend and Statistically Significant
Todos Santos Ck	Todos Santos Creek	16	12/24/2012-2/19/2014	-0.43333	0.019781	Decreasing Trend and Statistically Significant

Table 4-14. Tabular summary of un-ionized ammonia concentrations temporal trends and significance at several monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
305PNTO1b	Pinto Lake	12	6/10/2005-5/22/2006	0	1.00E+00	No trend
305PNTO1m	Pinto Lake	12	6/10/2005-5/22/2006	0.12121212	6.38E-01	Increasing Trend and Not Statistically Significant
305PNTO1s	Pinto Lake	12	6/10/2005-5/22/2006	0.18181818	4.59E-01	Increasing Trend and Not Statistically Significant
305PNTO2b	Pinto Lake	12	6/10/2005-5/22/2006	-0.54545455	1.38E-02	Decreasing Trend and Statistically Significant
305PNTO2m	Pinto Lake	12	6/10/2005-5/22/2006	0.09090909	7.37E-01	Increasing Trend and Not Statistically Significant
305PNTO2s	Pinto Lake	12	6/10/2005-5/22/2006	0.19847907	3.72E-01	Increasing Trend and Not Statistically Significant
305PNTO3b	Pinto Lake	12	6/10/2005-5/22/2006	0.21541011	3.35E-01	Increasing Trend and Not Statistically Significant
305PNTO3m	Pinto Lake	12	6/10/2005-5/22/2006	0.18181818	4.59E-01	Increasing Trend and Not Statistically Significant
Amesti Ck	Amesti Creek	17	12/16/2012-4/1/2014	-0.08118136	6.50E-01	Decreasing Trend and Not Statistically Significant
CCC Ck	CCC Creek	41	2/11/2013-4/1/2014	0.02444995	8.22E-01	Increasing Trend and Not Statistically Significant

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
County Dock	Pinto Lake	10	8/1/2013-3/19/2015	-0.28888889	2.91E-01	Decreasing Trend and Not Statistically Significant
Haul out area by County Dock	Pinto Lake	7	12/16/2013-7/1/2014	-0.61904762	6.90E-02	Decreasing Trend and Not Statistically Significant
Pinto Ck	Pinto Creek	6	2/1/2012-4/1/2014 No samples 2013	0.06666667	1.00E+00	Increasing Trend and Not Statistically Significant
Pinto Mobile Homes Ck	Unnamed tributary to CCC Creek	3	2/8/2013-4/1/2014	-	-	Inconclusive due to inadequate sample size
PintoLakeDock	Pinto Lake	98	6/10/2005-5/22/2006, 5/15/2009-3/19/2015 No samples 2007-2008	-0.28050976	4.34E-05	Decreasing Trend and Statistically Significant
PLAMESTI	Amesti Creek	4	2/9/2015-1/19/2016	-	-	Inconclusive due to inadequate sample size
Todos Santos Ck	Todos Santos Creek	27	12/24/2012-4/7/2015	0.07122507	6.20E-01	Increasing Trend and Not Statistically Significant
Villa del Paraiso	Pinto Lake	10	12/16/2013-3/19/2015	-0.68888889	4.69E-03	Decreasing Trend and Statistically Significant

Table 4-15. Tabular summary of chlorophyll *a* concentrations temporal trends and significance at several monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
305PNTO1s	Pinto Lake	12	6/10/2005-5/22/2006	-0.33333	0.15259	Decreasing Trend and Not Statistically Significant
305PNTO2s	Pinto Lake	12	6/10/2005-5/22/2006	-0.35116	0.113903	Decreasing Trend and Not Statistically Significant
Amesti Ck	Amesti Creek	11	1/20/2013-4/8/2013	0.418182	0.086561	Increasing Trend and Not Statistically Significant
CCC Ck	CCC Creek	34	2/11/2013-1/8/2014	-0.17611	0.145822	Decreasing Trend and Not Statistically Significant
PintoLakeDock	Pinto Lake	282	6/10/2005-5/22/2006, 4/8/2010-6/19/2015 No Samples 2007-2009	-0.0491	0.219102	Decreasing Trend and Not Statistically Significant
Todos Santos Ck	Todos Santos Creek	20	1/20/2013-2/7/2014	0.596308	0.000244	Increasing Trend and Statistically Significant

Table 4-16. Tabular summary of microcystins concentrations temporal trends and significance at several monitoring sites in the Pinto Lake catchment.

Monitoring Site Tag	Associated Waterbody	No. of Samples	Temporal Representation	tau	p-value	Interpretation of Concentration Temporal Trends and Significance
County Dock	Pinto Lake	41	5/6/2013-7/1/2014, 3/19/2015, 8/16/2016-9/29/2016 One Sample 2015	0.140846	1.96E-01	Increasing Trend and Not Statistically Significant
Disc Hole 14	Pinto Lake	30	5/6/2013-11/12/2013, 12/31/2014, 3/19/2015-9/23/2016 One Sample 2014	0.119678	3.53E-01	Increasing Trend and Not Statistically Significant
Eucalyptus Grove	Pinto Lake	25	4/3/2013-9/24/2013	-0.25676	7.51E-02	Decreasing Trend and Not Statistically Significant
Haul out area by County Dock	Pinto Lake	32	9/10/2013-9/29/2016	0.523571	3.15E-05	Increasing Trend and Statistically Significant
PintoLakeDock	Pinto Lake	485	9/28/2006-11/1/2006, 4/18/2010-10/26/2016 No Samples 2007-2009	-0.03945	1.95E-01	Decreasing Trend and Not Statistically Significant
Villa del Paraiso	Pinto Lake	58	4/3/2013-9/29/2016	0.190073	3.62E-02	Increasing Trend and Statistically Significant

4.5 Surface Water Quality Seasonal Trends

Seasonal trends in nutrient water quality data are presented in Figures 4-21 through 4-50. While there is substantial variability between different water quality monitoring sites (and in some cases, depths) throughout the Pinto Lake catchment, some constituents demonstrate notable seasonal patterns.

Often phosphorous and nitrogen concentrations appear to be higher in the tributaries (e.g. CCC Creek) compared to lake samples throughout all seasons. This is not unexpected, phosphorus concentrations tend to be higher in streams than in lakes.

Total phosphorous tends to spike in the fall, decline over the early winter months, increase a bit in the spring, and decline again in the summer months.

Higher concentrations of total nitrogen and nitrate as N in the early months of the year for CCC Creek and Pinto Lake sampling sites show higher concentration in beginning and end of the year (winter months) and a general decrease in spring through fall months.

Un-ionized ammonia shows a similar pattern of generally lower concentrations spring through fall at the Pinto Lake Dock monitoring site.

Orthophosphate as P demonstrates a slight sinuosity over the course of the year for some of the lake surface sampling sites with peaks in spring and fall and dips in winter and summer months. The near bottom sampling site at PintoLake_Buoy2 shows a slightly opposite trend with increasing concentrations occurring throughout spring and summer months, with decreases occurring toward the end of fall into winter months (Figure 4-37)

Chlorophyll *a* concentrations appear to increase at the Pinto Lake Dock site from spring through fall and drop off at the end of the year during the winter months.

Microcystin patterns show an increase in concentration over the spring months with an apparent peak/spike in the late summer/early fall for each of the County dock sites toward the north end of the lake (County Dock site, the Haul out area near the County Dock site), as well as the Pinto Lake Dock site at the south end of the lake (Figures 45-47). Villa del Paraiso shows a slightly similar trend with highest concentrations occurring in the later summer/early fall, however the pattern is not as noticeable for the remaining sites Disc Hole 14 and the Eucalyptus Grove (included for completeness).

Figure 4-15. Box and whisker plot of total phosphorus (mg/L) values from Pinto Lake catchment site, CCC Creek. Values plotted per month to show seasonal difference in phosphorus values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

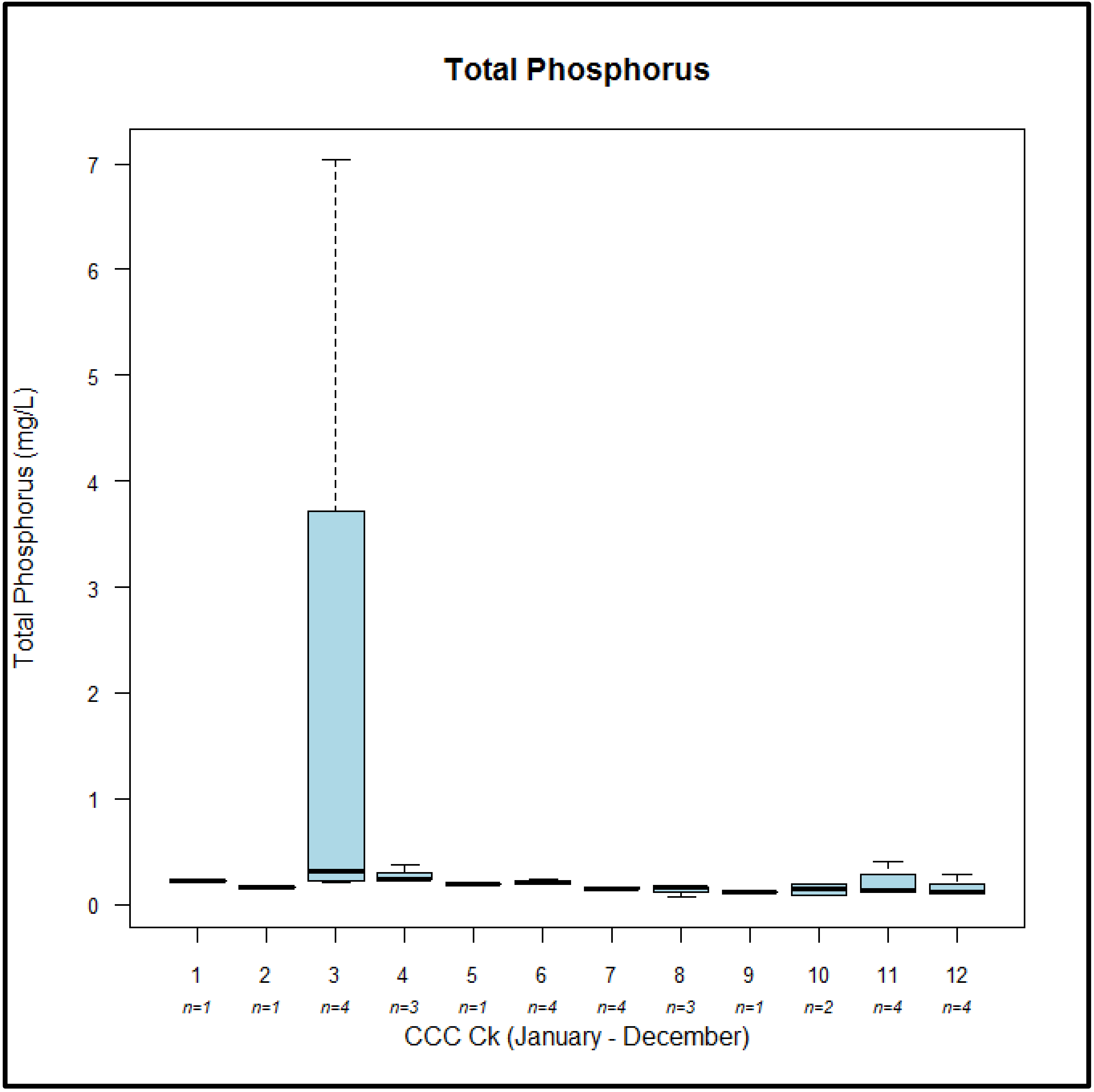


Figure 4-16. Box and whisker plot of total phosphorus (mg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in phosphorus values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

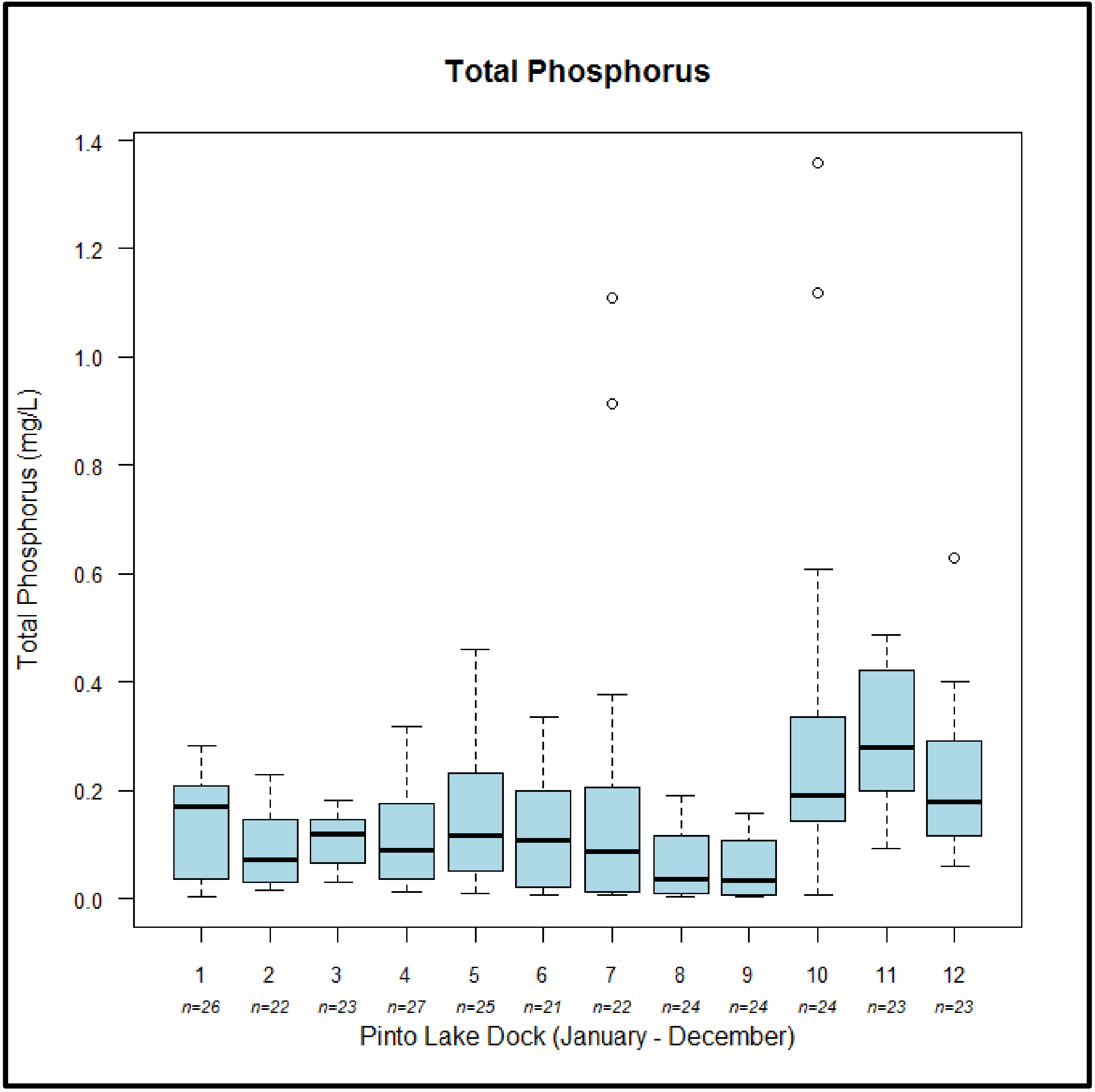


Figure 4-17. Box and whisker plot of total nitrogen (mg/L) values from Pinto Lake catchment site, CCC Creek. Values plotted per month to show seasonal difference in nitrogen values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

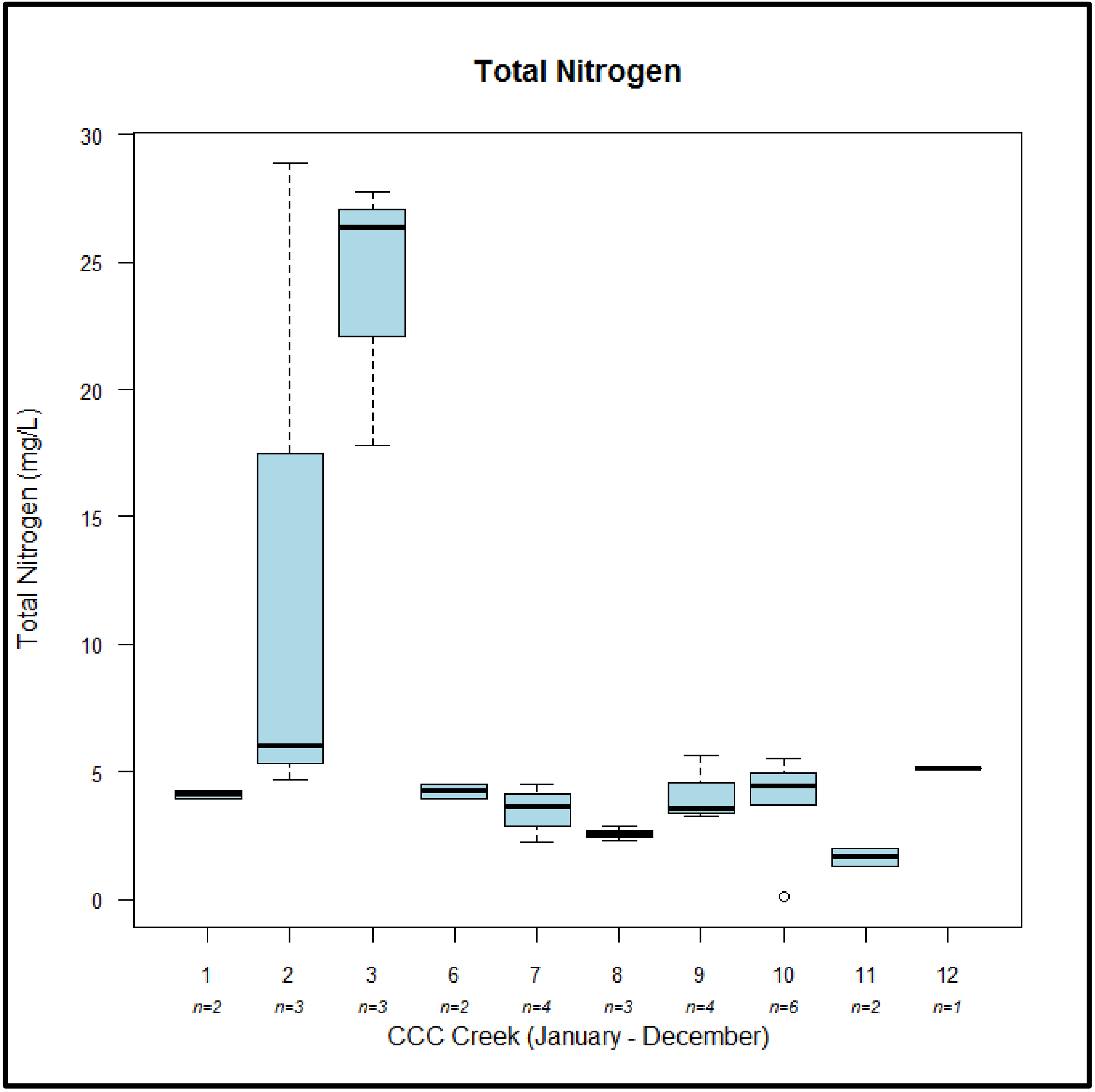


Figure 4-18. Box and whisker plot of total nitrogen (mg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in nitrogen values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

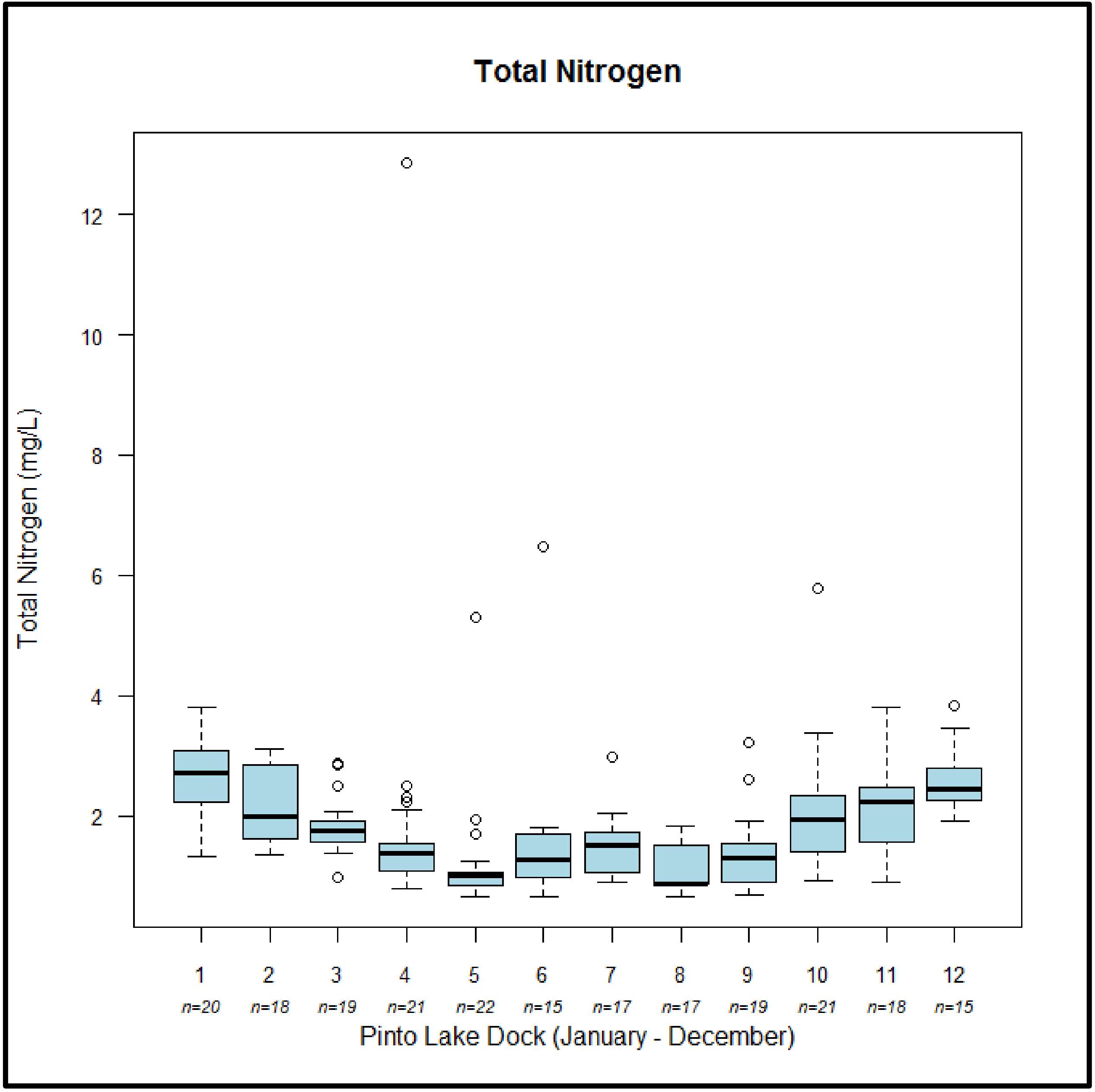


Figure 4-19. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, CCC Ck. Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

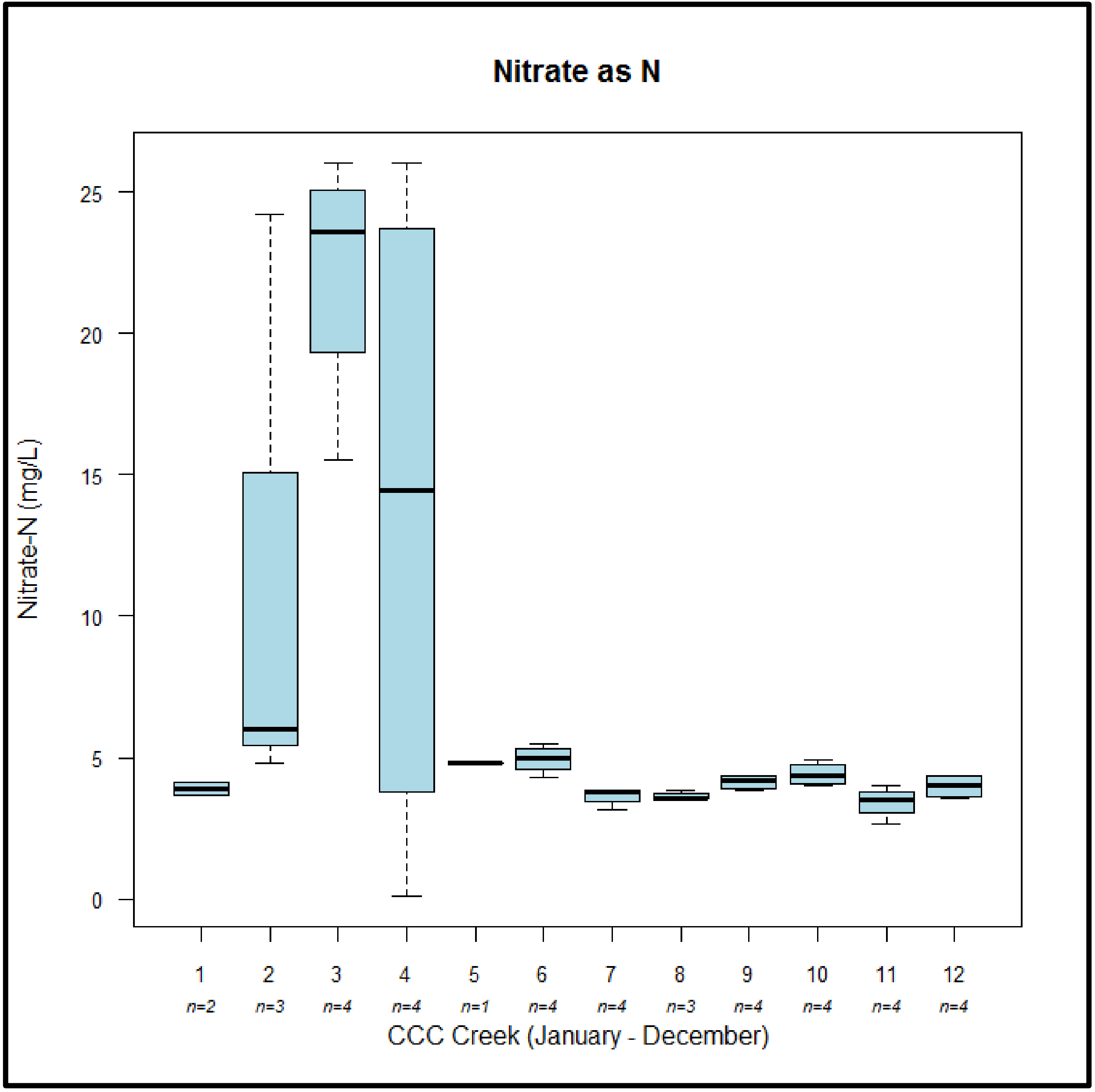


Figure 4-20. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy1. Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

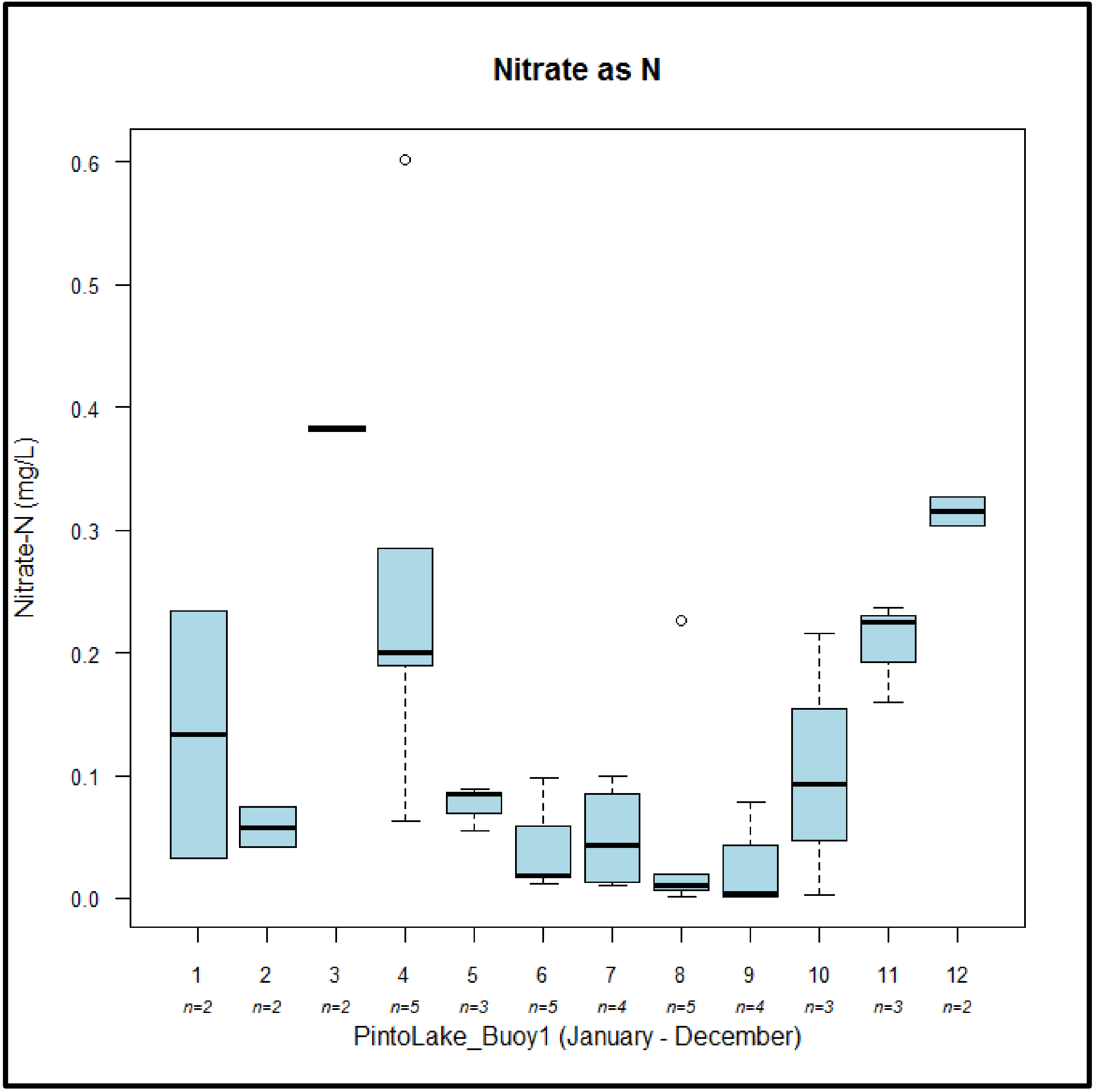


Figure 4-27. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2b (b=samples taken near “bottom”). Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

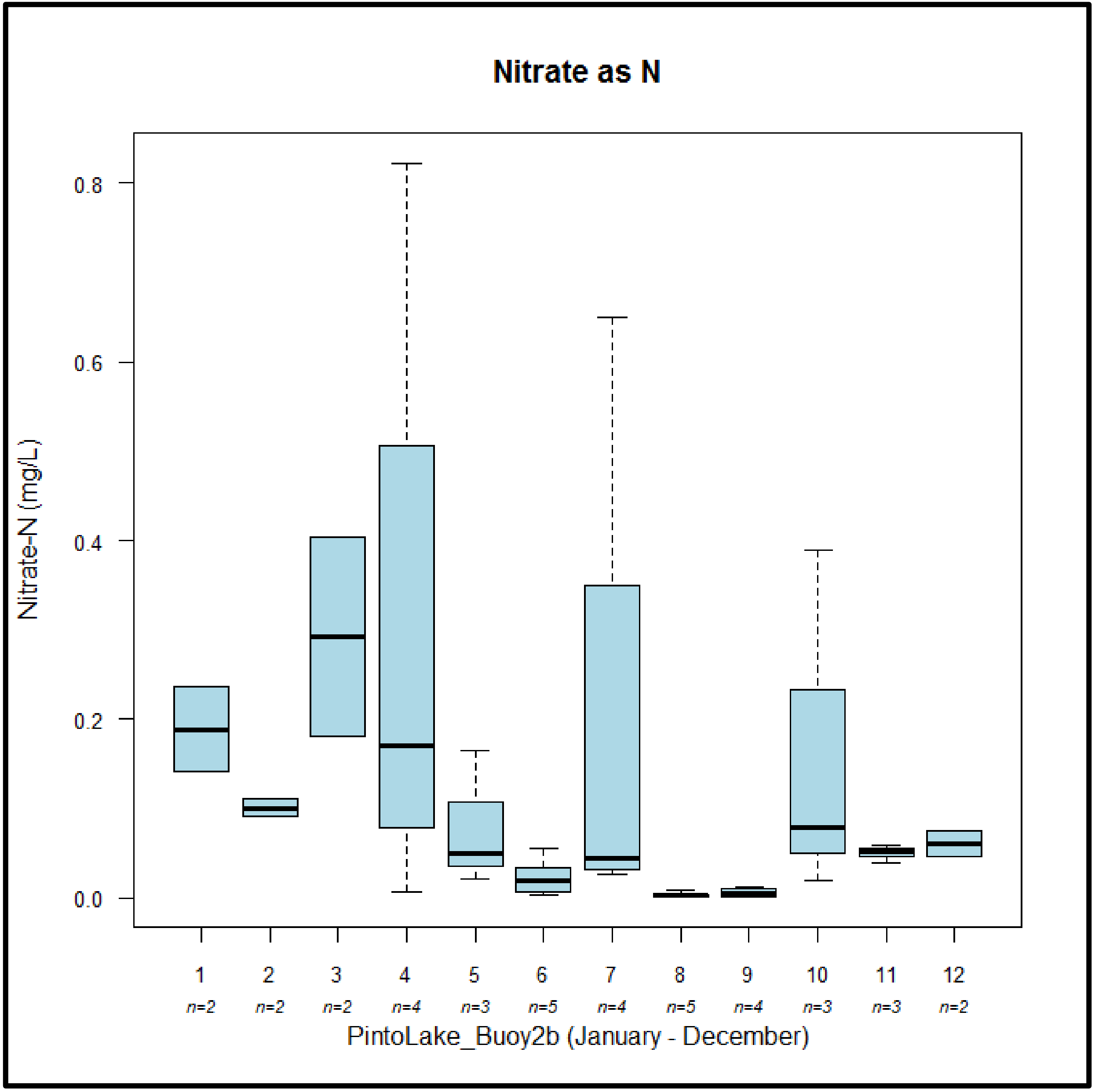


Figure 4-28. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2m (m=samples taken “midcolumn”). Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

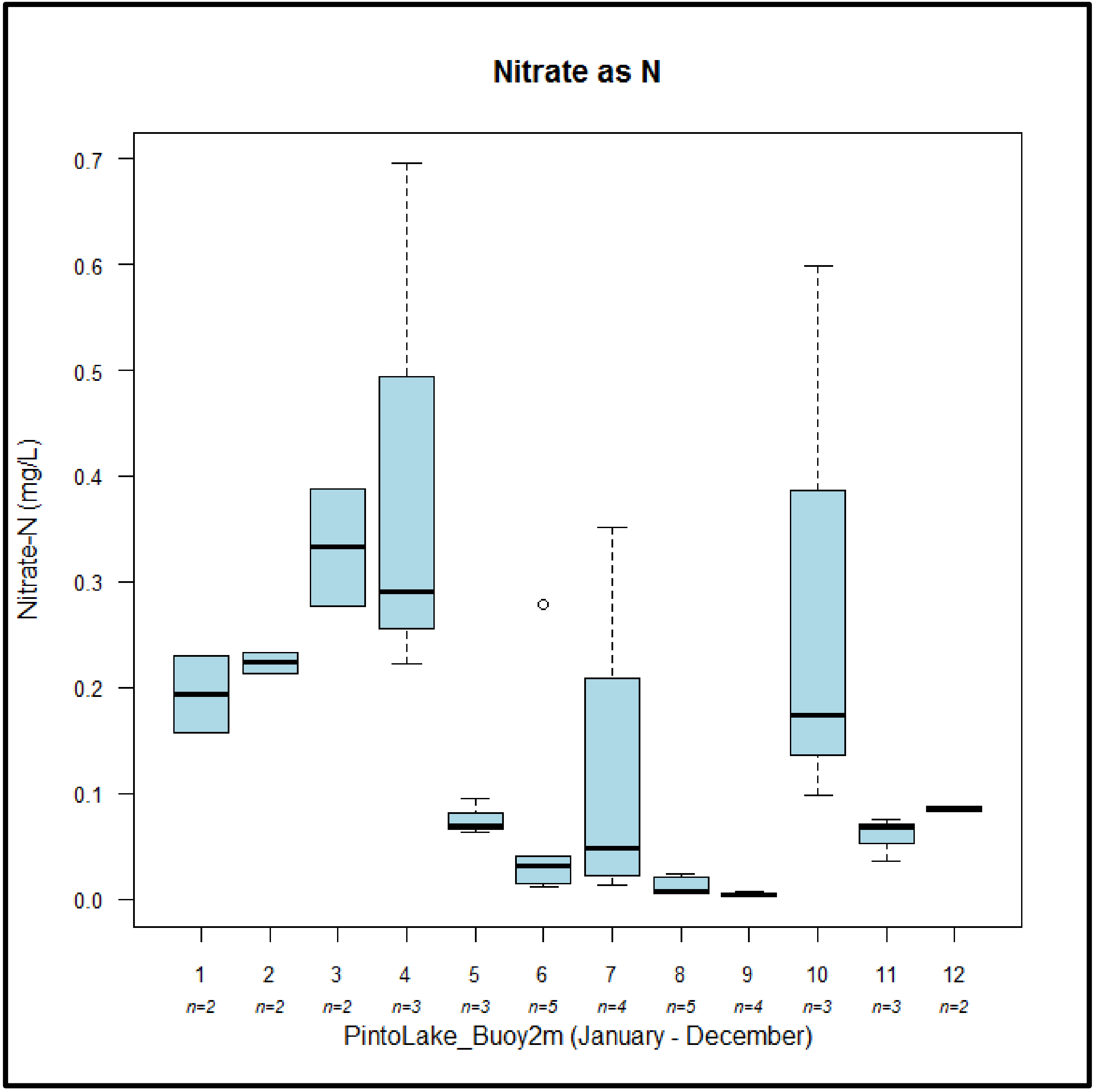


Figure 4-29. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2s (s=samples taken at the “surface”). Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

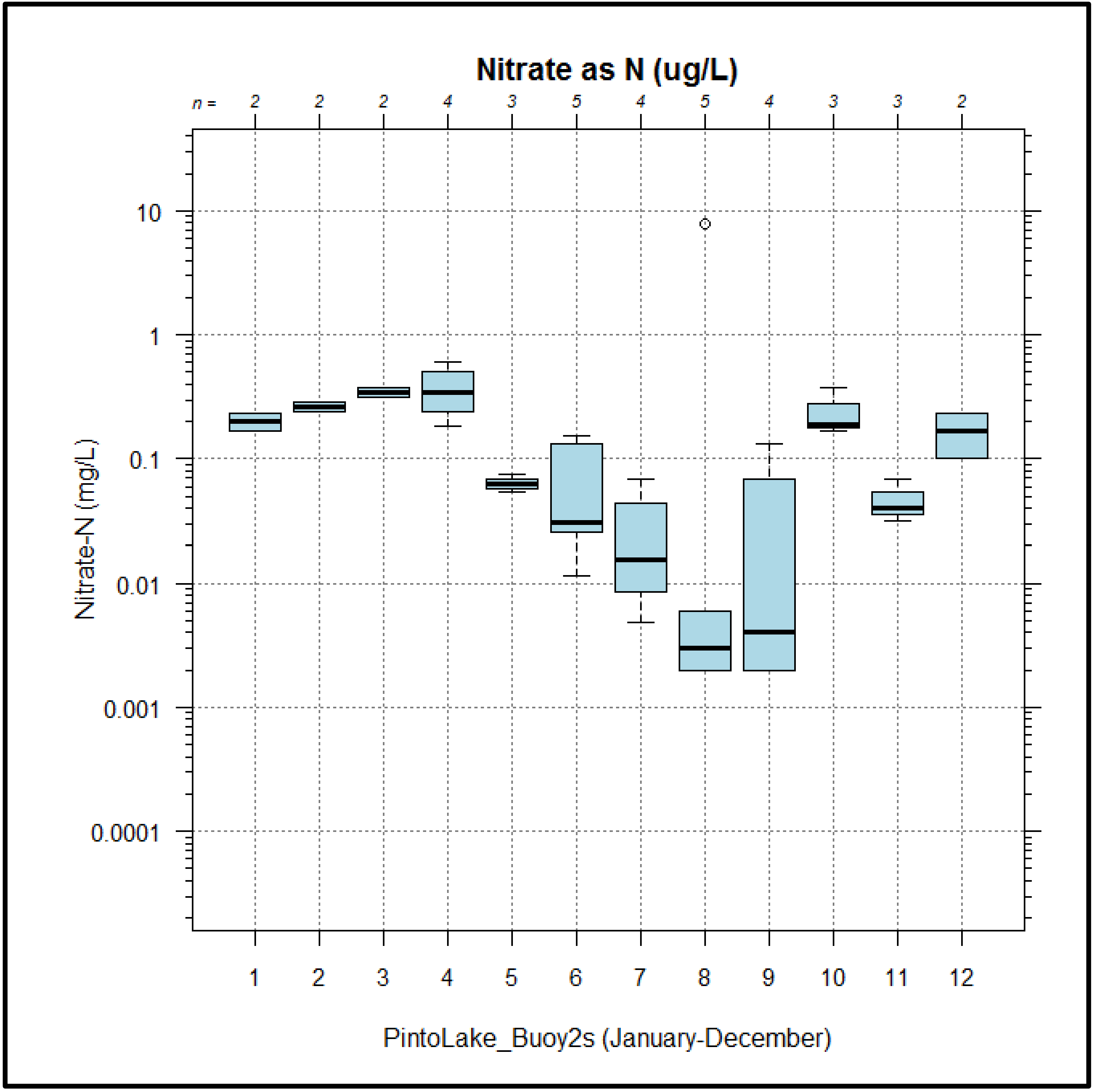


Figure 4-30. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy3. Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

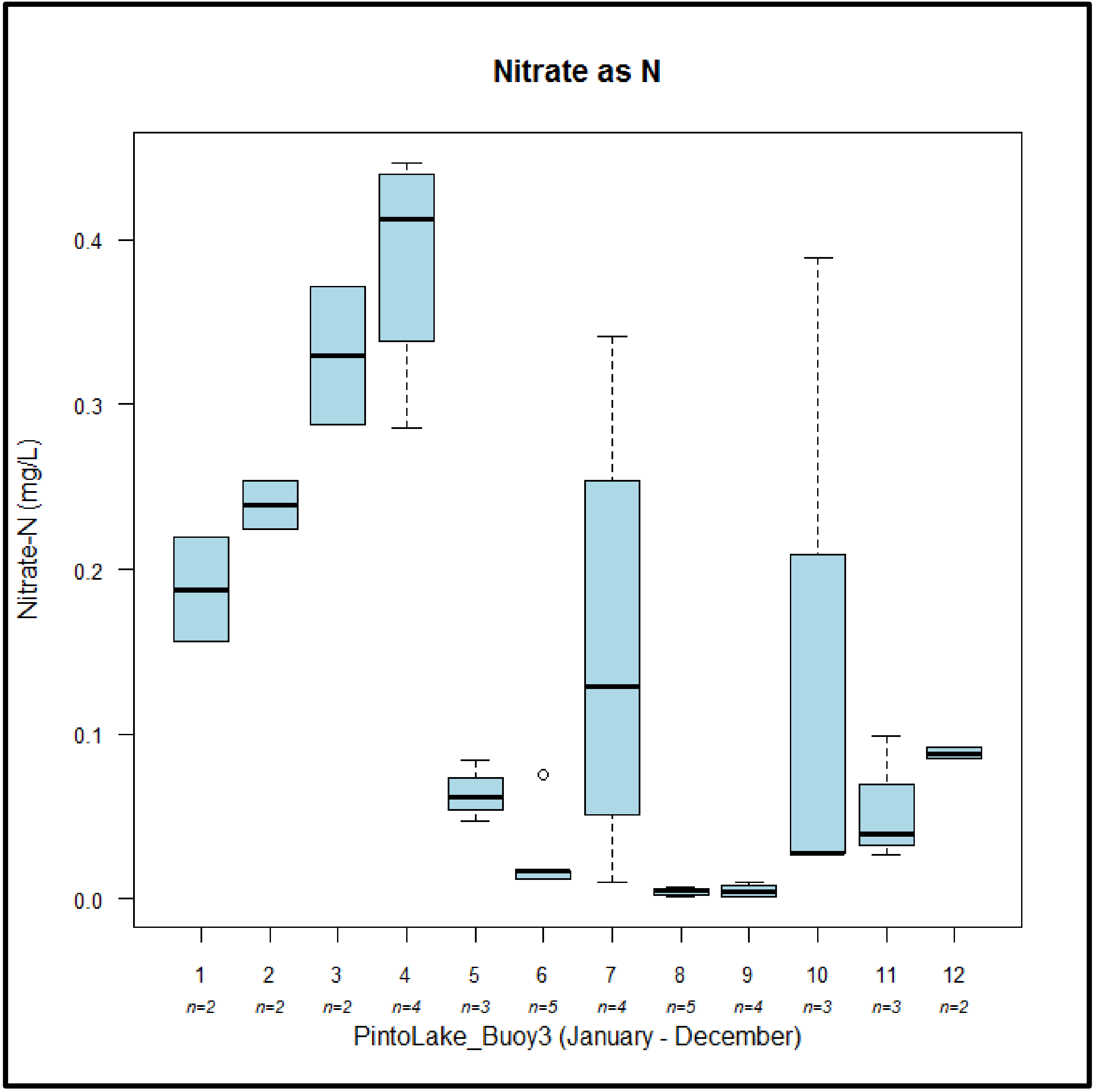


Figure 4-31. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy4. Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

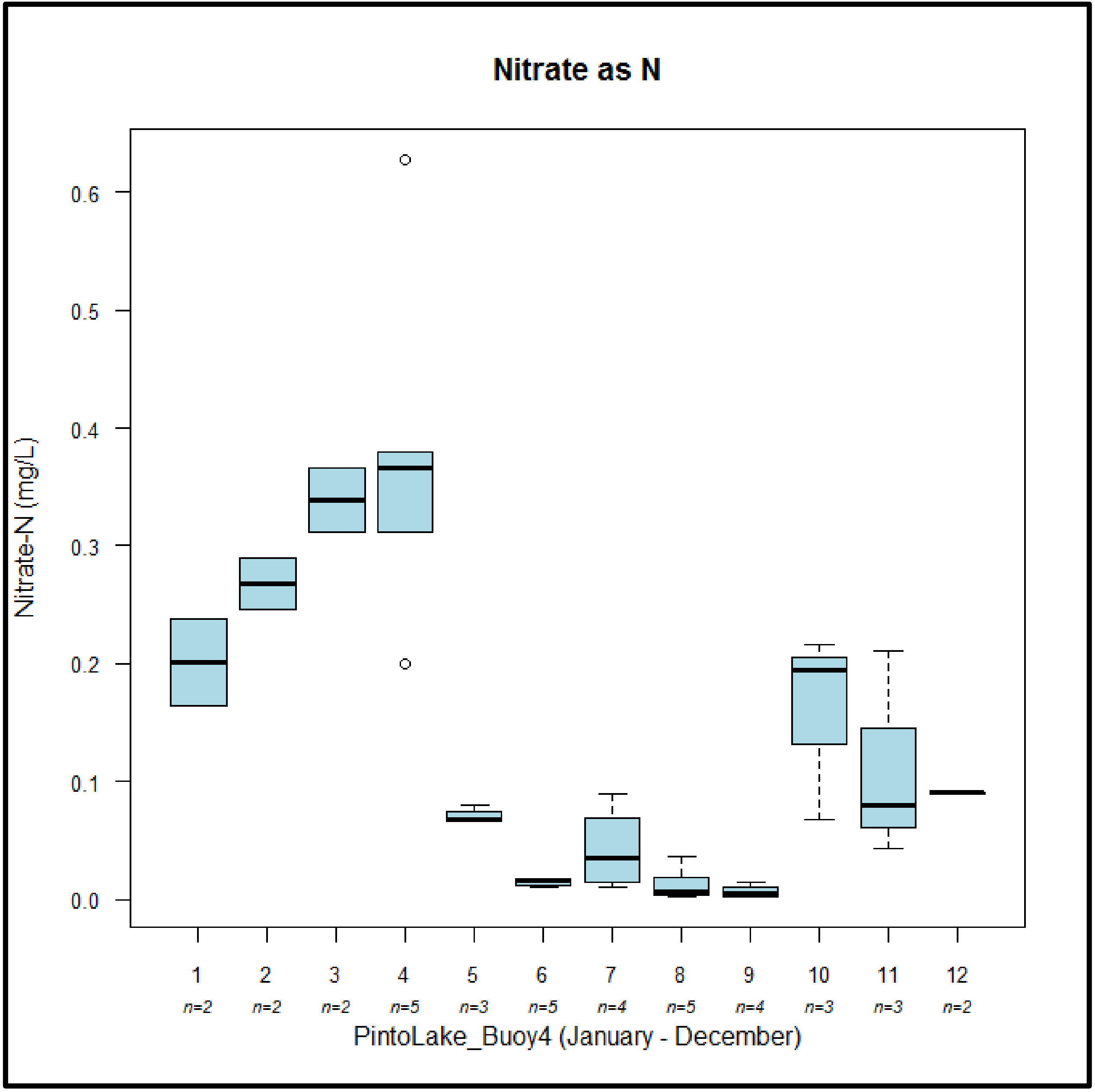


Figure 4-32. Box and whisker plot of nitrate as N (mg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in nitrate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

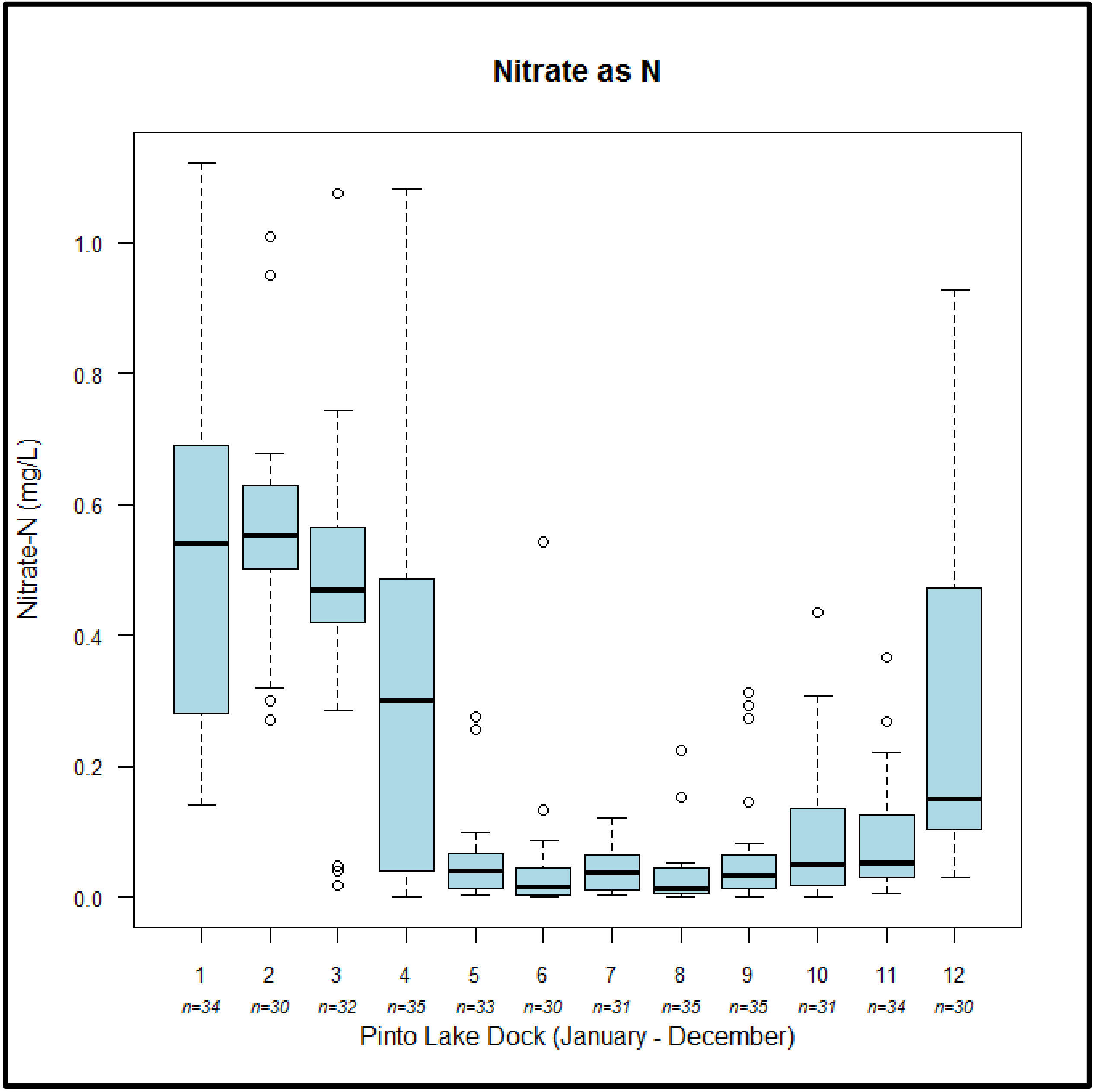


Figure 4-33. Box and whisker plot of un-ionized ammonia (mg/L) values from Pinto Lake catchment site, CCC Ck. Values plotted per month to show seasonal difference in un-ionized ammonia values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

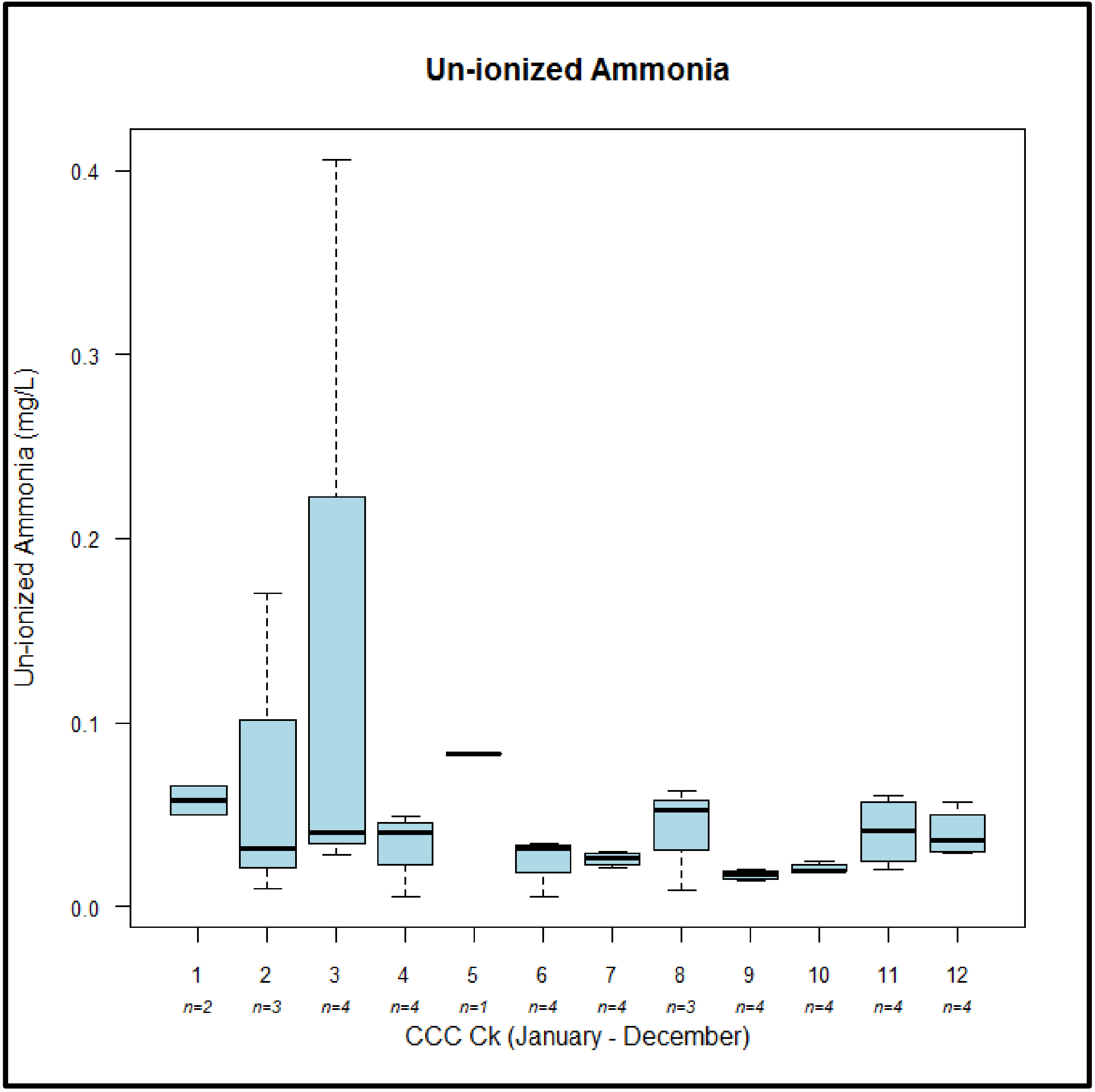


Figure 4-34. Box and whisker plot of un-ionized ammonia (mg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in un-ionized ammonia values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

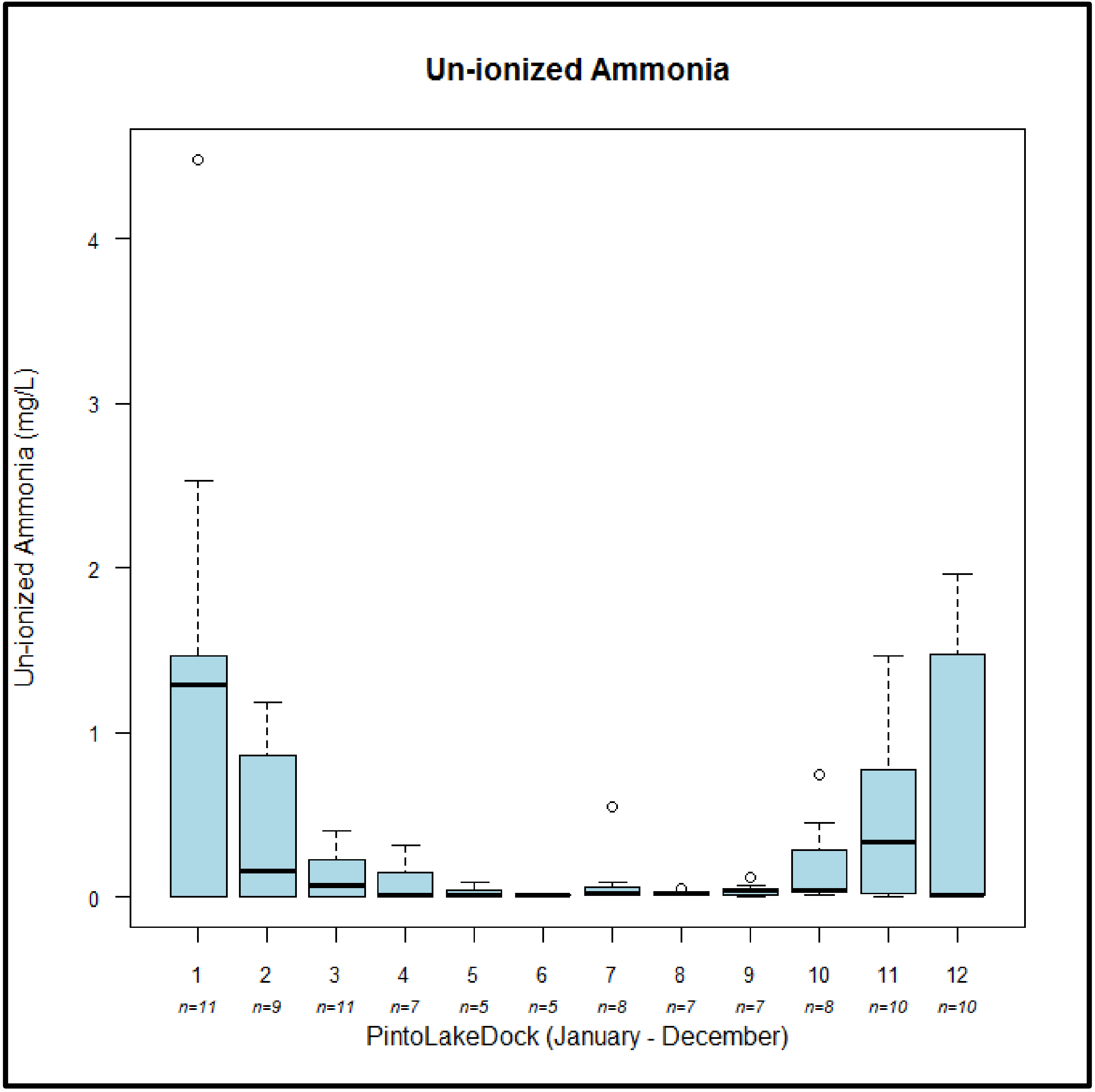


Figure 4-35. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, CCC Creek. Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

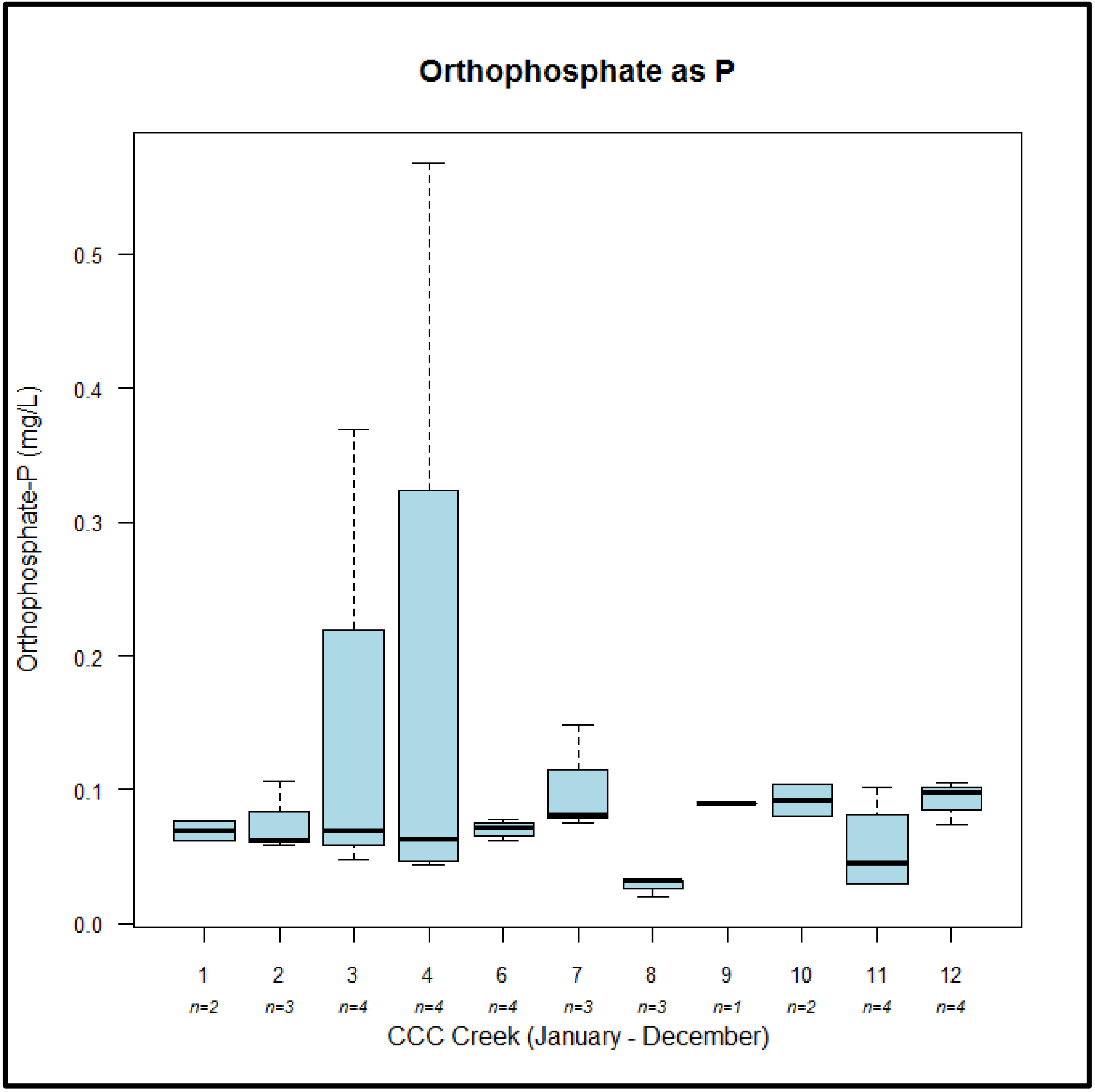


Figure 4-36. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy1. Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

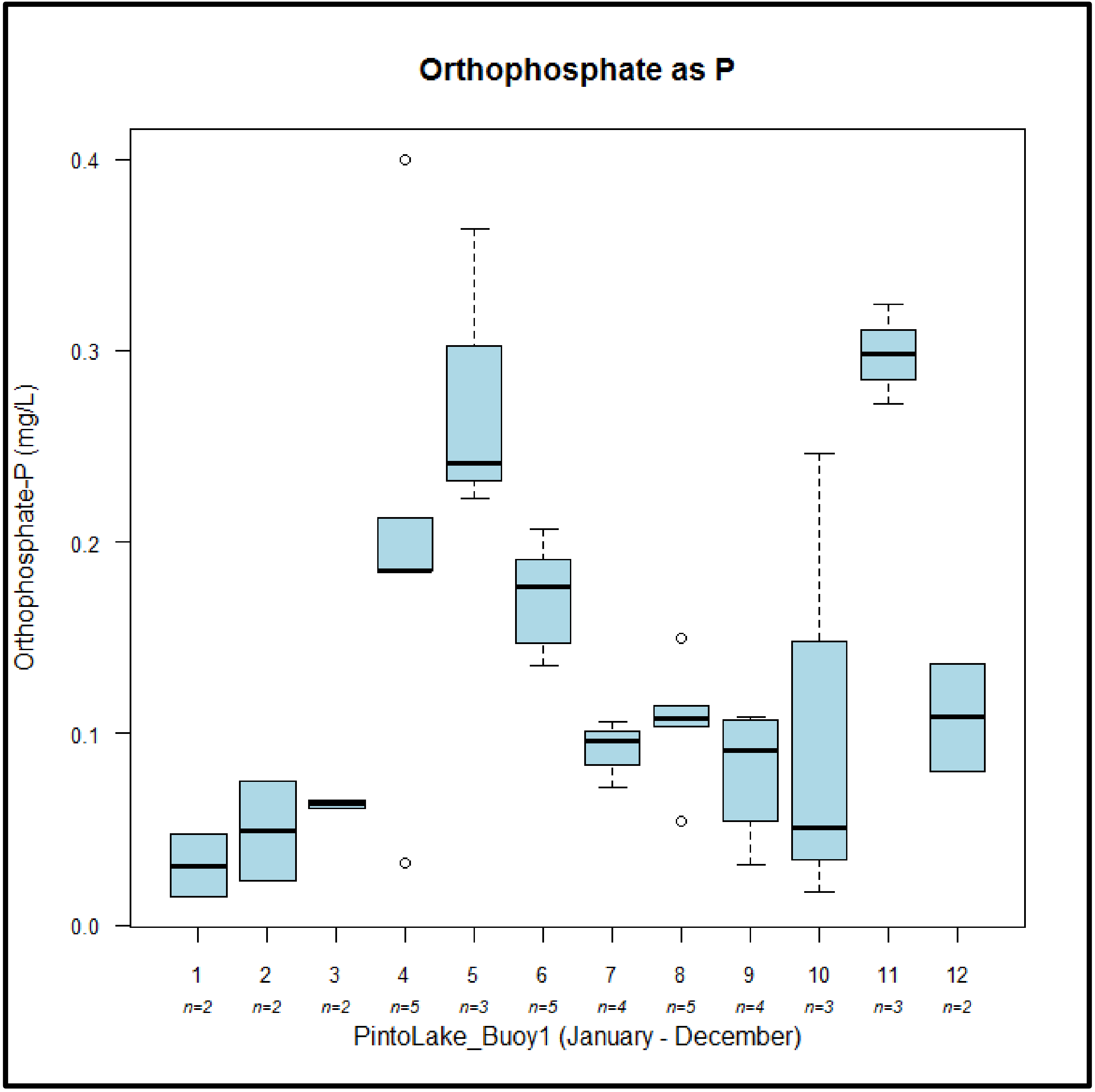


Figure 4-37. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2b (b=samples taken near "bottom"). Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

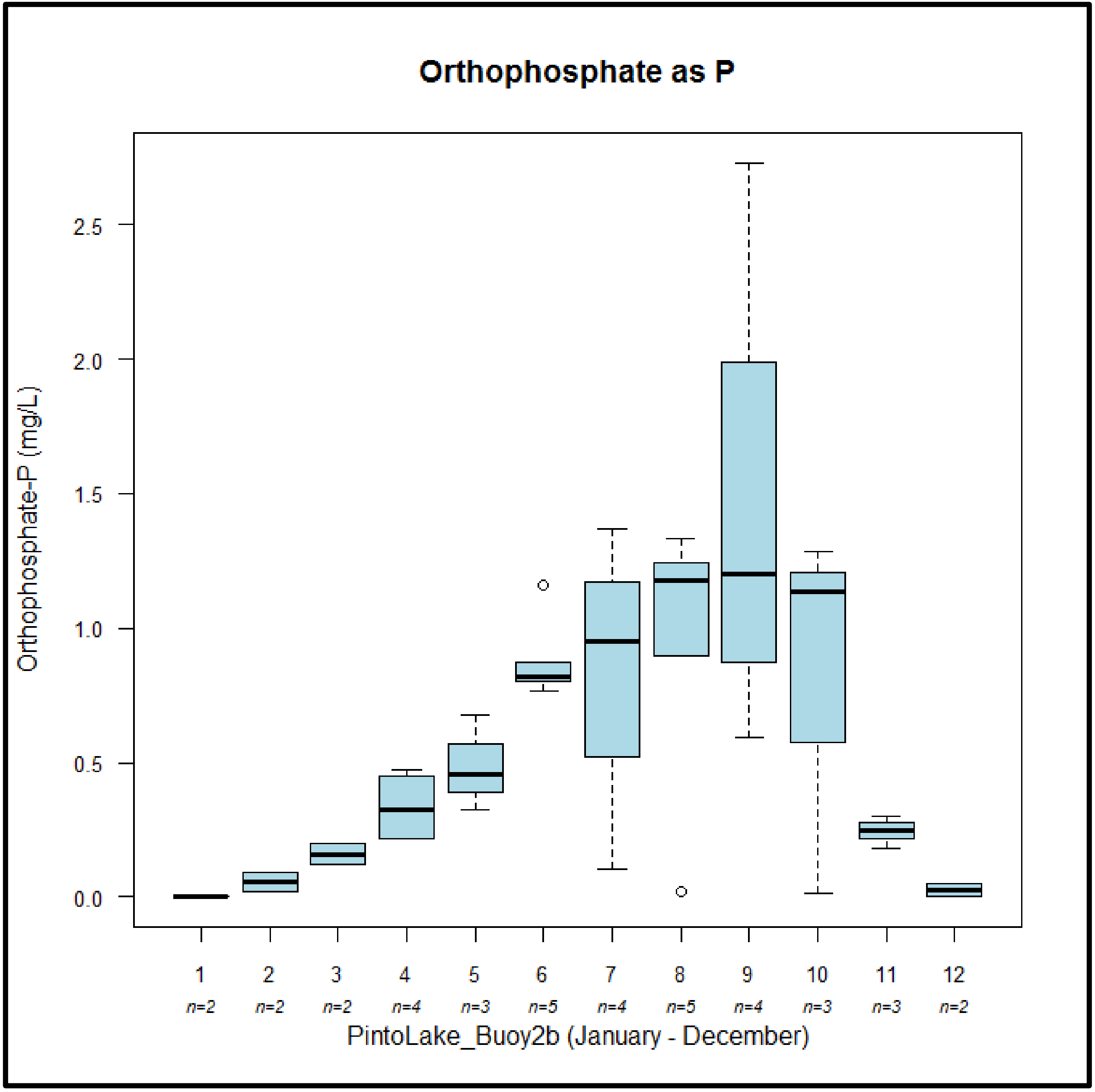


Figure 4-38. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2m (m=samples taken “midcolumn”). Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

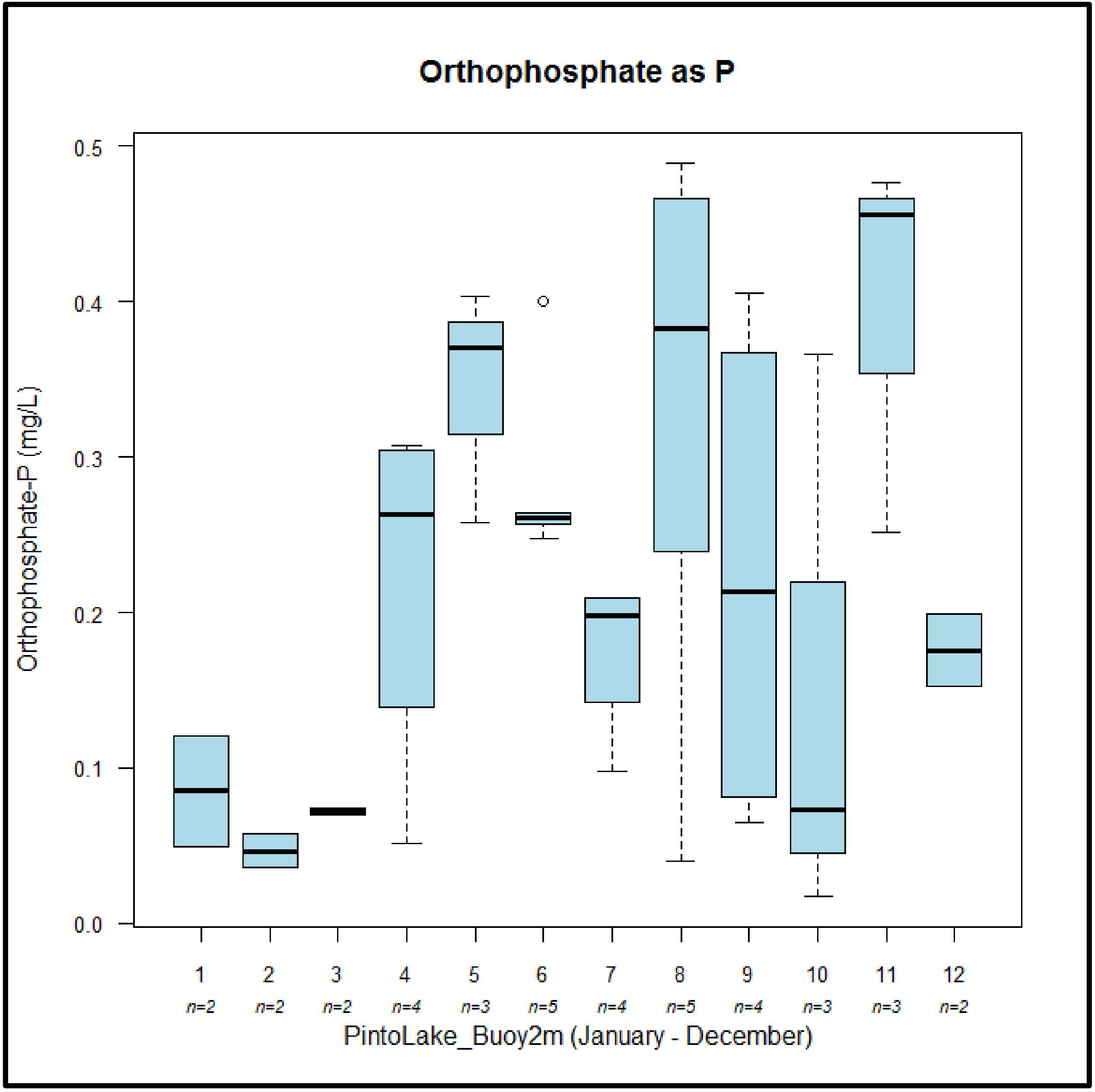


Figure 4-39. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy2s (s=samples taken at the "surface"). Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

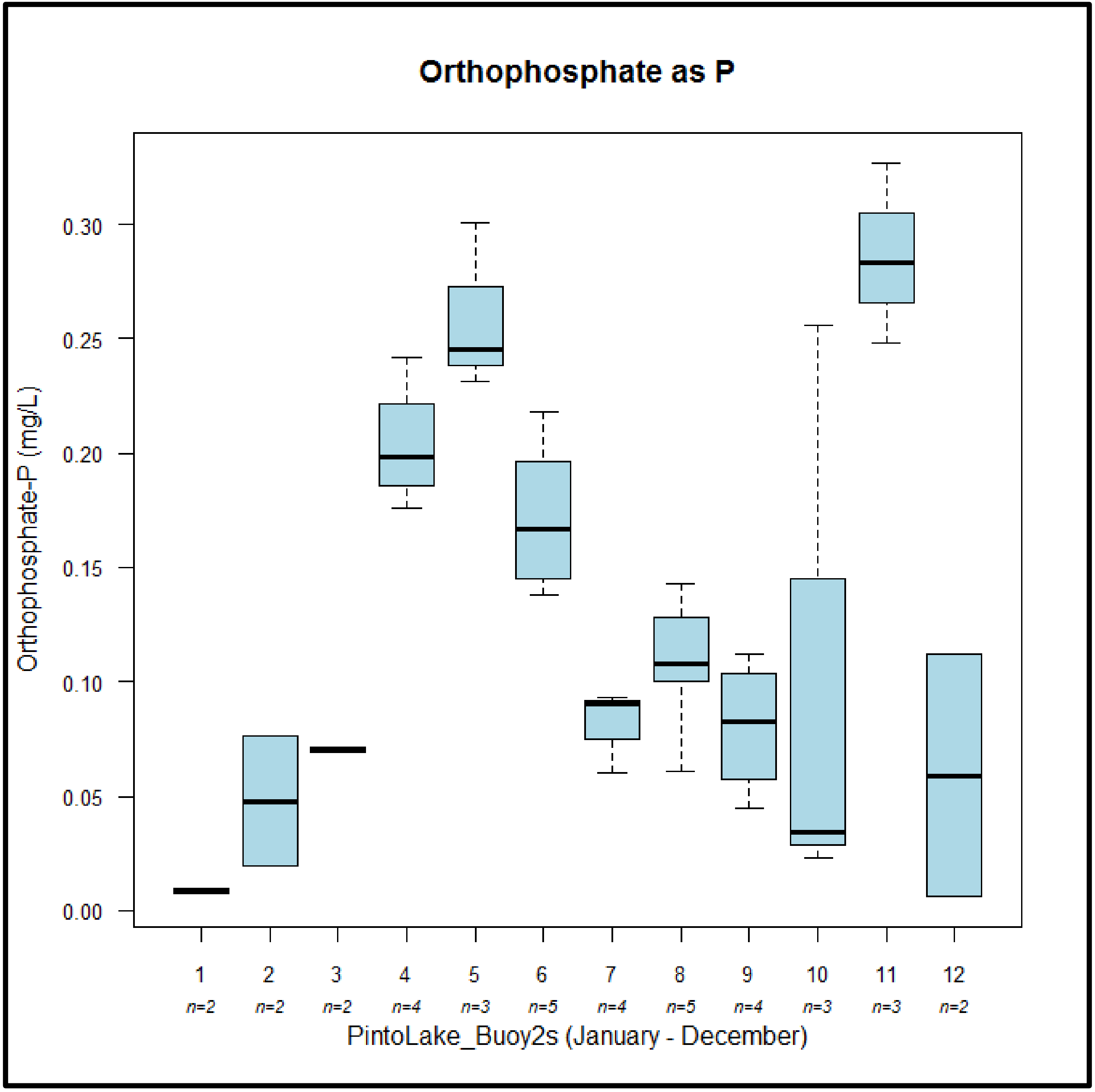


Figure 4-40. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy3. Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

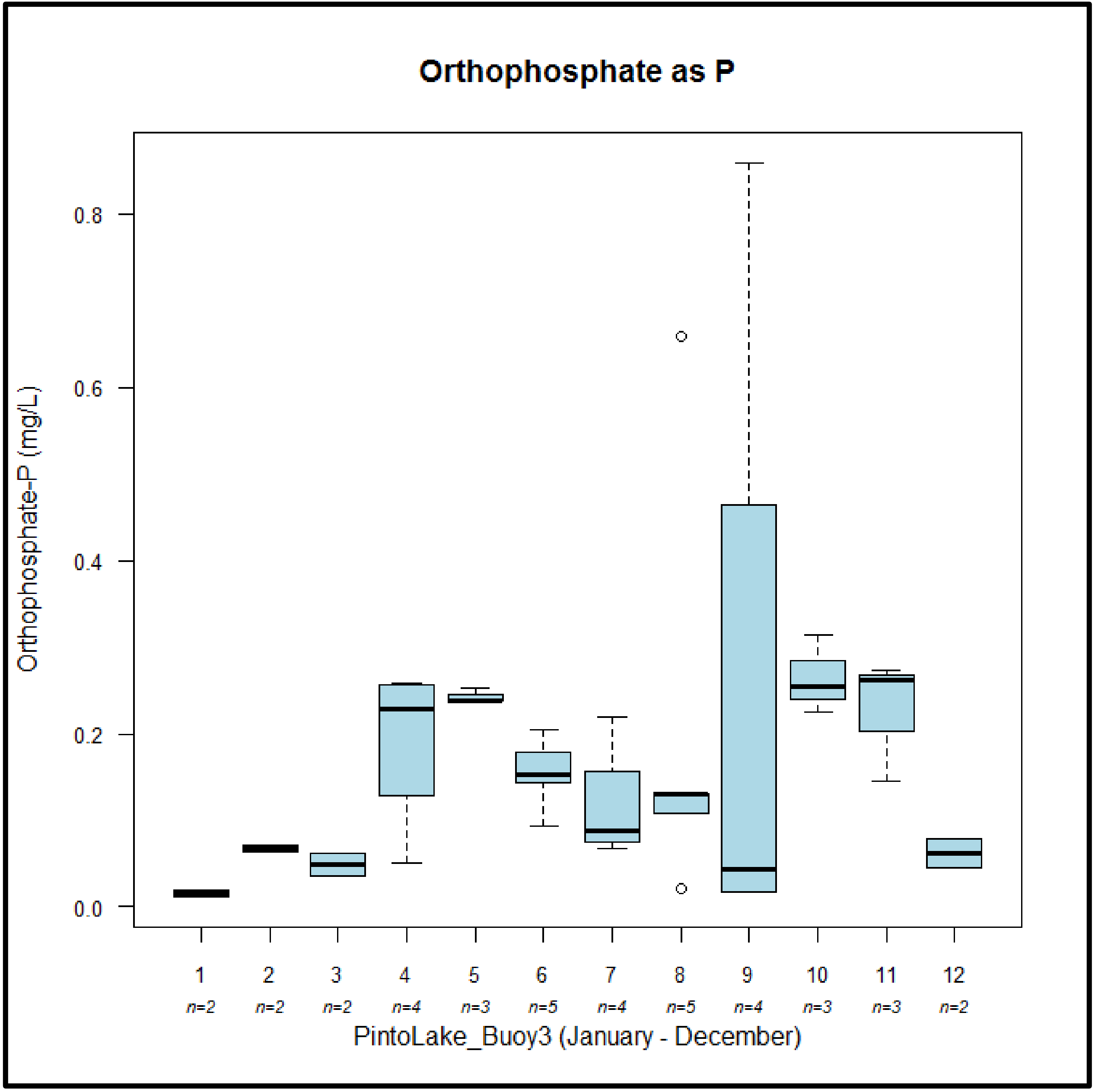


Figure 4-41. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLake_Buoy4. Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

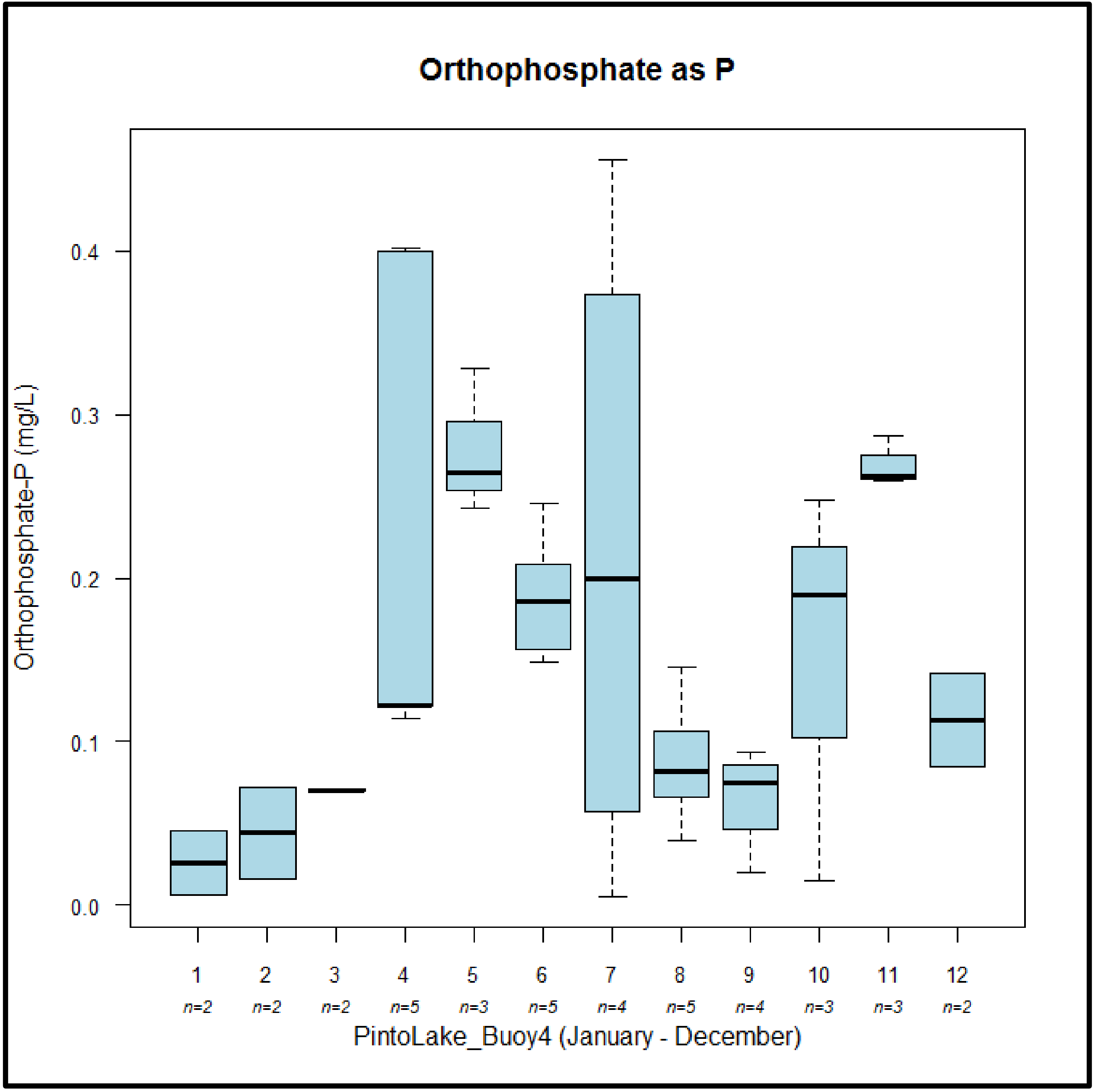


Figure 4-42. Box and whisker plot of orthophoshate as P (mg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in orthophosphate values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

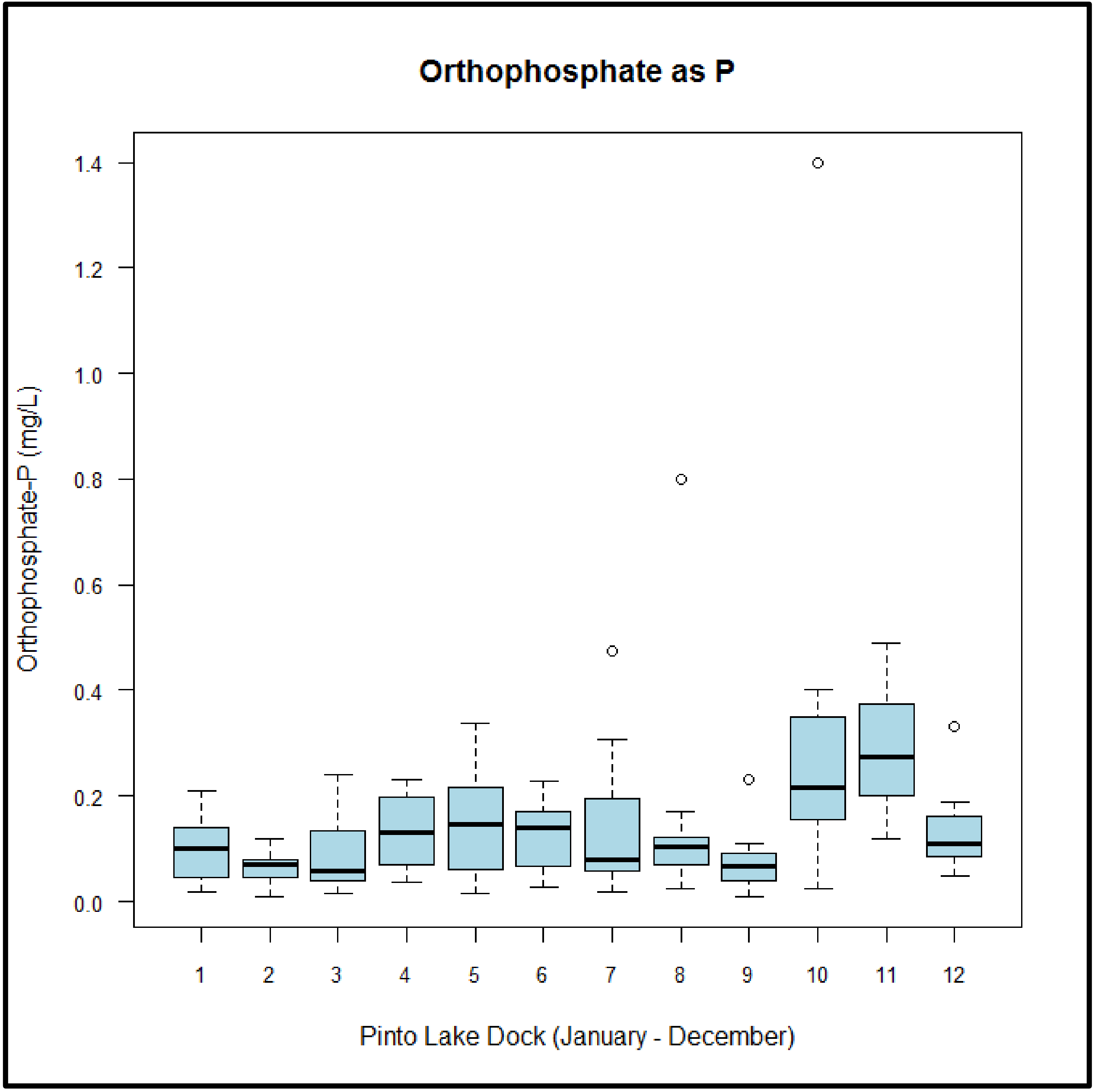


Figure 4-43. Box and whisker plot of chlorophyll *a* (µg/L) values from Pinto Lake catchment site, CCC Creek. Values plotted per month to show seasonal difference in chlorophyll *a* values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

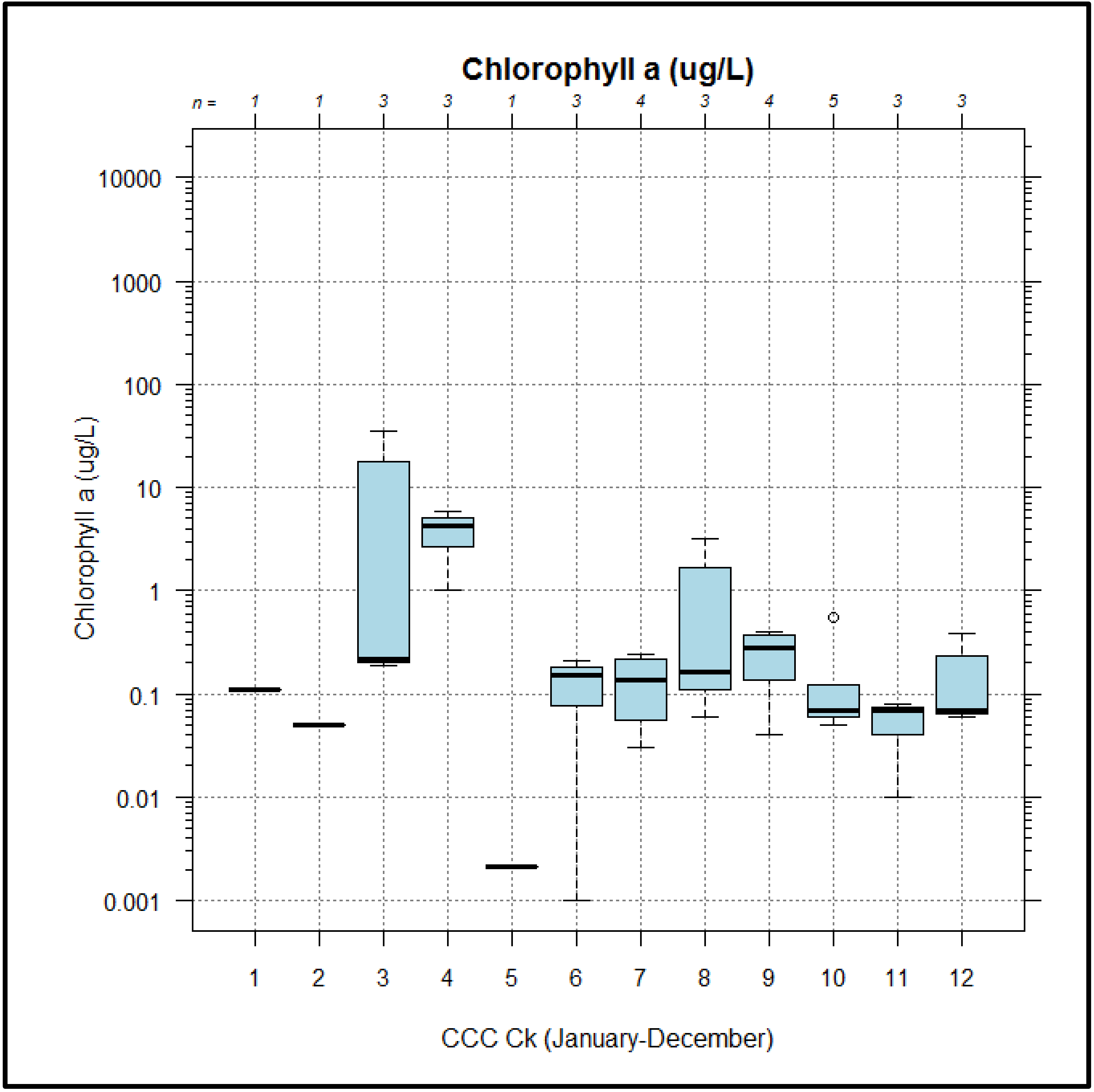


Figure 4-44. Box and whisker plot of chlorophyll *a* (µg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in chlorophyll *a* values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

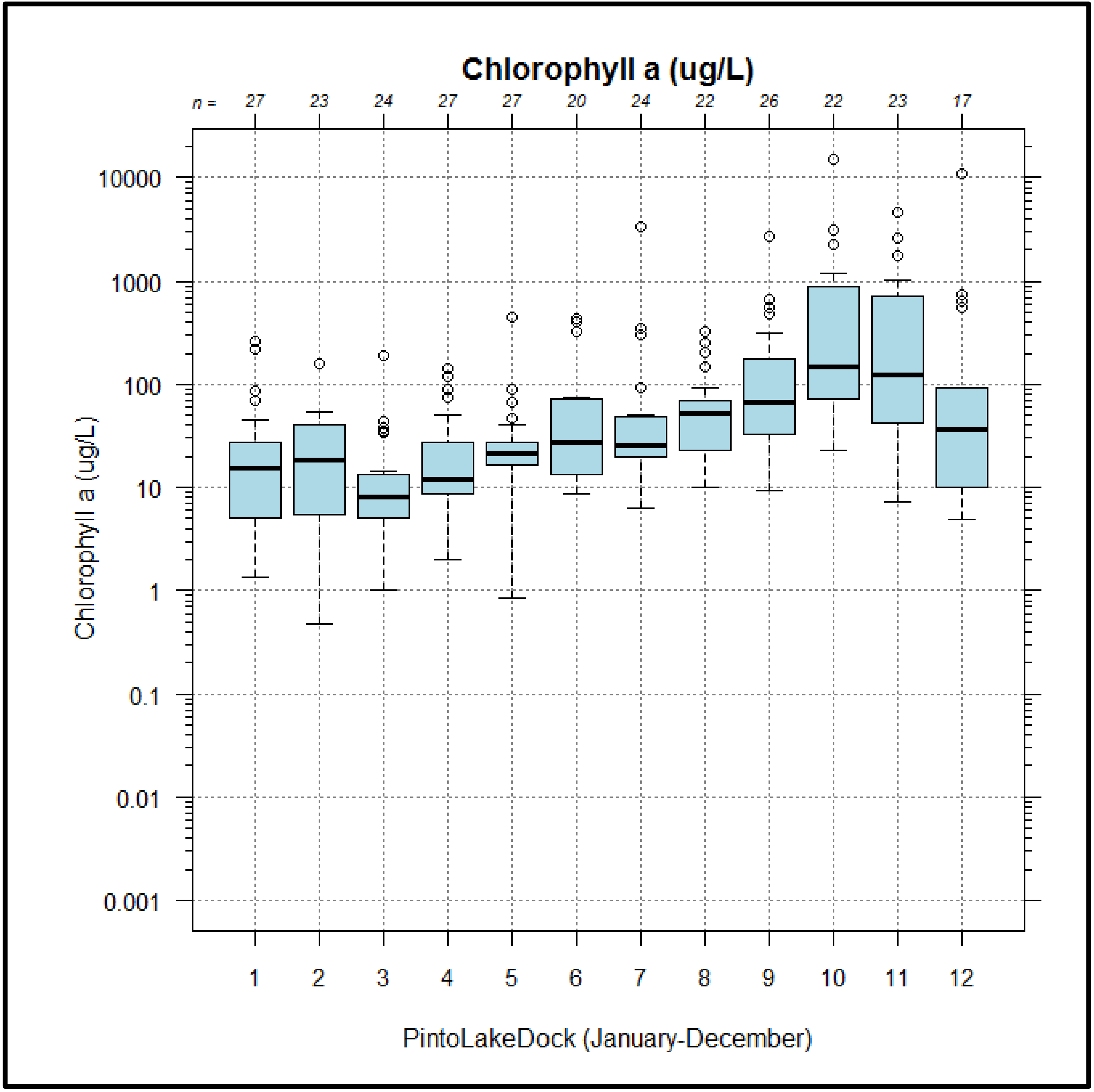


Figure 4-45. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, County Dock. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

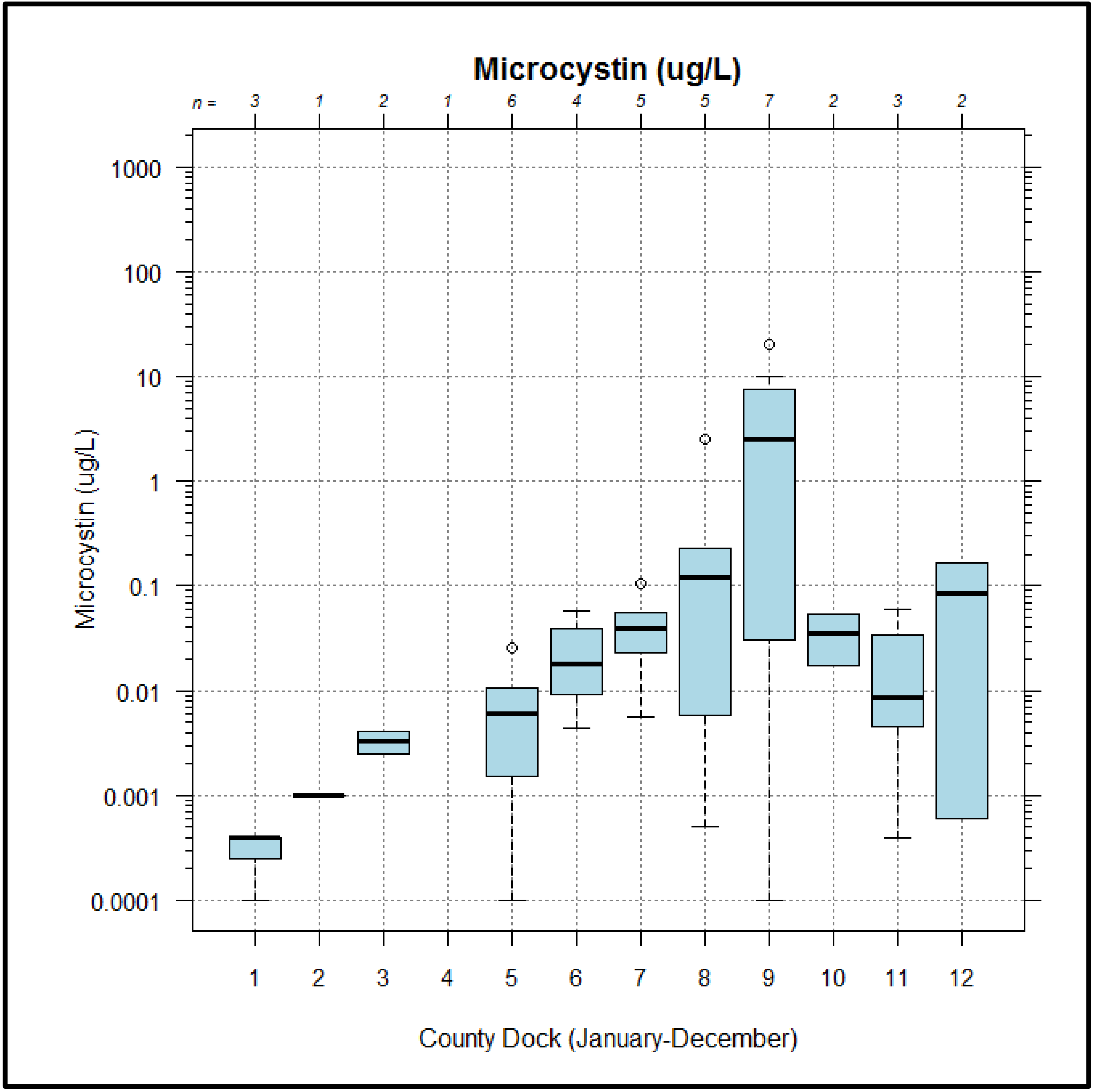


Figure 4-46. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, Disc Hole 14. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December). *Note missing calendar months January-February, and April.*

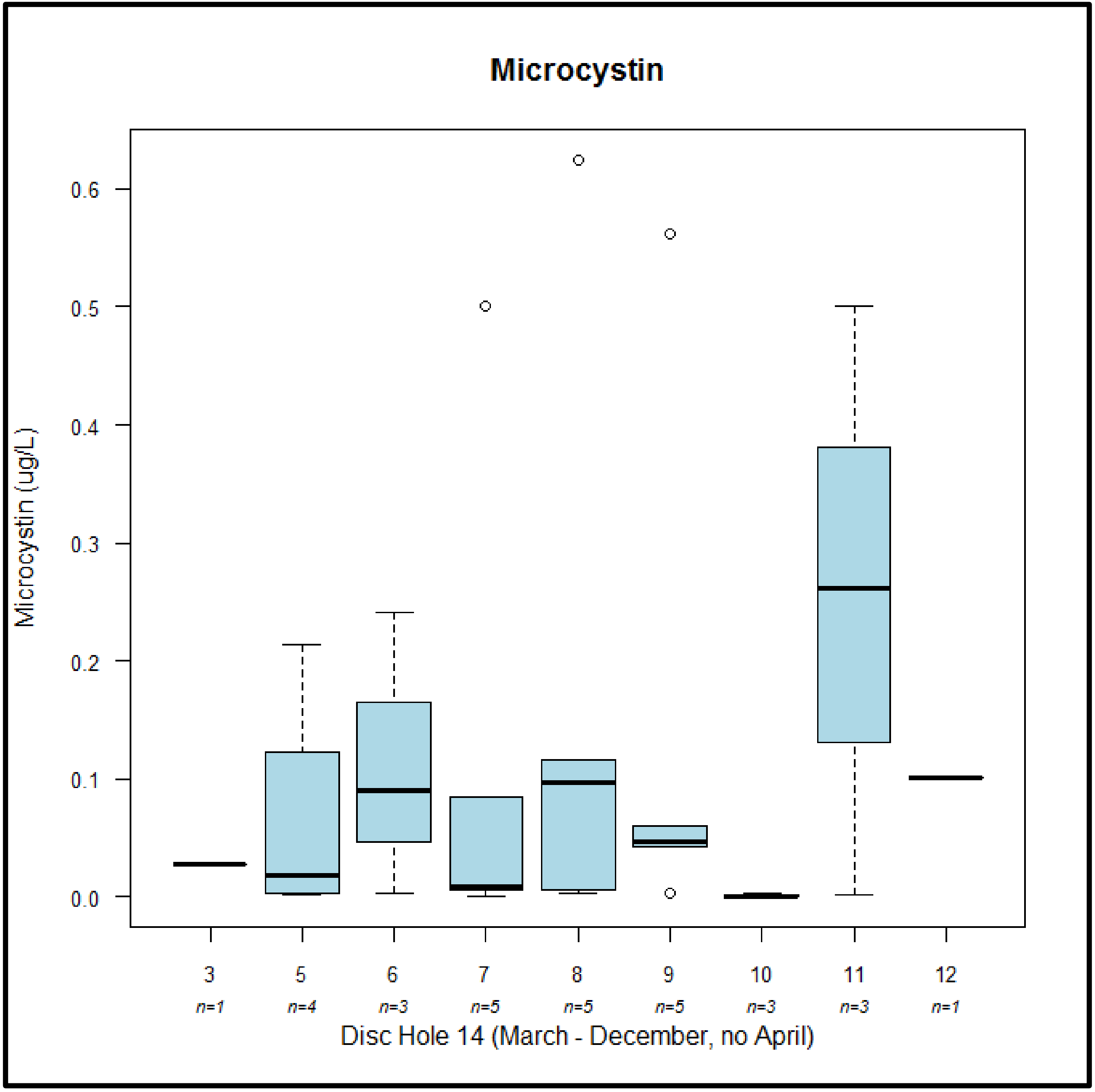


Figure 4-47. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, Eucalyptus Grove. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December). *Note missing calendar months January-March, October-Decemeber.*

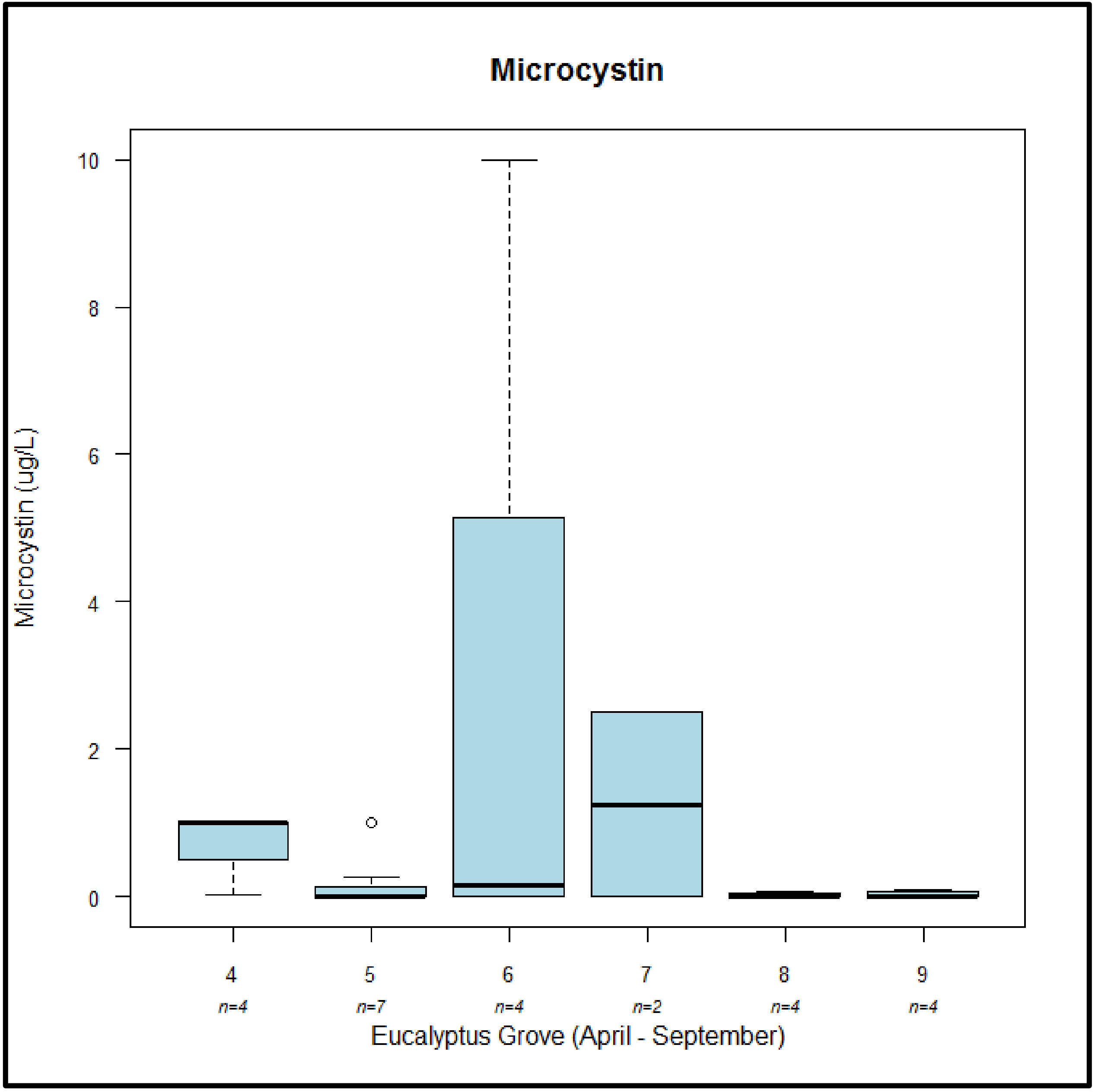


Figure 4-48. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, Haul out area by County Dock. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

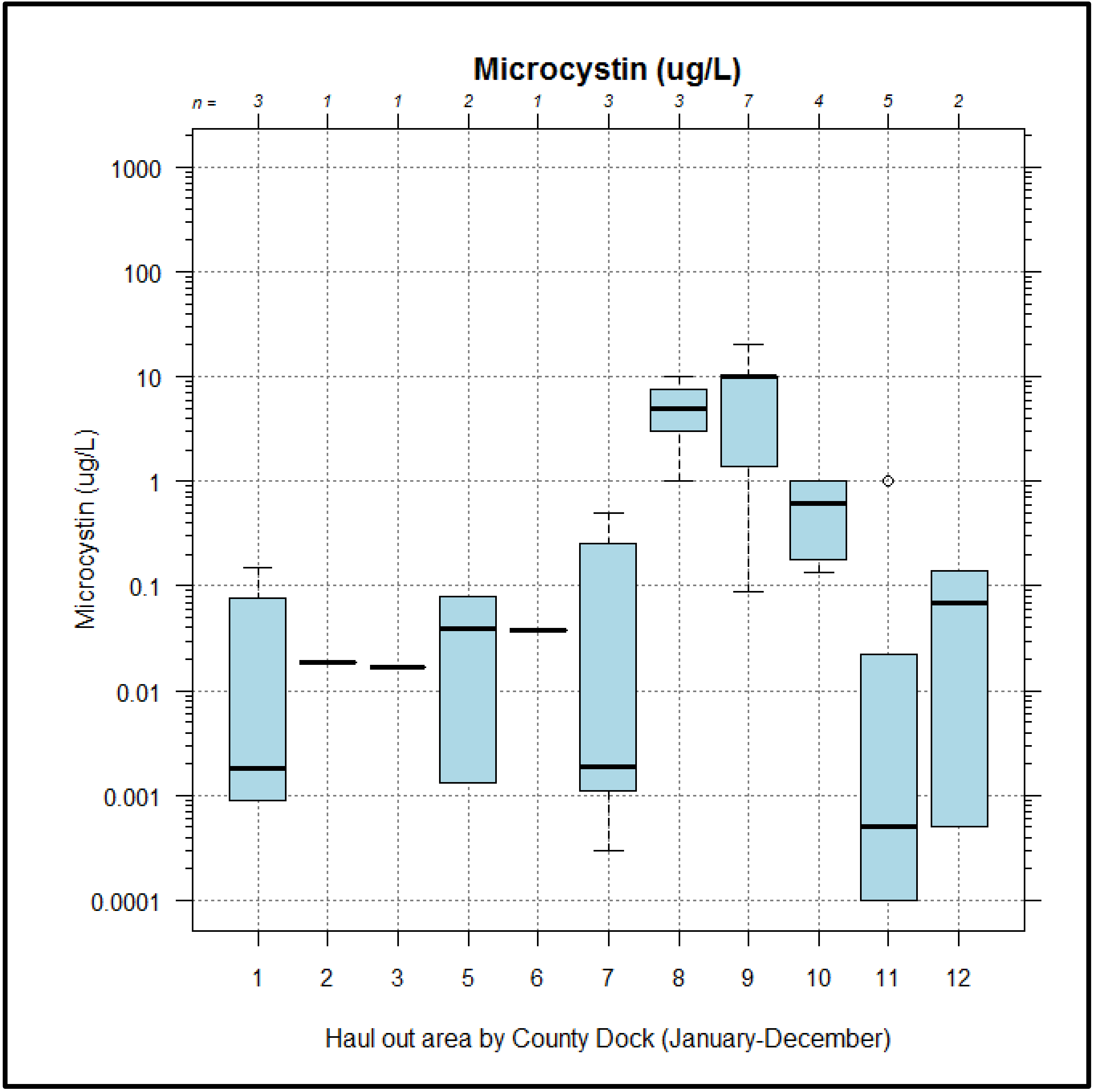


Figure 4-49. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, PintoLakeDock. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).

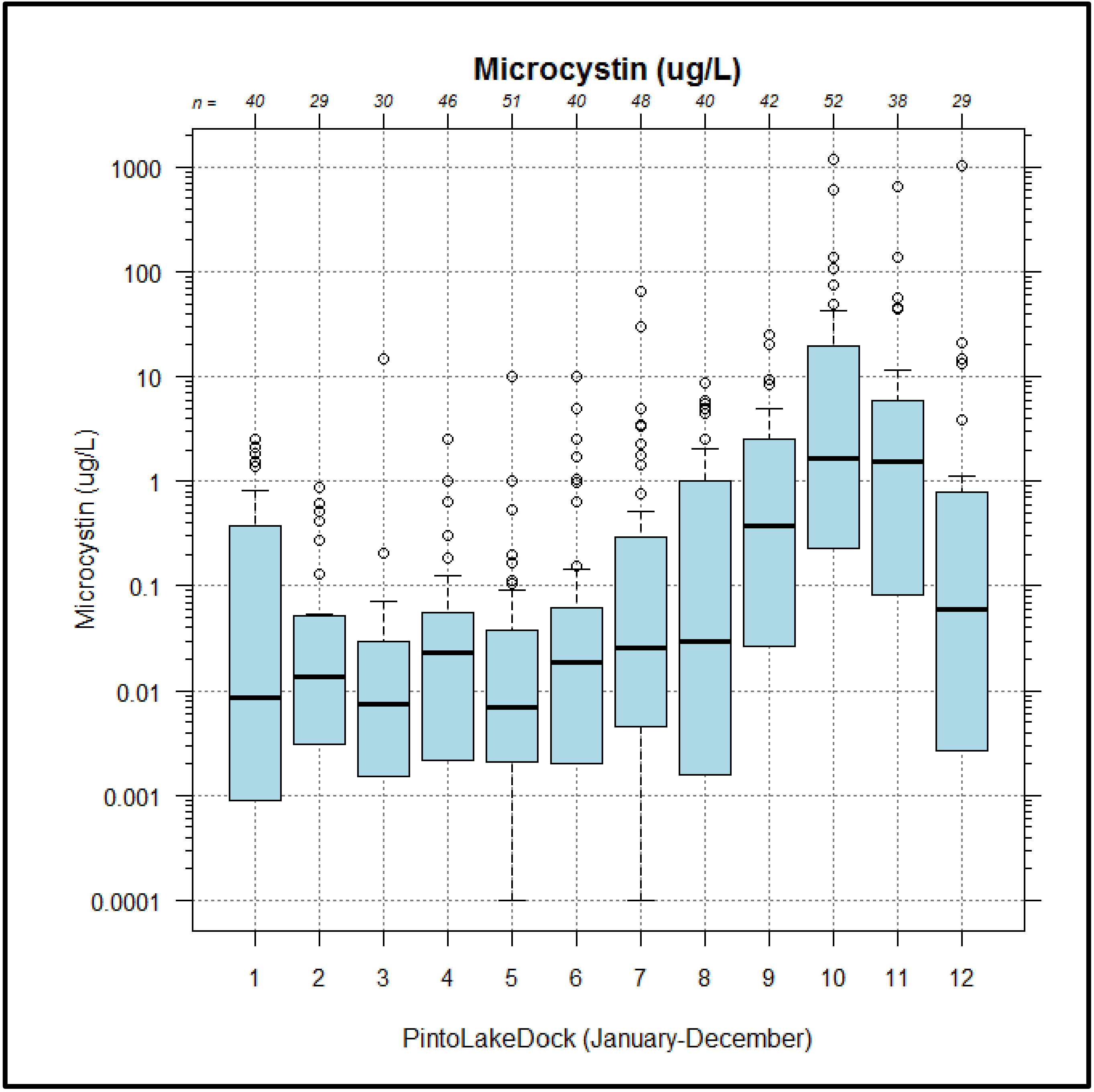
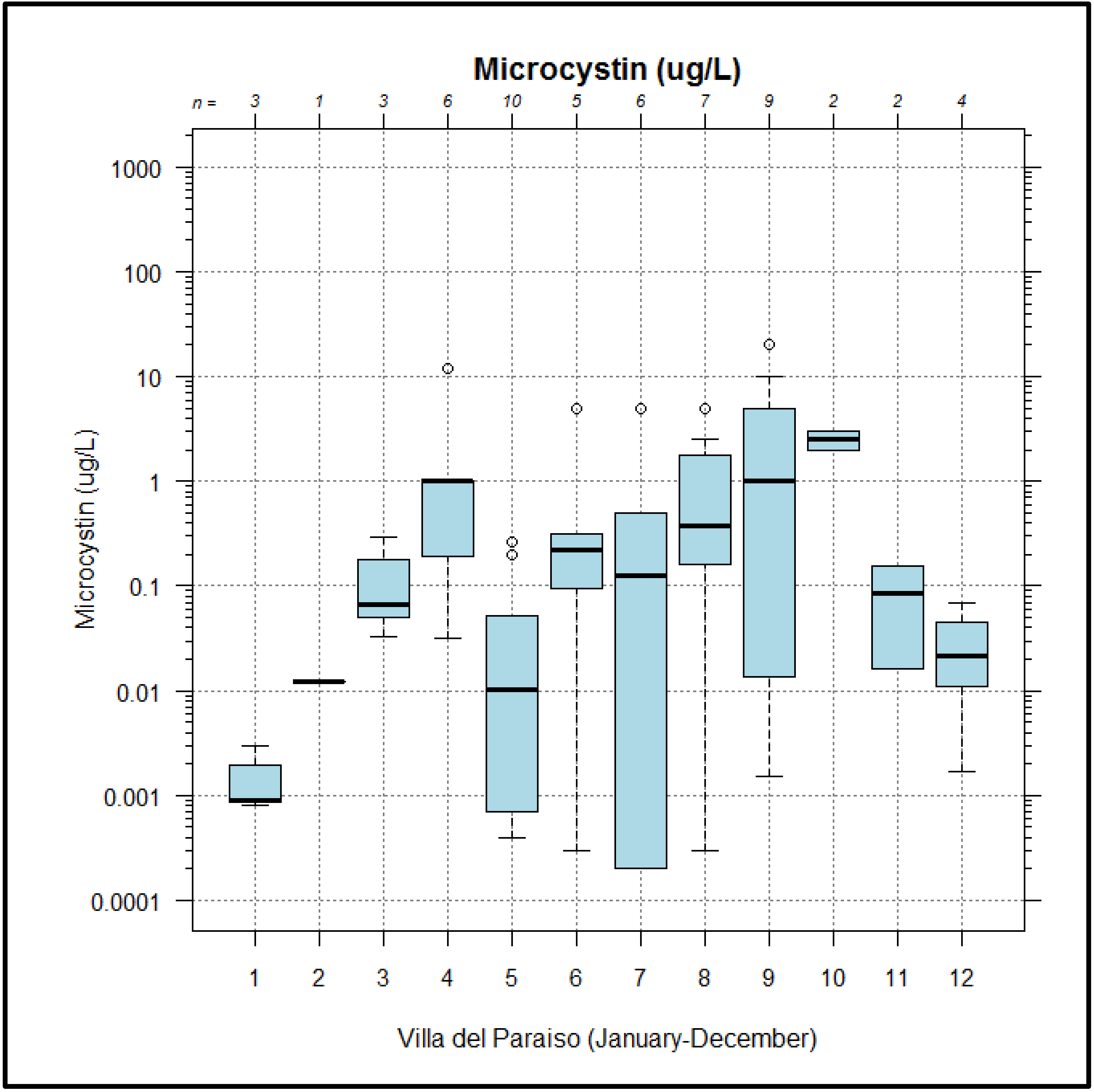


Figure 4-50. Box and whisker plot of microcystin (µg/L) values from Pinto Lake catchment site, Villa del Paraiso. Values plotted per month to show seasonal difference in microcystin values. Numbers on the x-axis correspond to calendar months (e.g., 1 = January, 12 = December).



4.6 Depth Profile Sample Trends

In any given lake, seasonal differences in temperature and the mixing effects of wind can influence lake hydraulics, lake chemistry, and lake water stratification, as previously discussed in Section 2.3. At Pinto Lake, tributary stream flows, air temperature, water temperature, heat transfer, and wind can seasonally affect lake hydraulics, and nutrient concentrations at various lake depths, as further outlined below.

Winter and spring months bring in higher volume flows from the surrounding tributaries due to increased rainfall and runoff within the watershed. Data collected between 2009-2011 (Stanfield, 2013) show that lake surface water in winter months is typically cool with an average temperature of less than 14°C and the water column tends to be well-mixed.

In spring and summer months, increased air temperature and solar radiation raise surface water temperatures significantly, averaging around 22°C. During these months, deeper waters near the lake bottom remain much cooler, generally around 13°C. This difference in water temperatures during summer months creates a seasonal thermocline[77], causing the lake to be stratified into two distinct thermal layers (the upper, warmer epilimnion, and the lower, colder, hypolimnion). A graphic illustration of this natural process was previously shown in Figure 2-6 on page 25. This stratification reduces the amount of mixing of the deeper nutrient-rich waters below the thermocline.

Eventually the seasonal thermocline disappears as the lake warms up in the autumn, which leads again to the mixing of the two layers. This mixing results in additional nutrients being distributed throughout the entire water column (Ketley et al., 2013, CSUMB and Resource Conservation District of Santa Cruz County, 2013). Figure 4-21 illustrates depth profile nutrient concentration trends resulting from seasonal and temperature effects on the lake waters.

Figure 4-22 and Figure 4-23 illustrate depth stratified sampling data over an annual period near the central part of Pinto Lake (monitoring site Pinto Lake buoy 2 – sampling locations were previously shown in Figure 4-1 on page 116). These data highlight that seasonal and thermal dynamics can result in chemical stratification of lake waters, with a phosphorus enriched bottom water layer in the summer and early fall, with mixing of the water layers in the fall and winter.

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[77] A thermocline is a transition layer between warmer water at a lake surface, and the cooler deep water below.

Figure 4-21. Figure from CSUMB and Resource Conservation District of Santa Cruz County, 2013. (A) Graph of summer nutrient concentrations, and graph of temperature (red line), and dissolved oxgen (blue line) illustrating thermal stratification of lake waters and nutrient-enrichment of deep waters (hypolimnion). (B) Graph of winter nutrient concentrations, and graph of temperature (red line), and dissolved oxgen (blue line) in Pinto Lake, illustrating a well mixed system.

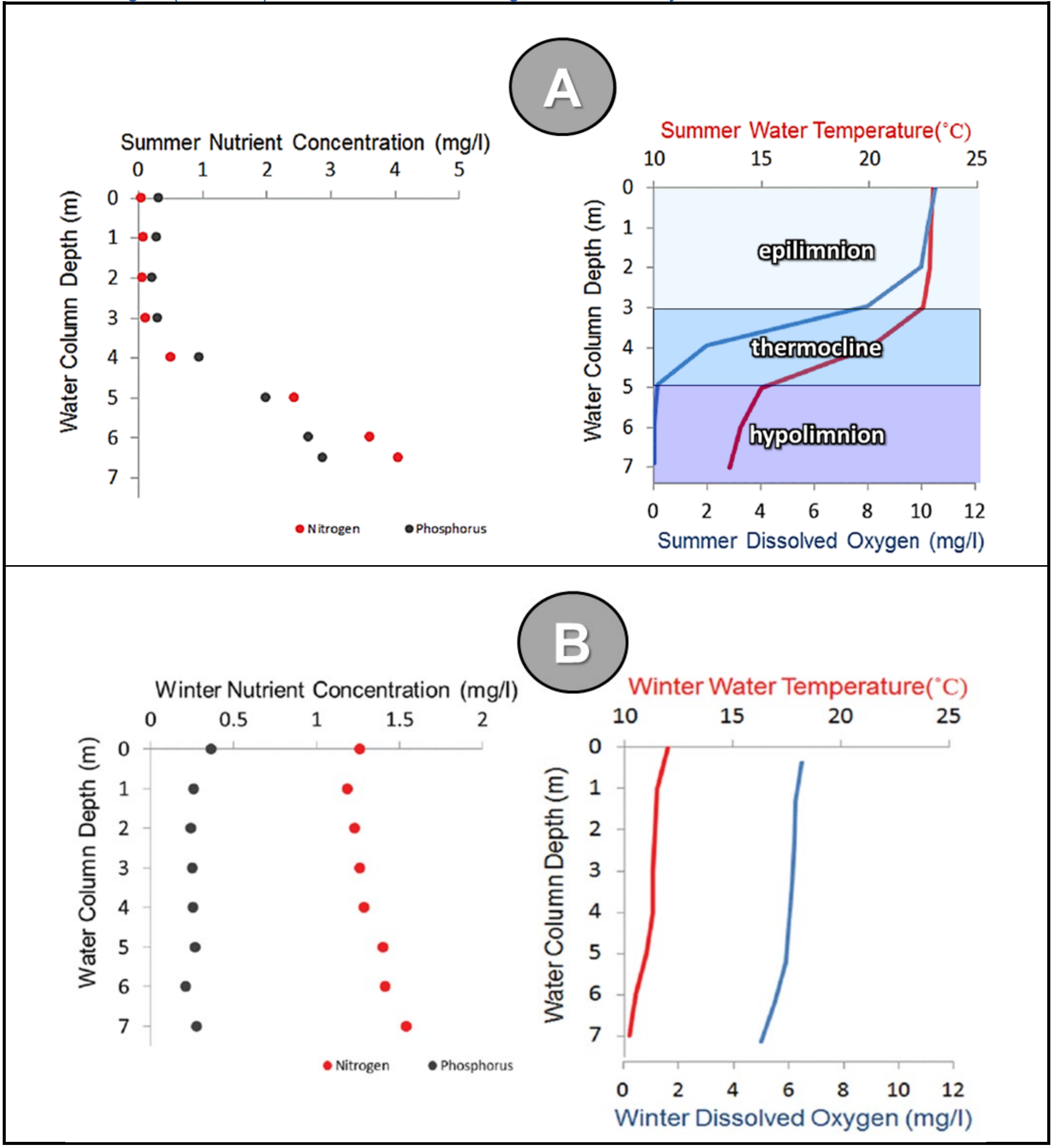


Figure 4-22. Stratified depth sampling graph showing phosphorus water quality at different depth intervals near the central area of Pinto Lake (monitoring site PintoLakeBuoy2). The data dispersion show how seasonal and thermal changes cause a chemical stratification in water quality, resulting in phosphorus-enriched lake bottom waters during the summer and early fall months.

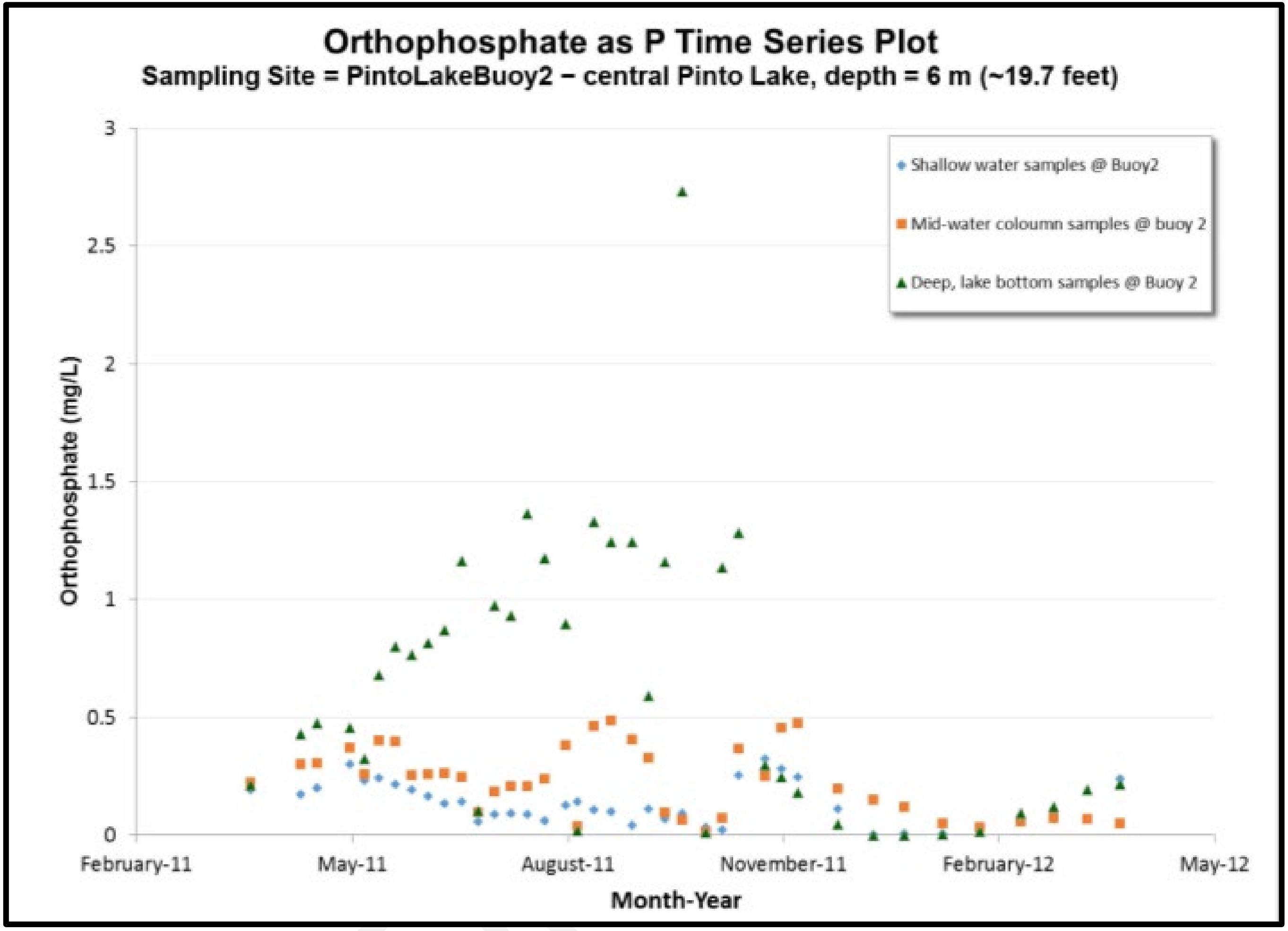
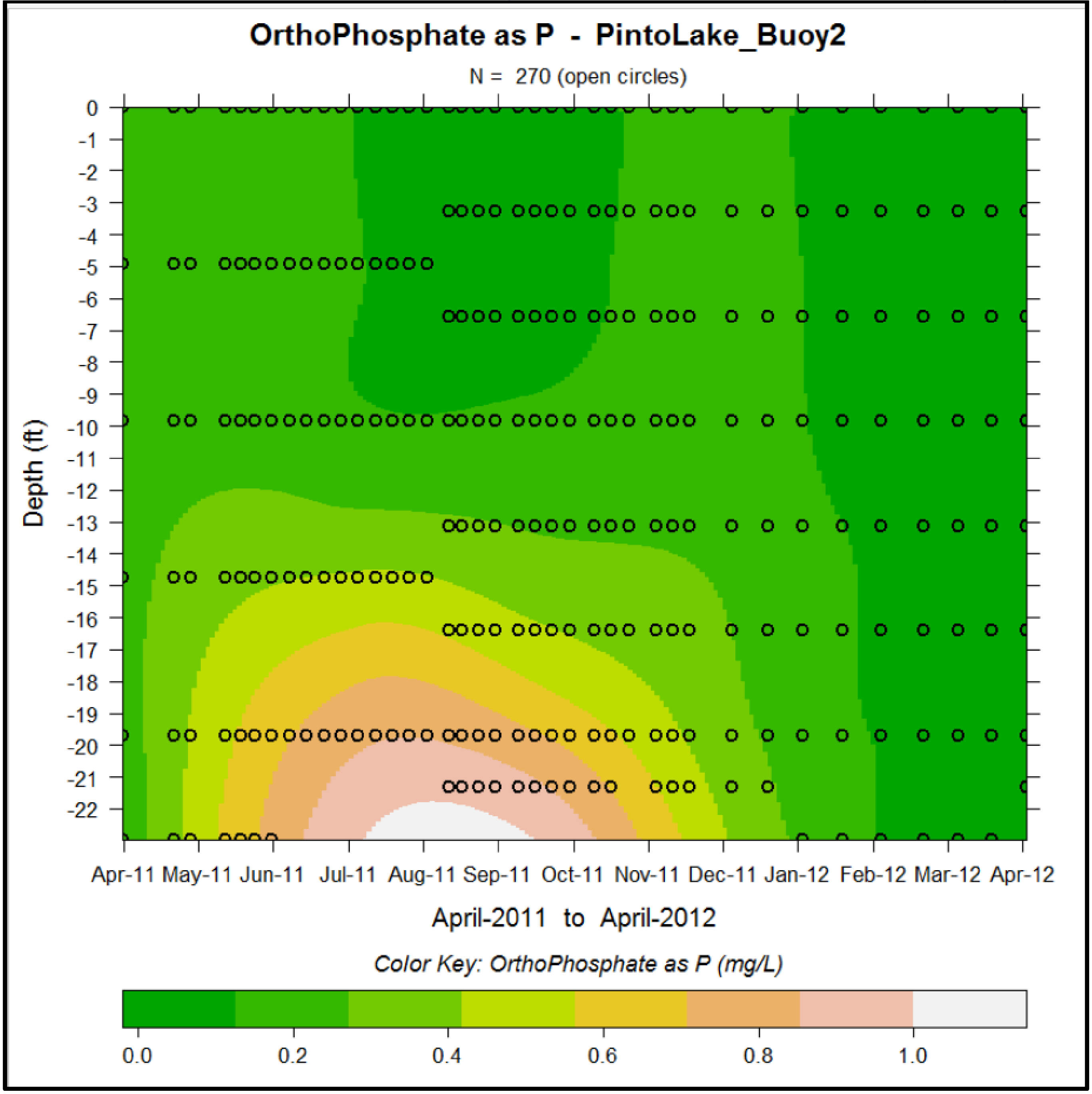


Figure 4-23. A contour plot illustrating three variables at the Pinto Lake buoy2 sampling site: 1) time (x-axis), 2) lake depth (y-axis), and 3) concentration of orthophosphate (color contour gradients). The open circles represent individual, discrete depth-based sampling events; concentration gradients are interpolated between the sampling events. The contour plot thus simultaneously displays how phosphorus water quality varies through time (April 2011-April 2012) and at different depths in the central portion of Pinto Lake. Noteworthy is the period of time (late spring through late summer) when the thermocline results in chemical stratification and phosphorus-enriched deep bottom waters. In the fall and winter, the thermocline breaks down allowing lake waters to become more chemically homogenized.



4.7 Chlorophyll *a*:Total Phosphorus Ratio

Chorophyll-*a*:Total Phosphorus (Chl:TP) ratios are a good proxy for nutrient enrichment in lakes. The expression of algal biomass, relative to phosphorus concentrations can be gauged by looking at the

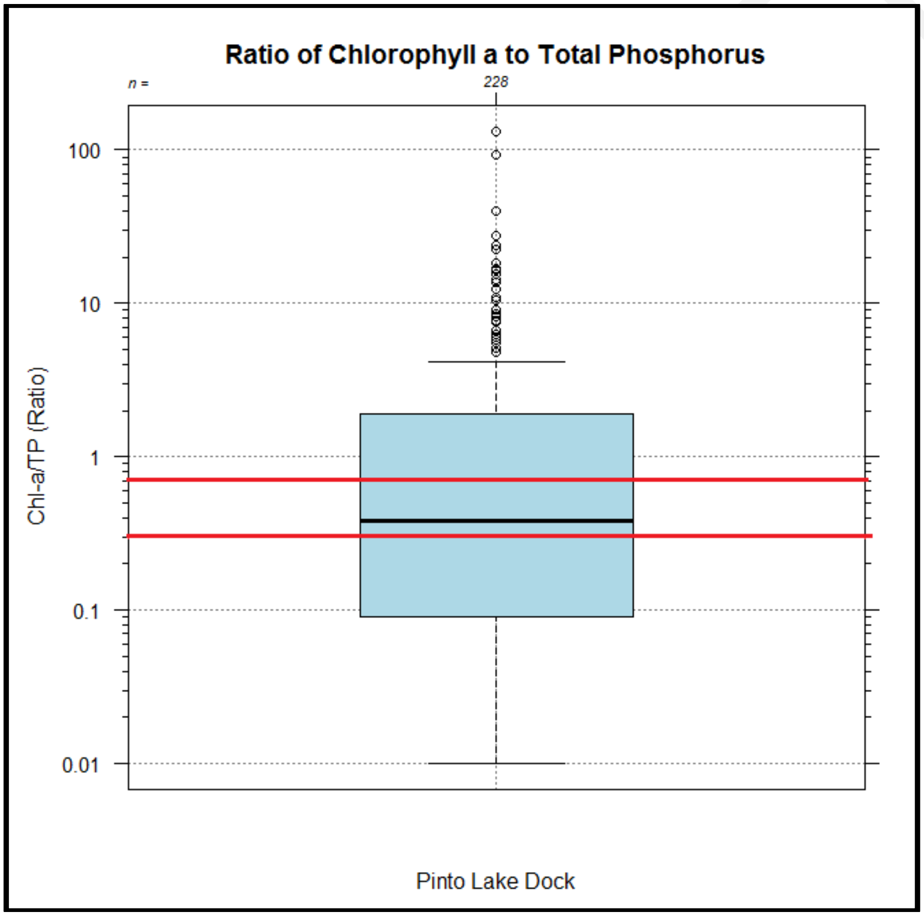
Chl:TP ratios[78]. Worldwide averages of Chl:TP are reported to be around 0.3. These values ranges from 0.3 to 1.0 and can be as high as 1.5. If the Chl:TP ratio is > 1.5, this may indicate eutrophic conditions[79]. These ratios should be considered informal, non-regulatory screening values since considerable variation in Chl:TP ratios undoubtedly exist based on ecoregional or local conditions (see Figure 4-25).

Table 4-17 and Figure 4-24 illustrate Pinto Lake waters (at sampling site “PintoLakeDock”) frequently exceeds the worldwide average Chl:TP ratio of 0.3 (56% of the time). The median value at the Pinto Lake dock is 0.4 and twenty-eight percent of samples exceed a Chl:TP ratio of 1.7 at PintoLakeDock.

Table 4-17. Statistics of chlorophyll *a* to total phosphorus (Chl:TP) ratios in Pinto Lake.

Monitoring Site Tag	**Associated Waterbody**	**No. of Samples**	**Temporal Representation**	**mean**	**min**	**25%**	**Median**	**75%**	**90%**	**Max**	**Number of samples**
PintoLakeDock	Pinto Lake	228	4/18/2010-4/26/2015	3.2	0.0	0.1	0.4	1.9	132.5	132.5	228

Figure 4-24. Boxplot showing values of chlorophyll *a* to total phosphorus (Chl:TP) ratios in Pinto Lake at the sampling station PintoLakeDock. Note that the lowest red line indicates a value of 0.3, which is the worldwide average value of chlorophyll *a*- to total phosphorus (Chl:TP) ratios, while the second red line indates a value of 0.7, which are much higher than normal and would be expected to represent eutrophic conditions.



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[78] Chlorophyll maxima and chlorophyll: total phosphorus ratios in Missouri reservoirs, PowerPoint presentation. The Missouri Department of Natural Resources. https://dnr.mo.gov/env/wpp/cwforum/docs/presentation-Chloropohl-Max.pdf

[79] Source: Ohio Environmental Protection Agency and Tetra Tech webinar entitled *“Understanding Nutrient Issues Affecting, Ohio Lakes”*, November 2016. Webinar sponsored by the U.S. Environmental Protection Agency’s Watershed Academy.

Table 4-18. Littoral chlorophyll *a* to total phosphorus (Chl:TP) ratios in select lakes from USEPA nutrient Ecoregion level 1[80], sublevel 11 (Mediterranean California). Worldwide average Chl:TP is reported to be around 0.33, Chl:TP ratios greater than 0.7 are much higher than normal and would be expected to represent eutrophic conditions. For a location map of the sampled sites, refer to Figure 4-26.

SITE_ID	**GNIS lake name**	**Sampling Date**	**TP-Total phosphorus (mcg/L)**	**Chlorophyll *a*, littoral [A](mcg/L)**	**Chlorophyll *a* :TP ratio**
NLA12_CA-101	Nicasio Reservoir	7/9/2012	25.30	14.00	0.55
NLA12_CA-101	Nicasio Reservoir	9/24/2012	36.00	14.00	0.39
NLA12_CA-102	Lake Henshaw	8/28/2012	23.90	99.00	4.14
NLA12_CA-105	Lake Greenhaven	7/11/2012	688.00	12.00	0.02
NLA12_CA-108	Kerckhoff Lake	8/8/2012	4.80	9.00	1.88
NLA12_CA-112	Lake Mildred	7/25/2012	7.50	3.40	0.45
NLA12_CA-119	New Melones Lake	8/7/2012	4.10	8.00	1.95
NLA12_CA-121	Lake Success	6/19/2012	12.30	2.80	0.23
NLA12_CA-141	*Name not given*	8/22/2012	33.70	21.00	0.62
NLA12_CA-143	*Name not given*	5/2/2012	26.80	2.70	0.10
NLA12_CA-145	Los Alamitos Percolation Ponds	7/30/2012	33.60	17.00	0.51
NLA12_CA-157	*Name not given*	6/18/2012	4.10	3.40	0.83
NLA12_CA-168	*Name not given*	5/21/2012	434.00	111.00	0.26
NLA12_CA-172	*Name not given*	5/23/2012	14.80	0.80	0.05
NLA12_CA-174	*Name not given*	6/11/2012	77.70	6.70	0.09
NLA12_CA-180	Folsom Lake	7/10/2012	4.10	3.40	0.83
NLA12_CA-181	*Name not given*	8/29/2012	39.70	6.00	0.15
NLA12_CA-188	Upper San Leandro Reservoir	8/6/2012	25.60	13.00	0.51
NLA12_CA-190	*Name not given*	7/16/2012	123.00	33.00	0.27
NLA12_CA-206	*Name not given*	8/20/2012	5.60	1.60	0.29
NLA12_CA-R01	Alpine Lake	7/20/2012	31.00	0.64	0.02
NLA12_CA-R03	Lake McClure	7/22/2012	16.00	5.04	0.32

Statistical summary for **Chlorophyll *a* :TP ratio**:
mean value = 0.66,
median value = 0.36

[A] The littoral zone refers to lake water near the shoreline.
Water quality data source: U.S. Environmental Protection Agency, National Lakes Assessment (2012).

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[80] USEPA, NA_Eco_Level1, May 1, 2010. http://www.epa.gov/wed/pages/ecoregions.htm

Figure 4-25. Boxplot showing values of chlorophyll *a* to total phosphorus (Chl:TP) ratios in Pinto Lake at the sampling station PintoLakeDock and a grouping of values from the Ecoregion Xeric West. See Figure 4-27 for a map of the Xeric West.

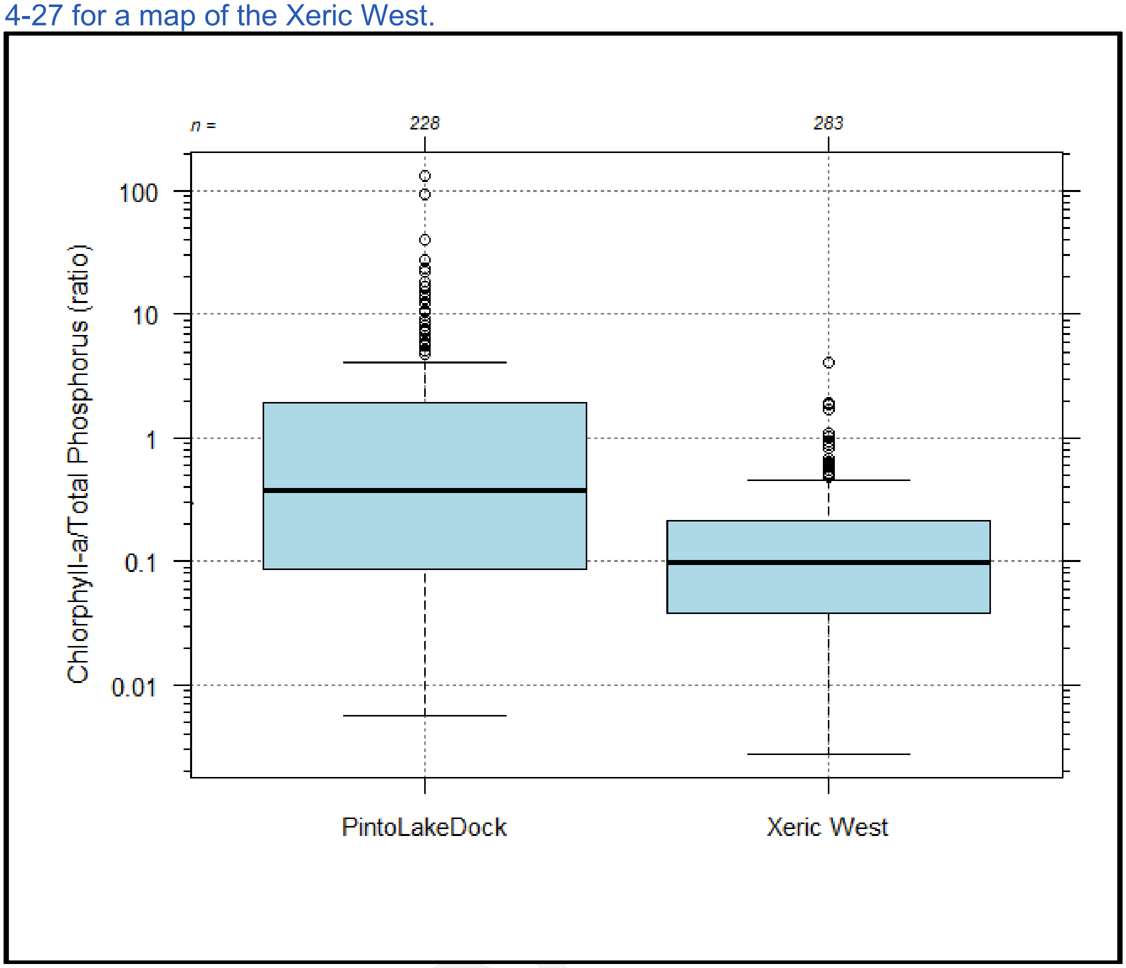


Figure 4-26. Map of USEPA nutrient Ecoregion level 1, sublevel 11 (Mediterranean California) and lakes sampled by the National Aquatic Resources Survey in 2012.

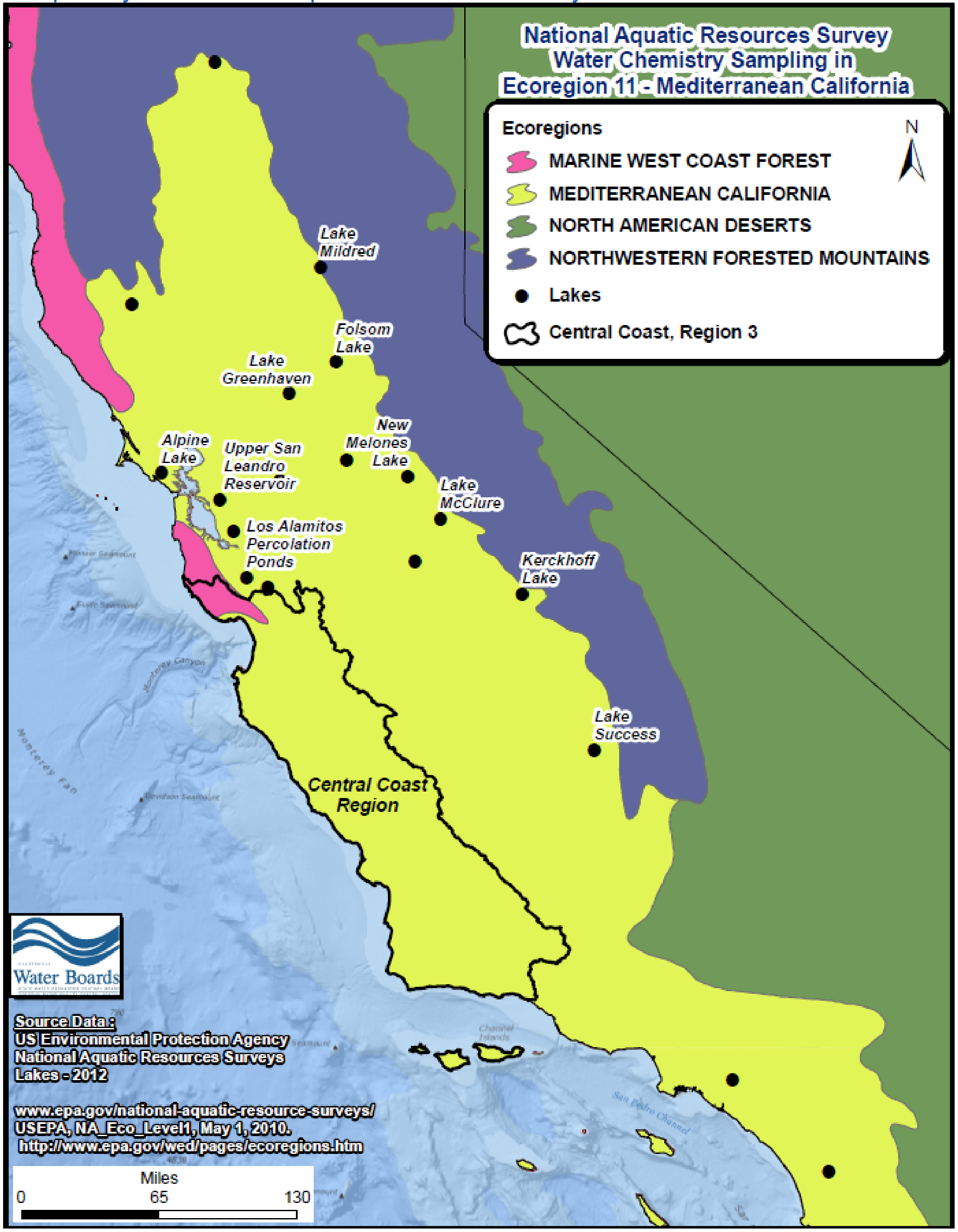
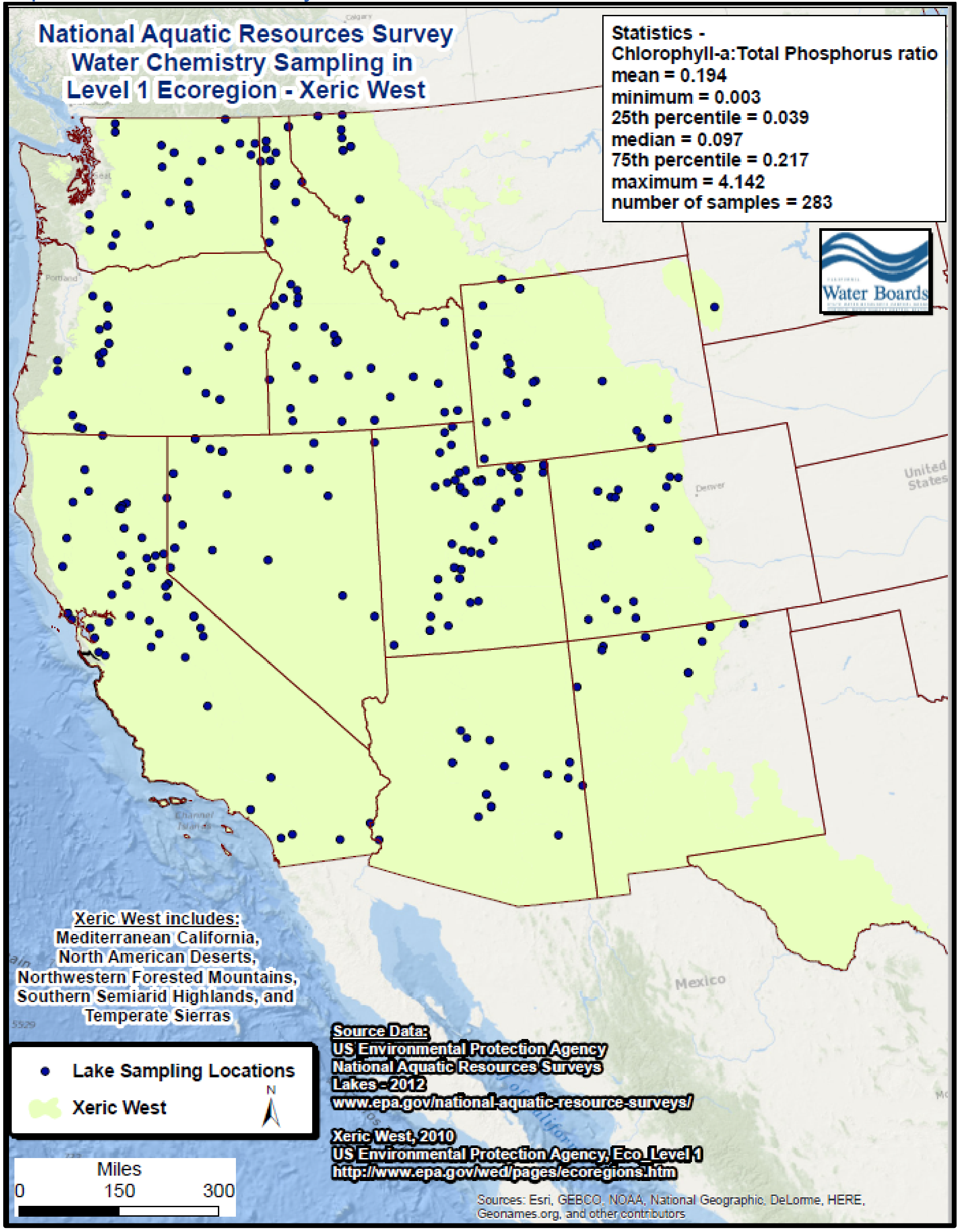


Figure 4-27. Map of USEPA Nutrient Ecoregion level 1, (Xeric West) and lakes sampled by the National Aquatic Resources Survey in 2012.



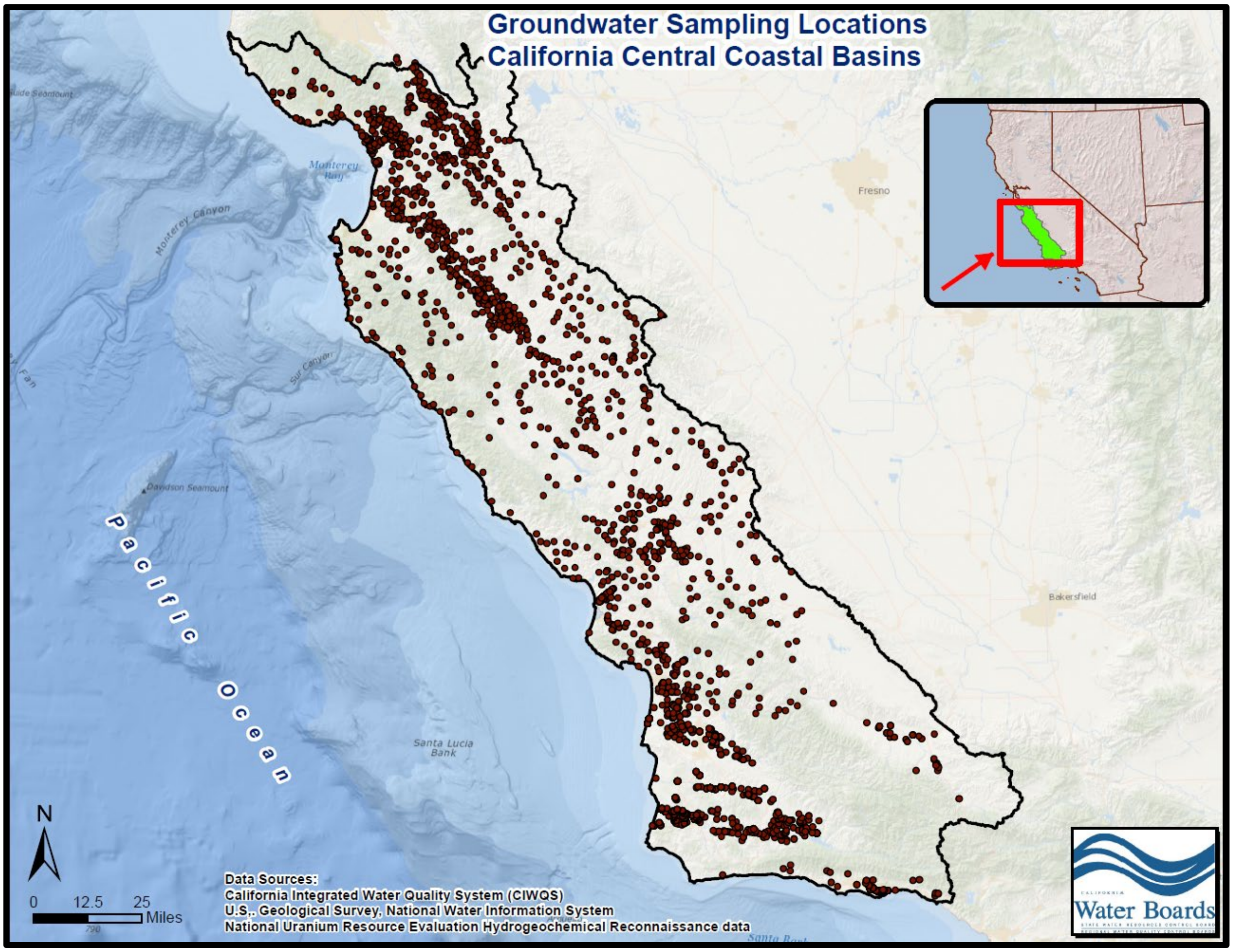
4.8 Groundwater Quality Data Summary

> *"There is a growing awareness that long-term over-application of manure and chemical fertilizer contributes to phosphorus movement into the groundwater system, resulting in a significant groundwater source of phosphorus to streams and lakes, as well as potential contamination of the groundwater resources."*
>
> ➔ U.S. Geological Survey, National Water Quality Assessment Program, Fact Sheet 2012-3004.

The intent of this section of the report is to present numerical summaries of shallow groundwater quality data compiled for this TMDL project. This report does not attempt to assess water quality impairments in accordance with federal Clean Water Act section 303(d) and the California Listing Policy. Thus at this time, data and statistical summaries presented herein are for informational purposes only.

Groundwater data was compiled on a regional basis, to allow comparison of regional groundwater data to groundwater data in the Pajaro Valley groundwater basin and with shallow groundwater located hydraulically upgradient of Pinto Lake (refer back to Figure 2-31 on page 61 for a summary of groundwater elevation and estimated shallow groundwater flow directions). Figure 4-28 illustrates the location of groundwater sampling sites in[81] the California central coast region used in data compilation for this report. Figure 4-29 illustrates a higher-resolution map view of groundwater sampling sites in the Pajaro Valley groundwater basin (Santa Cruz County) and in the vicinity of Pinto Lake.

Figure 4-28. Regional map view of sampling sites in California central coastal basins used for statistical summaries of nutrient water quality in groundwaters. Statistical summaries are presented in Table 4-19 and Table 4-20.



Data Sources:
California Integrated Water Quality System (CIWQS)
U.S. Geological Survey, National Water Information System
National Uranium Resource Evaluation Hydrogeochemical Reconnaissance data

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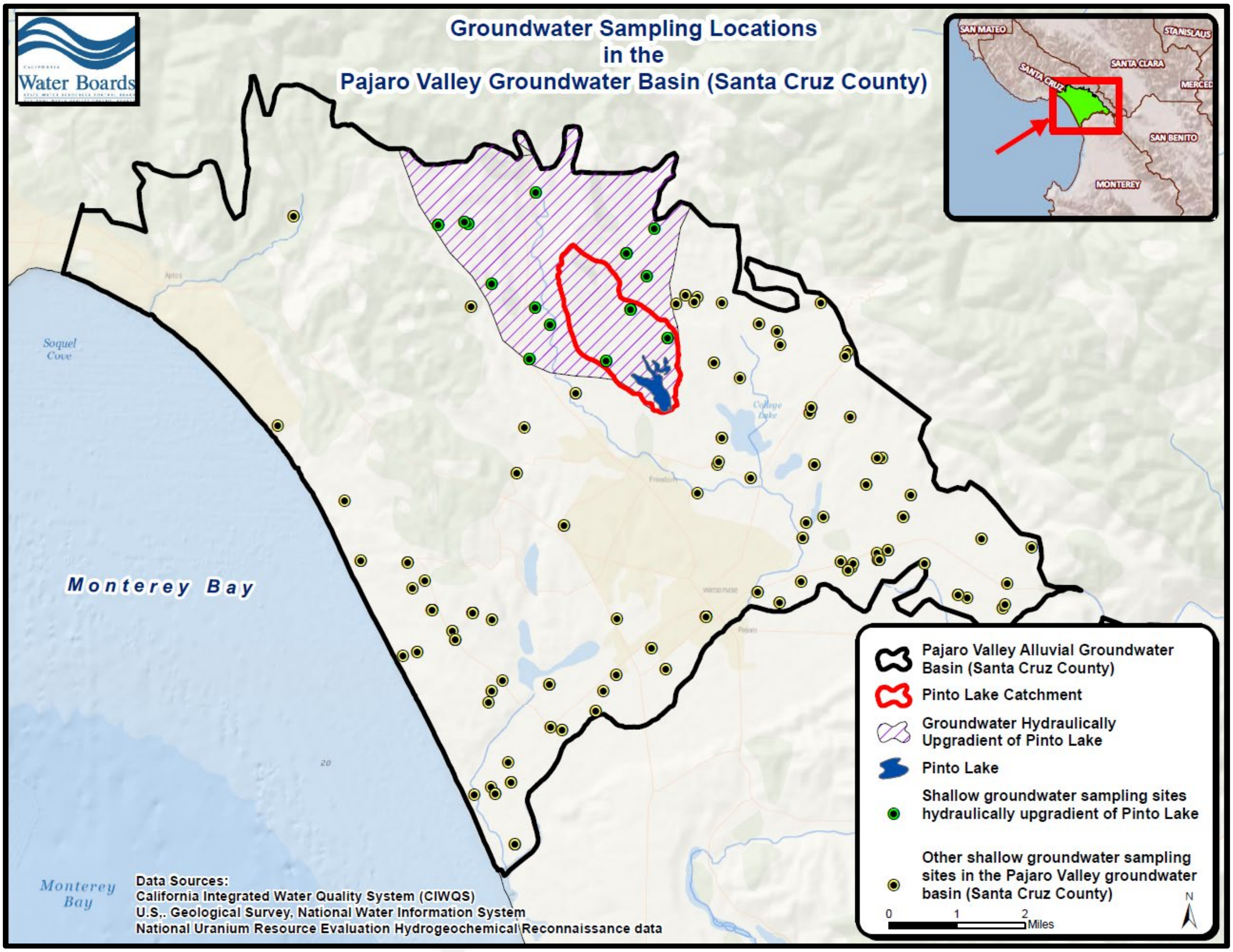
[81] Refer back to footnote 67 on page 40 [*****revise footnote reference] for a description of our attempt to isolate data representative of shallow, recently recharged groundwater.

Figure 4-29. Higher resolution map view of sampling sites in the Pajaro Valley groundwater basin used for statistical summaries of nutrient water quality in groundwaters. Statistical summaries are presented in Table 4-19 and Table 4-20.



Data Sources:
California Integrated Water Quality System (CIWQS)
U.S,. Geological Survey, National Water Information System
National Uranium Resource Evaluation Hydrogeochemical Reconnaissance data

Statistical summaries of regional groundwater bodies, groundwater in the Pajaro Valley groundwater basin, and groundwater upgradient of Pinto Lake, which is thus presumed to flow towards and into the lake, are presented in Table 4-19 and Table 4-20.

Table 4-19. Summary statistics for available groundwater nitrate data (reporting units= nitrate as N, mg/L) and exceedances of California drinking water standard at three different scales: 1) in groundwater bodies of the central coast region; 2) in the Pajaro Valley groundwater basin; 3) and in shallow groundwater hydraulically upgradient of Pinto Lake.

Groundwater Body (or Bodies)	No. of Samples	Temporal Representation		Arithmetic Mean	Min	10%	25%	50% (median)	75%	90%	Max	No. of Samples Exceeding 10 mg/L (MUN Standard)	% of Samples Exceeding 10 mg/L
Shallow groundwaters in California Central Coastal Basin aquifers (refer back to Figure 4-28)	1,586	Aug. 2012	Aug. 2015	12	0.002	0.1	0.4	3.4	13.9	36.0	188	474	30%
Shallow groundwater of the Pajaro Valley Groundwater Basin in Santa Cruz County (refer back to Figure 4-29)	85	June 2013	June 2015	7.43	0.059	0.10	0.20	1.2	9.0	25.5	48.2	19	22%
Shallow groundwater hydraulically upgradient of Pinto Lake (refer back to Figure 4-29)	12	June 2013	July 2014	1.58	0.10	0.38	1.18	1.3	1.75	2.8	4.3	0	0%

Table 4-20. Summary statistics for available groundwater phosphate data (reporting units= phosphate as P, mg/L) and exceedances of a generic lake criteria for phosphorus water quality criteria at three different scales: 1) in groundwater bodies of the central coast region; 2) in the Pajaro Valley groundwater basin; 3) and in shallow groundwater hydraulically upgradient of Pinto Lake. Comparisons to the generic lake criteria for phosphorus are for informational purposes only as this criteria is not a regulatory standard in California.

Groundwater Body (or Bodies)	No. of Samples	Temporal Representation		Arithmetic Mean	Min	10%	25%	50% (median)	75%	90%	Max	No. of Samples Exceeding 0.2 mg/L (generic lake criteria)[1]	% of Samples Exceeding 0.2 mg/L
Shallow groundwaters in California Central Coastal Basin aquifers (refer back to Figure 4-28)	1,976	Sept. 1978	Aug. 2015	0.16	0	0.01	0.023	0.068	0.16	0.33	7.84	366	18%

Groundwater Body (or Bodies)	No. of Samples	Temporal Representation		Arithmetic Mean	Min	10%	25%	50% (median)	75%	90%	Max	No. of Samples Exceeding 0.2 mg/L (generic lake criteria)[1]	% of Samples Exceeding 0.2 mg/L
Shallow groundwater of the Pajaro Valley Groundwater Basin in Santa Cruz County (refer back to Figure 4-29)	152	Aug 1981	Sept. 2005	0.087	0.0001	0.02	0.04	0.07	0.09	0.14	1.2	5	3%
Shallow groundwater hydraulically upgradient of Pinto Lake (refer back to Figure 4-29)	12	Jan. 1980	Aug. 1983	0.059	0.0002	0.0013	0.025	0.05	0.01	0.12	0.16	0	0%

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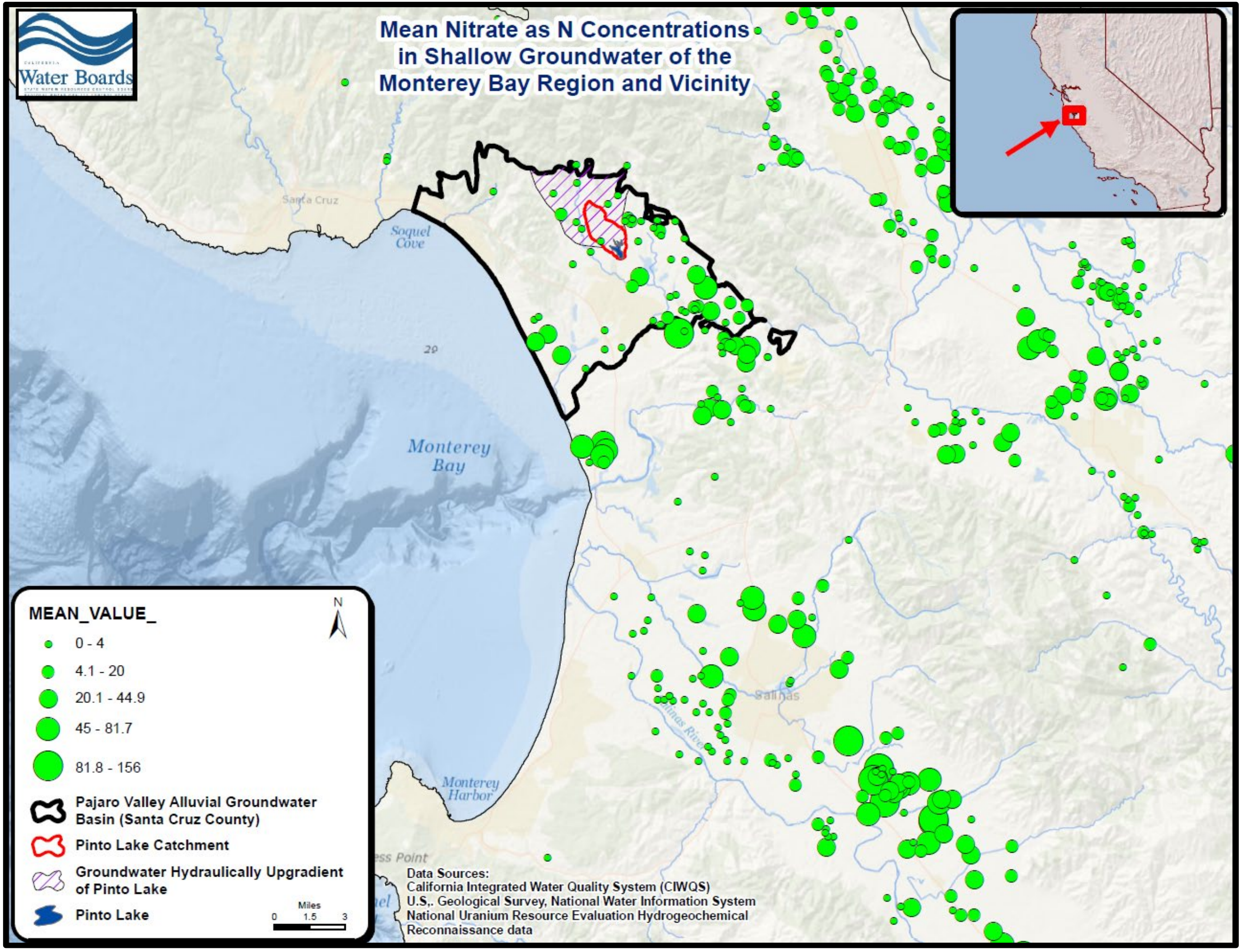
[1] A concentration of 0.2 mg/L phosphate represents the 75% percentile of all phosphate lake water quality criteria reported by states to the U.S. Environmental Protection Agency. As of July 2015, there were 19 different lake phosphate water quality criteria reported for lakes in various states. The 75th percentile is a statistical threshold which represents that 75% of all reported lake criteria values were *lower* than 0.2 mg/L, and 25% of reported lake criteria were *higher* than 0.2 mg/L. This value is a screening threshold for informational purposes but should not be considered a TMDL numeric target.

Figure 4-30 presents information on the spatial distribution of average (arithmetic mean) nitrate as N concentrations in shallow groundwaters based on available data. Shallow groundwaters located hydraulically upgradient of Pinto Lake on average tend to be relatively low in nitrate as N (generally less than 2 mg/L, refer back to Table 2-16 on page 63).

Figure 4-30. Bubble map illustrating mean nitrate as N concentrations in shallow groundwaters in the Monterey Bay region and vicinity. The data show relatively low mean nitrate concentrations in shallow groundwater hydraulically upgradient of Pinto Lake.



Data Sources:
California Integrated Water Quality System (CIWQS)
U.S,. Geological Survey, National Water Information System
National Uranium Resource Evaluation Hydrogeochemical Reconnaissance data

Figure 4-31 presents information on the spatial distribution of average (arithmetic mean) total phosphate as P concentrations in shallow groundwaters based on available data. Shallow groundwaters located hydraulically upgradient of Pinto Lake on average tend to be relatively low in total phosphate as P (generally less than 0.06 mg/L, refer back to Table 4-20 on page 199).

It is worth noting that, according to Dr. John Holz (lake limnologist, HAB Aquatic Solutions, LLC), lakes generally do not receive significant phosphorus loads from groundwater[82] (personal communication, January 2017). This reporting, along with generally low phosphate concentrations in groundwater upgradient of Pinto Lake appear to suggest that groundwater loads of phosphorus to Pinto Lake are not significant or substantial.

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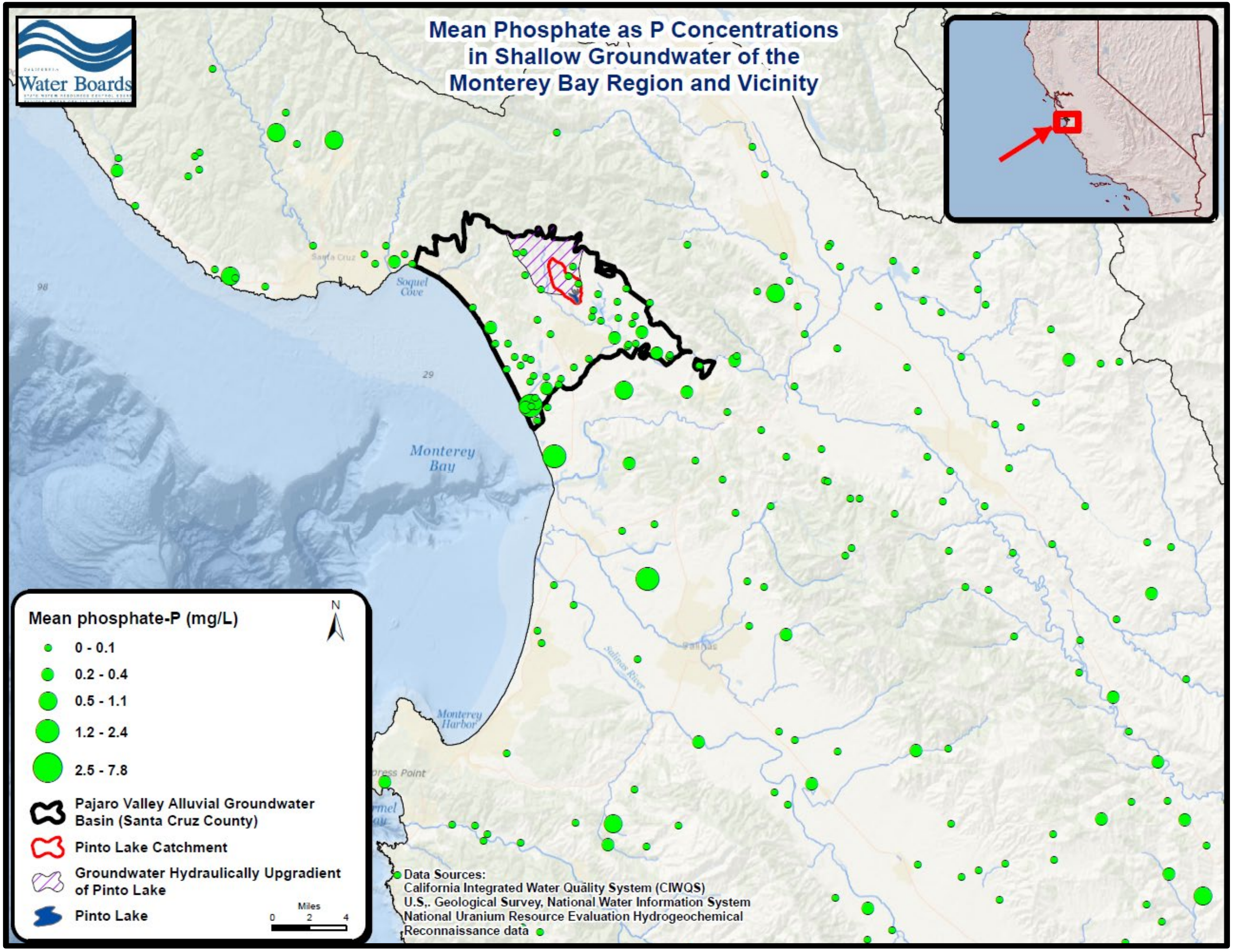
[82] Dr. Holz told us that are some unique cases of substantial groundwater phosphorus loading to lakes in the Midwest, typically due to unique hydrologic conditions associated with “sandpit lakes”.

Figure 4-31. Bubble map illustrating mean phosphate as P concentrations in shallow groundwaters in the Monterey Bay region and vicinity. The data show relatively low mean phosphate concentrations in shallow groundwater hydraulically upgradient of Pinto Lake, which appear to be close to natural, ambient background levels for phosphate.



4.9 Photo Documentation of Cyanobacteria Blooms

City of Watsonville staff have periodically photo-documented cyanobacteria blooms in Pinto Lake. Figure 4-32 presents photographic documentation of cyanobacteria blooms in Pinto Lake. We emphasize that these photos represent conditions that are episodic and are not a constant baseline condition. Cyanobacteria blooms are generally limited to late summer and fall in Pinto Lake.

It is also important to recognize that, in any given lake or reservoir, some cyanobacteria blooms can potentially result from natural conditions. Cyanobacteria are a natural occurring organism that has existed on earth for billions of years. While an overall goal of this TMDL is to significantly reduce excessive and harmful cyanobacteria blooms, some baseline level of biomass, algae, and cyanobacteria are naturally occurring.

Figure 4-32. Photo documentation of cyanobacteria blooms in Pinto Lake (photos submited by City of Watsonville staff).

4.10 Water Quality Standards Attainment Assessment

Table 4-21 presents a status summary of potential impairments of designated beneficial uses of surface waters in the Pajaro River basin. There remains uncertainty about the spatial extent of impairments, as lakes are complex hydrologically and not all areas of the lake have been routinely sampled over longer time periods. However, the Central Coast Water Board protocol is to conservatively and presumptively presume that an identified impairment could impact all reaches of the lake, pending acquisition of further information or data to rule out upstream impairments. The focus of pollution control addressed in this TMDL is phosphorus. Watershed improvement management actions to reduce phosphorus loads will reduce the frequency and toxicity of nuisance cyanobacteria blooms and is are anticipated to address secondary biostimulation problems, such as dissolved oxygen, impairing the lake.

Table 4-21. Tabular summary of water phosphorus and nutrient-related water quality impairments at Pinto Lake.

		Biostimulatory Substances^{A}	Cyanotoxin (microcystin) REC-1, REC-2, AGR 0.8ug/L	Cyanotoxin (microcystin) MUN 0.3ug/L	Unionized ammonia WARM, SPWN 0.025mg/L	Total ammonia MUN 30mg/L	Nitrate as N MUN, GWR^{C} 10mg/L	Nitrate as N AGR 30mg/L	Dissolved oxygen WARM 5.0mg/L	Dissolved oxygen SPWN 7.0mg/L	Median Dissolved oxygen General WQ 85% Saturation
Waterbody	Monitoring Site ID		Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?
Pinto Lake	305PNTO1b	ND	ND	ND	**Yes**	ND	No	No	**Yes**	**Yes**	ND
Pinto Lake	305PNTO1m	ND	ND	ND	**Yes**	ND	No	No	**Yes**	**Yes**	ND
Pinto Lake	305PNTO1s	IS	ND	ND	**Yes**	ND	No	No	IS^{B}	**Yes**	ND
Pinto Lake	305PNTO2b	ND	ND	ND	**Yes**	ND	No	No	**Yes**	**Yes**	ND
Pinto Lake	305PNTO2m	ND	ND	ND	**Yes**	ND	No	No	**Yes**	**Yes**	ND
Pinto Lake	305PNTO2s	IS	ND	ND	**Yes**	ND	No	No	IS	**Yes**	ND
Pinto Lake	305PNTO3b	ND	ND	ND	**Yes**	ND	No	No	**Yes**	**Yes**	ND
Pinto Lake	305PNTO3m	ND	ND	ND	**Yes**	ND	No	No	IS	**Yes**	ND
Pinto Lake	County Dock	IS	**Yes**	**Yes**	**Yes**	ND	No	No	ND	ND	ND
Pinto Lake	Disc Hole # 14	IS	No	**Yes**	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	Eucalyptus Grove	IS	**Yes**	**Yes**	ND	ND	ND	ND	ND	ND	ND
Pinto Lake	Haul out area by County Dock	IS	**Yes**	**Yes**	**Yes**	ND	IS	IS	ND	ND	ND
Pinto Lake	PintoLakeDock	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	**Yes**	**Yes**
Pinto Lake	PintoLake_Buoy1	IS	ND	ND	IS	ND	No	No	ND	ND	ND
Pinto Lake	PintoLake_Buoy1b	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PintoLake_Buoy1m	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PintoLake_Buoy2b	ND	ND	ND	ND	ND	No	No	ND	ND	ND
Pinto Lake	PintoLake_Buoy2m	ND	ND	ND	ND	ND	No	No	ND	ND	ND
Pinto Lake	PintoLake_Buoy2s	ND	ND	ND	ND	ND	No	No	ND	ND	ND
Pinto Lake	PintoLake_Buoy3	ND	ND	ND	ND	ND	No	No	ND	ND	ND
Pinto Lake	PintoLake_Buoy4	IS	ND	ND	IS	ND	No	No	ND	ND	ND

		Biostimulatory Substances[A]	Cyanotoxin (microcystin) REC-1, REC-2, AGR 0.8ug/L	Cyanotoxin (microcystin) MUN 0.3ug/L	Unionized ammonia WARM, SPWN 0.025mg/L	Total ammonia MUN 30mg/L	Nitrate as N MUN, GWR[C] 10mg/L	Nitrate as N AGR 30mg/L	Dissolved oxygen WARM 5.0mg/L	Dissolved oxygen SPWN 7.0mg/L	Median Dissolved oxygen General WQ 85% Saturation
Waterbody	Monitoring Site ID		Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?
Pinto Lake	PintoLake_Buoy4b	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PintoLake_Buoy4m	IS	ND	ND	IS	ND	No	No	ND	ND	ND
Pinto Lake	PL0	ND	ND	ND	ND	ND	No	No	ND	ND	ND
Pinto Lake	PL05	ND	ND	ND	ND	ND	IS	IS	ND	ND	ND
Pinto Lake	PL3	ND	ND	ND	ND	ND	IS	IS	ND	ND	ND
Pinto Lake	PL5	ND	ND	ND	ND	ND	IS	IS	No	No	**Yes**
Pinto Lake	PL55	ND	ND	ND	ND	ND	IS	IS	ND	ND	ND
Pinto Lake	PL6	ND	ND	ND	ND	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS2b	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS2m	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS2s	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS3b	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS3m	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	PLS3s	IS	ND	ND	IS	ND	IS	IS	ND	ND	ND
Pinto Lake	Villa del Paraiso	IS	**Yes**	**Yes**	**Yes**	ND	No	No	ND	ND	ND
Pinto Lake Outflow	Pinto Lake Outflow	ND	ND	ND	IS	ND	IS	IS	ND	ND	ND
Amesti Creek	Amesti Creek	Not assessed	ND	ND	**Yes**	ND	No	No	ND	ND	ND
Amesti Creek	PLAMESTI	Not assessed	ND	ND	**Yes**	ND	IS	IS	ND	ND	ND
CCC Creek	CCC	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
CCC Creek	CCC Creek	Not assessed	ND	ND	**Yes**	ND	**Yes**	No	ND	ND	ND
CCC Creek	PLCCC	Not assessed	ND	ND	**Yes**	ND	IS	IS	ND	ND	ND
Pinto Creek	Pinto Ck	Not assessed	ND	ND	**Yes**	ND	IS	IS	ND	ND	ND

		Biostimulatory Substances[A]	**Cyanotoxin (microcystin) REC-1, REC-2, AGR 0.8ug/L**	**Cyanotoxin (microcystin) MUN 0.3ug/L**	**Unionized ammonia WARM, SPWN 0.025mg/L**	**Total ammonia MUN 30mg/L**	**Nitrate as N MUN, GWR[C] 10mg/L**	**Nitrate as N AGR 30mg/L**	**Dissolved oxygen WARM 5.0mg/L**	**Dissolved oxygen SPWN 7.0mg/L**	**Median Dissolved oxygen General WQ 85% Saturation**
Waterbody	Monitoring Site ID		Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?
Pinto Creek	Pinto Creek – Ruby Ranch Rd.	Not assessed	ND	ND	**Yes**	ND	IS	IS	ND	ND	ND
Unnamed tributary to CCC Creek	Pinto Mobile Homes Creek	Not assessed	ND	ND	**Yes**	ND	IS	IS	ND	ND	ND
Pioneer Creek	Pioneer Creek	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Todos Santos Creek	Todos Santos Creek	Not assessed	ND	ND	**Yes**	ND	No	No	ND	ND	ND
Ditch	AM105	Not assessed	ND	ND	ND	ND	No	No	ND	ND	ND
Ditch	AM1132	Not assessed	ND	ND	ND	ND	No	No	ND	ND	ND
Ditch	AM114	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Ditch	AM115	Not assessed	ND	ND	ND	ND	IS	IS	ND	ND	ND
Ditch	AM117	Not assessed	ND	ND	ND	ND	IS	IS	ND	ND	ND
Ditch	PL85	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Ditch	PPI0100	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Ditch	PPI0150	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Ditch	PPI0580	Not assessed	ND	ND	IS	ND	IS	IS	ND	ND	ND
Total Waterbody/Pollutant Combinations addressed in this TMDL											

[A] “Biostimulatory substances” describes the expression of biostimulation in the form of excess algal cover as brought about by excess nutrients and is represented by the nonattainment of the following objectives: Total Phosphorus exceeding 0.172 mg/L (USEPA ecoregional criteria for California chaparral and oak woodlands), microcystin concentrations exceeding 0.8 µg/L (OEHAA recreational waters advisory level), and chlorophyll a concentrations exceeding 15 µg/L (State of Oregon criteria. If unacceptable exceedance frequencies are observed for **all three parameters** as assessed by the identified Listing Policy guidelines, then the water quality sample is not attaining the Basin Plan biostimulatory substances objective.

[B] There were not enough data to determine whether there were impacts at this water quality monitoring location, so in the absence of sufficient data, we could not assess the status of impairment.

		Biostimulatory Substances[A]	**Cyanotoxin (microcystin) REC-1, REC-2, AGR 0.8ug/L**	**Cyanotoxin (microcystin) MUN 0.3ug/L**	**Unionized ammonia WARM, SPWN 0.025mg/L**	**Total ammonia MUN 30mg/L**	**Nitrate as N MUN, GWR[C] 10mg/L**	**Nitrate as N AGR 30mg/L**	**Dissolved oxygen WARM 5.0mg/L**	**Dissolved oxygen SPWN 7.0mg/L**	**Median Dissolved oxygen General WQ 85% Saturation**
Waterbody	Monitoring Site ID		Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Exceeding Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?	Depressed Below Numeric Threshold or Guideline?

[C] The groundwater recharge (GWR) beneficial use is recognition by the state of the fundamental nature of the hydrologic cycle, and that surface waters and ground water are not closed systems that act independently from each other. Underlying groundwaters are, in effect, receiving waters for lake or stream waters that infiltrate and recharge the subsurface water resource. Most surface waters and groundwaters of the central coast region are both designated with the MUN (drinking water) and AGR (agricultural supply) beneficial uses. Water quality objectives protective of MUN and AGR therefore applies to both the surface waters, and to the underlying groundwater. Thus, numeric water quality objective supporting MUN and AGR designations of groundwater can be relevant to consider in TMDLs where surface waters are designated as a recharge source for the underlying subsurface waters.

4.10.1 Tabular Summaries of All Identified Impacted Waterbodies

Table 4-22 presents a status summary of whether designated beneficial uses of surface waters in the Pinto Lake watershed are being supported.

Table 4-22. Status summary of Pinto Lake watershed designated beneficial uses that could potentially be impacted by nutrient pollution.

Designated Beneficial Use	Water Quality Objective, or recommended level [A]	Beneficial Use Supported?[B]	Impacted waterbody
MUN (drinking water supply)	10 mg/L (nitrate as N)	No	CCC Creek
	0.3 μg/L microcystins[C]	No	Pinto Lake
AGR (irrigation water supply)	30 mg/L (nitrate as N) *(for sensitive crops)*	Yes[D]	None
AGR (livestock watering)	100 mg/L (nitrate as N)	Yes	All assessed stream reaches in the Pinto Lake watershed are supporting the nitrate as N livestock water quality objective based on available data.
GWR (groundwater recharge)	10 mg/L (nitrate as N) in conjunction with situation specific lines of evidence [E]	Yes	None identified.
Aquatic Habitat beneficial uses (WARM, SPWN)	Basin Plan's biostimulatory substances objective expressed as: nitrate as N and total nitrogen as N:	1.1 mg/L to 8.0 mg/L orthophosphate as P: 0.04 mg/L to 0.3 mg/L	TBD[F]
	15 μg/L chlorophyll *a*	No	Pinto Lake, Todos Santos Creek
Aquatic Habitat beneficial uses (WARM, SPWN)	Un-ionized ammonia Basin Plan objective 0.025 mg/L	No	Pinto Lake, Pinto Creek, Amesti Creek, CCC Creek, Todos Santos Creek, unnamed tributary to CCC Creek
REC-1 (water contact recreation)	0.8 μg/L microcystins [G]	No	Pinto Lake
	15 μg/L chlorophyll *a*	No	Pinto Lake, Todos Santos Creek
(WILD) Wildlife habitat	0.9 μg/L microcystins[A]	No	Pinto Lake
	15 μg/L chlorophyll *a*	No	Pinto Lake, Todos Santos Creek

[A] Refer to Table 3-2

[B] Based on exceedance frequencies published in the California 303(d) Listing Policy – see Section 3.4.

[C] US Environmental Protection Agency, Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins (June 2015)

[D] The University of California Agricultural Extension Service guideline values are flexible, and may not necessarily be appropriate due to local or

Designated Beneficial Use	Water Quality Objective, or recommended level [A]	Beneficial Use Supported?[B]	Impacted waterbody

special conditions of crop, soil, and method of irrigation. Staff conservatively selected the uppermost threshold value (30 mg/L) which therefore conservatively identifies stream reaches where the designated AGR use may be detrimentally impacted.

[E] Refer to Section **Error! Reference source not found.** and the California Listing Policy Section 3.11 (State Water Board, 2004)

[F] Biostimulatory impairments include both stream reaches that are expressing a range of biostimulation-eutrophication indicators, and stream reaches that are contributing to downstream biostimulation impairment. Note that States must address downstream pollution impacts to receiving waters in accordance with federal regulations – 40 C.F.R. 131.10(b).

[G] OEHHA public health action level for algal toxins – May 2012. Includes microcystins LA, LR, RR, and YR.

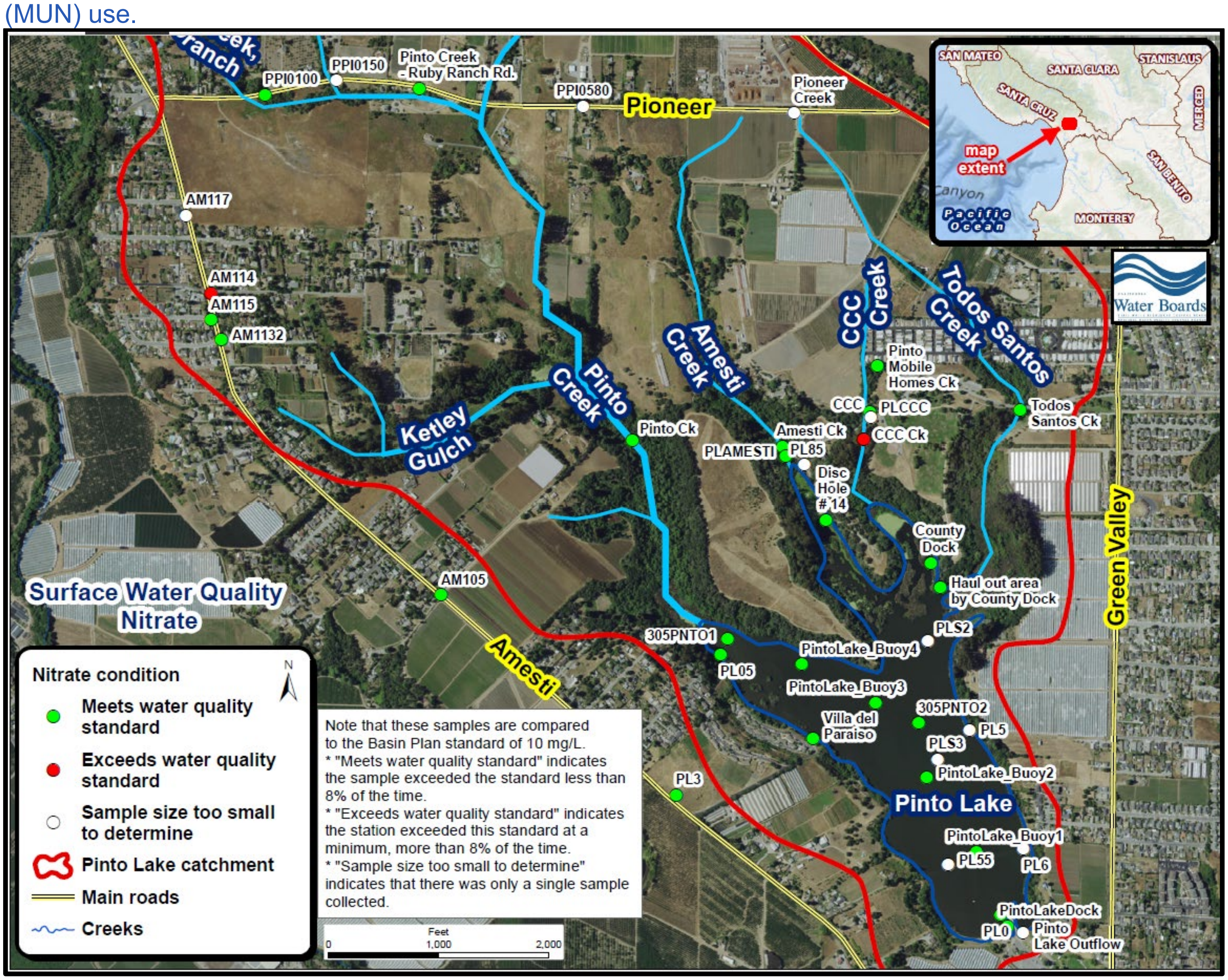
Table 4-23. Tabular summary of waterbodies impacted by nutrient pollution in this TMDL report.

Waterbody Name	Waterbody Identifier	USGS Watershed Cataloging Unit*	Pollutant	Pollutant Category	Listed on the 2014 303(d) List for nutrient-related impairments?	Addressed in this TMDL?
Pinto Lake	CAL3051003020020124122807	18060002 (Pajaro River basin)	Ammonia	Nutrients	List on 303(d) List (TMDL required list)	Yes
			Chlorophyll *a*	Nutrients	List on 303(d) List (TMDL required list)	Yes
			Cyanobacteria hepatotoxic microcystins	Miscellaneous	List on 303(d) List (TMDL required list)	Yes
			Low Dissolved Oxygen	Nutrients	Do Not Delist from the 303(d) List (TMDL required list)	Yes
			Scum/Foam-unnatural	Nuisance	List on 303(d) List (TMDL required list)	Yes
			pH	Miscellaneous	List on 303(d) List (TMDL required list)	Yes
Amesti Creek	Not yet assigned???	18060002 (Pajaro River basin)	Ammonia	Nutrients	Not listed	Yes
CCC Creek	Not yet assigned???	18060002 (Pajaro River basin)	Ammonia	Nutrients	Not listed	Yes
			Nitrate as N (MUN) 10 mg/L	Nutrients	Not listed	Yes
Unnamed tributary to CCC Creek	Not yet assigned???	18060002 (Pajaro River basin)	Ammonia	Nutrients	Not listed	Yes
Pinto Creek	Not yet assigned???	18060002 (Pajaro River basin)	Ammonia	Nutrients	Not listed	Yes
Todos Santos Creek	Not yet assigned???	18060002 (Pajaro River basin)	Ammonia	Nutrients	Not listed	Yes
Total number of waterbody/pollutant combinations addressed in this TMDL (are we including pH?)						12

4.11 Water Quality Standards Attainment Assessment; Maps and Summaries

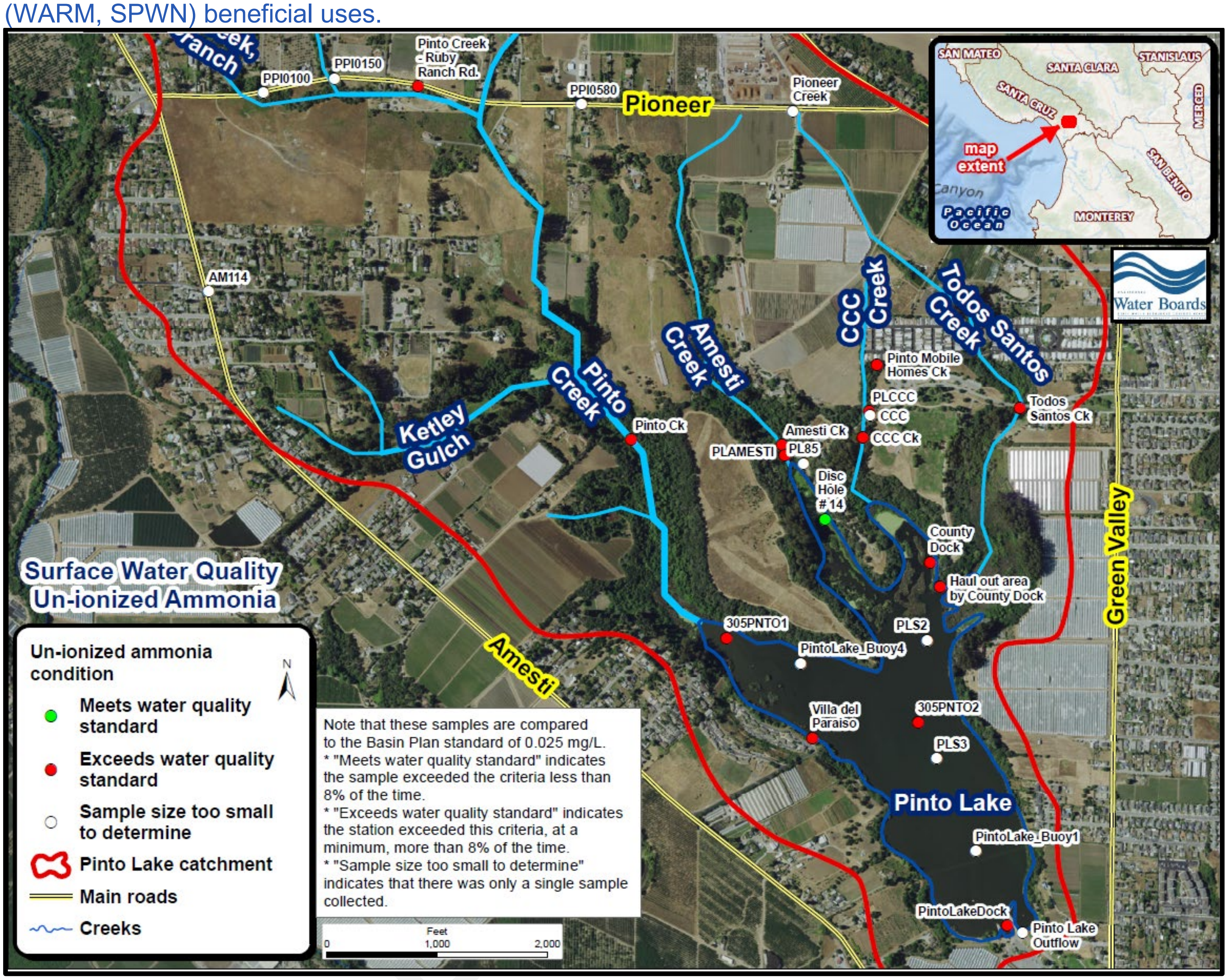
The standards and water quality objectives being used to assess water quality conditions were previously presented in Table 3-2. Summary statistics of water quality parameters and exceedance frequencies as compared to water quality standards were previously presented in Section 4.10. Next, these exceedance frequencies are compared to the guidelines used to determine whether or not these waterbodies are attaining water quality standards or not in accordance with the the California Listing Policy . In addition, the numeric criteria and indicators used to assess the Basin Plan's narrative water quality objective for biostimulatory substances were previously presented in Section 3. On the basis of these data and assessment methodologies, water quality for various constituents is summarized below.

Figure 4-33. Nitrate, as N, water quality standards attainment assessment of the drinking water supply (MUN) use.



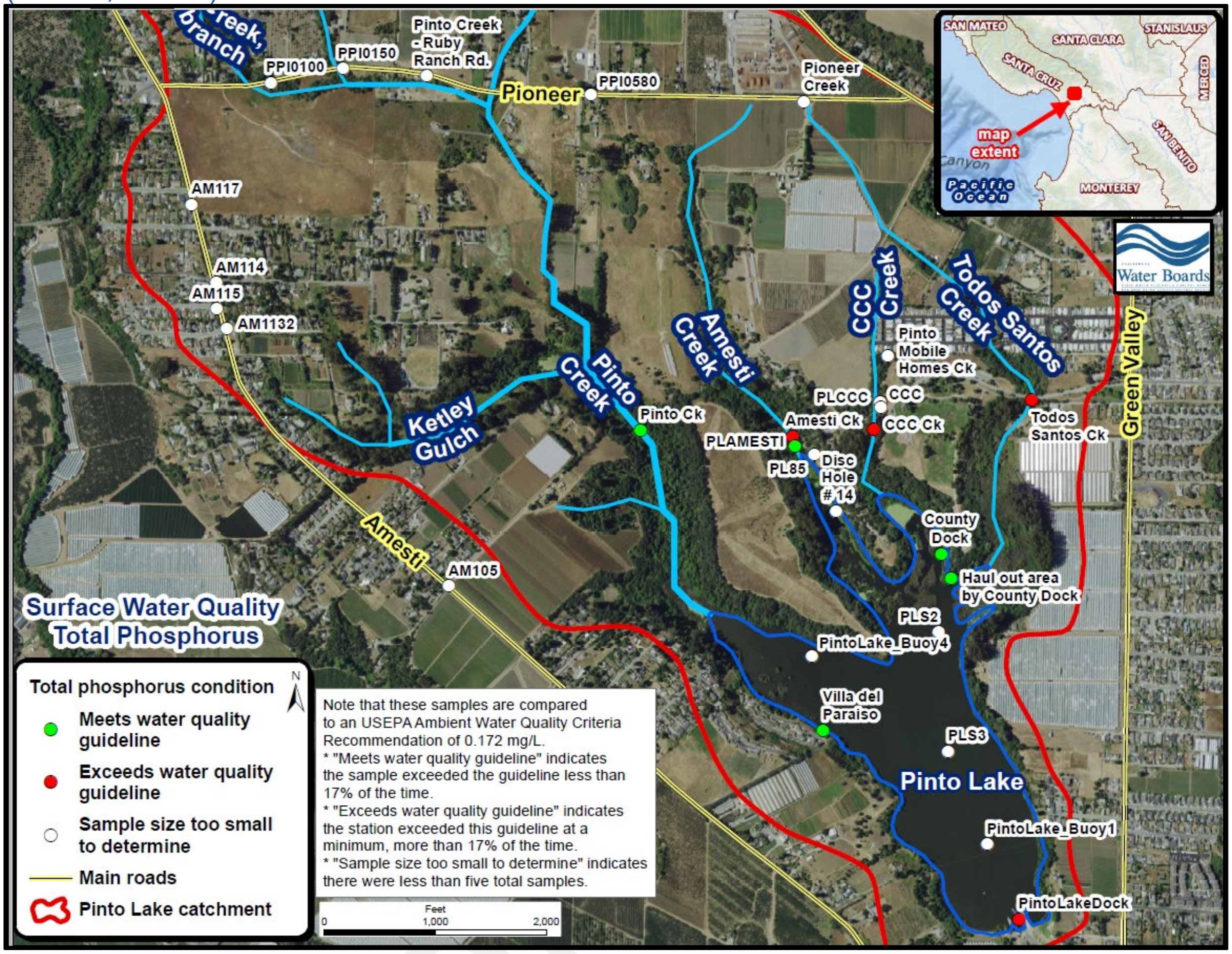
Note that these samples are compared to the Basin Plan standard of 10 mg/L.
* "Meets water quality standard" indicates the sample exceeded the standard less than 8% of the time.
* "Exceeds water quality standard" indicates the station exceeded this standard at a minimum, more than 8% of the time.
* "Sample size too small to determine" indicates that there was only a single sample collected.

Figure 4-34.Un-ionized ammonia, water quality standards attainment assessment of the aquatic habitat (WARM, SPWN) beneficial uses.



Note that these samples are compared to the Basin Plan standard of 0.025 mg/L.
* "Meets water quality standard" indicates the sample exceeded the criteria less than 8% of the time.
* "Exceeds water quality standard" indicates the station exceeded this criteria, at a minimum, more than 8% of the time.
* "Sample size too small to determine" indicates that there was only a single sample collected.

Figure 4-35. Total phosphorus water quality standards attainment assessment of the aquatic habitat (WARM, SPWN) beneficial uses.



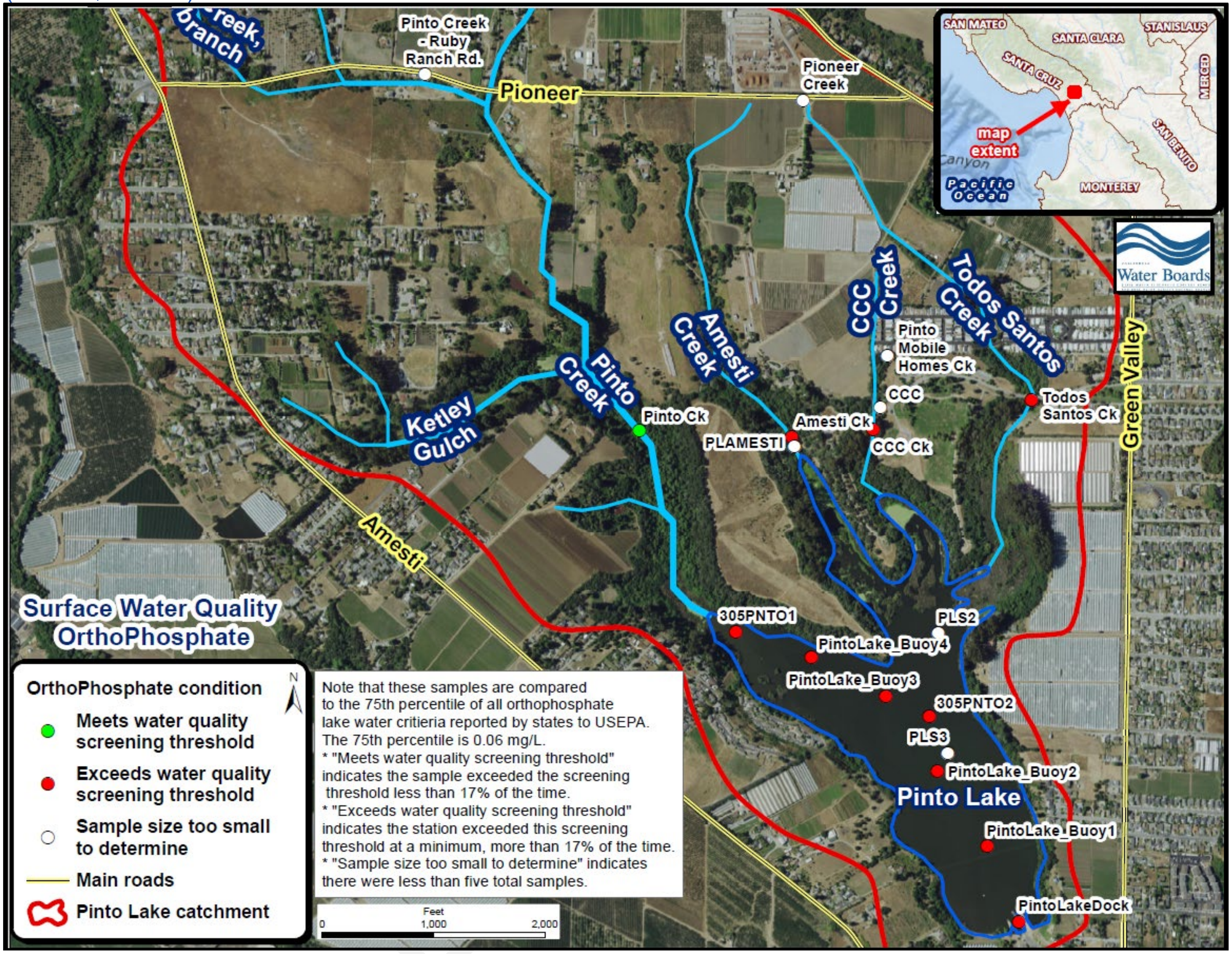
Note that these samples are compared to an USEPA Ambient Water Quality Criteria Recommendation of 0.172 mg/L.

* "Meets water quality guideline" indicates the sample exceeded the guideline less than 17% of the time.

* "Exceeds water quality guideline" indicates the station exceeded this guideline at a minimum, more than 17% of the time.

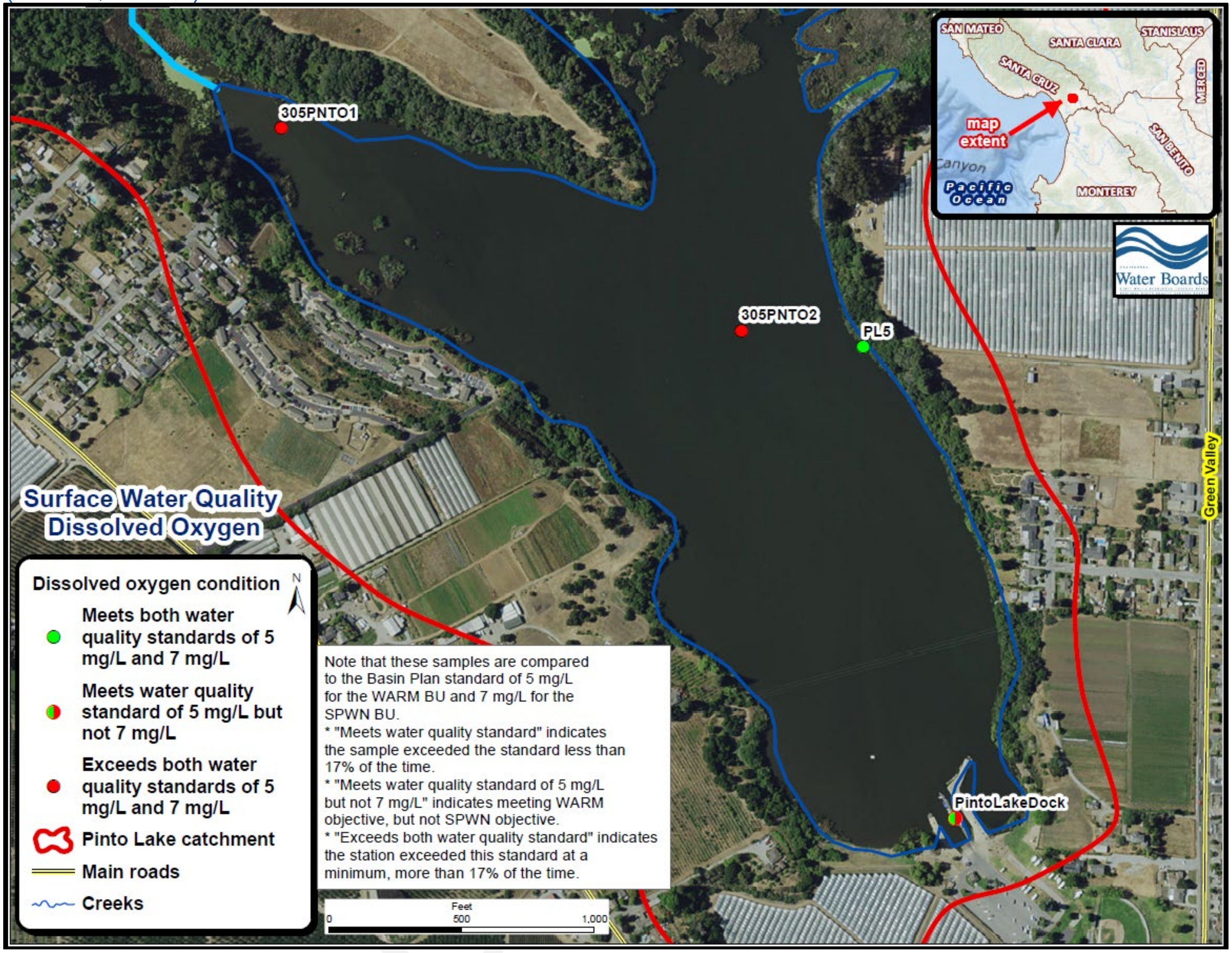
* "Sample size too small to determine" indicates there were less than five total samples.

Figure 4-36. OrthoPhosphate water quality standards attainment assessment of the aquatic habitat (WARM, SPWN) beneficial uses.



Note that these samples are compared to the 75th percentile of all orthophosphate lake water critieria reported by states to USEPA. The 75th percentile is 0.06 mg/L.
* "Meets water quality screening threshold" indicates the sample exceeded the screening threshold less than 17% of the time.
* "Exceeds water quality screening threshold" indicates the station exceeded this screening threshold at a minimum, more than 17% of the time.
* "Sample size too small to determine" indicates there were less than five total samples.

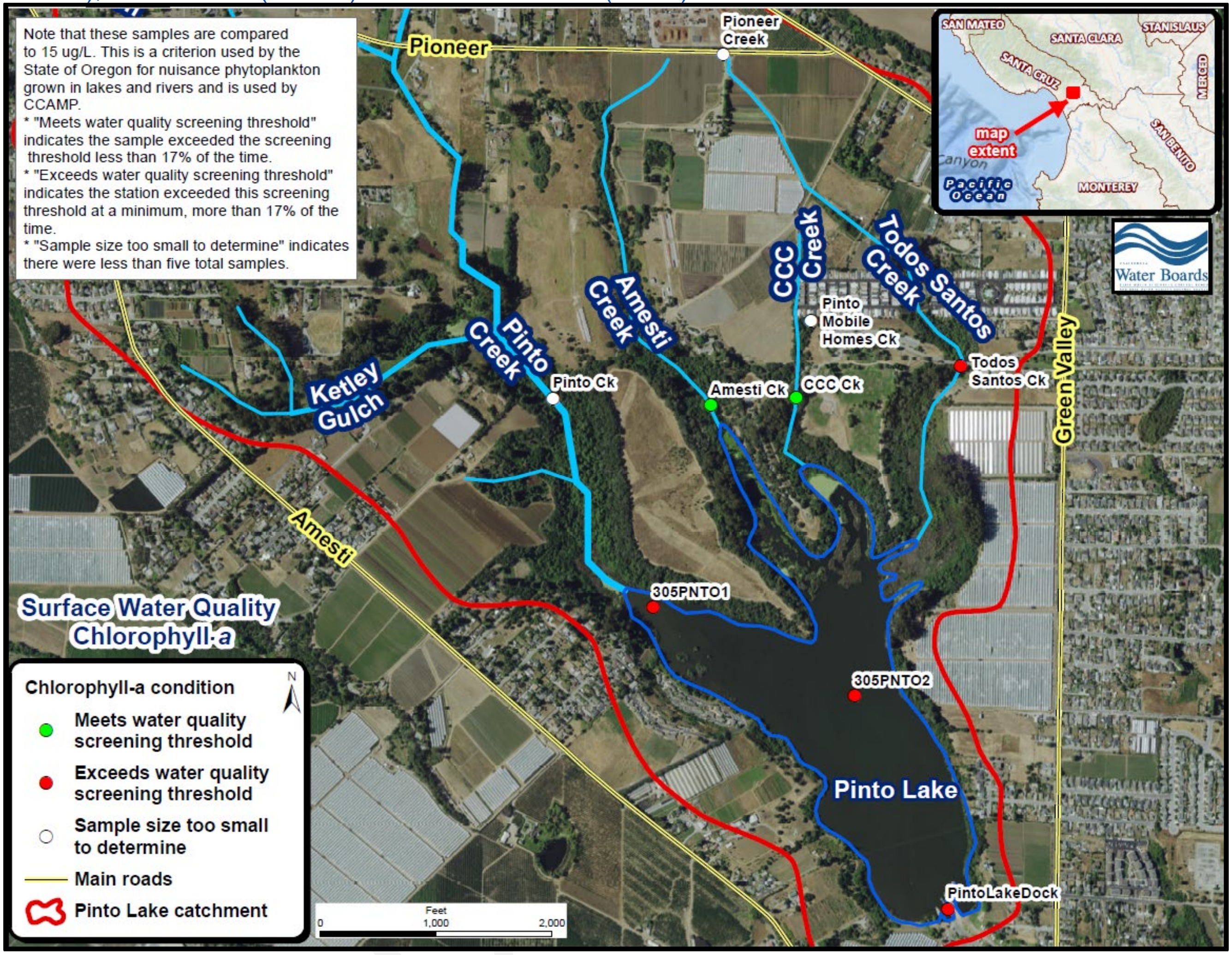
Figure 4-37. Dissolved oxygen water quality standards attainment assessment of the aquatic habitat (WARM, SPWN) beneficial uses.



Note that these samples are compared to the Basin Plan standard of 5 mg/L for the WARM BU and 7 mg/L for the SPWN BU.

* "Meets water quality standard" indicates the sample exceeded the standard less than 17% of the time.
* "Meets water quality standard of 5 mg/L but not 7 mg/L" indicates meeting WARM objective, but not SPWN objective.
* "Exceeds both water quality standard" indicates the station exceeded this standard at a minimum, more than 17% of the time.

Figure 4-38. Chlorphyll *a* water quality standards attainment assessment of the aquatic habitat (WARM, SPWN), recreational (REC-1) and wildlife habitat (WILD) beneficial uses.



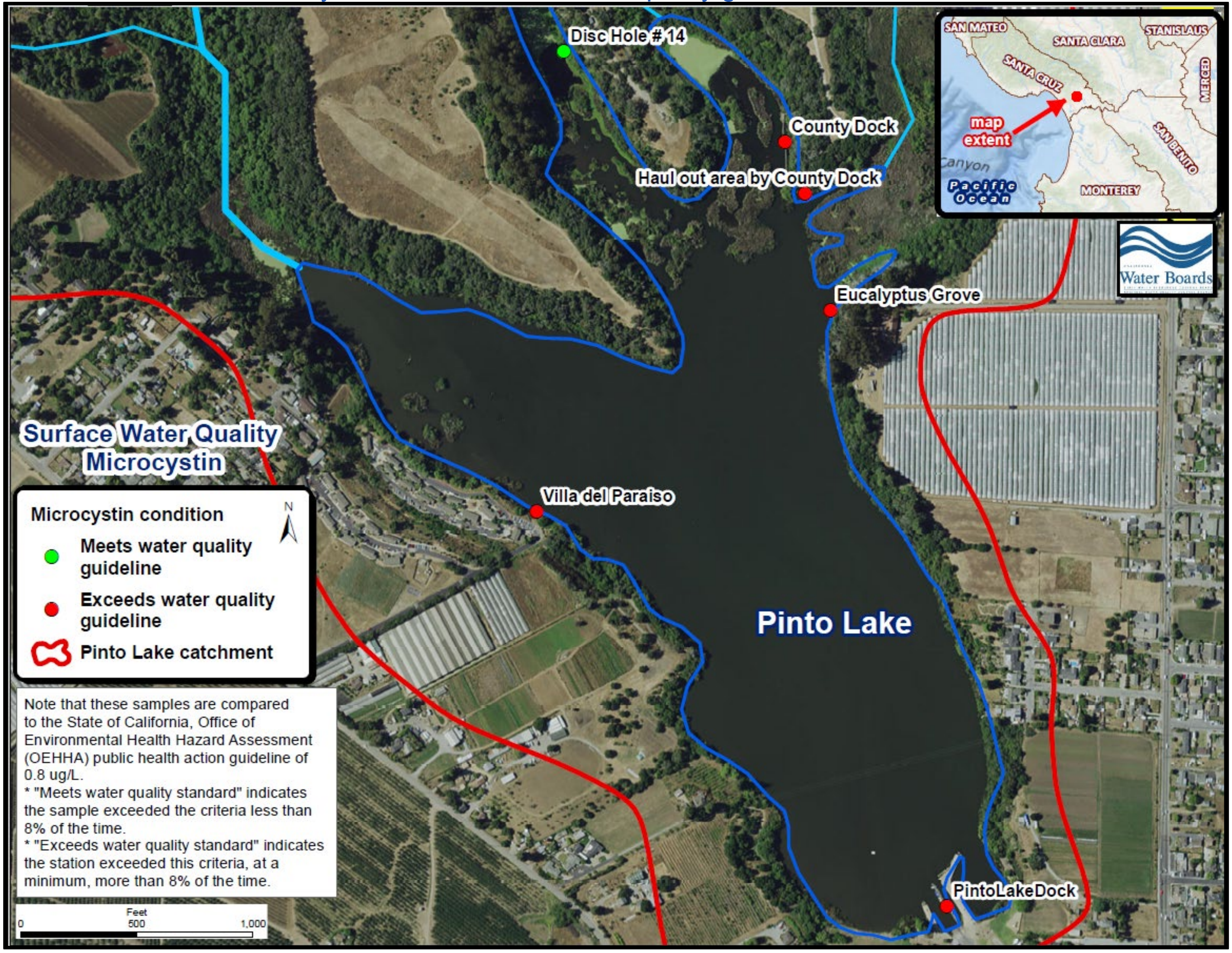
Note that these samples are compared to 15 ug/L. This is a criterion used by the State of Oregon for nuisance phytoplankton grown in lakes and rivers and is used by CCAMP.

* "Meets water quality screening threshold" indicates the sample exceeded the screening threshold less than 17% of the time.

* "Exceeds water quality screening threshold" indicates the station exceeded this screening threshold at a minimum, more than 17% of the time.

* "Sample size too small to determine" indicates there were less than five total samples.

Figure 4-39. Microcystin water quality standards attainment assessment of the **water contact recreation** (REC-1) and **wildlife habitat** (WILD) beneficial uses. Note that we compared the WILD beneficial use to a microcystin concentration of 0.9 µg/L (REC-1 is using 0.8 µg/L microcystin). Whether we compared the samples to the 0.8 µg/L or 0.9 µg/L standard, the excedances presented in this figure are identical. Note that DiscHole#14 is the only site that meets the water quality guidance for recreational contact.

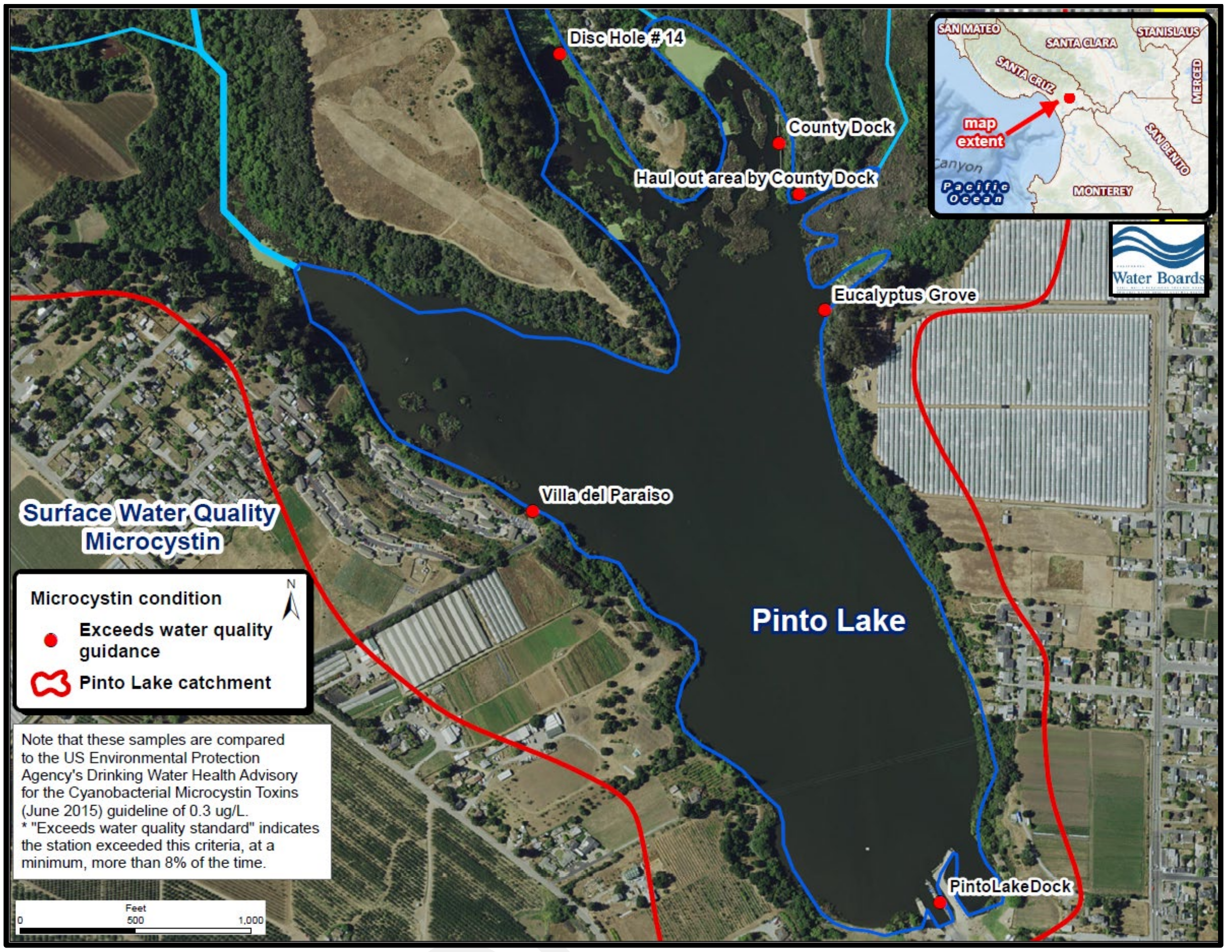


Note that these samples are compared to the State of California, Office of Environmental Health Hazard Assessment (OEHHA) public health action guideline of 0.8 ug/L.

* "Meets water quality standard" indicates the sample exceeded the criteria less than 8% of the time.

* "Exceeds water quality standard" indicates the station exceeded this criteria, at a minimum, more than 8% of the time.

Figure 4-40. Microcystin water quality standards attainment assessment of the **municipal** (MUN) beneficial use.



Note that these samples are compared to the US Environmental Protection Agency's Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins (June 2015) guideline of 0.3 ug/L.
* "Exceeds water quality standard" indicates the station exceeded this criteria, at a minimum, more than 8% of the time.

4.12 Problem Statement

Cyanobacteria blooms, associated toxicity, and water quality degradation have been documented problems in Pinto Lake for many years. Recent grant-funded lake alum treatments appear to have temporarily reduced the severity and toxicity of cyanobacteria blooms since 2017. Effectiveness of one-time lake alum treatments are known to have less effectiveness over time, therefore continuing adaptive lake and watershed management practices and strategies need to be implemented.

University of California at Santa Cruz researchers have analyzed Pinto Lake water quality and bloom toxicity data using a statistical predictive model. Based on this analysis, it was determined that phosphorus was the principal drivers of Pinto's toxic cyanobacteria blooms (as reported by CSUMB and RCD of Santa Cruz County, 2013). Internal loading from the lake sediments and seasonal runoff from the watershed are estimated to contribute nutrients to Pinto Lake. It should be noted that the internal loading of nutrients derived from the lake sediments account for a much higher load of the lake's nutrients (refer to report Section 6.12 on page 242).

The strong relationship between phosphorus and toxic cyanobacteria blooms suggests that management efforts should focus on reducing water column phosphorus availability as a primary goal.

5 WATER QUALITY TARGETS

5.1 Primary Target for Microcystin (Recreational Beneficial Uses)

Microcystins are toxins produced by cyanobacteria (blue-green algae) and are associated with cyanobacteria blooms and biostimulation in surface waterbodies[83]. The Basin Plan does not contain numeric water quality objectives for microcystins. However, the Basin Plan contains a narrative toxicity water quality objective applicable to nutrient pollution and cyanobacteria blooms at Pinto Lake, as follows.

> ***General toxicity objective for all inland surface waters, enclosed bays, and estuaries***
> *"All waters shall be maintained free of toxic substances in concentrations which are toxic to, or which produce detrimental physiological responses in, human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, toxicity bioassays of appropriate duration, or other appropriate methods as specified by the Regional Board."*

Because illnesses are considered detrimental physiological responses in humans, the narrative toxicity objective applies to cyanotoxins. Possible health effects of exposure to cyanotoxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects including poisoning (refer back to Section 1.4).

The California Office of Environmental Health Hazard Assessment has published final microcystin public health action levels[84] for human recreational uses of surface waters. These are not regulatory standards, but are suggested public health action levels. This public health action level is 0.8 µg/L for human recreational uses of water. Therefore, we propose the TMDL numeric water quality target for microcystins[85] as follows:

Text Box 5-1. Numeric target for microcytin protective of recreational beneficial uses.

> Microcystin concentration not to exceed 0.8 µg/L.
>
> ➔ Source: California Office of Environmental Health Assessment, Human Health Action Level for the Microcystin Toxins in Recreational Waters (Report entitled: *Toxicological Summary and Suggested Action Levels to Reduce Potential Adverse Health Effects of Six Cyanotoxins*, May 2012)

This target is therefore protective of the REC-1 and REC-2 designated beneficial uses of Pinto Lake.

With respect to beneficial uses of Pinto Lake to support wildlife habitat (WILD), scientifically-based numeric water quality criteria to protect wildlife from toxicity associated with microcystin are not available at this time. However, based on available information we conclude it is reasonable to assume that the aforementioned microcystin target of 0.8 µg/L should be expected to be protective of livestock, and avian and mammalian wildlife at the lake (refer back to Table 3-2 on page 103).

5.2 Secondary Target for Microcystin (Domestic and Municipal Supply Beneficial Uses)

While the primary human health concern at Pinto Lake is for risk of cyanotoxin ingestion associated with recreational uses of the lake, it is important to note that the Basin Plan also designates Pinto Lake as a

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[83] See: U.S. Environmental Protection Agency. Drinking Water Treatability Database.

[84] California Office of Environmental Health Hazard Assessment. 2012. *Toxicological Summary and Suggested Action Levels to Reduce Potential Adverse Health Effects of Six Cyanotoxins* (Final, May 2012).

[85] Includes microcystins LA, LR, RR, and YR

source of municipal or domestic water supply. Therefore, while the first-order water quality goal is to reduce microcystins in Pinto Lake to restore recreational beneficial uses, Central Coast Water Board staff also identified numeric targets for microcystin protective of human health for domestic and municipal water supply (MUN).

At this time, we are not aware of any current use of Pinto Lake waters for the MUN beneficial use; however, the Basin Plan recognizes that this is a potential or future use of lake waters. In contrast, Pinto Lake is currently and frequently used for recreational beneficial uses by thousands of people every year.

Therefore, from the perspective of the TMDL, while the first-order water quality goal of the TMDL is to reduce microcystin concentrations to restore recreational beneficial uses, it is also necessary to establish a secondary longer term goal for water quality based on microcystin numeric targets protective of domestic and municipal water supply. The U.S. Environmental Protection Agency recently published health-based water quality advisories for microcystin in drinking water supply. Since physiological response to cyanotoxin can vary with age, a more conservative advisory for microcystin exposure in infants was established at 0.3 µg/L, and a less stringent advisory for adults over the age of 21 was established at 1.6 µg/L. At this time, we conclude it is prudent for TMDL purposes to identify the more conservative and protective numeric target for microcystin for drinking water supply beneficial uses as shown in Text Box 5-2.

Text Box 5-2. Numeric target for microcytin protective of domestic and municipal water supply beneficial uses (MUN).

Microcystin concentration not to exceed 0.3 µg/L.

This value represents a U.S. Environmental Protection Agency health advisory based on microcystin exposure to infants, and is the most conservative numeric target. The U.S. Environmental Protection Agency health advisory for adults is 1.6 µg/L for people over the age of 21.

➔ Source: U.S. Environmental Protection Agency (2015) Drinking Water Health Advisory for the Cyanobacterial Microcystin Toxins (EPA-820R15100, June 2015)

5.3 Target for Nitrate (Human Health Standard)

The purpose of this target is to meet the water quality objective for nitrates in municipal and domestic drinking water sources (MUN). The Basin Plan contains a health-based numeric water quality objective for nitrate (as nitrogen) which is 10 mg/L nitrate as N. Therefore, the TMDL nitrate numeric target protective of the domestic and municipal water supply beneficial use is set at the Basin Plan water quality objective as follows:

Text Box 5-3. Numeric target for nitrate as nitrogen protective of domestic and municipal water supply beneficial use.

Nitrate as nitrogen concentration not to exceed 10 mg/L.

➔ Source: Water Quality Control Plan for the Central Coastal Basin, Table 3-2.

5.4 Target for Un-ionized Ammonia

The purpose of this target is to protect surface waters of our region against toxicity. The Basin Plan contains a numeric water quality objective for un-ionized ammonia, and thus the TMDL numeric target for un-ionized ammonia is as follows:

Text Box 5-4. Numeric target for un-ionized ammonia as nitrogen to protect surface waters from toxicity.

> Un-ionized ammonia as nitrogen concentration not to exceed 0.025 mg/L.
>
> ➔ Source: Water Quality Control Plan for the Central Coastal Basin, Chapter II.A.2. Objectives for All Inland Surface Waters, Enclosed Bays, and Estuaries

5.5 Targets for Biostimulatory Substances (Total Phosphorus)

> *"(N)umerous long-term studies of lake ecosystems in Europe and North America show that controlling algal blooms and other symptoms of eutrophication depends on reducing inputs of a single nutrient: phosphorus."*
>
> *➔ Schindler, et al., 2016, published in Environmental Science & Technology*

Numeric water quality targets for nitrogen and phosphorus (biostimulatory substances) are necessary to develop estimates of acceptable levels of nutrient loading to Pinto Lake. It is widely recognized by scientific agencies and resource professionals that excessive nutrient inputs to lakes are a primary driver of harmful algal blooms.

> ***Nutrient enrichment: A key factor in occurrences of cyanoHABs***
>
> *"One of the key causes of cyanoHABs is nutrient enrichment. When nutrients from agricultural and urban areas are transported downstream, they can cause cyanoHABs in reservoirs, which can impair drinking-water quality and result in closures of recreational areas."*
>
> *➔ U.S. Environmental Protection Agency webpage, "The Science of Harmful Algal Blooms", https://www.usgs.gov/news/science-harmful-algae-blooms accessed October 2016.*

> *"Cyanobacteria (also known as blue-green algae) are photosynthetic bacteria found naturally in fresh water systems that can produce toxins. Under certain conditions, blooms occur,* ***particularly in systems over-enriched by nutrients with elevated temperature, sufficient light intensity, and decreased water flow****."*
>
> *➔ Karen Worcester, Senior Environmental Scientist, Central Coast Ambient Monitoring Program manager, in Executive Officer's Report for the May 2015 Central Coast Water Board meeting.*
>
> *(emphasis added by Central Coast Water Board staff)*

> *Nutrient loading is the primary driver in harmful algal blooms.*
>
> *➔ Oral communication, November 2016 from Rick Wilson, Environmental Specialist and agricultural expert for the State of Ohio Environmental Protection Agency's Nonpoint Source program. From a November 30, 2016 EPA Watershed Academy webinar entitled "Understanding Nutrient Issues Affecting Ohio's Inland Lakes"*

Also noteworthy, according to recent findings by researchers from the University of Alberta, University of Wisconsin-Madison, Tufts University, University of Minnesota-Duluth, and University of Ottawa, control of harmful algal blooms in lakes largely depends on reductions in phosphorus loading:

> *"…numerous long-term studies of lake ecosystems in Europe and North America show that controlling algal blooms and other symptoms of eutrophication* ***depends on reducing inputs of a single nutrient: phosphorus****."*
>
> *➔ D. W. Schindler, et al., 2016, published in Environmental Science & Technology*
>
> *(emphasis added by Central Coast Water Board staff)*

Numeric nutrient criteria are a critical tool for protecting and restoring waters at risk of nutrient pollution. USEPA has published current numeric criteria for lakes and reservoirs developed by various states for nitrogen, phosphorus, and other parameters. Nutrient numeric criteria are developed by states to represent thresholds of nutrient levels in lakes and reservoirs which are presumed to be reasonably protective of water quality and the designated uses of lake waters.

Numeric criteria are often developed for a specific lake or reservoir, as the risks of nutrient pollution vary regionally and even vary from lake to lake. These water quality criteria were reported by USEPA as of July 2015 and are summarized in Table 5-1. The information in this table is for informational value only. It should be noted that this reporting is a “snapshot” of the current state of nutrient criteria nationwide as states continue to make progress towards developing and refining nutrient criteria. For comparison purposes, the USEPA ecoregional reference criteria for subecoregion III-6 is illustrated on this table. The USEPA ecoregion III-6 reference criteria is within the high-end of national total phosphorus criteria for lakes and reservoirs, falling between the 90th and 95th percentile of all reported national total phosphorus lake and reservocriteria.

Table 5-1. Summary statistics of nutrient and nutrient-related numeric water quality criteria for lakes and reservoirs as developed by various states and reported by USEPA (July 2015).

	mean	**0%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**Max**	**Number of waterbodies**
Chlorophyll *a* (µg/L)	24.6	0.6	5	10	18	35	35	-	60	281
Orthophosphate as P (mg/L)	0.9	0.001	0.002	0.0065	0.017	0.062	2.17	-	7	8
Phosphate as P (mg/L)	4.2	0.01	0.01	0.03	0.09	0.2	0.215	-	6.6	16
Total Nitrogen (mg/L)	0.9	0.087	0.204	0.253	0.413	1	2.76	-	4	63
Total Phosphorus (mg/L)	0.09	0.005	0.013	0.015	0.040	0.04	0.1	0.253	5.5	341
USEPA Ecoregional Reference Criteria for Total Phosphorus (mg/L) = 0.17 mg/L see report section 2.8, provided here for comparison purposes	-	-	-	-	-	-	-	-	-	-
Turbidity (NTU)	28.3	10	10	13.75	25	43.75	50	-	50	6

Source data: USEPA, State Development of Numeric Criteria for Nitrogen and Phosphorus http://cfpub.epa.gov/wqsits/nnc-development/
State criteria are reported for the following states and territories: American Samoa, Arizona, California, Colorado, Florida, Georgia, Illinois, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, Nevada, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, Puerto Rico, Rhode Island, South Carolina, Texas, Vermont, Virginia, West Virginia, and Wisconsin.

It should be noted that this TMDL uses a multiple lines of evidence approach for assessing progress towards later quality management goals. These include the use of water quality criteria for chlorophyll *a*, microcystin, and dissolved oxygen, as described in this section of the report. While reductions in total phosphorus concentrations and loads should lead to improvements in these other water quality parameters, de-listing the lake from the CWA Section 303(d) List will ultimately depend on achieving acceptable levels of biomass and cyanotoxins.

5.6 Targets for Nutrient-Response Indicators

Low dissolved oxygen, chlorophyll *a,* and algal toxins (microcystins) are nutrient-response indicators and represent both a primary biological response to excessive nutrient loading in waterbodies which exhibit biostimulatory conditions, and a direct linkage to the support or impairment of designated beneficial uses. The justification for their inclusion as numeric targets in this TMDL can conceptually be emphasized with the following technical guidance published as part of California’s nutrient numeric criteria approach:

> *"As a first and critical step, it is proposed in this study that* ***nutrient criteria not be defined solely in terms of the concentrations of various nitrogen and phosphorus species****,* ***but also include consideration of primary biological responses to nutrients*****. It is these biological responses that correlate to support or impairment of uses. It is proposed that the consideration of biological responses be* ***in addition to**** *chemical concentrations in the final form of the nutrient criteria. Further, the development of chemical concentration criteria should be closely linked to the evaluation of biological responses."*
>
> *Progress Report - Development of Nutrient Criteria in California: 2003-2004 (Tetra Tech, Inc., October 2004, prepared for U.S. EPA Region IX)*
>
> *(* emphasis added by Central Coast Water Board staff)*

Further, the U.S. Environmental Protection Agency likewise recognizes biological response indicators are a necessary component of measuring and tracking nutrient pollution:

> *The purpose of these guiding principles is to offer clarity to states about an optional approach for developing a numeric nutrient criterion that integrates causal (nitrogen and phosphorus)* ***and response parameters**** *into one water quality standard…These guiding principles apply when states wish to rely on* ***response parameters to indicate that a designated use is protected****, even though a nitrogen and/or phosphorus level is/are above an adopted threshold.*
>
> *U.S. Environmental Protection Agency (USEPA, 2013b). Guiding Principles on an Optional Approach for Developing and Implementing a Numeric Nutrient Criterion that Integrates Causal and Response Parameters. EPA-820-F-13-039.*
>
> *(* emphasis added by Central Coast Water Board staff)*

Dissolved oxygen (DO) and chlorophyll *a* impairments in the Pinto Lake catchment are not directly addressed in the TMDL implementation plan in terms of calculating loads (TMDLs) or setting waste load or load allocations for these constituents. However, reductions in nutrient loading are anticipated to be beneficial in attainment of water quality standards for DO and chlorophyll *a* and restoring the waterbodies to a desired condition. Note that this approach regarding nutrient pollution and dissolved oxygen has similarly been used in previous USEPA-approved TMDLs[86]. Therefore, the current 303(d) listings for dissolved oxygen and chlorophyll *a* that are associated with identified biostimulatory problems are addressed by the TMDLs established herein.

It is important to reiterate that nutrient concentrations by themselves constitute indirect indicators of biostimulatory conditions and there is an interrelationship between high nutrient loads, excessive algal growth, and the subsequent impacts of excessive algae on dissolved oxygen and aquatic habitat. Accordingly, staff is also proposing dissolved oxygen and chlorophyll *a* numeric targets to ensure that streams do not show evidence of biostimulatory conditions; additionally, numeric targets identified for DO and chlorophyll *a* in this TMDL will be used as indicator metrics to assess primary biological response to future nutrient water column concentration reductions, and compliance with the Basin Plan's biostimulatory substances objective.

5.6.1 Dissolved Oxygen

The Basin Plan contains the following water quality objectives for dissolved oxygen (DO):

Text Box 5-5. Numeric targets for dissolved oxygen protective of aquatic habitat beneficial uses.

- For warm beneficial uses and for waters not mentioned by a specific beneficial use, dissolved oxygen concentrations shall not be reduced below 5.0 mg/L at any time.

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[86] For example: Wabash River Nutrient and Pathogen TMDL, Final Report. Indiana Dept. of Environmental Management, 2006. Approved by USEPA under section 303(d) of the Clean Water Act on Sept. 22, 2006.

- For spawning beneficial uses, dissolved oxygen concentrations shall not be reduced below 7.0 mg/L at any time.
- Median values for dissolved oxygen should not fall below 85% saturation as a result of controllable conditions.

➔ Source: Water Quality Control Plan for the Central Coastal Basin.

In addition, due to the nature of algal respiration and photosynthesis and since daytime monitoring programs are unlikely to capture most low DO crashes, it is prudent to identify a numeric guideline that can measure daytime biostimulatory problems on the basis of DO supersaturation. Peer-reviewed research in California's central coast region (Worcester et al., 2010) has established an upper limit of 13 mg/L for DO to screen for excessive DO saturation, and addresses the USEPA "Gold Book" water quality standard for excessive gas saturation. Of monitoring sites evaluated in the central coast region that are supporting designated aquatic habitat beneficial uses and do not show signs of biostimulation, DO virtually never exceeded 13 mg/L at any time[87]. Note that the 13 mg/L DO saturation target is not a regulatory standard, but can be used as a TMDL nutrient-response indicator target to assess primary biological response to nutrient pollution reduction. Accordingly, staff proposes the numeric target for DO supersaturation indicative of biostimulatory conditions as follows:

Text Box 5-6. Numeric target for dissolved oxygen protective of aquatic habitat beneficial uses.

Dissolved oxygen concentrations not to exceed 13 mg/L.

➔ Source: Worcester, K., Paradies D.M., and Adams, M. 2010. Interpreting Narrative Objectives for Biostimulatory Substances for California Central Coast Waters. Central Coast Ambient Monitoring Program, California Central Coast Water Board, Technical Report.

Note that this TMDL is addressing biostimulatory impairments; as such only dissolved oxygen impairments that are credibly linked to biostimulation problems (i.e., elevated algal biomass, wide diel swings in DO/pH, and elevated nutrients) will be addressed in this TMDL. It is important to recognize that there are other factors that affect the concentration of dissolved oxygen in a waterbody. Oxygen can be introduced by additions of higher DO water (e.g., from tributaries); additions of lower DO water (groundwater baseflow), temperature (warm water holds less oxygen than cold water), and reductions in oxygen due to organic decomposition. Dissolved oxygen impairments that are not credibly linked to biostimulation impairments will potentially be addressed in another TMDL process, or in a future water quality standards action.

5.6.2 Chlorophyll *a*

Chlorophyll *a* is an algal biomass indicator. The Basin Plan does not include numeric water quality objectives or criteria for chlorophyll *a*. Staff considered a range of published numeric criteria.

Due to substantial seasonal variation in chlorophyll *a* concentrations in Pinto Lake we are identifying seasonal targets for this constituent.

For the growing season, when biomass is generally higher and cyanobacteria blooms more frequent we are proposing a numeric target for chlorophyll *a* of 25 µg/L. This value comes from a USEPA guidance threshold for ecoregion III, as previously reported in report Section 2.8. This value is presumed to represent a lightly-impacted reference conditions for lakes of ecoregion III. Based on the seasonal trends of chlorophyll *a* concentrations at Pinto Lake, and the seasonal trends in cyanobacteria blooms, this chlorophyll a target will apply for the period June 1 through November 30.

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[87] Of 2,399 samples at these reference sites, only about 1% of the samples ever exceeded 13 mg/L DO.

The State of Oregon uses an average chlorophyll *a* concentration of > 15 µg/L as a criterion for nuisance phytoplankton growth in lakes and rivers[88]. The state of North Carolina has set a maximum acceptable chlorophyll *a* standard of 15 µg/L for cold water (lakes, reservoir, and other waters subject to growths of macroscopic or microscopic vegetation designated as trout waters), and 40 µg/L for warm water (lakes, reservoir, and other waters subject to growths of macroscopic or microscopic vegetation not designated as trout waters)[89]. A chlorophyll *a* concentration of 8 µg/L is recommended as a threshold of eutrophy for plankton in EPA's Nutrient Criteria Technical Guidance Manual for Rivers and Streams (USEPA, 2000a). The central coast region has used 40 µg/L as stand-alone evidence to support chlorophyll *a* listing recommendations for the 303(d) List.

A recent peer-reviewed study conducted by CCAMP reports that in the California central coast region, inland streams that do not show evidence of eutrophication all remained below the chlorophyll *a* threshold of 15 µg/L (Worcester et al., 2010). As this value is consistent with several values reported in published literature and regulations shown above, and as the CCAMP study by Worcester et al. is central coast-specific, staff proposes the numeric target for chlorophyll *a* indicating biostimulatory conditions as follows:

Text Box 5-7. Seasonal targets for chlorophyll *a* to implment the Basin Plan biostimulatory substances water quality objective.

Growing season (June 1 through November 30)

- Water column chlorophyll *a* concentrations not to exceed 25 µg/L.

Wet season (December 1 through May 31)

- Water column chlorophyll *a* concentrations not to exceed 15 µg/L.

6 SOURCE ANALYSIS

6.1 Introduction: Source Assessment Using STEPL Model

Both nitrogen and phosphorus reach surface waters at an elevated rate as a result of human activities (USEPA, 1999a). In this TMDL Report nutrient source loads were estimated using the US Environmental Protection Agency's Spreadsheet Tool for Estimating Pollutant Loads, version 4.1 (STEPL). STEPL is a watershed-scale water quality spreadsheet model developed by Tetra Tech, Inc. for the USEPA. This spreadsheet tool can be used for estimating watershed pollutant loads for nutrients (Nandi et al., 2002). STEPL can also be used to evaluate load reductions that could result from the implementation of various management practices.

STEPL was selected for its relative ease in application, the minimal amount of required input data, and because of its endorsement by the USEPA. In terms of data requirements, and algorithms used to estimate runoff and pollutant loads, STEPL is reportedly very similar to other simple models such the Generalized Watershed Loading Functions[90] model (Tetra Tech, 2010). STEPL employs simple algorithms to calculate long-term average annual watershed nutrient loads from different land uses and source categories. STEPL provides a Visual Basic (VB) interface to create a customized, spreadsheet-

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[88] Oregon Administrative Rules (OAR). 2000. Nuisance Phytoplankton Growth. Water Quality Program Rules, 340-041-0150.

[89] North Carolina Administrative Code 15A NCAC 02B .0211(3)(a).

[90] More commonly known by its acronym, GWLF. The GWLF model was developed at Cornell University to estimate nitrogen and phosphorus loading from relatively large agricultural and urban watersheds.

based model in Microsoft (MS) Excel. STEPL calculates watershed surface runoff, nutrient loads, including nitrogen and phosphorus based on various land uses and watershed characteristics.

Worth noting is that STEPL has been used previously in USEPA-approved TMDLs to estimate source loading[91]. It should be recognized that, as with any relatively simple watershed model, STEPL outputs are subject to significant uncertainties and the model pollutant load estimates should not be considered definitive or conclusive. However, STEPL is useful tool in estimating the long-term average relative proportions of various source categories (Nejadhashemi et al., 2011).

The annual nutrient loading estimate in STEPL is calculated based on the runoff volume and the pollutant concentrations in the runoff water as influenced by factors such as the land use distribution, precipitation data, soil characteristics, groundwater inputs, and management practices. Additional documentation and information on the model can be found at: http://it.tetratech-ffx.com/steplweb/models$docs.htm.

STEPL input parameters used in this TMDL project are outlined in Table 6-1. should be emphasized that average annual nutrient load estimates calculated by STEPL are indeed estimates and subject to uncertainties; actual loading at the stream-reach scale can vary substantially due to numerous factors over various temporal and spatial scales.

Due to uncertainties inherent in this analysis, we rounded STEPL estimates of nutrient loading from source categories to only two significant figures. Based on guidance from the STEPL support help desk, we also applied an attenuation factor for the export of sediment/nutrient loads as the loads move through the nested subcatchments towards Pinto Lake[92].

Table 6-1. Spreadsheet Tool for Estimating Pollutant Loads version 4.1 (STEPL) input data.

Input Category	STEPL Input Data	Sources of STEPL Input Data
Mean Annual Rainfall	Range = 23.9 – 26.4 inches/year depending on location of individual subwatersheds	PRISM precipitation dataset, accounting for orographic effects. Refer back to report Section 2.9,**Error! Reference source not found.**
Mean Rain Days/Year *(where daily precipitation event >0.01 inches)*	58 days per year	http://www.weatherbase.com/weather/weather.php3?s=374940&cityname=Watsonville-California-United-States-of-America&units=metric Watsonville, California
Weather Station *(for rain correction factors)*	San Francisco WSO Airport Provided as a default in STEPL	San Francisco WSO Airport as provided in STEPL version 4.0 *(this is the closest weather station to the Pinto Lake catchment available in STEPL version 4.1 for rain correction factors)*
Land Cover	STEPL spreadsheets	Farmland Mapping and Monitoring Program (2014) data. Refer back to Table 2-4 in report Section 2.2.
Urban Land Use Distributions (%) *(impervious surfaces categories)*	Modified based on interpretation of aerial imagery and area measurements take in GIS.	Staff modified the urban land use distributions because there are no commercial, industrial or institutional land uses in the watershed. Other land uses were calculated using aerial imagery and the area measurement tool in ArcGIS.
Agricultural Animals	STEPL spreadsheets	Estimates of quantities of agricultural animals by individual subcatchment from field visits and personal communication with the Resources Conservation District (RCD) of Santa Cruz.

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[91] For example, see USEPA, 2010: Decision Document for Approval of White Oak Creek Watershed (Ohio) TMDL Report. February 25, 2010; and Indiana Dept. of Environmental Management, 2008. South Fork Wildcat Creek Watershed Pathogen, Sediment, and Nutrient TMDL.

[92] In STEPL, the sediment delivery ratio (SDR) is a function of watershed size. STEPL allows the option of treating a nested set of subwatersheds or subcatchments as a single watershed, which lowers the calculated SDR value and lowers the associated total nitrogen and total phosphorus loads being exported from the landscape (email communication, STEPL helpdesk, October 31, 2014).

Input Category	STEPL Input Data	Sources of STEPL Input Data
Septic system discharge and failure rate data	STEPL spreadsheets	The number of septic systems per subcatchment was obtained through personal communication with John Ricker (Santa Cruz County). Population per septic system was from data reported by U.S. Census Bureau. Septic failure rate percentage was obtained from the County of Santa Cruz website: http://scceh.com/Home/Programs/LandUse,SewageDisposalWasteWaterManagement/HistorySepticRepairRegulations.aspx – refer to report Section 6.7. We used a septic failure rate of 2% which was the failure rate identified for septic systems in the Pajaro River Basin TMDL (2016).
Hydrologic Soil Group (HSG)	D	U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database – refer back to Figure 2-46 in report Section 2.12
Soil N and P concentrations (%)	N = 0.07% P = 0.01%	Data available from the International Geosphere–Biosphere Programme Data Information System; Post and Mann (1990); the Kearney Foundation of Soil Science–University of California, Davis; sediment cores taken in the creek arms in October of 2014 by the City of Watsonville. Refer back to report Section 2.12 and Text Box 2-6.
NRCS reference runoff curve numbers	Urban A=51, B=68, C=79, D=84. Cropland A 67, B=78, C=85, D=89. Pastureland A=39, B=61, C=74, D=80. Forest A=32, B=58, C=72, D=79. Garden Products Facility A=61, B=75, C=83, D=87.	Runoff Curve Numbers of Urban Areas (ARC II), Urban Hydrology for Small Watersheds, Technical Release TR-55, USDA, NRCS, Tables 2-2a, 2-2b, and 2-2c, 1986. Urban numbers were chosen based on National Land Cover Database (NLCD) analysis showing average impervious area in urban areas is approximately 20%. This corresponds to a residential district by average lot size of 1 acre. Cropland numbers correspond to the fact that most row crops are grown in straight rows. Most growers implement "row alignment" (pers. Comm. Lozano, 2017[93]) which is a practice that reduces runoff. Therefore "good" hydrologic conditions were chosen for this land use. Pastureland numbers correspond to pasture, grassland, or range-continuous forage for grazing; hydrologic condition, good. Forest numbers correspond with woods-grass combination (orchard or tree farm); hydrologic conditions, good. Garden Products Facility numbers correspond with residential district by average lot size of ¼ acre. This corresponds to the fact that approximately 40% of this area is impervious due to structures and roads.
Universal Soil Loss Equation (USLE) Parameters	STEPL spreadsheets USLE inputs for each individual subwatershed, based on county-level USLE data	County-level USLE data as developed and reported by Tetra Tech, Inc. for use in STEPL version 4.0. See: http://mingle.tetratech-ffx.com/steplweb2/steplweb.html

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[93] Lozano, Sacha. Resource Conservation District of Santa Cruz County. Personal communication via email May 8, 2017.

Input Category	STEPL Input Data	Sources of STEPL Input Data
Nutrient (total N and total P) concentrations in runoff (mg/L)	Cropland mean N = 11.4 mg/L mean P = 0.64 mg/L Urban Lands N = 1.9 to 3.62 mg/L (range) P = 0.15 to 0.5 mg/L (range) Grazing Lands (aka, rangeland) mean N = 0.25 mg/L mean P = 0.21 mg/L Woodlands mean N = 0.2 mg/L mean P = 0.1 mg/L Garden Products Facility mean N = 1.1 mean P = 4.3	• Agricultural lands mean N runoff concentration data from Southern California Coastal Water Research Project, Technical Report 335 (Nov. 2000), Appendix C; and the U.S. Dept. of Agriculture's MANAGE database – refer to **Error! Reference source not found.** in report Section 6.5. • Agricultural lands mean P runoff concentration data from Southern California Coastal Water Research Project, Technical Report 335 (Nov. 2000), Appendix C • Urban lands N runoff concentrations from commercial, industrial, residential, transportation, and open space land categories were derived from the arithmetic means of N concentrations reported in the National Stormwater Quality Database (version 3, Feb. 2, 2008) – see **Error! Reference source not found.** in report Section **Error! Reference source not found.**. Urban N runoff concentrations for institutional, urban-cultivated, and vacant land categories are the default valued provided in STEPL version 4.0. • Urban lands P runoff concentrations from commercial, industrial, residential, transportation, and open space land categories were derived from the arithmetic means of P concentrations reported in the National Stormwater Quality Database (version 3, Feb. 2, 2008) – see **Error! Reference source not found.** in report Section **Error! Reference source not found.**. Urban P runoff concentrations for institutional, urban-cultivated, and vacant land categories are the default valued provided in STEPL version 4.0. • Grazing lands mean N runoff concentration. from California Rangeland Watershed Laboratory rangeland presentation for stream water quality (average of the concentrations given for moderate grazing intensity and no grazing land use categories) http://rangelandwatersheds.ucdavis.edu/Recent%20Outreach/tate%20oakdale%20mar%202012.pdf • Grazing lands (aka, rangeland) mean P runoff concentration is derived from the arithmetic mean of dissolved P concentrations in runoff from all land use categories defined as native grasses, native grasslands, and native prairie reported in the U.S. Dept. of Agriculture MANAGE database (version year 2013). • Woodlands mean N runoff concentration: staff used STEPL version 4.0 default values for "forest" land use category • Woodlands mean P runoff concentration: staff used STEPL version 4.0 default values for "forest" land use category • Garden Products Facility mean values were calculated using data submitted via their Stormwater Annual Reports dated 2011 through 2014.
Nutrient (nitrate and phosphorus) concentrations in shallow groundwater (mg/L)	All land uses NO_3-N = 1.3 P = 0.05	• Median groundwater nitrate (NO_3-N) and phosphorus concentrations values are derived on the basis of data available from the U.S. Geological Survey National Water Information System; California Integrated Water quality System (CIWQS); and National Uranium Resource Evaluation Hydrogeochemical Reconnaissance data. Refer back to the discussion in report Section 2.10.

Assumptions: we assumed composted manure was not applied to cultivated cropland in the Pinto Lake catchment, and it is presumed that chemical fertilizers are almost universally used for fertilization in the river basin. This assumption is supported by reporting from local resource professionals and local stakeholders.

6.2 Urban and Residential Runoff/Stormwater

Urban runoff, in the form of municipal separate storm sewer system (MS4) discharges, can be a contributor of nutrients to waterbodies. USEPA policy explicitly specifies that National Pollutant Discharge Elimination System (NPDES)-regulated urban stormwater discharges are point source discharges and, therefore, must be addressed by the waste load allocation component of a TMDL. The Central Coast Water Board is the permitting authority for NPDES urban stormwater permits in the central coast region. According to the U.S. Environmental Protection Agency and the State Water Resources Control Board, all NPDES-permitted point sources identified in a TMDL must be given a waste load allocation, even if their current load to receiving waters is zero.

Figure 6-1 illustrates the locations and extent of currently enrolled MS4 permit entities in the Pinto Lake catchment and vicinity. The County of Santa Cruz is the only permitted MS4 entity in the Pinto Lake catchment (see Table 6-2).

Within residential areas, potential controllable nutrient sources can include lawn care fertilizers, grass clippings, organic debris from gardens and other green waste, trash, and pet waste (Tetra Tech, 2004). Many of these pollutants enter surface waters via runoff without undergoing treatment. Impervious cover characterizes urban areas and refers to roads, parking lots, driveways, asphalt, and any surface cover that precludes the infiltration of water into the soil. Pollutants deposited on impervious surface have the potential of being entrained by discharges of water from storm flows, wash water, or excess lawn irrigation, etc. and routed to storm sewers, and potentially being discharged to surface water bodies.

Figure 6-1. Boundaries of permitted MS4 jurisdictional boundaries in Pinto Lake catchment and vicinity..

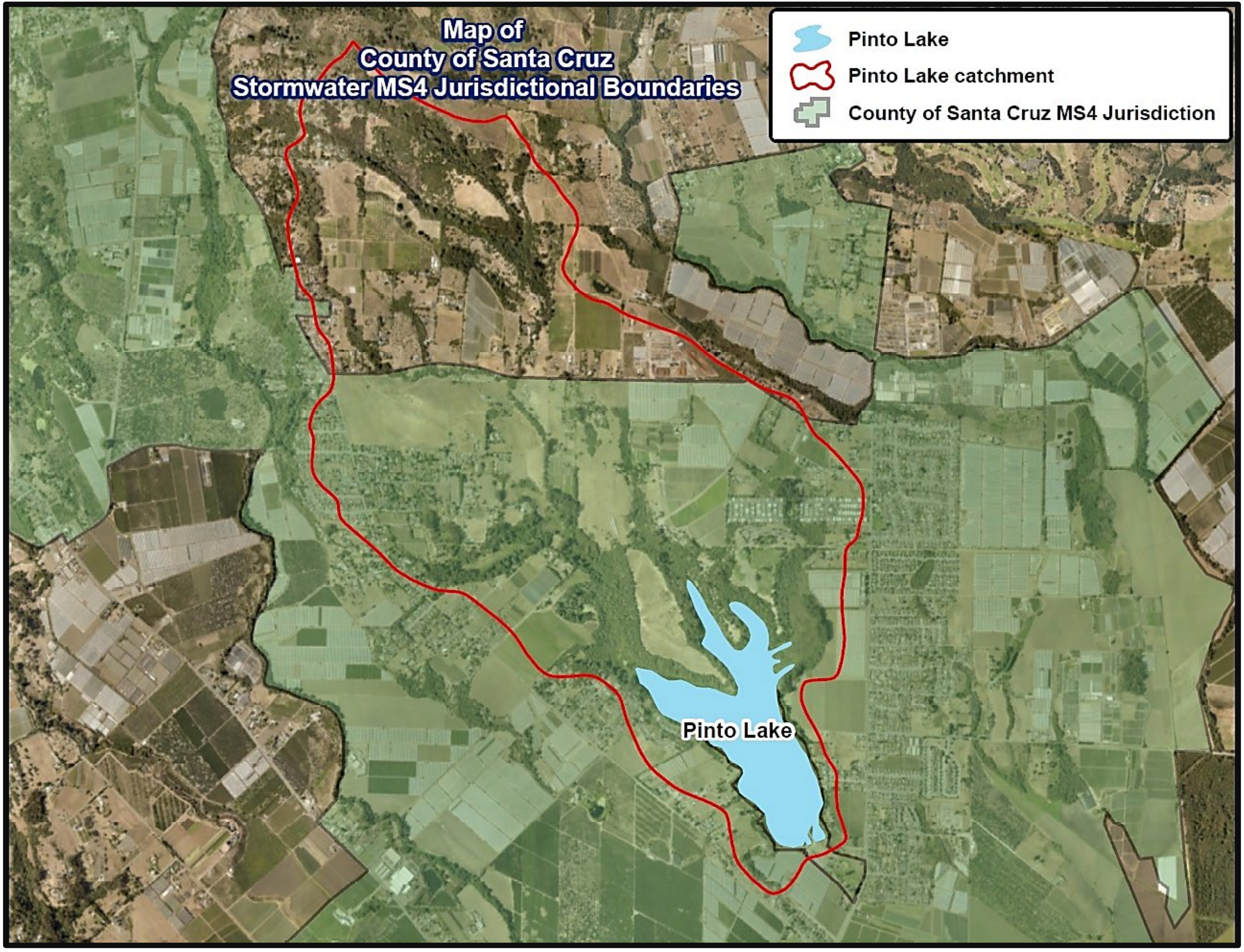

Table 6-2. Identification of enrolled municipal stormwater permit entities with NPDES-permitted jurisdictions in the Pinto Lake catchment.

Type	Status	Responsible Entity
Phase II Small MS4	Active	County of Santa Cruz

Average annual nutrient loads delivered to surface waterbodies in the Pinto Lake catchment from residential runoff were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-3. These data indicate that stormwater from MS4s is estimated to be a source of nutrient and sediment loading to Pinto Lake.

Table 6-3. Estimated average annual watershed nutrient and sediment loads delievered to Pinto Lake from urban and residential runoff (i.e., municipal stormwater discharges) in the Pinto Lake catchment.

Source	P Load (lbs/yr)	N Load (lbs/yr)	Sediment Load (tons/yr)
Urban and Residential Runoff	150	920	20

6.3 Industrial & Construction Stormwater

According to guidance from the State Water Resources Control Board, all NPDES point sources should receive a waste load allocation (communication from Jonathan Bishop, Chief Deputy Director and Phil Wyels, Assistant Chief Counsel, State Water Resources Control Board, August 2014), and thus NPDES–permitted industrial stormwater and construction stormwater entities should be considered during TMDL development. Similarly, USEPA guidance recommends disaggregating stormwater sources in the waste load allocation of TMDL where feasible, including disaggregating industrial and construction stormwater discharges (USEPA, 2014b). At the time of this TMDL development, there were no permitted stormwater construction activities in the Pinto Lake catchment.

As of June 2019 there is only one active NPDES stormwater-permitted industrial facility in the Pinto Lake catchment[94], identified as Sun Land Garden Products. This facility processes and distributes soil amendments, compost, and mulch. Table 6-4 presents a summary of the facility. This facility is located in the Amesti Creek subcatchment on the north side of Pioneer Road (refer back to Figure 2-11 on page 30).

Table 6-4. Sun Land Garden Products, Inc. NPDES permit information.

Facility/Address	NPDES Permit Category	Latitude Longitude	Industrial Classification –Regulated Activity	Facility Size	Industrial Areas Exposed to Storm water Runoff	Receiving Water	Flow
Sun Land Garden Products Inc. 90 Pioneer Rd Watsonville California	General Permit to Discharge Storm Water Associated with Industrial Activity (WQ General Order No. 2014-0057-DWQ)	36.97214 -121.77654	Processing and distribution of potting soil mixes, compost and mulch.	21.7 acres	6.687 acres	Pinto Lake	Indirectly

Sources of information: State Water Board, Notice of Intent to Comply, dated June 22, 2015, submitted by Sun Land Garden Product, Inc. Storm Water Prevention Plan, prepared for Sun Land Garden Products Watsonville Facility, June 2015.

Sun Land Garden Products facility is required to submit water quality monitoring data on an annual basis. Table 6-5 summarizes available monitoring data for total phosphorus in runoff from this facility.

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[94] On the basis of information publicly available in the State Water Resource Control Board’s Storm Water Multiple Applications & Report Tracking System (SMARTS). https://smarts.waterboards.ca.gov/smarts/faces/SwSmartsLogin.jsp

Table 6-5. Statistical summary of water quality monitoring results for total phosphorus (mg/L) at monitoring site SW-1, Sun Land Garden Products Pioneer Road facility.

Monitoring site	Date Range	Number of samples	Arithmetic mean	Median	75th percentile	25th percentile
SW-1	Feb. 2011 to Dec. 2014	28	4.2	2.1	5.8	1.8

Point sources, such as NPDES stormwater discharges, do not lend themselves well to representation in the STEPL approach to estimating source loads as discussed previously in Section 6.1. However, phosphorus loading from the Sun Land Garden Products facility can be approximated using an export coefficient model (ECM) approach (Reckhow et al., 1980). The ECM requires the use of nutrient export coefficients. Nutrient export coefficients are the amounts of nitrogen or phosphorus exported from an area over a specific time period and are generally applied to a specific land use. They are typically expressed as kilograms of phosphorus per hectare per year, or pounds of nitrogen per acre per year, or some other mass-area-time unit.

Unfortunately, we are unable to identify estimated phosphorus loading coefficients in the published literature for an industrial facility similar to Sun Land Garden Products. In the absence of this information, we estimated a phosphorus export loading coefficient for the facility in an indirect manner using data reported in the U.S. Department of Agriculture's (USDA) MANAGE Database[95]. We identified agricultural watersheds in the MANAGE Database with measured surface runoff phosphorus concentrations in a similar range as observed in the Sun Land facility data (1.8 to 5.7 mg/L total P). Then we extracted the associated phosphorus loading export coefficient estimates associated with these watersheds in the MANAGE database and presumed these represent plausible phosphorus loading export coefficients from the Sun Land facility. It should be noted that the MANAGE database is weighted towards agricultural watersheds in the Midwest and southeastern U.S., introducing a possible geographic bias.

Table 6-6. Statistical summary of phosphorus loading export coefficients from agricultural watersheds with total phosphorus concentration in runoff in the range 1.8 to 5.7 mg/L in the USDA's MANAGE database.

Data sources	Number of database records	Average ratio of particulate P to total P	Range of total P concentrations in surface runoff	Total P export (kg/ha) Arithmetic mean	Total P export (kg/ha) 75th percentile	Total P export (kg/ha) 25th percentile
USDA MANAGE nutrient export database	40	0.8	1.91 mg/L to 5.67 mg/L	2.62	3.32	0.53

Using the average total phosphorus export coefficient from Table 6-6 (2.62 kg/ha, or 5.78 lbs./ha) and the facility size from Table 6-4 (21 acres, or 8.5 hectares) results in an estimated average annual export load of 50 pounds of total phosphorus from the Sun Land facility (see Table 6-11). We rounded the annual estimated phosphorus load to one significant figure given the uncertainties noted above.

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[95] Manage Nutrient Database - Nutrient Loss Database for Agricultural Fields in the US. The primary objective of this effort was to compile measured annual nitrogen (N) and phosphorus (P) load and concentration data representing field-scale transport from agricultural land uses. http://www.ars.usda.gov/Research/docs.htm?docid=11079

Table 6-7. Estimated average annual total phosphorus load discharged from the Sun Land Garden Products facility .

Source	Total Phosphorus Load (lbs/yr)
NPDES stormwater permitted facility- Sun Land Garden Products, Inc.	50

6.4 Wastewater Treatment Facilities

Most homes and businesses in the United States send their wastewater to a treatment plant via sewer connection. Wastewater contains nitrogen and phosphorus from human waste, food, certain soaps and detergents, and can therefore be a potential risk of nutrient pollution to surface waters[96]. TMDLs routinely assess the potential risk of water pollution from wastewater treatment plants.

There are no NPDES permitted wastewater treatment facilities in the Pinto Lake catchment. A collection system collects wastewater from some urbanized areas in the catchment and this wastewater is then treated outside the catchment. Furthermore, reporting from State Water Board's Sanitary Sewer Overflow Reduction Program[97] indicates there were no sanitary sewer overflows, discharges, or spill incidents in the catchment from 2007 to June 2017.

Since there are no permitted wastewater treatment plants in the Pinto Lake catchment, nor are we aware of any plans to build one in the foreseeable future, the waste load allocations in the catchment for this source category will be set at zero.

6.5 Cropland

Fertilizers or compost applied to cropland can constitute a significant source of nutrient loads to waterbodies. The primary concern with the application of fertilizers on crops or forage areas is that the application can exceed the uptake capability of the crop. If this occurs, the excess nutrients become mobile and can be transported to either nearby surface waters, to groundwaters, or the atmosphere (Tetra Tech, April 29, 2004). California fertilizer application rates on specific crop types are available from the U.S. Department of Agriculture, National Agricultural Statistics Service, as shown in Table 6-8.

Table 6-8. California reported fertilizer application rates (National Agricultural Statistics Service).

Crop	Application Rate per Crop Year (pounds per acre) in California			Source
	Nitrogen	Phosphate	Potash	
Tomatoes	243	133	174	2007 National Agricultural Statistics (NASS) report
Sweet Corn	226	127	77	2007 NASS report
Rice	124	46	34	2007 NASS report
Cotton	123	74	48	2008 NASS report
Barley	73	19	7	2004 NASS report
Oats[1]	64	35	50	2006 NASS report
Head Lettuce	200	118	47	2007 NASS report
Cauliflower	232	100	43	2007 NASS report
Broccoli	216	82	49	2007 NASS report
Celery	344	114	151	2007 NASS report

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[96] U.S. Environmental Protection webpage: Nutrient Pollution the Sources and Solutions: Wastewater. Accessed July 2017.

[97] http://www.waterboards.ca.gov/water_issues/programs/sso/#ssomaps

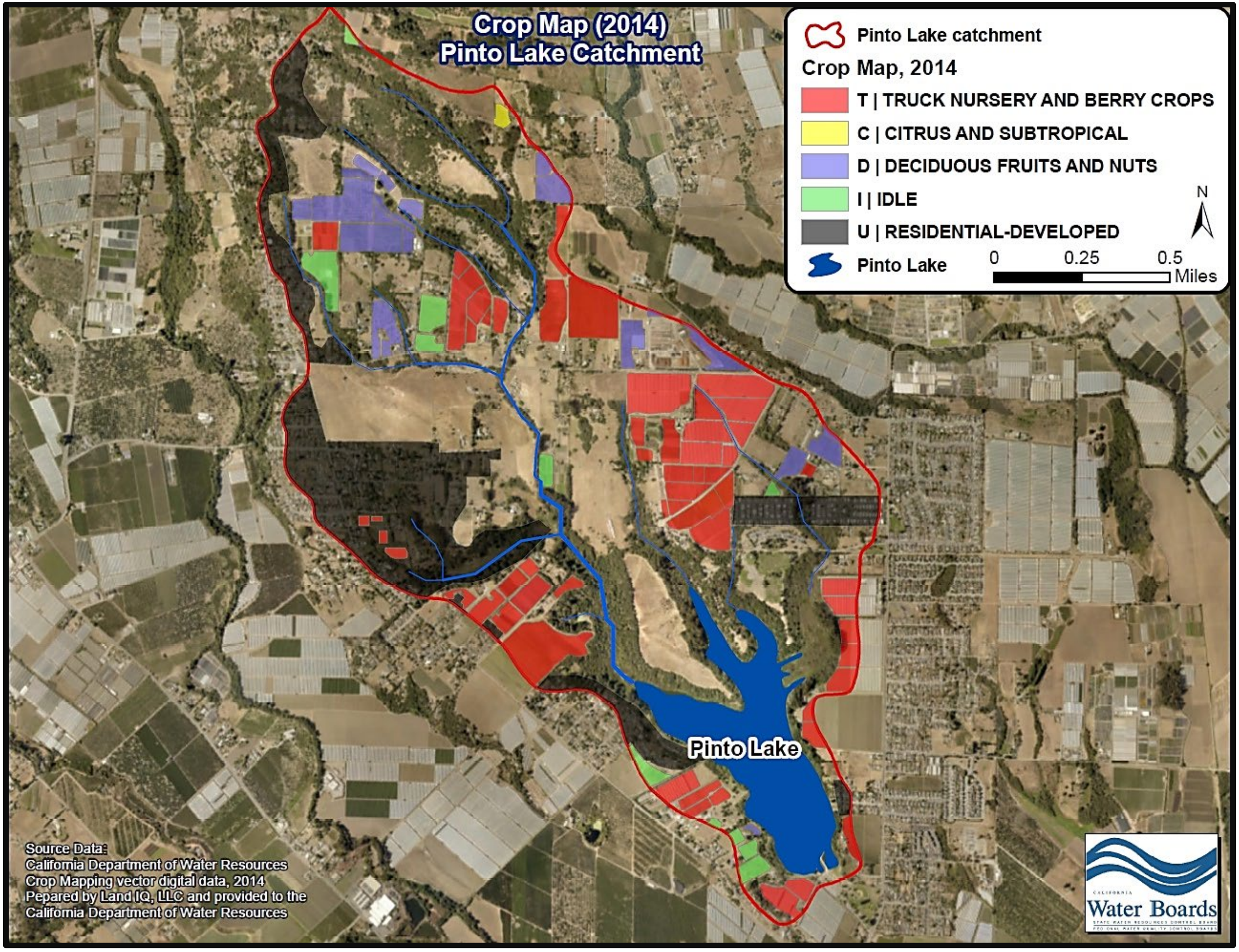
Crop	Application Rate per Crop Year (pounds per acre) in California			Source
	Nitrogen	Phosphate	Potash	
Asparagus	72	20	46	2007 NASS report
Spinach	150	60	49	2007 NASS report
Strawberries[2]	155	88	88	University of Delaware Ag, Nutrient Recommendations on Crops webpage

[1] insufficient reports to publish fertilizer data for P and potash; used national average from 2006 NASS report for P and K

[2] median of ranges, calculated from table 1, table 4, and table 5 @ http://ag.udel.edu/other_websites/DSTP/Orchard.htm

As of summer 2016 there were approximately 25 agricultural ranches and farming operations in the Pinto Lake catchment enrolled in the Central Coast Water Board's, irrigated lands regulatory program[98]. The most common agricultural product currently grown in the catchment are berry crops (see Figure 6-2).

Figure 6-2. Crop map for Pinto Lake catchment, year 2014



Source Data:
California Department of Water Resources
Crop Mapping vector digital data, 2014
Pepared by Land IQ, LLC and provided to the
California Department of Water Resources

Hoop houses are an agricultural practice that is relatively common in the Pajaro Valley of Santa Cruz county. Hoop houses are white, cylindrical shaped canopies used to cover small green plants, such as cane berries. They are used to grow many of the cane berries in the Pinto Lake catchment. Many

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[98] Information available for State Water Resources Control Board's Geotracker information management system.

growers may choose to grow their cane berries under hoop houses because they decrease wind pressure, provide a more humid growing condition, and deliver a higher internal concentration of carbon dioxide to the plants[99].

University of California farm advisor Dr. Michael Cahn[100] reported that the plastic covering these hoop houses are typically removed in the wintertime. Thus, with no plastic covering the hoops during the rainy season, additional impervious surface is not added to the catchment during the wet season. Consequently, the use of hoop houses should not result in increased volume of runoff leaving the fields during the winter months. Generally, when the rain subsides the plastic is replaced. It should be noted that there might be a small fraction of growers that may put plastic on earlier to speed up growth of the plants. If there are late spring rains, this practice could lead to increased run-off. However, a majority of the growers do not use the plastic until the crop is at the flowering/fruiting stage.

Average annual nutrient and sediment loads delivered to surface waterbodies in the Pinto Lake catchment from irrigated cropland were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-9. These data indicate that cropland is estimated to be a significant source of nutrient and sediment loading to Pinto Lake.

Table 6-9. Estimated average annual watershed nutrient and sediment loads delievered to Pinto Lake from cropland runoff in the Pinto Lake catchment.

Source	P Load (lbs/yr)	N Load (lbs/yr)	Sediment Load (tons/yr)
Cropland runoff	650	4,430	1,000

6.6 Grazing Lands

Grazing lands, as defined by the Farm Mapping and Monitoring Program (FMMP) land cover dataset used in this report refers to lands where the vegetation is suitable for cattle foraging; it does not imply those lands are necessarily actively being grazed by livestock.

The only human activity associated with grazing lands that could conceivably contribute to nutrient loading to surface waterbodies is livestock grazing. Livestock and other domestic animals that spend significant periods of time in or near surface waters can contribute significant loads of nitrogen and phosphorus through their manure because they use only a portion of the nutrients fed to them and the remaining nutrients are excreted (Tetra Tech, 2004). The remainder of nutrients loads to streams from grazing lands is associated with natural background.

It is important to note that the Pajaro River basin (which includes the Pinto Lake catchment) is currently subject to a Domestic Animal Waste Discharge Prohibition and livestock owners are subject to compliance with an approved indicator bacteria TMDL load allocation. As a practical matter, implementation efforts of owners and operators of livestock and domestic animals to comply with this prohibition and with the indicator bacteria load allocations will also reduce the risk of nitrogen and phosphorus loading to surface waters from domestic animal waste.

Average annual nutrient and sediment loads delivered to surface waterbodies in the Pinto Lake catchment from grazing lands were estimated on the basis of the STEPL input parameters previously identified in Section 7.1 – these estimated loads are tabulated in Table 6-10. An uncertainty here is that these estimates may underestimate nutrient loading from domestic animals, because horses and

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[99] http://www.motherearthnews.com/diy/garden-yard/hoop-house-zm0z11zmat, accessed 5/5/2017.

[100] Personal communication with Dr. Michael Cahn, farm advisor, irrigation and water resources specialist, UC Cooperative Extension, April 28, 2017.

livestock may also be found on rural residential lands in the catchment not formally classified as grazing land by the FMMP dataset.

Table 6-10. Estimated average annual watershed nutrient and sediment loads delievered to Pinto Lake from grazing lands runoff in the Pinto Lake catchment.

Source	P Load (lbs/yr)	N Load (lbs/yr)	Sediment Load (tons/yr)
Grazing lands runoff	60	630	50

6.7 Septic Systems

In any given watershed, septic systems can locally be a source of nitrogen and phosphorus to groundwater and surface water resources. Thus, it can be important to consider septics as a source category in TMDL development. Worth noting is that septic in regulation and local ordinance are referred to as a type of onsite wastewater treatment system, thus the words “septic system” and “onsite wastewater treatment system” may be used interchangeably, depending on context.

According to the USEPA, the distribution and density of septic systems vary widely by region and by state[101]. Statewide, California has a relatively low distribution of its population served by septic systems – around 10 percent. In contrast, in the New England states, about half the population uses septic systems[102].

Previously, Figure 2-20 presented an estimated spatial distribution of septic systems in the Pinto Lake catchment. Based on the Census Bureau data presented previously in Section 2.6, we estimate about half the population living in the Pinto Lake catchment is served by septic systems. The majority of these households are located on the west side of Pinto Lake along Amesti Road, and in areas north of Pioneer Road.

Estimating nutrient loads to waterbodies from septic systems requires estimating the septic failure rate. A septic system that works properly allows the cleaning and treatment of household wastewater by naturally occurring soil organisms and bacteria before it reaches the groundwater. A septic failure occurs when the system or a component of the system threatens public health or the environment by inadequately treating wastewater. Failures can cause household wastewater to rise to the surface of the ground (“daylighting”), back up into the residence it serves, and/or be discharged to a surface water such as a ditch, creek, or lake.

A septic failure rate specific for the Pinto Lake area is not available. However, the County of Santa Cruz has reported septic failure rates in other parts of the county to be between 1% and 5% on an annual basis[103]. Therefore, we presume that a failure rate of 3% is reasonable to use for septic systems in Pinto Lake.

A conceptual understanding of the hydrogeologic setting of the septic systems on the west side of Pinto Lake is necessary. Figure 6-3 presents a stratigraphic interpretation of the shallow subsurface in residential areas on the west side of Pinto Lake[104]. Noteworthy is that most septic systems in this area are likely separated from deeper, water-saturated permeable aquifer sands by a thick (>15 feet) clay layer. It is thus generally unlikely that substantial amounts of septic effluent phosphorus could migrate

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[101] USEPA septic systems webpage, http://water.epa.gov/infrastructure/septic/FAQs.cfm#faq2

[102] *Ibid*

[103] Personal communication 2 May 2017 Mr. John Ricker, Program Manager, County of Santa Cruz Environmental Health Department.

[104] Our stratigraphic interpretation is based on soil boring logs publically available from the County of Santa Cruz.

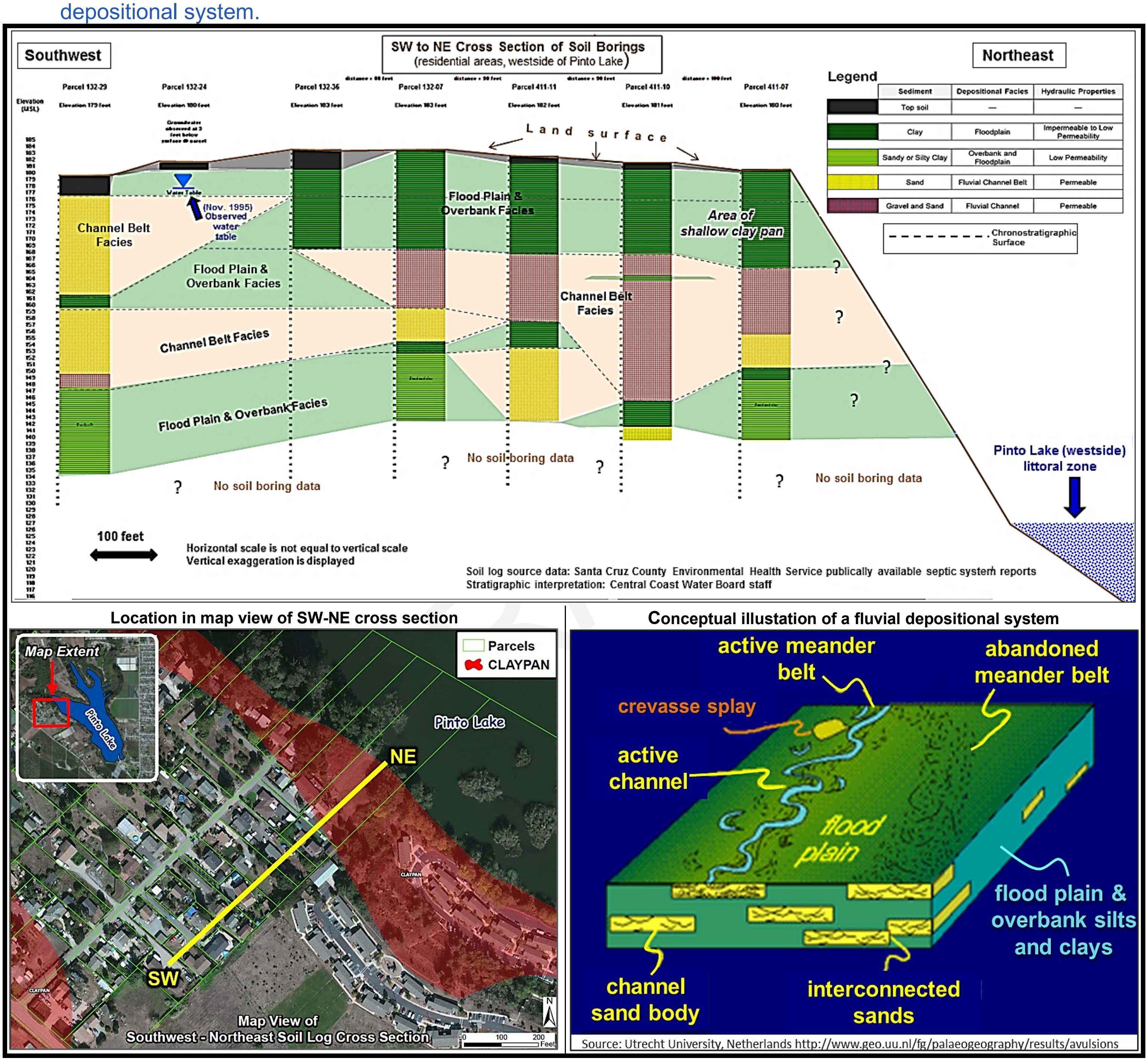
downward to the permeable layers and get into Pinto Lake via subsurface groundwater flows. Thus, to the extent there is a septic risk to Pinto Lake, one would expect it to be from daylighting effluent when it results in overland flow.

"*I would expect nutrient contribution (to Pinto Lake) from septic systems to* ***come from surface failures*** *as nutrients, particularly phosphate do not move that readily through clay soils. Although a number of systems do use deeper seepage pits that could get down into more permeable layers."*

➔ Mr. John Ricker, County of Santa Cruz Water Resources Division Director

(emphasis and parenthetical clarification added by Central Coast Water Board staff)

Figure 6-3. Stratigraphic interpretation of shallow subsurface (southwest-northeast cross section) of residential areas on the west side of Pinto Lake, an accompanying map showing the location of the cross section in map view, and a conceptual illustration in block model form of a fluvial (riverine and creek) depositional system.



Soil log source data: Santa Cruz County Environmental Health Service publically available septic system reports
Stratigraphic interpretation: Central Coast Water Board staff

Source: Utrecht University, Netherlands http://www.geo.uu.nl/fg/palaeogeography/results/avulsions

The County of Santa Cruz has an active surveillance and inspection program for household septic systems in the Pinto Lake catchment. At this time, there is significant uncertainty about the nature and scope of potential septic nutrient loading to Pinto Lake. The County of Santa Cruz reports that the last time they did an aerial surveillance, septic problems around Pinto Lake were not that widespread[105].

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[105] Personal communication, 7 July 2015, Mr. John Ricker, County of Santa Cruz Water Resources Division Director.

Limited amounts of water quality data in ditches from the Amesti Road area were not very high in phosphorus (<15 mg/l phosphate as phosphorus), although there were some observations of elevated nitrate (>1.5 mg/L nitrate as nitrogen)[106]. The County reports they are prepared to do more water quality testing and surveillance as appropriate.

We used the STEPL spreadsheet tool to estimate loads to Pinto Lake originating from septic discharges. Table 6-11 presents the loading estimates. Our estimates must be considered conservative (worst case scenario) approximations because we calculated loads from *all* septic systems in the lake catchment, not just septic systems in proximity to the lake. In reality, many septic systems located far from the lake (e.g. around and north of Pioneer Road (refer back to Figure 2-20 on page 44) likely would not be expected to contribute nutrient loads to the lake due to fate and transport considerations.

Worth noting here, the STEPL spreadsheet tool estimates an estimated average total phosphorus load of 17 pounds/year from the septic systems which are proximal to the lake in the Lakeside Areas subcatchment (refer back to subcatchments map of the Pinto Lake watershed in Figure 2-11 on page 30). Most of the homes on septic systems in the Pinto Lake catchment are actually located in the Pinto Lake mainstem subcatchment, in a residential cluster of homes south of Pioneer Road and located a considerable distance from the lake (see Figure 2-20 on 44). About half of the nutrient loads calculated in the STEPL spreadsheet tool are attributable to this residential cluster. Due to the distance from the lake (~1 mile), there is uncertainty about the impact from to the lake from these residential septics source.

Table 6-11. Estimated average annual watershed nutrient loads (lbs./year) delievered to surface waterbodies from onsite wastewater treatment systems (e.g., septic systems) in the Pinto Lake catchment.

Source	Total phosphorus load (lbs/yr)	Total nitrogen load (lbs/yr)
Septic systems in Pinto Lake catchment[A]	150	390

[A] The majority of houses on septic systems in the Pinto Lake catchment occur in a residential cluster south of Pioneer Road in the Pinto Creek mainstem subcatchment, a considerable distance from the lake (see Figure 2-20 on page 44). About half of the nutrient loads (84 lbs./yr.) calculated in the STEPL spreadsheet tool are attributable to this residential cluster. Due to the distance from the lake (~1 mile), there is uncertainty about the impact to the lake from this residential area septics source.

6.8 Undeveloped Areas and Woodlands

Streams in lightly disturbed or undeveloped woodlands and open space are generally characterized by low concentrations of nutrients in surface waters on the basis of regional data previously presented in Section 2.8, and on the basis of water quality data collected from undeveloped stream basins across the conterminous United States – see Table 6-12. Thus, surface waters and surface runoff from woodland and undeveloped upland areas of the Pinto Lake catchment would be expected to have quite low nutrient concentrations relative to other types of land use categories which are more influenced by human activities.

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[106] Personal communication, 8 July 2015, Mr. John Ricker, County of Santa Cruz Water Resources Division Director.

Table 6-12. Mean annual flow-weighted nutrient concentrations observed in streams in undeveloped basins of the conterminous United States.

Water Quality Parameter	No. of sampled streams	Arithmetic Mean	Min	25%	50% (median)	75%	90%	Max	No. Exceeding Drinking Water Standard (>10 mg/L)	% Samples Exceeding 10 mg/L
Nitrate as N	82	0.15	0.00	0.03	0.09	0.20	0.44	0.77	0 of 82	0%
Total nitrogen	63	0.39	0.10	0.17	0.25	0.50	0.72	2.57	N.A.	N.A.
Total phosphorus	63	0.04	0.02	0.02	0.02	0.04	0.08	0.20	N.A.	N.A.

Source data: Clark et al. (2000). Nutrient Concentrations and Yields in Undeveloped Basins of the United States.

Average annual nutrient and sediment loads delivered to surface waterbodies in the Pinto Lake catchment from undeveloped areas and woodlands were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-13.

Table 6-13. Estimated average annual nutrient and sediment loads delievered to Pinto Lake from undeveloped areas and woodlands runoff in the Pinto Lake catchment.

Source	P Load (lbs/yr)	N Load (lbs/yr)	Sediment Load (tons/yr)
Undeveloped areas and woodlands	100	250	23

6.9 Wetlands

There are about 85 acres of wetlands in the Pinto Lake catchment. Wetlands are an important part of the landscape and can serve as sinks, sources, and transformers of nutrients, largely dependent on local ecosystem biogeochemistry (Reddy et al., 2010). Wetlands can enhance and protect water quality by removing nitrogen, phosphorus, sediment, and pesticides. On balance, restoration of degraded wetlands has been shown to be beneficial for nutrient uptake and capture (California State University, Monterey Bay and Resource Conservation District of Santa Cruz County, 2013).

However, wetlands can be a net contributors of nutrients depending on localized hydrologic and environmental conditions. One scientific peer reviewer for this TMDL project noted that older wetlands can be a source of phosphorus, while a second peer reviewer for this TMDL project noted that, in general our assumption of negligile contribution from Pinto Lake wetlands is reasonable.

Consequently, it is important to recognize that healthy, functioning wetlands in the Pinto Lake catchment may provide important environmental benefits, including but not limited to water quality protection. Indeed, a local resource professional informed us that the extensive wetlands around lower Pinto Creek likely act to filter pollutants, therefore reducing sediment and nutrient loads to the lake from Pinto Creek (oral communication, October 4, 2016, Jackie McCloud, City of Watsonville, Environmental Projects Manager).

Based on the aforementioned information, in this TMDL report we presume that average annual nutrient loads to Pinto Lake from wetlands are relatively negligible and do not contribute to phosphorus-driven water quality problems and cyanobacteria blooms in the lake.

In fact, restoration of degraded wetlands – if and where needed – could improve their capacity to act as nutrient and sediment sinks. Researchers have suggested that an inventory and study of the condition of existing Pinto Lake watershed wetland and riparian resources, and measures needed to restore them is recommended (California State University, Monterey Bay and Resource Conservation District of Santa Cruz County, 2013).

6.10 Shallow Groundwater

Shallow groundwater can flow into lakes and streams and can locally be a substantial source of surface water especially during low flow conditions or during the dry season. Phosphorus in groundwater is generally expected to result from leaching of geologic materials in the subsurface. Nitrogen in groundwater can occur from both leaching of anthropogenic sources at the land surface, and from natural sources. Report Section 2.10 addresses shallow groundwater in the Pinto Lake catchment in more detail.

Controllable, anthropogenic phosphorus leaching to groundwater is presumed to be relatively negligible in this TMDL report; phosphorus readily binds to sediment, is relatively insoluble, and is generally not expected to be leached to groundwater from surface sources in substantial amounts. However, it should be recognized that soils have a finite capacity to store phosphorus, and once the capacity of soil to adsorb phosphorus is exceeded, the excess will dissolve and move more freely with water either towards a surface waterbody or downward to an aquifer.

Average annual nutrient loads delivered to Pinto Lake from shallow groundwater were estimated on the basis of the STEPL input parameters previously identified in Section 6.1 – these estimated loads are tabulated in Table 6-14. These estimates suggest that phosphorus loads from groundwater to Pinto Lake are relatively negligible compared to other sources of phosphorus.

Table 6-14. Estimated average annual nutrient loads delievered to Pinto Lake from groundwater inflow.

Source	Total phosphorus load (lbs/yr)	Total nitrogen load (lbs/yr)
Shallow groundwater inflow to lake	22	560

6.11 Direct Atmospheric Deposition

Atmospheric inputs of nutrients in rainfall are a source of loading in any watershed. Because nitrogen can exist as a gaseous phase (while phosphorus cannot), nitrogen is more prone to atmospheric transport and deposition. Phosphorus associated with fine-grained airborne particulate matter can also exist in the atmosphere (USEPA, 1999a). Atmospheric deposition also occurs on the land surfaces throughout any given watershed and these loads could ultimately be transported to a waterbody if entrained in runoff. These loads would be considered part of the ambient background load, in contrast to the direct atmospheric deposition onto the lake surface being addressed here.

Atmospheric deposition of nitrogen to Pinto Lake was previously addressed in more detail in report Section 2.9.

The STEPL spreadsheet model staff used in source analysis does not estimate atmospheric inputs of nutrients to surface waterbodies. Consequently, staff used available information on atmospheric nutrient loading and lake morphology to develop estimates independent of the STEPL spreadsheet (see Table 6-15).

Atmospheric phosphorus can be found in organic and inorganic dust particles. The general atmospheric deposition rate for total phosphorus can be estimated as 0.6 kg of phosphorus/ha/year (USEPA 1994, as reported in San Diego Regional Water Quality Control Board, 2006).

A tabular summary of the estimates for nutrient atmospheric deposition in Pinto Lake based on the aforementioned information is presented in Table 6-16. In general, we consider direct atmospheric deposition to be a non-controllable source load outside the scope of feasible source control within the Pinto Lake catchment. To our knowledge, the Central Coast Water Board has not contemplated regulation of atmospheric loads of nutrients at watershed-scales. Therefore, at this time, we are not recommending any regulatory measures addressing this source category.

Table 6-15. Nutrient direct atmospheric deposition on Pinto Lake: parameters considered and used.

Parameters Considered	Estimates
Estimated surface area of Pinto Lake	104 acres, or 42 hectares[A]
Estimated average annual atmospheric deposition rate of total nitrogen to streams in the Pajaro River basin	9.0 kg/hectare per year
Estimated average annual atmospheric deposition rate of total phosphorus to streams in the Pajaro River basin	0.6 kg/hectare per year

[A] See Table 2-9 on page 38.

Table 6-16. Estimated average annual nutrient loads delievered to Pinto Lake from direct atmospheric deposition.

Source	Total phosphorus load (lbs/yr)	Total nitrogen load (lbs/yr)
Direct atmospheric deposition	55	830

6.12 Internal Lake Loading

A substantial amount of phosphorus loading to Pinto Lake originates from lake-bottom sediment which contain in-situ reservoirs of sediment-bound phosphorus. Internal lake loading of phosphorus has previously been assessed by researchers from California State University-Monterey Bay, the City of Watsonville, and the Resource Conservation District of Santa Cruz County.

In this report, we rely on the internal lake loading quantified and reported by these researchers (see Text Box 6-1) .

Text Box 6-1. Internal lake loading estimates provided to the Central Coast Water Board.

Internal Lake Loading

“Low dissolved oxygen conditions found during the summer significantly increase the release of sediment-bound phosphorus into the water column. This process is called internal loading and in many lakes is a significant source of nutrients. To evaluate internal loading at Pinto Lake, sediment cores were collected from lake sediments and incubated to estimate nutrient flux. Based on the flux tests, it is estimated that 1,100 – 2,645 pounds of phosphorus (total) is released to the water column by lake sediments on an annual basis. This release of phosphorus from sediments is most likely exacerbated by the sediment mixing activities of benthivorous fishes (such as carp) and invertebrates.”

➔ Pinto Lake Total Maximum Daily Load Planning and Assessment Project (April 2013). Clean Water Act 319 NPS-SWRCB Grant Agreement #10-443-553-02 Final Report. Prepared by Robert Ketley City of Watsonville Public Works, Arianne Rettinger Resource Conservation District of Santa Cruz County, and Marc los Huertos California State University Monterey Bay.

Table 6-17 presents tabular summary of estimates for annual loads to Pinto Lake derived from phosphorus released from lake bottom sediments, based on the 2013 grant-funded study noted above. These estimates indicate that internal loading from phosphorus associated with lake bottom sediments is the largest single source of phosphorus to Pinto Lake. Worth noting here is that one peer reviewer for this TMDL project stated that these internal loads may be underestimated, while a second peer reviewer stated that the internal flux rate is generally supported by mass balance calculation. While there is undoubtedly uncertainty associate with the stakeholder-derived estimates for internal loading, at this time we maintain the estimates are adequate to begin to support TMDL adoption and implementation.

Table 6-17. Estimated average annual phosphorus loads delievered to Pinto Lake from internal lake loading.

Source	Minimum estimated total phosphorus load (lbs/yr)	Average estimated total phosphorus load (lbs/yr)	Maximum estimated total phosphorus load (lbs/yr)
Internal lake loading from lake bottom sediments	1,100	1,900	2,645

6.13 Source Analysis Summary

Dr. Thomas Johengen, Ph.D., University of Michigan, a peer reviewer for this TMDL project, stated that our source analysis estimates of nutrient yields from agricultural lands in the Pinto Lake catchment is reasonable, though generally higher than estimates he is familiar with from the agricultural Maumee River watershed in the Midwest. Dr. Dale M. Robertson , U.S. Geological Survey a peer reviewer for this TMDL project, stated that the STEPL spreadsheet model can over-estimate downstream loading unless instream decay is incorporated. Indeed, we used guidance from the STEPL TetraTech helpdesk consultant to incorporate downstream attenuation of nutrients in our STEPL estimates.

Table 6-18 presents a summary of nutrient source categories and estimated annual watershed nutrient and sediment loads to the Pinto Lake catchment, rounded to two significant figures owing to uncertainties. These estimates indicate that internal loading from phosphorus associated with lake bottom sediments is the largest single source of phosphorus to Pinto Lake. Cultivated cropland and residential area runoff constitute major sources of nutrients from the watershed to the lake. Septic systems may be a significant load of nutrients to the watershed, however most of the septic watershed nutrient load is attributable to a residential cluster of homes south of Pioneer Road in the Pinto Creek mainstem subcatchment and located up to about one mile northwest of Pinto Lake. Due to the distance from the lake (~1 mile), there is uncertainty about the impact to the lake from these residential septics. Lakeside homes along Amesti Road may be a relatively small source of nutrient pollution to the lake.

Table 6-18. Estimated average annual watershed nutrient and sediment source loads to the Pinto Lake catchment on the basis of recent vintage land use and water quality data compiled in this report.

Sources	Total phosphorus load (lbs/yr)	Total nitrogen load (lbs/yr)	Sediment Load (tons/yr)
Urban and residential runoff	150	920	20
Industrial facility runoff	50	not assessed insufficient data	not assessed insufficient data
Cropland	650	4,430	1,000
Grazing land and pasture	60	630	50
Onsite Wastewater Treatment Systems (septic systems)	150	390	not applicable
Undeveloped areas and woodlands	100	250	23
Wetlands	presumed negligible	presumed negligible	presumed negligible
Shallow groundwater	22	560	not applicable

Direct atmospheric Deposition	55	830	not assessed insufficient data
Internal lake loading from lake bottom sediments	1,900 (average) 1,100 to 2,645 (range)	Not assessed	not applicable
Estimated average annual total load	3,100 (based on average value for internal lake loading)	8,000 (watershed load only, internal loading from lake bottom sediments not assessed)	1,100 minimum (not all sources assessed)

7 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

7.1 Existing Loading & Loading Capacity

Loading capacity: The greatest amount of loading that a water can receive without violating water quality standards.

➔ Code of Federal Regulations, 40 CFR Part 130 § 130.2(f).

The purpose of this section is to present estimates of the existing phosphorus loads to Pinto Lake and the lake's loading capacity. The loading capacity (also called assimilative capacity) is the greatest amount of a pollutant that a waterbody can assimilate and still meet water quality standards [CFR §130.2(f)].

In Report Sections 7.1.1 and 7.1.2, we will present two approaches for assessing the estimated loading capacity of Pinto Lake. A weight of evidence approach, which combinses two or more methodologies for assessing loading capacity, are anticipated to provide a final loading capacity of greater scientific validity. The remainder of this section presents supporting and supplemental information associated with assessments of the loading capacity of Pinto Lake

In general, harmful algal bloom and cyanobacteria problems in lakes nationwide are due to phosphorus. There are a few nitrogen-limited lakes in the nation, but most lake management programs across the United States focus on phosphorus control (personal communication January 2017, Dr. John C. Holz, limnologist at HAB Aquatic Solutions, LLC). The idea in reducing phosphorus loading is to make phosphorus limiting, and the way to do that is to reduce phosphorus inputs even if they are not currently limiting productivity in the lake.

There is no loading capacity per se for nuisance aquatic plants, cyanobacteria, or their associated toxins. The algae and cyanobacteria simply grow in response to favorable conditions and nutrient availability. As such, the watershed management focus of this TMDL is phosphorus control. This includes identifying existing loading conditions and plausible load reductions from controllable source categories necessary to improve water quality to an acceptable level and reduce the frequency and toxicity of cyanobacteria blooms.

As reported previously, university researchers and local public agencies have analyzed Pinto Lake water quality and bloom toxicity data and determined that phosphorus is the principal driver of Pinto's toxic cyanobacteria blooms. The largest source of phosphorus loading to the lake is internal and comes from lake bottom sediments. Seasonal runoff from the watershed also contributes nutrients to Pinto Lake.

In general, the loading capacity of a pollutant is equal to the TMDL for a waterbody – both concepts (loading capacity – TMDL) represent the maximum amount of pollution a waterbody can receive and still meet water quality standards. The TMDL itself however represents a mathematical equation – it is the summation of the point source and nonpoint source pollutant loads, natural background loads, and any margin of safety deemed necessary which collectively add up to the total allowable load (loading capacity).

While there is no prescribed or required methods for impaired waters analysis and TMDL development in California, staff must nonetheless identify a technical rationale and supporting documentation for the recommended regulatory action (State Water Board, 2005). Text Box 7-1 presents relevant USEPA guidance concerning the range of acceptable techniques to identify loading capacity and quantify TMDLs are presented below:

Text Box 7-1. USEPA guidance concerning the range of acceptable techniques to identify a waterbody's loading capacity and quantifying its total maximum daily load.

- TMDLs are developed using a range of techniques, from simple mass balance calculations to complex water quality modeling approaches (USEPA TDML webpage accessed August 2019).
- USEPA guidance states that selection of the appropriate method for determining loads is based on the complexity of the problem, the availability of resources, time constraints, the availability of monitoring data, and the management objectives under consideration (USEPA, 1999b).
- Simple methods can be used to support an assessment of the relative significance of difference sources, and to guide decisions for management plans (USEPA, 1997).

With the above USEPA guidance in mind, we chose an appropriate technique to identify loading capacity and total maximum daily load commensurate with time constraints, resources, and taking into account current conditions at Pinto Lake as follows.

Recent vintage data show reduced phosphorus loading to the lake, and a significant decrease in the duration and severity algal blooms. Most data compilation and data analysis for this TMDL occurred in 2017 and relied largely on pre-2015 data. However, as shown in recent vintage water quality monitoring data taken subsequent to implementation of management practices and lake alum treatment, it appears that significant progress towards attaining water quality goals is being made, and many water quality goals are being achieved at this time. Post alum treatment results show dramatic decreases in in-lake phosphorus loadings, as well as a significant decrease in the duration and severity of the fall microcystin toxicity (see Figure 7-1).

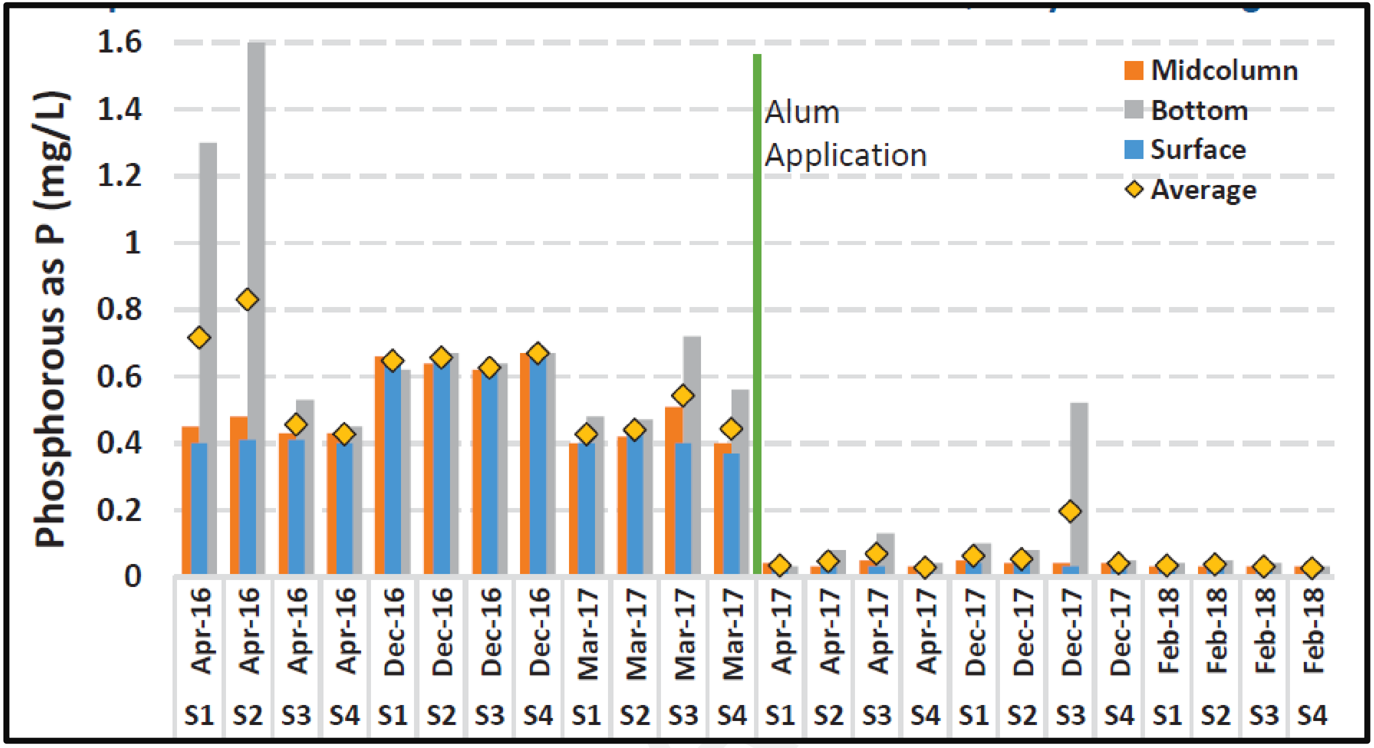
> *"Post alum treatment results show dramatic decreases in in-lake phosphorus loadings, as well as a significant decrease in the duration and severity of the fall microcystin toxicity."*
>
> *"Due to the shorter toxic conditions, the City only had to close the lake for approximately three weeks in fall 2017 as opposed to the approximately three months in the previous fall 2016."*
>
> *"The average microcystin concentration post alum treatment was 1.27 ppb, which is a 98% reduction in concentration."*
>
> ➔ *Pinto Lake Restoration Project Final Report, 31 May 2018. Clean Water Act 319(h) NPS Implementation Grant Program, Agreement number 14-424-253. Prepared by City of Watsonville, Resource Conservation District of Santa Cruz County, and other stakeholders (City of Watsonville at al., 2018)*

Additionally, informal reporting from City of Watsonville through the fall of 2018 also appeared to show a sustained decrease in the duration and severity of microcystin toxicity compared to water quality results taken prior to the 2017 lake alum treatment (data source: weekly sampling results, communicated weekly by City of Watsonville staff to Central Coast Water Board staff via email).

The Central Coast Water Board web-published a summary fact sheet in 2018 detailing the water quality improvements being observed at Pinto Lake subsequent to the alum treatment project.

Additional information on recent watershed improvement activities at Pinto Lake is documented in Section 4.14 of the report entitled *Draft Implementation Strategy Report for Pinto Lake (August 2018)* developed as supplementary document supporting this TMDL report.

Figure 7-1. Recent water quality improvements at Pinto Lake: graph showing phosphorus concentrations at four Pinto Lake water quality monitoring sites spanning the time fram pre-alum application to post-alum application.



In light of the forgoing information, we maintain the recent and substantial improvements in TMDL water quality goals at Pinto Lake render the need for time and resource intensive water quality modeling unnecessary based on current lake conditions. This is consistent with USEPA guidance previously highlighted in Text Box 7-1. TMDLs do not preclude for the possibility of future studies, revisions, modifications, and updates. The Central Coast Water Board will consider future work and supplemental studies on Pinto Lake in the future, as warranted.

Report Sections 7.1.1 and 7.1.2 below outline two approaches for assessing the estimated loading capacity of Pinto Lake.

7.1.1 Steady-State Mass Balance-Volumetric Approach

Steady-state approaches rely on the assumption of conservation of mass into a waterbody. USEPA identifies a simple mass balance approach in which lake volume can be multiplied by a target pollutant concentration define an allowable loading capacity for the lake.

> “To calculate the TMDL, the target concentration can simply be multiplied by the lake volume and an appropriate conversion factor, resulting in an allowable in-lake monthly load. A mass balance calculation could then be used to identify the allowable incoming watershed load, after subtracting out the losses (e.g., settling, uptake, outflow).”
>
> - USEPA (2007). Options for the Expression of Daily Loads in TMDLs.

A steady-state, mass balance-volumetric approach as outlined by USEPA above can result in substantial uncertainties, particularly in the absence of data concerning loses to lake outflow. At this time we do not have sufficient data to be able to model a robust nutrient budget. A robust nutrient budget accounts for all sources and sinks of nutrients in a lake system by quantifying external loading, outflow rates; this includes surface water and groundwater inflows, and nutrient loses due to lake outflow, evaporation, and settling.

Nonetheless, while we are unable to develop a robust nutrient budget model at this time it worth noting that the USEPA-approved Central Coast Water Board's mercury TMDL for Hernandez Reservoir used a simple volumetric approach to estimate the reservoirs loading capacity.

In developing our assessment of existing loading and loading capacity, we first considered stakeholder-derived estimates for existing total phosphorus loading and stakeholder-derived management goals for total phosphorus reduction. Stakeholder water quality management goals can be considered as a baseline for comparison with water quality goals developed in this TMDL report.

Text Box 7-2 presents stakeholder-defined management goals (source: City of Watsonville et al. 2018). The outcome of these management goals is intended to reduce the frequency and toxicity of cyanobacteria blooms, evaluated by concentration of microcystins.

Text Box 7-2. Stakeholder-derived water quality management goals for Pinto Lake used to support development of this TMDL report (source: City of Watsonville et al., 2018).

1. Reduce 50% of the sediment bound phosphorus load from the watershed over the course of the useful life of the selected sediment control practices.
2. Reduce internal loading of phosphorus in Pinto Lake by 80%.

Table 7-1 presents estimates for stakeholder-derived loading capacity and percent reduction from existing load to reach the loading capacity.

Table 7-1. Stakeholder-dervied existing loading and desired load reduction goals. This table shows existing total phosphorus load in Pinto Lake, target load, and load reduction objectives based on stakeholder-defined water quality management goals (source: City of Watsonville et al., 2018).

Nutrient Source Category	Stakeholder-derived estimated average existing average annual total phosphorus load (lbs./yr.)	Stakeholder-derived Target phosphorus load (Loading capacity) (lbs./yr.)	Load reduction (lbs./yr.)	Percentage reduction to achieve target loading capacity
Internal lake loading from lake bottom sediment	1,500	380	1,520	80%
Watershed runoff load	420	210	210	50%
Summary totals	**2,320**	**590**	**1,730**	**50 to 80%**

Table 7-2 presents our estimated inputs of annual source loads of total phosphorus to Pinto Lake based on data within this report. It is important to be aware that these source inputs do not represent a lake nutrient budget, as they do not account for phosphorus losses due to sinks and outflow from the lake.

Table 7-2. Water Board-derived estimated average annual source load inputs of total phosphorsus to Pinto Lake (derived from Table 6-18). Reported here to two significant figures. It is important to be aware that these source inputs do not represent a lake nutrient budget, as they do not account for phosphorus losses due to outflow from the lake.

Source Load Categories	Existing Annual Total Phosphorus Source Load Inputs to Pinto Lake (pounds per year)
External load from the watershed	1,100
Internal load from sediment flux	1,500
External load from shallow groundwater inflow	20
Load from direct atmospheric deposition	60
Total estimated average annual load	2,700

Table 7-3 represents the total annual phosphorus loading to Pinto Lake. This includes 1) nutrient loading from the surrounding watershed (external loading); 2) nutrient loading from internal nutrient flux from the sediments (internal loading); and 3) accounts for phosphorus losses due to outflow from the lake. While we do not have outflow data necessary for a robust nutrient lake budget, we attempted to make first order approximation of Pinto Lake outflow by analogy to a nearby waterbody. College Lake is a seasonal lake located 1.5 miles southeast of Pinto Lake. In the wet season when the lake is inundated it is similar in hydrologic scale to Pinto Lake (size in acres, and inflows in acre-ft. per year). College Lake is reported to have a potential outflow of 300 acre feet per year (PVWMA, 2016). We use the College Lake outflow as an analogy and a first-order approximation of what surface water outflow from Pinto Lake is anticipated to be.

Our estimate of existing annual phosphorus loading to Pinto Lake is about 20 percent higher than stake-holder derived estimates. We consider this a reasonable deviation from the stakeholder estimate; it is not clear if the stakeholder-derived estimate accounts for outflow and nutrient losses from the lake, and the stakeholder estimate appears to be limited to surface water inputs from three major tributaries. This would naturally result in a lower estimate of loading than the approach we took in this report. While recognizing the differences in the aforementioned estimates and the uncertainties involved, we consider there to be reasonably good agreement between our loading estimates and load reduction estimates and those derived by stakeholders.

Table 7-3. Estimated phosphorus mass balance for Pinto Lake, on the basis of volumentric estimates, outflow estimates, and with a comparison to stakeholder derived managment objective for loading capacity. Due to uncertainties we report values to two significant figures.

	Tributary Creeks Estimated Inflow to Pinto Lake (acre-ft.)	Estimated Total Annual Load Inputs to Pinto Lake (lbs.)	Estimated Surface Water Outflow from Pinto Lake (acre-ft.)	Estimated Annual Load Discharged in Outflow from Lake (lbs.)	Remaining Load into the Lake (load inputs minus load discharged in outflow)	Stakeholder-derived Loading Capacity for Pinto Lake (lbs./year)	Percent Load Reduction to Achieve Stake-Holder Derived Loading Capacity
Total Phosphorus	1,100	2,700 sediment flux ~ 1,500 watershed load ~ 1,100	300	130	2,570	590	77%

7.1.2 California NNE BATHTUB Spreadsheet Model Approach

We supplement the mass balance-volumetric steady-state approach outlined in the previous section with the California BATHTUB Lake Model Tool. The California BATHTUB approach allows us to use secondary factors such as chlorophyll, Secchi depth, and cyanobacteria concentrations to define allowable phosphorus loading.

The California BATHTUB Tool was developed by Tetra Tech. for California State Water Resource Control Board to analyze water quality response in lakes and reservoirs to different nutrient loading scenarios. This model was selected to supplement our loading capacity analysis for Pinto Lake because it is an effective tool for predicting growing season lake response to nutrient loading scenarios.

The objective of the California BATHTUB model spreadsheet tool application is to establish screening level nutrient loading targets for lakes and reservoirs by estimating algal response to nutrients while accounting for hydraulic residence time, light availability, and other key variables. The program performs water and nutrient balance calculations in a steady-state, spatially-segmented hydraulic network that accounts for advective transport, diffusion, and nutrient sedimentation.

Mass balances are computed in BATHTUB at steady state over an appropriate averaging period. Steady-state approximation means that only seasonal or annual average loads and conditions are simulated, although the loads and conditions may change from year to year. In other words, the model does not represent day-to-day changes in flow, loads, or nutrient concentrations. Although this approach represents a compromise, it has proven effective in practice.

The tool is a Microsoft Excel spreadsheet, and is intended to be a simple but effective tool for predicting growing season chlorophyll a lake response to a number of inputs. The tool also allows the user to specify a chlorophyll a target and predicts the probability that current conditions will exceed the target, as well as showing allowable N and P loading combinations necessary 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 Secchi depth. TetraTech reports this spreadsheet tool is appropriate for smaller lakes.

The loading capacity of nutrients for Pinto Lake depends on numeric targets and mass loadings from both external and internal sources. We used California BATHTUB model to calculate loading capacity for the lake. The model performs water and nutrient balance calculations under steady-state conditions. the NNE model accounts for outflow indirectly by using inflow and lake volume to calculate residence time. This calculation assumes a constant volume, so that inflow is equal to outflow. The California BATHTUB tool is not a dynamic model so it is not able to evaluate a change in storage

The California BATHTUB spreadsheet tool allows the user to input physical, chemical, and biological parameters. The input parameters are listed below.

- “Lake Volume”
- “Surface Area”
- “Mixed Depth”
- “Net Evap-Precip Rate”
- “Secchi Depth at Typical Chl a”
- “Typical Chl a”
- “P Load”
- “N Load”
- “Ortho P”

- “Inorg N”
- “Inflow”
- “Chl a Target”

BATHTUB model output is an N-P Frontier. The N-P Frontier is a range of nitrogen and phosphorus loads at which a desired chlorophyll target will be met. Below, we outline the BATHTUB model set up for Pinto Lake.

BATHTUB model inputs

Lake Volume: 1.25 106 m3. This value is from in Table 2-9 of the Total Maximum Daily Load for Phosphorus to Address Cyanobacteria Blooms in Pinto Lake, Santa Cruz County, California (TMDL). It was determined by volumetric analysis.

Surface Area: 420064 m2. This value is from in Table 2-9 of the TMDL. It was determined by volumetric analysis.

Mixed Depth: 3 m. This value is from Figure 2-7 of the TMDL. It was provided by stakeholder input (CSUMB and RCD of Santa Cruz County, 2013).

Net Evap-Precip Rate: 14 in./year. This value is from visual interpretation of NOAA climate prediction graphs (NOAA 2020a, 2020b). These graphs feature a low-resolution, national spatial scale. A more precise estimate may be possible using local weather station data. It is unknown if there are local evaporation rate data for the Pinto Lake area.

Secchi Depth at Typical Chl a: 0.52 m. This value was calculated from an equation relating secchi depth to chlorophyll concentration (Lorenzen 1980). The equation was:

$$Z\_SD=(-\ln(0.20))/(\alpha-\beta C)$$

where is Z_SD is sechi depth, α is the light extinction coefficient not due to chlorophyll, β is the light extinction coefficient due to chlorophyll, and C is chlorophyll concentration. In waters with high chlorophyll concentrations (> 40 ug/l) that would otherwise be clear the effects of α on secchi depth are negligible. The α parameter was dropped from the equation since the typical chlorophyll concentration of Pinto Lake was determined to be sufficiently high (153 ug/l). The value for β (0.02) was published with the equation (Lorenzen 1980).An alternative method of estimating secchi depth at the typical chlorophyll concentration would be to use secchi depth data provided by the City of Watsonville. This data was collected only at the Pinto Lake Dock site and do represent the general condition of the lake. Nor were they paired with chlorophyll data so they cannot be used to estimate the chlorophyll-secchi depth relationship directly. These data were used to compute the average growing season secchi depth of 0.81 m at the Pinto Lake Dock site for the years 2014--2016 (pre-alum treatment). The average chlorophyll concentration at the Pinto Lake Dock site was 53.99 ug/l. Using this value as input for the equation gives an estimated secchi depth 1.49 m.

Typical Chl a: 150 ug/l. This value was calculated as an average of averages. Data were collected at three sites: PNTO1s (n = 12), PNTO2s (n = 12), and Pinto Lake Dock (n = 282). Values were averaged by site and then the site averages were averaged to account for imbalanced sample sizes. "Typical" is assumed to mean the average growing season value. Based on seasonal trends of increasing chlorophyll a concentrations, and frequency of cyanobacteria blooms in Pinto Lake, we define growing season for purposes of modeling to is assumed to be June—November. Due to uncertainty we rounded to two significant figures.

P Load: 1500 kg. This value if from Table 6-18 of the TMDL. Due to uncertainty, we rounded to two significant figures. External loading was estimated by source analysis. Internal loading was provided by stakeholder input (Ketley et al, 2013). “P Load” was assumed to refer to annual load of total phosphorus.

N Load: 9700 kg. This value was calculated from Table 6-18 of the TMDL. Due to uncertainty, we rounded to two significant figures. External loading was estimated by source analysis. The proportion of internal loading to total load for N was assumed to be the same as for P (0.61). This assumption was tested by reviewing published proportions of internal to total loading for N (0.67) and P (0.68) (Lai 2008). “N Load” was assumed to refer to annual load of total nitrogen.

Ortho P: 887 kg. This value was calculated as a proportion of P Load. The proportion (0.63) was assumed to be the same as the proportion of average concentrations of ortho P (0.18 mg/l) to total P (0.28 mg/l). Average concentrations were calculated using data from Pinto Lake Dock, Amesti Creek, CCC Creek, Pinto Creek, and Todos Santos Creek due to the relative abundance of data from and the broad spatial distribution of these sites. Values were averaged by site and then the site averages were averaged to account for imbalanced sample sizes. It was assumed that averaging concentration data from the lake inlets and outlet would compensate for the lack of data from middle portions of lake itself. “Ortho P” was assumed to refer to annual load of orthophosphate.

Inorg N: 8394 kg. This value was calculated using the same methodology as Ortho P above. The proportion of inorganic N to total N (0.87) was assumed to be the same as the proportion of average concentrations of inorganic N (2.21 mg/l) to total N (2.56 mg/l). It was assumed that “Inorg N” referred to annual load of inorganic N and that inorganic N was the sum of nitrate and ammonia.

Inflow: 2.0 hm^3. This value was calculated as the sum of annual runoff estimates of Amesti, CCC, Pinto, and Todos Santos Creeks shown in Table 2-7 of the TMDL. Due to substantial uncertainty concerning inflow to the lake , we rounded to one significant figure. This does not include volume of precipitation captured directly or baseflow.

Chl a Targets: 25 ug/l. This is a target for the growing season, which we define as June to November. In general, wet season Chl a concentrations are expected to be lower than in the growing season. This 25 ug/l threshold is a USEPA developed guideline the applies broadly to ecoregion III lakes (see Report section 2.8).

Calibration

The model generates estimated values for four variables that can be checked against observed values. Calibration factors for these variables were adjusted by trial and error until the estimated values approximated the observed values.

Growing Season Average Chl a. This estimate was checked against the Typcial Chl a value of 153 ug/l and was adjusted by a "Chlororphyll a (Kc)" calibration factor of 2.6.

Predicted Median Secchi Depth. This estimate was checked against the Secchi Depth at Typical Chl a value of 0.52 m and was adjusted by a "Secchi Depth (Ks)" calibration factor of 2.

Growing Season P Conc. This estimate was checked against mean growing season P concentration (0.21 mg/l). P concentration was calculated using a similar method as for the concentrations calculated for “Ortho P” except that only data collected during the growing season was used. “P Conc.” was assumed to refer to total P concentration. This estimate was adjusted by a "Phosphorus (Kp)" calibration factor of 1.

Growing Season N Conc. This estimate was checked against mean growing season N concentration (2.62 mg/l). This value was calculated by the same method as for “Growing Season P Conc”. Only data from Pinto Lake Dock and CCC creek were used because there were no data collected during the growing season for total N from Amesti, Pinto, or Todos Santos Creeks. “N Conc.” was assumed to refer to total N concentration. This estimate is adjusted by a "Nitrogen (Kn)" calibration factor of 1.

Uncertainties

This BATHTUB model has dataset requirements which could not be rigorously met due to lack of data. Data for some model inputs were not available so estimates were used instead. Spatial and temporal imbalances in the dataset were partially compensated for by site averaging. These measures introduce uncertainty. There is substantial uncertainty with the accuracy and precision of the resulting N-P frontier as a consequence of these data gaps.

California BATHTUB Spreadsheet Model Output

The resulting N-P Frontiers (Table 7-4) predict ranges of N-P load combinations which are expected to meet a cyanobacteria bloom season (June through November) chlorophyll *a* target concentration of 25 mcg/l. Based on this N-P frontier, we identify a proposed loading capacity for phosphorus of 200 pounds which should meet the chlorophyll a target at a total nitrogen:total phosphorus ratio of about ten. We chose this loading capacity threshold from the N-P frontier because an TN:TP ratio of around ten is reasonable for Pinto Lake and other lakes in ecoregion III (refer back to Section 2.8). Higher allowable loads identified on the BATHTUB N-P frontier (310 to 490 pounds of phosphorus) occur at very low TN:TP ratios of between 3.6 and 5.7; these are nutrient ratio conditions we do not generally expect are reasonable or achievable in ecoregion III lakes.

Table 7-4. California BATHTUB spreadsheet model nitrogen-phosphorus (N-P) frontier for Pinto Lake. This is a range of allowable annual N-P loading to meet an identfied chlorophyll *a* target during the dry season (June through November) of 25 mcg/L. Due to uncertainties inherent in the modeling input, loads are shown here to two significant figures.

Total Phosphorus (pounds TP)	Total Nitrogen (pounds TN)	TN:TP ratio	Chlorophyll *a* target (growing season)
LFL (light or flow limited)	LFL (light or flow limited)	Not applicable	25 mcg/L
90	3700	42.2	25 mcg/L
130	2000	15.2	25 mcg/L
200	1800	9.2	25 mcg/L
220	1800	8.2	25 mcg/L
310	1800	5.7	25 mcg/L
490	1700	3.6	25 mcg/L

Identification of a plausible loading capacity requires synthesizing information about the existing input loads to the lake, comparing it to the loading capacity, and estimating a percent reduction from existing load to achieve the loading capacity. Table 7-5 presents information about source input loads to Pinto Lake based on information previously provided in this report. Table 7-6 presents estimated annual total phosphorus load, loading capacity, and percent phosphorus reduction required based on California BATHTUB modeling and data provided within this report.

Based on the information provided in Table 7-6 we estimate phosphorus load reductions of up to 90 percent may be needed to achieve the lakes loading capacity. This should be considered a worst-case scenario, since we are applying conservative assumption in developing this TMDL and for establishing a margin of safety. Actual load reductions to achieve water quality standards and restore the lake to an acceptable condition may be less than identified here.

Table 7-5. Estimated average annual source load inputs of total phosphorsus to Pinto Lake (derived from Table 6-18) . Reported here to two significant figures. It is important to be aware that these source inputs do not represent a lake nutrient budget, as they do not account for phosphorus losses due to outflow from the lake.

Source Load Categories	Existing Annual Total Phosphorus Source Load Inputs to Pinto Lake (pounds per year)
External load from the watershed	1,100
Internal load from sediment flux	1,500
External load from shallow groundwater inflow	20
Load from direct atmospheric deposition	60
Total estimated average annual load	2,700

Table 7-6. Estimated annual total phosphorus load, loading capacity, and percent phosphorus reduction required based on California BATHTUB modeling and data provided within this report.

	Tributary Creeks Estimated Inflow to Pinto Lake (acre-ft.)	Estimated Total Annual Load Inputs to Pinto Lake (lbs.)	Estimated Surface Water Outflow from Pinto Lake (acre-ft.)	Estimated Annual Load Discharged in Outflow from Lake (lbs.)	Remaining Load into the Lake (load from inflow minus load in outflow)	Loading Capacity of Pinto Lake (BATHTUB Model)	Percent Reduction Required
Total Phosphorus	1,100	2,700 sediment flux ~ 1,500 watershed load ~ 1,100	300	130	2,570	200	~90%

7.2 TMDL and Allocations

Key Terms

TMDL: *The sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background. TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.*

➔ *Code of Federal Regulations, 40 CFR Part 130 § 130.2(i).*

Wasteload allocation: *The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution.*

➔ *Code of Federal Regulations, 40 CFR Part 130 § 130.2(h).*

Load allocation: *The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished.*

➔ *Code of Federal Regulations, 40 CFR Part 130 § 130.2(g).*

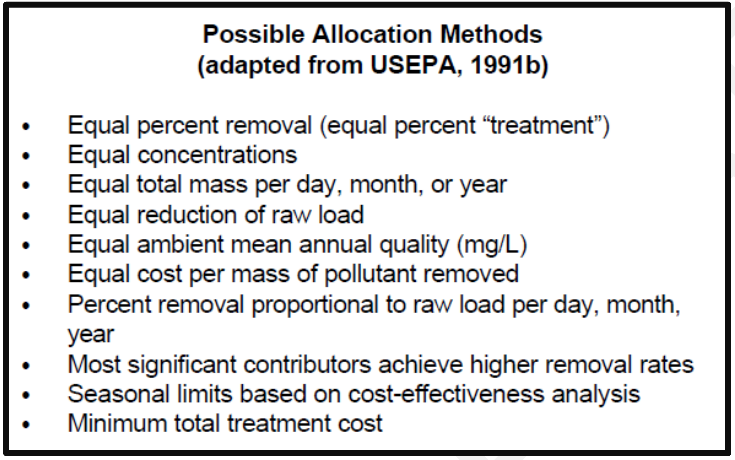
TMDLs are often expressed as maximum daily loads. However, as specified in 40 CFR 130.2(I), TMDLs may be expressed in other terms when appropriate. For this case, the TMDL is expressed in terms of allowable annual loadings of phosphorus because the growth of phytoplankton and macrophytes responds to changes in annual rather than daily loadings of nutrients. University researchers and local agencies have identified phosphorus loading as the primary driver of nuisance cyanobacteria blooms in Pinto Lake, therefore this TMDL identifies the major watershed improvement effort should be directed towards phosphorus control. This phosphorus-control management goal is expressed here as a TMDL and source pollutant allocations based on phosphorus. A target goal of 200 pounds of total phosphorus loading to the lake based on BATHTUB modeling was previously identified in Section 7.1.2.

Although there are many ways to express the distribution of the maximum allowable pollutant load, the concept of allocation is central to the TMDL process because it reinforces the importance of identifying what sources need to be addressed to eliminate the impairment.

Load-based allocations (e.g., allowable loads or needed load reductions per unit of time) are a required element of the TMDL submittal. The allocations provide a framework for identifying the specific source reduction levels needed to address individual sources, categories of sources, or subcategories of sources.

There are many ways to distribute pollutant allocations for the source categories identified in a TMDL. Figure 7-2 presents a range of possible allocation methods recommended by USEPA.

Figure 7-2. Possible allocation methods recommended by USEPA (source: USEPA, 1999b).



Possible Allocation Methods
(adapted from USEPA, 1991b)

- Equal percent removal (equal percent "treatment")
- Equal concentrations
- Equal total mass per day, month, or year
- Equal reduction of raw load
- Equal ambient mean annual quality (mg/L)
- Equal cost per mass of pollutant removed
- Percent removal proportional to raw load per day, month, year
- Most significant contributors achieve higher removal rates
- Seasonal limits based on cost-effectiveness analysis
- Minimum total treatment cost

For this TMDL, we recommend an allocation method that relies on an equal percent removal scheme, while also recognizing that higher rates of removal are warranted for the most significant contributor of pollutant loads to the lake. The highest contributor of phosphorus loads to Pinto Lake, and the source requiring the most intensive and focused effort at control, is the internal phosphorus loading to the water column from lake bed sediments. With these objectives in mind, Table 7-7 presents the proposed phosphorus-based allocation distribution intended to address nuisance cyanobacteria blooms in Pinto Lake.

Lastly, In TMDLs the allocation component does not identify specific implementation measures; those measures are identified in the implementation plan (see the report entitled *Draft Implementation Strategy Report for Pinto* Lake dated August 2018 and developed as supplementary document supporting this TMDL report).

Table 7-7. Phosphorus-based allocations to address nuisance cyanobacteria blooms in Pinto Lake.

Phosphorus Source	**Current total phosphorus loading[1] (pounds per year.)**	**Target total phosphorus load allocation (pounds per year)**	**% reduction**
− Waste Load Allocations −	-	-	-
Urban stormwater-runoff	130	20	85%
Industrial facility stormwater-runoff	45	7	85%
− Load Allocations −	-	-	-
Cropland/Irrigated Lands	580	87	85%
Grazing land and pasture	50	8	85%
Onsite Wastewater Treatment Systems (septic systems)	130	20	85%
Undeveloped areas and woodlands	90	14	85%[2]
Wetlands	Presumed negligible	-	Not applicable
Shallow groundwater	20	3	85%[2]
Direct atmospheric deposition	45	45	Not applicable[3]
Internal lake loading from lake bottom sediments	1,300	41	~99% (achieve via alum treatment)
Total	2,400	200	

[1] These are total phosphorus loads which account for input loads minus loads lost from outflow (derived from Table 7-6).

[1] Background loads which are not directly controllable through an existing regulatory program. Load reductions are anticipated to be achieved via ongoing nonregulatory actions (such as grant funded projects), and through peripheral benefits provided by implementation associated with core regulatory programs.

[3] Direct atmospheric deposition on the lake is considered a natural background source for which there is no feasible regulatory or non-regulatory approach to reduce loading at this time.

7.2.1 Alternative Pollutant Load Expressions to Facilitate TMDL Implementation

The phosphorus-based waste load allocations and load allocations outlined above are based on conservative assumptions, as outlined previously, and subject to uncertainty. As such, Central Coast Water Board staff recommend supplemental and alternative indicators to indicate progress towards, and achievement of the TMDLs. USEPA guidance provides that TMDL submissions may include alternate pollutant load expressions in order to facilitate implementation of the applicable water quality standards (USEPA, 2006). The recommended secondary, alternative TMDL load expressions are articulated below in Text Box 7-1.

Text Box 7-3. Alternative TMDL pollutant load expressions to facillitate implementation.

Attaining receiving water TMDL secondary numeric targets for nutrient-response indicators (i.e., dissolved oxygen water quality objectives, chlorophyll a targets and microcystin targets) in Pinto Lake **may constitute a demonstration of attainment of the phosphorus-based load allocations identified in report section 7.2. Secondary numeric targets are identified in report Section 5.**

7.2.2 Antidegradation Requirements

It is important to emphasize that state water quality standards are subject to antidegradation requirements, as previously outlined in report Section 3.3. State and federal antidegradation policies require, in part, that where surface waters are of higher quality than necessary to protect beneficial uses, the high quality of those waters must be maintained unless otherwise provided by the policies. Therefore, antidegradation requirements are a component of every water quality standard. Text Box 7-4 articulated antidegradation expectations for this TMDL.

Text Box 7-4. Antidegradation expectations for the Pinto Lake phosphorus TMDL.

Wherever the existing quality of water in a stream reach, lake, or waterbody are better than necessary* to support the designated beneficial uses, that water quality shall be maintained and protected, unless and until warranted pursuant to provisions in federal and state antidegradation policies (See Section II.A, Anti-degradation Policy in the Central Coast Basin Plan)

* *this means water quality is better-lower than the numeric water quality objective/criteria*

7.3 Margin of Safety

The Clean Water Act and federal regulations require that TMDLs provide an explicit and/or implicit margin of safety (MOS) to account for uncertainty concerning the relationship between pollution controls and water quality responses (see 40 CFR 130.7(c)(1)). An explicit MOS can be provided by reserving (i.e., not allocating) part of the TMDL, thus requiring greater source load reductions. An implicit MOS can be provided by conservative assumptions in the TMDL analysis.

There are some uncertainties associated in the Pinto Lake Nutrient TMDL. There are uncertainties regarding the inherent seasonal and annual variability in delivery of phosphorus and nitrogen for external sources and nutrient cycling within the lake. Due to the uncertainty, we selected conservative numeric targets by establishing the targets under a critical lake volume when nutrient concentrations would be increased.

Likewise, conservative assumptions were made when developing the loading and allocations, by assuming a constant value for internal loading. These conservative approaches address the MOS requirement for TMDLs.

7.4 Linkage Analysis

The goal of the linkage analysis is to establish a link between pollutant loads and water quality. This, in turn, supports that the loading capacity specified in the TMDLs will result in attaining the numeric target. The linkage analysis therefore represents the critical quantitative link between the TMDL and attainment of the water quality standards.

The proposed TMDLs will result in the attainment of the general toxicity water quality objective, and therefore the restoration of applicable beneficial uses of waterbodies in the TMDL project area. This is because the numeric targets are set equal to the nutrient water quality objectives, expressed as concentrations of nutrients that will prevent aquatic plant and algal nuisance in flowing waters. The numeric targets are used directly to calculate the loading capacity (TMDLs). Requiring the responsible parties for nitrogen compounds and orthophosphate loading to reduce nitrate discharges to the numeric water quality objectives and targets will establish a direct link between the TMDL targets and sources.

If the biostimulatory substances water quality objective changes in the future (i.e., from a narrative objective to a numeric objective), the numeric targets would be equal to the new water quality objectives, and a new loading capacity would be calculated to meet the new numeric targets.

7.5 Critical Conditions & Seasonal Variation

According to State Water Board guidance[107], TMDL reports must include a consideration of critical conditions and seasonal factors. Critical conditions represent a description of when and under what conditions the impairment occurs. Specifically, the evaluation of temporal patterns in water quality data can provide substantial insight because the analysis identifies the times of greatest impairment and because many of the factors affecting critical conditions exhibit seasonal variations (e.g., flow and weather conditions, and source activity).

Due to the wet and dry weather seasons in central coastal California, the external watershed nutrient loads to Pinto Lake is expected to generally occur during storm water runoff events associated with the winter and spring months. During the dry season the lake is expected to receive relatively little external watershed loading.

The internal loading of nutrients from sediments can provide a source of nutrients to the lake water column year round. However, it should be noted that substantial releases of sediment-bound phosphorus from the lake sediments to the water column is generally associated with seasonal, hydrologic, and biogeochemical conditions which are more prevalent in the late summer to early fall months, as described previously in report Section 2.3 and Figure 2-6 on page 25 and Figure 2-7 on page 26, and as reported by CSUMB and RCD of Santa Cruz County (2013) .

Considering the critical conditions when developing the TMDL provides assurance that even under critical water quality conditions, water quality objectives will be met as the TMDL is implemented. The critical condition for the attainment of beneficial uses at Pinto Lake occurs during the summer and early fall months, mostly commonly from August to late October. Development of a toxic cyanobacterial blooms in Pinto Lake have been documented with cyanobacterial cell densities and the concentration of microcystin increasing in the warm summer and autumn months. In this period, together with the seasonal increase in temperature and sunlight, there were levels of phosphorus and nitrogen sufficient to promote the development of the toxic cyanobacterial blooms. In the summer and early fall there is the release of nutrients from the sediments. At the same time, there is very little water inflow and decreased lake level due to evaporation. These seasonal variations cause increased nutrient concentrations. During the dry periods, when there is no external loading to the lake, the internal recycling of nutrients is the most important source of nutrient loading and the driver of eutrophic conditions such as algal blooms.

The Pinto Lake nutrient TMDL accounts for seasonal and critical conditions of the summer months by assigning a load allocation to the lake sediments and requiring load reductions from watershed sources of nutrients to the lake. This will help to alleviate the source of nutrients during the critical summer and early fall months. For loading estimation, our lake volumetric analysis is based on a digital lake polygon that comports reasonably well with areal lake extent for late summer conditions. Therefore, our volumetric analysis should reasonably approximate a critical condition, when lake levels, water volume, and loading capacity are near their annual minimum.

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[107] State of California, S.B. 469 TMDL Guidance: A Process for Addressing Impaired Waters in California, June 2005. Approved by Resolution 2005-0050.

8 PUBLIC PARTICIPATION

Public outreach and public involvement are a part of TMDL development and the state's basin planning process. Moreover, the U.S. Environmental Protection Agency encourages and expects the states to engage the public in the development of TMDL projects.

> *"EPA supports public engagement in the state's listing of impaired water bodies and TMDL process….EPA policy is to afford the public a chance to provide input and to ensure all viewpoints and suggestions are considered. Entities such as landowners, watershed or environmental organizations, homeowners associations, local businesses, citizen advocates and others all have unique perspectives. Local citizens sometimes know more about what is happening in their watersheds than state agencies, and this knowledge can be a valuable aspect in listing decisions and TMDL development."*
>
> ➔ USEPA "Impaired Waters and TMDLs: Public Participation" (webpage accessed August 2017)

Published U.S. Environmental Protection Agency guidance (USEPA, 2000) states that, among other things, the public's role in the TMDL development process can be to:

- Provide data and information and work with the state in the TMDL development process.
- Review and comment on a proposed TMDL.
- Provide independent analysis to the state. Stakeholders are not simply limited to review and comment on state work.
- Attend public TMDL meetings to become informed and to provide oral feedback.
- Contact state staff by correspondence or phone communication at any time during the TMDL development process with questions, comments, and feedback.

Our public engagement process included regular TMDL updates, progress reports, scheduled public meetings, and solicitation of public feedback via our stakeholder email subscription list consisting of over 175 stakeholders. These stakeholders represented a wide range of interests, including agricultural interests, local residents, public agencies, environmental groups, local businesses, researchers, local resource professionals, and others. Sections 8.1 through 8.4 below outline additional details concerning on our public engagement process.

8.1 Public Meetings and CEQA Scoping Workshop

Central Coast Water Board staff engaged with stakeholders during the development of the TMDL through email correspondence and telephone contact. Central Coast Water Board staff engaged with the following individuals and entities during public workshops or during TMDL development:

- Agricultural consultants, including Grower Shipper Association
- California Department of Fish and Wildlife
- Central Coast Water Quality Preservation, Inc.
- City of Watsonville staff
- County of Santa Cruz staff
- Driscoll's berry farms
- Friends of Pinto Lake
- Other individuals and local residents interested in Pinto Lake water quality
- Pajaro Valley Water Management Agency staff
- Pinto Lake 319(h) grant Technical Advisory Committee
    - City of Watsonville staff
    - HAB Aquatics
    - Robert Ketley
    - Santa Cruz County staff
    - UC Santa Cruz

- Representatives of commercial farms, nurseries, and ranches
- Researchers affiliated with California State University, Monterey Bay
    - Scott Blanco
    - Dr. Marc Los Huertos
    - Erin Stanfield
- Santa Cruz Resource Conservation District staff
- Sun-Land Garden Products
- U.S. Department of Agriculture, Natural Resources Conservation Service staff
- U.S. Environmental Protection Agency staff
- UC Davis

We conducted a public workshop in the City of Watsonville on July 22, 2014. The goal of this workshop was to present some background information on TMDLs and water quality in Pinto Lake, engage and inform stakeholders, and solicit input, questions, and comments.

The California Environmental Quality Act (CEQA) requires staff to conduct a scoping meeting[108] when drafting any water quality control plan amendments. The purpose of a scoping meeting is to seek input from public agencies and members of the public on the range of project actions, alternatives, reasonably foreseeable means of compliance, significant impacts to be analyzed, cumulative impacts if any, and mitigation measures. On May 5, 2015, staff emailed a notice that we would be holding a CEQA scoping meeting on June 2, 2015. Attached to that notice, we distributed a *Scoping Document* and *Fact Sheet* to provide stakeholders with some information about the project in advance of the meeting. Additionally, stakeholders were also invited to provide written comments if they were unable to attend the meeting in person. Staff conducted a stakeholder scoping meeting on June 2, 2015. During the meeting, staff addressed questions and comments from attendees.
Placeholder text: Make sure to insert public workshop we will hold before the Board meeting.

8.2 Stakeholder Data Solicitation

The USEPA encourages that we solicit data and information from local agencies and other stakeholders. Consequently, we sent a data solicitation request to all stakeholders via email on August 2, 2015. In the data solicitation email, we informed stakeholders they could voluntarily submit data to us to support TMDL development for Pinto Lake. We appreciate City of Watsonville staff, Dr. Raphe Kudela (UC Santa Cruz), Scott Blanco and Erin Stanfield (CSUMB), and the County of Santa Cruz staff for providing data we used during TMDL development.

8.3 Progress Reports and Information Sharing

One of our objectives for this TMDL project was to keep stakeholders abreast of our progress throughout the development of the project. We periodically posted interim TMDL progress reports on the Central Coast Water Board’s website with the intent of sharing our progress with stakeholders as we moved forward with TMDL development. We posted these interim progress reports on our website in April 2015, November 2015, and April 2017.

In addition, we periodically posted supplementary information on the Pinto Lake TMDL project page and sent out via emails and information regarding funding opportunities, information on health and scientific topics concerning cyanobacteria, information on potential lake management measures aimed at reducing nutrient pollution, and information concerning opportunities for technical assistance.

8.4 Public Review and Comment Period

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[108] California Code Regulations, Title 23, Division 3, Chapter 27, Article 1 § 3775.5; Public Resources Code 21083.9.

Placeholder text: Central Coast Water Board staff's efforts to inform and involve the public included a public comment period. The staff report, resolution, basin plan amendment, and TMDL report were made available for a 45-day public comment period commencing on **DATE.** This provided interested parties an opportunity to provide comment prior to any Central Coast Water Board hearing regarding these TMDLs. Staff solicited public comments from a wide range of stakeholders including owners/operators of agricultural operations, representatives of the agricultural industry, representatives of environmental groups, academic researchers and resource professionals, representatives of local, state, and federal agencies, representatives of city and county stormwater programs, representatives of NPDES–permitted ~~industrial and construction~~ facilities, ranchers and representatives of the livestock industry, representatives of Native American tribal groups, representatives of environmental justice groups, and other individuals and groups interested in the water quality of streams in the Pinto Lake catchment.

Central Coast Water Board staff received X comment letters from:

Placeholder text: The public comments received and Central Coast Water Board staff responses are included in in the documentation of this TMDL project. Central Coast Water Board staff appreciates the comments provided by these interested parties. Some of the comments prompted us to clarify and improve information and narrative in the TMDL project documents.

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