California Regional Water Quality Control Board
Central Coast Region

TMDL PROGRESS REPORT

Pajaro River Basin:
River Basin Setting and Water Quality Standards

Draft Progress Report

to support

Development of Total Maximum Daily Loads
For Nutrients in Streams of the Pajaro River Basin

March, 2014

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This document is a draft work in progress, please do not reference or cite.

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PREFACE

The purpose of this progress report is to present information on the river basin setting and water quality standards for the Pajaro River Basin which will support the development of nutrient total maximum daily loads (TMDLs) for streams of the river basin. This document is a draft work in progress; please do not reference or cite.

1 INTRODUCTION

1.1 Clean Water Act Section 303(d)

Section 303(d) of the federal Clean Water Act requires every state to evaluate its waterbodies, and maintain a list of waters that are considered "impaired" either because the water exceeds water quality standards or does not achieve its designated use. For each water on the Central Coast's "303(d) Impaired Waters List", the California 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 which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

The State 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. In addition to creating this list of waterbodies not meeting water quality standards, the Clean Water Act mandates each state to develop Total Maximum Daily Loads (TMDLs) for each waterbody listed. Simply put, TMDLs are strategies or plans to address and rectify impaired waters identified on the federal Clean Water Act section 303(d) list. The Central Coast Regional Water Quality Control 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 the Porter-Cologne Water Quality Control Act §13242.

1.2 Pollutants Addressed and Their Environmental Impacts

The pollutants addressed in this TMDL are nitrate, low dissolved oxygen, and chlorophyll *a*. In addition, to protect waters from biostimulatory substances, orthophosphate is included as a pollutant. Nitrate pollution of both surface waters and groundwater has long been recognized as a problem in parts of the Pajaro River Basin. While nitrogen fertilizer inputs are essential for maintaining the economic viability of agriculture worldwide, elevated levels of nitrate can degrade municipal and domestic water supply, groundwater, and also can impair freshwater aquatic habitat. Some streams in the Pajaro River Basin frequently have exceeded the water quality objective for nitrate in drinking water therefore do not support designated drinking water supply (MUN) beneficial uses and may be impaired for designated groundwater recharge (GWR) beneficial uses[1]. The Water Quality Control Plan for the Central Coast Region, 2011 (Basin Plan) explicitly requires that the designated GWR beneficial use of streams be

[1] "Beneficial uses" is a regulatory term which refers to the legally-protected current, potential, or future designated uses of the waterbody. The Water Board is required by law to protect all designated beneficial uses.

maintained, in part, to protect the water quality of the underlying groundwater resources[2]. It is widely recognized by scientists and resource professionals that there is a critical need to continue to improve best management practices to reduce nitrogen releases to the environment from human activities, while maintaining the economic viability of farming operations (for example, Shaffer and Delgado, 2002).

Regarding nitrate-related health concerns, it has been well-established that infants below six months who are fed formula made with water containing nitrate in excess of the U.S. Environmental Protection Agency's safe drinking water standard (i.e., 10 milligrams of nitrate-N per liter) are at risk of becoming seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome, also known as methemoglobinemia.[3] The well-established linkage between nitrate and methemoglobinemia alone should be sufficient to warrant TMDL development. High nitrate levels may also affect the oxygen-carrying ability of the blood of pregnant women[4]. There is some evidence to suggest that exposure to nitrate in drinking water is associated with adverse reproductive outcomes such as intrauterine growth retardations and various birth defects such as anencephaly; however, the evidence is inconsistent (Manassaram et al., 2006). Additionally, some public health concerns have been raised about the linkage between nitrate and cancer. Some peer-reviewed epidemiological studies have suggested elevated nitrate in drinking water may be associated with elevated cancer risk (for example, Ward et al. 2010); however currently there is no strong evidence linking higher risk of cancer in humans to elevated nitrate in drinking water. Further research is recommended by scientists to confirm or refute the linkage between nitrates in drinking water supply and cancer.

Another water quality impairment addressed in this TMDL which is associated with nutrients is biostimulation. Biostimulation can result in eutrophication of the waterbody. While nutrients - specifically nitrogen and phosphorus – are essential for plant growth, and are ubiquitous in the environment, they are considered pollutants when they occur at levels which have adverse impacts on water quality; for example when they cause toxicity or eutrophication. Eutrophication is the excessive and undesirable growth of algae and aquatic plants that may be caused by excessive levels of nutrients. Eutrophication effects typically occur at somewhat lower nutrient concentrations than toxic effects. Either of these modes of water quality impairment 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.

In addition to detrimental impacts to aquatic habitat, algal blooms resulting from biostimulation may also constitute a potential health risk and public nuisance to humans, their pets, and to livestock. The majority of freshwater harmful algal blooms (HABs) reported in the United States and worldwide is due to one group of algae, cyanobacteria (CyanoHABs, or blue-green algae), although other groups of algae can be harmful (Worcester and Taberski, 2012). Possible health effects of exposure to blue-green algae blooms and their toxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects[5]. At high levels, exposure can result serious illness or death. These effects are not theoretical; worldwide animal poisonings and adverse human health effects have been reported by the World Health Organization (WHO, 1999). 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 blue-green algae. 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. Additionally, algal toxins have been implicated in the deaths of central California southern sea otters according to recent findings (Miller et al., 2010). Currently, there reportedly have been no confirmations of human deaths in the U.S. from exposure to algal toxins,

[2] See Basin Plan, Chapter 2 Beneficial Use Definitions, page II-19
[3] U.S. Environmental Protection Agency: http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm
[4] California Department of Public Health www.cdph.ca.gov/certlic/drinkingwater/Pages/Nitrate.aspx
[5] California Department of Public Health website http://www.cdph.ca.gov

however many people have become ill from exposure, and acute human poisoning is a distinct risk (source: Dr. Wayne Carmichael of the Wright State University-Department of Biological Sciences, as reported in NBC News, 2009).

Also noteworthy is that TMDL development intended to address nitrate pollution risks to human health and address degradation of aquatic habitat is consistent with the Water Board's highest identified priorities. The Water Board's two highest priority missions[6] (listed in priority order) are presented below:

Water Board Top Two Priorities (July 2012)
1) "Preventing and Correcting Threats to Human Health" ✓ *Nitrate contamination is by far the most widespread threat to human health in the central coast region* 2) "Preventing and Correcting Degradation of Aquatic Habitat" ✓ *"Including requirements for aquatic habitat protection in Total Maximum Daily Load Orders"*

The U.S. Environmental Protection Agency (USEPA) recently reported that nitrogen and phosphorus pollution, and the associated degradation of drinking and environmental water quality, has the potential to become one of the costliest and most challenging environmental problems the nation faces[7]. Over half of the nation's streams, including some steams in the Pajaro River Basin, have medium to high levels of nitrogen and phosphorus. According to USEPA, nitrate drinking water standard violations have doubled nationwide in eight years, and it has been widely demonstrated that drinking water supplies in the Pajaro River Basin have locally been substantially impacted by nitrate. Algal blooms, resulting from the biostimulatory effects of nutrients, are steadily on the rise nationwide; related toxins have potentially serious health and ecological effects. Placeholder text: Biostimulation of surface waters in the Pajaro River Basin are documented in this report; these water quality impairments may also be contributing to localized, episodic adverse downstream impacts to ecologically sensitive coastal and estuarine areas of the Monterey Bay National Marine Sactuary, as demonstrated by marine researchers.

1.3 Updating & Replacement of the 2005 Pajaro River Nitrate TMDL

Upon approval by the Office of Adminstration Law these TMDLs supercede and replace the TMDL *entitled "Pajaro River and Llagas Creek Total Maximum Daily Load for Nitrate"* which was approved by Resolution No. R3-2005-0131 on December 2, 2005 by California Regional Water Quality Control Board Central Coast Region, and subsequently approved by the U.S. Environmental Protection Agency on October 13, 2006. The 2005 Pajaro River nitrate TMDL addressed only nitrate surface water impairments for the drinking water supply beneficial use (MUN); the current TMDLs will update and supercede the 2005 nitrate TMDL by addressing nutrient-related impairments to all relevant designated beneficial uses of streams in the Pajaro River Basin.

1.4 A Note on Spatial Datasets & Scientific Certainty

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 TMDL project area. Spatial data of these types are routinely used 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

[6] See Staff Report for the July 11, 2012 Water Board meeting.
[7] U.S. Environmental Protection Agency: Memorandum from Acting Assisstant Administrator Nancy K. Stoner. March 16, 2011. Subject: "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions".

accurately render all local, real-time, or site-specific conditions. When reviewing TMDLs, the U.S. Environmental Protection Agency 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 are proposed to 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 U.S. Environmental Agency (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[8]. Conceptually, this issue is highlighted by reporting from the U.S. National Research Council as shown below:

> *"**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."*
>
> *From: 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)*

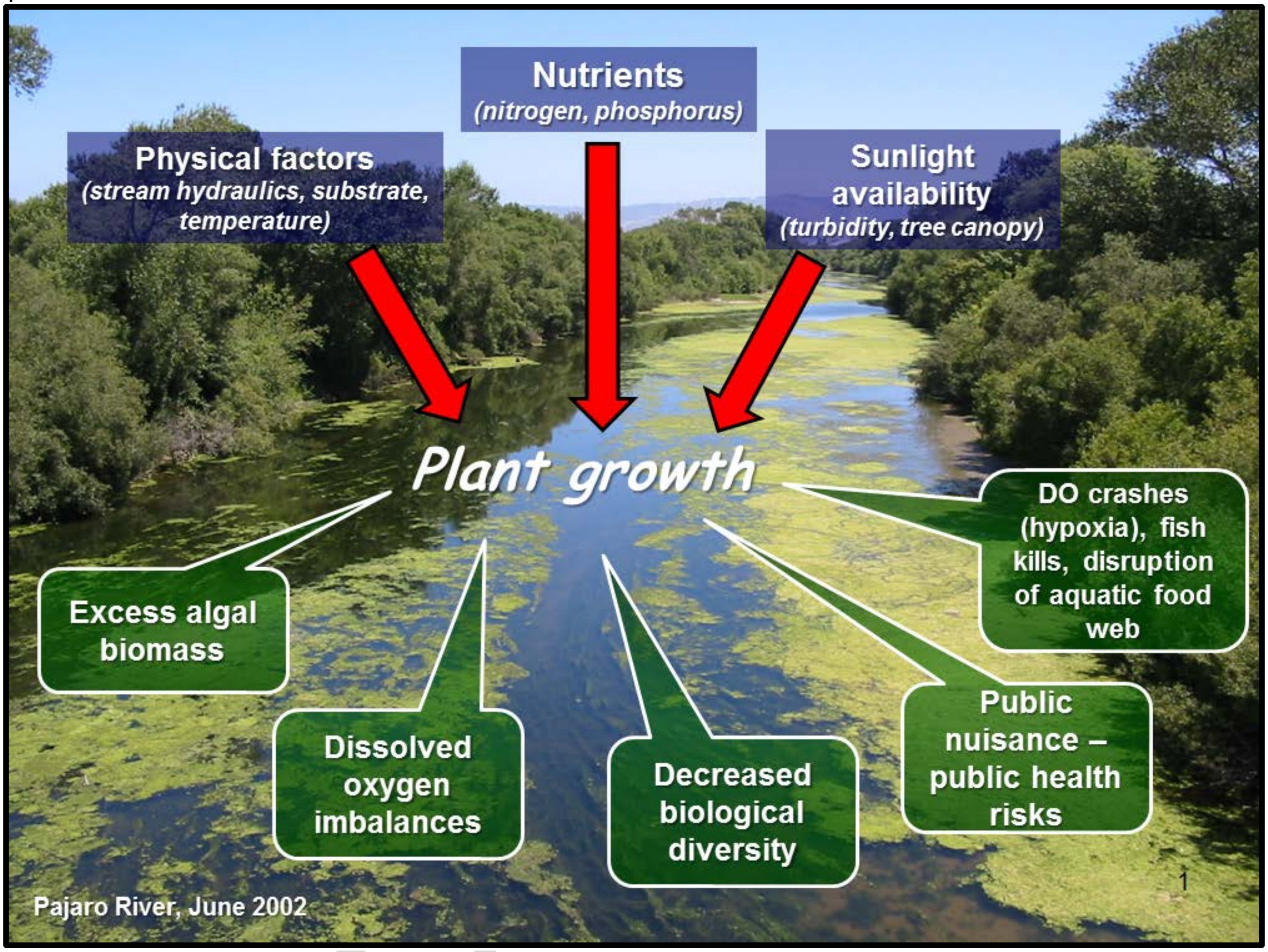
2 RIVER BASIN SETTING

2.1 Informational Background

Understanding and assessing variation in river basin characteristics can be important in the development of water quality criteria for nutrients. It is important to recognize that documenting high nitrogen and phosphorus concentrations is not sufficient in and of itself to demonstrate a risk of eutrophication. Research has demonstrated the shortcomings of using ambient nutrient concentrations within a waterbody alone to predict eutrophication, particularly in streams (TetraTech, 2006). TetraTech (2006) notes that except in extreme cases, nutrients alone do not impair beneficial uses. Rather, they cause indirect impacts through algal growth, low dissolved oxygen, etc., that impair uses. These impacts are associated with nutrients, but result from a combination of nutrients interacting with other physical and biological factors. Other factors that can combine with nutrient enrichment to contribute to biostimulatory effects include light availability (shading and tree canopy), stream hydraulics, geomorphology, geology, and other physical and biological attributes (see Figure 2-1).

[8] U.S. National Research Council − National Academies of Science, 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

Figure 2-1. Biostimulation (excessive aquatic plant growth) can result from a combination of contributing factors – and the consequences of biostimulation may include a cascade of detrimental environmental impacts.



As such, nutrient criteria need to be developed to account for natural variation existing at the regional and/or watershed-scale. To reiterate: nutrient water column concentration data by itself is generally not sufficient to evaluate biostimulatory conditions and develop numeric nutrient criteria. Waterbodies in the TMDL project area have substantial variation in stream hydraulics, stream morphology, tree canopy and other factors. Accordingly, the Project Report presents information on relevant physical and biological watershed characteristics for the TMDL project area that can potentially be important to consider with regard to development of nutrient criteria. Therefore, staff endeavored to characterize the river basin as fully as possible both to assist in development of defensible nutrient water quality criteria (where needed) and to assess natural inputs of nutrients in the watershed. The information and data on watershed conditions are presented in this section of the project report.

2.2 TMDL Project Area & Watershed Delineation

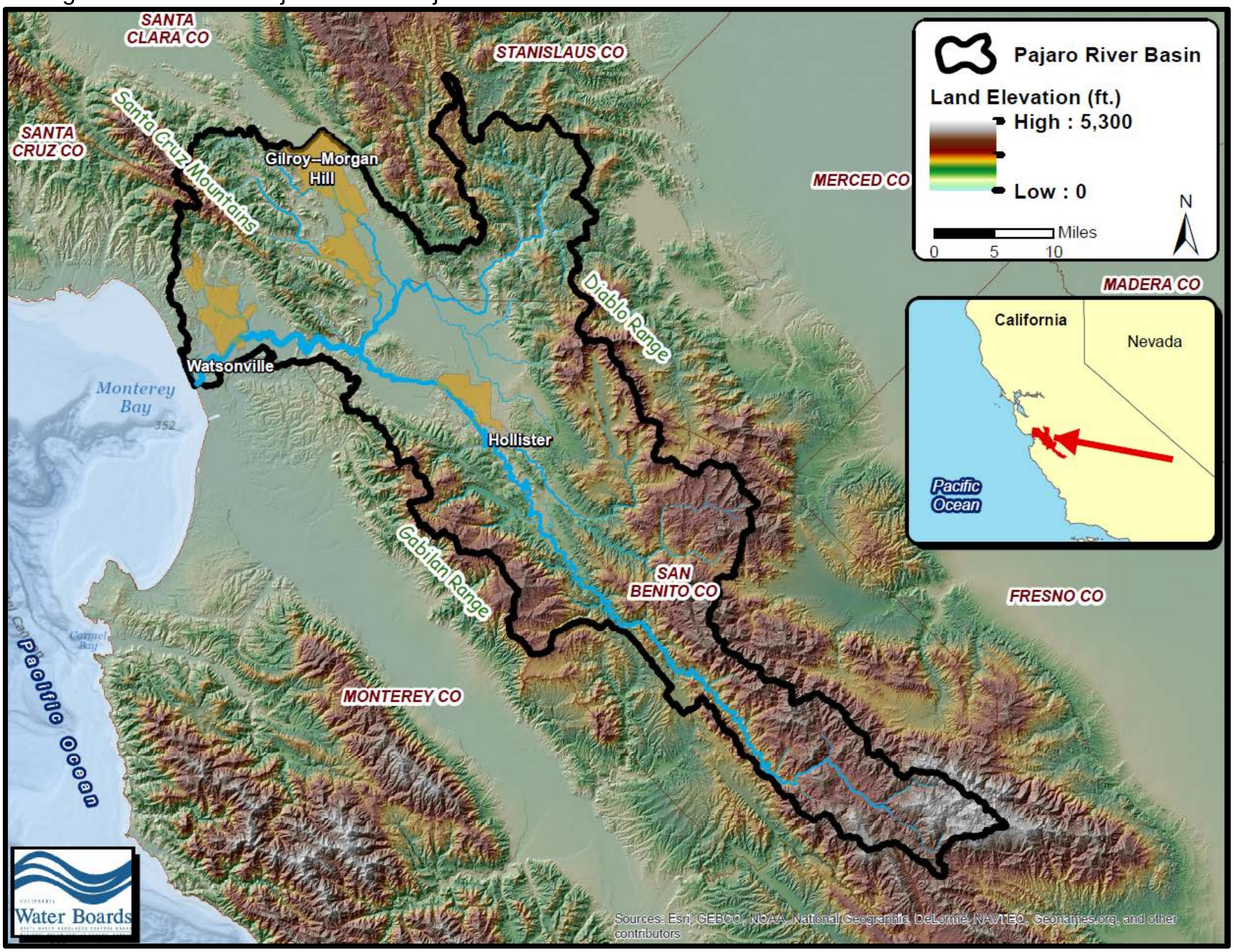
The geographic scope of this TMDL project[9] encompasses approximately 1,300 square miles of the Pajaro River Basin located in parts of Santa Clara, Santa Cruz, San Benito, and Monterey counties (see Figure 2-2). The Pajaro River mainstem begins just west of San Felipe Lake (also called Upper Soda

[9] In the context of this report, the terms “TMDL project area” and “Pajaro River Basin” are used interchangeably and refer to the same geographic area.

Lake) approximately 5 miles east-southeast of the city of Gilroy. From there, the Pajaro River flows west for 30 miles through south Santa Clara Valley, through the Chittenden Gap, past the city of Watsonville, and ultimately forming an estuary/lagoon system at the river mouth at the coastal confluence with Monterey Bay. A sand bar forms across the mouth of the Pajaro River in many years, and thus direct discharge into Monterey Bay occurs only episodically when the sand bar is breached. Major tributaries of the Pajaro River include the San Benito River, Pacheco Creek, Llagas Creek, Uvas Creek, and Corrilitos Creek.

Agriculture, including livestock grazing lands and cultivated crop land, is the current dominant human land use in the Pajaro River Basin. Urbanized land use comprises 4% of the river basin's land area. Undeveloped lands, including grassland, shrubland and forest also comprise substantial parts of the upland reaches of the river basin within an ecosystem characterized by oak woodland, annual grasslands, montane hardwood, and coastal scrub (source: National Land Cover Dataset, 2006; Calif. Dept. of Forestry and Fire Protection, 1977).

Figure 2-2. TMDL Project area – Pajaro River basin.



ESRI™ ArcMap® 10.1 was used to create watershed layers for the TMDL project area. Drainage boundaries of the TMDL project area can be delineated on the basis of the Watershed Boundary Dataset[10], which contain digital hydrologic unit boundary layers organized on the basis of 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.

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 heirachy used in this TMDL project[A].

Hydrologic Unit	**Drainage Area mi²** **(approx.)**	**Example(s)**	**Spatial Data Reference** **(USGS Hydrologic Unit Code shapefiles)**
Basin	≥ 1,000	Pajaro River Basin	HUC-8
Subbasin	> 250 to < 1,000	San Benito River Subbasin	2 or 3 HUC-10s [B] *(spatial dissolve)*
Watershed	~ 100 to ~ 250	Llagas Creek Watershed	HUC-10
Subwatershed	> 10 to < 100	Salsipuedes Creek Subwatershed	HUC-12
Catchment	~ 1 to < 10	Beach Road Ditch Catchment Tar Springs Creek Catchment	National Hydrography Dataset catchment shapefiles

[A] Based on adaptation from Jonathan Brant (Phd) and Gerald J. Kauffman, MPA, PE (2011) Water Resources and Environmental Depth Reference Manual for the Civil PE Exam.
[B] This is approximately equivalent to "Hydrologic Area" in the CalWater 2.2 watershed convention, and is developed here to allow for distinct drainage areas that are smaller than a river basin, but larger than a USGS watershed.

The Pajaro River Basin is delineated at the HUC-8 hydrologic unit scale (HUC 18060002). Individual watersheds at the HUC-10 hydrologic unit scale which are nested within the Pajaro River Basin were delineated by digitally clipping HUC-10 watershed shapefiles using the Pajaro River Basin shapefile as a mask. Based on HUC delineations, there are three distinct subbasins nested within the Pajaro River Basin: the 1) Pajaro River Subbasin[11]; the 2) San Benito River Subbasin[12]; the 3) Pacheco Creek Subbasin[13] (see Figure 2-3). There are eight distinct watersheds, delineated at the HUC-10 scale, located within these three subbasins, as shown in Figure 2-3. A total of 36 subwatersheds, delineated at the HUC-12 scale are nested with the Pajaro River Basin (subwatersheds are shown in Figure 2-4). A summary of the Pajaro River Basin's watershed hierarchy is presented in Table 2-2.

[10] 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.

[11] In the CalWater 2.2 watershed convention, this area corresponds approximately to the Watsonville, Santa Cruz Mountains, and South Santa Clara Valley hydrologic areas.

[12] In the CalWater 2.2 watershed convention, this area corresponds to the San Benito River hydrologic area.

[13] In the CalWater 2.2 watershed convention, this area corresponds approximately to the Pacheco-Santa Ana Creek hydrologic area.

Figure 2-3. Subbasins and watersheds nested within the Pajaro River Basin.

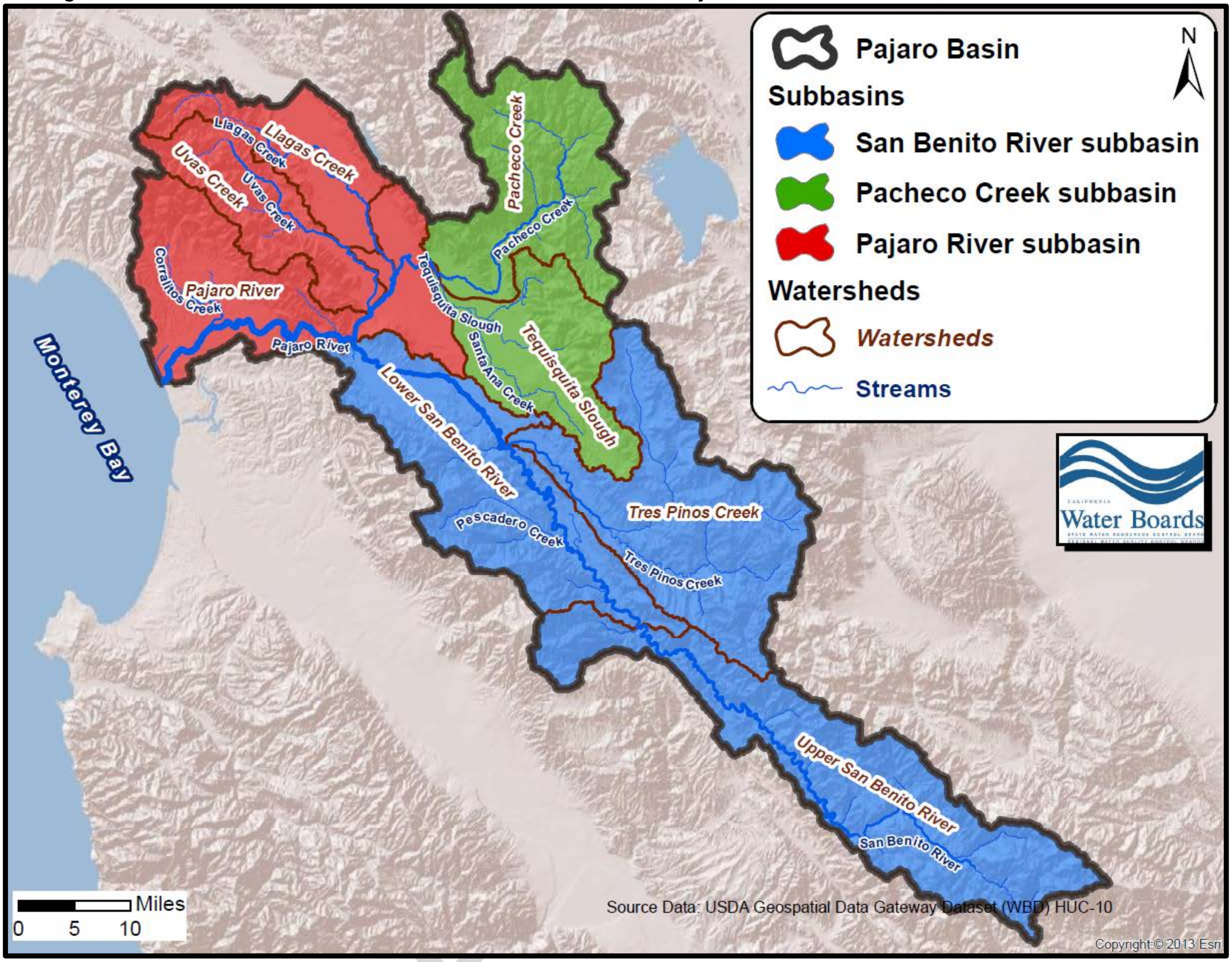


Table 2-2. TMDL watershed hierarchy (basins, subbasins, watersheds, and subwatersheds).

Name	Hydrologic Scale	Data Source (HUC)	Drainage Area (square miles)
Pajaro River Basin	**Basin**	WBD 8-digit Hydrologic Unit Code *HUC # 18060004*	1,300.6
Pajaro River Subbasin[A]	**Subbasin** *within the Pajaro River Basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000203* *1806000204* *1806000208*	355.6
San Benito River Subbasin[B]	**Subbasin** *within the Pajaro River Basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000205* *1806000206* *1806000207*	660.8

Name	Hydrologic Scale	Data Source (HUC)	Drainage Area (square miles)
Pacheco Creek Subbasin[C]	**Subbasin** *within the Pajaro River Basin*	Spatial dissolve on WBD 10-digit Hydrologic Unit Codes *1806000201* *1806000202*	284.2
Llagas Creek Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000203*	84.6
Pajaro River Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000208*	184.3
Uvas Creek Watershed	**Watershed** *within the Pajaro River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000204*	86.7
Lower San Benito River Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000207*	198.2
Upper San Benito River Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000205*	243.2
Tres Pinos Creek Watershed	**Watershed** *within the San Benito River Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000206*	219.4
Pacheco Creek Watershed	**Watershed** *within the Pacheco Creek Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000202*	167.9
Tequisquita Slough Watershed	**Watershed** *within the Pacheco Creek Subbasin*	WBD 10-digit Hydrologic Unit Code *HUC # 1806000201*	116.3
Subwatersheds of the Pajaro River Basin	**Subwatersheds**	WBD 12-digit Hydrologic Unit Codes See Figure 2-4 and Table 2-3 for subwateshed information	

[A] *In the CalWater 2.2 watershed convention, this subbasin corresponds approximately to the Watsonville, Santa Cruz Mountains, and South Santa Clara Valley hydrologic areas.*
[B] *In the CalWater 2.2 watershed convention, this subbasin corresponds to the San Benito River hydrologic area.*
[C] *In the CalWater 2.2 watershed convention, this subbasin corresponds to the Pacheco-Santa Ana Creek hydrologic area.*

Within each HUC-10 watershed, higher resolution subwatershed delineation of project area stream reaches and associated drainage areas were delineated on the basis of HUC-12 shapefiles. According to the Watershed Boundary Dataset's HUC-12 delineations, there are 36 distinct subwatersheds within the Pajaro River Basin. Figure 2-4 illustrates the individual subwatersheds developed for the TMDL project area. Table 2-3 tabulates the names and the areal sizes of the subwatersheds. It should be noted that at high-resolution spatial scales (e.g., individual parcels), site specific engineering can result in parcel-scale drainage that runs counter to topographic elevation direction. Thus, the lower spatial resolution drainage patterns of watersheds and subwatershed delineations may not neccessarily represent hydrologic drainage patterns at localized parcel and catchment scales.

Figure 2-4. Map of subwatersheds (HUC-12s) with numeric identifiers located within the Pajaro River Basin. The subwatershed names with their associated numeric identifiers are tabulated in Table 2-3.

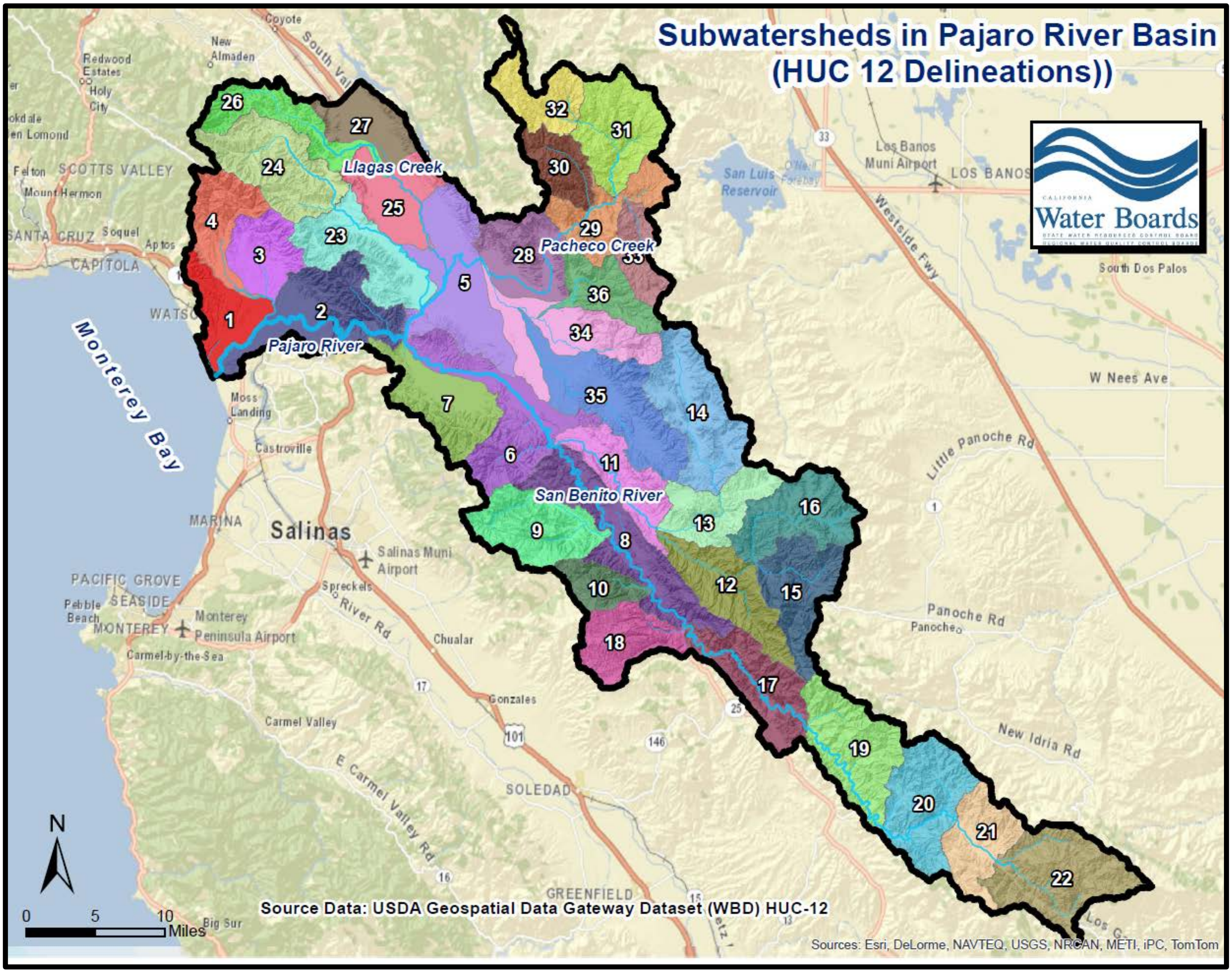


Table 2-3. Tabulation of Pajaro River Basin subwatersheds with numeric identifiers.

Subwatershed Numeric ID	Subwatershed (HUC 12) Name	Acres	Square Miles	The subwatershed (HUC12) is located within this watershed (HUC 10)
1	Watsonville Slough Frontal	15,551	24.3	Pajaro River Watershed
2	Lower Pajaro River	33,285	52.0	Pajaro River Watershed
3	Salsipuedes Creek	15,881	24.8	Pajaro River Watershed
4	Corralitos Creek	17,789	27.8	Pajaro River Watershed
5	Upper Pajaro River	35,467	55.4	Pajaro River Watershed
6	Bird Creek-San Benito River	32,742	51.2	Lower San Benito River Watershed
7	San Juan Canyon	24,415	38.1	Lower San Benito River Watershed
8	Paicines Reservoir-San Benito River	33,976	53.1	Lower San Benito River Watershed
9	Pescadero Creek	25,665	40.1	Lower San Benito River Watershed
10	Stone Creek	10,060	15.7	Lower San Benito River Watershed
11	Lower Tres Pinos Creek	17,851	27.9	Tres Pinos Creek Watershed

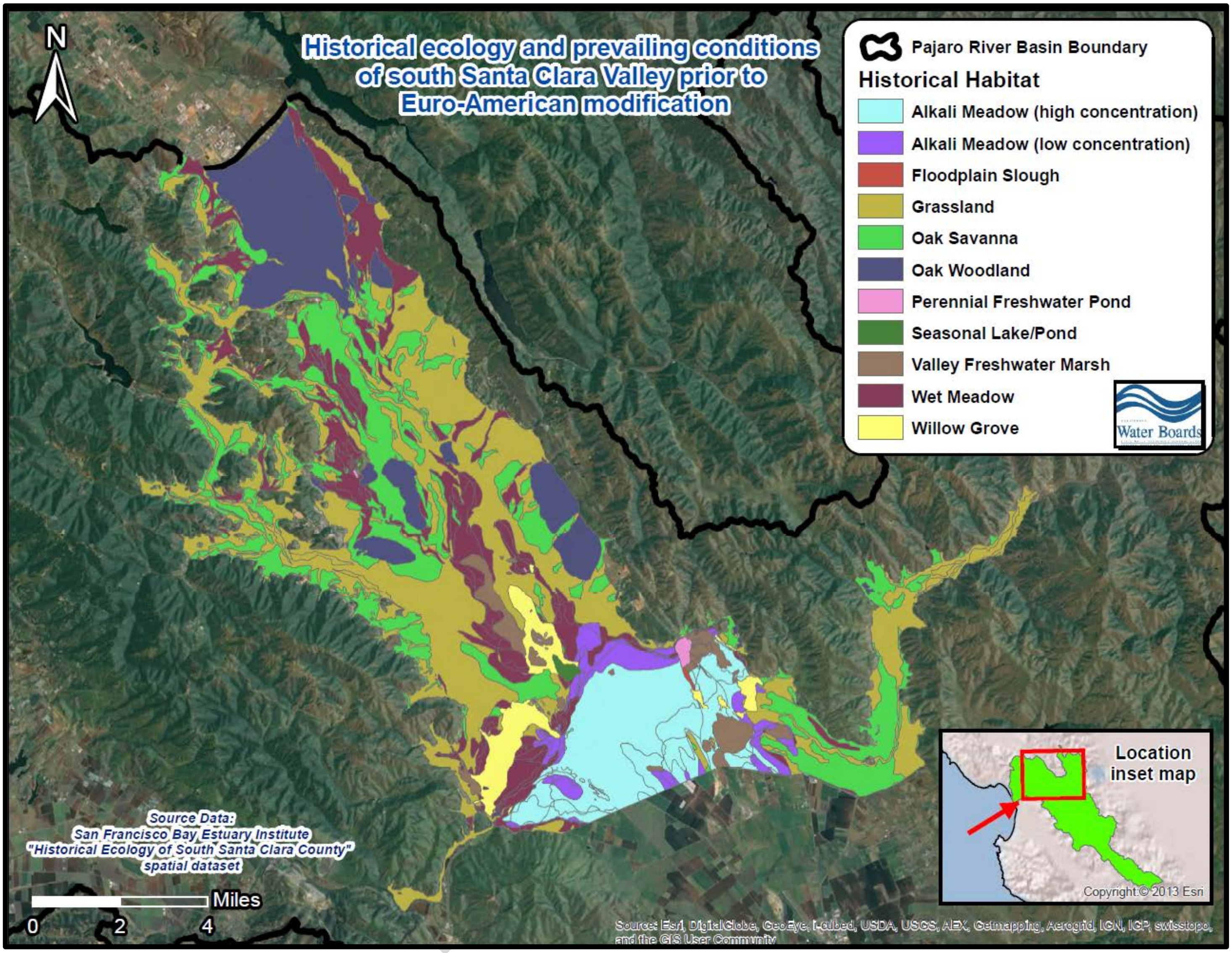
Subwatershed Numeric ID	Subwatershed (HUC 12) Name	Acres	Square Miles	The subwatershed (HUC12) is located within this watershed (HUC 10)
12	Middle Tres Pinos Creek	22,997	35.9	Tres Pinos Creek Watershed
13	Los Muertos Creek	18,928	29.6	Tres Pinos Creek Watershed
14	Quien Sabe Creek	32,669	51.0	Tres Pinos Creek Watershed
15	Upper Tres Pinos Creek	23,240	36.3	Tres Pinos Creek Watershed
16	Las Aguilas Creek	24,730	38.6	Tres Pinos Creek Watershed
17	Sulphur Creek-San Benito River	24,174	37.8	Upper San Benito River Watershed
18	Willow Creek	18,585	29.0	Upper San Benito River Watershed
19	Rock Springs Creek-San Benito River	29,781	46.5	Upper San Benito River Watershed
20	James Creek-San Benito River	28,740	44.9	Upper San Benito River Watershed
21	Hernandez Reservoir-San Benito River	19,512	30.5	Upper San Benito River Watershed
22	Clear Creek-San Benito River	34,843	54.4	Upper San Benito River Watershed
23	Lower Uvas Creek	25,690	40.1	Uvas Creek Watershed
24	Upper Uvas Creek	29,823	46.6	Uvas Creek Watershed
25	Lower Llagas Creek	20,007	31.3	Llagas Creek Watershed
26	Upper Llagas Creek	18,737	29.3	Llagas Creek Watershed
27	Little Llagas Creek	15,392	24.1	Llagas Creek Watershed
28	Lower Pacheco Creek	21,986	34.4	Pacheco Creek Watershed
29	Upper Pacheco Creek	18,334	28.6	Pacheco Creek Watershed
30	Cedar Creek	12,766	19.9	Pacheco Creek Watershed
31	Lower North Fork Pacheco Creek	25,771	40.3	Pacheco Creek Watershed
32	Upper North Fork Pacheco Creek	17,079	26.7	Pacheco Creek Watershed
33	South Fork Pacheco Creek	11,518	18.0	Pacheco Creek Watershed
34	Tequisquita Slough	25,964	40.6	Tequisquita Slough Watershed
35	Santa Ana Creek	33,717	52.7	Tequisquita Slough Watershed
36	Arroyo De Las Viboras	14,742	23.0	Tequisquita Slough Watershed
Total		832,406	1,300.6	

2.3 Land Use & Land Cover

Land use conditions play an important role in pollutant loading to water resouces in any given watershed, thus evaluating land use–land cover is an important part of TMDL development. Historical land cover conditions in parts of the Pajaro River Basin (south Santa Clara Valley), prior to Euro-american modification, are available as spatial datasets from the San Francisco Bay Estuary Institue[14] (see Figure 2-5). These datasets provide some insight into what land cover conditions were in historical lowland ecosystems of the Pajaro River Basin prior to substantial human modification. The lowlands associated with the Santa Clara Valley in historic times were characterized predominantly by grasslands, oak savanah, oak woodlands, freshwater marshes, wet meadows, and alkali meadows.

[14] Source data – originator - Robin Grossinger, San Francisco Estuary Institute. Title: *South Santa Clara Valley Historical Landscape*. This database contains several feature classes representing a reconstruction of the historical landscape and prevailing conditions of south Santa Clara Valley prior to Euro-American modification. This dataset integrates many sources of data describing the historical features of south Santa Clara Valley. Extensive supporting information, including bibliographic references and research methods, can be found in the south Santa Clara Valley report. Online linkage: http://gis.sfei.org/geofetch/catalog/search/search.page

Figure 2-5. Historical ecology and landscape conditions of the southern Santa Clara Valley prior to Euro-American modification.



Modern land use and land cover in the project area can be evaluated from digital data provided by the California Department of Conservation Farmland Mapping and Monitoring Program. The Farmland Mapping and Monitoring Program maps are updated every two years with the use of aerial photographs, a computer mapping system, public review, and field reconnaissance. For this data analysis report, the 2010 Farmland Mapping and Monitoring Program mapping data was used. Figure 2-6 illustrates land use and land cover in the Pajaro River Basin. In general, agricultural lands, and developed or urbanized lands comprise the majority the lowlands areas within the river basin. Upland areas are characterized chiefly by grasslands, woodlands, and natural areas.

Figure 2-6. Pajaro River Basin land use – land cover (year 2010).

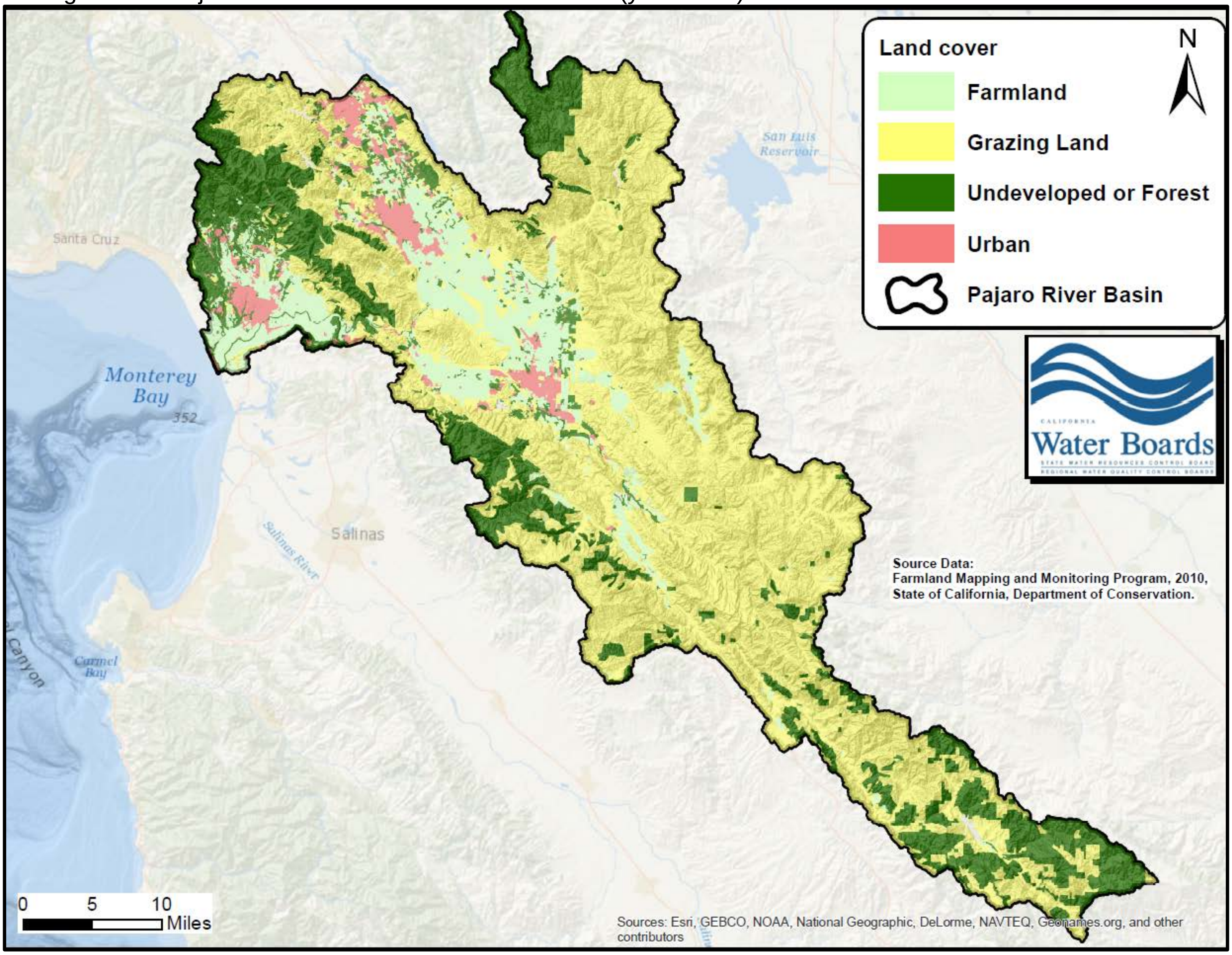
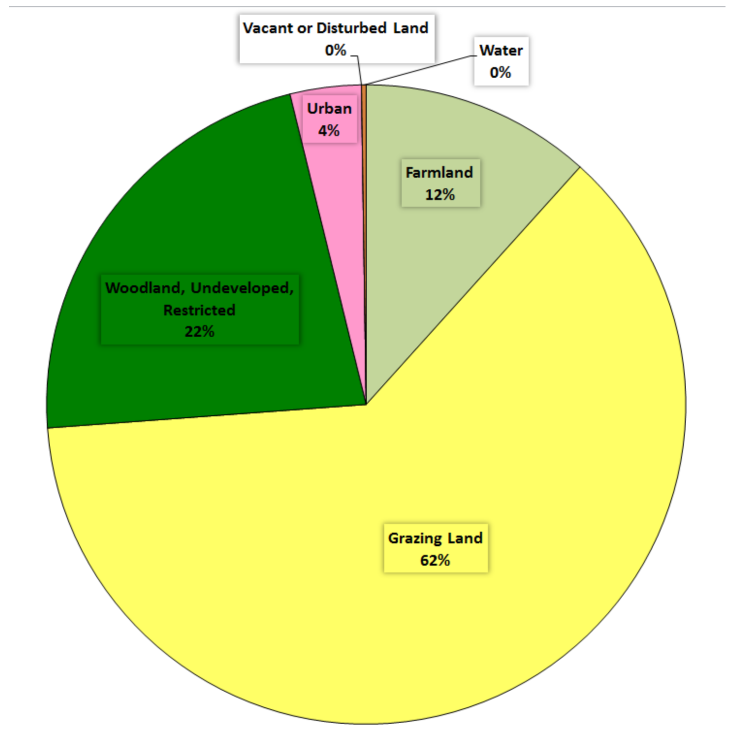


Table 2-4 tabulates the distribution of land cover in the Pajaro River Basin. The river basin as a whole is largely comprised of grazing lands, woodlands and undeveloped areas. Agricultural lands and urban lands are concentrated in the south Santa Clara Valley, and the Pajaro Valley. The overwhelming majority of identified stream water quality impairments are associated with stream reaches in these lowland areas.

Table 2-4. Tabulation of land use/land cover in Pajaro River Basin (year 2010).

Land Cover (Year 2010)[A,B]	Acres	Land Use - Land Cover Pie Chart
Urban	29,945	
Farmland	97,114	
Grazing Land	517,322	
Other Land (Woodland, Undeveloped, or Restricted)	185,867	
Water	1,964	
Vacant or Disturbed Land	12	
Total	832,225	

[A] Source: Calif. Dept. of Conservation, Farmland Mapping and Monitoring Program (2010)

[B] The total acreage in this table is nominally smaller (by less than 200 acres) than the size of the Pajaro River Basin reported in Section 2.2 of this report because staff did not include Farmland Mapping and Monitoring data for the small portions of the Merced and Stanislaus Counties. The Pajaro River Basin includes small areas (approximately 181 acres) of Merced and Stanislaus counties; as a matter of efficiency is is not necessary to obtain and tabulate the Farmland Mapping and Monitoring data for these Counties because they comprise only a negligible portion of the river basin – i.e., a fraction of one percent of the river basin's area.

Table 2-5 presents acreage estimates of land use-land cover acreage in all the subwatersheds occurring within the Pajaro River Basin (completion of this table is pending).

Table 2-5. Land use - land cover by subwatershed (year 2010)[A], units = acres.

Subwatershed (HUC12)	Farmland	Urban	Undeveloped, Forest, or Restricted	Grazing Lands	Vacant or Disturbed Land	Total
Watsonville Slough Frontal						
Lower Pajaro River						
Salsipuedes Creek						
Corralitos Creek						
Upper Pajaro River						
Bird Creek-San Benito River						
San Juan Canyon						
Paicines Reservoir-San Benito River						
Pescadero Creek						
Stone Creek						
Lower Tres Pinos Creek						
Middle Tres Pinos Creek						

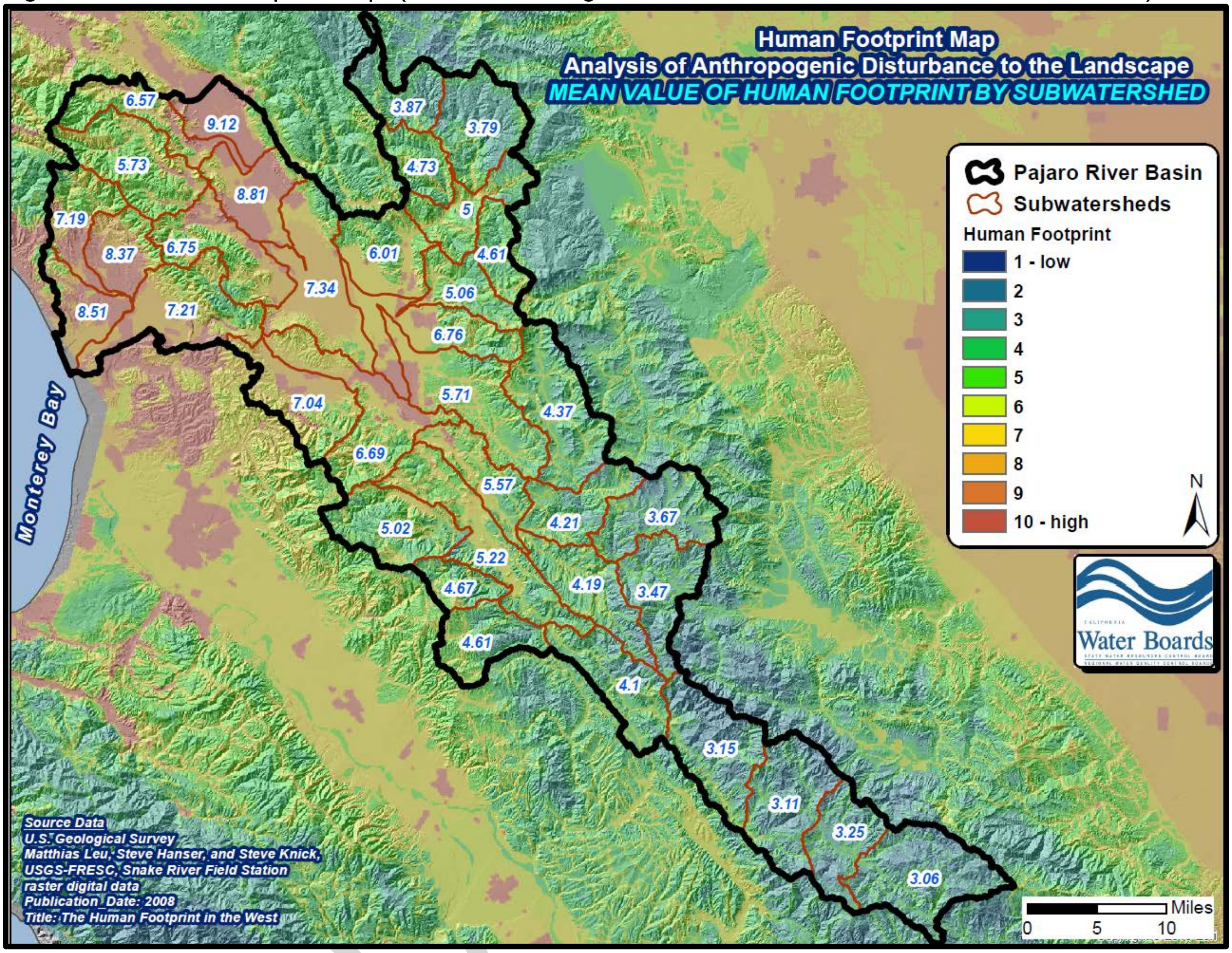
Subwatershed (HUC12)	Farmland	Urban	Undeveloped, Forest, or Restricted	Grazing Lands	Vacant or Disturbed Land	Total
Los Muertos Creek						
Quien Sabe Creek						
Upper Tres Pinos Creek						
Las Aguilas Creek						
Sulphur Creek-San Benito River						
Willow Creek						
Rock Springs Creek-San Benito River						
James Creek-San Benito River						
Hernandez Reservoir-San Benito River						
Clear Creek-San Benito River						
Lower Uvas Creek						
Upper Uvas Creek						
Lower Llagas Creek						
Upper Llagas Creek						
Little Llagas Creek						
Lower Pacheco Creek						
Upper Pacheco Creek						
Cedar Creek						
Lower North Fork Pacheco Creek						
Upper North Fork Pacheco Creek						
South Fork Pacheco Creek						
Tequisquita Slough						
Santa Ana Creek						
Arroyo De Las Viboras						

[A] Land use-Land cover dataset: Calif. Dept. of Conservation Farmland Mapping and Monitoring Program (2010)

Human disturbance to the landscape varies spatially across any given river basin, and in the context of TMDL development it is important to be aware of this variation. The degree of human disturbance to the landscape can be quantified with data available from the U.S. Geological Survey[15] – Figure 2-7 presents the "human footprint" in the Pajaro River Basin. Human footprint is a measure of human disturbance to the landscape. Human footprint values range from 1 (pristine conditions) to 10 (extremely modified by humans). In general, lowland and valley areas of river basins have the highest human footprint, whereas upland areas of the river basin will have lower human footprint. For example, human footprint values range from about 3 to 4 in lightly impacted subwatersheds of the Upper San Benito Subbasin and the Upper Pacheco Creek Subbasin. In contrast, human footprint values range from about 7 to 9 in highly modified subwatersheds of the Santa Clara Valley and Watsonville coastal plain.

[15] "The Human Footprint in the West" is a geospatial dataset originated by Matthias Leu, Steve Hanser, and Steve Knick, U.S. Geological Survey, Snake River Field Station.

Figure 2-7. Human footprint map (refer back to Figure 2-4 and Table 2-3 for subwatershed names).



2.4 Hydrology

Assessing the hydrology of a watershed is an important step in evaluating the magnitude and nature of nutrient transport and loading in waterbodies. The entire drainage area contributing to flow in the Pajaro River Basin encompasses over 1,300 square miles (refer back to Figure 2-2). Figure 2-8 illustrates some regional hydrographic features and hydrologic characteristics within the Pajaro River Basin.

Due to highly variable climatic, hydrologic, anthropogenic, and geomorphic influences within the river basin, stream flows in various stream reaches can range spatially from perennial or sustained flow, to infrequent seasonal or intermittent flows – refer again to Figure 2-8 for illustrations of these variations.

Figure 2-8. Hydrography of the Pajaro River Basin.

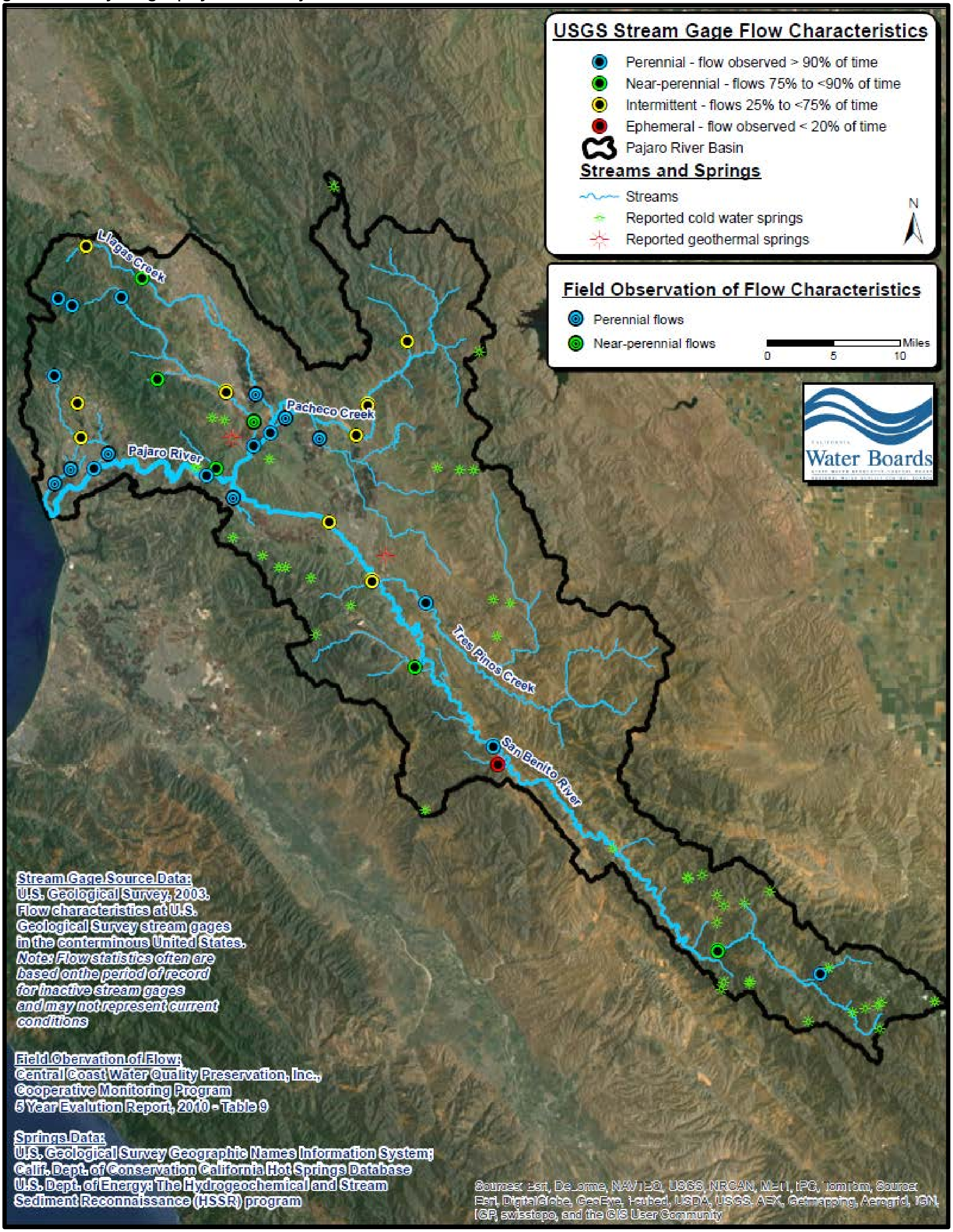


Table 2-6 presents flow statistics for select stream reaches in the Pajaro River Basin on the basis of U.S. Geological Survey stream gages. Due to local climatic and hydrologic conditions, or land modfications stream reaches in the river basin range from ephemeral and intermittent flows, to perennial and near-perennial flows.

Table 2-6. Flow statistics from U.S. Geological Survey stream gages in the Pajaro River Basin. Flow units = cubic feet per sec.; drainage area units = sq. miles; BFI = base flow index.

Station No.	Station Name	Period of Record	Ave. Flow	MIN	P10	P25	P50	P75	P90	P95	P99	Max Flow	BFI	Drain Area
11152900	Cedar C Nr Bell Station	1961-1982	4.4	0.0	0.0	0.0	0.0	0.6	4.2	16.0	92.0	832	0.176	13
11153000	Pacheco C Nr Dunneville	1939-1982	34.5	0.0	0.0	0.0	2.0	8.9	38.0	124.0	698.2	7730	0.198	146
11153470	Llagas C Ab Chesbro Res Nr Morgan Hill	1971-1982	9.6	0.0	0.0	0.0	0.6	5.3	22.0	46.0	153.6	508	0.37	10
11153500	Llagas C Nr Morgan Hill	1951-1971	15.5	0.0	0.0	1.1	4.1	16.0	33.0	48.0	178.1	1230	0.603	20
11153700	Pajaro R Nr Gilroy	1959-1982	60.2	0.0	0.5	2.1	5.3	13.0	67.0	245.8	1220.0	11700	0.307	399
11154100	Bodfish C Nr Gilroy	1959-1982	3.8	0.0	0.0	0.1	0.4	1.8	7.0	16.0	63.0	505	0.331	7
11154200	Uvas C Nr Gilroy	1959-1992	38.5	0.0	0.0	0.0	0.0	6.4	61.0	180.2	746.2	6520	0.154	71
11154700	Clear C Nr Idria	1993-2000	5.5	0.1	0.5	1.0	1.9	5.1	14.0	22.0	45.0	464	0.726	14
11156000	San Benito R Bl M C Nr Hernandez	1949-1963	12.4	0.0	0.0	0.8	1.7	4.8	24.0	79.0	160.3	754	0.402	108
11156450	Willow C Trib Nr San Benito	1964-1969	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	12	0.018	1
11156700	Pesdero C Nr Paicines	1959-1970	1.6	0.0	0.0	0.2	0.6	1.5	2.5	3.8	21.0	160	0.674	38
11157500	Tres Pinos C Nr Tres Pinos	1940-2000	18.2	0.0	0.5	1.2	3.0	6.5	18.0	50.0	290.8	9000	0.431	208
11158500	San Benito R Nr Hollister	1949-1983	37.3	0.0	0.0	0.0	2.5	18.0	40.0	97.0	715.0	8390	0.253	586
11158600	San Benito R A Hwy 156 Nr Hollister	1970-2000	42.5	0.0	0.0	0.0	1.8	11.0	41.0	173.0	800.0	19800	0.289	607
11158900	Pesdero C Nr Chittenden	1970-1981	3.0	0.0	0.0	0.1	0.3	1.5	5.8	14.0	52.0	191	0.38	10
11159150	Corralitos C Nr Corralitos	1957-1972	8.6	0.0	0.1	0.1	0.5	4.1	18.0	41.0	134.0	997	0.232	11
11159200	Corralitos C A Freedom	1956-2000	16.9	0.0	0.0	0.0	0.4	5.5	35.0	81.0	301.8	2290	0.181	28
11159500	Pajaro R A Watsonville	1911-1973	93.8	0.0	0.1	1.0	5.4	26.0	70.0	368.2	2100.4	6570	0.53	1272
11153900	Uvas C Ab Uvas Res Nr Morgan Hill	1961-1982	28.1	0.0	0.3	0.8	2.7	14.0	50.0	116.0	475.6	3390	0.313	21
11156500	San Benito R Nr Willow Creek School	1939-2000	28.1	0.0	0.2	0.5	3.9	24.0	58.0	93.0	382.4	5000	0.471	249
11159000	Pajaro R A Chittenden	1939-2000	173.1	0.0	1.2	4.3	12.0	39.0	270.0	777.5	3420.0	21700	0.344	1186

Data source: U.S. Geological Survey, 2003. *Flow characteristics at U.S. Geological Survey stream gages in the conterminous United States.* Open File Report 03-146.

Staff developed visual representations of flow varation in the Pajaro River Basin in Figure Figure 2-9 and Figure 2-10. Figure 2-9 illustrates mean annual flow estimates within the project area, based on U.S. Geological Survey flow gage data and NHDplus estimates of mean annual flow[16].

[16] U.S. Geological Survey gages provide measured daily flow records (online linkage: http://ca.water.U.S. Geological Survey.gov/). NHDplus provies modeled mean annual flow estimates; staff used values for the attribute “MAFlowU”. MAFflowU are based on the Unit Runoff Method (UROM), which was developed for the National Water Pollution Control Assessment Model (NWPCAM) (Research Triangle Institute, 2001). Values in “MAFlowV” are based on methods from Vogel et al., 1999. NHDplus uses two flow estimation procedures, both developed by using the HydroClimatic Data Network (HCDN) of gages.

Figure 2-9. Estimated mean annual discharge in streams of the lower Pajaro River Basin, units=cubic feet/sec, based on stream gage data and NHDplus estimates.

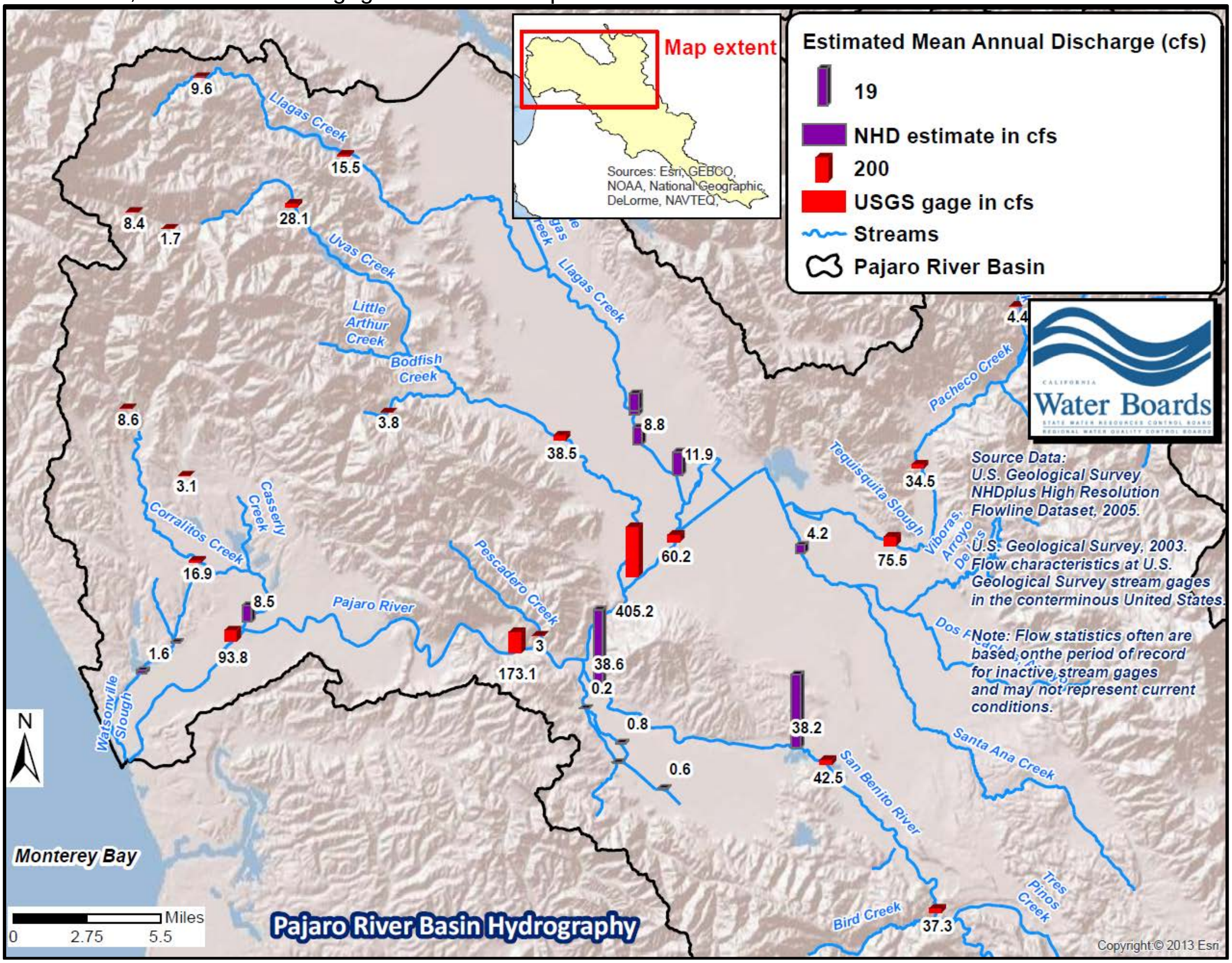
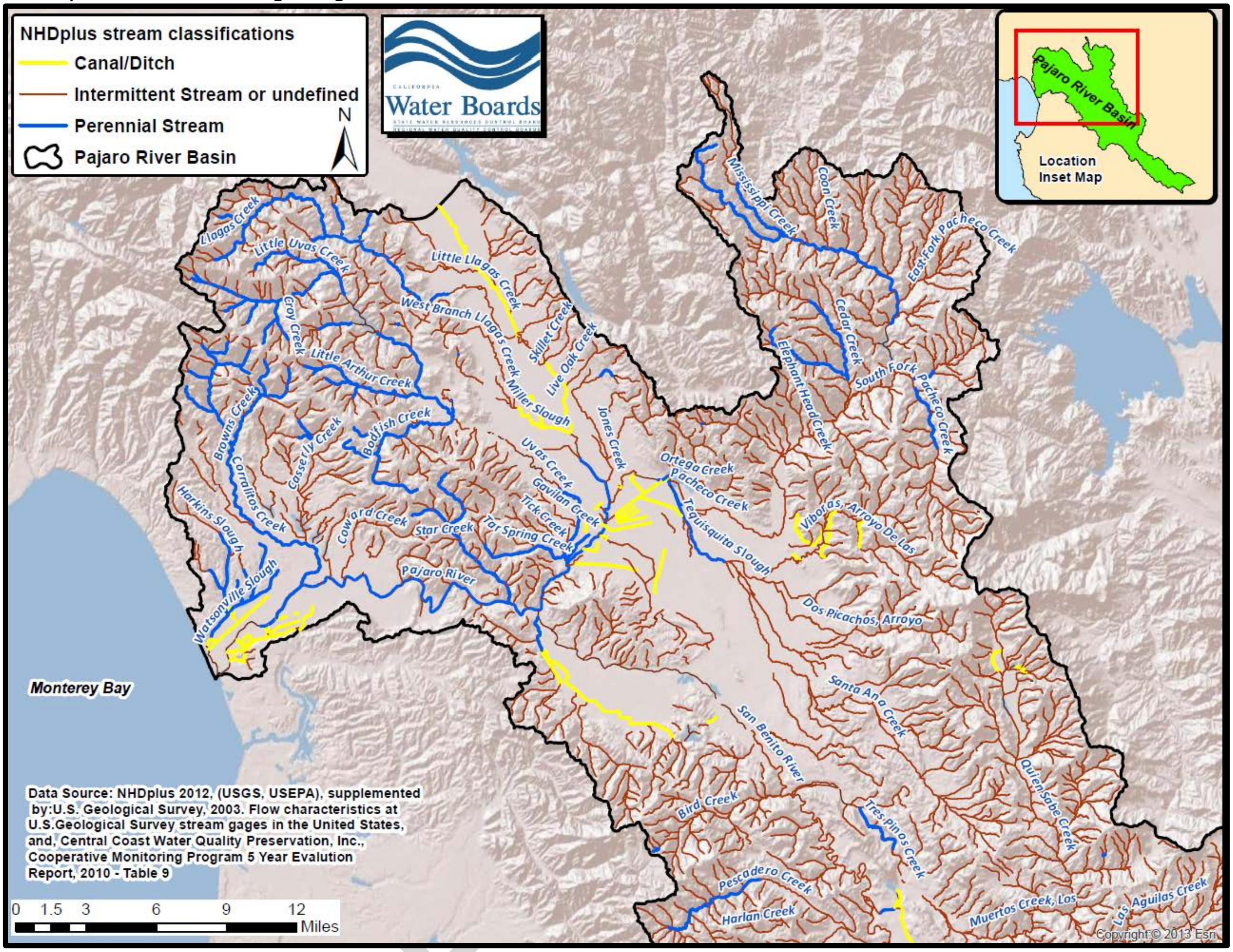


Figure 2-10 illustrates the estimated hydrographic stream channel classifications in the project area. The source of these hydrographic stream classification attributes is from the USGS's high resolution National Hydrography Dataset Plus (NHDplus)[17], supplemented by field observation of flow patterns. It should be noted that the NHDplus stream channel classifications carry no formal regulatory status, and have not necessarily been field-checked. In the NHDplus metadata these are described as "value-added" geospatial attributes created to supplement the NHDFlowline shapefiles.

[17] The NHDPlus Version 1.0 is (2005) was created by the U.S. Environmental Protection Agency and the U.S. Geological Survey and is an integrated suite of application-ready geospatial data sets that incorporate many of the best features of the National Hydrography Dataset (NHD) and the National Elevation Dataset (NED). The NHDPlus includes a stream network (based on the 1:100,000-scale NHD), improved networking, naming, and "value-added attributes" (VAA's). NHDPlus also includes elevation-derived catchments (drainage areas) produced using drainage enforcement techniques.

Figure 2-10. Non-regulatory stream classification on the basis of NHDplus flow line attributes and Cooperative Monitoring Program field observations.



Riparian characterisitcs are often considered in nutrient TMDL development, because riparian cover, canopy shading, and riparian health can play a role in the nature and risk of nutrient pollution of water resources. Stream riparian landscape characteristics have been published as digital datasets by the U.S. Environemental Protection Agency's Landscape Ecology Branch[18]. Figure 2-11, Figure 2-12, and Figure 2-13 present estimated percentage of stream length that is adjacent to various land cover categories (i.e., cropland, urban, and natural landscape). Table 2-7 tablulates weighted averages of the the digital riparian landscape characteristics shown in the aforementioned figures. As would be expected, significant proportions of lowland stream reaches of the Pajaro Valley and southern Santa Clara Valley are located adjacent to croplands and developed urban/residential areas. In contrast, as expected, stream reaches of the San Benito River Subbasin are largely adjacent to natural landscapes.

[18] The EMAP-West metrics, developed by the U.S. Environmental Protection Agency's Landscape Ecology Branch, were generated with an ArcView extension called ATtILA (Analytical Tools Interface for Landscape Assessments). The wemap3k_atmetrics dataset contains metric information from four metric groups; landscape characteristics, riparian characteristics, human stresses and physical characteristics. Derived from the National Land Cover Dataset, DEM, DEM slope, roads, census block groups and streams datasets used in the ATtILA processing.

Figure 2-11. Estimated percentage of stream reach length which is adjacent to cropland.

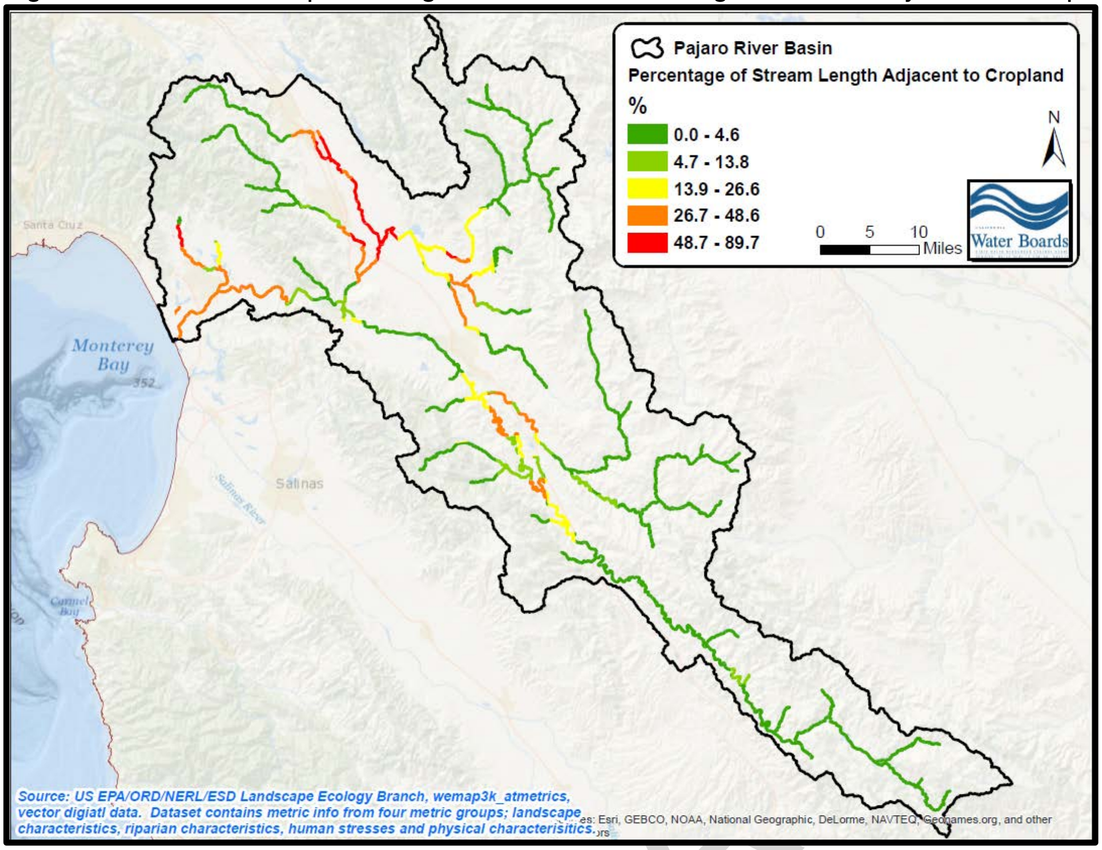


Figure 2-12. Estimated percentage of stream reach length which is adjacent to urban land.

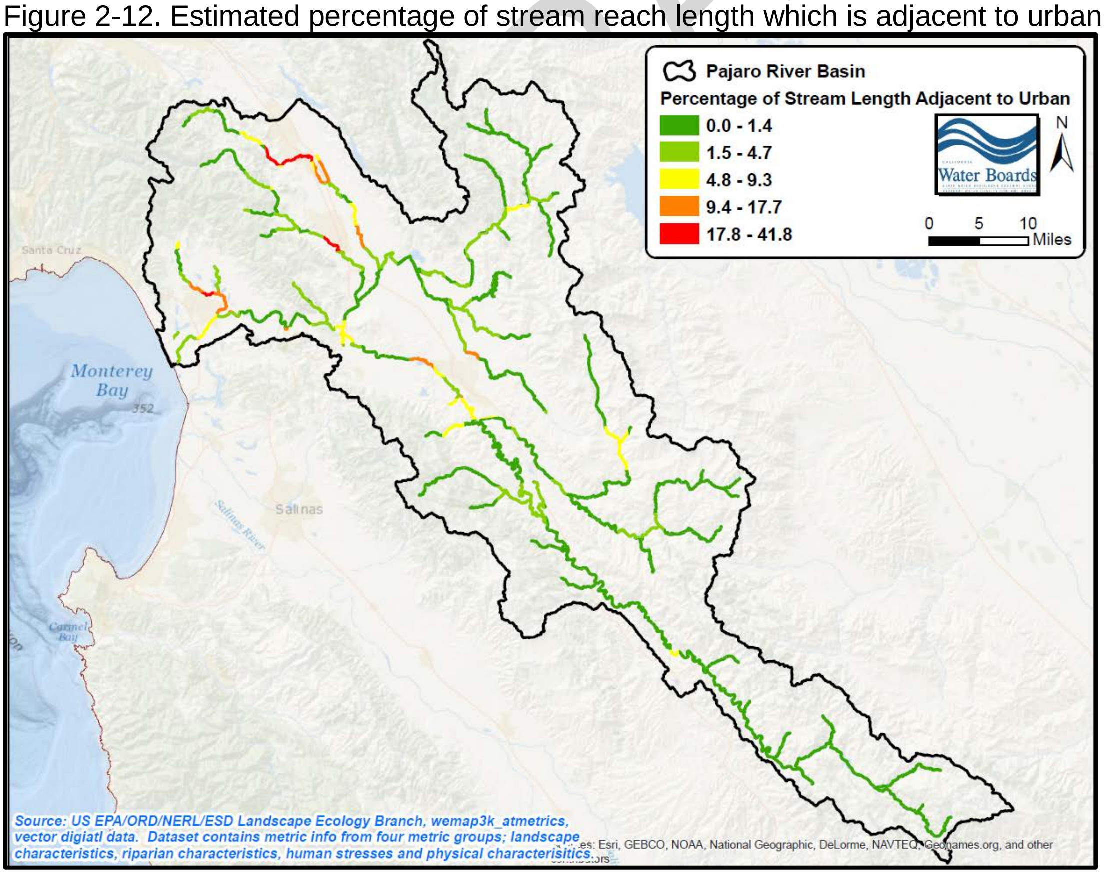


Figure 2-13. Estimated percentage of stream reach length which is adjacent to all natural land.

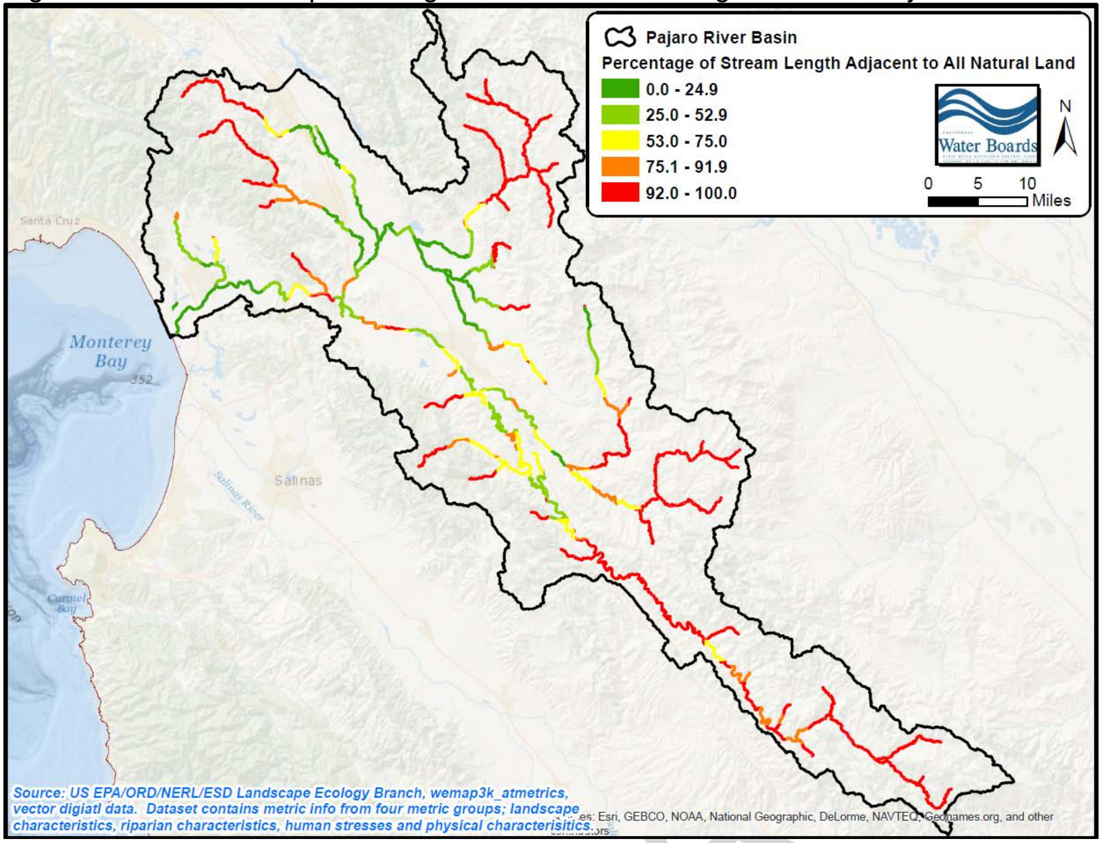


Table 2-7. Weighted percentages of select land cover categories occurring within a 100 meter buffer of higher order streams (source data: EMAP-West[19]).

	Land Cover Proportions[A]: Percentages of Land Cover Categories within 100 meter Buffer of Higher Order Streams[B, C]		
Hydrologic Area[D]	Weighted % of land within 100 m stream buffer that is CROPLAND	Weighted % of land within 100 m stream buffer that is URBAN	Weighted % of land within 100 m stream buffer that is ALL NATURAL land cover
Pajaro River Basin	**12.6**	**2.6**	**73.2**
Pajaro River Subbasin	**30.0**	**7.4**	**52.7**
Pacheco Creek Subbasin	**11.8**	**1.4**	**67.0**
San Benito River Subbasin	**4.6**	**0.9**	**85.4**

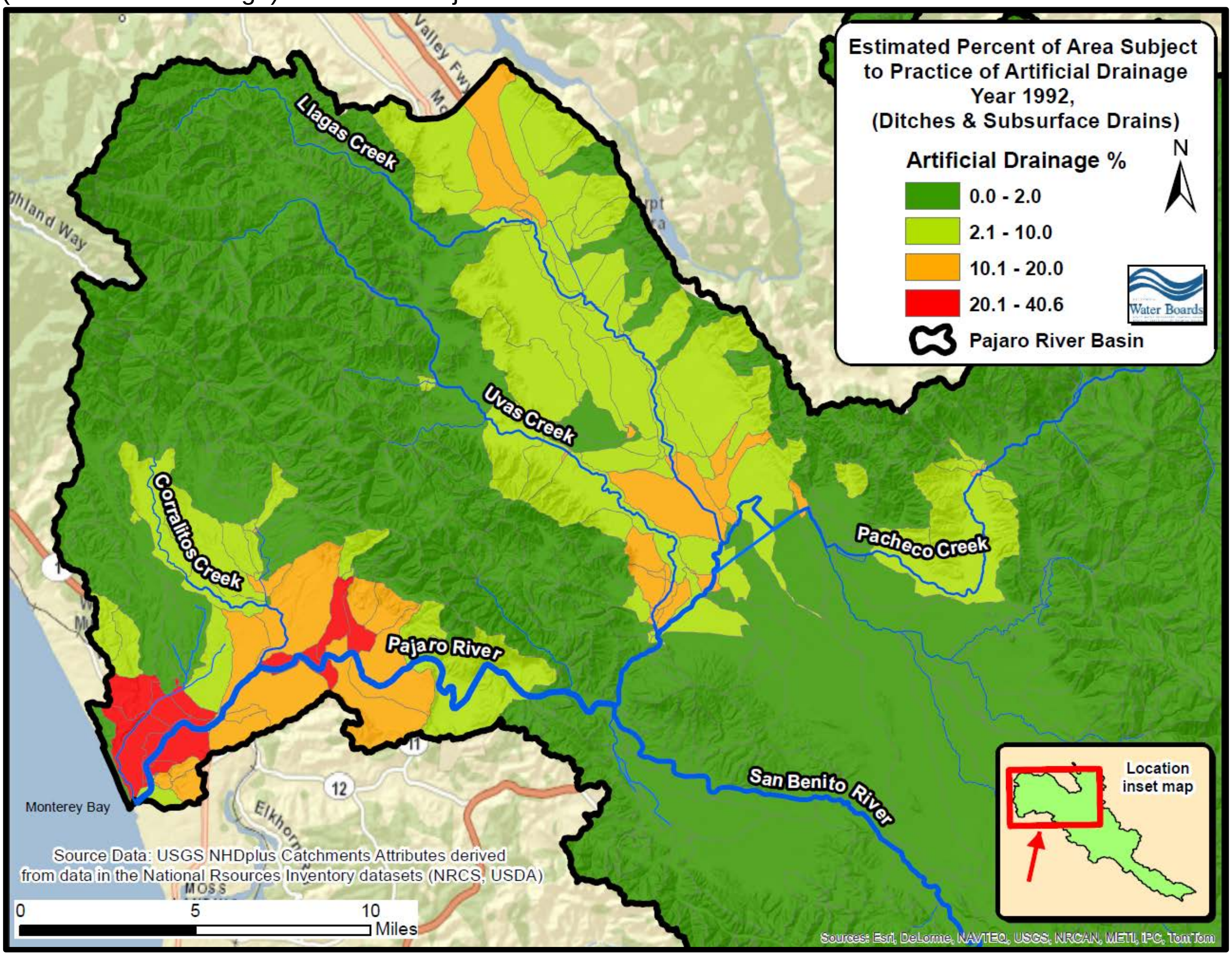
[A] *Source Data: EMAP-West Landscape Metrics, U.S. Environmental Protection Agency – Landscape Ecology Branch.*
[B] *Does not include Strahler first-order head water stream reaches*
[C] *Cropland, Urban, and All Natural land categories do not sum to 100% for a given hydrologic area because grasslands, wetlands, and shrubland were not included in this land cover tabulation.*
[D] *Refer back to Figure 2-3 for a map showing location of the subbasins within the Pajaro River Basin.*

Agricultural watersheds are often characterized by a significant amount of artificial drainage, and TMDL development should be cognizant of this fact. Artificial drainage, such as agricultural runoff, can be an important contributor to flows in some waterbodies of the Pajaro River Basin. In watersheds dominated by agriculture, artificial drainage systems can act as efficient conveyance systems to rapidly transport excess water from agricultural soils. Consequently artificial drainage can considerably increase the

[19] *Ibid*

amount of nutrients exported from agricultural fields to waterways (Strock et al., 2007). Figure 2-14 illustrates the estimated percentage of land area that is subject to the practice of artificial drainage, such as ditches and tile drains. The estimations are from U.S. Geological Survey NHDplus catchment attribute datasets, are intended for informational value only, are based on data derived by the National Resource Inventory conducted by the NRCS for the year 1992[20], which is the best available dataset to estimate artificial drainage. Thus, this dataset is presumed to represent a plausible gross regional approximation of the current percentage of land area subject to artificial drainage practices[21]. The data indicates that artificial drainage is most intensive in the lowermost areas of the Pajaro River Basin (i.e., Pajaro Valley) as well as in localized areas around the Llagas Creek, and lower Uvas Creek watersheds.

Figure 2-14. 1992 vintage estimate of percentage of land area subject to artificial drainage practices (ditches & tile drainage) in northern Pajaro River Basin.



[20] This tabular dataset was created by the U.S. Geological Survey and represents the estimated area of artificial drainage for the year 1992 and irrigation types for the year 1997 compiled for every catchment of NHDPlus for the conterminous United States. The source datasets were derived from tabular National Resource Inventory (NRI) datasets created by the National Resources Conservation Service. Artificial drainage is defined as subsurface drains and ditches.

[21] It should be noted that the information is this figure should be considered very qualitative and substantital changes at local scales may have occurred since 1992.

2.5 Geomorphology

In this TMDL report, Pajaro River Basin geomorphology is considered in the development of nutrient numeric water quality targets. Because eutrophication is generally assumed to be limited to slow-moving waters in low gradient streams, lakes, ponds, estuaries and bays, a review of project area geomorphology provides insight into where higher risk of biostimulatory effects are to be expected. In high gradient streams (steep slopes), the residence time of nutrients may be too short to allow nutrient assimilation by primary producers and so impacts on water quality may be minimal. As reported in TetraTech (2006), Dodds et al. (2002) report a negative correlation of benthic chlorophyll a to gradient, consistent with Biggs (2000) work on scour/accrual effects. Also high gradient streams in steeper terrains keep water aerated diminishing the potential for anoxic zones (USEPA, 2001). USEPA reports that headwater systems in temperate zones usually have been found to be limited by phosphorus, thus it is generally assumed that eutrophication effects are expected in downstream ecosystems.

As such, the nutrient concentration that results in impairment in a high-gradient, shaded stream may be much different from the one that results in impairment in a low-gradient, unshaded stream (TetraTech, 2006). However, it is important to note that it is generally presumed that excess nutrients in head water reaches will ultimately end up in a receiving body of water where the nutrient concentrations and total load may degrade the water resource.

An additional reason for assessing geomorphic conditions in the watershed is that geomorphic conditions can potentially be used in grouping streams into categories as consistent with nutrient water quality target development guidance from USEPA.

Further, California central coast researchers have reported a linkage between geomorphology and biostimulatory impairments in the Pajaro River Basin:

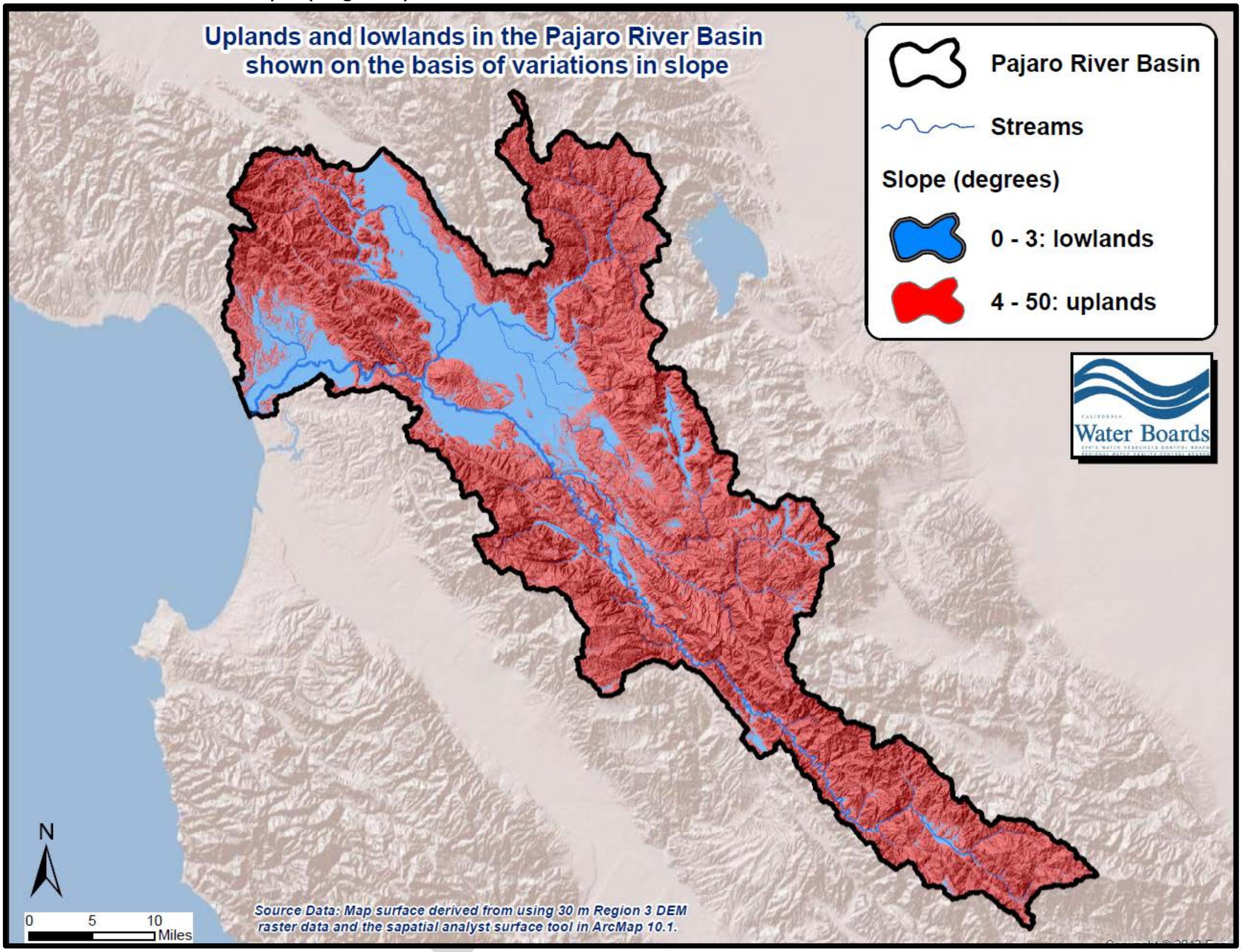
"*Sections of the Pajaro River watershed have been listed by the State of California as impaired for nutrient and sediment violations under the Clean Water Act ……**The best evidence linking elevated nutrient concentrations to algae growth was shown <u>when the stream physiography, geomorphology</u>, and water chemistry <u>were incorporated into the survey and analysis</u>."***

***emphasis added*

From: University of California, Santa Cruz (2009). Final Report: Long-Term, High Resolution Nutrient and Sediment Monitoring and Characterizing In-stream Primary Production. Proposition 40 Agricultural Water Quality Grant Program (Project Lead: Dr. Marc Los Huertos).

Figure 2-15 broadly illustrates the distribution of lowlads and uplands in the Pajaro River Basin, on the basis of variations in slope as derived from a 30 meter digital elevation model.

Figure 2-15. Map showing distribution of lowlands and uplands in the Pajaro River Basin on the basis of variations in land slope (degrees).



Generalized landscape geomorphic provinces of the Pajaro River Basin are presented in Figure 2-16. Landscapes of the northern parts of the river basin include the coastal Watsonville Plain and the inland, intermontane Santa Clara Valley. These lowlands are characterized by gently sloping to nearly level floodplains, alluvial fans, and stream terraces. These lowlands are dissected by a series or northwest-southeast trending highlands including the Santa Cruz Mountains, the Leeward Hills, and the Western Diablo Range. Landscapes of the southern parts of the Pajaro River Basin are dominantly characterized by uplands, including the Gabilan Range and the Diablo Range.

Figure 2-16. Landscapes of the Pajaro River Basin on the basis of U.S. Forest Service ecosubregions.

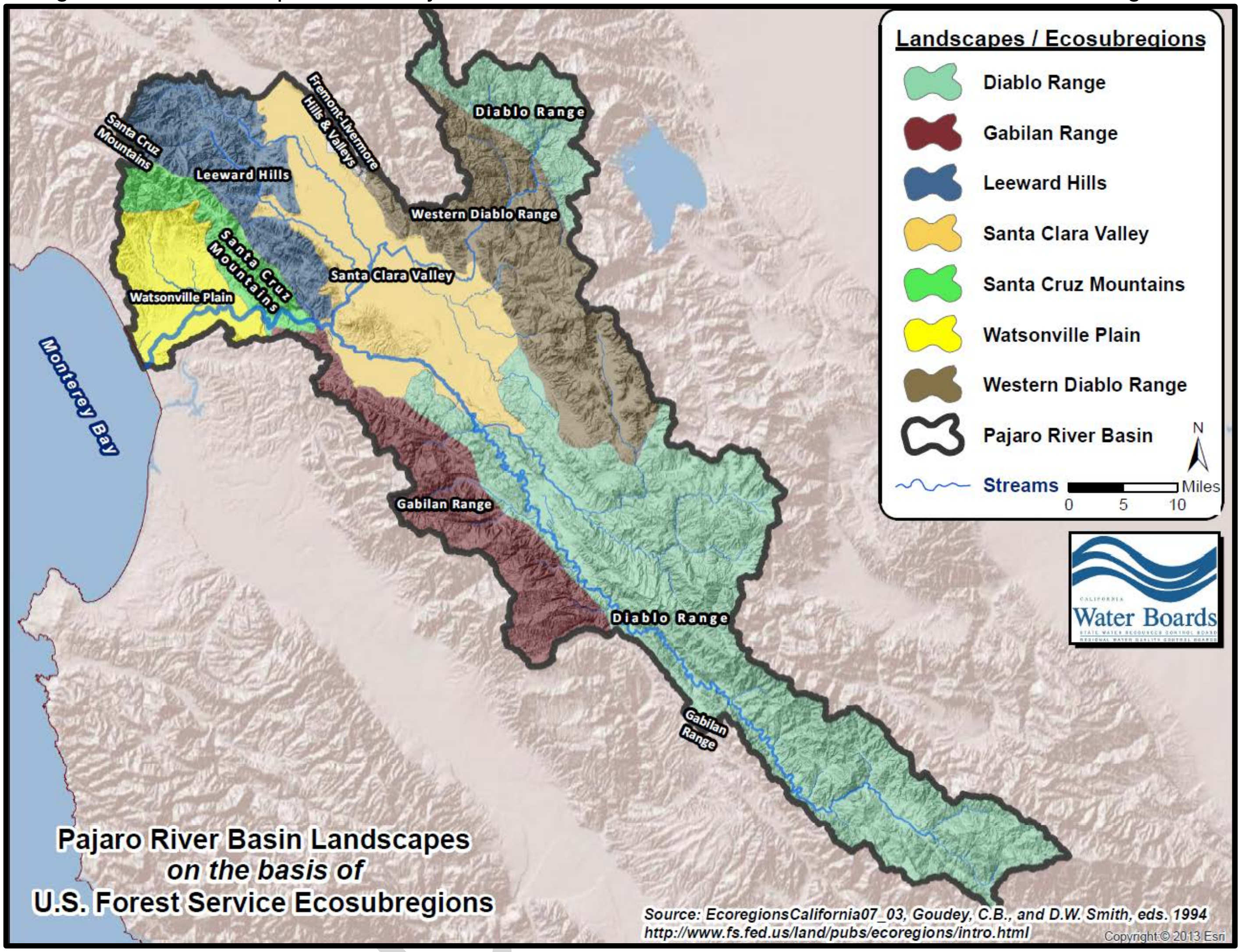
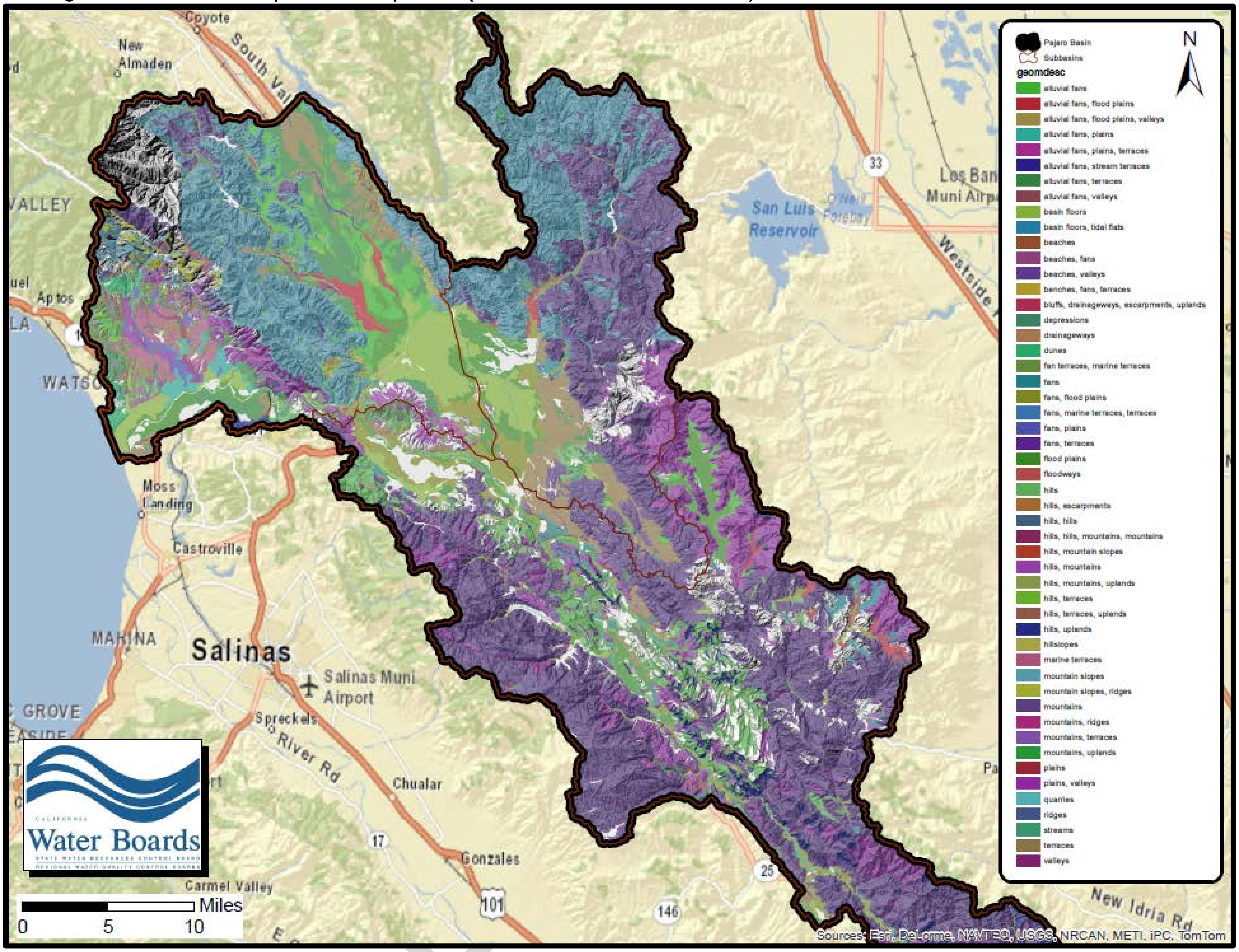


Figure 2-17 illustrates geomorphic landscape descriptions of the Pajaro River Basin; these geomorphic descriptions are available from U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database. Low gradient areas such as basin floors, flood plains, sloughs, and alluvial valleys are physiographic areas that are likely to be at higher risk of summertime algal growth and excessive algal biomass, relative to higher gradient, higher canopy, and non-perennial flow upland areas.

Figure 2-17. Geomorphic descriptions (source: NRCS-SSURGO).



2.6 Nutrient Ecoregions

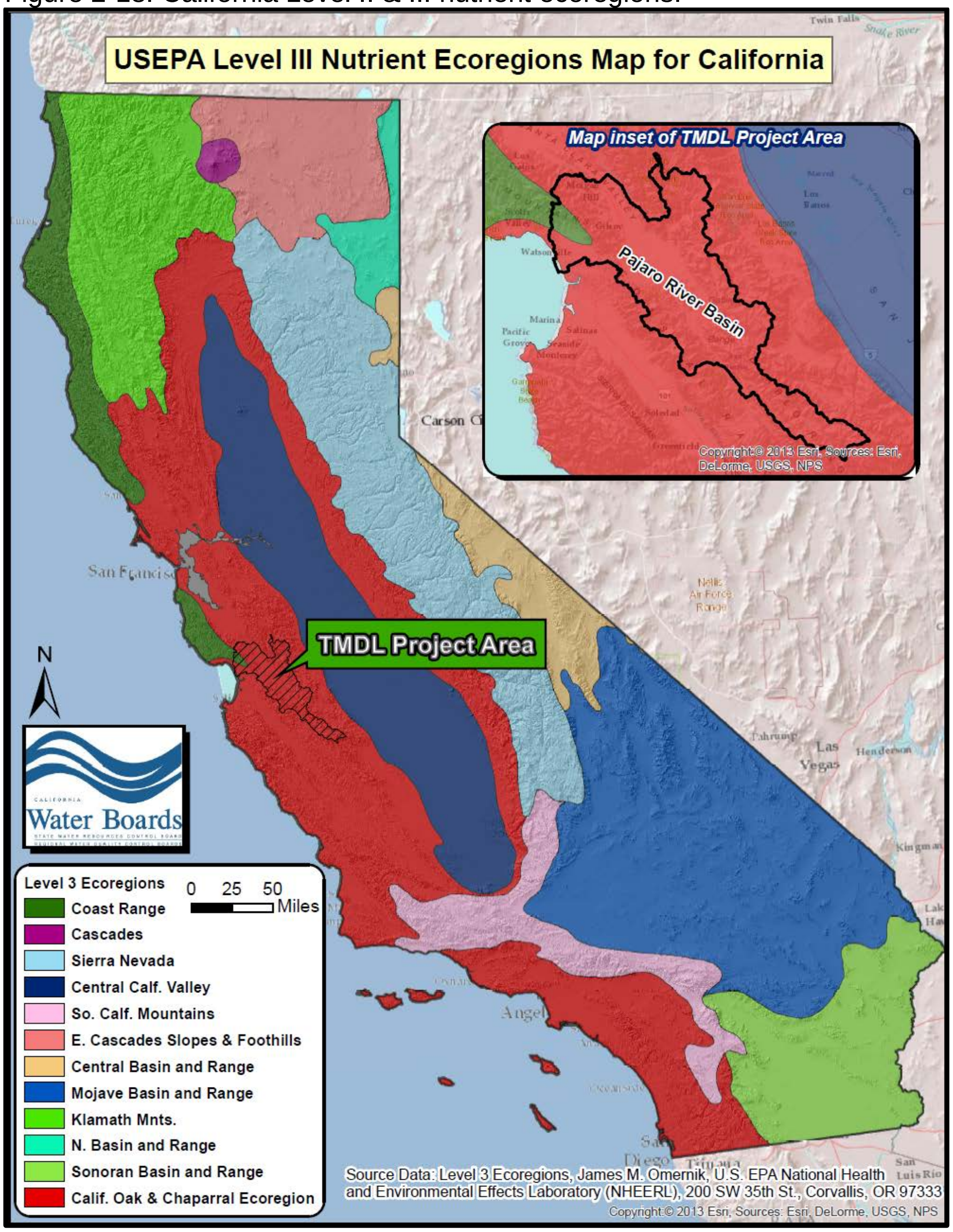
Nutrient ecoregions are USEPA designations for subregions of the United States that denote areas with ecosystems that are generally similar (e.g., physiography, climate, geology, soils, land use, hydrology). The Pajaro River Basin is located largely in Ecoregion III subecoregion 6 – Southern and Central California Chaparral and Oak Woodlands[22] (see Figure 2-18). 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 region 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. A small portion of the Pajaro River Basin (approximately 40 square miles of the Santa Cruz Mountains) is located in Ecoregion II subecoregion 1 – Coast Range[23] (see Figure 2-18). The primary distinguishing characteristic of this subecoregion is its highly productive, rain-drenched coniferous forests that cover the low mountains of the Coast Range. Sitka spruce and

[22] Also referred to throughout this report more concisely as "Nutrient Subecoregion 6".
[23] Also referred to throughout this report more concisely as "Nutrient Subecoregion 1."

coastal redwood forests originally dominated the fog-shrouded coast, while a mosaic of western red cedar, western hemlock, and seral Douglas-fir blanketed inland areas. Today Douglas-fir plantations are prevalent on the intensively logged and managed landscape.

Ecoregional natural variation illustrates that a single, uniform regulatory 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., the ecoregional, watershed, or subwatershed-scales. Therefore, note that some subsequent elements or sections of this Project Report will reference nutrient water quality conditions in Ecoregion III subecoregion 6 (i.e., Calif. Oak and Chapparal subecoregion).

Figure 2-18. California Level II & III nutrient ecoregions.



In 2000, the USEPA published ambient numeric criteria to support the development of State nutrient criteria in rivers and streams of Nutrient Ecoregion II and III. Narrative from the 2000 USEPA guidance is reproduced below (emphasis added):

> (The 2000 report) presents EPA's nutrient criteria for **Rivers and Streams in Nutrient Ecoregion II and 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 CWA. Under section 303(c) of the CWA, States and authorized Tribes have the primary responsibility for adopting water quality standards as State or Tribal law or regulation. The standards must contain scientifically defensible water quality criteria that are protective of designated uses. **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 for the criteria for their water quality standards.
>
> In developing these criteria recommendations, EPA followed a process which included, to the extent they were readily available, the following elements critical to criterion derivation:
>
> **Historical and recent nutrient data in Nutrient Ecoregion II & III:** Data sets from Legacy STORET, NASQAN, NAWQA and EPA Region10 were used to assess nutrient conditions from 1990 to 1998.
>
> **Reference sites/reference conditions in Nutrient Ecoregion II & III:** Reference conditions presented are based on 25th percentiles of all nutrient data including a comparison of reference condition for the aggregate ecoregion versus the subecoregions. States and Tribes are urged to determine their own reference sites for rivers and streams within the ecoregion at different geographic scales and to **compare** them to EPA's reference conditions.
>
> The intent of developing ecoregional nutrient criteria is to represent conditions of surface waters that are minimally impacted by human activities and thus protect against the adverse effects of nutrient over enrichment from cultural eutrophication. EPA's recommended process for developing such criteria includes physical classification of waterbodies, determination of current reference conditions, evaluation of historical data and other information (such as published literature), use of models to simulate physical and ecological processes or determine empirical relationships among causal and response variables (if necessary), expert judgment, and evaluation of downstream effects. To the extent allowed by the information available, EPA has used elements of this process to produce the information contained in this document. **The values for both causal (total nitrogen, total phosphorus) and biological and physical response (chlorophyll *a*, turbidity) variables <u>represent a set of starting points</u> for States and Tribes to use in establishing their own criteria in standards to protect uses.** The values presented in this document generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment and are based on information available to the Agency at the time of this publication. However, States and Tribes should critically evaluate this information in light of the specific designated uses that need to be protected.
>
> *-from: Ambient Water Quality Criteria Recommendations – River and Streams in Nutrient Ecoregion III, USEPA December 2000.*

Note that USEPA defines a reference stream as follows:

> *"A reference stream is a least impacted waterbody within an ecoregion that can be monitored to establish a baseline to which other waters can be compared. Reference streams are not necessarily pristine or undisturbed by humans."*

EPA proposed that the 25th percentiles of all nutrient data could be assumed to represent unimpacted reference conditions for each aggregate ecoregion, and also provided a comparison of reference condition for the aggregate ecoregion versus the subecoregions. These 25th percentile values were characterized as criteria recommendations that could be used to protect waters against nutrient over-enrichment (USEPA, 2000a). However, EPA also noted that States and Tribes may "need to identify with greater precision the nutrient levels that protect aquatic life and recreational uses."

For reference, USEPA's 25th percentiles (representing unimpacted reference conditions) for the California Oak and Chapparal Subecoregion (i.e., nutrient subecoregion 6) are presented in Table 2-8.

25th percentile criteria for the Coastal Range Subecoregion (i.e., nutrient subecoregion 1) are presented in Table 2-9.

Table 2-8. USEPA Reference conditions for Level III subecoregion 6 streams.

Parameter	25th Percentiles based on all seasons data for the Decade
Total Nitrogen (TN) – mg/L	0.52
Total Phosphorus (TP) – mg/L	0.03
Chlorophyll *a* – μg/L	2.4
Turbidity - NTU	1.9

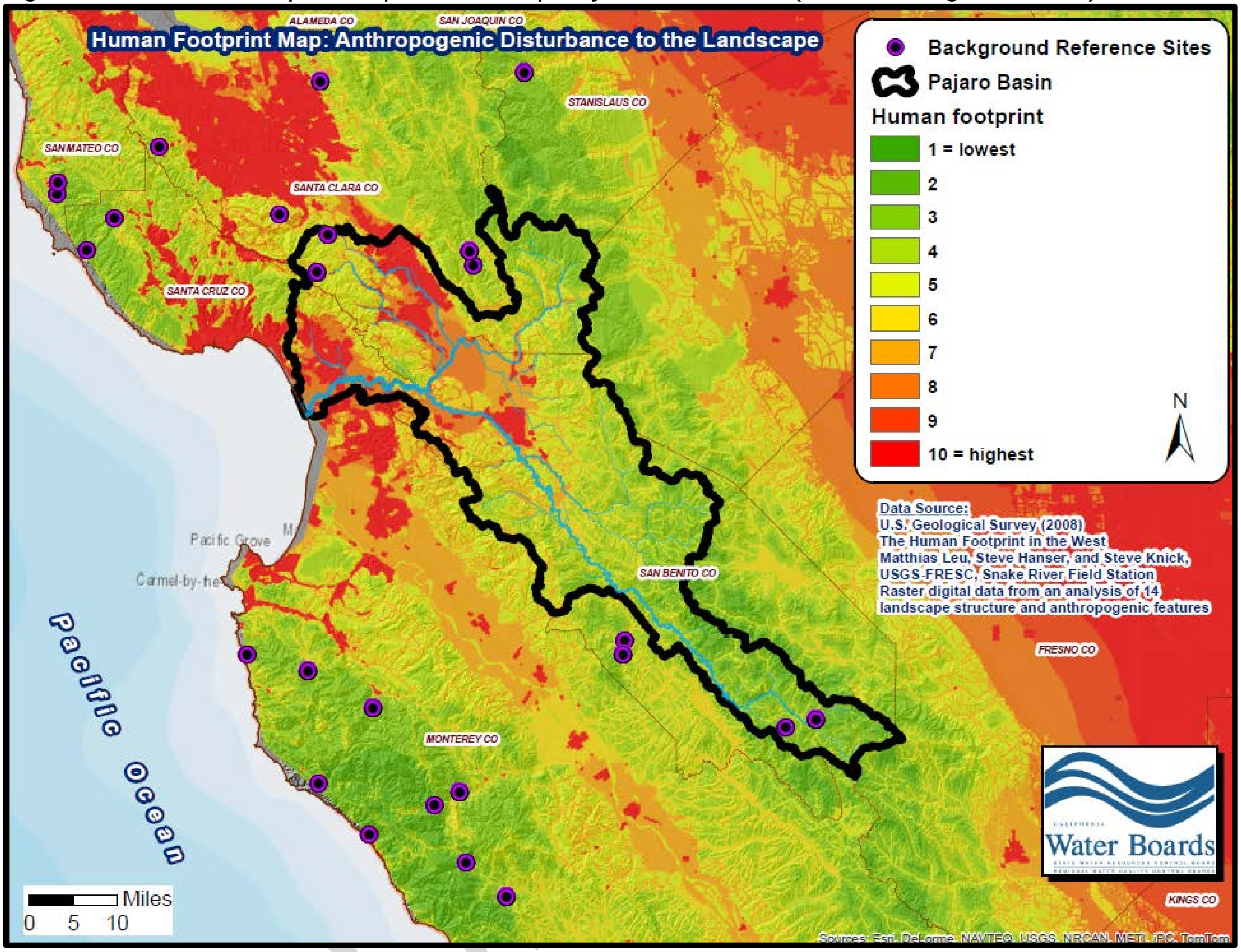
Table 2-9 . USEPA Reference conditions for Level II subecoregion 1 streams.

Parameter	25th Percentiles based on all seasons data for the Decade
Total Nitrogen (TN) – mg/L	0.14
Total Phosphorus (TP) – mg/L	0.010
Chlorophyll *a* – μg/L	1.53
Turbidity - NTU	1.08

It should be re-emphasized that the above ecoregional criteria are not regulatory standards, and USEPA in fact considers them “starting points” developed on the basis of data available at the time. USEPA 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.

One way to establish reference conditions appropriate for stream reaches of the Pajaro River Basin, is to apply the USEPA reference stream methodology (75th percentile approach) for water quality data from natural or lightly-disturbed headwater and tributary reaches in and around the Pajaro River Basin. The 75th percentile was chosen by USEPA since it is likely associated with minimally impacted conditions, and will be protective of designated uses. Staff can also calculate the 90th percentiles of nitrate and orthophosphate in these reaches to assess a plausible high-end concentration of these constituents that might be expected in lightly-disturbed areas. Figure 2-19 illustrates stream water quality monitoring sites in natural or lightly-disturbed areas in and around the Pajaro River Basin that could be considered in the development of reference water quality conditions.

Figure 2-19. Human footprint map and water quality reference sites (natural background sites).



2.7 Climate & Atmospheric Deposition

Precipitation data can be used, in conjunction with other physical metrics, to estimate flow for ungaged streams. For example the California State Water Resources Control Board (SWRCB) uses a precipitation-based proration method to estimate flow at ungaged streams (SWRCB, 2002). Further, having a good estimate of precipitation is also a necessary input parameter of the USEPA STEPL source analysis spreadsheet tool staff used for source assessment.

Precipitation rain gage data in the Pajaro River Basin is available from the National Oceanographic and Atmospheric Administration - Western Regional Climate Center (http://www.wrcc.dri.edu). The Pajaro River Basin has a Mediterranean climate, with the vast majority of precipitation falling between November and April (see Table 2-10).

Table 2-10. Project Area rain gage precipitation records.

Station	Elevation (ft)	Climatic Paramter	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**

Station	Elevation (ft)	Climatic Paramter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gilroy[A] **(1906-2013)**	194	Average Precipitation (inches)	4.70	3.74	3.24	1.40	0.39	0.10	0.05	0.05	0.32	0.90	2.21	3.72	**20.83**
Morgan Hill[A] **(1948-2013)**	375	Average Precipitation (inches)	4.83	4.72	3.21	1.50	0.29	0.00	0.03	0.00	0.04	0.95	2.39	3.70	**21.68**
Hollister 2[A] **(1948-2013)**	275	Average Precipitation (inches)	2.78	2.75	2.15	1.01	0.35	0.06	0.03	0.05	0.29	0.70	1.62	2.06	**13.86**
Pacines 5W[A] **(1948-2011)**	905	Average Precipitation (inches)	3.26	2.82	2.41	1.20	0.34	0.05	0.04	0.04	0.24	0.62	1.86	2.83	**15.71**
Corrilitos (COR) [B]	450	Average Precipitation (inches)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**27.05**
Burrell Station (BRL) [B, C]	1,850	Average Precipitation (inches)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**42.60**

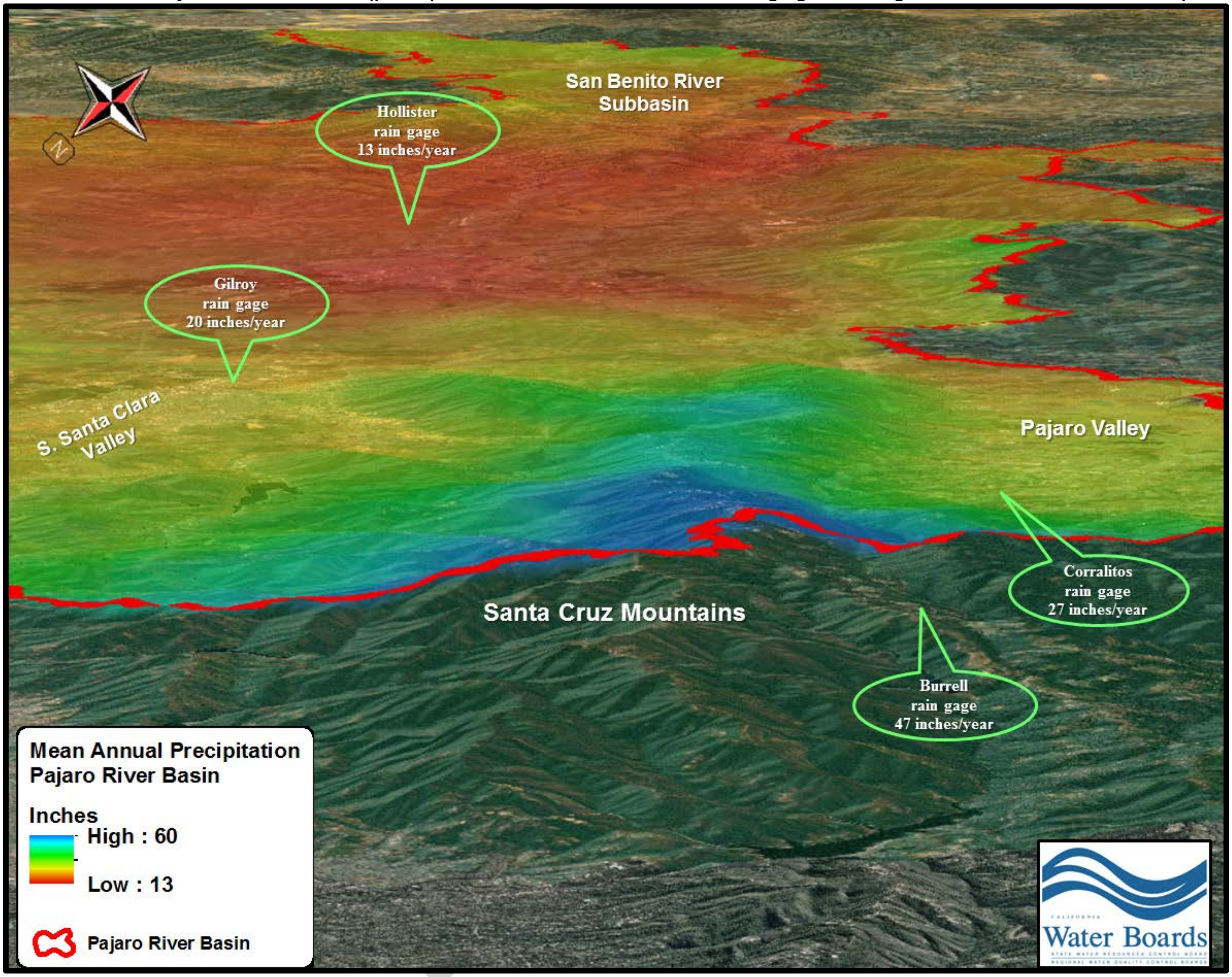
A: Western U.S. COOP weather station (Source: NOAA Western Regional Climate Center)
B: Calif. Dept. of Forestry weather station – data published in the California Natural Resources Agency CERES database
C: Located in Soquel Creek watershed of Santa Cruz mountains, 3.5 miles west of Pajaro Basin watershed boundary.
NR = not reported

It is important to recognize that rainfall gauging stations have limited spatial distribution, and that gauging stations tend to be located in lower elevations where people live. Consequently, these locations can bias estimates of regional rainfall towards climatic conditions at lower elevations. The topography of the California central coast region however, can result in significant orographic enhancement of rainfall (i.e., enhancement of rainfall due to topographic relief and mountainous terrain – for example, refer back to the higher-elevation Burrell Station rain gauge station shown previously in Table 2-10).

Note that elevations in the Pajaro Basin range from sea level to over 3,000 feet above mean sea level. Topography, elevation, and atmospheric circulation patterns can have pronounced effects on precipitation patterns. For example, the coastal Santa Cruz mountains create a substantial orographic effect as moist marine air is lifted, cooled, and condenses passing over the mountains. A noteworthy example is illustrated by rain gage records from March 12-17, 2012 when a couple of remote rain gages in the Santa Cruz mountains near Ben Lomond and Boulder Creek received between 16 and 20 inches of rain over those five days. Meanwhile, during those same five days in San Jose (only 25 miles to the northeast on the downslope side of the Santa Cruz mountains), only two-thirds of an inch of rain fell[24]. Figure 2-20 is an illustration of the orographic effect of the Santa Cruz Mountains. Clearly, it is not appropriate to treat rainfall as a relatively uniform spatial attribute of the Pajaro River Basin.

[24] National Weather Service, San Francisco Bay Area, Public Information Statement dated April 11, 2012 and entitled "March 2012 Regional Climate Summary.

Figure 2-20. Illustration of orographic effects in the Pajaro River Basin – oblique view looking southeast across the Pajaro River Basin (precipitation source data from rain gages and gridded PRISM estimates)

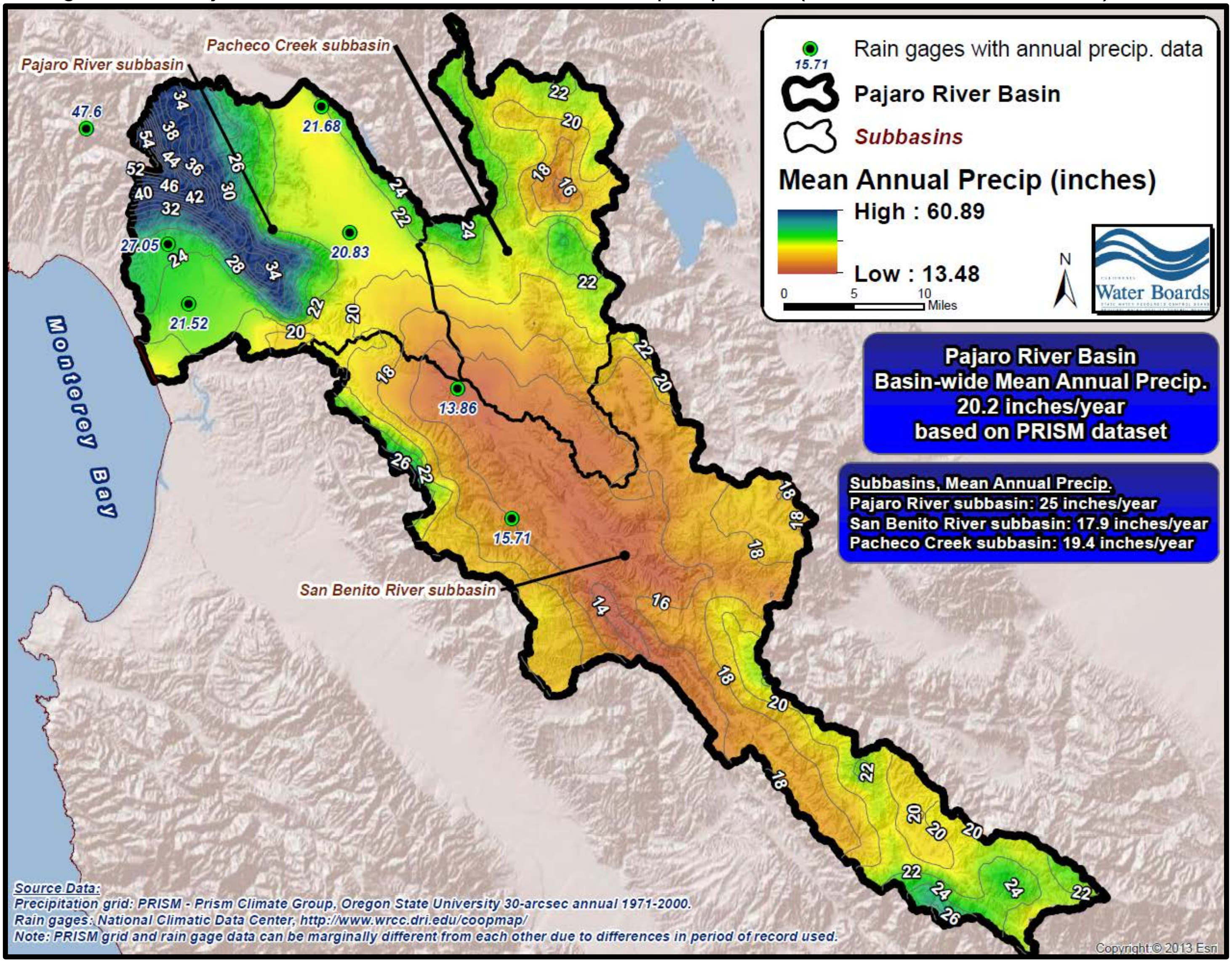


Therefore, due to climatic spatial variability, mean annual precipitation estimates for the Pajaro River Basin may be assessed using the Parameter-elevation Regressions on Independent Slopes Model (PRISM)[25]. PRISM is a climate mapping system that accounts for orographic climatic effects and is widely 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. PRISM is also the U.S. Department of Agriculture's official climatological dataset and PRSIM is used by the U.S. National Weather Service to spatially interpolate rainfall frequency estimates. An isohyetal map for estimated mean annual precipitation in the TMDL project area, with overlays of the hydrologic subbasin boundaries, is presented in Figure 2-21. The precipitation range estimates shown in Figure 2-1 comport reasonably well with precipitation range estimates reported by the County of Santa Clara[26].

[25] 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 incorporates a digital elevation model, and expert knowledge of climatic variation, including rain shadows, coastal effects, and orographic effects. Online linkage: http://www.prism.oregonstate.edu/

[26] The *2007 Drainage Manual* published by the County of Santa Clara states: *"Mean annual precipitation ranges from 10 inches in the inland valley areas to 56 inches at the top of the Santa Cruz Mountains."*

Figure 2-21. Pajaro River Basin estimated mean annual precipitation (1971-2000, source: PRISM).



Due to spatial variation in rainfall, it is prudent to develop not only a basin-wide estimate of mean annual rainfall, but also estimates of mean annual rainfall at the smaller subbasin scale. For example, it is clear that regional precipitation patterns and intensity in the Pajaro River Subbasin are different than in the San Benito River Subbasin. Consequently, based on the statistical summaries as calculated by ArcMap® 10.1 for digitally clipped PRISM rainfall grids, average precipitation estimates in the in the TMDL project area can be summarized as follows:

Table 2-11. Mean annual precipitation estimates within the Pajaro River Basin (1970-2000).

Hydrologic Area	Estimated mean annual precipitation, accounting for orographic effects (period of record 1971-2000)
Pajaro River Basin (basin-wide)	20.2 inches/year
Pajaro River Subbasin	25 inches/year
Pacheco Creek Subbasin	19.4 inches/year
San Benito River Subbasin	17.9 inches/year

Noteworthy is that staff's estimate of a Pajaro River basin-wide mean of 20.2 inches of rainfall annually comports reasonably well with an estimate developed by consulting engineers − in 2001 Raines, Mellon and Carella, Inc. estimated a Pajaro basin-wide average annual rainfall of approximately 19 inches (RMC, 2001).

Since development of nutrient numeric water quality targets are intended to take into account regional physical, hydrologic, and climatic variation, staff also considered additional climatic parameters for the Pajaro River Basin. Figure 2-22 illustrates estimates for mean annual potential evapotranspiration[27] (PET) and aridity indices[28] (AI) in the river basin. PET and AI are climatic parameters used to characterize degree of aridity or humidity at regional scales. Potential evapotranspiration (PET) rates in the Pajaro River Basin average 1,317 millimeters per year, with a range of 1,101 to 1,526 millimeters/year. PET is lower in the Pajaro Valley and Santa Cruz Mountains, and is marginally higher in the Pacheco Creek and San Benito River subbasins (refer to Figure 2-22). Pajaro River Basin aridity index (AI) values average 0.37, with a range of 0.255 to 0.778.

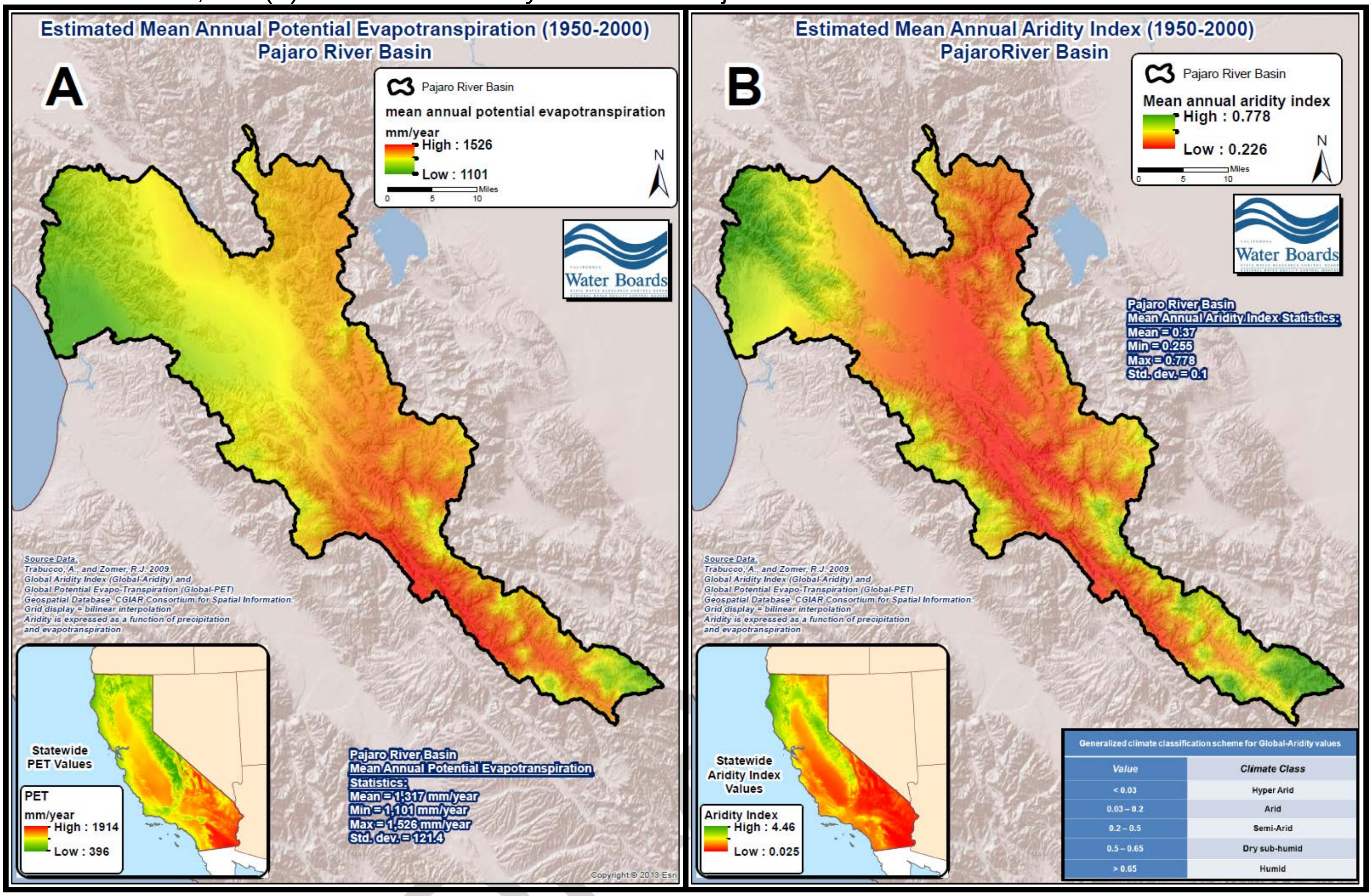
Practically speaking, the AI data show that most of the Pajaro River Basin would be characterized by a semi-arid climate on the basis of aridity index values – however, the Santa Cruz mountains portion of the river basin is characterized by a dry sub-humid to humid climate (refer to Figure 2-22).

While there is some climatic variability in the Pajaro River Basin on the basis of PET and AI, the magnitude and scale of the variation is not as large and substantial as variation observed at the statewide scale, or even at the scale of the central coast region (refer to Figure 2-22).

[27] Potential evapotranspiration is the amount of water that would be removed from the surface if the amount of water present were not a limiting factor. In other words, the potential evapotranspiration over the Sahara desert is very large because the amount of evaporation that *could* take place there is huge. However, because there isn't any water there to be evaporated the evapotranspiration that actually takes place is quite small.

[28] Aridity is expressed as a generalized function of precipitation and potential evapotranspiration. Lower aridity index (AI) values indicate increasingly arid conditions; by convention AI values from 0 to 0.5 indicate hyper-arid, to arid, to semi-arid conditions, whereas AI values greater than 0.5 indicate sub-humid to humid climatic conditions.

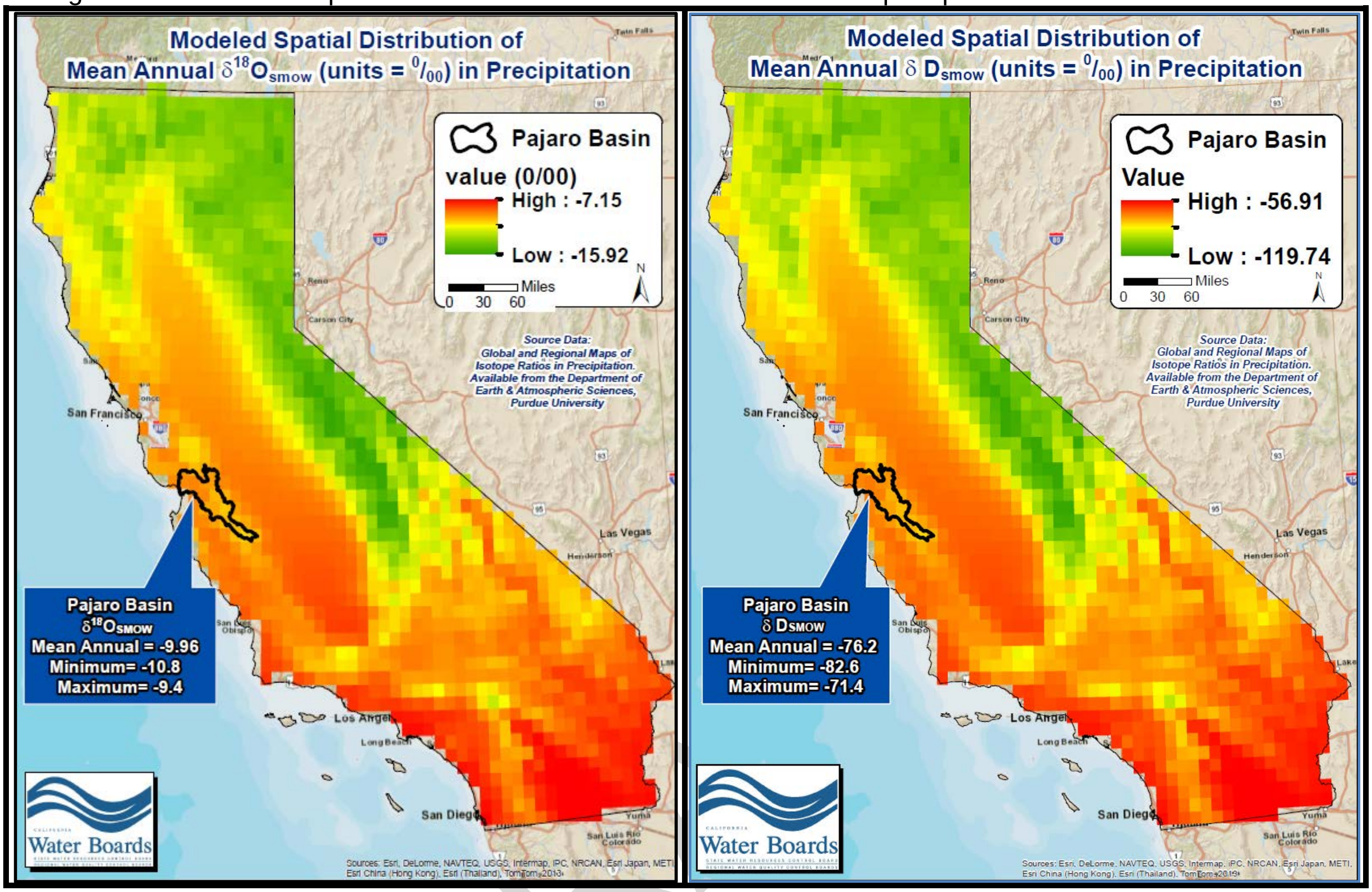
Figure 2-22. Climatic parameters: (A) estimated mean annual potential evapotranspiration in the Pajaro River Basin; and (B) mean annual aridity index in the Pajaro River Basin.



Staff also compiled information on isotopes in precipitation. Isotopes in groundwater, in surface water, and in precipitation are used to give insight into the movement and distribution process of waters within the hydrologic cycle. A growing number of hydrologic studies rely on water isotope tracers to determine the geospatial origin and transport of water, geological, or biological materials. Isotopes commonly used in these types of investigations include the heavy stable isotopes of the water molecule: deuterium (D) and oxygen-18 (^{18}O), and others. Figure 2-23 presents the modeled spatial distribution of $\delta^{18}O_{smow}$ and δD_{smow} ratios in California precipitation, on the basis of data developed by the Purdue University Department of Earth and Atmospheric Sciences[29].

[29] Global and Regional Maps of Isotope Ratios in Precipitation. Department of Earth & Atmospheric Sciences, Purdue University, West Lafayette, Indiana. Online linkage: http://wateriso.eas.purdue.edu/waterisotopes/index.html

Figure 2-23. Modeled spatial distribution of $\delta^{18}O$ and δD in California precipitation.



Based on the modeled spational distribution of isotope ratios, Table 2-12 presents summaries of the mean and range of isotope ratios in the Pajaro River Basin and in the state of California.

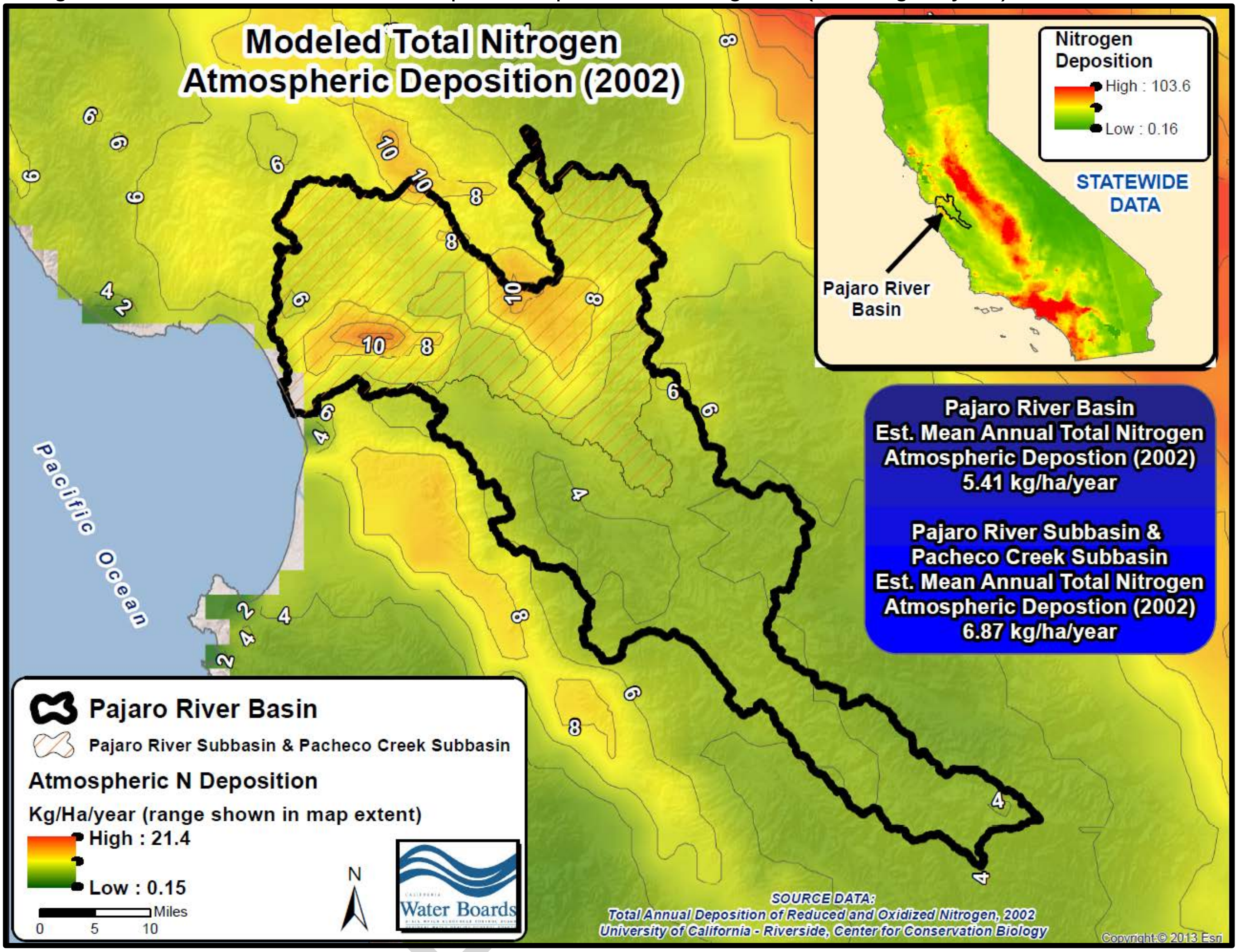
Table 2-12. Summary table showing annual mean and range of isotope ratios in precipitation.

Geographic Location	Mean Annual $\delta^{18}O_{smow}$	Range $\delta^{18}O_{smow}$	Mean Annual δD_{smow}	Range δD_{smow}
Pajaro River Basin (basin-wide)	–9.96	–10.8 to –9.4	–76.2	–82.6 to –71.4
California (state-wide)	–10.7	–15.9 to –7.2	–82.5	–119.7 to –56.9

Input of nutrients in rainfall can be a significant source of loading in any given watershed. Because nitrogen can exist as a gaseous phase (while phosphorus cannot), nitrogen is more prone to atmospheric transport and deposition. It is important to recognize however that atmospheric deposition of nutrients is typically more significant in lakes and reservoirs, than in creeks or streams (USEPA, 1999). This is because the surface area of a stream is typically small compared to the area of a reservoir or a watershed. Figure 2-24 presents estimated total atmospheric deposition for the year 2002 in California and in the Pajaro River Basin on the basis of a deposition model developed by the University of California-Riverside Center for Conservation Biology[30].

[30] 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.

Figure 2-24. Estimated annual atmospheric deposition of nitrogen-N (units=kg/ha/year).

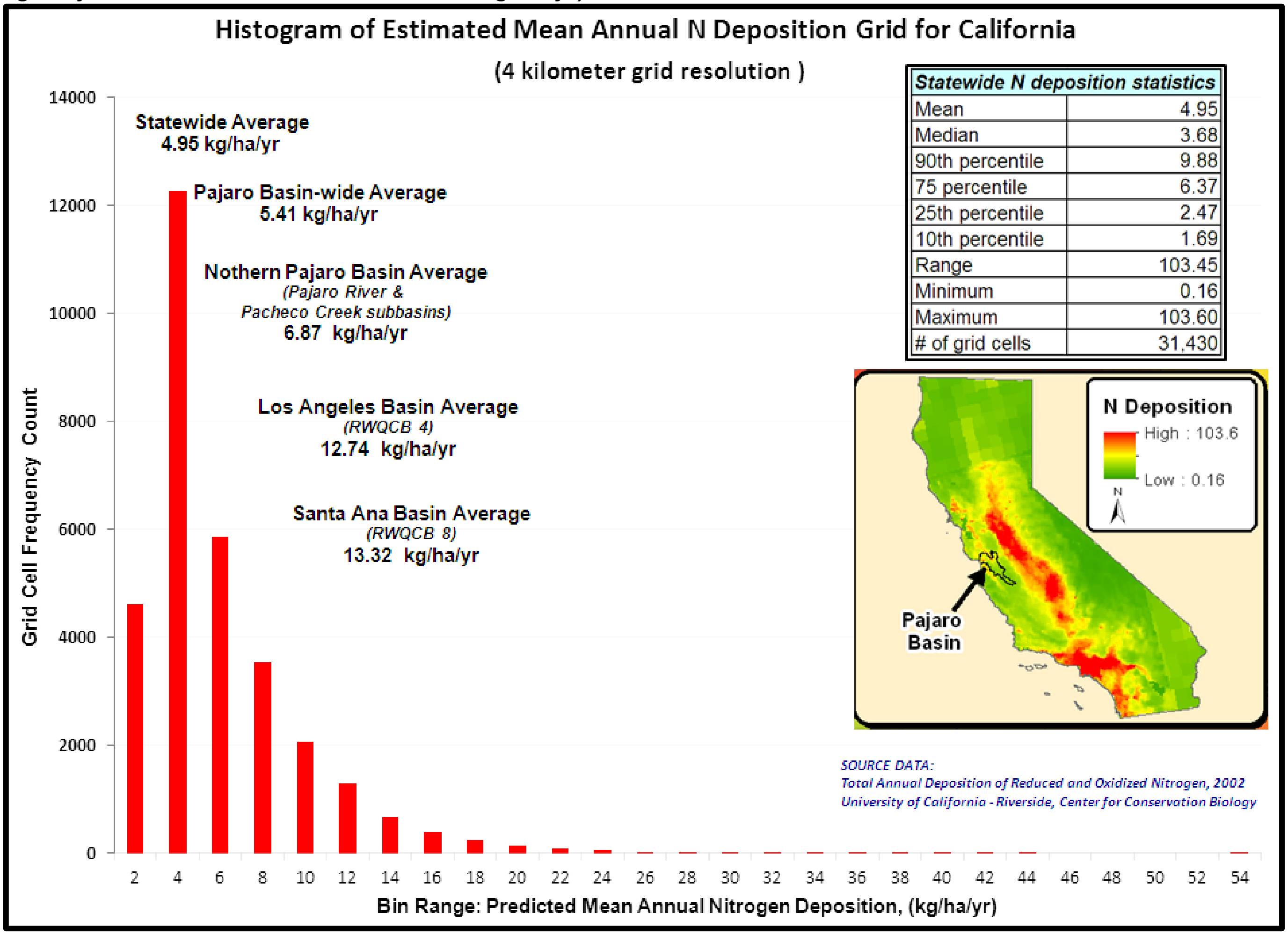


Based on the University of California-Riverside model, atmospheric deposition to total nitrogen in the Pajaro River Basin can be characterized as follows:

Estimated average basin-wide annual atmospheric of total nitrogen for the *Pajaro River Basin:*
5.41 kg/hectare per year
Estimated average annual atmospheric of total nitrogen in the *Pajaro River and Pacheco Creek subbasins:*
6.97 kg/hectare per year

Figure 2-25 illustrates a histogram of the gridded atmospheric total nitrogen depostion model, and summary average depostion estimates for various regions of the state. Based on summary statistics of the gridded nitrogen deposition data, the 25th percentile is 2.5 kg/ha and the median is 3.7 kg/ha – these values presumably could represent a plausible range for lightly-impacted or natural ambient conditions in California. Estimated atmospheric depostion of nitrogen in the Pajaro Basin (5.41 kg/ha) is marginally higher than the aforementioned ambient condition; however deposition in the river basin is substantially lower than in highly developed areas of southern California such as the Los Angeles Basin and the Santa Ana Basin (see Figure 2-25).

Figure 2-25. Histogram of variation in estimated statewide mean annual atmospheric nitrogen (N) deposition (2002) based on UC-Riverside gridded spatial model of N-deposition rates. Note that average N atmospheric deposition in the Pajaro River Basin (5.41 kg/ha/yr) is substantially less than areas of the state characterized by high average rates of N atmospheric deposition (e.g., Los Angeles Basin = 12.74 kg/ha/yr, and Santa Ana Basin = 13.32 kg/ha/yr)



2.8 Tree Canopy & Vegetation

Nutrient-related impacts and biostimulation may often occur in areas where the river is wide, water is shallow, and tree canopy is open and light is readily available. As such, having estimates of variations in tree canopy cover are important to consider in the development of numeric nutrient criteria. Tree canopy and shading can vary from zero percent, particularly along coastal sloughs and water conveyance structures, to significantly higher in other types of water bodies (see Figure 2-26 and Figure 2-27).

An additional reason for developing plausible canopy distribution data for this TMDL project is that nutrient water quality target development tools staff used require input for canopy as a parameter influencing sunlight availability, and thus affecting algal photosynthesis.

Figure 2-26. Percent tree canopy in the Pajaro River Basin and vicinity.

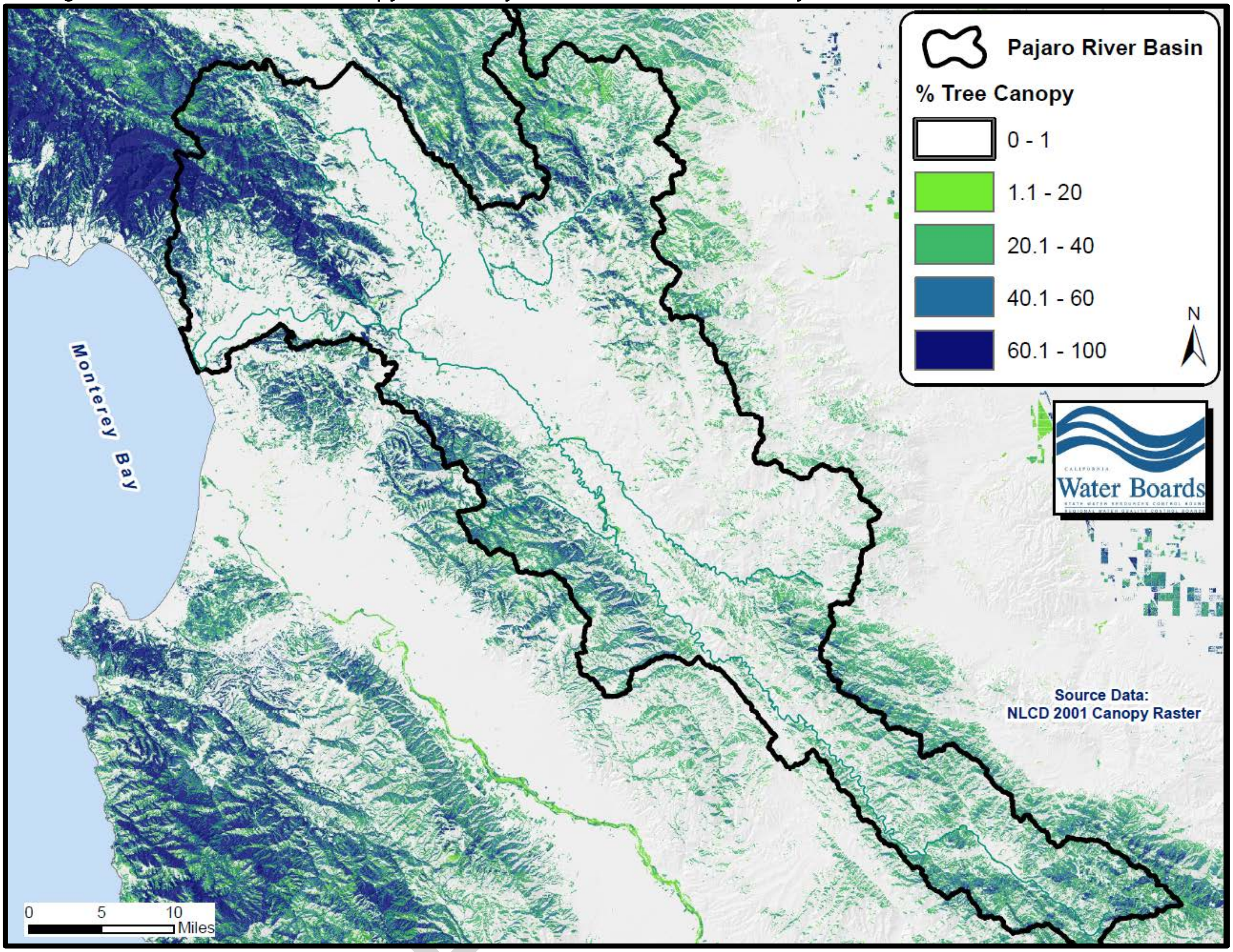
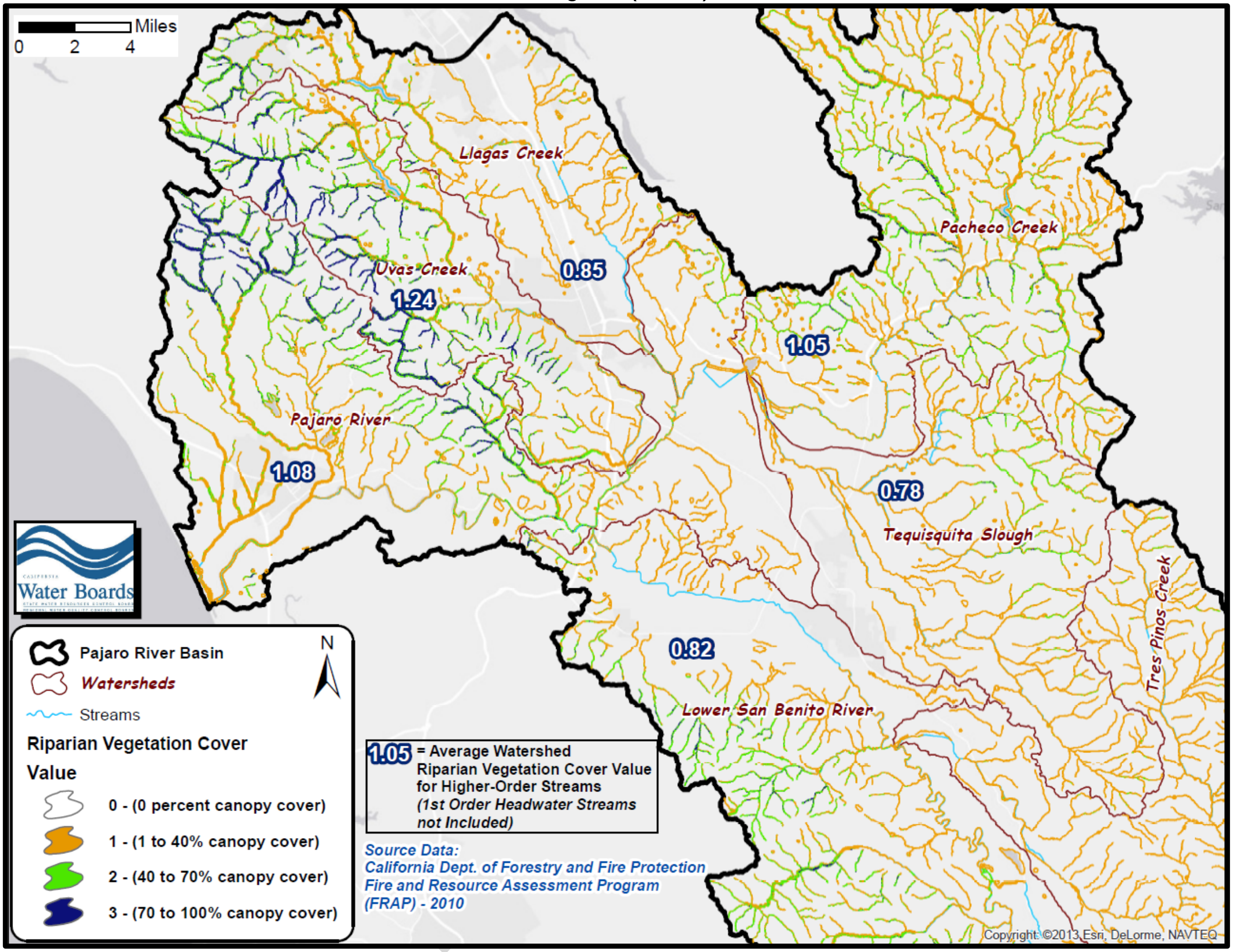


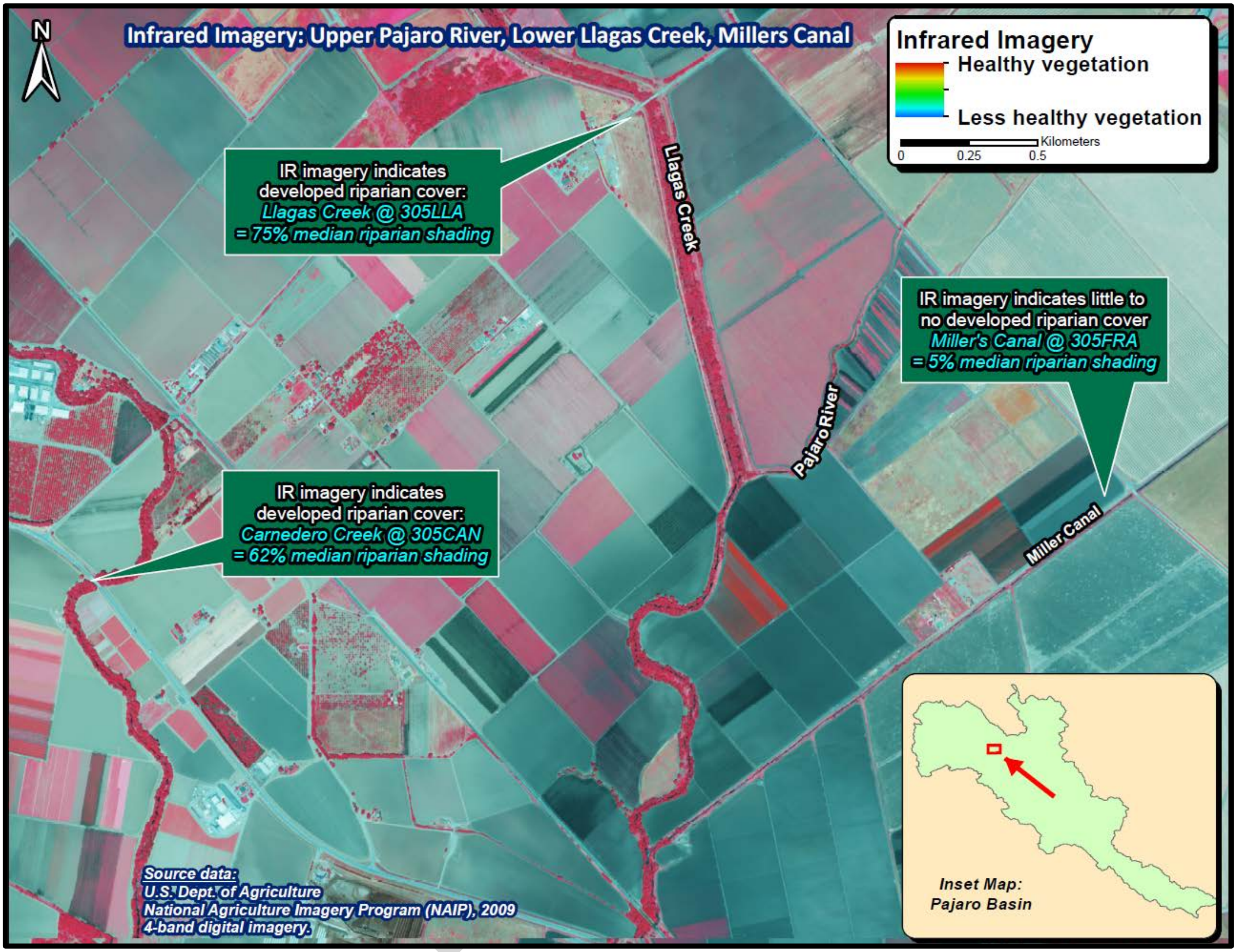
Figure 2-27 presents riparian spatial data which illustrates that, in general, higher amounts (%) of riparian cover are often expected in upland ecosytems of the Pajaro River Basin (for example, in the upland stream reaches in the Santa Cruz Mountains); in contrast valley floor and lowland stream reaches (i.e., southern Santa Clara valley) are often characterized by lower amounts (%) of riparian cover.

Figure 2-27. Riparian vegetation cover values, based on 2010 Calif. Dept. of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP).



Other methods are available to staff to assess the spatial distribution of riparian vegetative cover. One such methodology is infrared (IR) spectral analysis. IR imagery is available from the National Agricultural Imagery Program, a program which collects and processes IR aerial photography. The usefulness of this IR analysis in aerial imagery is based on the fact that most objects exhibit a neglible IR reflectance, but actively growing plants exhibit a high IR reflectance and stressed plants (either from disease or drought) exhibit a reduction in their IR reflectance. Figure 2-28 illustrates variations in riparian canopy cover in reaches of the upper Pajaro River, lower Llagas Creek, and Miller's canal on the basis of IR reflectance.

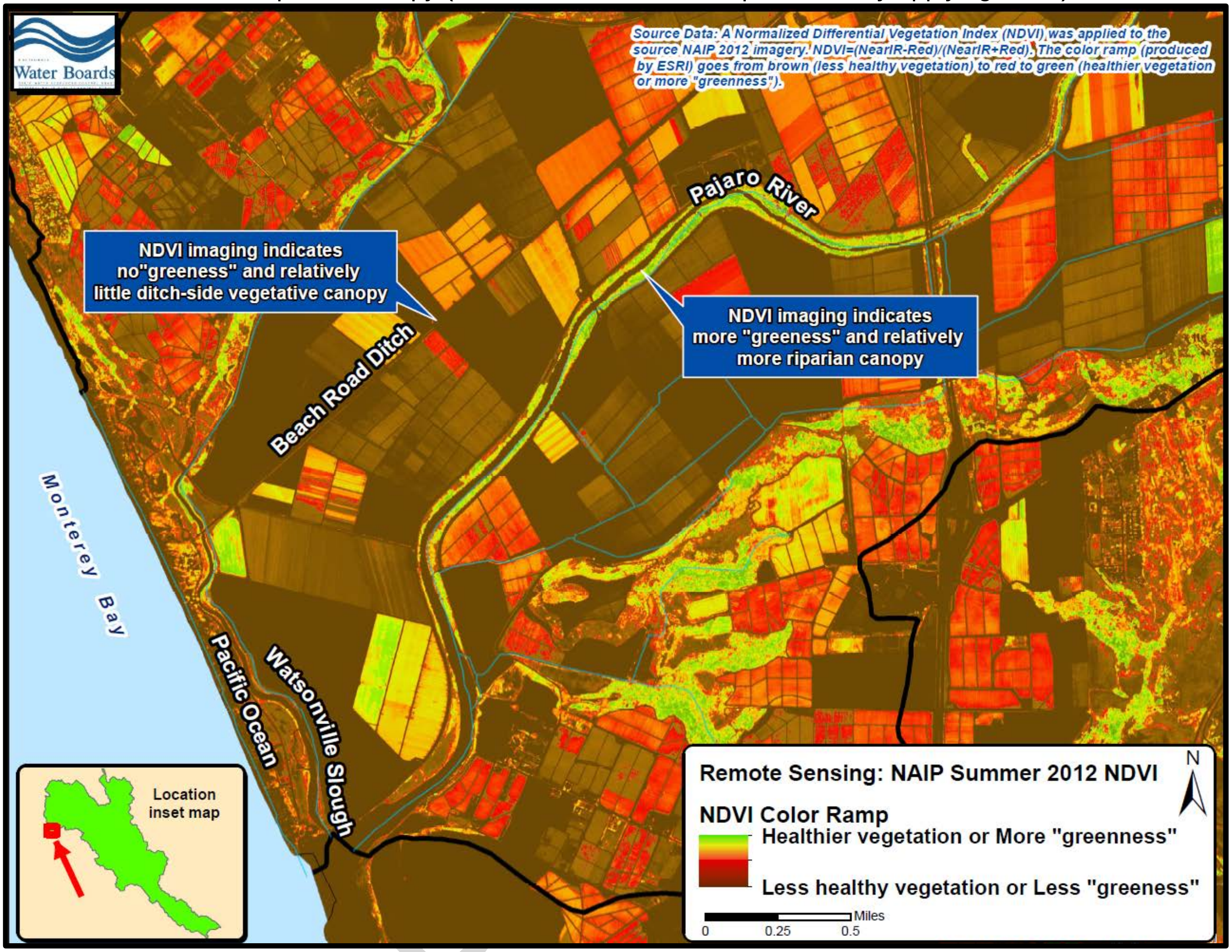
Figure 2-28. Infrared spectral image (2009) of upper Pajaro River, lower Llagas Creek, and Miller's canal area.



Normalized Differential Vegetation Index (NDVI) is an imaging methodology in which the infrared and the red band are processed to provide a measurement of the density of plant growth. The NDVI process creates an image dataset that mainly represents greenery. NDVI imagery has been produced by the California Department of Fish and Wildlife[31]. Figure 2-29 illustrates a Summer 2012 NDVI image of the lowermost Pajaro River Basin near Watsonvile and the confluence with Monterey Bay. The NDVI color ramp goes from brown (less healthy vegetation, or bare soil) to red to green (healthier vegetation or more “greenness”).

[31] California Dept. of Fish and Wildlife. Map Services. Online linkage: http://www.dfg.ca.gov/biogeodata/gis/map_services.asp

Figure 2-29. Lower Pajaro River NDVI image illustrating stream reaches with little to no riparian canopy, and areas with more riparian canopy (NAIP summer 2012 data presented by applying NDVI).



2.9 Groundwater

TMDLs do not directly address pollution of groundwater by controllable sources. However, shallow groundwater baseflow pollutant inputs to streams, and groundwater recharge designated beneficial uses of streams may be considered in the context of TMDL development. It is well known that groundwater discharge to surface waters can be a source of nutrients, salts, boron, or other pollutants to any given surface waterbody. The physical connection between surface waters and groundwater is widely recognized by scientific agencies 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."*
>
> From: U.S. Geological Survey, 1998. Circular 1139: "Groundwater and Surface Water – A Single Resource"

"While ground water and surface water are often treated as separate systems, they are in reality highly interdependent components of the hydrologic cycle. Subsurface interactions with surface waters occur in a variety of ways. Therefore, the potential pollutant contributions from ground water to surface waters should be investigated when developing TMDLs."

From: U.S. Environmental Protection Agency, Guidance for Water Quality-Based Decisions: The TMDL Process – Appendix B. EPA 440/4-91-001

"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."

From: California Department of Water Resources: Relationship between Groundwater and Surface Water
http://www.water.ca.gov/groundwater/groundwater_basics/gw_sw_interaction.cfm

In addition to the U.S. Geological Survey reporting shown above regarding the potential for polluted streams to degrade underlying groundwater, it is similarly recognized by local resource professionals that subsurface infiltration of river waters can affect, alter, or degrade the water quality and supply of an underlying groundwater resource:

"The Pajaro River flows west across the San Andreas Rift Zone… to its confluence of Salsipuedes Creek at the City of Watsonville. The distinguishing feature of the East Area is that its groundwater is recharged primarily from the Pajaro River…Boron originates from geological sources, generally in the San Benito watershed… Related to this recharge, wells in this area produce mixed-ion or sodium-carbonate water, with virtually every well in the East Area having a boron concentration exceeding 0.2 mg/L. ***This local boron concentration is a water-quality fingerprint of recharge*** *(sic)* ***Pajaro River waters*.****"*

From: Pajaro Valley Water Management Agency, Draft Environmental Impact Report for the Basin Management Plan Update, October 2013.

"Category 2 is recent or young groundwater…The TDS range for this category is 300-1,100 mg/L ***depending on the source of the recharging water* (Pajaro River, Corralitos and Carneros Creek****, precipitation, and applied water). The best quality groundwater in this basin…is outside the spheres of influence of the seawater intrusion* ***and the plume of poor quality water associated with Pajaro River infiltration*.****"*

From: California Department of Water Resources, California's Groundwater Bulletin 118, Pajaro Valley Groundwater Basin.

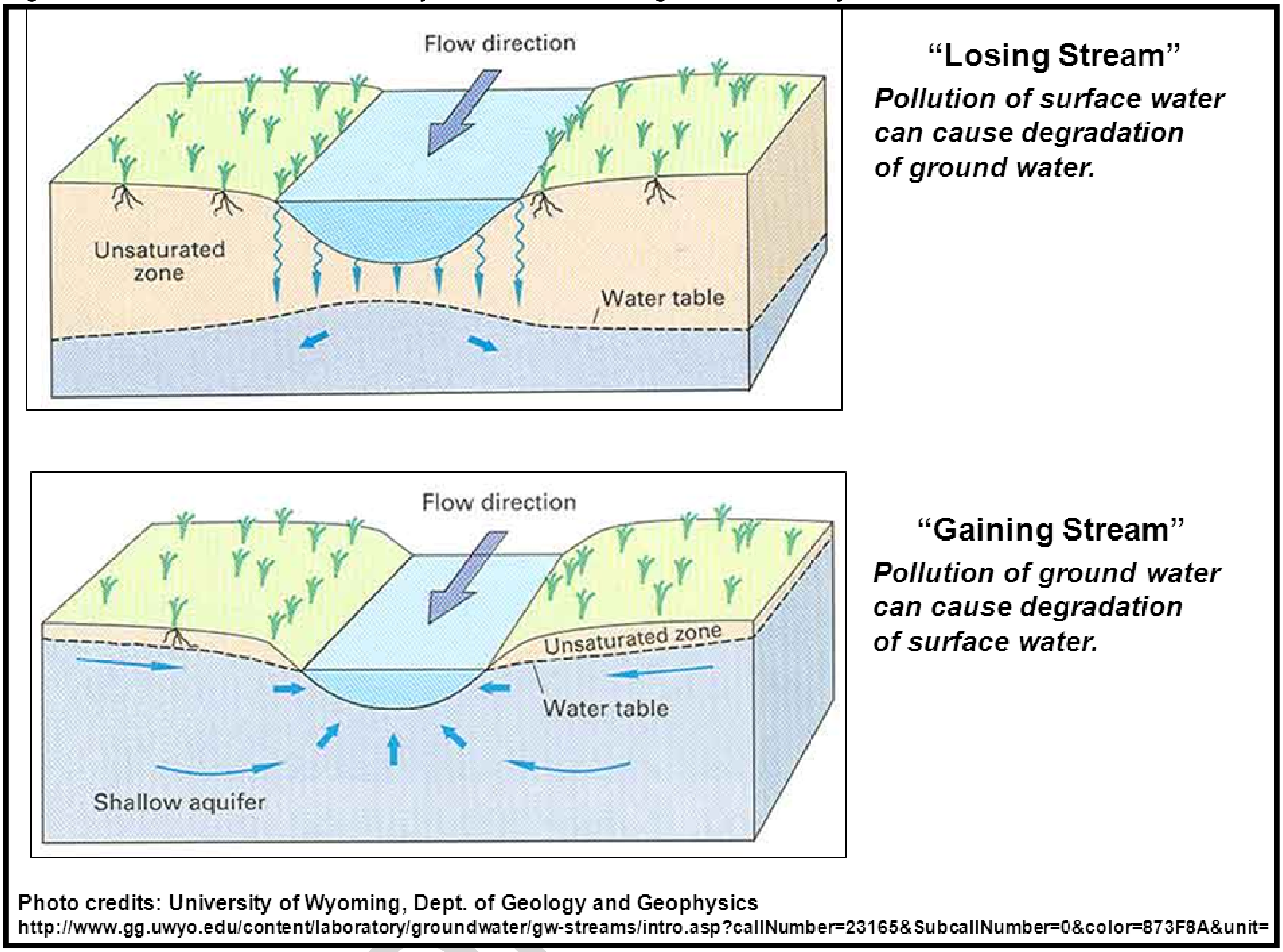
***** emphasis added by Central Coast Water Board staff

To highlight the importance of the nexus between surface waters and groundwaters, it is worth noting that a water budget hydrologic model reported by the Pajaro Valley Water Management Agency indicates that stream infiltration accounts for 30% of all water inputs into Pajaro Valley groundwater basin aquifers[32].

The range of information discussed above is illustrated conceptually in Figure 2-30.

[32] Pajaro Valley Water Management Agency, Annual Simulated Water Budget. Inputs – 16,000 acre feet stream recharge + 35,000 acre feet from precipitation and applied water + 2,000 acre feet from subsurface inflow. Onlike linkage: http://www.pvwma.dst.ca.us/hydrology/hydrologic-modeling.php

Figure 2-30. Streams are intimately connected to the ground water system.

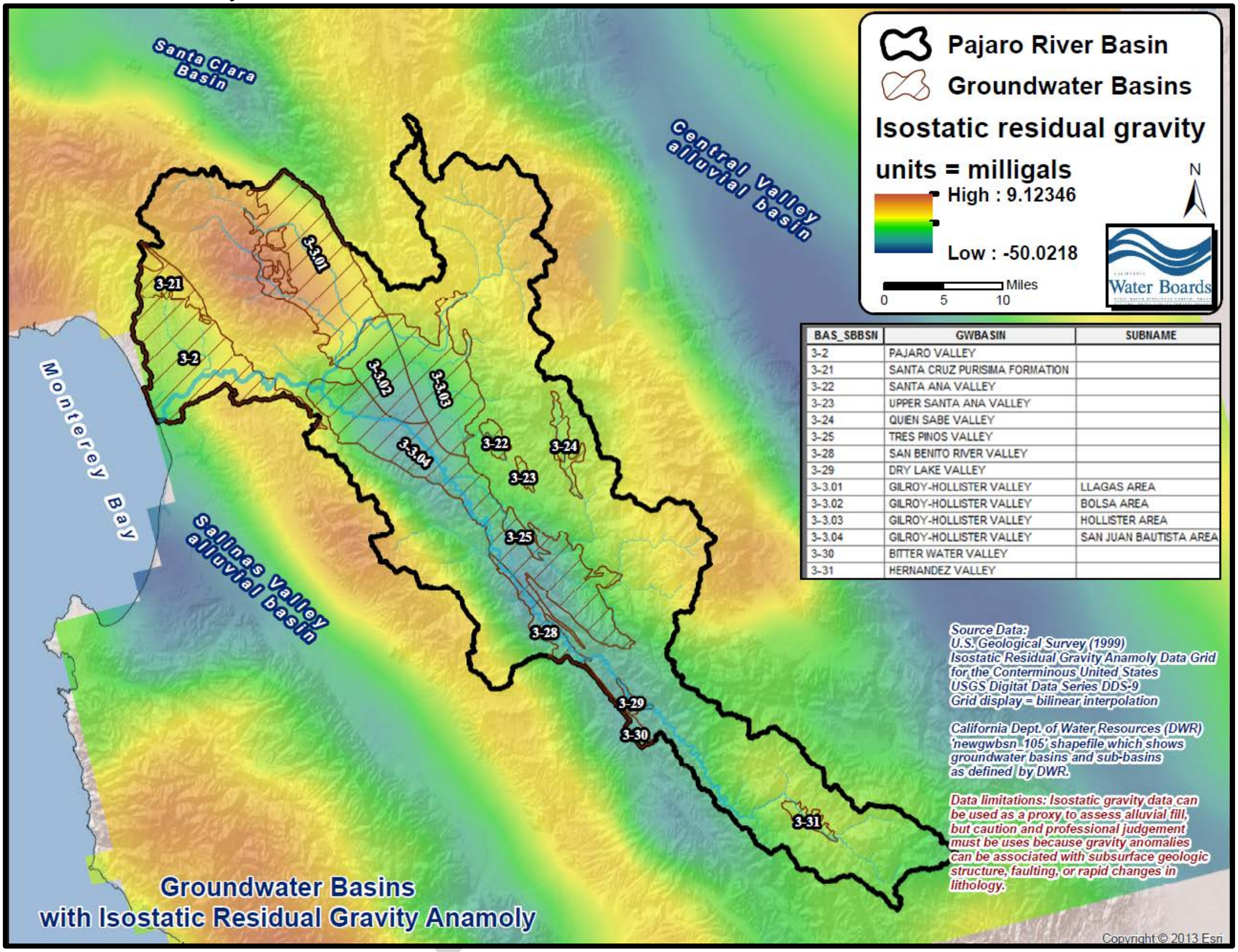


Based on the aforementioned concepts and information, it is relevant to consider the nexus between groundwaters and surface water in this TMDL project. In addition, groundwater information is needed for the pollutant source characterization spreadsheet model used in the TMDL project.

As with any watershed study, it is warranted to be congnizant of the distribution of alluvial groundwater basins located within the Pajaro River Basin. Alluvial groundwater basins in and around the Pajaro River Basin with an isostatic residual gravity anomalies overlay[33] are presented in Figure 2-31. Note that groundwater basins are three-dimensional in architecture, and gravity data can thus give some insight into the shape and distribution of alluvial basins. A number of groundwater basins and subbasins underlie the Pajaro River Basin; hydrologic communication between these groundwater basins are limited to an extent by faulting and geologic structure.

[33] Isostatic gravity anomaly data are a geophysical attribute that measures density contrasts, and can be used as a proxy to assess the presence and depth/thickness of alluvial fill. Caution and professional judgement must be used, because gravity anomalies can also be associated with subsurface geologic structure, fauts, and rapid changes in lithology. Data source: U.S. Geological Survey, *Isostatic residual gravity anomaly data grid for the conterminous U.S.*, 1999.

Figure 2-31. Groundwater basins in the Pajaro River Basin with regional isostatic residual gravity anomalies overlay.

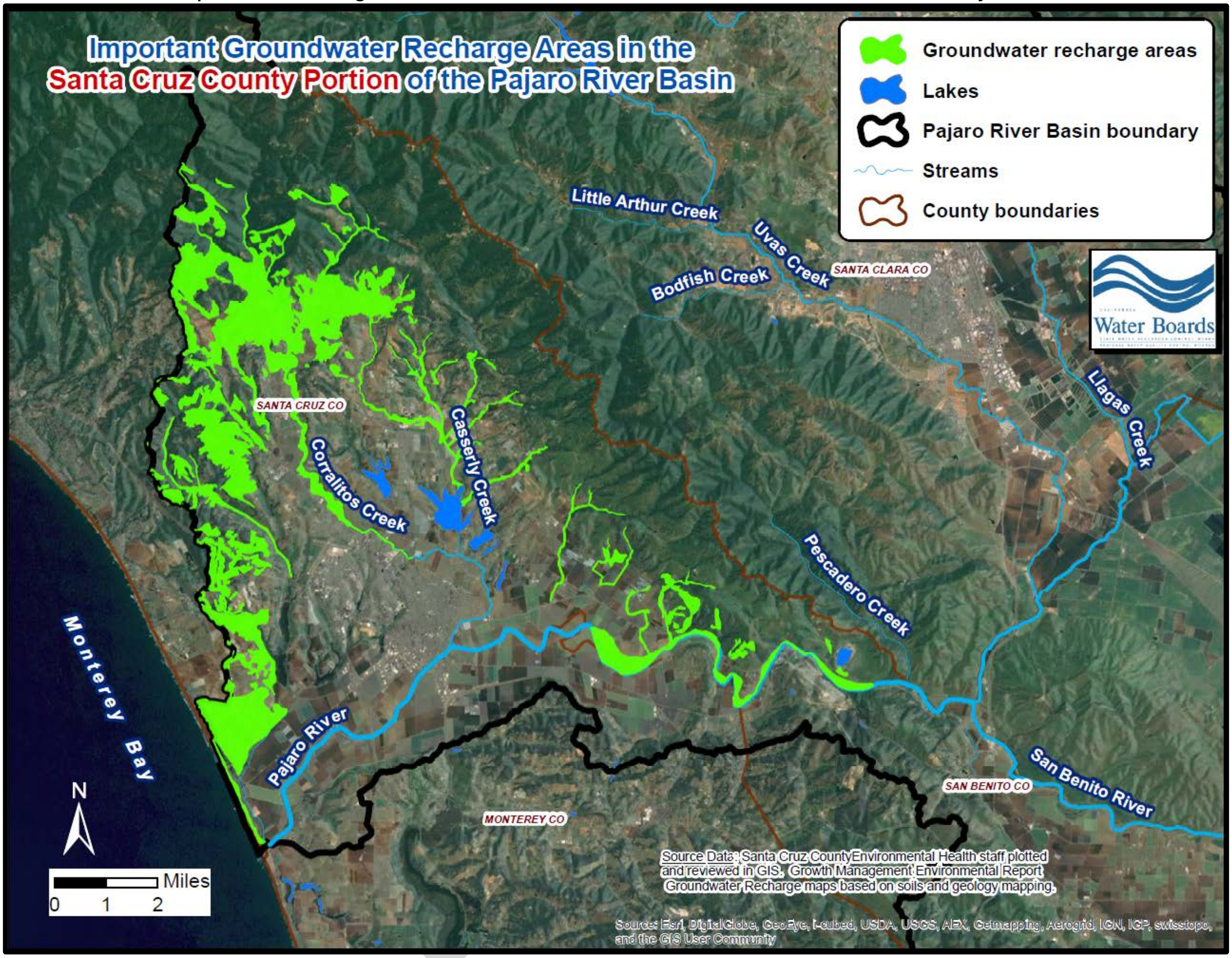


BAS_SBBSN	GWBASIN	SUBNAME
3-2	PAJARO VALLEY	
3-21	SANTA CRUZ PURISIMA FORMATION	
3-22	SANTA ANA VALLEY	
3-23	UPPER SANTA ANA VALLEY	
3-24	QUIEN SABE VALLEY	
3-25	TRES PINOS VALLEY	
3-28	SAN BENITO RIVER VALLEY	
3-29	DRY LAKE VALLEY	
3-3.01	GILROY-HOLLISTER VALLEY	LLAGAS AREA
3-3.02	GILROY-HOLLISTER VALLEY	BOLSA AREA
3-3.03	GILROY-HOLLISTER VALLEY	HOLLISTER AREA
3-3.04	GILROY-HOLLISTER VALLEY	SAN JUAN BAUTISTA AREA
3-30	BITTER WATER VALLEY	
3-31	HERNANDEZ VALLEY	

The County of Santa Cruz Department of Environmental Health Service has published spatial data highlighting areas which are particularly important for groundwater recharge in the Santa Cruz County portion of the Pajaro River Basin[34], which are presented in Figure 2-32. On the basis of these data, It is worth noting that some reaches of the Pajaro River are considered a particularly important source of groundwater recharge.

[34] County of Santa Cruz Dept. fo Environmental Health Service. GIS Layer Number = 36/ Original Mapping Source: Growth Management Environmental Report Groundwater Recharge Maps based on soils and geology mapping.

Figure 2-32. Important groundwater recharge areas of the Santa Cruz County portion of the Pajaro River Basin. Note important recharge areas associated with some inland reaches of the Pajaro River.



An additional reason for developing groundwater data for this TMDL project is that many nutrient loading models require data input for shallow groundwater nutrient concentrations to allow for baseflow load estimates to surface waters. Indeed, shallow groundwater zones and perched groundwater, which can contribute to stream flows, are known to exist in the Pajaro River Basin:

*"… stream flow in lower Pacheco Creek (from Highway 156 and downstream) was **the result of perched groundwater resurfacing***, which maintained surface flows to San Felipe Lake".*

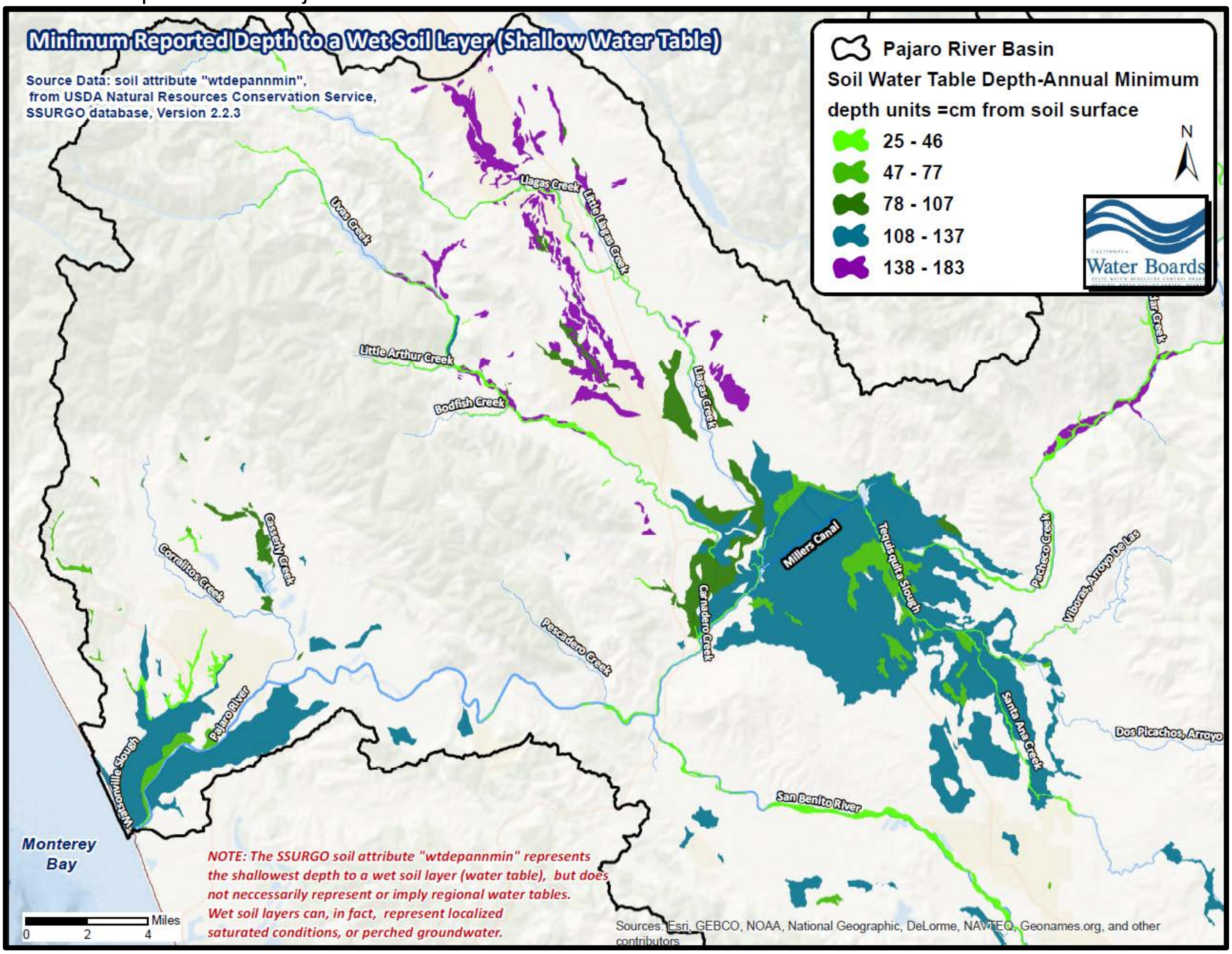
*"**Perched groundwater** from Lower Llagas Creek sustains the portion of the Pajaro River between Llagas Creek and Miller Canal."*

From: Casagrande (2011). Aquatic Species and Habitat Assessment of the Upper Pajaro River Basin, Santa Clara and San Benito Counties, California: Summer 2011.

***** *emphasis added*

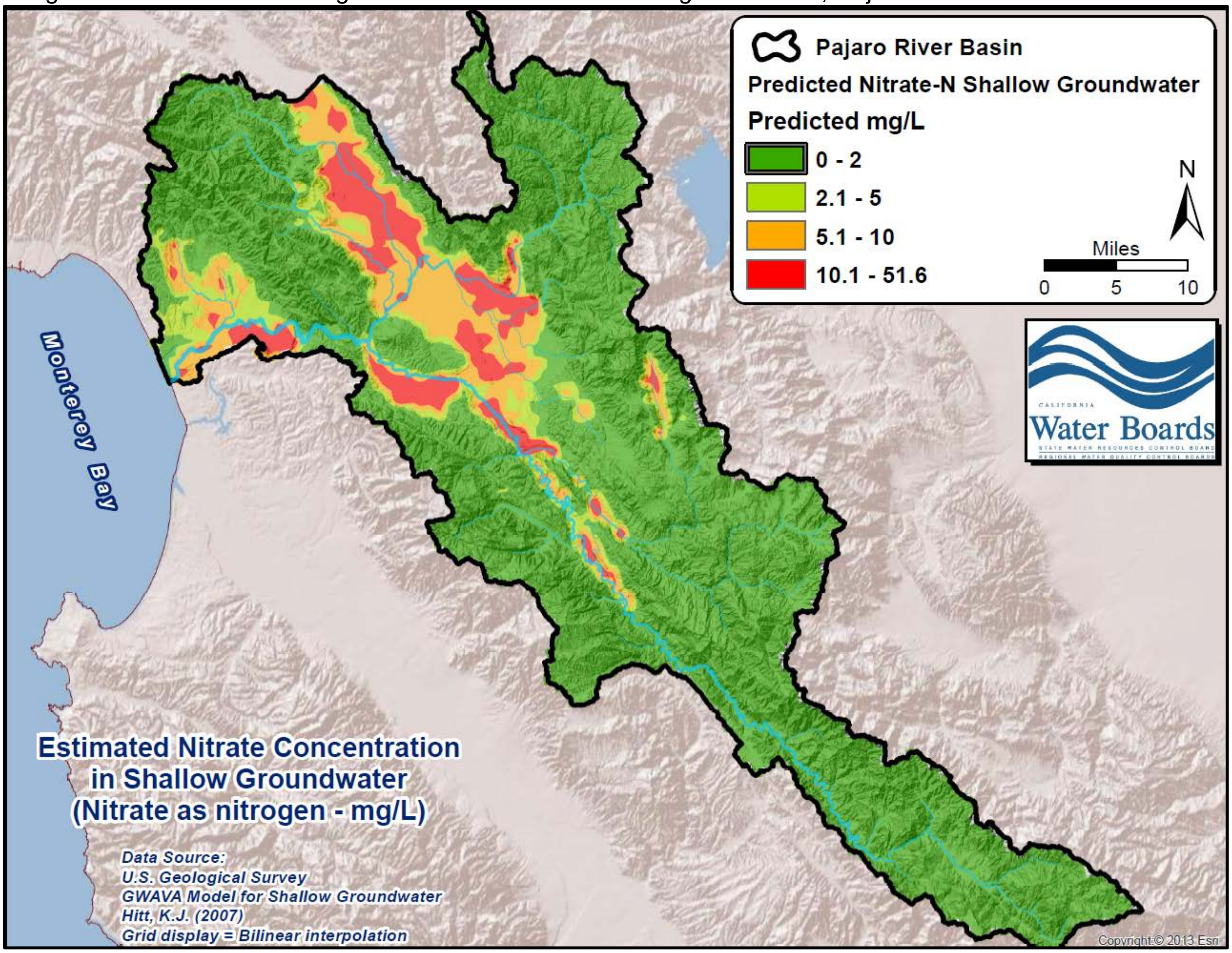
Shallow groundwater or perched groundwater zones can provide base flows to streams and can be a major source of surface water flows during the summer season. The water stored in wetland and riparian areas can also contribute base flow to a stream during times of the year when surface water would otherwise cease to flow (DWR 2003). Therefore, dissolved nitrate in groundwater can be important nitrate sources during dry periods or low flow periods. Therefore, it is relevant to consider the scope and importance of shallow groundwater and base flow contributions to stream reaches in the Pajaro River Basin. Figure 2-33 illustrates the minimum reported depth (centimeters) to a wet soil layer (shallow groundwater) in northern parts of the Pajaro River Basin, based on soils data available from the U.S. Department of Agriculture Natural Resource Conservation Service. These reported data do not represent or imply all possible or known locations of shallow or perched groundwater, but do constitute best available spatial data for the distribution of occurences of shallow groundwater. In the Pajaro Valley, these shallow groundwater horizons are typically associated with lowland areas in the Pajaro Valley, the Santa Clara Valley, and within the riparian corridors of many stream reaches.

Figure 2-33. Annual minimum reported depth (cm) to a wet soil layer (shallow groundwater) in the northern parts of the Pajaro River Basin.



As previously noted, stream baseflow resulting from these shallow water-bearing hydrogeologic zones can contribute to nutrient loading to streams. Figure 2-34 illustrates the estimated nitrate as nitrogen concentration in project area shallow, recently-recharged groundwater (data source: U.S. Geological Survey GWAVA model[35]).

Figure 2-34. Nitrate as nitrogen concentrations in shallow groundwater, Pajaro River Basin.



Nitrate groundwater concentrations are not uniform throughout the project area, and to a significant extent are related to land use/land cover. Source assessment tools used by staff require inputs of nitrate concentrations in shallow groundwater for specific land use categories. Therefore, these paired land use/groundwater concentration estimates are presented in Figure 2-35 and in Table 2-13.

As one would expect, the agricultural, alluvial valley floor basin has substantially higher predicted nitrate concentrations than predicted nitrate in the alluvial fill and fractured bedrock groundwaters of upland and rangeland areas.

[35] 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. Online linkage: http://water.U.S. Geological Survey.gov/GIS/metadata/U.S. Geological Surveywrd/XML/gwava-s_out.xml

Figure 2-35. Estimated NO3-N concentrations and averages in shallow groundwaters of 1) the alluvial basin floor areas; and 2) the upland regions of the Pajaro River Basin.

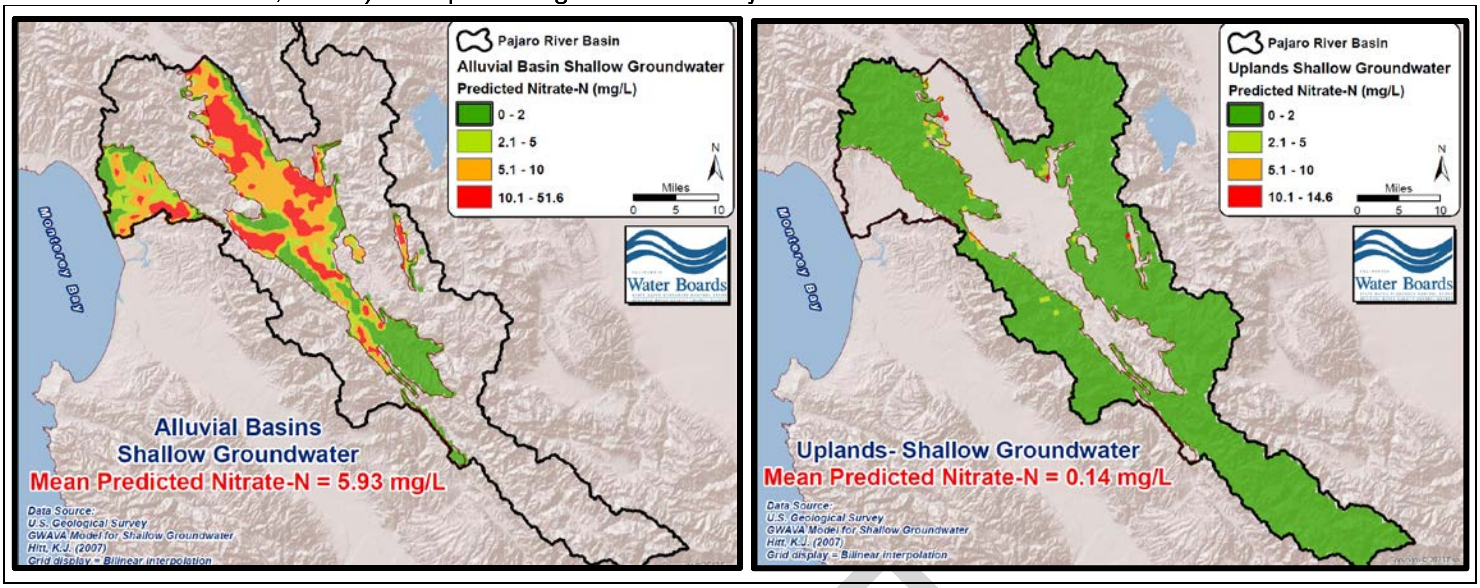


Table 2-13. Measured nitrate-N concentrations and average measures of nitrate-N in shallow groundwaters beneath U.S. urbanized areas (table – source NAWQA studies 1991-1998).

Shallow Ground Water Concentrations in the United States - USGS National Nutrients Synthesis Project

	NO3 + NH4 - Summary Statistics of the **Median Values** Reported for the Suite of Samples From Each Study Area									
Land Use	Number of Observations	Min	25th percentile	Mean	Mean	Median	75th percentile	90th percentile	Max	Ave. % of Times Samples Exceeded Nitrate MCL
Agriculture	1228	0.09	0.47	3.89	3.89	2.82	6.35	9.25	13.02	19.5
Urban	633	0.12	0.72	1.80	1.80	1.56	2.62	3.92	5.37	2.6
Undeveloped Land	81	0.09	0.11	0.25	0.25	0.15	0.37	0.50	0.59	0.0

Data from: USGS (U.S. Geological Survey). 2000. National statistical analysis of nutrient concentrations in ground water, compiled Bernard T. Nolan.

Also noteworthy is that nitrate-impacted groundwater has both a natural, ambient background load, and a load attributable to human activities. Natural, background nitrate concentrations in groundwater in the alluvial valley floor reaches[36] of the Pajaro River Basin can be approximated using data obtained by Moran et al., 2011 in an agriculturlal valley basin area located in the Salinas Valley of central Monterey County. Using isotopic data, Moran et al. (2011) found that precipitation-derived ambient nitrate from observed wells in agricultural areas adjacent to the Arroyo Seco River were always at concentrations less than 4 mg/L, with a mean for all the observed ambient groundwater samples calculated as 1.21 mg/L nitrate[37,38].

[36] It should be noted that ambient, background groundwater nitrate in alluvial valley basins with thick soil profiles may be different (possibly higher) than background nitrate found in bedrock aquifers and alluvial fill of many upland areas. Moran et al. (2011) indicate that rainwater which percolates through alluvial valley soil profiles would interact with soil nitrogen during infiltration and recharge.

[37] The estimate that natural, background nitrate in alluvial valley groundwater is approximately an order of magnitude lower than anthropogenic nitrate in groundwater underlying agicultural areas is consistent with the Salinas Valley and Tulare Lake basin study of the University of California-Davis (2012). In this University of California-Davis study the authors reported that “natural nitrate is a comparatively unimportant source of groundwater N”.

[38] Moran et al. (2011) report nitrate as NO3; however staff chose to report this value as nitrate-N herein, because in staff’s judgement and based on the body of scientific literature, it is plausible that any alluvial valley groundwater less than about 5 mg/L nitrate-NO3 could be representative of ambient background conditions, or conditions that have no significant human

Based on the aforementioned information, estimated shallow groundwater nitrate-N concentrations in the Pajaro River Basin can be summarized as follows:

- **ALLUVIAL VALLEY AMBIENT BACKGROUND:** *Ambient natural background nitrate concentration that would be expected in unimpacted shallow groundwater underlying the alluvial valley floor:*
  - **1.21 mg/L**
- **AGRICULTURAL AREAS:** *Average, shallow groundwater concentration expected to underlie agricultural areas of the Pajaro River Basin:*
  - **5.93 mg/L**
- **URBAN AREAS:** *Average, shallow groundwater concentration attributable to urban influence that would be expected to underlie urban areas of the Pajaro River Basin:*
  - **1.8 mg/L**[39]
- **WOODLAND, RANGELAND, UPLAND REACHES:** *Average, shallow groundwater concentration that would be expected in bedrock aquifers and alluvial fill underlying woodland and rangeland in upland ecosystems of the Pajaro River Basin:*
  - **0.14 mg/L**

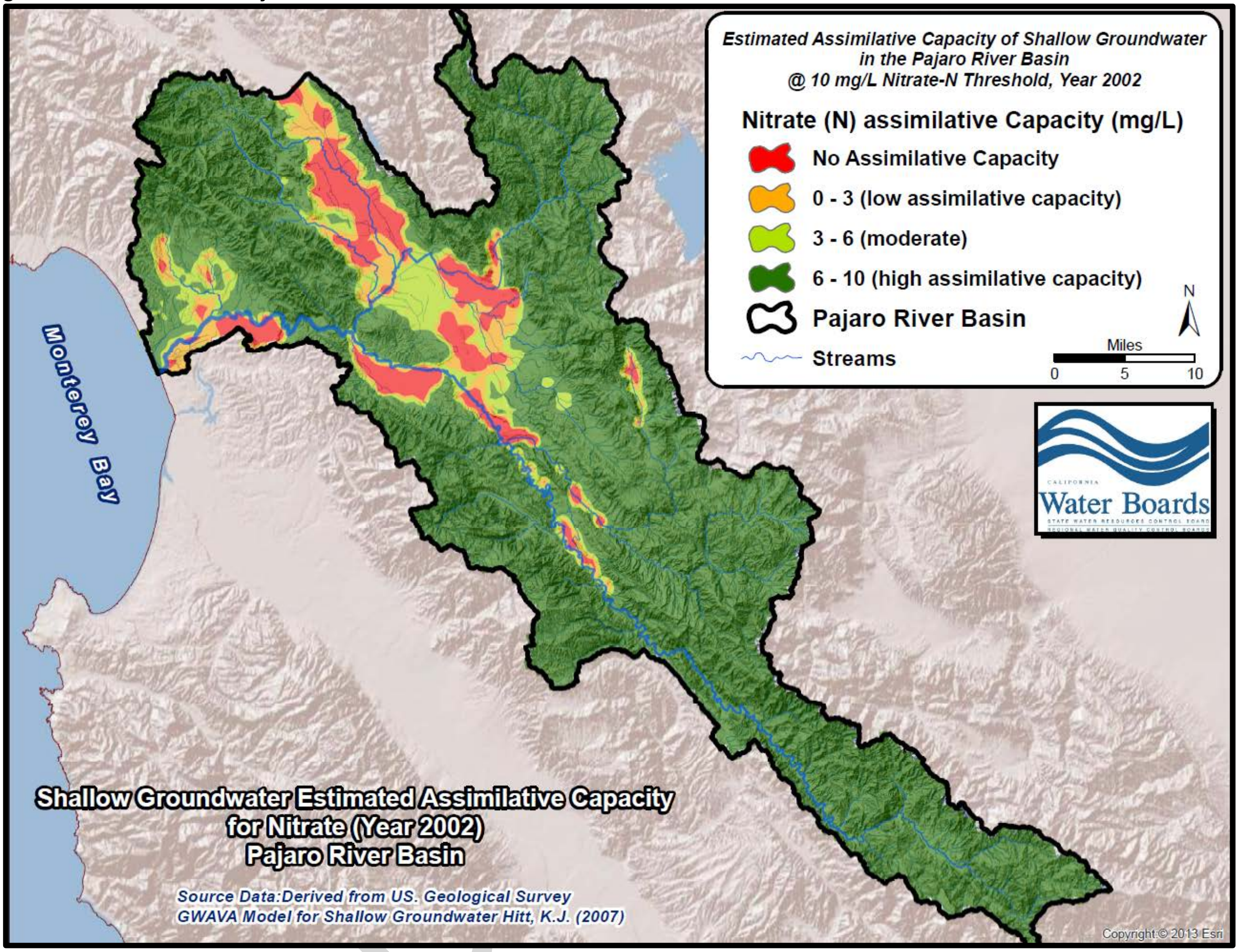
It may be important to consider a potential nexus between surface water pollution and groundwater pollution. Recall that stream infiltration and its potential impacts on underlying groundwater quality was discussed earler in this section of the report. Figure 2-36 illustrates the estimated assimilative capacity of shallow groundwater (less than 15 meters below ground surface) in the Pajaro River Basin. Assimilative capacity refers to the capacity of the waterbody to receive waste without exceeding water quality standards. As suggested by Figure 2-36, there are alluvial valley floor areas in the Pajaro River Basin that have little to no assimilative capcity left to receive more pollution, and thus subsurface infiltration of polluted stream water may be a concern in these areas[40].

impacts. Further, staff endeavors to develop biostimulatory targets that would not be infeasible to achieve because of plausible background conditions.

[39] Average of national median values, refer back to table in Table 2-13

[40] It should be noted that groundwaters are considered receiving waters for streams which recharge the groundwater resource; this was recognized when California adopted the groundwater recharge (GWR) beneficial use for surface waters in state water quality control plans. The Central Coast Basin Plan requires the Central Coast Water Board to protect the designated groundwater recharge (GWR) beneficial use of stream waters in recognition of the intimate connection of groundwater and surface waters through the hydrologic cycle and – in part – to protect and maintain water quality in the underlying groundwater resource.

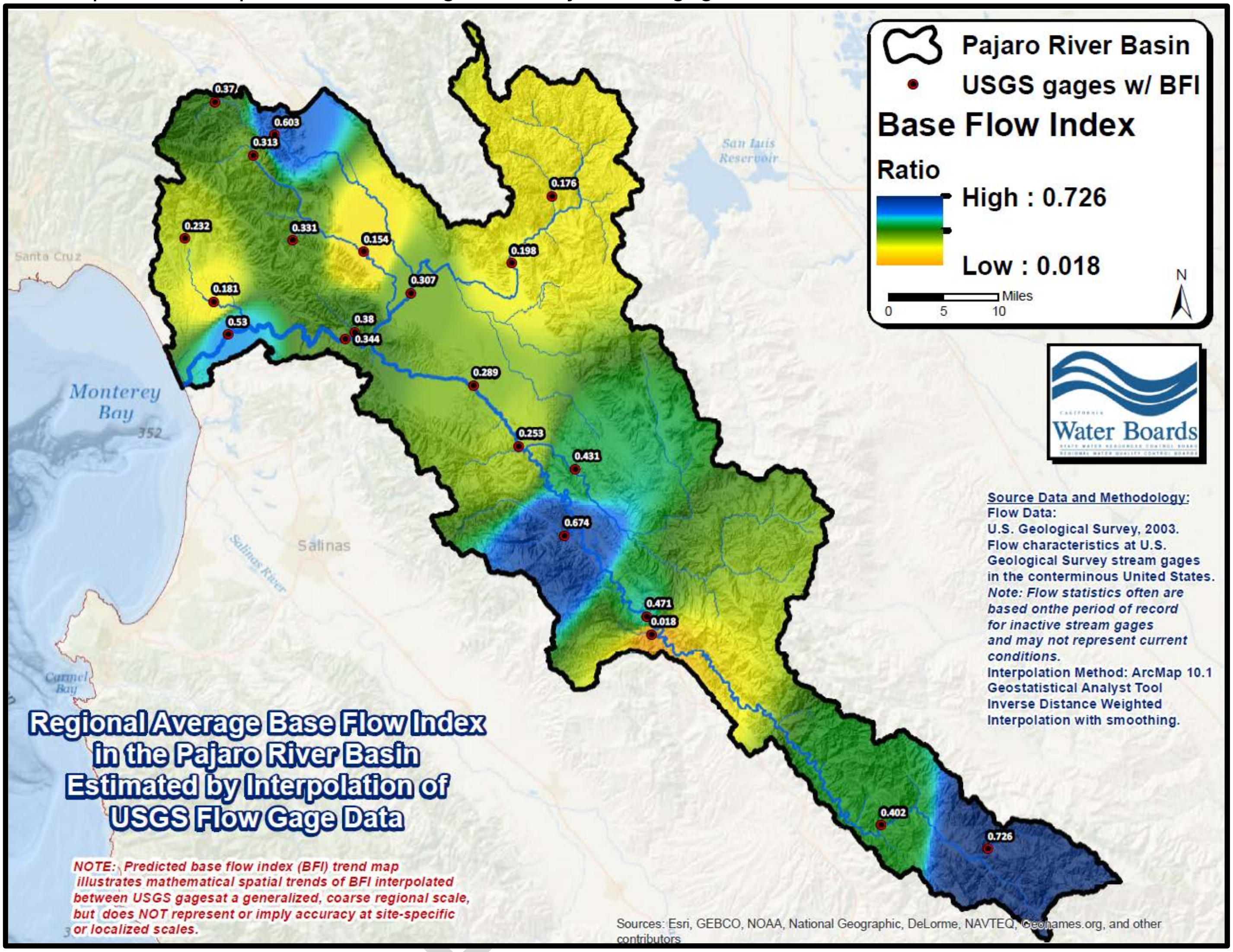
Figure 2-36. Estimated assimilative capacity for nitrate (year 2002) in shallow, recently recharged groundwater of the Pajaro River Basin.



As noted previously, groundwater inputs to streamflow as baseflow is a hydrologic process that varies in magnitude and importance based on numerous physical, climatic, geomorphic, geologic, and characteristics. Figure 2-37 illustrates regional estimates and spatial variation of base flow[41] (measured as base flow indices) in the Pajaro River Basin. This map should be considered a coarse, gross regional approximation of base flow indices mathematically interpolated between stream gages; there will be substantial variation in the magnitude of base flow at localized and site-specific scales.

[41] Baseflow is the component of stream flow that can be attributed to groundwater discharge into streams.

Figure 2-37. Estimated regional average base flow indices in the Pajaro River Basin, on the basis of interpolation of reported U.S. Geological Survey stream gage data.



Because groundwater exists in three-dimensional space it is relevant to be cognizant of potential spatial variation in groundwater-bearing zones. It is well known that due to the depositional nature of alluvial and fluvial systems, the shallow subsurface stratigraphic architecture of the Pajaro Valley and the Santa Clara Valley are highly heterogeneous both laterally and vertically (for example, see Figure 2-38). Perched or shallow groundwater systems are likely to occur in shallow, laterally discontinuous permeable zones (sands and gravel), which are nested within or interfinger with fine-grained aquitard strata (silts and clays).

Figure 2-38. Generalized stratigraphic interpretation of subsurface (0 to 600 feet below ground surface) in coastal areas of the lower Pajaro River Basin and vicinity, on the basis of geophysical log data.

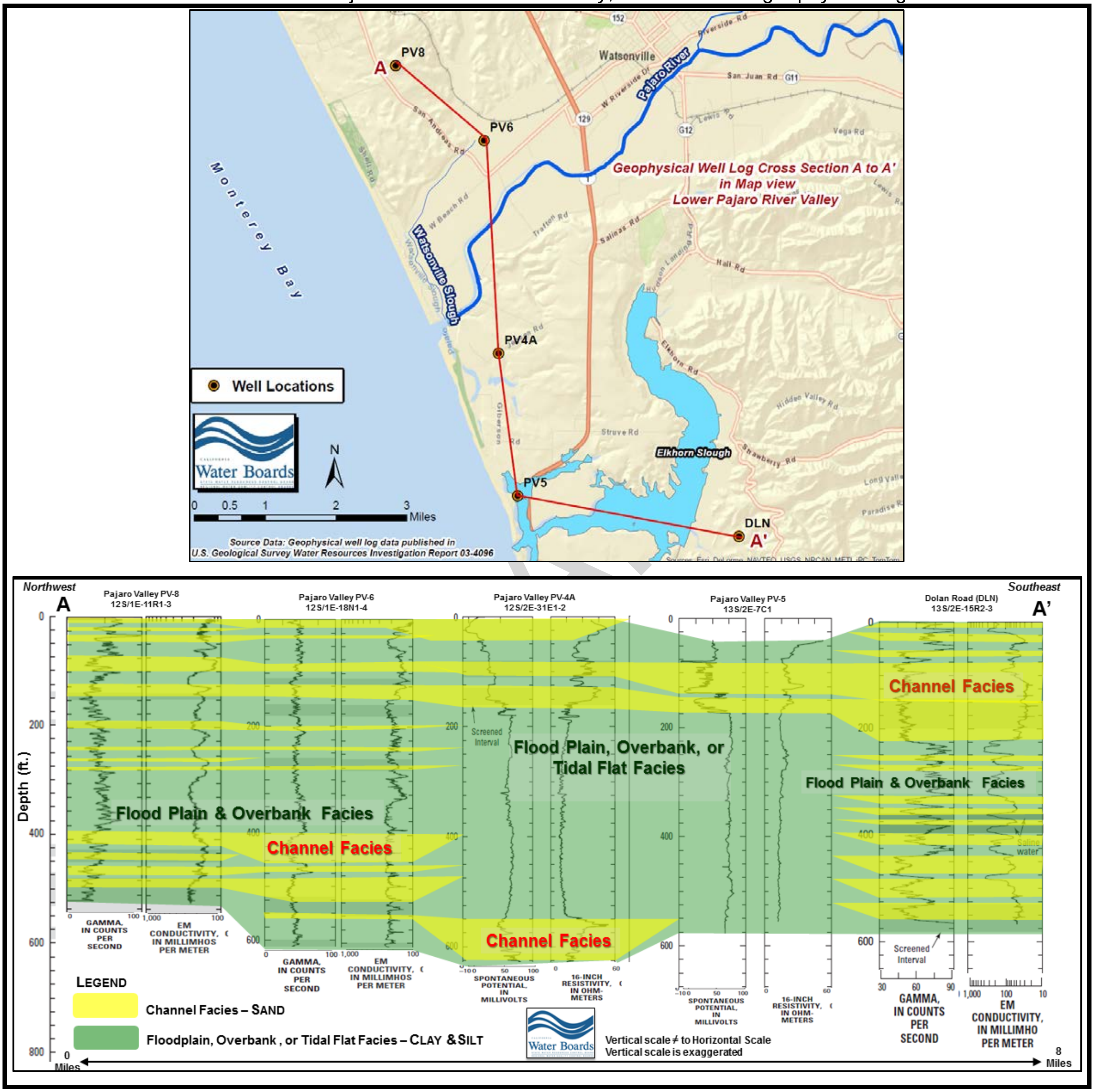
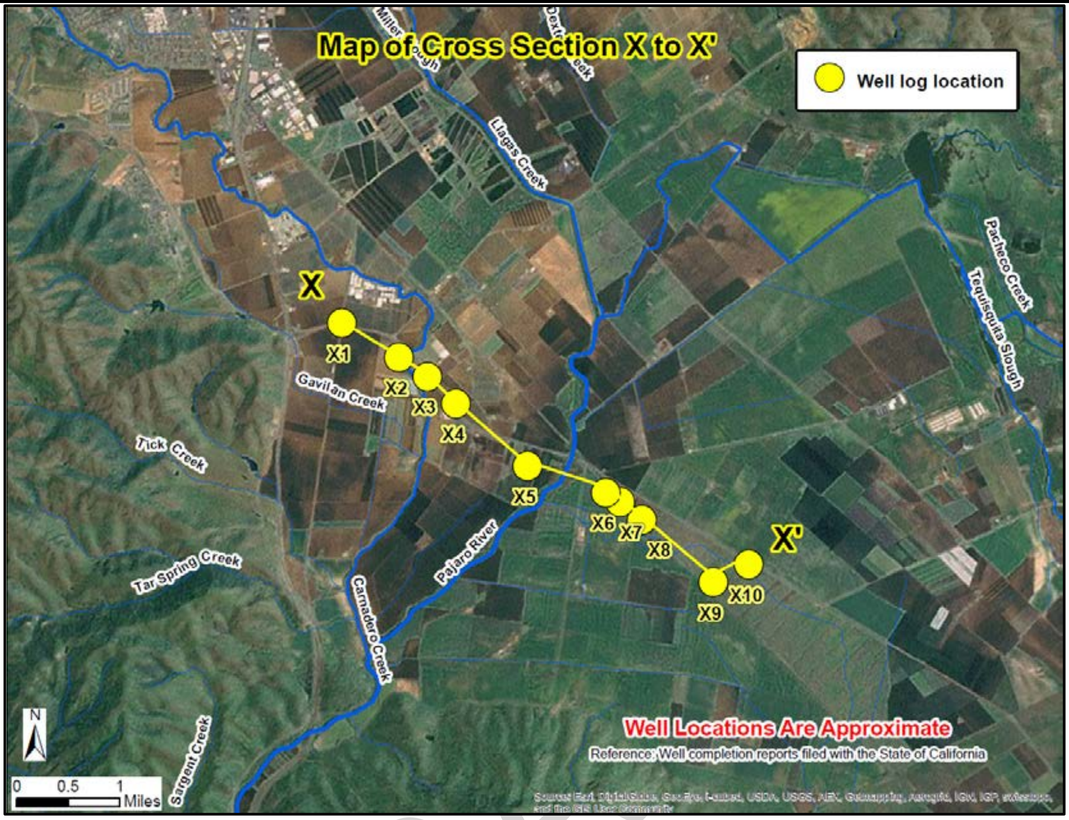
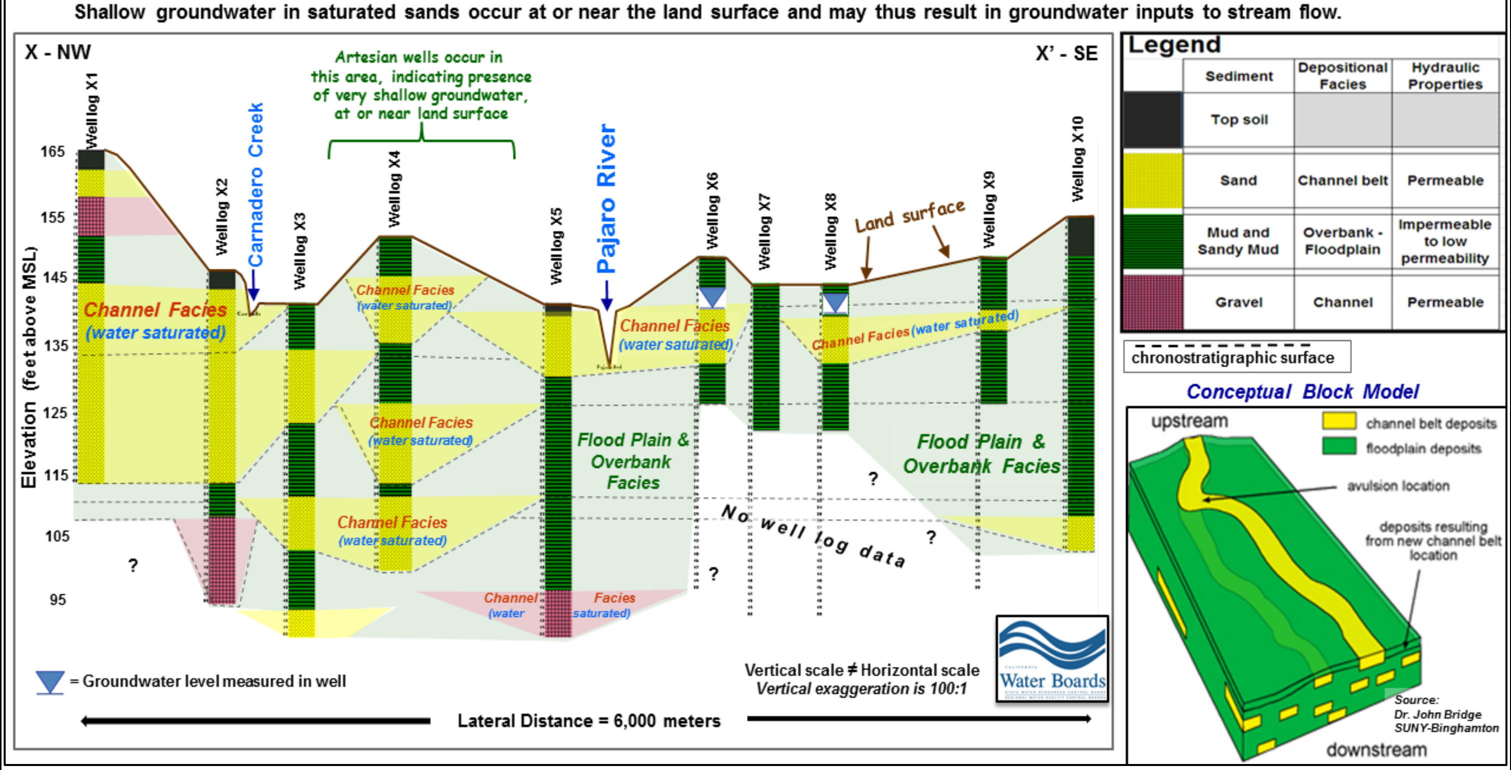


Figure 2-39 illustrates that shallow, laterally-discontinuous high permeability facies (channel belt sands and gravels) locally occur at very shallow depths in basin floor reaches of the Pajaro River Basin. These shallow, discontinuous permeable strata would be expected to be potential zones for perched groundwater horizons, and conduits for shallow groundwater flow and baseflow contributions to streams.

Figure 2-39. Map and stratigraphic interpretation of cross section X – X' near confluence of Pajaro River and Carnadero Creek, south of Gilroy on the basis of well log data.



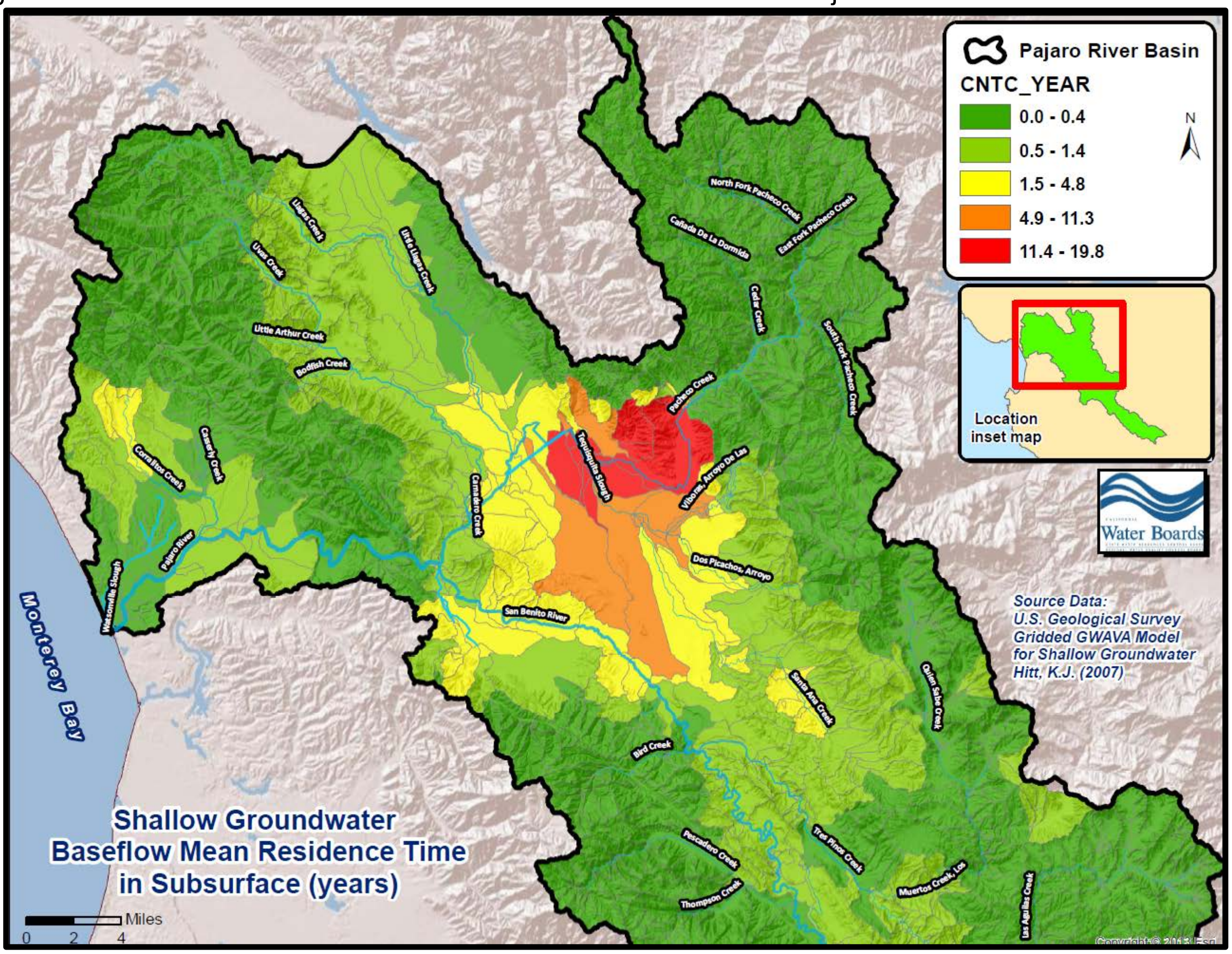
Stratigraphic interpretation of shallow subsurface (0 to 50 ft. below ground surface) near confluence of Pajaro River and Carnadero Creek. Shallow groundwater in saturated sands occur at or near the land surface and may thus result in groundwater inputs to stream flow.



Interpreted from well log data available from the State Water Resources Control Board's GAMA Geotracker database.

Finally, it may be important to consider the possibility of existing legacy pollution of shallow groundwater, and the residence time in the subsurface before the groundwater is expressed as baseflow. Legacy pollution (associated with long-residence times in groundwater) may be unrelated to current land use practices, and could potentially be a result of land use practices that occurred many years ago. From an implementation perspective, it could be important to consider whether nitrate pollutant loads in shallow groundwater may express themselves as creek base flow relatively rapidly; or alternatively whether the subsurface residence time of baseflow is on the order of years to decades. Figure 2-40 illustrates estimated mean groundwater baseflow residence time in the subsurface[42] on the basis of NHD catchments. It should be noted that "contact time", as defined by the U.S. Geological Survey (U.S. Geological Survey) metadata for this dataset represents an "average" amount of time groundwater is in the subsurface before being expressed as stream baseflow.

Figure 2-40. Estimated baseflow mean contact time in the northern Pajaro River Basin.



2.10 Geology

Geology may have a significant influence on natural, background concentrations of nutrients. Stein and Kyonga-Yoon (2007) report that catchment geology was the most influential environmental factor on variability in water quality from natural areas in undeveloped stream reaches located in Ventura, Los

[42] Data source: Attributes for NHDplus Catchments, Contact Time, 2002. This dataset was created by the U.S. Geological Survey and represents the average contact time, in units of days, compiled for every catchment of NHDplus for the conterminous United States. Contact time is the baseflow residence time in the subsurface.

Angeles, and Orange counties, California. As such, in evaluating the effect of anthropogenic activities on nutrient loading, it is also relevant to consider the potential impact on water quality which might result from local geology and rock geochemistry.

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. The mean annual average of nutrient concentrations (wet weather plus dry weather samples), as shown in Table 7 of Stein and Kyonga-Yoon (2007), indicates undeveloped stream reaches underlain by igneous rock had mean nutrient concentrations of: total nitrogen=1.12 mg/L, total phosphorus = 0.03 mg/L. In contrast, undeveloped stream reaches underlain by sedimentary rock in contrast had mean nutrient concentrations of: total nitrogen = 1.36 mg/L, total phosphorus = 0.06 mg/L.

- Regional Geologic Setting

The 1,300 square mile Pajaro River Basin extends across three distinct geologic provinces[43]. To a large extent, geologic provinces in the river basin are defined by the location of the northwest-trending San Andreas Fault. Figure 2-41 illustrates geologic provinces of the Pajaro River Basin, with a gammay-ray radiometric map overlay. Aerial measurements of gamma-ray flux measure natural background radioactivity in surficial geologic materials[44], and can provide insight into geologic variation. West of the San Andreas Fault, coastal areas of the lowermost Pajaro River Basin, and western margins of the San Benito River subbasin in the Gabilan Range[45], are part of the distinct Salinian Block geologic terrain which is associated with the Central Coastal geologic province (see U.S. Geological Survey, 1995). The Central Coastal geologic province is characterized by a prevailing Pliocene to Oligocene stratigraphy (including the Miocene-age Monterey Formation) and series of ranges and intermontane valleys exhibiting northwest-oriented topographic and geologic structural trends typical of this part of California: The granitic nature of bedrock and basement rock of the Salinian Block is illustrated by the gamma-ray radiometric data – high radiometric signatures in surficial geologic materials of the Gabilan Range are typical of outcropping acidic to intermediate igneous rock, such as granite and granodiorite (see Figure 2-41).

East of the San Andreas Fault, most of the rest of the Pajaro River Basin is associated with the Northern Coastal geologic province; this province includes the Diablo Range, the Santa Clara Valley, the San Francisco Bay Area, and the northern Coast Ranges. This geologic province is characterized by a prevailing Holocene to Pliocene stratigraphy. Further, in contrast to the granitic nature of basement rock of the Central Coastal geologic province, the basement rock of the Northern Coastal geologic province is characterized by highly deformed marine sedimentary rock of the Jurrasic-Cretaceous Franciscan Complex (U.S. Geological Survey, 1995). Lastly, parts of the upper San Benito River subbasin are associated with the San Joaquin Basin geologic province – basement rock of the western San Joaquin Basin geologic province is presumed to be the Coast Range ophiolite and rocks of the Franciscan Complex (U.S. Geological Survey, 2007).

The broadly-defined geologic provinces of the Pajaro River Basin can be subdivided into distinct smaller scale fault blocks which vary in basement rock compostion, strucutal style, and stratigraphy, (see McLaughlin, et al, 2001). These fault blocks are bounded by faults and fault zones; for example the San Andreas faul zone and the Caleveras Fault zone. Examples of fault blocks within the Pajaro River Basin

[43] The convention for geologic provinces used here is based on digital data from U.S. Geological Survey, 2000 – U.S. GEOLOGICAL SURVEY Digital Data Series DDS-60: *Geologic Provinces of the World, 2000 World Petroleum Assessment, all defined provinces.* Geologic provinces are defined on the basis structural style, dominant lithologies, and age of the geologic strata.

[44] Low levels of naturally-occurring radioactive elements occur in all rock material. Aerial gamma-ray surveys measure the gamma-ray flux produced by the radioactive decay of the naturally occurring elements K-40, U-238, and Th-232 in the top few centimeters of rock or soil.

[45] Figure 3-2 previously illustrated the location of major mountain ranges associated with the Pajaro River Basin.

includes the Santa Cruz block (associated with the Pajaro Valley), and the New Almaden Block (which includes the Uvas and Llagas Creek watersheds). Geologic attributes of these fault blocks, such as faulting, rock types, hydrostratigraphy influence the nature and distribution of water resources of the Pajaro River Basin.

Figure 2-41. Gamma-ray radiometric map (represented as color gradient) and geologic provinces of the Pajaro River Basin.

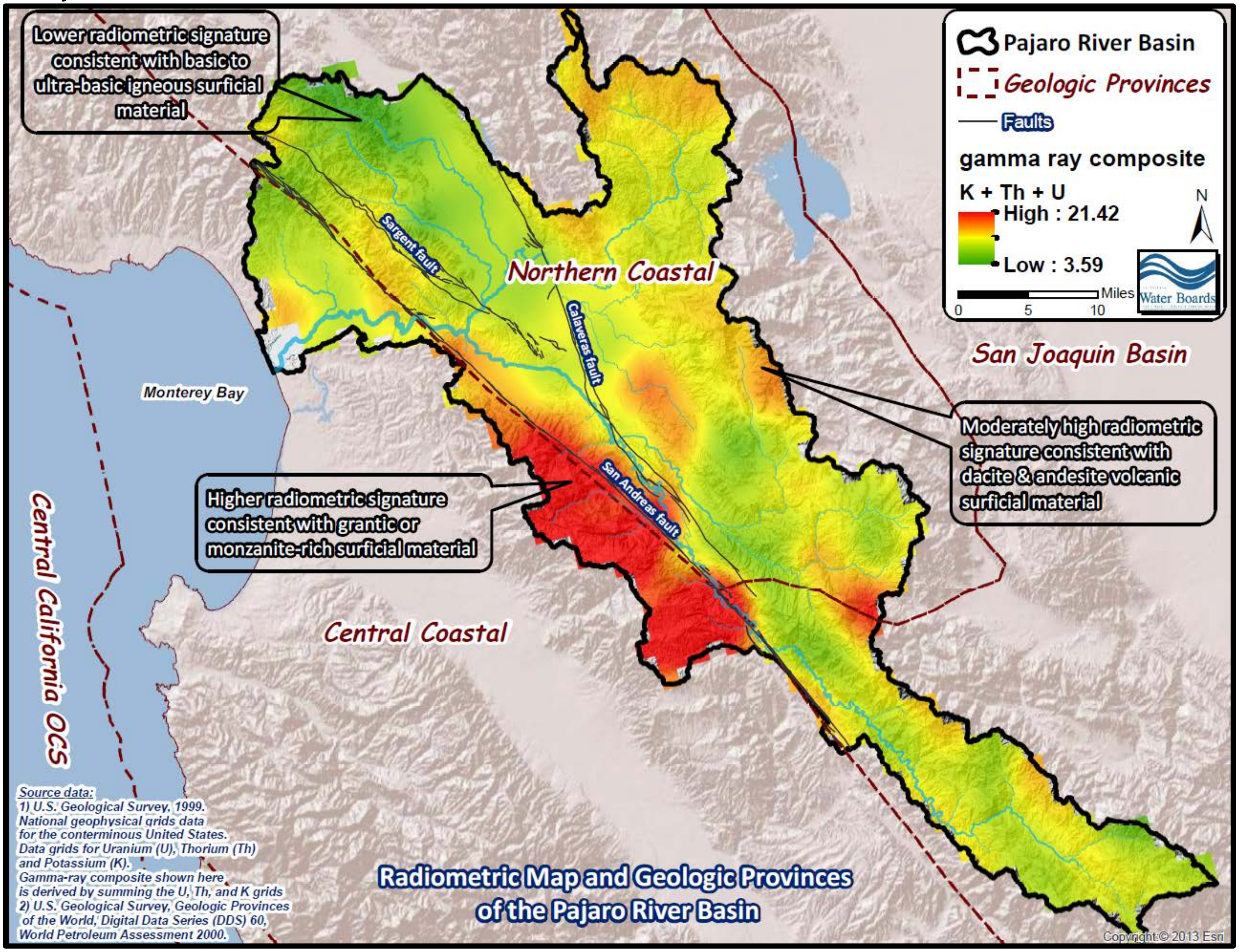
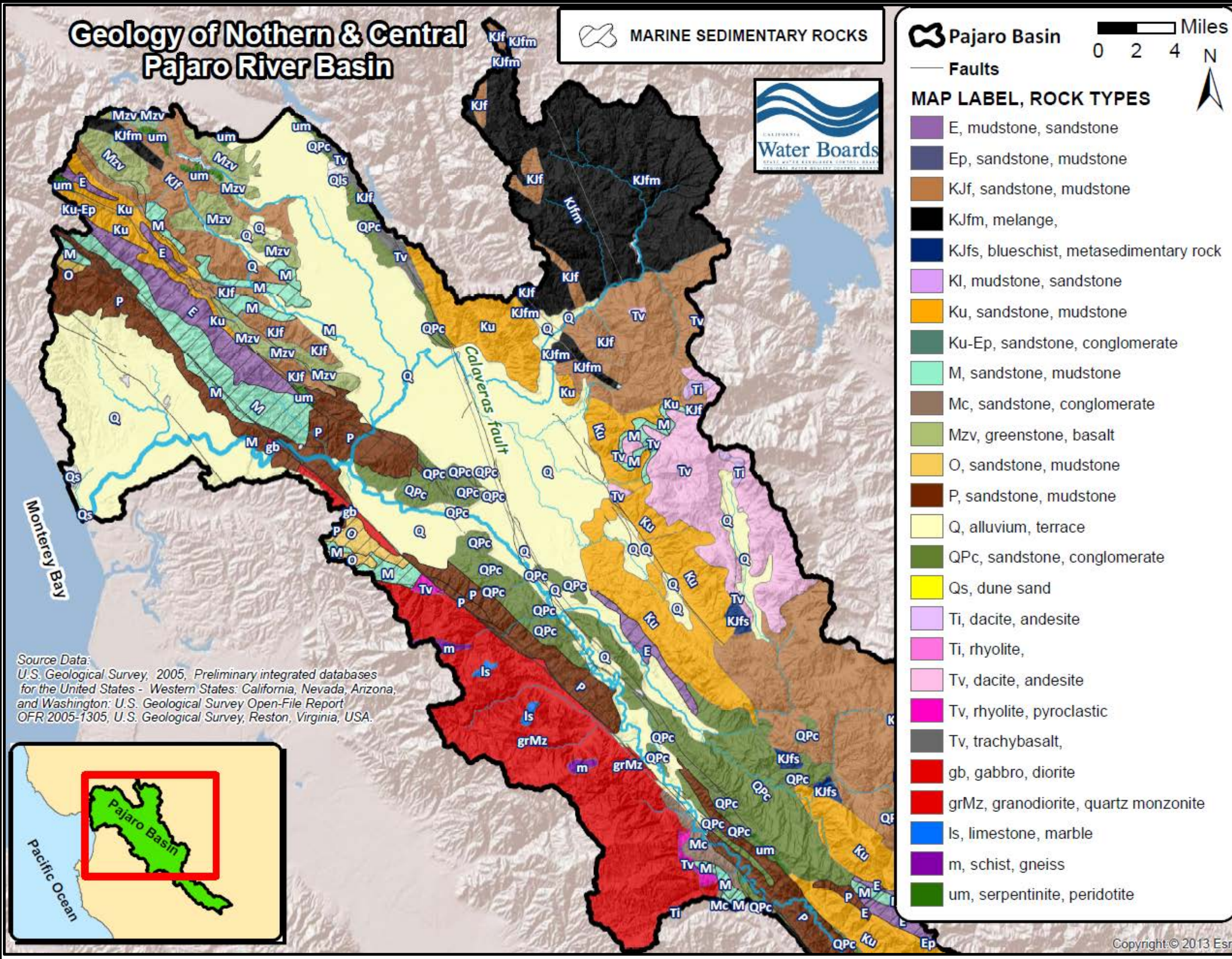


Figure 2-42 presents a generalized geologic map of the Pajaro River, Pacheco Creek, and lower San Benito River subbasins. Geology in the Pajaro River Basin include unconsolidated Quaternary deposits along stream reaches and valleys of lowland areas of the river basin; Tertiary and Mesozoic sedimentary rocks in many upland areas of the river basin; granodiorites and quartz monzonites in the Gabilan Range, and mafic and ultramafic rocks (basalt, greenstone, and serpentinite) in some upland reaches of the Santa Cruz Mountains (Llagas and Uvas Creek watersheds).

Surficial geologic materials in the Pajaro River Basin include thick deposits (>100 feet) of alluvial sediments in lowland reaches and stream valleys of the river basin, and discontinuous or patchy distributions of residual clastic materials derived from erosion of igneous, metamorphic and sedimentary rocks in upland reaches of the river basin.

Figure 2-42. Generalized geologic map of the northern and central Pajaro River Basin.



Unit Label	Unit Age	Unit Label	Unit Age	Unit Label	Unit Age
Q	Pliocene to Holocene	Ep	Paleocene	KJf	Jurassic to Cretaceous
Qls	Quaternary	Ti	Tertiary	Mzv	Jurassic to Cretaceous
QPc	Miocene to Pleistocene	Tv	Tertiary (2.5-3.5 Ma)	um	Middle to Late Jurassic
Qs	Quaternary	Tv	Tertiary (9.5-13 Ma)	gb	Triassic to Cretaceous
P	Miocene to Pleistocene	Tv	Tertiary (22-24 Ma)	ls	Paleozoic to Mesozoic
Mc	Oligocene to Pleistocene	Ku-Ep	Late Cretaceous to Paleocene	m	Early Proterozoic to Cretaceous
M	Oligocene to Pliocene	Ku	Late Cretaceous		
O	Eocene to Miocene	grMz	Early to Late Cretaceous		
E	Paleocene to Oligocene	KJfs	Early Cretaceous		

➢ Nitrogen Geochemistry

It is important to note that while the aforementioned researchers indicate that catchment geology can influence "nutrient" concentrations, for clarity's sake in fact igneous and metamorphic geology are likely to only influence phosphorus concentrations. Phosphorus is a relatively common minor element in all crystalline mineral assemblages, in contrast nitrogen is not a typical minor element found in crystalline material[46]. Nitrogen-enriched minerals are rare, and are only found in nitrate minerals formed in highly-arid evaporative environments[47]. The Pajaro River Basin does not contain nitrate-enriched evaporative sedimentary rocks.

With regard to non-mineralogical forms of nitrogen, organic nitrogen is more abundant in sedimentary rocks than in igneous or metamorphic rocks. Nitrogen in sedimentary rocks is typically associated with organic matter, which is commonly deposited with sedimentary strata, mostly marine shales and mudstones (University of California-Davis, 2012). Some organic-rich marine shales can contain 600 ppm nitrogen on average (U.S. Geological Survey, 1985). Note that in contrast, organic compounds are only an infrequent and trace component in most igneous or metamorphic rocks. The TMDL project area is largely comprised of igneous, metamorphic, and sandy-silty sedimentary rock assemblages, and available data does not indicate the presence of significant amounts of organic-enriched mudstones or shales deposited in marine depositional environments (see Figure 2-42). Consequently, there does not appear to be a significant geologic reservoir in the project area that could contribute to elevated nitrogen loads to surface waters.

Indeed, from the nitrogen-cycling perspective, soils are in fact the most concentrated and active ambient reservoir for nitrogen in the geosphere (Illinois State Water Survey website, 2011). Almost all soil nitrogen exists in organic compounds. As such, ambient background nitrogen concentrations in TMDL project area surface waters are more likely to be associated with the natural nitrogen cycle (e.g., soils, nitrification, and atmospheric deposition), and are not likely to be associated with watershed geology.

Another geologic attribute of the Pajaro Basin that one might consider as a background source of nitrogen are natural oil seeps. Crude oils are complex mixtures of hydrocarbons containing minor amounts of sulfur and nitrogen as well as other elements. Natural oil seeps are not generally considered as a source of background nitrogen in U.S. Environmental Protection Agency-approved nitrogen TMDLS. However, some scientific researchers have noted that oil seeps can be a source of water degradation at localized scales[48] – therefore as a matter of due diligence staff evaluated possible nitrogen contributions from natural oil seeps in the Pajaro Basin.

In general, California natural crude oils reportedly have relatively high nitrogen content relative to crude oils from other petroleum-producing areas of the United States (Smith, 1968). Historical published chemical analyses from central coast oil fields in Ventura and Santa Barbara counties indicate the nitrogen content of these crude oils range from 1.25 to 1.7 percent composition (Rogers, 1919).

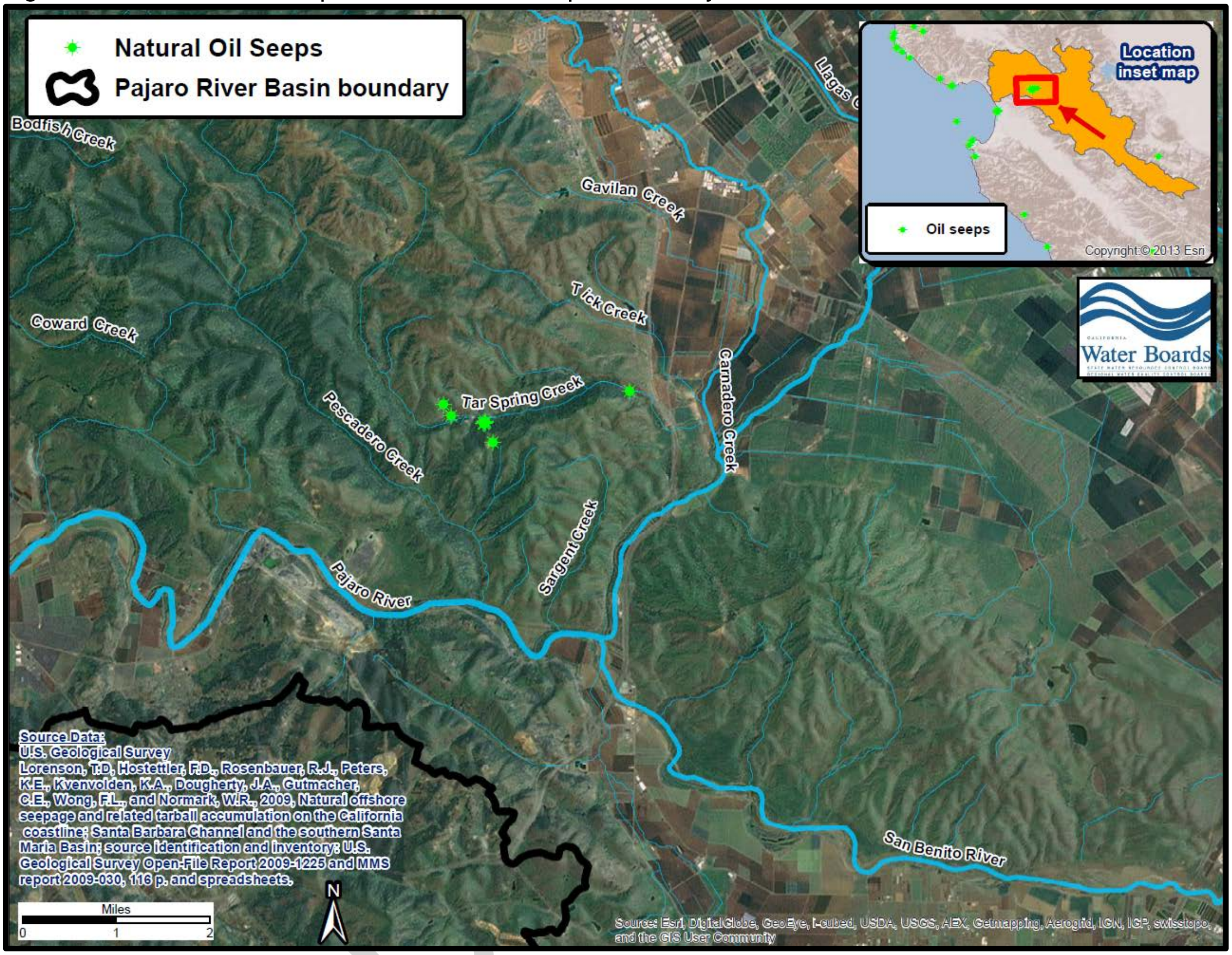
Note that Figure 2-43 illustrates the locations of reported natural oil seeps in the Pajaro River Basin; these seeps are located along Tar Springs Creek which is located in the Lower Uvas Creek subwatershed (refer back to map of subwatersheds previously presented in Figure 2-4). It should be noted that published field reconnasaince report that some of these oil seeps actively discharge, while other seeps are inactive (California Dept. of Conservation−Division of Oil and Gas, 1987). The maximum reported seep discharge along Tar Springs Creek was reported to discharge between zero to two gallons per day (California Dept. of Conservation−Division of Oil and Gas, 1987).

[46] For example, the average nitrogen content of igneous rocks is reported to be 46 part per million (ppm). By comparison, the trace elements cesium, lanthanum, vanadium, and neodymium are reportedly more abundant in igneous rocks than nitrogen (see: USGS, 1985, *Study and Interpretation of the Chemical Characteristics of Natural Water.* USGS Water-Supply Paper 2254).

[47] For example, the unique, nitrate-rich mineral deposits in the Atacama Desert of northern Chile (see: USGS, 1981. Professional Paper 1188, *Geology and Origin of the Chilean Nitrate Deposits*)

[48] See: *Environmental Science: A Global Concern 6th ed.* 2001. William P. Cunningham and Barbara Woodworth Saigo. Summary outline as accessed Jan. 2014 at: http://zoology.muohio.edu/oris/cunn06/

Figure 2-43. Location of reported natural oil seeps in the Pajaro River Basin.



Based on available data, it is possible to calculate a plausible estimate of the total mass of nitrogen discharged to land from reported natural oil seeps in the Pajaro Basin. It should be emphasized that these estimates should be considered maximum values ("worst case" scenario), based on a maximum observed seep discharge of 2 gallons per day − as noted previously some of these oil seeps are inactive and in fact are not discharging to land and thus have a discharge rate of zero. Table 2-14 presents plausible estimates for the maximum amount of nitrogen dischared to land in the Pajaro Basin from these natural oils seeps. Accordingly, staff estimates that a maximum of approximately 3.7 pounds nitrogen per day are discharged to land from reported natural oil seeps in the northern Pajaro River Basin.

Table 2-14. Estimated maximum amount of nitrogen discharged to land from natural oils seeps in Pajaro River Basin

Ave. specific gravity of central coast crude oil (kg/m^3)[A]	Ave. mass of one gallon of central coast crude oil (pounds)	Maximum seep discharge rate (gallons/day)[B]	Total number of identified seeps[C]	Maximum total mass of crude oil dishcarged (pounds/day)	Average nitrogen content of crude oil (weight percent)[D]	Approximate total pounds of nitrogen discharged
943	**15.7**	**2**	**8**	(15.7 x 2) 8 = **251**	**1.48%**	**3.7 lbs/day** ***or*** **1,351 pounds/year**

[A] Data source: Rogers, 1919
[B] Data source: California Dept. of Conservation−Division of Oil and Gas, 1987

[C] Data source: Spatial data, see Figure 2-43. Note that some oil seeps appear to be on top of one another at this scale.
[D] Data source: Rogers, 1919

Even assuming all of this land-discharged nitrogen from oil seeps is transported to a surface waterbody, this represents a miniscule fraction of nitrogen loading to the Pajaro River and its tributaries. Based on the aforementioned information it is implausible that natural oil seeps in the TMDL project area are a significant or noteworthy contributing factor to the exceedances of nitrogen water quality objectives found locally in surface waters of the Pajaro River Basin.

- Phosphorus Geochemistry

Rocks and natural phosphatic deposits are the main natural reservoirs of phosphorus inputs to aquatic systems (USEPA, 1999). The potential for these natural phosphorus inputs may be assessed using digital data for California geology and rock geochemistry available from the U.S. Geological Survey's Mineral Resources On-line Spatial Data webpage and National Geochemical Database (http://mrdata.U.S. Geological Survey.gov/). Refer back to Figure 2-42 for a depiction of the geology of the northern and central Pajaro River Basin. As noted previously, sedimentary lithology is identified in the Stein and Kyonga-Yoon (2007) study as contributing relatively higher natural levels of phosphorus to aquatic systems.

- *Phosphorus-prone Miocene Marine Sedimentary Rocks in California*

An additional line of evidence is available based on information published by the U.S. Geological Survey. In the central coast region of California, most phosphate-enriched rocks are associated with Miocene-aged marine sedimentary rocks; specifically Miocene mudstones and phosphatic shales (U.S. Geological Survey, 2002). Phosphatic facies have been reported in the literature to exist in the Miocene-age Monterey and Santa Margarita formations (U.S. Geological Survey, 2002). These unusual phosphatic deposits were formed in marine basins under special paleo-oceanic and tectonic conditions that existed along the western North American continental margin during the middle to late Miocene Epoch, approximately 7 to 15 million years ago (White, undated PowerPoint presentation). These marine phosphatic deposits were subsequently tectonically uplifted and are now exposed on land in parts of the California Coast Ranges.

Indeed, it is worth noting that modern phosphate deposition also locally occurs in today's marine basins of the California continental margin, depending on site-specific sedimentological and geochemical conditions (see Figure 2-44). This illustrates that phosphorus-enriched geologic materials are not anamolous throughout modern, or geologic times.

Figure 2-44. Reported modern phosphate deposits in marine basins of the California continental margin.

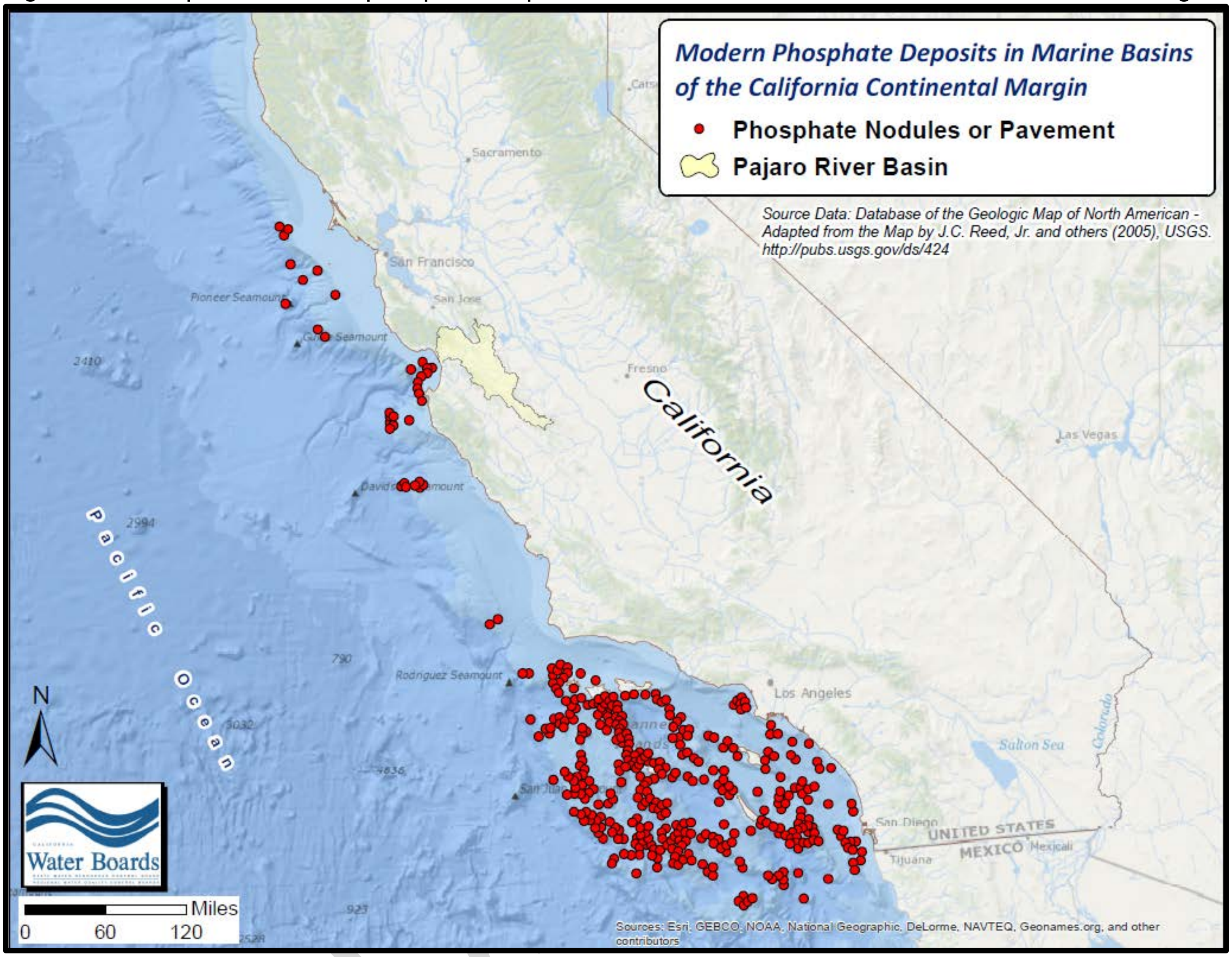


Figure 2-45 illustrates the distribution of Miocene-aged marine sedimentary rocks of the California central and sourthern coastal regions; these distributions constitute areas where there is presumably potential for phosphate-enriched mudstones and shales. Phosphorus geochemical samples (as weight percent P_2O_5) are available from the U.S. Geological Survey national geochemical database – sampling locations are illustrated on Figure 2-45. Staff disaggregated U.S. Geological Survey rock and sediment phosphorus geochemical samples from the California central coast region into two groupings: samples collected from 1) areas containing Miocene-aged marine sedimentary rocks, and 2) areas NOT containing Miocene-aged marine sedimentary rocks.

Cursory data review using histograms and quantile comparison plots in R[49] indicated that the raw phosphorus geochemical data was not normally distributed, while the log-transformed data appears to be normally distributed. Consequently, a non-parametric statistical evaluation approach was used. A two-sample Wilcoxon Test[50] of the two groupings of rock and sediment phosphorus geochemical data indicates that geologic materials in areas of Miocene marine sedimentary deposits are generally higher in phosphorus concentration (median = 0.440 P_2O_5 weight percent) than phosphorus in areas NOT

[49] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org

[50] Also widely known as the Mann-Whitney test.

containing Miocene marine sedimentary deposits (median = 0.228 P_2O_5 weight percent). In other words, the median of Miocene geologic materials are about twice as high in phosphorus (weight %) than the median of non-Miocene geologic materials. Further, the differences in phosphorus content is highly statistically significant (P-value = 2.2e-16)[51] indicating a very small probability of observing this difference by random chance.

Practically speaking, this suggests that geologic materials associated with Miocene marine deposits throughout California's central coast are generally higher in phosphorus content than geologic materials not associated with Miocene marine deposits. R statistical summaries and Wilcoxon Test outputs for the Miocene and Non-Miocene samples are presented in Figure 2-46.

[51] By convention, P-values are considered to indicate statistical significance when the P-value < 0.05.

Figure 2-45. Map of Miocene-age marine sedimentary rocks in California, and locations of US Geological Survey phosphorus rock and sediment geochemical sampling locations.

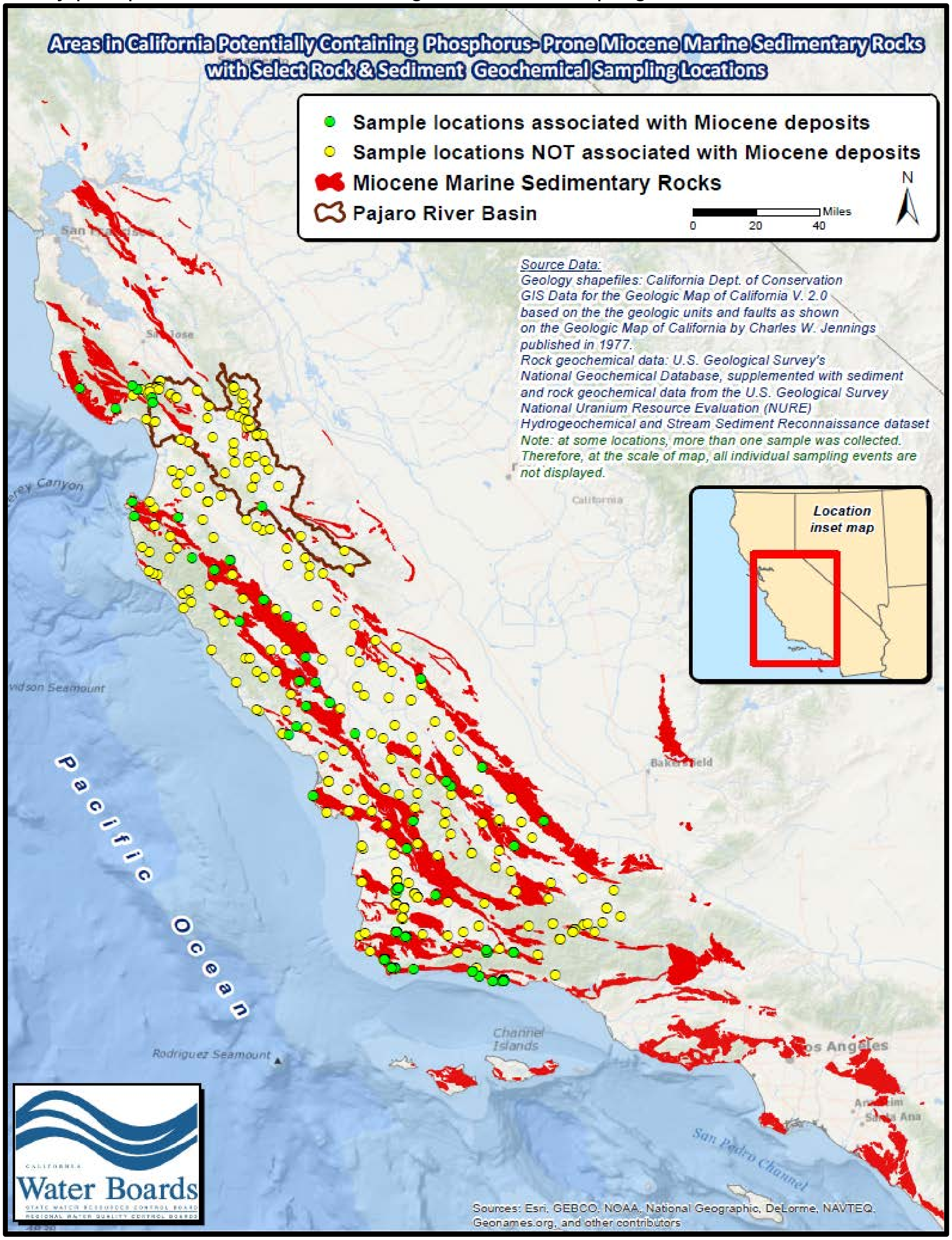


Figure 2-46. R outputs for Miocene and non-Miocene geologic materials samples.

R numerical summary for 1) phosphorus geochemical data in areas associated with Miocene marine deposits and 2) phosphorus geochemical data in areas not associated with Miocene marine deposits (refer to Figure 2-45 for sampling locations). Note that the statistical summary shows that Miocene geologic materials of the central coast region are routinely higher in phosphorus content than non-Miocene geologic materials.

```
> numSummary(P_Miocene_NonMiocene_2[,"phosphorus"],
+   groups=P_Miocene_NonMiocene_2$geologic_age, statistics=c("mean", "sd",
+   "IQR", "quantiles"), quantiles=c(0,.25,.5,.75,1))
                 mean       sd  IQR    0%  25%    50%  75% 100% data:n
Miocene     1.4119441 2.632683 1.22 0.005 0.26 0.4400 1.48 28.0    590
Non-Miocene 0.5746667 1.456723 0.40 0.006 0.09 0.2275 0.49 21.8    534
```

R two-sample Wilcoxon test output for 1) phosphorus geochemical data in areas associated with Miocene marine deposits and 2) phosphorus geochemical data in areas not associated with Miocene marine deposits (refer to Figure 2-45 for sampling locations).

```
> tapply(P_Miocene_NonMiocene_2$phosphorus,
+   P_Miocene_NonMiocene_2$geologic_age, median, na.rm=TRUE)
    Miocene Non-Miocene
     0.4400      0.2275

> wilcox.test(phosphorus ~ geologic_age, alternative="two.sided",
+   data=P_Miocene_NonMiocene_2)

        Wilcoxon rank sum test with continuity correction

data:  phosphorus by geologic_age
W = 220626.5, p-value < 2.2e-16
alternative hypothesis: true location shift is not equal to 0
```

With regard to the phosphorus content of various rock types, Table 2-15 and Figure 2-47 presents statistical summaries of the P_2O_5 weight percent of sampled rock types in the California central coast region. Note that sedimentary rock, such as sandstone and in particular, shale tends to be elevated in phosphorus content relative to other rock types[52].

[52] Note that these statistical summaries report values for phosphorite, which is an unusual and rare chemical sedimentary rock containing abnormally high amounts of phosphate.

Table 2-15. R numerical summary for phosphorus content (P_2O_5 weight %) reported in rock samples collected in the California central coastal region watersheds.

Output

	mean	sd	IQR	0%	25%	50%	75%	100%	data:n
CHERT	0.2612500	0.2060380	0.3625	0.05	0.0800	0.175	0.4425	0.59	16
igneous basic	0.2336364	0.1199394	0.1550	0.05	0.1350	0.250	0.2900	0.49	11
igneous intermediate	0.1800000	0.1824829	0.1650	0.06	0.0750	0.090	0.2400	0.39	3
limestone	0.2720000	0.3751933	0.0700	0.06	0.0800	0.130	0.1500	0.94	5
phosphorite	1.7700000	0.2828427	0.2000	1.57	1.6700	1.770	1.8700	1.97	2
sandstone	0.3350000	0.3187415	0.3125	0.09	0.1325	0.180	0.4450	1.19	14
shale	1.2406950	1.7844005	1.1300	0.05	0.3000	0.480	1.4300	21.50	777

Figure 2-47. Box and whiskers plot of phosphorus content (P_2O_5 weight %) in select rock type samples in the California central coastal region watersheds (sample locations: see Figure 2-45)

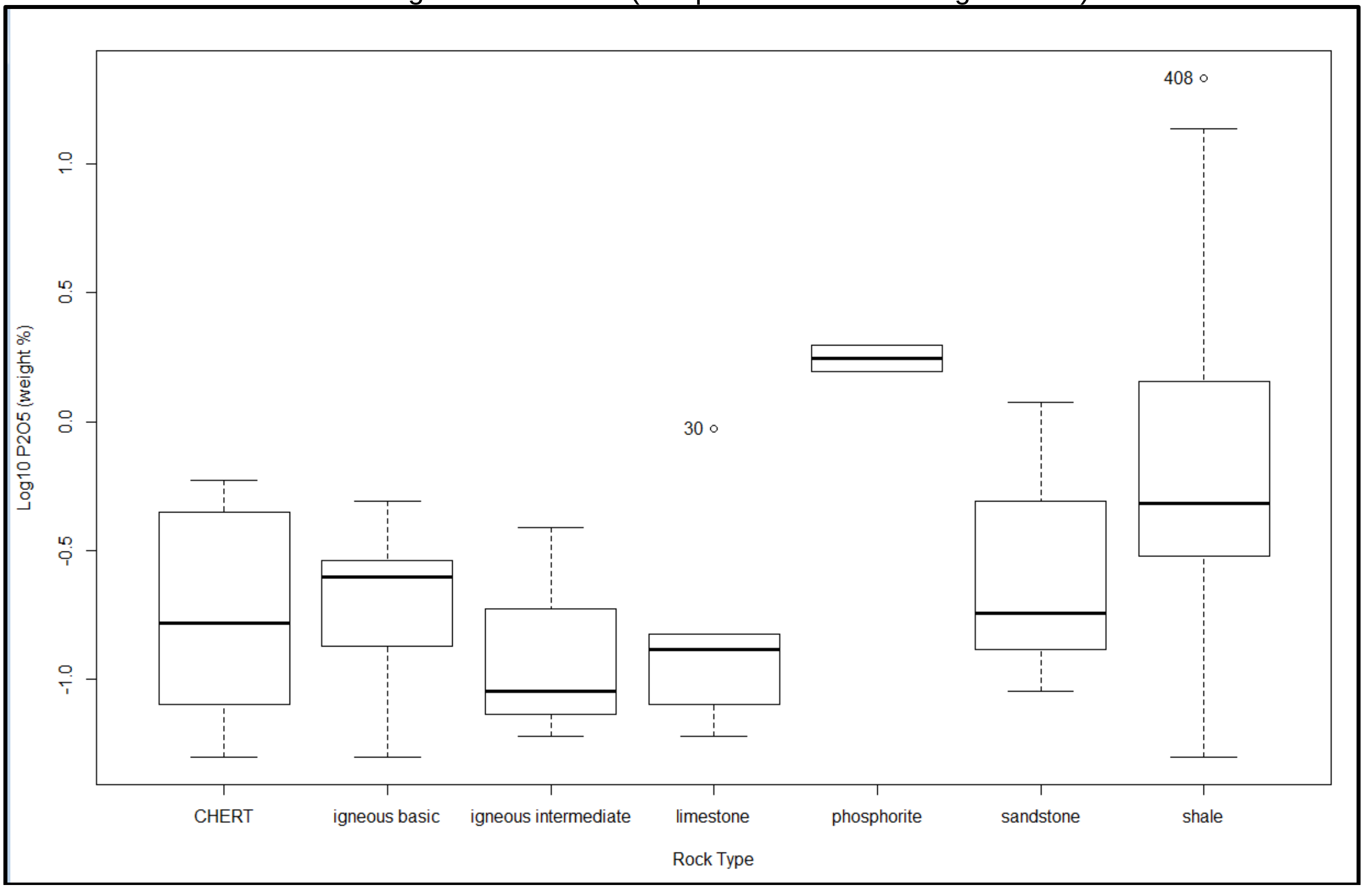
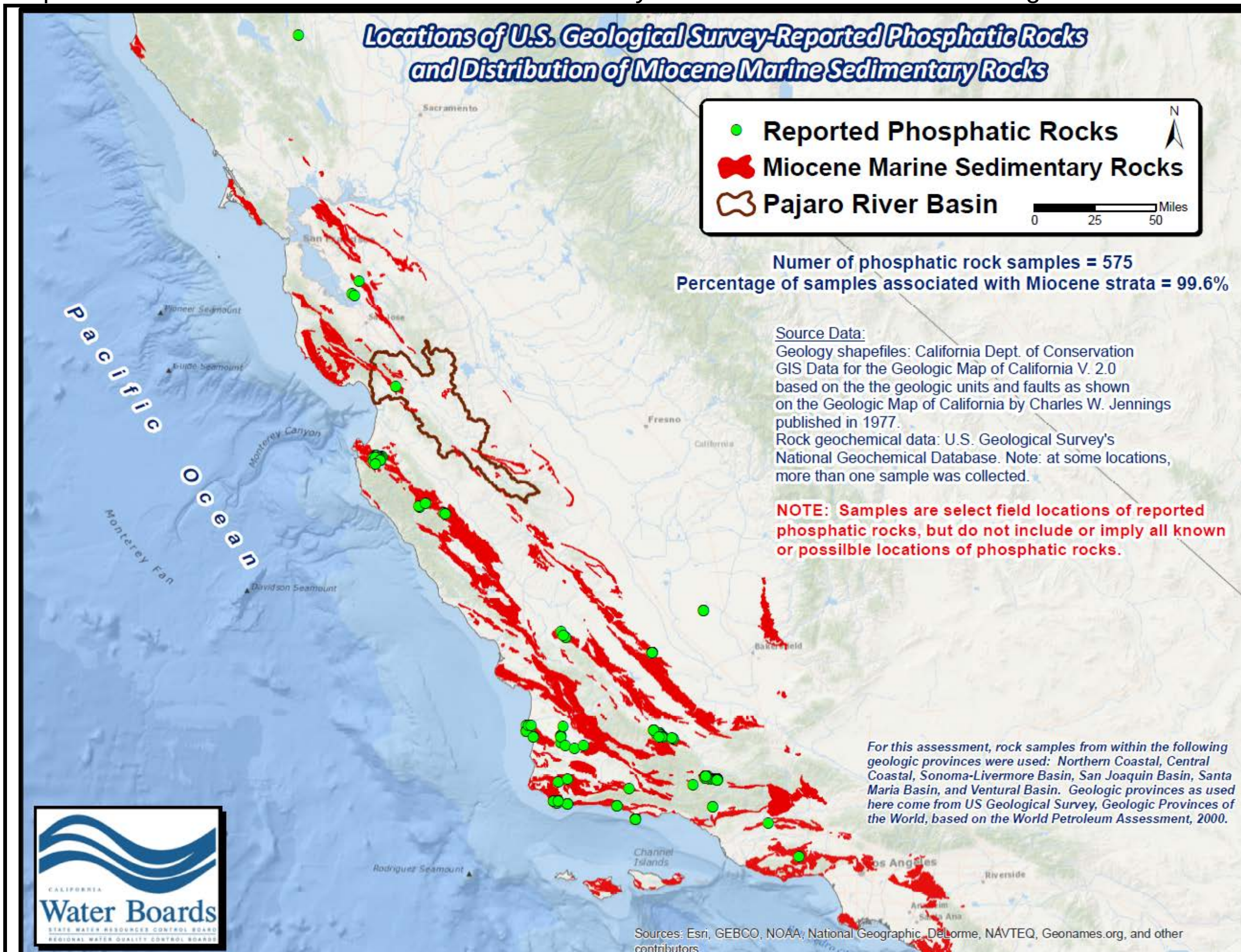


Figure 2-48 illustrates the locations of phosphatic rocks that have been sampled in the California. Noteworthy is that virtually all of these samples come from Miocene strate, as illustrated on Figure 2-48.

Figure 2-48. Map showing 1) locations of U.S. Geological Survey-reported phoshatic rocks; and 2) reported distribution of Miocene marine sedimentary rocks. Table that details findings included.



Stratigraphy/Formation	Geologic Age	Phosphatic Lithologies Present and Reported	Number of Reported Rock Geochemical Samples from the Formation
Santa Margarita Formation	Miocene	Phosphatic mudstones, phosphatic conglomerate, phosphorite, phosphatic sandstone, phosphatic siltstone,	411
Chamisal Formation	Miocene	Phosphatic sandstone	4
Monterey Group	Miocene	Phosphatic mudstone, phospatic conglomerate, phosphatic dolomite, phosphatic limestone, phosphorite, phosphatic siltstone, phosphatic sandstone	156
Great Valley Sequence	Cretaceous	Phosphatic siltstone	1
Modelo Shale	Miocene	Phosphatic pellets	1
Sisquoc Formation	Pliocene	Phospatic conglomerate	1
Temblor Formation	Miocene	Phosphatic sandstone	1

The occurrence of Miocene marine rocks in the Pajaro River Basin is illustrated in Figure 2-49. It is worth nothing that Pescadero Creek drains areas containing Miocene geologic materials (see Figure 2-49) and the phosphate as P concentration in water samples collected from Pescadero Creek tends to be quite high, with an average of 3 mg/L, according to the Central Coast Ambient Monitoring Program website[53]. Water quality samples from other stream reaches in the Pajaro River Basin are typically around 0.5 mg/L phosphate as P, or lower. It should be emphasized here that the presence of Miocene marine rocks should not be construed universally as strong evidence of a natural phosphorus influence on water resources, only that Miocene marine rocks of California are prone to being relatively higher in phosphorus. It is beyond doubt that there is substantial variation in the geochemistry and lithology of California's Miocene deposits.

Figure 2-49. Distribution of Miocene marine sedimentary rocks in the northern Pajaro River Basin.

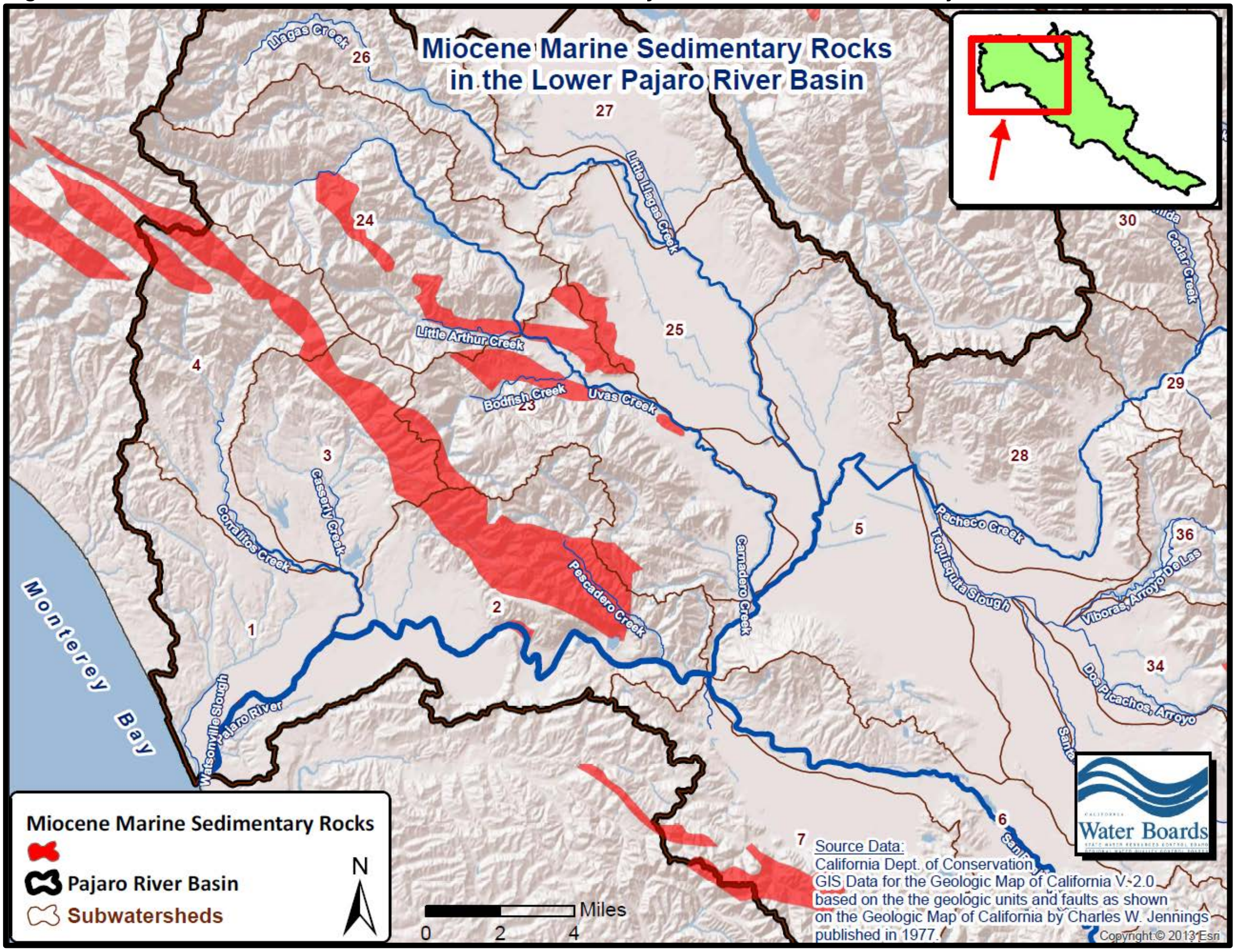
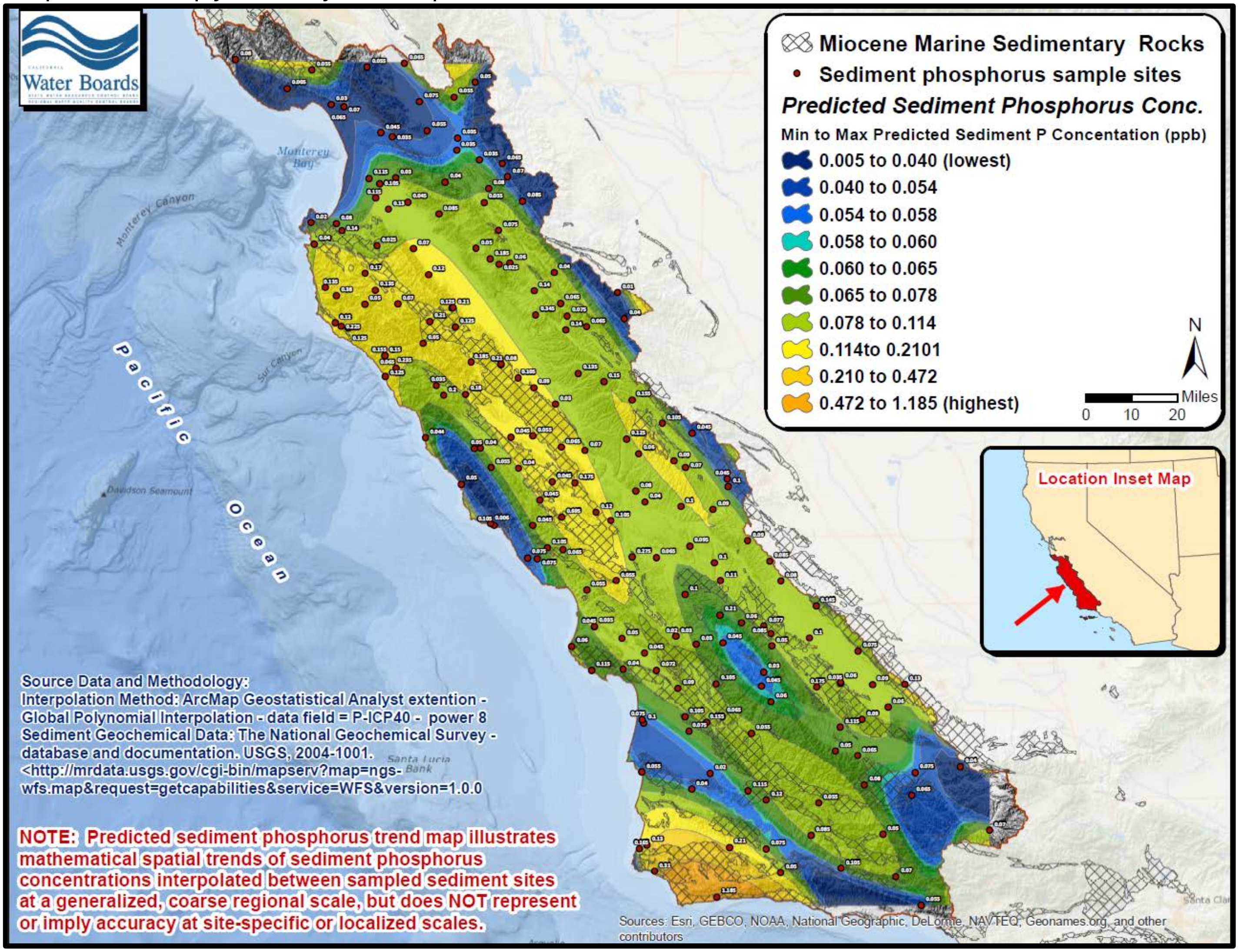


Figure 2-50 presents predicted spatial trends of sediment phosphorus concentrations based on a mathematical interpolation between sampling locations. Areas of the central coast region with the highest sediment phosphorus concentrations are often geographically associated with Miocene marine deposits. It should be noted that some areas of Miocene deposits soil samples have relatively moderate or average phosphorus concentrations. In general, the map suggests that sediments high in phosphorus concentrations can often be located in drainages associated with Miocene deposits, but this in not universally true and there is evidently substantial variation and undoubtedly there are other confounding factors influencing phosphorus concentrations in stream beds.

[53] Online linkage: http://www.ccamp.org/

Figure 2-50. Map showing interpolated values of sediment phosphorus concentrations in the California central coast region. The map illustrates predicted mathematical spatial trends of sediment phosphorus concentrations interpolated at a generalized coarse regional scale between sampled sites, but does NOT represent or imply accuracy at site-specific or localized scales.



In summary, geologic materials are generally not expected to cause exceedences of nutrient water quality criteria in the Pajaro River Basin. However it is important to recognize that phosphorus-prone Miocene marine sedimentary rocks (primarily associated locally with fault blocks of the Santa Cruz Mountains) may be expected to influence nutrient water quality, and in particular water column phosphorus concentrations locally in some stream reaches. Published water quality guidelines for phosphorus may be anticipated to be unachievable locally in some stream reaches that drain phosphatic sediments associated with Miocene marine sedimentary deposits on the basis of high observed phosphate concentrations in Pescadero Creek.

2.11 Soils & Stream Substrates

Soils have physical and hydrologic characteristics which may have a significant influence on the transport and fate of nutrients. 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 are illustrated in Figure 2-51 and Figure 2-52. 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 nutrient loads to surface waters.

An additional reason for developing soils data for this TMDL project is because the STEPL source estimation spreadsheet tool used in this project report requires input for soil conditions. Accordingly, this section of the project report summarizes relevant soils information.

Figure 2-51. Median annual Total N and Total P export for various soil textures.

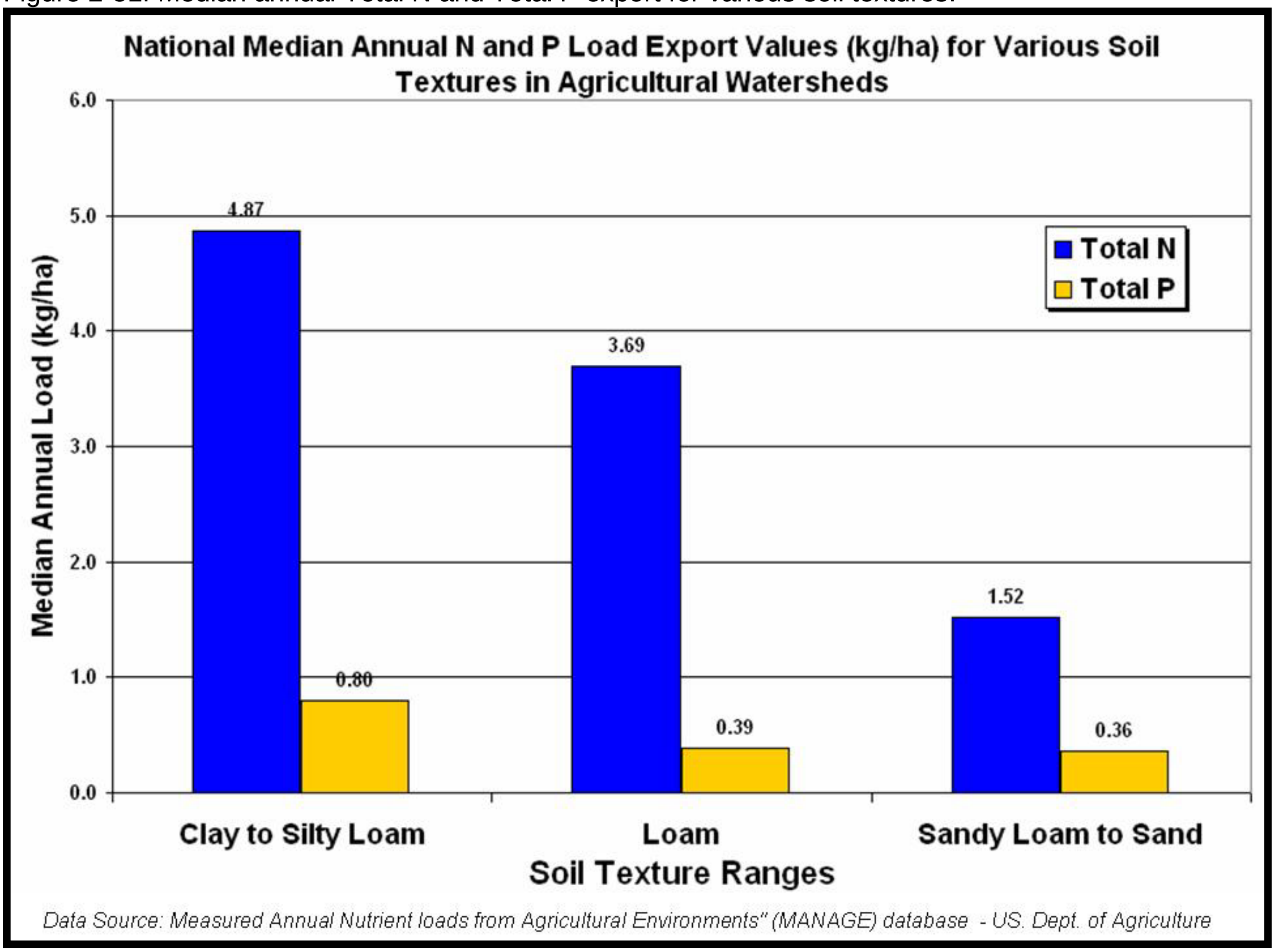
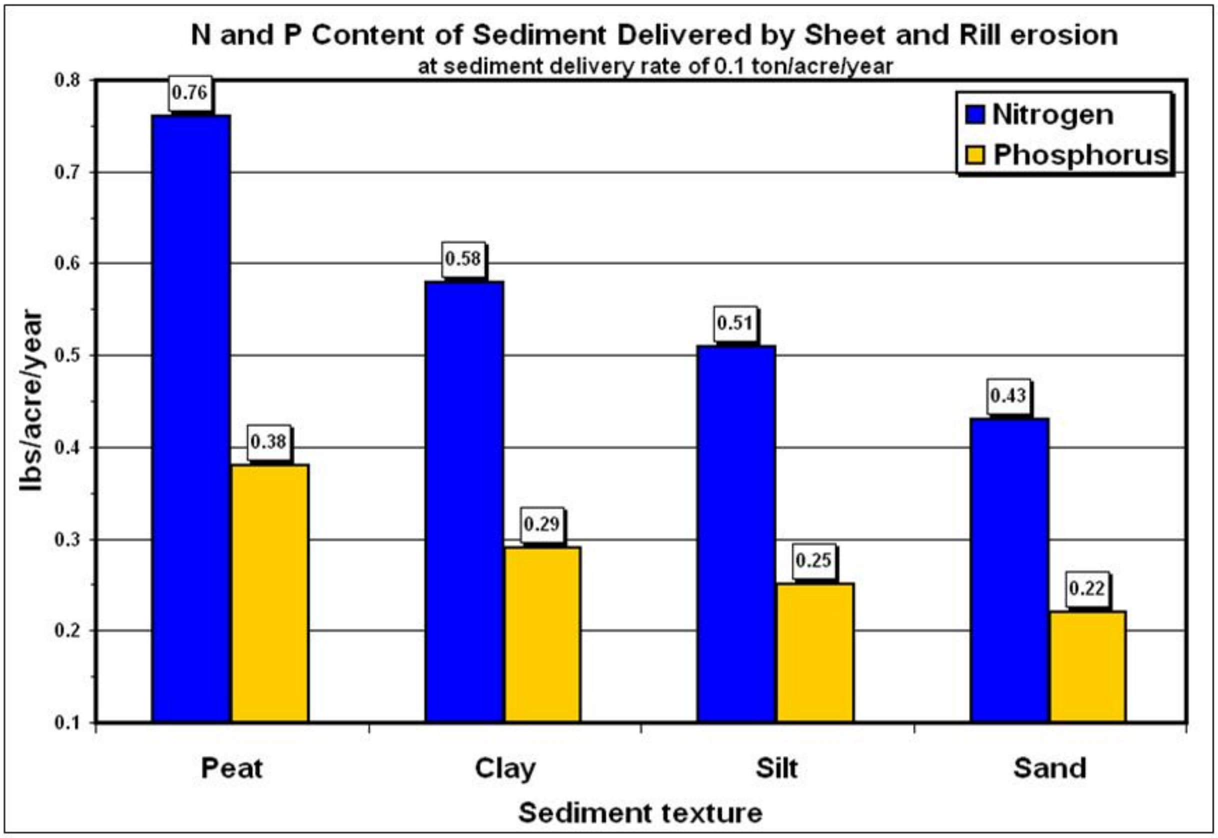


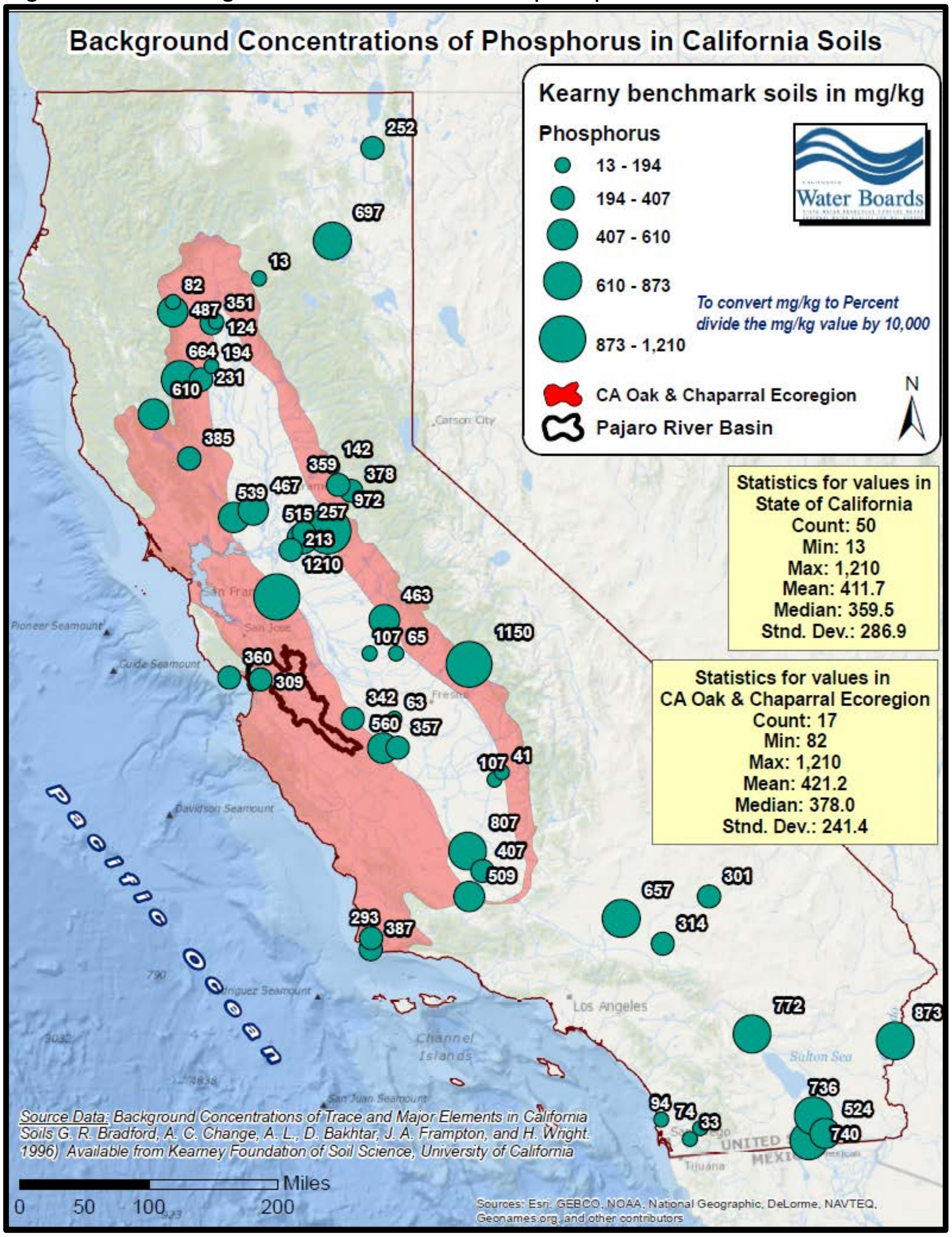
Figure 2-52. N and P content of sediment delivered by sheet and rill erosion.



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.*

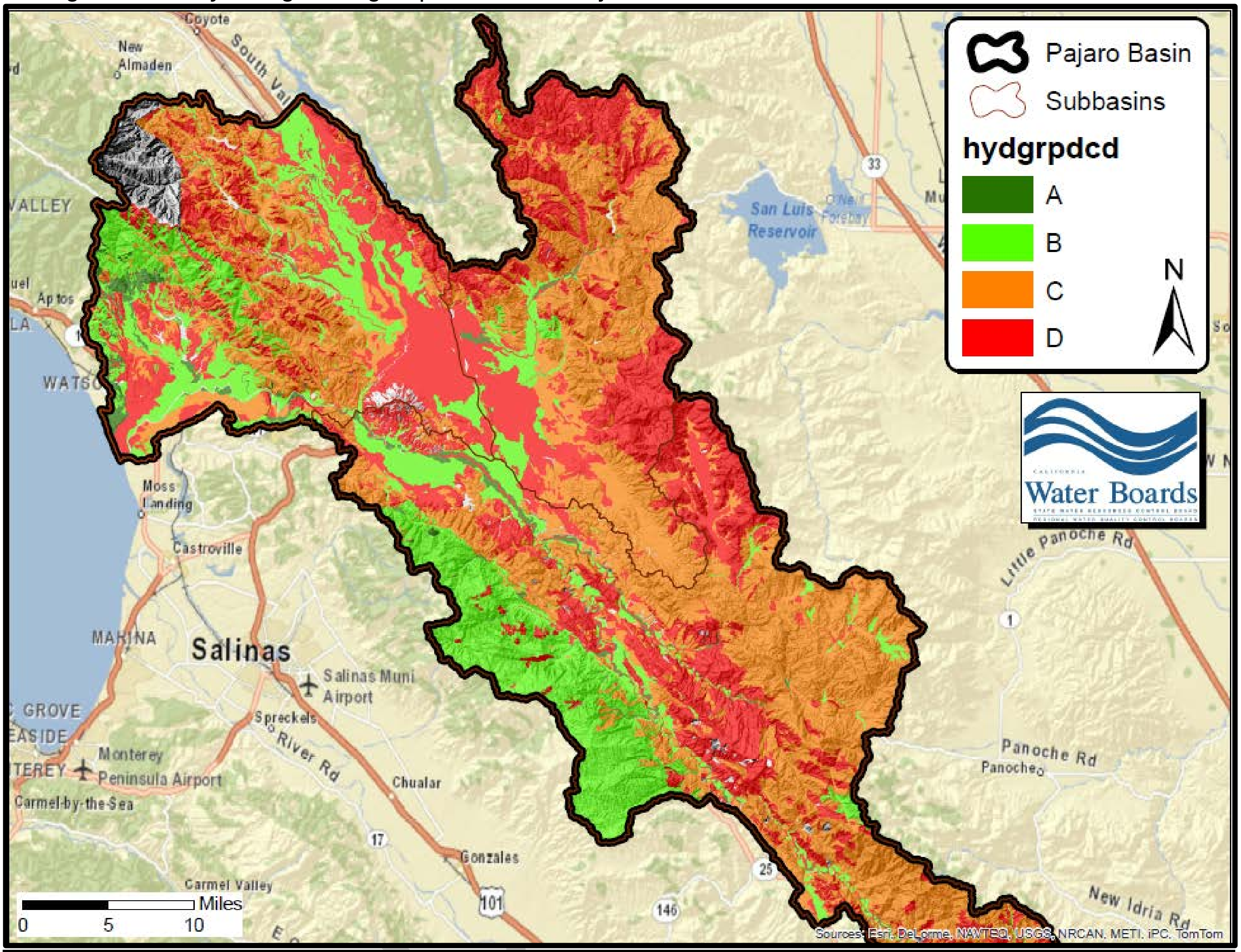
In nutrient TMDLs, it can be important to evaluate background, ambient concentrations of nutrients in soils. Additionally, the spreadsheet source estimation tool used in this TMDL project requires inputs for soil nutrients concentrations. Information on background soil concentrations of trace and major elements, including phosphorus, in California soils is available from the University of California–Kearney Foundation of Soil Science (Kearney Foundation, 1996). Figure 2-53 illustrates background concentrations of phosphorus in California soils on the basis of Kearney benchmark soils selected from throughout the state (Kerney Foundation, 1996). Note that the median soil phosphorus content in benchmark soils from within the California Oak and Chaparral Subecoregion is 378 mg/kg (0.0378 weight percent) – this value thus may constitute a plausible average background soil phosphorus content for the Pajaro River Basin (for a discussion of nutrient ecoregions refer back to Section 2.6).

Figure 2-53. Background concentrations of phosphorus in California soils.



The soil survey for the counties comprising the Pajaro River Basin was compiled by the U.S. Department of Agriculture National Resources Conservation Service (NRCS) and is available online under the title of Soil Survey Geographic (SSURGO) Database. SSURGO has been updated with extensive soil attribute data, including Hydrologic Soil Groups. Hydrologic Soil Groups are a soil attribute associated with a mapped soil unit, which indicates the soil's infiltration rate and potential for runoff. Figure 2-54 illustrates the distribution of hydrologic soil groups in the project area along with a tabular description of the soil group's hydrologic properties.

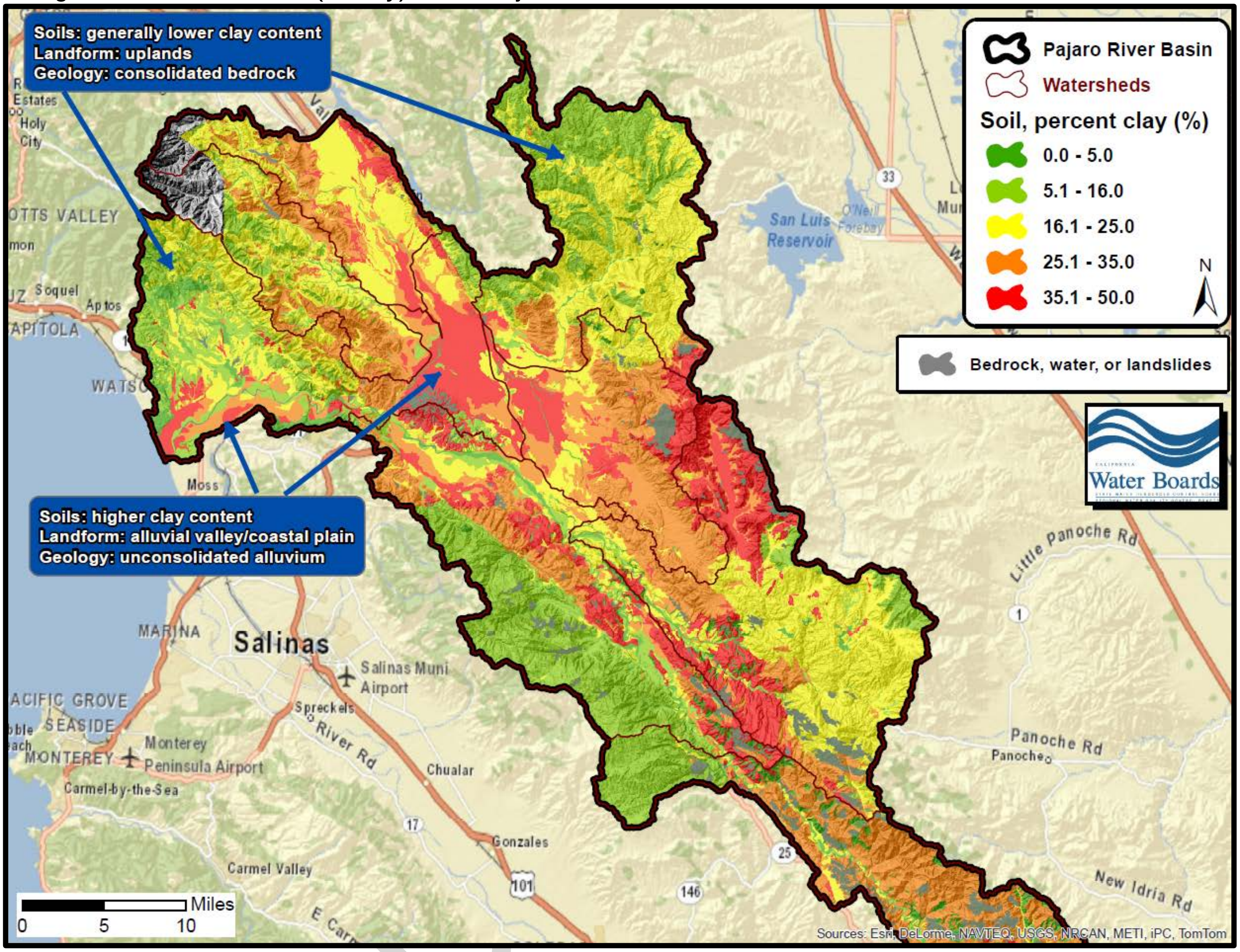
Figure 2-54. Hydrologic soil groups in TMDL Project Area.



Hydrologic Soil Group Descriptions:	
A	Well-drained sand and gravel; high permeability
B	Moderate to well-drained; fine to moderately course texture; moderate permeability
C	Poor to moderately well-drained; moderately fine to fine texture; slow permeability
D	Poorly drained; clay soils, or shallow soils over nearly impervious layers(s)

Additionally, the benthic sediment composition of streams is an important factor to consider, because the physical characteristics of stream substrates may play a role in algal productivity; for example, by influencing the turbidity (and therefore, light availability) of the overlying water column. Benthic stream sediment compostion often reflects the parent soil and sediment material from withing the catchment or subwatershed. It should be recognized that unlike sand, silt, or gravel, which are typically transported as bedload, clay is often transported in colloidal suspension in the water column even at very low stream velocities, thereby contributing to ambient turbidity. Figure 2-55. illustrates the distribution of soil texture in the Pajaro River Basin, on the basis of percent clay content.

Figure 2-55. Soil texture (% clay) in the Pajaro River Basin.



Further, some biocriteria modeling tools used to assess nutrient targets (e.g., California NNE benthic biomass model tool) require input of turbidity information to calculate the water column light extinction coefficient. As noted above, turbidity, to a large extent, may result from the magnitude of suspended fine-grained particulate matter such as clay and fine silt in the water column[54]. Consequently, staff considered whether local soil physical characteristics available via SSURGO mapping databases (as shown, for example in soil texture spatial data in Figure 2-55. and Figure 2-54) represent an approximation of the physical characteristics of soil particle-size distributions found in proximal stream substrates. Presumably, local mapped soil properties (e.g., the quantity and spatial distribution of clay, silt, sand) are a proxy that reasonably reflects the particle size distribution expected in adjacent stream substrates.

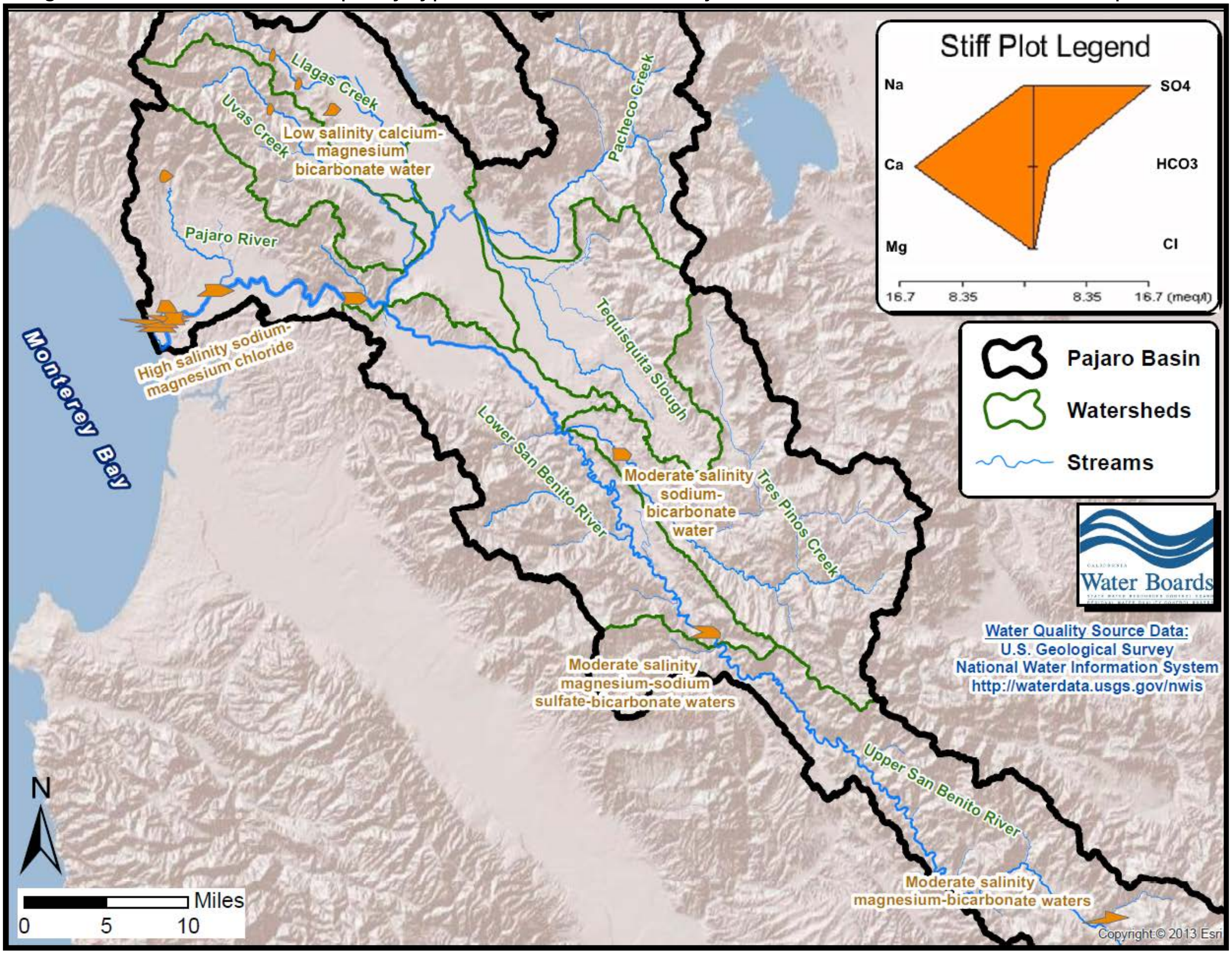
2.12 General Water Quality Types

U.S. Environmental Protection Agency guidance on development of water quality criteria for biostimulatory substances, such as nitrate, recommend that these criteria be developed taking into account spatial, physical, hydraulic, and chemical variation in streams within any given region or basin.

[54] SWRCB, Surface Water Ambient Monitoring Program. Sediment Sources and Transport, and Impacts. Fact Sheet 5.2.1.0

Error! Reference source not found. illustrates generalized variations in water quality types in streams of the Pajaro River Basin on the basis of Stiff diagrams. Stiff diagrams are a representation of general minerals and electrical conductivity. Much of the data represented here are from pre-1990 sampling events, so these should be considered historical, or baseline conditions in the river basin.

Figure 2-56. General water quality types in streams of the Pajaro River Basin on the basis of Stiff plots.



Surface water quality in the upper San Benito and Tres Pinos watersheds can be characterized as moderate salinity, magnesium-bicarbonate waters (Mg-HCO_3) or sodium bicarbonate–sulfate (Na-HCO_3-SO_4) waters. Surface water quality in the Llagas, Uvas, and Upper Corrilitos Creek watersheds, draining the Santa Cruz Mountains, can be generally characterized as lower salinity, magnesium-bicarbonate (Mg-HCO_3) or calcium-bicarbonate waters (Ca-HCO_3). The lower reaches of the river basin, which includes the Pajaro River, can be characterized as higher salinity sodium–magnesium bicarbonate–sulfate waters (Na-Mg HCO_3-SO_4). Limited data from agricultural ditches in the lowermost reaches of the river basin, near Watsonville, were characterized by higher salinity sodium chloride waters (Na-Cl).

2.13 Fish & Wildlife

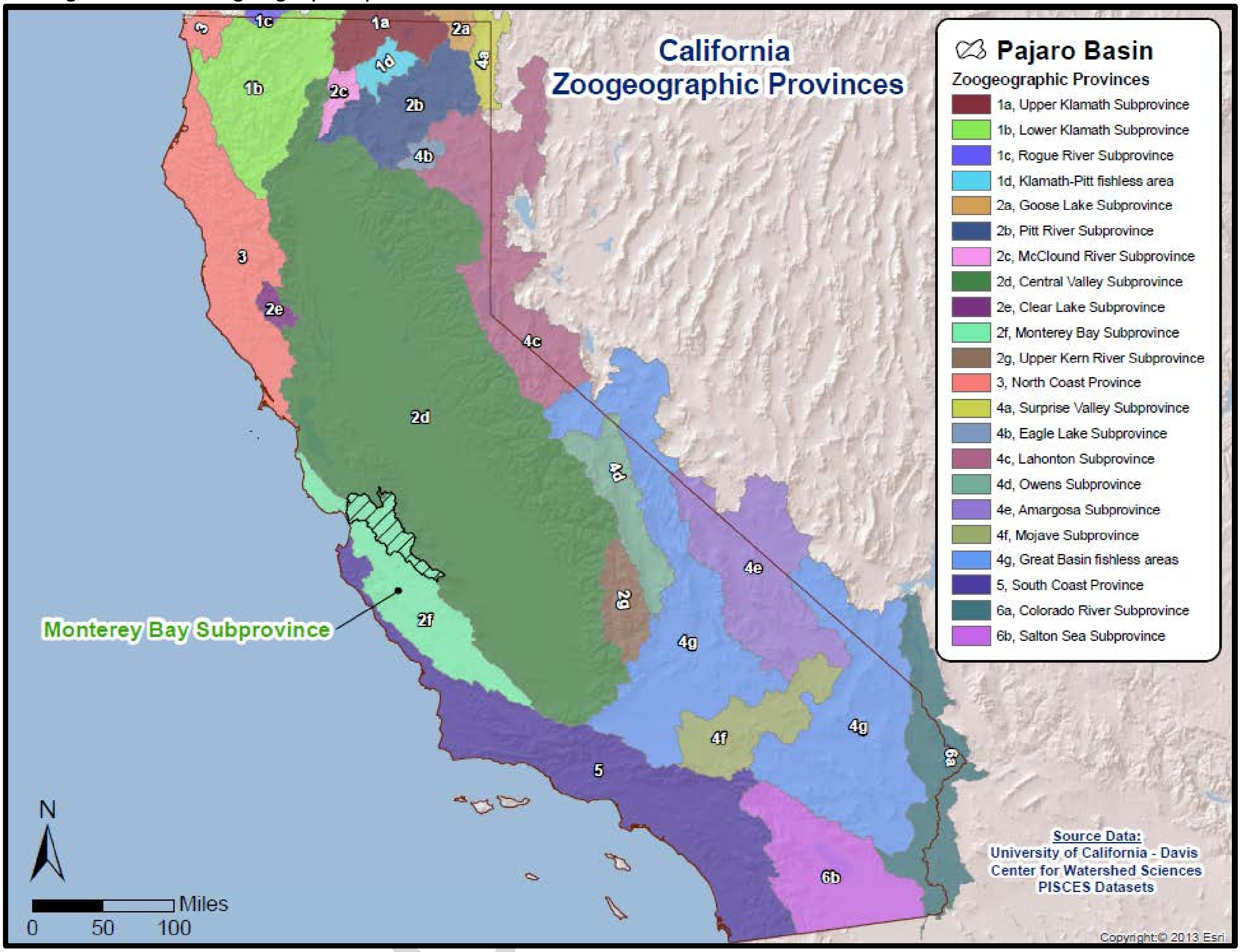
Water quality plays an important role in fish and wildlife habitat. A number of the designated aquatic habitat beneficial uses for project area waterbodies (refer to Section 3.2 and Table 3-2) may be adversely affected by higher than natural nutrient levels and associated water quality stressors (wide DO and pH swings) that occur within the project area. Biostimulatory impairments, or toxicity associated with elevated nutrients and/or unionized ammonia 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. Consequently, it is relevant to be cognizant of and consider available information on aquatic habitat and fish resources in the project area. Is should also be noted that while there remains a fairly significant extent of viable estuarine and brackish water habitat in the Monterey Bay and northern Santa Cruz County coastal areas, the cumulative effect of human activities in the last century has severely degraded, reduced and restricted viable fresh water habitat in the Pajaro River Basin.

Further, it has long been recognized that biostimulation, excess nutrients, and water quality degradation has substantially degraded aquatic habitat locally in surface waters of the Pajaro River Basin. For example, over 20 years ago Swanson and Associates (1993) reported high nutrient levels in surface waters entering the Pajaro River lagoon which were resulting in dense phytoplankton blooms adversely impacting the natural oxygen balance of lagoon waters, and resulting in “shading” which limited natural benthic aquatic plant growth in deeper sections of the lagoon. Additionally, Smith in 1982 (as reported in Moyle et al., 1995) attributes disappearance of monterey roach fish in Monterey Bay watersheds to habitat alteration and lowered water quality including low dissolved oxygen.

Additionally, the California Department of Fish and Game reported in the second edition of *Fish Species of Special Concern in California* that 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 drainages of the State* (Moyle, et al., 1995). Note that researchers have recently reported that, due to the continuing impacts of anthropogenic changes, California is likely to lose a large proportion of its remaining native fish diversity (Marchetti et al., 2006). Stream reaches in the Pajaro River basin provide a range of potential warm freshwater, cold freshwater, and estuarine aquatic habitat. Also, modified and artificial drainage channels may locally and episodically provide migratory habitat or reproductive habitat for fishes and amphibians (Dr. Jerry Smith, written personal communication, July 3, 2013) – indeed, carp and fathead minnow have been observed spawning in Miller’s Canal and in a flooded ditch that flows to Miller’s Canal (J.R. Casagrande, 2010).

One way to beging to assess freshwater aquatic habitat of the Pajaro River Basin is to review regional information and the spatial distribution of California’s zoogeographic provinces – see Figure 2-57. The 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, this subprovince had an array of native fish species from the Central Valley floor, as well as saltwater dispersant fishes including the Pacific Lamprey, threespine stickleback, prickly sculpin, and steehead (Moyle, 2002).

Figure 2-57. Zoogeographic provinces of California.



Special Status Aquatic Species (Fish and Amphibians)

The TMDL project area provides habitat to six special-status aquatic species[55] (fish, amphibians, and a crustacean) listed under the federal Endangered Species Act (ESA), and include:

- South-central California Coast steelhead DPS (Federal Status: threatened);
- Tidewater goby (Federal Status: endangered);
- California red-legged frog (Federal Status: threatened);
- California tiger salamander (Federal and State Status: threatened)
- Santa Cruz long-toed salamander (Federal and State Status: endangered)
- Vernal pool fairy shrimp (Federal Status: threatened)

Aquatic Species of Special Concern (Fish and Turtle)

A Species of Special Concern (SSC) is a species, subspecies, or distinct population of an animal native to California that currently satisfies one or more criteria, as defined by the California Department of Fish

[55] Source: Calif. Dept. of Fish and Game – California Natural Diversity Database, 2013

and Wildlife (CDFW)[56]. "Species of Special Concern" is an administrative designation and carries no formal legal status. The intent of designating SSCs is to focus attention on animals at conservation risk and achieve conservation and recovery of these animals before they meet California Endangered Species Act criteria for listing as threatened or endangered. In terms of aquatic species, the TMDL project area provides habitat for the following aquatic Species of Special Concern that do not currently have special status legal protection:

- Rainbow Trout (fish), designated by CDFW as a Class 1 species *(population threatened)*
- Tidewater Goby (fish), designated by CDFW as a Class 1 species (*qualify as endangered*)
- Monterey Hitch (fish), designated by CDFW as a Class 2 species *(population vulnerable)*
- Monterey Roach (fish) designated by CDFW as a Class 3 species
- Riffle Sculplin (fish) designated by CDFW as a Class 4 species
- Central California Roach (fish), designated by CDFW as a Class 3 species
- White Sturgeon (fish), designated by CDFW as a Class 4 species
- Pacific Lamprey (fish), designated by CDFW as a Class 3 species
- Western pond turtle, which is designated by CDFW as a special concern species (noted to occupy the Pajaro River Flood Control Channel[57],

Clusters of Fish Recommended for Coordinated Ecosystem-Level Management

The California Department of Fish and Game (DFG) have recommended coordinated special ecosystem management strategies for regional clusters of potentially endangered species with similar environmental requirements (Moyle et al., 1995). These DFG-identified fish clusters carry no formal legal status but constitute recommendations as part of a systematic effort towards protecting and restoring fish resources of the State. DFG recommended a cluster of fish species needing coordinated ecosystem management for Monterey Bay streams (Moyle et al., 1995), which includes the following fish species found within the TMDL project area:

- Winter steelhead
- Monterey roach
- Monterey hitch
- Speckled dace
- Sacramento sucker
- Tidewater goby

Fish Resources in Project Area

Figure 2-58 illustrates estimated current presence of native fish assemblages in the Pajaro River Basin and their presumed distributions. It should be noted that 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[58]. Figure 2-59 illustrates the estimated number of native species losses (extirpations) locally by individual subwatersehd within the Pajaro River Basin.

Table 2-16 presents a tabulation of current estimated species range for native fishes by subwatershed within the Pajaro River Basin. Table 2-17 presents a tabulation of recent field observations of native and introduced fish species, reported in surveys by Casagrande (2011) and others.

[56] See DFG species of special concern webpage, accessed Janaury 2014, online linkage: http://www.dfg.ca.gov/wildlife/nongame/ssc/.

[57] Source: Kittleson Environmental Consulting, 2009 Pajaro River Western Pond Turtle Survey – Draft Report, October 22, 2009.

[58] 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.

Figure 2-58. Best-known current ranges for native fish assemblages in Pajaro Basin (2012).

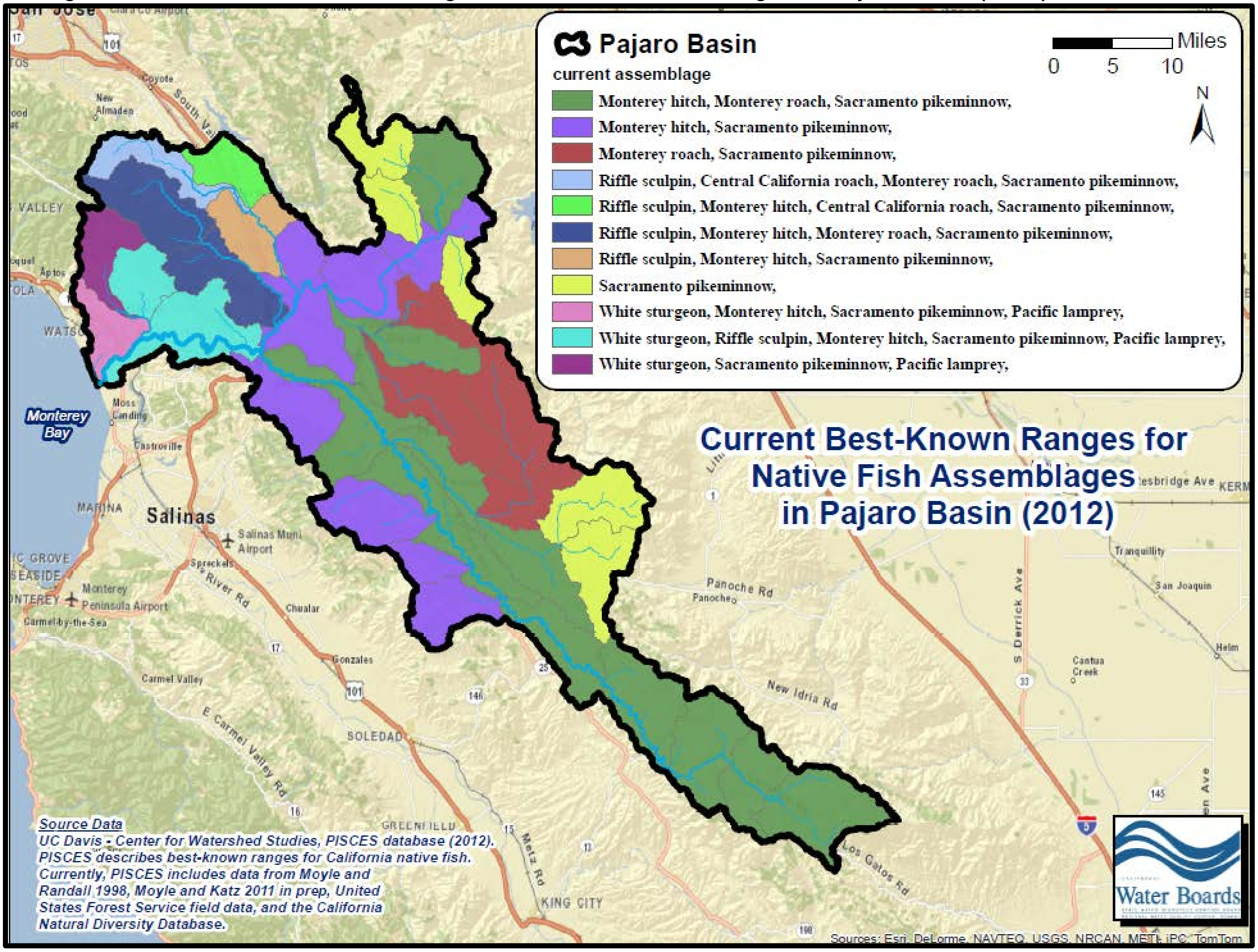


Figure 2-59. Estimated number of native species losses (extirpations) locally by individual subwatershed (source: PICSES database).

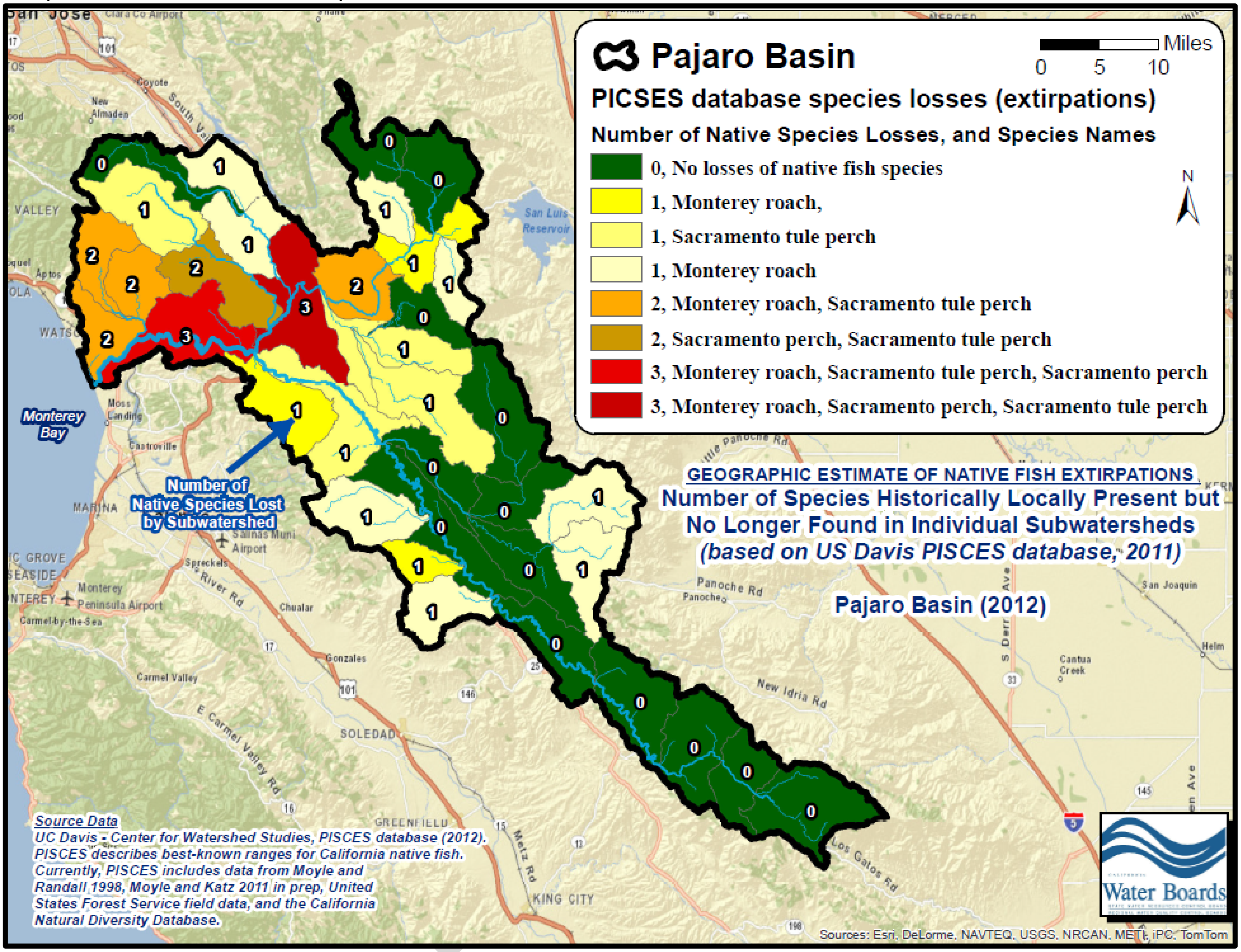


Table 2-16. Current estimated range (best professional judgment[A]) of native riverine fish species in the Pajaro River Basin.

Subbasin	Subwatershed	Rainbow Trout *Oncorhynchus mykiss*	Tidewater Goby *Eucyclogobius newberryi*	Monterey Hitch *Lavinia exilicauda*	Monterey Roach *Lavinia symmetricus subditus*	Sacramento Pikeminnow *Ptychocheilus grandis*	Riffle Sculpin *Cottus gulosus*	Central Calif. Roach *Lavinia symmetricus symmetricus*	White Sturgeon *Acipenser transmontanus*	Pacific Lamprey *Lampetra tridentata*	Speckled Dace *Rhinichthys osculus*	Threespine Stickleback *Gasterosteus aculeatus*	Staghorn Sculpin *Leptocottus armatus*
Pajaro River Subbasin	Upper Pajaro River	x		x		x					x		
	Upper Llagas Creek	x			x	x	x	x			x	x	
	Little Llagas Creek			x		x	x	x				x	
	Lower Uvas Creek	x		x	x	x	x				x		
	Upper Uvas Creek	x		x	x	x	x					x	
	Lower Llagas Creek	x		x		x	x						
	Watsonville Slough Frontal			x		x			x	x		x	x
	Lower Pajaro River	x	x	x		x	x		x	x	x	x	x
	Salsipuedes Creek	x		x		x	x		x	x		x	
	Corralitos Creek	x				x			x	x		x	
Pacheco Creek Subbasin	Tequisquita Slough	x		x	x	x							
	Lower North Fork Pacheco Creek	x		x	x	x							
	Lower Pacheco Creek	x		x		x							
	Upper Pacheco Creek			x		x							
	Santa Ana Creek				x	x					x		
	Arroyo De Las Viboras				x	x							
	South Fork Pacheco Creek	x				X							
	Cedar Creek	x				X							
	Upper North Fork Pacheco Creek					x							
San Benito River Subbasin	Paicines Reservoir-San Benito River	x		x	x	x					x		
	Bird Creek-San Benito River	x		x	x	x					x		
	Lower Tres Pinos Creek			x	x	x					x		
	Middle Tres Pinos Creek			x	x	x					x		
	Rock Springs Creek-San Benito River	x		x	x	x					x		
	Sulphur Creek-San Benito River	x		x	x	x					x		
	James Creek-San Benito River	x		x	x	x					x		
	Clear Creek-San Benito River	x		x	x	x					x		
	Hernandez Reservoir-San Benito River	x		x	x	x					x		
	San Juan Canyon			x		x					x		
	Stone Creek			x		x					x		
	Pescadero Creek	x		x		x					x		
	Willow Creek			x		x					x		
	Quien Sabe Creek				x	x							
	Los Muertos Creek				x	x					x		

Subbasin	Subwatershed	Rainbow Trout *Oncorhynchus mykiss*	Tidewater Goby *Eucyclogobius newberryi*	Monterey Hitch *Lavinia exilicauda*	Monterey Roach *Lavinia symmetricus subditus*	Sacramento Pikeminnow *Ptychocheilus grandis*	Riffle Sculpin *Cottus gulosus*	Central Calif. Roach *Lavinia symmetricus symmetricus*	White Sturgeon *Acipenser transmontanus*	Pacific Lamprey *Lampetra tridentata*	Speckled Dace *Rhinichthys osculus*	Threespine Stickleback *Gasterosteus aculeatus*	Staghorn Sculpin *Leptocottus armatus*
	Upper Tres Pinos Creek					x					x		
	Las Aguilas Creek					x					x		

[A] Source: Unviersity of California, Davis Center for Watershed Studies, PISCES database. THE PISCES database describes the best-known ranges for California's native fishes. The data are compiled from multiple sources and fish biology experts and is stored and exported as range maps.

Table 2-17. Field survey observations of native and introduced fish in the Pajaro River Basin.

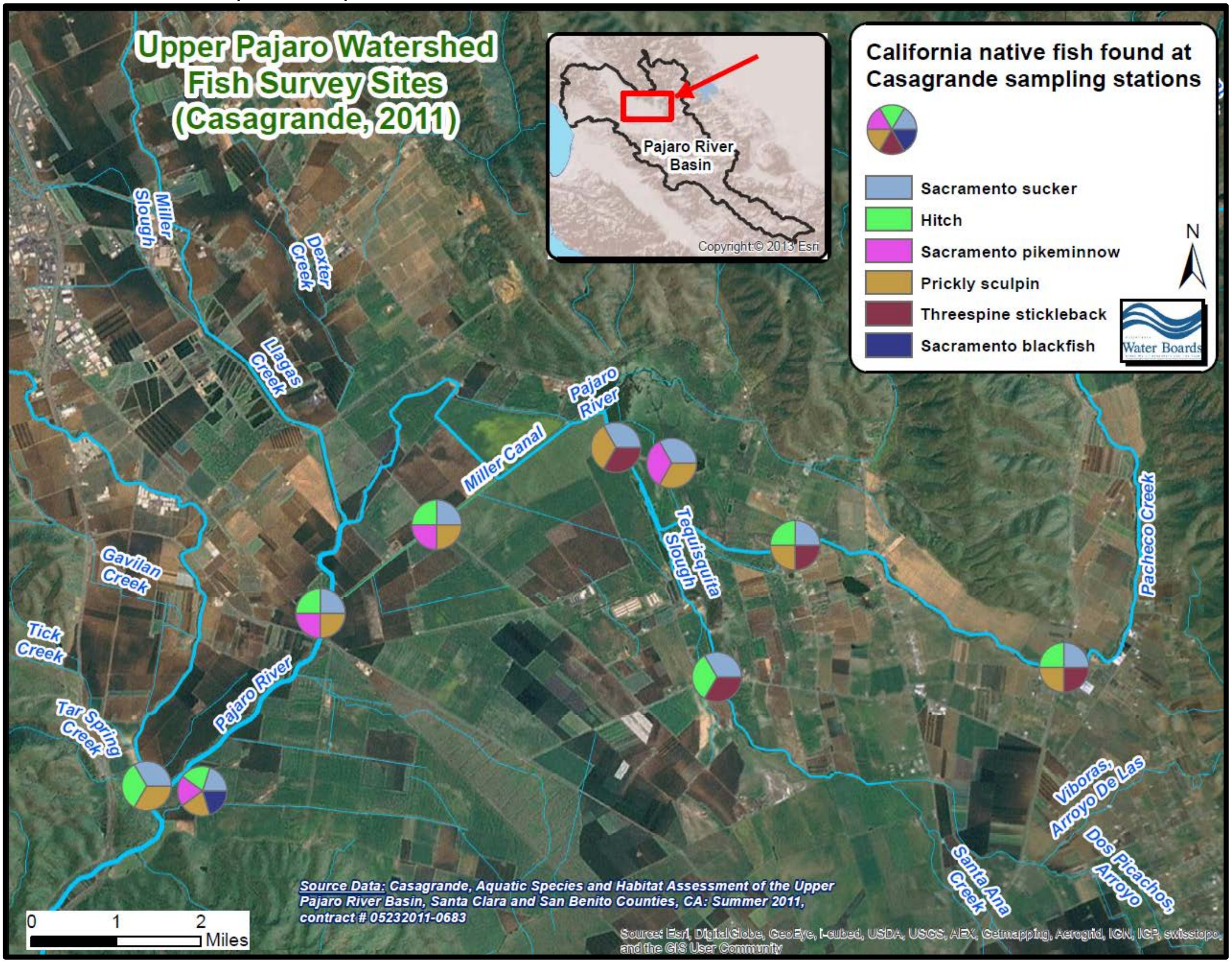
Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
Pajaro River Watershed (Upper)	Pajaro River @ Carnadero Creek Confluence	Sacramento Sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Abundant	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Sacramento blackfish	*Orthodon microlepidotus*	Rare	
		Bluegill	*Lepomis macrochirus*	Rare	
		Black crappie	*Pomoxis nigromaculatus*	Rare	
		White catfish	*Ameiurus catus*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
		Goldfish	*Carassius auratus*	Rare	
		Stripped bass	*Morone saxatilis*	Common	
		Prickly sculpin	*Cottus asper*	Common	
		Fathead minnow	*Pimephales promelas*	Rare	
	Pajaro River @ Miller Canal Confluence	Sacramento Sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Rare	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Brown Bullhead	*Ameiurus nebulosus*	Rare	
		Stripped Bass	*Morone saxatilis*	Common	
		Prickly sculpin	*Cottus asper*	Common	
		Common carp	*Cyprinus carpio*	Rare	
	Miller's Canal @ Frazer Lake Road	Sacramento sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Common	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Prickly sculpin	*Cottus asper*	Abundant	
		Bluegill	*Lepomis macrochirus*	Rare	
		Fathead minnow	*Pimephales promelas*	Rare	
		Mosquitofish	*Gambusia affinis*	Rare	
		Common carp	*Cyprinus carpio*	Not reported	
Pajaro River Watershed (Lower)	Beach Road Drainage Ditch	Mosquito fish	*Gambusia affinis*	Abundant	Kittleson (2005)
		Threespine stickleback	*Gasterostus aculaetus*	Common	
	Harkins Slough	Sacramento blackfish	*Orthodon microlepidotus*	Not reported	Swanson Hydrology and Geomorphology (2003)
		Stickleback	*Gasterostus*	Not reported	

Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
Pajaro River Watershed (Lower)		Carp	*Cyprinus carpio*	Not reported	
		Mosquito fish	*Gambusia*	Not reported	
		Black crappie	*Pomoxis nigromaculatus*	Not reported	
	Struve Slough	Stickleback	*Gasterostus*	Not reported	
	Larkin Creek from Harkins Slough upstream to about Windsong Way	Mosquito fish	*Gambusia*	Not reported	
		Stickleback	*Gasterostus*	Not reported	
		Prickly sculpin	*Cottus asper*	Not reported	
	Pajaro River Estuary	Brown smoothhound	*Mustelus henlei*	Rare	Swanson and Associates (1993)
		Round stingray	*Urolophus halleri*	Rare	
		Pacific herring	*Clupea harengis*	Abundant	
		Pacific sardine	*Sardinops sagax*	Uncommon	
		Northern anchovy	*Engraulis mordax*	Common	
		Coho (adult)	*Oncorhynchus kisutch*	Rare	
		Steelhead (hatchery)	*Oncorhynchus mykiss*	Uncommon	
		Plainfin midshipman	*Porichthys notatus*	Rare	
		Topsmelt	*Atherinops affims*	Abundant	
		California Grunion	*Leuresthes tenuis*	Uncommon	
		Threespine stickleback	*Gasterosteus aculeatus*	Common	
		Bay pipefish	*Syngnathus leptorhynchus*	Common	
		Staghorn sculpin	*Leptocottus armatus*	Abundant	
		Striped bass	*Morone saxatilis*	Uncommon	
		Shiner surfperch	*Cymatogaster aggregata*	Uncommon	
		Walleye surfperch	*Hyperprosopon argenteum*	Uncommon	
		White surfperch	*Phanerodonfurcatus*	Rare	
		Barred surfperch	*Amphistichus argentus*	Rare	
		Pile surfperch	*Damalichthys vacca*	Rare	
		Arrow goby	*Clevlandia ios*	Abundant	
		Tidewater goby	*Eucyclogobius newberryi*	Common	
		California Halibut	*Paralichthyes californicus*	Uncommon	
		Diamond Turbot	*Hypsopsetta guttulata*	Rare	
		English sole	*Parophyrs vetulus*	Uncommon	
		Starry Flounder	*Platichthyes stellatus*	Common	
Uvas Creek Watershed	Lower Carnadero Creek	Sacramento sucker	*Catostomus occidentalis*	Common	Casagrande (2011)
		California roach	*Lavinia symmetricus*	Common	
		Hitch	*Lavinia exilicauda*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		steelhead	*Oncorhynchus mykiss*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
Tequisquita Slough Watershed	Tequisquita Slough @ Shore Road	Sacramento sucker	*Catostomus occidentalis*	Rare	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Rare	
		Threespine stickleback	*Gasterosteus aculeatu*	Rare	
		Fathead minnow	*Pimephales promelas*	Rare	

Watershed (HUC 10)	Waterbody	Fish Species Observed	Scientific Name	Relative Abundance	Literature Source
		Common carp	*Cyprinus carpio*	Rare	
		Mosquitofish	*Gambusia affinis*	Common	
	Tequisquita Slough upstream of San Felipe Lake	Sacramento sucker	*Catostomus occidentalis*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		Threespine stickleback	*Gasterosteus aculeatu*	Abundant	
		Green sunfish	*Lepomis cyanellus*	Rare	
		Fathead minnow	*Pimephales promelas*	Common	
		Common carp	*Cyprinus carpio*	Rare	
		Brown bullhead	*Ameiurus nebulosus*	Common	
Pacheco Creek Watershed	Pacheco Creek @ Hwy 156	Sacramento sucker	*Catostomus occidentalis*	Rare	Casagrande (2011)
		Hitch	*Lavinia exilicauda*	Common	
		Prickly sculpin	*Cottus asper*	Abundant	
		Threespine stickleback	*Gasterosteus aculeatu*	Common	
		Green sunfish	*Lepomis cyanellus*	Common	
	Pacheco Creek @ Lovers Lane	Sacrmento sucker	*Catostomus occidentalis*	Rare	
		Hitch	*Lavinia exilicauda*	Rare	
		Prickly sculpin	*Cottus asper*	Common	
		Threespine stickleback	*Gasterosteus aculeatu*	Rare	
		Green sunfish	*Lepomis cyanellus*	Common	
		Largemouth bass	*Micropterus salmoides*	Rare	
		Common carp	*Cyprinus carpio*	Rare	
	Pacheco Creek upstream of San Felipe Lake	Sacramento sucker	*Catostomus occidentalis*	Common	
		Sacramento pikeminnow	*Ptychocheilus grandis*	Rare	
		Prickly sculpin	*Cottus asper*	Abundant	
		Green sunfish	*Lepomis cyanellus*	Rare	
		Bluegill	*Lepomis macrochirus*	Rare	

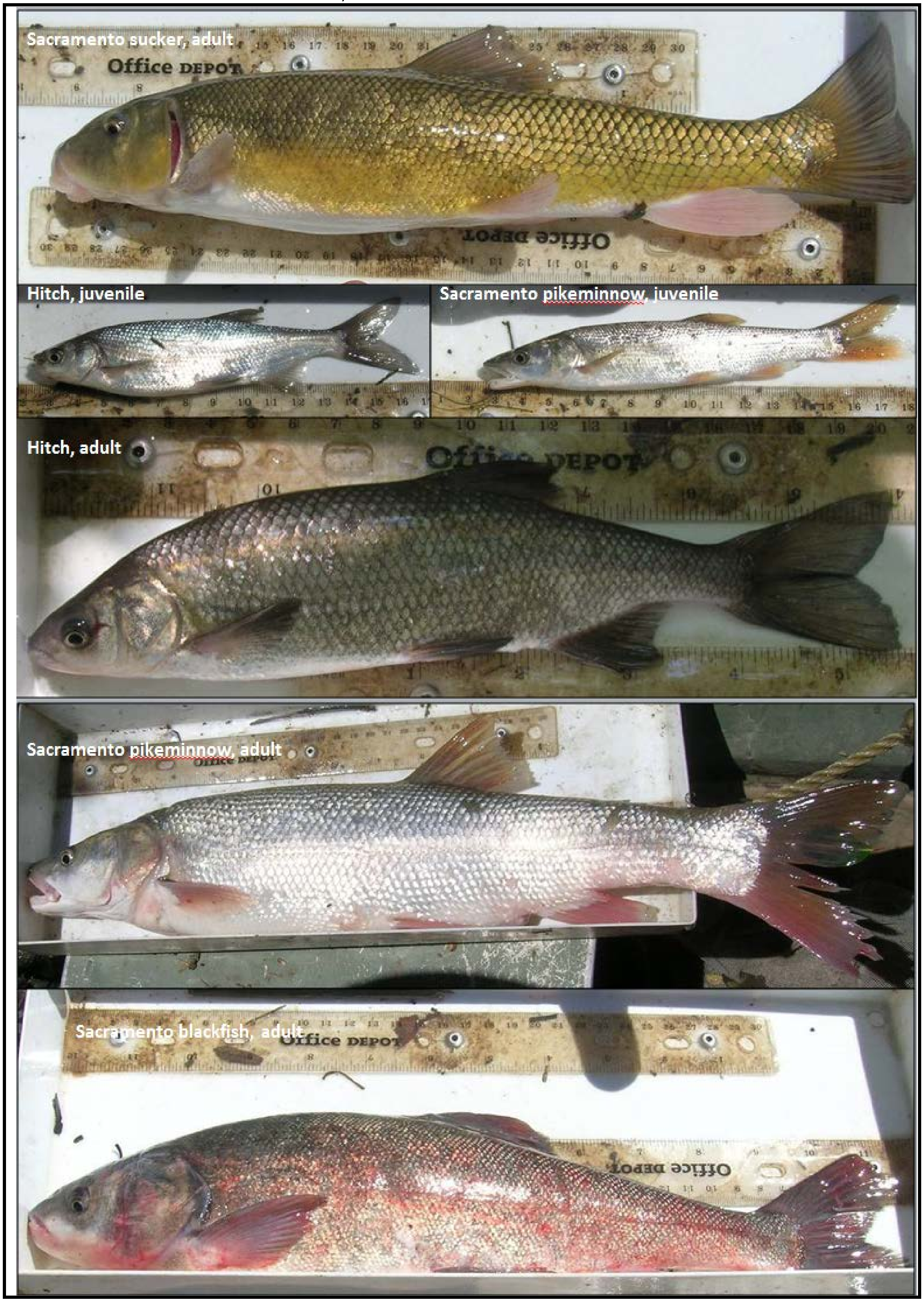
Casagrande (2011) assessed aquatic species in the upper Pajaro River Subbasin and the lower Pacheco Creek Subbasin in the summer of 2011 and found a total of 19 fish species; 8 native and 11 non-native species. The fish survey sites reported by Casagrande (2011) are illustrated in Figure 2-60.

Figure 2-60. Fish survey sites, upper Pajaro Watershed. Survey data from Casagrande 2011 (only native fish are shown in pie charts).



Casagarande (2011) also provided photo documentation of various fish species inhabiting the upper Pajaro River subbasin and the lower Pacheco Creek subbasin. The photos from the Casagrande 2011 fish survey are illustrated in Figure 2-61.

Figure 2-61. Photo documentation of some aquatic species in TMDL project area. Photo credits: Joel Casagrande (2011). Note that all fish photos were taken in the upper Pajaro River subbasin and/or the lower Pacheco Creek subbasin, unless otherwise noted.




Prickly sculpin, juvenile adult
Office DEPOT
Threespine stickleback, juvenile adult
Steelhead, juvenile
Bluegill-green sunfish hybrid, adult (left); bluegill, adult (center-left); and green sunfish (center-right, juvenile and right, adult)


Largemouth bass, adult from San Felipe Lake.
Striped bass, adult
Fathead minnow
Goldfish, adult
Common carp, sub-adult

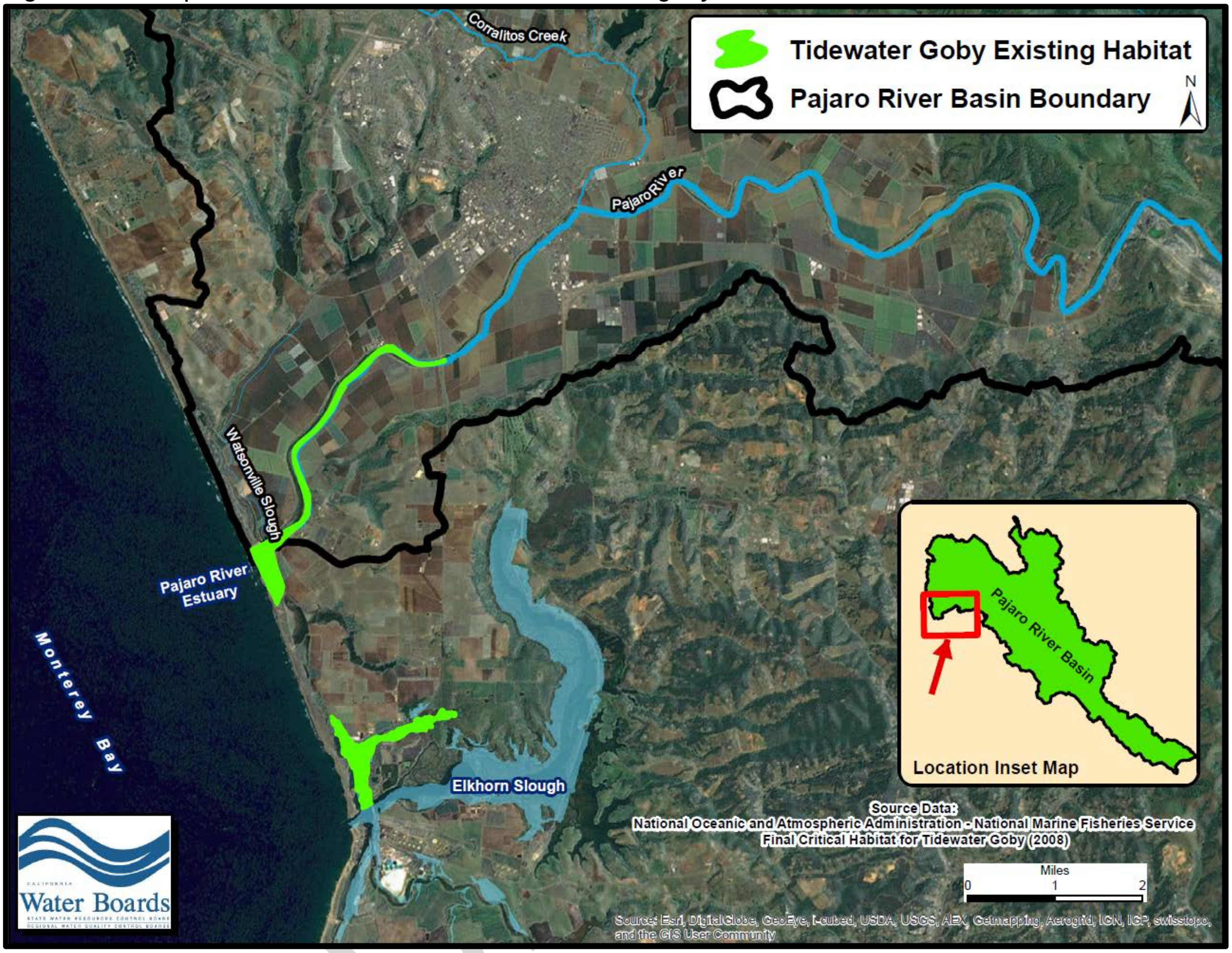

Common carp, adult, gravid
Brown bullhead, adult, gravid
Office DEPOT
White catfish, adult,
Mosquitofish, adult female
Water boatman,
Corixidae
California floater mussel shells on the bank of
Pacheco Creek immediately upstream of its
confluence with San Felipe Lake, 6 May 2006.
Photo source in Casagrande 2011

Tidewater Goby Critical Habitat & Steelhead Migratory and Spawning Habitat

Figure 2-62 illustrates identified critical habitat for the endangered tidewater goby in coastal confluence areas of the Pajaro River Basin. "Critical habitat" is a term defined and used in the federal Endangered Species Act. It refers to specific geographic areas that contain features essential to the conservation of a threatened or endangered species and that may require special management and protection. Critical habitat may include areas that are not currently occupied by the species but that will be needed for its recovery[59].

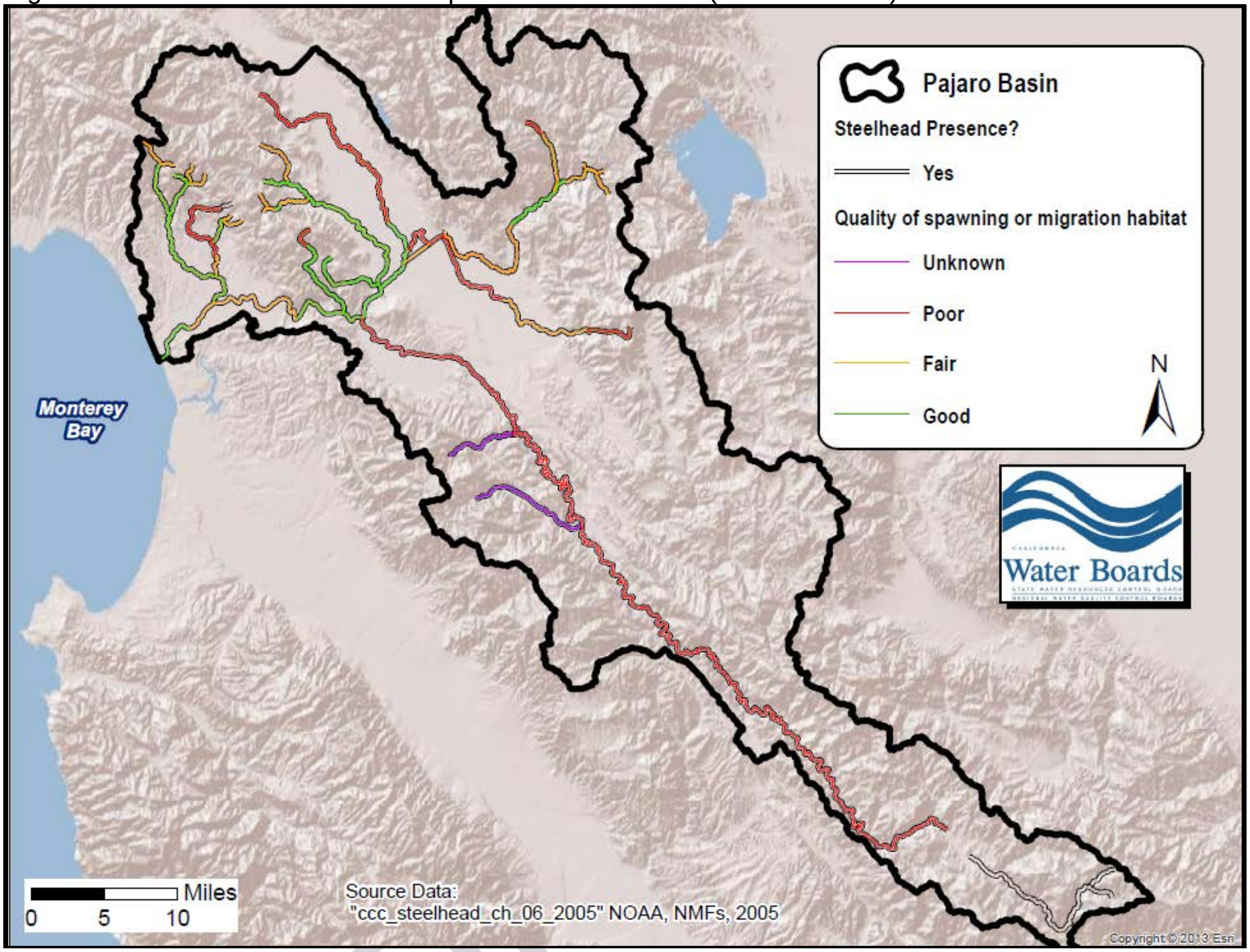
[59] See U.S. Fish and Wildlife Service, Critical Habitat frequently asked question webpage. Online linkage: http://www.fws.gov/endangered/what-we-do/critical-habitats-faq.html

Figure 2-62. Reported critical habitat areas for tidewater goby.



The Pajaro River and some tributaries provide migration and/or spawning habitat for steelhead trout, a federally listed endangered species. Figure 2-63 illustrates steelhead presence or absence in the Pajaro River Basin. This is observational data for the status of salmonid occupancy in a stream segment (stream reaches known or believed to be used by steelhead) but does not imply the existence of routine, robust and viable steelhead runs in all assessed reaches. The data is based on the South-central California Coast Evolutionary Significant Unit (SCCC-ESU) and was compiled by the National Marine Fisheries Service (NOAA Fisheries) Southwest Regional Office (SWR) in an effort to designate Critical Habitat for Steelhead in California.

Figure 2-63. Steelhead distribution – presence or absence (source: NOAA)



The NOAA-National Marine Fisheries Service (NMFS) reported Water Board staff in a letter dated November 10, 2011[60] that on January 5, 2006, the SCCC steelhead DPS was reaffirmed listed as threatened under the Federal Endangered Species Act. NMFS also indicated to Water Board staff that the most recent status review concluded that populations of SCCC-DPS steelhead are likely to become extinct in the next 50 years without intervention (Good et al., 2005 as reported by NMFS staff, personal communication, Nov. 10, 2011).

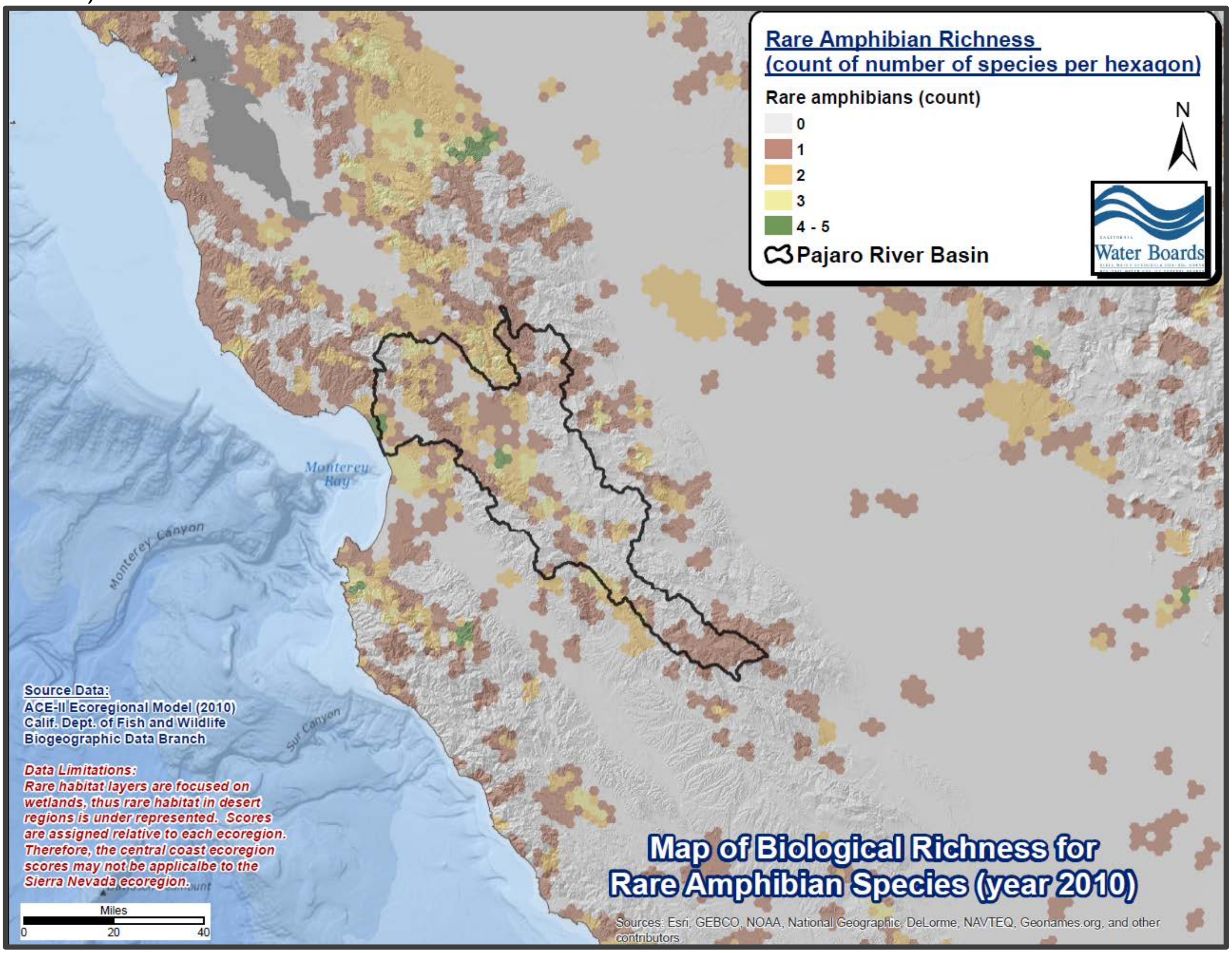
Habitat components for the survival and recovery of SCCC steelhead include, but are not limited to, uncontaminated estuarine areas and substrate and sufficient water quality to support growth and development. NMFS reports that the Pajaro, Salinas, Nacimiento/Arroyo Seco, and Carmel Rivers have experienced declines in steelhead runs of 90 percent or more during the last 30 years. Central Coast estuaries and lagoons play important roles in steelhead growth and survival.

Finally, it is important to recognize that the Water Board is required to protect, maintain, or restore aquatic habitat beneficial uses of waters of the State broadly for the full spectrum of species dependent on aquatic habitats, for example: vegetation, fish or wildlife, including invertebrates (refer to Section 3.1.4). Noteworthy is that the Pajaro River Basin contains many areas that are known to contain a number of rare amphibian species (see Figure 2-64) on the basis of biological richness data compiled by

[60] Letter to Water Board staff from NOAA-NMFS, Steve A.Edmundson, Southwest Regional Habitat Manager, Habitat Conservation Division, dated November 10, 2011.

the California Department of Fish and Wildlife – thus highlighting the fact that viable freshwater aquatic habitat is critical for an entire terrestrial ecosystem in the broadest sense.

Figure 2-64. Map of biological richness for rare amphibian species, Pajaro River Basin and vicinity (year 2010).



2.14 Downstream Impacts

It is important to recognize that excess nutrients in inland streams which drain alluvial or headwater reaches will ultimately end up in a receiving body of water (lakes, rivers, estuaries, bays, etc.) where the nutrient concentrations and total load may degrade the water resource. The U.S. Environmental Protection Agency (USEPA) Scientific Advisory Board has stressed the importance of recognizing downstream impacts associated with excessive nutrients with respect to developing numeric nutrient concentration criteria for inland streams (USEPA, 2010, Worcester et al., 2010) – furthermore, downstream water quality must be protected in accordance with federal water quality standards regulations[61]. Numeric targets developed for inland surface streams should generally be applied to also minimize downstream impacts of nutrients in receiving waterbodies, which are exhibiting signs of eutrophication. In other words, tributary streams themselves may not exhibit detrimental water quality impacts associated with biostimulation, but because they may drain into a receiving waterbody that *is* showing signs of excessive biostimulation, the downstream effects of the tributaries should be considered.

For example, Furlong Creek, located in the Lllagas Crek Watershed, does not appear to be currently exhibiting biostimulatory problems despite the fact that water column nutrient concentrations are quite high; for example dissolved oxygen balance in the creek to be generally withing acceptable ranges. However Furlong is discharging its nutrient loads to receiving waters in Llagas Creek and the Pajaro River – some reaches of these downstream reveiving waters do indeed show biostimulatory problems.

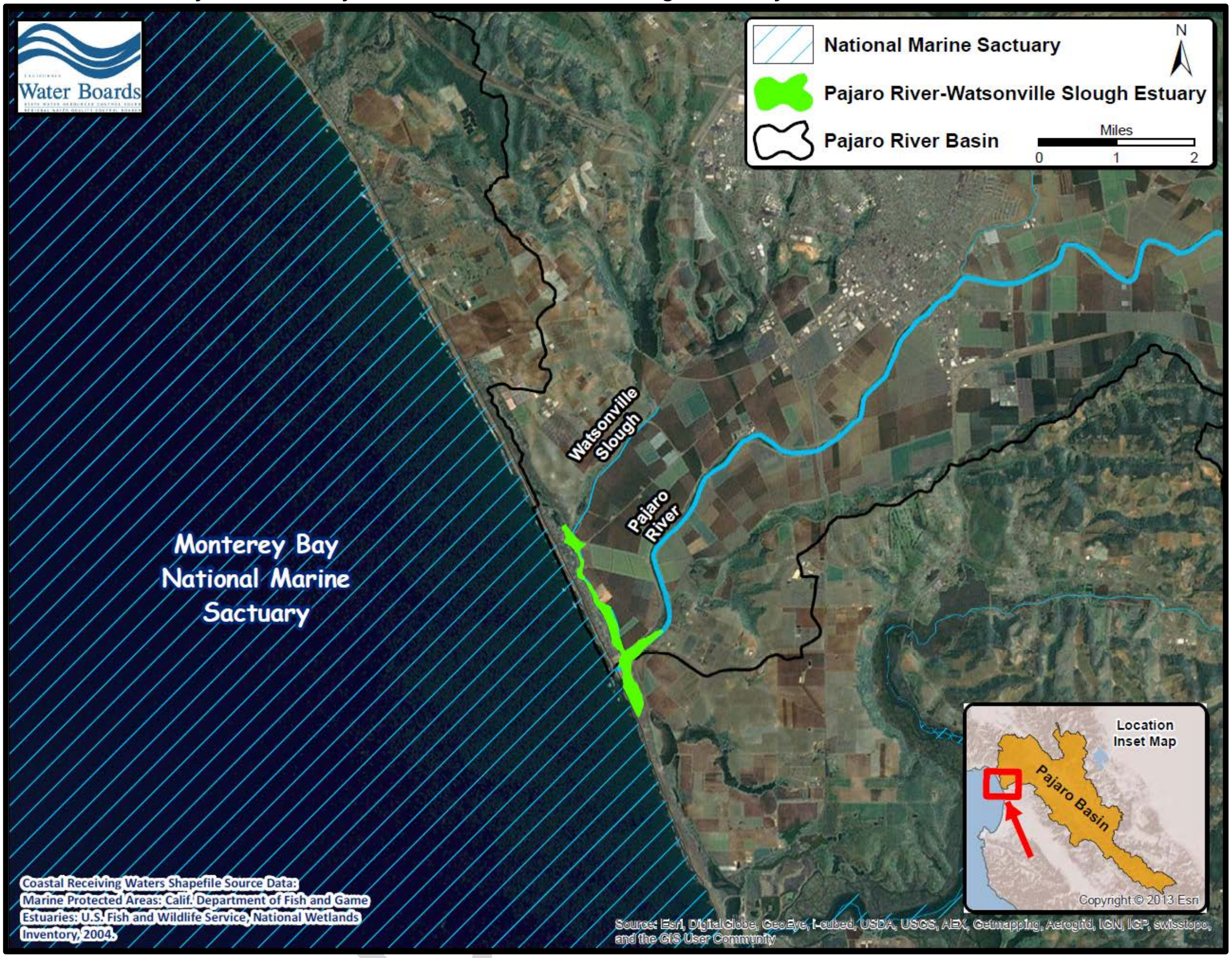
Furthermore, TMDL project area waterbodies ultimately drain into the Pajaro River-Watsonville Slough Estuary, and periodically into Monterey Bay when the estuary is open to ocean waters. As such, the Pajaro River-Watsonville Slough Estuary and Monterey Bay coastal waters represent the coastal confluence receiving waters for Pajaro River Basin streams. 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 2-65). The Monterey Bay National Marine has legally established goals and conservation objectives[62]. The Montery Bay National Marine Sactuary was established and is managed in part to sustain, conserve, and restore the protected area's natural biodiversity, populations, habitats, fisheries, and ecosystems.

As noted previously in Section 1.2, algal toxins resulting, in part, from nutrient-enriched inland streams of the Pajaro River Basin have resulted in deaths of the endangered California southern sea otters, according to recent findings by researchers. Therefore, it is important to be cognizant that pollutant loads from freshwater sources within the Pajaro River Basin are discharging into coastal confluence waterbodies that are formally recognized and managed as sensitive ecological receiving waters.

[61] 40 C.F.R. 131.10(b) states: *"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."*

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

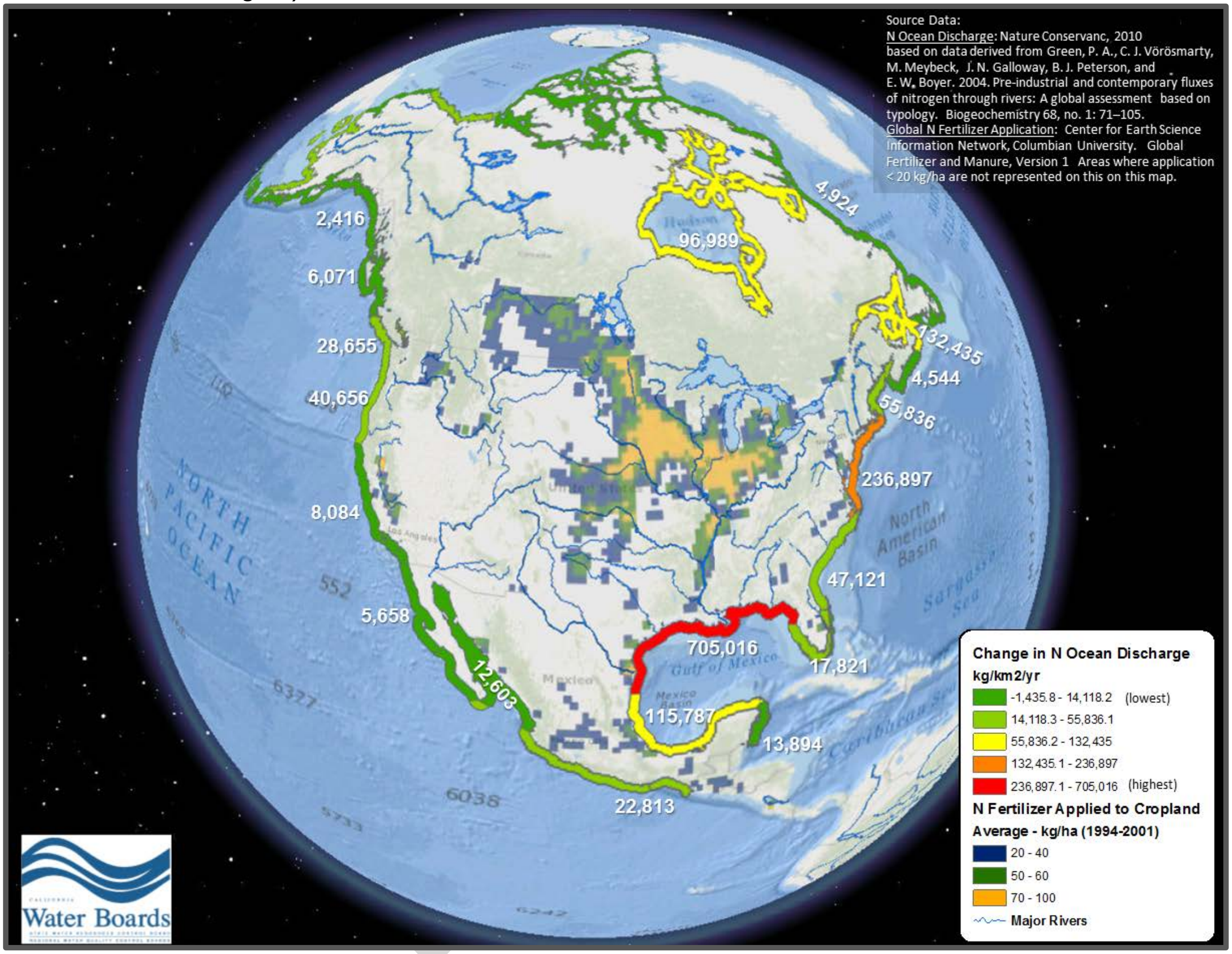
Figure 2-65. Coastal confluene receiving waters of the Pajaro River Basin: Monterey Bay National Marine Sanctuary and the Pajaro River-Watsonville Slough Estuary.



Indeed, nutrient impacts to coastal waters have been recognized as a significant national environmental problem. According to the U.S. Environmental Protection Agency, 78% of assessed coastal waters in the nation exhibit eutrophication[63]. However, according to data published by Green et al. (2004), it should be noted that at regional-scales, California coastal waters are relatively unimpacted by land-based nitrogen discharges as compared to other coastal areas of the United States (see Figure 2-66). For example, California coastal waters do not have nutrient-related problems even approaching the scale and severity of the Gulf of Mexico hypoxia zone, also known as the Gulf of Mexico “dead zone,” which is caused by nutrient enrichment originating from the Mississippi River Basin.

[63] U.S. Environmental Protection Agency: Memorandum from Acting Assisstant Administrator Nancy K. Stoner. March 16, 2011. Subject: “Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions”.

Figure 2-66. Globe view showing 1) estimated increase in discharges of nitrogen to coastal waters between pre-industrial times and contemporary times by marine ecoregion (units = kg nitrogen/km^2/year); and 2) estimated nitrogen fertilizer applied to cropland (where application >20 kg/ha), by grid cell (years 1994-2001, units = kg/ha).

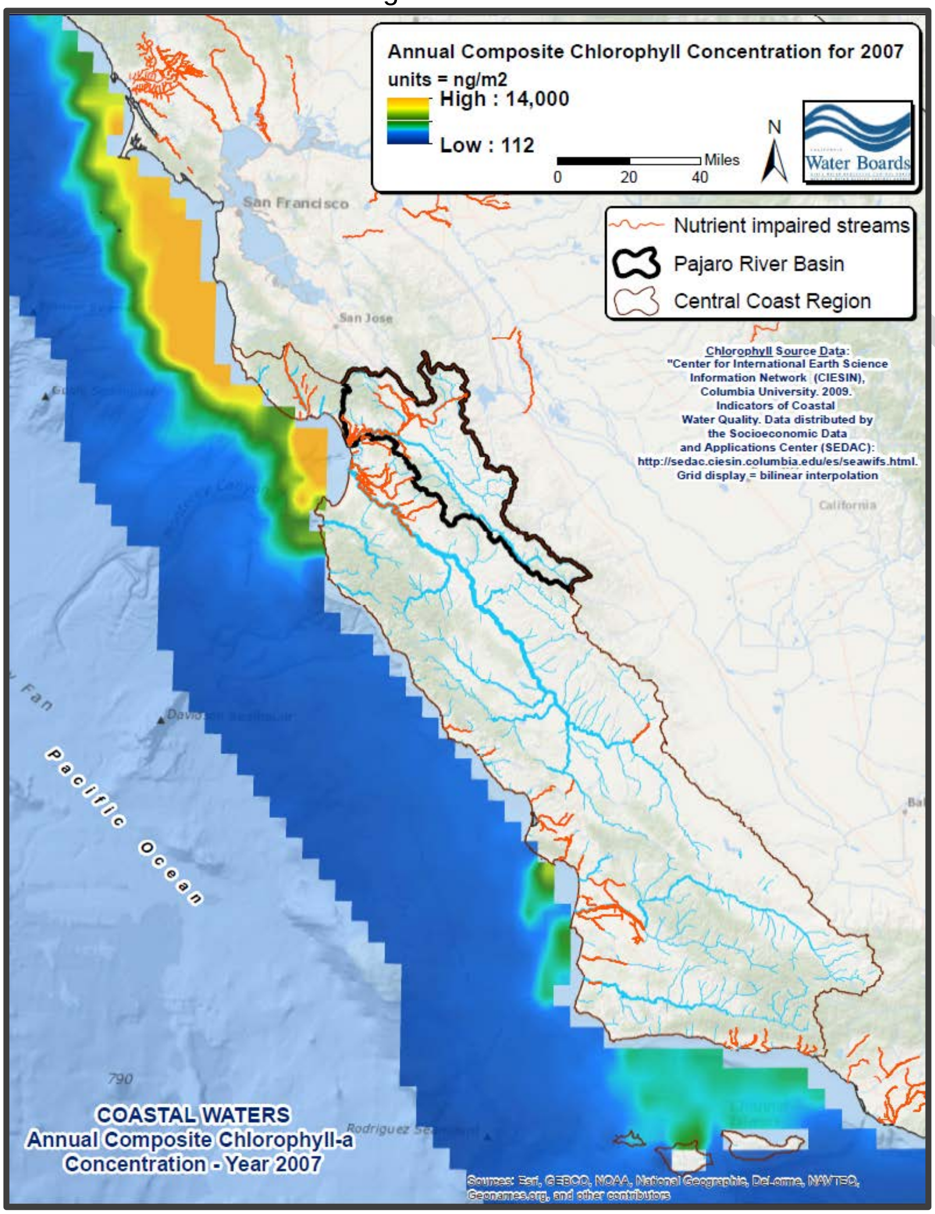


While California offshore coastal waters – at marine ecoregional scales – are generally in relatively good condition with respect to nutrient pollution, at more localized scales researchers have reported a number of problems in some near-shore coastal areas in the Monterey Bay National Marine Sanctuary. Some of these near shore coastal areas are characterized by elevated levels of nitrates, sediment, pesticides, and fecal baceteria which originate, in part, from freshwater sources such as runoff and inland streams of Monterey Bay watersheds (Monterey Bay National Marine Estuary–Santuary Integrated Monitoring Network website, accessed March, 2014). In addition, Lane et al. (2009) provided evidence that algal blooms in Monterey Bay may periodically result from sources of nitrogen associated with Pajaro River discharges. It should be noted however, that algal blooms in Monterey Bay may also be periodically caused by ocean basin upwelling processes which are unrelated to human activities.

Chlorophyll-a is a water quality parameter that is a proxy for measuring biomass and algae. Spatial data compiled and reported by the Goddard Space Flight Center and the Center for International Earth

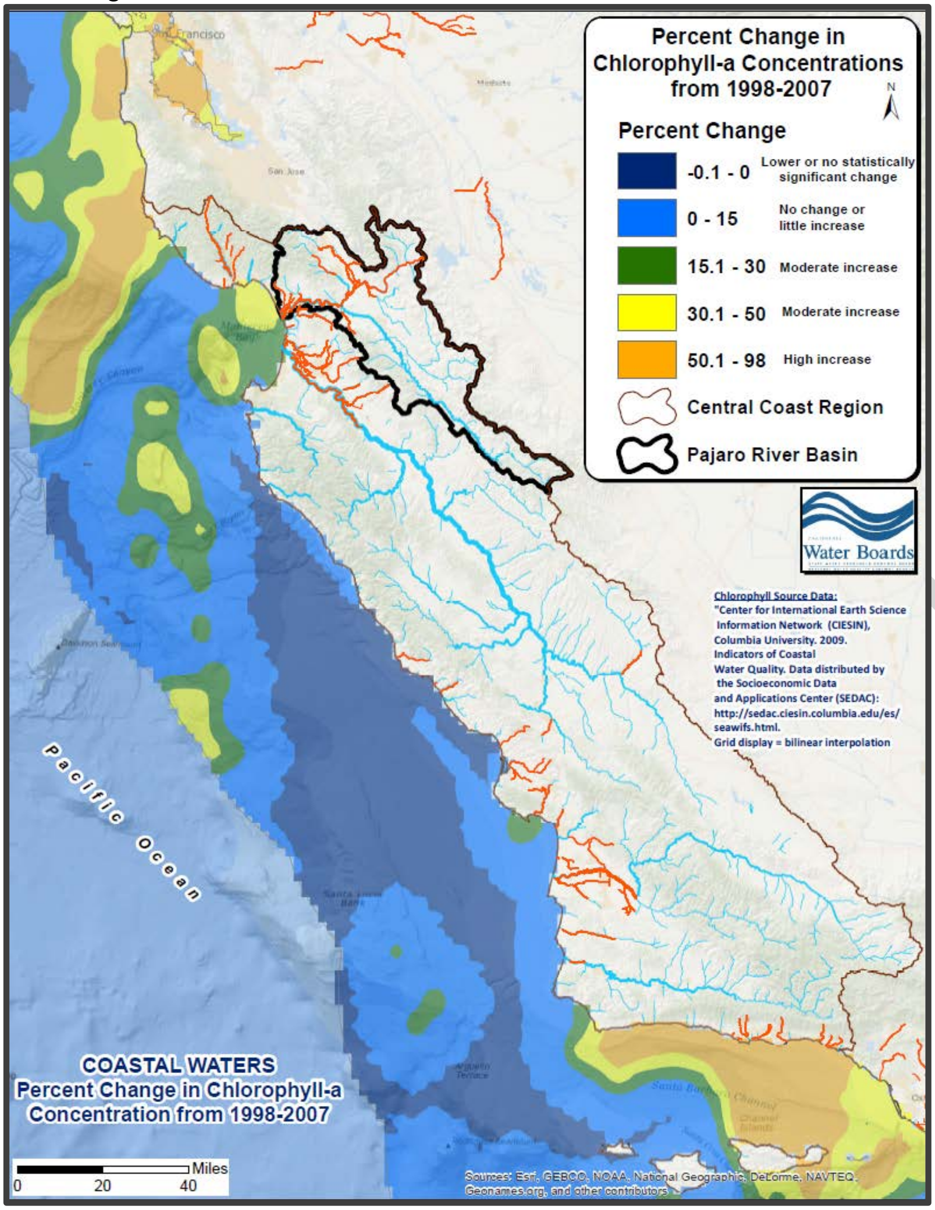
Science Information Network - CIESIN - Columbia University[64] illustrate trends of chlorophll-a concentrations on a pixel-by-pixed basis. Annual composite chlorophyll-a concentrations in California central coastal waters for 2007 are shown in Figure 2-67. Trends in changing concentrations from 1999-2007 are shown in Figure 2-68; these data suggest statistically significant increases in chlorophyll-a concentrations from 1998-2007 locallty in coastal waters of Monterey Bay and in the southern California coastal waters. It should be noted statistical significance is a measure of the association between two variables, but does not prove causation. Chlorphyll-a concentration can be related to many factors besides nutrient loads; for example, the extent and persistence of cloud cover and solar radiation, or ocean upwelling processs which are not anthropogenic in nature.

Figure 2-67. Map illustrating estimated annual composite chlorophyll-a concetrations for the year 2007, in the California central coast region.



[64] Goddard Space Flight Center - GSFC, and Center for International Earth Science Information Network - CIESIN - Columbia University. 2009. Indicators of Coastal Water Quality: Change in Chlorophyll-a Concentration 1998-2007. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). http://sedac.ciesin.columbia.edu/data/set/icwq-change-in-chlorophyll-a-concentration-1998-2007.

Figure 2-68. Map highlighing coastal waters characterized by statistically significant change (% increase) in chlorophyll-a concentrations (green-yellow-orange shades), and coastal waters characterized by no statistically significant increases or little change (blue shades) between 1998 and 2007, California central coast region.



In summary, due to reported river-based nutrient related water quality impacts in near-shore coastal areas of Monterey Bay, and impacts to the endangered southern sea otter originating from the Pajaro River Basin, this TMDL does consider and take into account biostimulatory impariments and downstream impacts to receiving coastal marine and estuarine 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[65]." Water quality standards are provisions of state and federal law intended to implement the

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

federal Clean Water Act. In accordance with state and federal law, California's water quality standards consist of:

- Beneficial uses, 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, 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.
- Anti-degradation policies, which are implemented to maintain and protect existing water quality, and high quality waters.

Therefore, beneficial uses, water quality objectives, and anti-degradation policies collectively constitute water quality standards. Beneficial uses, relevant water quality objectives, and anti-degradation requirements that pertain to this TMDL are presented below in Section 3.1, Section 3.2, and Section 3.3 respectively.

3.1 Beneficial Uses

California's water quality standards designate beneficial uses for each waterbody (e.g., drinking water supply, aquatic life support, recreation, etc.) and the scientific criteria to support that use. The California Central Coast Water Board is required under both State Federal Law to protect and regulate beneficial uses of waters of the state.

The Basin Plan states that surface water bodies within the region that do not have beneficial uses specifically designated for them are assigned the beneficial uses of "municipal and domestic water supply" and "protection of both recreation and aquatic life." The Water Board has interpreted this general statement of beneficial uses to encompass the beneficial uses of REC-1 and REC-2, MUN, along with all beneficial uses associated with aquatic life. The finding comports with the Clean Water Act's national interim goal of water quality [CWA Section 101(a)(2)] which provides for the protection and propagation of fish, shellfish and wildlife. As such, consistent with the Central Coast Basin Plan the Water Board has interpreted "aquatic life" as WARM, COLD, and SPWN for the 2008 impaired waterbody Clean Water Act 303(d) list. It should be noted that the COLD beneficial use may not be appropriate for all inland waterbodies which are not currently listed in Basin Plan Table 2-1. However, staff does not have the authority to unilaterally designate or de-designate beneficial uses within the context of a permit or in a project report. The State Water Resources Control Board (SWRCB) has indeed upheld that a basin plan amendment is the appropriate vehicle to de-designate beneficial uses(s) on a case-by-case basis (see for example, SWRCB, Order WQO 2002-0015). The Water Board could in the future conclude on a case-by-case basis that (for example) the COLD beneficial use does not apply to specific stream reaches that are not currently listed in Basin Plan Table 2-1 if dischargers or stakeholders present evidence that the uses are not existing and are highly-improbable. Alternatively, changes to beneficial uses designations in the Basin Plan can occur during the triennial Basin Plan review process; stakeholders, interested parties, and the general public may participate and submit data for the triennial review.

Table 3-1. Central Coastal Basin Plan (June 2011 edition) designated beneficial uses for Pajaro River Basin surface water bodies.

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Corralitos Lagoon					X	X	X	X									X	
Palm Beach Pond	X				X	X	X		X				X				X	
Pinto Lake	X	X		X	X	X	X		X		X						X	
Kelley Lake	X	X		X	X	X	X		X		X						X	
Drew Lake	X	X		X	X	X	X		X		X						X	

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Tynan Lake	X	X		X	X	X	X		X		X						X	
Warner Lake	X	X		X		X	X										X	
Pajaro River Estuary					X	X	X	X	X	X	X	X	X	X			X	X
Pajaro River	X	X	X	X	X	X	X	X	X	X	X				X		X	
San Benito River	X	X	X	X	X	X	X		X		X				X		X	
Bird Creek	X	X		X	X	X	X		X			X					X	
Pescadero Creek (S. Benito)	X	X		X	X	X	X	X	X	X	X						X	
Tres Pinos Creek	X	X	X	X	X	X	X		X		X						X	
Hernandez Reservoir	X	X		X	X	X	X		X		X				X	X	X	
Tequisquita Slough				X	X	X	X		X		X						X	
San Felipe Lake	X	X		X	X	X	X	X	X	X					X	X	X	
Pacheco Creek	X	X		X	X	X	X	X	X	X	X	X	X		X		X	
Pacheco Lake	X	X		X	X	X	X	X	X		X		X		X	X	X	
Llagas Creek (above Chesbro Res.)	X	X		X	X	X	X	X	X				X		X		X	
Chesbro Reservoir	X	X		X	X	X	X		X	X	X		X		X	X	X	
Llagas Creek (below Chesbro Res.)	X	X	X	X	X	X	X	X	X	X	X		X				X	
Alamias Creek	X	X		X	X	X	X	X	X	X	X						X	
Live Oak Creek	X	X		X	X	X	X	X	X	X							X	
Little Llagas Creek	X	X		X	X	X	X		X								X	
Carnadero Creek	X			X	X	X	X	X	X	X			X				X	
Uvas Creek, downstream	X	X	X	X	X	X	X	X	X	X	X		X				X	
Uvas Res.	X	X		X	X	X	X		X		X		X		X	X	X	
Little Arthur Creek	X	X		X	X	X	X	X	X	X	X						X	
Bodfish Creek	X	X		X	X	X	X	X	X	X	X		X				X	
Black Hawk Canyon Creek	X				X	X	X		X	X	X		X				X	
Uvas Creek, upstream	X			X	X	X	X	X		X	X		X		X		X	
Little Uvas Creek	X	X		X	X	X	X		X								X	
Swanson Canyon Creek	X			X	X	X	X										X	
Alec Canyon Creek	X			X	X	X	X	X		X	X						X	
Croy Creek	X			X	X	X	X		X				X				X	
Eastman Canyon Creek	X	X		X	X	X	X		X								X	
Pescadero Creek	X	X		X	X	X	X	X		X	X	X					X	
Soda Lake						X	X		X				X				X	
Salsipuedes Creek	X	X		X	X	X	X	X		X	X						X	
Corralitos Creek	X	X	X	X	X	X	X	X	X	X	X						X	
Browns Creek	X	X	X	X	X	X	X	X	X	X	X						X	
Gamecock Creek	X			X	X	X	X	X		X	X						X	
Ramsey Gulch	X			X	X	X	X	X		X	X						X	
Redwood Creek	X				X	X	X	X		X	X						X	
Mormon Gulch	X			X	X	X	X	X									X	
Clipper Gulch	X			X	X	X	X	X									X	
Cookhouse Gulch	X			X	X	X	X	X									X	

Waterbody Names	MUN	AGR	IND	GWR	REC1	REC2	WILD	COLD	WARM	MIGR	SPWN	BIOL	RARE	EST	FRESH	NAV	COMM	SHELL
Shingle Mill Gulch	X			X	X	X	X	X		X	X						X	
Rattlesnake Gulch	X			X	X	X	X	X									X	
Diablo Gulch Creek	X			X	X	X	X	X									X	
Eureka Gulch	X			X	X	X	X	X									X	
Rider Gulch Creek	X			X	X	X	X	X		X	X						X	
Watsonville Slough					X	X	X		X		X	X	X	X			X	
Struve Slough					X	X	X		X		X	X	X	X			X	
Hanson Slough					X	X	X		X		X	X	X	X			X	
Harkins Slough					X	X	X		X		X	X	X	X			X	
Galligan Slough					X	X	X		X		X		X	X			X	

MUN: Municipal and domestic water supply.
AGR: Agricultural supply.
IND: Industrial service supply
GWR: Ground water recharge.
REC1: Water contact recreation.
REC2: Non-Contact water recreation.
WILD: Wildlife habitat.
COLD: Cold Fresh water habitat
WARM: Warm fresh water habitat
MIGR: Migration of aquatic organisms.
SPWN: Spawning, reproduction, and/or early development
BIOL: Preservation of biological habitats of special significance.
RARE: Rare, threatened, or endangered species
EST: Estuarine habitat
FRESH: Freshwater replenishment.
COMM: Commercial and sport fishing.
SHELL: Shellfish harvesting..

A narrative description of the designated beneficial uses of project area surface waters which are most likely to be potentially at risk of impairment by water column nutrients are presented below.

3.1.1 Municipal and Domestic Water Supply (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 under certain conditions (see Basin Plan, Chapter 2, Section II.)

The nitrate numeric water quality objective protective of the MUN beneficial use is legally established as 10 mg/L[66] nitrate as nitrogen (see Basin Plan, Table 3-2). This level is established to protect public health (refer back to Section 1.2 for a description of health risks related to nitrate).

3.1.2 Ground Water Recharge (GWR)

*Uses of water for natural or artificial recharge of ground water for purposes of future extraction, **maintenance of water quality**, or halting of saltwater intrusion into freshwater aquifers. Ground water recharge includes recharge of surface water underflow. (emphasis added) - (see Basin Plan, Chapter 2, Section II.)*

The groundwater recharge (GWR) beneficial use is recognition 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. Most surface waters and ground waters of the central coast region are both designated with the MUN beneficial use. The MUN nitrate water quality objective (10 mg/L) therefore applies to *both* the stream waters, and to the underlying groundwater. This numeric water quality objective and the MUN designation of underlying groundwater is relevant to the extent that portions project area streams recharge the underlying groundwater resource. The Basin Plan GWR beneficial use explicitly states that the designated groundwater recharge use of surface waters are to be

[66] This value is equivalent to, and may be expressed as, 45 mg/L nitrate as NO3.

protected to maintain groundwater quality. Note that surface waters and ground waters are often in direct or indirect hydrologic communication. As such, where necessary, the GWR beneficial uses of the surface waters need to be protected so as to support and maintain the MUN beneficial use of the underlying ground water resource. Indeed, protection of the GWR beneficial use of surface waters has been recognized in approved California TMDLs[67]. The Basin Plan does not specifically identify numeric water quality objectives to implement the GWR beneficial use, however a situation-specific weight of evidence approach can be used to assess if GWR is being supported, consistent with Section 3.11 of the California Listing Policy (SWRCB, 2004). Section **Error! Reference source not found.** of this project report presents data, lines of evidence, and assessments regarding whether or not project area designated GWR beneficial uses are currently being supported.

3.1.3 Agricultural Supply (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.).*

In accordance with the Basin Plan, interpretation of the amount of nitrate which adversely effects of the agricultural supply beneficial of waters of the State use shall be derived from the University of California Agricultural Extension Service guidelines, which are found in Basin Plan Table 3-3. Accordingly, severe problems for sensitive crops could occur for irrigation water exceeding 30 mg/L[68]. It should be noted that The University of California Agricultural Extension Service guideline values are flexible, and may not necessarily be appropriate due to local conditions or special conditions of crop, soil, and method of irrigation.

High concentrations of nitrates in irrigation water can potentially create problems for sensitive crops (e.g., grapes, avocado, citrus, sugar beets, apricots) by detrimentally impacting crop yield or quality. Nitrogen in the irrigation water acts the same as fertilizer nitrogen and excesses may cause problems just as fertilizer excesses cause problems[69]. For example, according to Ayers and Westcot (1985)[70] grapes are sensitive to high nitrate in irrigation water and may continue to grow late into the season at the expense of fruit production; yields are often reduced and grapes may be late in maturing and have a lower sugar content. Maturity of fruit such as apricot, citrus and avocado may also be delayed and the fruit may be poorer in quality, thus affecting the marketability and storage life. Excessive nitrogen can also trigger and favor the production of green tissue (leaves) over vegetative tissue in sensitive crops. In many grain crops, excess nitrogen may promote excessive vegetative growth producing weak stalks that cannot support the grain weight. These problems can usually be overcome by good fertilizer and irrigation management. However, regardless of the type of crop many resource professionals recommend that nitrate in the irrigation water should be credited toward the fertilizer rate[71] especially when the concentration exceeds 10 mg/L nitrate as N[72]. Should this be ignored, the resulting excess input of nitrogen could cause problems such as excessive vegetative growth and contamination of

[67] for example, see RWQCB-Los Angeles Region, Calluguas Creek Nitrogen Compounds TMDL, 2002. Resolution No. 02-017, and approved by the State of California Office of Adminstrative Law, OAL File No. 03-0519-02 SR.

[68] The University of California Agricultural Extension Service guideline values are flexible, and may not necessarily be appropriate due to local conditions or special conditions of crop, soil, and method of irrigation. 30 mg/L nitrate-N is the recommended uppermost threshold concentration for nitrate in irrigation supply water as identified by the Univ. of Californnia Agricultural Extension Service which potentially cause severe problems for sensitive crops (see Table 3-3 in the Basin Plan). Selecting the.least stringent threshold (30 mg/L) therefore conservatively identifies exceedances which could detrimentally impact the AGR beneficial uses for irrigation water.

[69] 1 mg/L NO3-N in irrigation water = 2.72 pounds of nitrogen per acre foot of applied water.

[70] R.S. Ayers (Soil and Water Specialist, Univ. of Calif.-Davis) and D.W. Westcot (Senior Land and Water Resources Specialist – Calif. Central Valley Regional Water Quality Control Board) published in UN-FAO Irrigation and Drainage Paper 29 Rev.1

[71] Crediting of irrigation source-water nitrogen may not be a 1:1 relationship as some irrigation water may not be retained entirely within the cropped area.

[72] Colorado State University Extension - Irrigation Water Quality Criteria. Authors: T.A. Bauder, Colorado State University Extension water quality specialist; R.M. Waskom, director, Colorado Water Institute; P.L. Sutherland, USDA/NRCS area resource conservationist; and J.G. Davis, Extension soils specialist and professor, soil and crop sciences

groundwater[73]. It should be noted that irrigation water that is high in nitrate does not necessarily mean that in contains enough nitrate to eliminate the need for additional nitrogen fertilizer; however, the grower may be able to reduce and replace the amount of fertilizer normally applied with the nitrate present in the irrigation water[74].

Further, the Basin Plan provides water quality objectives for nitrate which are protective of the AGR beneficial uses for livestock watering. While nitrate (NO3) itself is relatively non-toxic to livestock, ingested nitrate is broken down to nitrite ($NO2^-$); subsequently nitrite enters the bloodstream where it converts blood hemoglobin to methemoglobin. This greatly reduces the oxygen-carrying capacity of the blood, and the animal suffers from oxygen starvation of the tissues[75]. Death can occur when blood hemoglobin has fallen to one-third normal levels. Resource professionals[76] report that nitrate can reach dangerous levels for livestock in streams, ponds, or shallow wells that collect drainage from highly fertilized fields. Accordingly, the Basin Plan identifies the safe threshold of nitrate-N for purposes of livestock watering at 100 mg/L[77].

Also noteworthy is that the AGR beneficial use of surface water not only applies to several stream reaches of the project area, but can also apply to the groundwater resources underlying those stream reaches. The groundwater in some of these reaches is recharged by stream infiltration. Therefore, the groundwater recharge (GWR) beneficial use of stream reaches provides the nexus between protection of designated AGR beneficial uses of both the surface waters and the underlying groundwater resource (refer back to Section 3.1.2).

3.1.4 Aquatic Habitat (WARM, COLD, MIGR, SPWN, WILD, BIOL, RARE, EST)

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.

COLD: Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.

MIGR: Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

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.

BIOL: Uses of water that support designated areas or habitats, such as established refuges, parks, sanctuaries, ecological reserves, or Areas of Special Biological Significance (ASBS), where the preservation or enhancement of natural resources requires special protection.

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

EST: Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals,

[73] University of Calif.-Davis, Farm Water Quality Planning Reference Sheet 9.10. Publication 8066. Author: S. R. Grattan, Plant-Water Relations Specialist, UC-Davis.

[74] Monterey County Water Resources Agency – Santa Clara Valley Water District, Fact Sheet 4. *Using the Nitrate Present in Soil and Water in Your Fertilizer Calculations.*

[75] New Mexico State University, Cooperative Exention Service. Nitrate Poisoning of Livestock. Guide B-807.

[76] University of Arkansas, Division of Agriculture - Cooperative Extension. "Nitrate Poisoning in Cattle". Publication FSA3024.

[77] 100 mg/L nitrate-N is the Basin Plan's water quality objective protective of livestock watering, and is based on National Academy of Sciences-National Academy of Engineering guidelines (see Table 3-3 in the Basin Plan).

waterfowl, shorebirds). An estuary is generally described as a semi-enclosed body of water having a free connection with the open sea, at least part of the year and within which the seawater is diluted at least seasonally with fresh water drained from the land. Included are water bodies which would naturally fit the definition if not controlled by tidegates or other such devices.

The Basin Plan water quality objectives protective of aquatic habitat beneficial uses and which is most relevant to nutrient pollution[78] is the biosimulatory substances objective and dissolved oxygen objectives for aquatic habitat. The biostimulatory substances objective is a narrative water quality objective that 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*."

The Basin Plan also requires that in waterbodies designated for WARM habitat dissolved oxygen concentrations shall not be depressed below 5 mg/L and that in waterbodies designated for COLD and SPWN dissolved oxygen shall not be depressed below 7 mg/L. Further, since unionized ammonia is highly toxic to aquatic species, the Basin Plan requires that the discharge of waste shall not cause concentrations of unionized ammonia (NH_3) to exceed 0.025 mg/L (as n) in receiving waters.

3.1.5 Water Contact Recreation (REC-1)

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. (see Basin Plan, Chapter 2, Section II.).

The Basin Plan water quality objective protective of water contact recreation beneficial uses and which is most relevant to nutrient pollution is the general toxicity objective for all inland surface water, enclosed bays, and estuaries (Basin Plan Chapter 3, section II.A.2.a.). The general toxicity objective is a narrative water quality objective that 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. 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 algal toxins. Possible heatlh effects of exposure to blue-green algae blooms and their toxins can include rashes, skin and eye irritation, allergic reactions, gastrointestinal upset, and other effects including poisoning (refer back to Section 1.2) Note that microcystins are toxins produced by cyanobacteria (blue-green algae) and are associated with algal blooms, elevated nutrients, and biostimulation in surface waterbodies. The State of California Office of Environmental Health Hazard Assessment (OEHHA) has published peer-reviewed public health action-level guidelines for algal cyanotoxins (microcystins) in recreational water uses; this public health action-level for microcystins is 0.8 μg/L[79] (OEHHA, 2012). This public health action level can therefore be used to assess attainment or non-attainment of the Basin Plan's general toxicity objective and to ensure that REC-1 designated beneficial uses are being protected and supported.

3.2 Water Quality Objectives & Criteria

The Central Coast Region's Water Quality Control Plan (Basin Plan) contains specific water quality objectives that apply to nutrients and nutrient-related parameters. In addition, the Central Coast Water

[78] 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.
[79] Includes microcystins LR, RR, YR, and LA.

Board uses established, scientifically-defensible numeric criteria to implement narrative water quality objectives, and for use in Clean Water Act Section 303(d) Listing assessments. These water quality objectives and criteria are established to protect beneficial uses and are compiled in Table 3-2.

3.3 Anti-degradation Policy

In accordance with Section II.A. of the Basin Plan, 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 anti-degradation policy. Also, see Section **Error! Reference source not found.** for a full description of anti-degradation requirements.

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

Constituent Parameter	Source of Water Quality Objective/Criteria	Numeric Target	Primary Use Protected
Unionized Ammonia as N	Basin Plan numeric objective	0.025 mg/L	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries *(toxicity objective)*
Nitrate as N	Basin Plan numeric objective	10 mg/L	MUN, GWR (Municipal/Domestic Supply; Groundwater Recharge)
Nitrate as N	Basin Plan numeric criteria (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*
Nitrate (NO3-N) plus Nitrite (NO2-N)	Basin Plan numeric 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 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 objective	Dissolved Oxygen shall not be depressed below 5.0 mg/L Median values should not fall below 85% saturation.	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries.
	Basin Plan numeric objective WARM, COLD, SPWN	Dissolved Oxygen shall not be depressed below 5.0 mg/L (WARM) Dissolved Oxygen shall not be depressed below 7.0 mg/L (COLD, SPWN)	Cold Freshwater Habitat, Warm Freshwater Habitat, Fish Spawning
	Basin Plan numeric 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 objective MUN, AGR, REC1, REC-2	The pH value shall neither be depressed below 6.5 nor raised above 8.3.	Municipal/Domestic Supply, Agricultural Supply, Water Recreation
	Basin Plan numeric objective WARM, COLD	pH value shall not be depressed below 7.0 or raised above 8.5	Cold Freshwater Habitat, Warm freshwater habitat
Biostimulatory Substances	Basin Plan narrative objective[A]	see report Section **Error! Reference source not found.**	General Objective for all Inland Surface Waters, Enclosed Bays, and Estuaries *(biostimulatory substances objective)* -- (e.g., WARM, COLD, REC, WILD, EST)
Chlorophyll *a*	Basin Plan narrative objective[A]	40 µg/L *Source: North Carolina Administrative Code, Title 151, Subchapter 2B, Rule 0211*	Numeric listing criteria to implement the Basin Plan biostimulatory substances objective for purposes of Clean Water Act Section 303(d) Listing assessments.
Microcystins *(includes Microcytins LA, LR, RR, and YR)*	Basin Plan narrative objective[B]	0.8 µg/L *Calif. Office of Environmental Health Hazard Assessment Suggested Public Health Action Level*	REC-1 (water contact recreation)

[A] *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)*

[B] *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)*

3.4 California CWA Section 303(d) Listing Policy

The Central Coast Water Board assesses water quality monitoring data for surface waters every two years to determine if they contain pollutants at levels that exceed protective water quality standards. In accordance with the Water Quality Control Policy for developing California's Clean Water Act (CWA) Section 303(d) List (SWRCB, 2004), water body and pollutants that exceed protective water quality standards are placed on the State's 303(d) List of impaired waters. The 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 (Listing Policy, Table 3.2). The minimum number of measured exceedances for toxicants is displayed in Table 3-3 and for conventional and other pollutants in Table 3-4.

With regard to the water quality constituents addressed in this TMDL, it is important to note that unionized ammonia and nitrate[80] are considered a toxicants, low dissolved oxygen, chlorophyll a and pH, are conventional pollutants. Thus, impairments by nitrate and unionized ammonia are assessed on the basis of Table 3-3, while impairments by dissolved oxygen and chlorophyll a are assessed on the basis of Table 3-4.

Table 3-3. Minimum number of measured exceedances needed to place a water segment on the 303(d) list for toxicants.

Sample Size	Number of Exceedances needed to assert impairment
2 – 24	2
25 – 36	3
37 – 47	4
48 – 59	5
60 – 71	6
72 – 82	7
83 – 94	8
95 – 106	9
107 – 117	10
118 – 129	11
For sample sizes greater than 129, the minimum number of measured exceedances is established where α and β < 0.2 and where |α - β| is minimized. α = Excel® Function BINOMDIST(n-k, n, 1 – 0.03, TRUE) β = Excel® Function BINOMDIST(k-1, n, 0.18, TRUE) where n = the number of samples, k = minimum number of measured exceedances to place a water on the section 303(d) list,	

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

Table 3-4. Minimum number of measured exceedances needed to place a water segment on the 303(d) list for conventional and other pollutants.

Sample Size	Number of Exceedances needed to assert impairment
5-30	5
31-36	6
37-42	7
43-48	8
49-54	9
55-60	10
61-66	11
67-72	12
73-78	13
79-84	14
85-91	15
92-97	16
98-103	17
104-109	18
110-115	19
116-121	20

For sample sizes greater than 121, the minimum number of measured exceedances is established where α and β < 0.2 and where |α - β| is minimized.
α = Excel® Function BINOMDIST(n-k, n, 1 – 0.10, TRUE)
β = Excel® Function BINOMDIST(k-1, n, 0.25, TRUE)
where n = the number of samples,
k = minimum number of measured exceedances to place a water segment on section 303(d) list

3.4.1 CWA Section 303(d) Listings in Pajaro River Basin

The final 2010 Update to the 303(d) List and 303(d)/305(b) Integrated Report for the Central Coast showing waterbodies with nutrient or potential nutrient-related impairments in the Pajaro River Basin are shown in Table 3-5. **Error! Reference source not found.** presents these 2010 303(d) listings in map view.

Table 3-5. 303(d) listed waterbodies.

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Beach Road Ditch	CAR3051003020080603123839	0.8	Miles	Low Dissolved Oxygen
Beach Road Ditch	CAR3051003020080603123839	0.8	Miles	Nitrate

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Carnadero Creek	CAR3053002019990223155037	1.8	Miles	Low Dissolved Oxygen
Carnadero Creek	CAR3053002019990223155037	1.8	Miles	Nitrate
Furlong Creek	CAR3053002019990222111932	8.5	Miles	Nitrate
Harkins Slough	CAR3051001320080603122917	7.3	Miles	Chlorophyll-a
Harkins Slough	CAR3051001320080603122917	7.3	Miles	Low Dissolved Oxygen
Llagas Creek (below Chesbro Reservoir)	CAR3053002020020319075726	16	Miles	Low Dissolved Oxygen
Llagas Creek (below Chesbro Reservoir)	CAR3053002020020319075726	16	Miles	Nutrients
McGowan Ditch	CAR3051003020100620223644	2.6	Miles	Nitrate
Millers Canal	CAR3053002020080603171000	2.1	Miles	Chlorophyll-a
Millers Canal	CAR3053002020080603171000	2.1	Miles	Low Dissolved Oxygen
Pacheco Creek	CAR3053002020020103133745	25	Miles	Low Dissolved Oxygen

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Pajaro River	CAR3051003019980826115152	32	Miles	Low Dissolved Oxygen
Pajaro River	CAR3051003019980826115152	32	Miles	Nitrate
Pajaro River	CAR3051003019980826115152	32	Miles	Nutrients
Pinto Lake	CAL3051003020020124122807	115	Acres	Chlorophyll-a
Pinto Lake	CAL3051003020020124122807	115	Acres	Low Dissolved Oxygen
Salsipuedes Creek (Santa Cruz County)	CAR3051003020080603123522	2.6	Miles	Low Dissolved Oxygen
San Juan Creek (San Benito County)	CAR3052005020090204001958	7.3	Miles	Low Dissolved Oxygen
San Juan Creek (San Benito County)	CAR3052005020090204001958	7.3	Miles	Nitrate
Struve Slough	CAR3051003020080603125227	2.8	Miles	Low Dissolved Oxygen
Tequisquita Slough	CAR3053002020011121091332	7.2	Miles	Low Dissolved Oxygen

WATER BODY NAME	WBID	ESTIMATED SIZE AFFECTED	UNIT	POLLUTANT
Uvas Creek (below Uvas Reservoir)	CAR3052002120080603163208	7.8	Miles	Low Dissolved Oxygen
Watsonville Creek	CAR3051003020080603171443	5.1	Miles	Low Dissolved Oxygen
Watsonville Creek	CAR3051003020080603171443	5.1	Miles	Nitrate
Watsonville Slough	CAR3051003019981209150043	6.2	Miles	Low Dissolved Oxygen

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