Santa Rosa Creek
Watershed Management Plan

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Prepared for:

California Department of Fish and Game

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EXECUTIVE SUMMARY

The Santa Rosa Creek Watershed Management Plan was funded by California Department of Fish and Game's (CDFG) Fisheries Restoration Grant Program to develop a technically sound plan that addresses the strategic and scientific needs for watershed management, restoration planning, and south-central California coast steelhead (*Oncorhynchus mykiss*) recovery in the Santa Rosa Creek watershed, and that will be effective within current and foreseeable land use, water supply, and land ownership patterns in the watershed. Specifically, the objectives of the watershed management plan are to assess existing conditions, prioritize limiting factors for steelhead, and identify and prioritize restoration recommendations to address these limiting factors and improve physical functions and ecological conditions in the watershed. The watershed management plan was developed through the collaboration of a broad spectrum of participants. Stakeholders representing community sectors including agriculture, business, the community services district, planning advisory groups and fishing interests, and who work or live in the watershed, met periodically throughout the development of the watershed management plan to advise and inform the process, contribute historic and current information, assist in evaluating the accuracy of existing conditions and to review information and provide comments. In addition, a Technical Advisory Committee reviewed key watershed management plan elements, and input from the public was solicited at three public workshops.

Physical processes and ecological conditions in the Santa Rosa Creek watershed have been affected by historical clearing of land, groundwater pumping, urban development, bank revetment, historical mercury mining, land management practices, and road building. These activities have increased hillslope erosion and fine sediment supply to creek channels, resulted in channel incision, exacerbated low flows in the summer and fall, degraded riparian and aquatic habitat conditions, created barriers to fish migration, decreased water and sediment quality, and introduced non-native invasive species. Several of these effects limit the population of steelhead in the watershed by dramatically reducing instream flows in the summer and fall, decreasing pool habitat and large woody debris for summer and winter rearing, restricting their migration, and possibly limiting the potential for lagoon rearing.

The watershed management plan includes a suite of management, restoration, and study recommendations based on the synthesis of existing watershed conditions, steelhead limiting factors analysis, results of a geomorphic assessment and benthic macroinvertebrate sampling conducted specifically for the watershed management plan, and input from stakeholders and technical advisors. The recommendations present multiple ways to address steelhead limiting factors and conserve and improve physical processes and ecological conditions in the watershed, and are designed to be implemented individually, or in combination, on a voluntary basis, by or with the consent of willing landowners. Recommendations are presented by their ultimate objective and are listed in order of their relative importance to steelhead habitat restoration:

- Increase Summer and Fall Instream Flows
- Restore the Riparian Corridor
- Reduce Fine Sediment Delivery to the Creek
- Conserve and Protect Open Spaces and Existing Land Uses
- Increase Large Woody Debris Supply and Retention
- Remove Barriers to Fish Passage
- Fill Key Data Gaps
- Reduce Mercury Supply

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1 INTRODUCTION

1.1 Purpose of and Need for a Watershed Management Plan

Santa Rosa Creek in northern San Luis Obispo County once supported one of the largest populations of steelhead (*Oncorhynchus mykiss*) along the central California coast south of San Francisco (Titus et al. 2006). Perennial flow in most years, suitable instream habitat conditions (e.g., riparian cover and spawning substrate), and few physical barriers contributed to the success of this species in the watershed. However, recent fish studies have suggested that the population has dropped significantly below historic levels, driven by a number of probable factors including land uses and urbanization, road building, and groundwater and surface water management (e.g., Nelson 1994, D. W. Alley & Associates 2008, Nelson et al. 2009). In response to the concerns about existing habitat conditions for the threatened steelhead trout, several state and local advocacy groups began to identify limiting factors for steelhead trout habitat in the watershed (D. W. Alley & Associates 2008, TLCSLOC 2010) and implement stream habitat restoration projects (see Section 1.5).

Resource agency representatives responsible for recovering steelhead trout populations began to acknowledge the need to consolidate and unify these various efforts and provide a strategic and scientifically-based plan for improving steelhead habitat in Santa Rosa Creek. In 2008, California Department of Fish and Game (CDFG) awarded Greenspace – The Cambria Land Trust (Greenspace) grant funding to develop a comprehensive watershed management plan based on technical and local input that identifies limiting factors in the watershed and identifies and prioritizes restoration activities and can effectively restore creek function within current and foreseeable land use, water supply, and other constraints in the watershed. As the basis for these recommendations, the watershed management plan includes other recent information on watershed (e.g., climate, hydrology, and water quality) and steelhead population conditions. Acknowledging that there was a lack of understanding of physical factors that influence watershed conditions, the grant also included an investigation of the watershed's geomorphology—the scientific study of landforms and the processes that shape them (Section 2.5 and Appendix A). To better understand water quality conditions and their influence on aquatic biota, the grant included sampling of the benthic macroinvertebrate population as well (Section 2.8.4 and Appendix B). The purpose of this watershed management plan is to address the restoration needs for watershed management in the Santa Rosa Creek watershed by assessing existing conditions, identifying limiting factors for steelhead, and identifying and prioritizing restoration recommendations to improve physical and ecological conditions and facilitate the recovery of steelhead in the watershed.

What are your concerns about the creek and watershed?

"I would hope for a cooperative effort that results in a healthy watershed."
- Public Meeting Participant

1.2 Goals and Objectives

The objectives of this watershed management plan are to:

- Document historical watershed conditions.
- Assess physical and biological conditions in the watershed.
- Determine factors limiting the steelhead population.
- Identify and prioritize actions to address limiting factors for steelhead.
- Recommend additional actions that will improve overall fish and wildlife habitat.

The goals of the watershed managements planning process are to:

- Provide a thorough compilation of historical and current conditions in the Santa Rosa Creek watershed and assessment of steelhead limiting factors.
- Provide opportunities to educate the community on watershed conditions and ecological processes.
- Build local support for and participation in watershed conservation and restoration.
- Provide a supporting document so that willing participants can seek funds for recommended steelhead projects from CDFG's Fisheries Restoration Grant Program.

1.3 Overview of the Watershed

Looking up the Santa Rosa Creek watershed

Santa Rosa Creek watershed lies within the southern portion of the California Coast Range—a northwest-trending series of mountains and basins along the coast from Santa Barbara north to the Oregon border (Figure 1-1). The 48 mi^2 (123 km^2) watershed is bounded to the east by the Santa Lucia Mountain range and the west by the Pacific Ocean. Bordering the watershed are the similarly sized watersheds of San Simeon Creek to the north, Adelaida Creek to the northeast, Paso Robles Creek to the east, and Villa Creek to the south. Santa Rosa Creek and its tributaries flow mostly unobstructed down steep hillslopes mantled with shallow soils and sparse shrub vegetation and through agricultural areas and the small town of Cambria before reaching the Pacific Ocean. Santa Rosa Creek travels 16 mi (25 km) from its headwaters, following a sinuous course to the west through a confined canyon that opens up into a relatively long, broad valley floor. The town of Cambria sits near the mouth of Santa Rosa Creek, downstream of the confluence with Perry Creek—the largest tributary in the watershed. Only four creeks have been named on topographic maps of the U.S. Geological Survey (USGS)—Santa Rosa, Perry, Green Valley, and Fiscalini creeks (USGS 1979a, 1979b), while an additional six streams have been unofficially designated as derived from past or current property owner names (e.g., D. W. Alley & Associates 2008). These tributaries are referenced throughout this report, as summarized below in Table 1-1 and shown in Figure 1-2. The topographic relief is typical of the southern Coast Range terrain, with steep upland areas and low-gradient valley bottoms bordering the lower reaches of Santa Rosa, Green Valley, and Perry creeks (Figure 1-2). Relatively higher elevations are present in the Santa Rosa Creek sub-watershed, which peaks at Cypress Mountain with an elevation of 2,933 ft (894 m). In comparison, the highest point in the Perry Creek sub-watershed (NE corner of the Green Valley sub-watershed) reaches an elevation of 1,419 ft (433 m). At its lowest elevation, Santa Rosa Creek flows through a lagoon contained by an annually formed sandbar at Moonstone Beach that breaches when streamflow begins to rise and ocean wave action increases in late fall.

Table 1-1. Santa Rosa Creek watershed and sub-watershed areas and stream lengths.

Sub-watershed [a,b]		Tributary location [c]		Area [d]		Stream length [e]	
USGS-designated stream name	**Unofficial stream name**	**mi**	**km**	**mi^2**	**km^2**	**mi**	**km**
Santa Rosa Creek [f]		n/a	n/a	24.6	63.6	15.8	25.4
Unnamed	*Taylor Creek*	3.5	5.6	2.4	3.8	2.4	3.8
Unnamed	*Curti Creek*	7.5	12.1	2.1	5.5	2.2	3.5
Unnamed	*Lehman Creek*	9.7	15.6	2.5	6.5	2.6	4.1
Unnamed	*East Fork Santa Rosa Creek* [g]	12.1	19.5	1.9	4.9	2.9	4.7
Unnamed	*North Fork Santa Rosa Creek* [h]	12.5	20.1	2.2	5.6	2.6	4.2
Unnamed	*Mora Creek*	12.5	20.1	2.6	6.8	3.0	4.8
Perry Creek		3.0	4.8	22.9	59.3	9.7	15.6
Fiscalini Creek		5.2	8.4	2.6	6.7	1.4	2.3
Green Valley Creek		6.0	9.7	12.2	31.5	7.9	12.8
Total Santa Rosa Creek Watershed				**47.5**	**123**	**15.8**	**25.4**

[a] Tributaries are indicated by the degree of text indentation (e.g., Taylor Creek is a tributary to Santa Rosa Creek, Green Valley Creek is a tributary to Perry Creek which is a tributary to Santa Rosa Creek).
[b] To help identify unnamed tributaries on USGS topographic maps (USGS 1979a, 1979b) that are referred to later in this document unofficial tributary names from D.W. Alley & Associates (2008) are also presented.
[c] Locations of Taylor, Curti, Lehman, East Fork Santa Rosa, North Fork Santa Rosa, and Perry creeks are based on the longitudinal station at which they enter mainstem Santa Rosa Creek, starting at the Santa Rosa Creek mouth. The location of Mora Creek is based on the longitudinal station at which it enters North Fork Santa Rosa Creek upstream from mainstem Santa Rosa Creek. Locations of Fiscalini and Green Valley creeks are based on longitudinal stations along Perry Creek upstream from mainstem Santa Rosa Creek.
[d] Sub-watershed area derived in a GIS using a USGS 10m Digital Elevation Model (DEM).
[e] Stream length derived in a GIS using a USGS 10m DEM-generated stream network with a contributing area threshold of 0.04 km^2.
[f] Santa Rosa Creek mainstem continues along the unofficially named "East Fork Santa Rosa Creek" per the USGS stream designation (USGS 1979b).
[g] This creek is also commonly known as Soto Creek (D. Dunlap, pers. comm., 2009).
[h] This creek is also commonly known as Macacci Creek (D. Dunlap, pers. comm., 2009).

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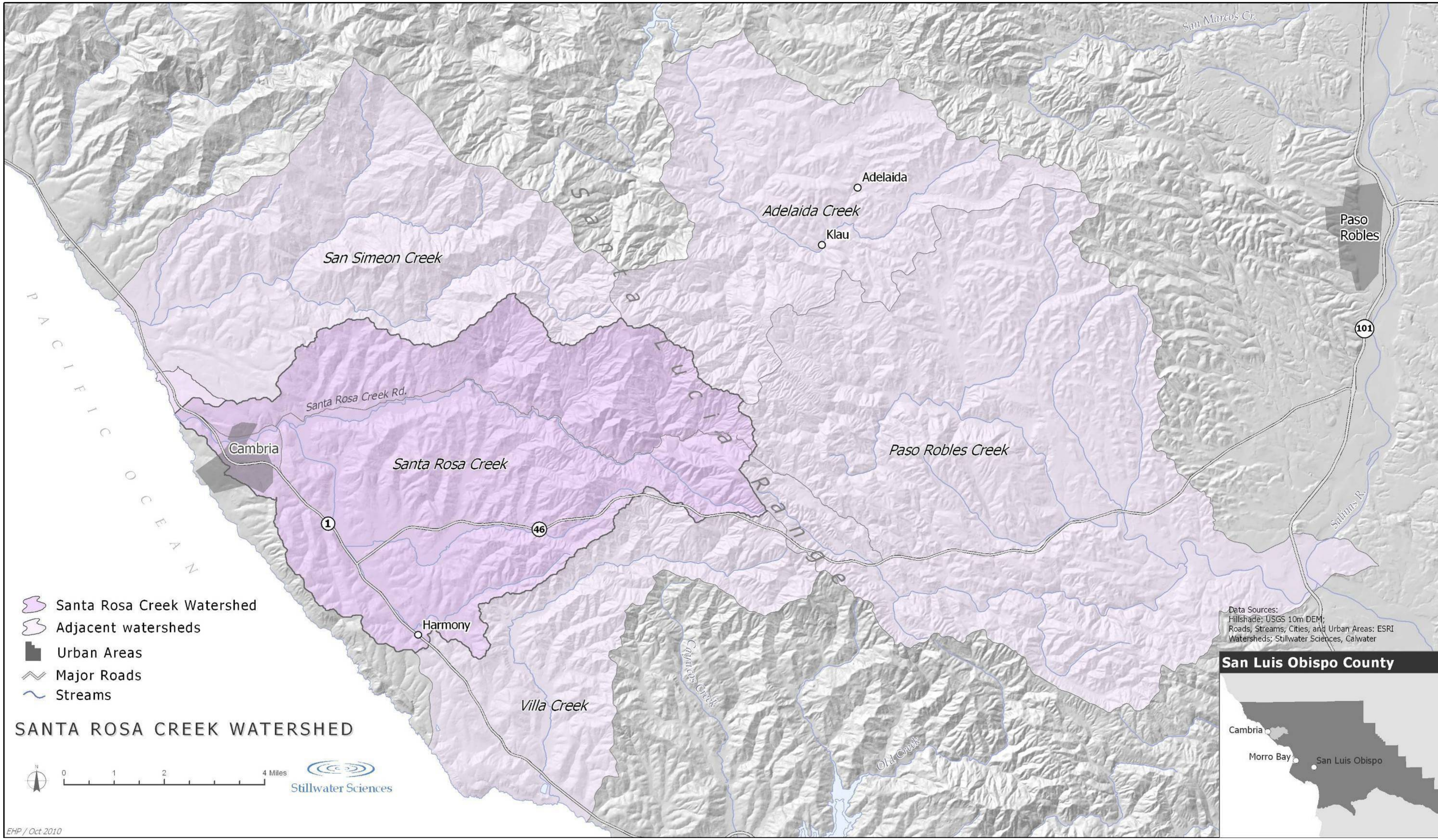

Figure 1-1. Santa Rosa Creek watershed and vicinity map.

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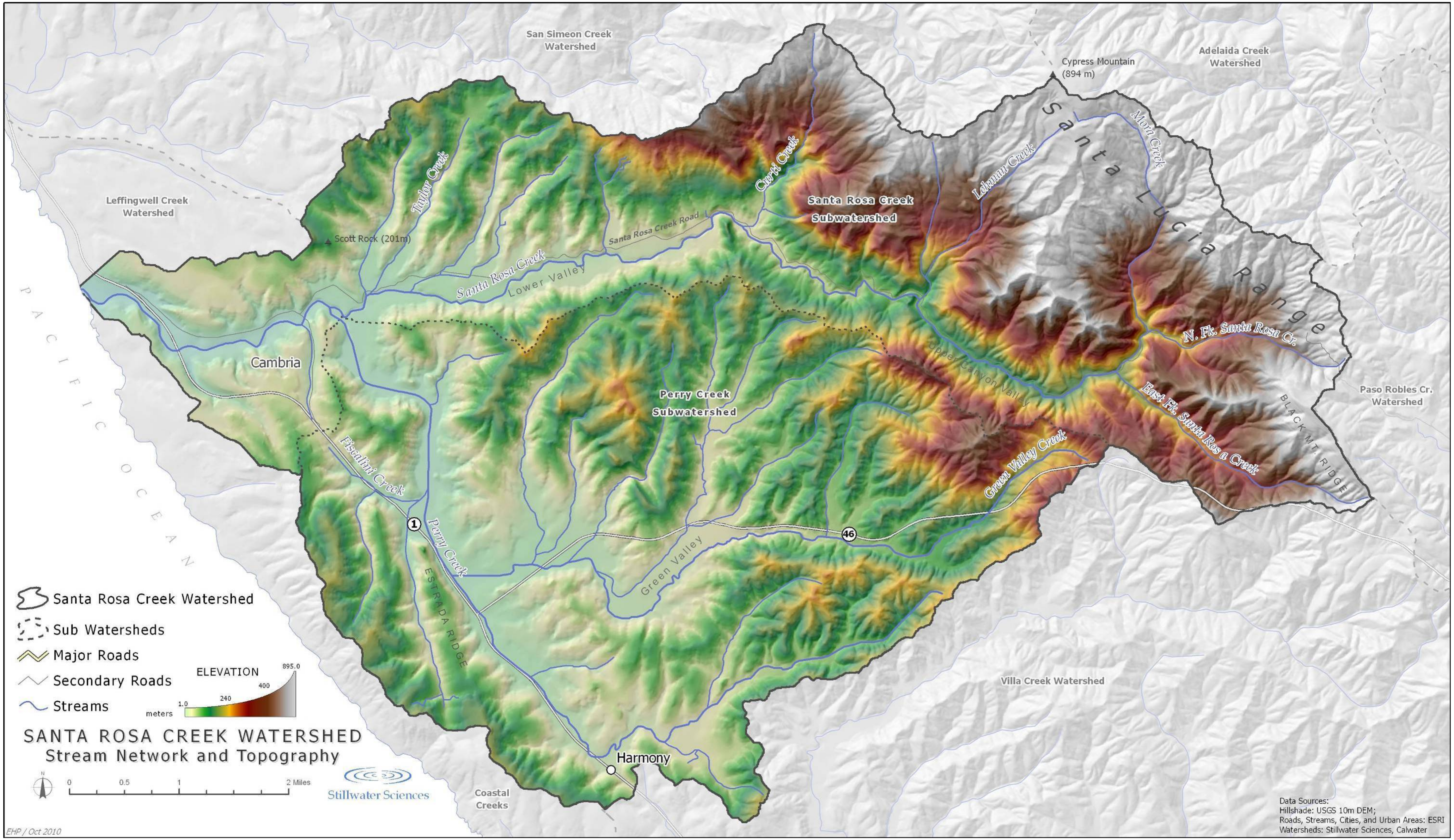

Figure 1-2. Santa Rosa Creek watershed stream network and topography.

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1.4 Stakeholder Involvement in the Watershed Management Plan

Recognizing that the development of a watershed management plan requires understanding and embracing the needs and concerns of local landowners, water users, and industry, the watershed management plan included the establishment of a stakeholders group. The role of stakeholders in formulating the watershed management plan is central to the success of its development and implementation, and their willingness to share information to shape the context of issues, marks a plan that will live beyond its written pages.

Stakeholders representing the various sectors that exist in the watershed, including agriculture, business, the community service district, planning advisory groups and fishing interests, were recruited to participate in the development of the watershed management plan. All stakeholders either work or live in the watershed. Stakeholders met periodically to contribute historic and current information, assist in reviewing the accuracy of existing conditions and other information, and provide comments. In addition, each stakeholder meeting included educational opportunities to offer background on a variety of topics related to steelhead ecology and watershed restoration, and increase awareness of and appreciation for the way in which watershed residents and businesses could voluntarily engage in restoration activities. Stakeholders' time and effort are recognized as being the cornerstone of continuing efforts to address factors limiting steelhead in the Santa Rosa Creek watershed, and are acknowledged throughout this document, as well as in the acknowledgements section at the end of this document (Section 5). Stakeholders met eight times between September 2009 and March 2011, representing a total of 240 person-hours, not including the time spent reviewing documents.

What are your concerns about the creek and watershed?

"Sustainable management of water for environment and people; enhance the productivity of ecosystem services of the watershed."

- Stakeholder

A Technical Advisory Committee (TAC) was convened to review and provide input to the watershed management plan to ensure that the data, analyses, and recommendations in the watershed management plan are correct, appropriate, and in keeping with local, regional, state, and federal efforts. TAC members are listed in the acknowledgements section at the end of this document.

In addition to stakeholders, the public was invited to attend three meetings during the course of the watershed management plan's development to facilitate information feedback between the TAC and the larger community and to provide a forum for education. The first meeting, held in January 2010, introduced the project to the public and sought input through a written questionnaire (Appendix C). The second meeting in August 2010 provided the public with a summary of watershed conditions. The third meeting in March 2011 unveiled the final watershed management plan and formally expressed gratitude to the community and stakeholders for their contributed time and effort.

1.5 Related Studies and Management Actions in the Watershed

A number of watershed management and restoration studies and/or actions have and are being conducted in the Santa Rosa Creek watershed. Several of these provided the impetus for this watershed management plan, while others support it by improving watershed conditions and incorporating a broad range of community members in the conservation and restoration of the watershed.

The Land Conservancy of San Luis Obispo County (TLCSLOC) recently completed the *Santa Rosa Creek Watershed Conservation Plan* (TLCSLOC 2010). The conservation plan compiled an extensive set of existing data for the watershed, collected additional data on upland erosion, and presents conservation strategies based on Natural Resources Conservation Service and California Rangelands resources. The synthesis of existing watershed conditions in this watershed management plan relied in part on the data compiled and collected by TLCSLOC (2010).

Rathbun et al. (1991) documented the status of four special-status declining reptiles, amphibians, and fishes in lower Santa Rosa Creek, which provided much of the basis for the *Lower Santa Rosa Creek Enhancement Plan* (Prunuske Chatham Inc. 1993). The lower creek plan, which was completed in 1993, described the ecological conditions and presented a plan for enhancing the reach of the creek from the Main Street Bridge to the ocean (Prunuske Chatham Inc. 1993). This watershed management plan updates and geographically expands upon the lower creek plan, and incorporates several of its enhancement measures.

Riparian buffer between Santa Rosa Creek and adjacent farmland

Many property owners in the watershed are already protecting watershed resources by implementing best management practices, and several local organizations, including Greenspace, the Cambria Community Services District (CCSD), Friends of Fiscalini Ranch Preserve, Cambria Forest Committee, and others, have completed enhancement, monitoring, and educational projects and events in the watershed. These have included:

- Water quality monitoring snap shot days (ongoing, approximately annually)
- Beach and creek cleanups (ongoing, annually)
- Ferrasci Road barrier removal (2011)
- Non-native eucalyptus tree removal downstream of Highway 1 (2010)
- Steelhead habitat enhancement, bank stabilization, and educational signs downstream of the Highway 1 Bridge (2007/2008)
- Burton Street Bridge barrier removal (2006)
- Fiscalini streambank stabilization (2005)
- San Luis Obispo County stream crossing inventory and fish passage evaluation (2005)
- Cambria forest management plan (2002)
- Santa Rosa Creek is Your Watershed educational program (2002)
- Watershed and Cambria forest conferences (2002 and 1991)

2 SYNTHESIS OF WATERSHED CONDITIONS

2.1 Historical Watershed Conditions and Watershed Impacts

Looking at a watershed's past provides insight into natural physical and ecological trends in addition to the identification of human-induced changes over time. An informed forecast of future watershed conditions can therefore be made based on synthesizing the understanding of past and present conditions. The information presented in this section summarizes general historical conditions in the watershed dating back to pre-European settlement in an attempt to illuminate the historical (both natural and human-induced) events that may have had an effect on physical processes and ecological conditions in the watershed (Figure 2-1).

Prior to European settlement along the California coast, the watershed is assumed to have been in a relatively undisturbed condition, responding only to fluctuating flood, drought, earthquake, and fire sequences, and with relatively minor impacts associated with the hunting and gathering practices of the local indigenous peoples. The first recorded accounts of Santa Rosa Creek valley are those made during the Portola Expedition where, in September 1769, the party encountered a "canyon… and arroyo[1] surrounded with hills of pine" (Hamilton 1974). On numerous instances, the expedition party noted flowing streams, both along what is now known as the mainstem Santa Rosa Creek and from many of its "springs", or tributaries (Hamilton 1974). Few other records of this area's natural resources were made for several decades despite the establishment of Mission San Miguel (1779) near present-day Paso Robles and the growing use of the Santa Rosa and San Simeon watershed areas for timber and wild game to support the Spanish population throughout the southern Coast Range region.

In 1840, Don Julian Estrada was granted possession of Rancho Santa Rosa—a 13,200-ac (53-km^2) land holding encompassing a portion of the western half of the watershed (Angel 1883, Hamilton 1974). Estrada drafted an illustration of his land in that year that depicts several notable features of the historical landscape, including Santa Rosa and San Simeon creeks draining to the ocean from steep upland areas, continuous pine forests upon hillsides surrounding lower Santa Rosa Creek near the area of present-day Cambria, a coastal trail parallel to the coastline, and, perhaps most interestingly, a "laguna", or lake along the narrow valley of lower Perry Creek (Figure 2-2). This lake is further described in Hamilton (1974) as a "shallow, broad lake… clogged with tules" fed by both Perry and Green Valley creeks, and bordered along its eastern shore by a coastal trail linking San Luis Obispo with San Simeon. The exact location of this lake is not precisely known, but it has been estimated to have formerly extended from the Perry and Green Valley creeks confluence north towards Santa Rosa Creek (Hamilton 1974; D. Dunlap, pers. comm., 2009). The lake was eventually drained by "Walker Ditch" in the early 1870s under the direction of the second owner of this portion of Rancho Santa Rosa, George Hearst, for the purpose of converting the wetland area to agricultural land (Hamilton 1974; D. Dunlap, pers. comm., 2009). The first official survey map of San Luis Obispo County published in 1874 does not depict the lake, indicating that it had already been drained when the survey was conducted, and instead shows a stream channel that generally follows the present-day stream course of lower Perry Creek (Harris 1874) (see Appendix A). Today, this artificial stream course of lower Perry Creek stands out from all other stream courses in the watershed as it follows long, straight segments connected by right-angle turns along the valley floor and north towards its confluence with Santa Rosa Creek.

[1] The Spanish word of "arroyo", as used in this account, translates to mean a small creek and not one that is necessarily incised, which is unlike the contemporary use of the word in the English language to mean an incised creek, typically those found in the American southwest.

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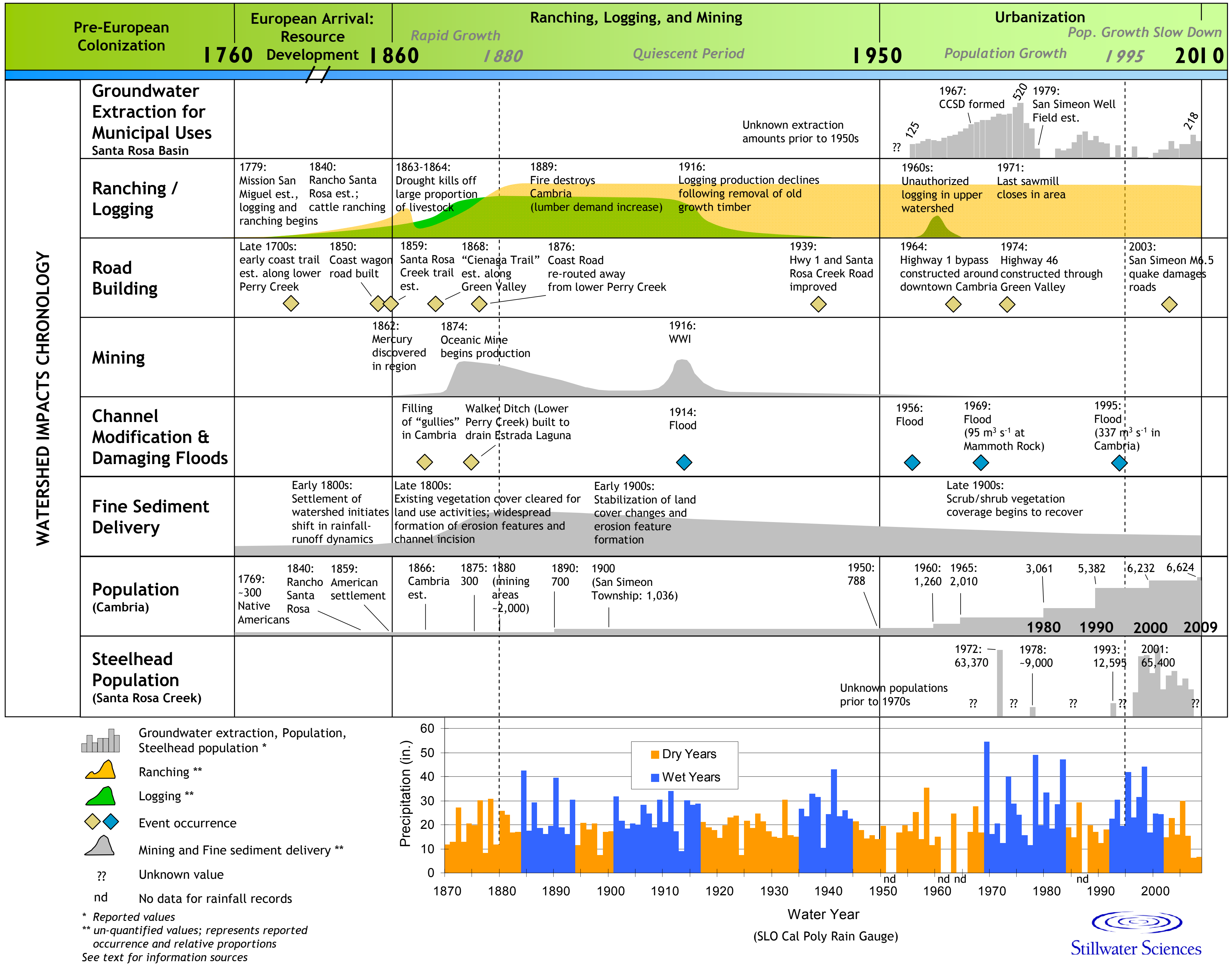

Figure 2-1. Chronology of watershed impacts and events. Precipitation records indicate periods of cumulatively wetter (blue) and drier (orange) periods in the watershed.

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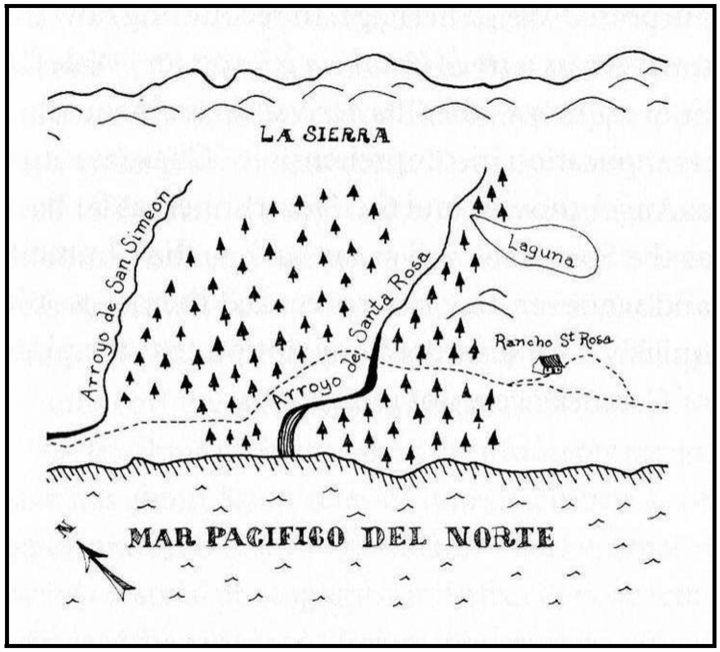
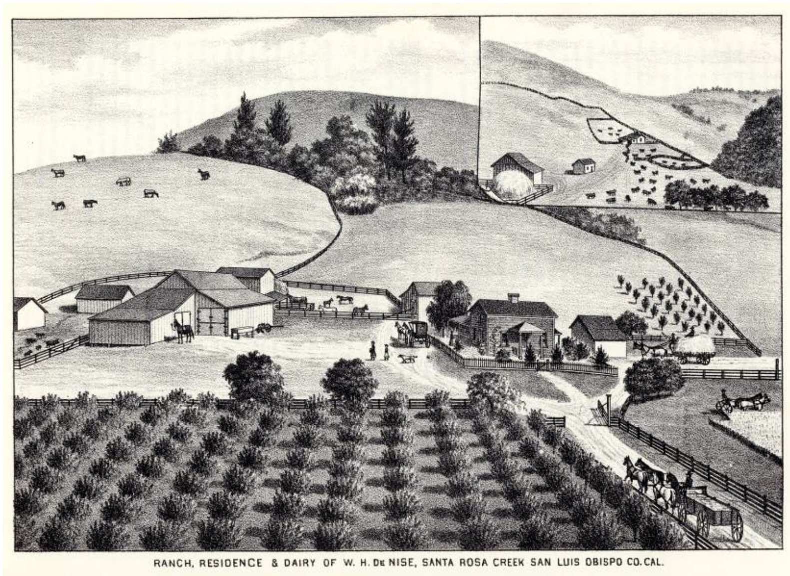


Figure 2-2. Illustration of Rancho Santa Rosa by Don Julian Estrada as part of his 1841 land grant application. Source: Coffman 1995.

The lagoon likely functioned as a settling basin for sediment delivered by tributaries of Perry Creek, and effectively served historically to separate the Perry Creek sub-watershed from the Santa Rosa Creek sub-watershed in terms of sediment delivery, especially of coarse sediments.

In the early 1800s, clearing of the land in support of agricultural activities—cattle ranching, crop cultivation, and logging—likely caused significant changes to rainfall-runoff relationships as trees, shrubs, and deep-rooted native perennial grasses in the valleys and upon hillslopes were degraded and replaced by shallow-rooted, non-native annual grass species that less effectively protect soil against erosion. Initially, cattle herds from Mission San Miguel were occasionally moved into the Santa Rosa Creek watershed because of ample sources of water and foraging vegetation even during the dry seasons (Hamilton 1974). Starting in the late 1850's, Americans and European immigrants began settling the watershed and greatly increased the pace of land clearing, which was reportedly achieved by cutting and/or burning the native vegetation (Coffman 1995; D. Dunlap, pers. comm., 2009). Historical accounts from across the coastal region tell of coordinated efforts by land owners to clear valley-bottom forests along major rivers (Boughton et al. 2006), which was likely practiced along Santa Rosa, Perry, and Green Valley creek valleys as very little forest cover remains but for some riparian stands closely bordering the stream channels (see Appendix A). Overall, these land uses coupled with episodic storm events resulted in several significant changes in the watershed, namely: (1) greater volumes of hillslope runoff generated per unit rainfall, with far greater volumes of fine sediment production throughout the watershed and increased gullying and shallow landslide potential on the steeper hillslopes; and (2) incision of the mainstem stream channels due to decreased stream bank stability and increased stream power allowing high flows to entrench the channel. Prior to incision, the Santa Rosa, Perry, and Green Valley creek channels would have supported higher groundwater elevations and more frequent inundation under lower flows, which supported the valley forests.

Between 1865 and 1885, a period of population growth and land development occurred in the watershed. Despite a die-off of beef cattle during the intense 1863–1864 drought, a shift to dairy farming, continued logging, and mining of cinnabar for mercury in the region maintained a steady rate of landscape alteration over the next two decades. Urban development and road building began the process of filling in small stream channels, especially those situated near Cambria (Hamilton 1974). By 1880, the landscape had been radically changed from its pre-European settlement condition and appeared very similar to present-day conditions, as represented in several illuminating sketches made during the 1870s (Angel 1883) that show grass-covered hillslopes and valley floors used for pasture with some relict patches of native riparian vegetation remaining near stream channels (Appendix A). Another notable feature depicted in two of these



DeNise ranch, residence, and dairy in the Santa Rosa Creek watershed, circa 1880 (Angel 1883)

illustrations is active hillslope erosion in the form of gullies, which remains a ubiquitous feature of the present-day landscape.

Beginning in 1874, cinnabar, the common ore of mercury, began to be mined at the Oceanic Mine in the Curti Creek sub-watershed. During peak production, ore was milled and processed into pure forms of mercury in a furnace located approximately ½-mile downhill from the mine (Eckel et al. 1941, as cited in CCRWQCB 1999). Mining production continued on and off through the 1900s, with a second peak around 1916 in support of World War I efforts (Hamilton 1974, Baker 2003). While land clearing, road building, and excavation associated with the mine likely resulted in increased fine sediment supply to Curti Creek and downstream, the mine's most deleterious impact has been to water quality. Iron-rich, red seepage from the mine and erosion of mercury-rich waste rock at the former mill site continue to pollute and discolor Curti Creek for most of the downstream distance to Santa Rosa Creek (CCRWQCB 1999, CDPH 2009).

Between 1920 and 1940, the rate of new land development leveled off as mining and logging operations declined, along with the transient population that supported those industries. These trends were driven, respectively, by falling mercury prices and by the near-depleted stock of old growth pine trees (Hamilton 1974). Through this period, dairy farming and crop cultivation continued, but likely did not increase in extent. In general, the landscape condition present during this period appeared very similar to the present-day condition (Appendix A). However, despite these seemingly unchanged conditions in many areas of the watershed, significant changes to specific areas did occur after this relatively quiescent period in the watershed's post-settlement history. The only available records of fish stocking in the watershed occurred during this time. Titus et al. (2006) cite a 1933 record of approximately 4,000 brown trout and a 1951 record of approximately 3,000 rainbow trout being planted in the watershed.

Starting in 1960 and extending through to the mid-1990s, the town of Cambria experienced a steady increase in population and, correspondingly, an increase in urban development in the form of new housing, commercial, and some industrial developments as driven by their tourism industry. According to County and U.S. Census data, Cambria's population (excluding the remainder of the watershed) increased from 788 to 5,382 between 1950 and 1990, representing 6.8-fold increase, while California as a whole experienced only a 2.8-fold increase. Recent population growth in Cambria since 2000, however, dropped considerably to only a 1.1-fold increase, which is below the state growth rate during the past decade (A. Ochs, pers. comm., 2009; U.S. Census Bureau 2003, 2009). This population growth slowdown period signifies stabilization not only of the Cambria population but also of development that would expand the town's urban footprint in the watershed.

The urbanization time period between 1960 and the 1990s also represented an expansion of groundwater pumping and stream diversions to irrigate crops and to provide drinking water to Cambria, which has reduced base flows in Santa Rosa Creek, and potentially within Perry and Green Valley creeks as well. A lowered groundwater table has led to subsidence in areas of the lower Santa Rosa Creek valley, which was observed in Cambria during 1976—the year with the highest municipal groundwater extraction (Yates and Van Konyenburg 1998). Groundwater lowering may have led to further degradation of mature riparian vegetation (in areas where riparian vegetation was not replaced by crops), which is reliant primarily on groundwater during the summer dry season. Large floodplain areas with extensive riparian vegetation may have attenuated floods within Santa Rosa Creek; the removal and degradation of large riparian stands would have therefore increased the "flashy" nature of flood events (i.e., higher flows over a shorter time period). Indeed, large floods in 1914, 1956, 1969, and 1995 have damaged properties situated upon floodplain areas (Hamilton 1974; D. Dunlap, pers. comm., 2009). As a result, bank revetments, or riprap, were subsequently installed along some reaches of Santa Rosa Creek near Cambria to protect floodplain developments from future flood-induced bank erosion. To date, however, no levees have been constructed along the creek or its tributaries, although Highway 1 serves as a low-lying berm to the west of downtown Cambria.

A very significant impact to the watershed from 1960 to the 1990s is the construction of roads; Highways 1 and 46, and Santa Rosa Creek Road. Each of these roads has altered runoff patterns as it traverses the landscape. The first trails and roads in the watershed closely followed the contours of the natural terrain. Their impact was likely limited only to vegetation removal and fine-sediment run-off. The present-day route of Santa Rosa Creek Road primarily follows the original wagon road from Cambria and east towards Paso Robles (Harris 1874, Hamilton 1974) and was paved in 1939. While paving may limit fine-sediment runoff from the road surface, it may also concentrate flow drainage near the stream channel and cause gullies to form on the out-board side of the road and into the creek. The route taken today by Highway 1 differs from that traced by the original "coast road" (Harris 1874, Hamilton 1974) and was cut into hillslopes and laid across small streams channels with culverts. Many of the culverts in the watershed have become partial if not complete barriers to fish migration and movement (see Section 2.7).

Completed in 1974, Highway 46 travels through Green Valley and is the most recent roadway constructed in the watershed, involving relatively large cut and fill sections that allow for a nearly straight path through the varied topography. The need for an extensive series of fill embankments and cuttings for Highway 46 greatly increased rates of fine sediment input to Green Valley Creek during and shortly after construction, and has led to on-going problems of embankment and culvert-related erosion, as well as accelerating runoff into Green Valley Creek. In addition, upper Green Valley Creek and numerous small streams have been virtually cut-off from lower Green Valley Creek, but for the presence of some culverts. Under normal circumstances, water may be conveyed completely through these culverts, but coarse sediment and large woody debris deposited at the culvert entrance during high flows causes blockages that deny the replenishment of gravel and cobble substrates and woody debris in the lower reaches. This adversely affects not only the channel morphology of Santa Rosa Creek but also the availability and complexity of steelhead trout habitat (D. W. Alley & Associates 2008, Nelson et al. 2009). An additional negative of all three major roadways in the watershed has been their effect on erosion associated with concentrating runoff towards the downslope side of the roads (see Section 2.7).

As stated above, the most recent time period between the mid-1990s and present day is generally characterized by a population growth slowdown and, accordingly, a reduction in additional urban development that would act to further alter the landscape, physical processes, and ecological conditions the watershed (see Section 2.2.4). This period also marks the initiation of several endeavors to restore ecologic and geomorphic function in Santa Rosa Creek, including the removal of fish passage barriers and bank-repair projects (see Section 1.5).

2.2 Land Use

2.2.1 Current land uses

The majority of the Santa Rosa Creek watershed is sparsely populated, with urban development concentrated downstream at the town of Cambria. As of 2009, the town supported a population of 6,624 (Cambria Chamber of Commerce, pers. comm., 2009). The remainder of the watershed is almost entirely under agriculture, with primary activities consisting of cattle ranching and limited crop cultivation, which require some level of water usage, primarily obtained via groundwater pumping. In Cambria, developments consist of a business district, which closely borders the lower 2.8 mi (4.5 km) of Santa Rosa Creek from Main Street Bridge to the lagoon area, and residential neighborhoods that extend to the north and south upon the adjacent hillsides. Tourism, primarily directed towards visitors traveling to Hearst Castle in nearby San Simeon, is the chief industry of Cambria. As of 2001, developed areas account for approximately 8% of the watershed area (Homer et al. 2004). Besides the town of Cambria, the only other significant elements of infrastructure in the watershed include three roadways: Highway 1, Highway 46, and Santa Rosa Creek Road. The roadways closely follow and occasionally cross, via bridge or culvert, portions of Santa Rosa, Perry, and Green Valley creeks.

Field ready for planting

2.2.2 Land use planning

The Santa Rosa Creek watershed is entirely within the unincorporated area of the County of San Luis Obispo, where current land use decisions and long range planning are governed by the County's General Plan Land Use Elements and Local Coastal Program. The overarching land use and resource management planning tools embedded in the Land Use Elements include the Resource Management System, the Framework For Planning (Inland) (2009), Coastal Zone Framework For Planning (1993), and Planning Areas. Two Planning Areas, separated by the Coastal Zone Boundary (Figure 2-3), cover the Santa Rosa Creek watershed: the North Coast Planning Area, which is governed by both the Coastal Act and County's General Plan Local Coastal Program, and the Adelaida Planning Area, governed by the General Plan.

The lower half of Santa Rosa Creek watershed is within the rural North Coast Planning Area (Figure 2-3, Coastal Zone Boundary), which covers 165,300 ac (668 km^2) along the San Luis Obispo County coastline, approximately 77,000 ac (311 km^2) of which are owned by the Hearst Corporation. Cambria is one of only two urban areas in the North Coast Planning Area (the other is San Simeon Acres in the San Simeon Creek watershed). Aside from two small commercial/retail parcels on Hearst Corporation property, the entire North Coast Planning Area is designated as agriculture, with two relatively small areas of rural land use north of Cambria and on the border of Monterey County. Table 2-1 summarizes the types of development projects completed between 2003 and 2008 in the North Coast Planning Area (outside the urban areas of Cambria and San Simeon Acres).

The upper half of the watershed is within the Adelaida Planning Area, which covers 208,008 ac (842 km^2) and borders the cities of Paso Robles, Atascadero and Morro Bay and the communities of Cayucos and Templeton. In 1990, the Adelaida Planning Area was extended over the ridge of the Santa Lucia range and onto the western coastal slope of the upper Santa Rosa Creek watershed. Table 2-1 summarizes the types of development projects completed between 2003 and 2008 in the Adelaida Planning Area.

As shown in Figure 2-3, the vast majority of land in the watershed is designated agriculture with small parts of the upper watershed designated as rural lands. A number of urban development types are allowed in these land use categories, including wineries and tasting rooms, bed and breakfasts, retail sales, restaurants, veterinary hospitals, residences, sale of farm equipment and supplies, camping, certain types of manufacturing, and communication facilities (San Luis Obispo County 1993).

Table 2-1. Completed development projects in the Adelaida and North Coast Planning Areas [a] of San Luis Obispo County between 2003 and 2008.

Type of development	Adelaida Planning Area [b]							North Coast Planning Area [b]						
	2003	2004	2005	2006	2007	2008	Total	2003	2004	2005	2006	2007	2008	Total
Winery facility	1	10	2	4	9	10	36	0	0	0	0	0	0	0
Misc. commercial	0	2	0	0	1	2	5	0	0	0	1	0	0	1
Commercial/ industrial addition/alteration	2	4	1	7	3	2	19	2	2	0	0	0	2	6
Farm support quarters	0	1	0	0	0	0	1	0	0	0	1	0	0	1
New single family dwelling	3	19	12	12	24	15	85	0	3	5	4	1	3	16
Guesthouse	1	2	3	1	4	2	13	0	0	0	2	0	0	2
Secondary dwelling	0	0	1	1	0	1	3	0	0	0	0	0	0	0
Mobile home	2	6	9	8	1	11	37	1	0	0	1	1	1	4
Swimming pool/spa; resident. & comm.	3	5	5	7	7	8	35	0	0	0	0	0	1	1
Radio/cell tower	0	0	2	1	2	1	6	0	1	1	0	0	0	2
Wind/solar system	0	5	4	14	11	18	52	0	1	1	0	1	3	6

[a] The Coastal Zone is the boundary between these two planning areas (Figure 2-3).
[b] Source: Permit Tracking Summaries 2003–2008, accessed at: www.slocounty.ca.gov/planning/Permits/

2.2.3 Growth trends in San Luis Obispo County

The 2008 Growth Assessment states that between 2000 and 2007, two of every five new homes built in the unincorporated County were built in rural areas outside of the urban communities. If this trend continues, the County estimates that population in the rural areas of the County will increase by 7,900 to 15,800 individuals by 2030. According to the County's 2006 General Plan Annual Progress Report, the Adelaida Planning Area is projected to see a population increase of 2,241 between 2010 and 2030. Table 2-1 of completed projects in the Adelaida Planning Area from 2003 through 2008 shows a trend toward water-intensive wineries and residential uses. To date, however, that development has occurred primarily on the eastern side of the Santa Lucia range on rural lands outside the urban areas of Paso Robles, Templeton, and Atascadero.

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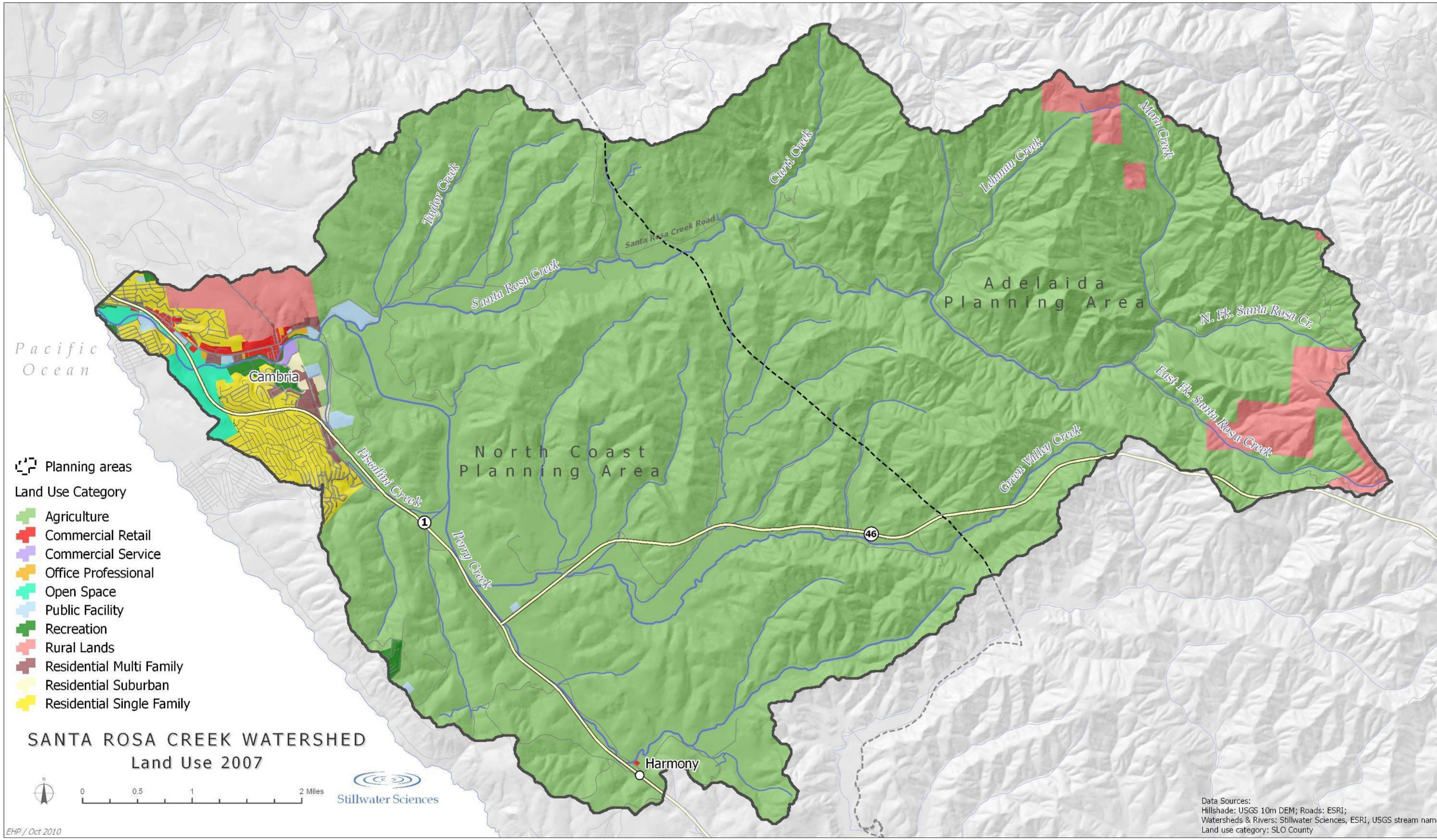

Figure 2-3. Land uses within the Santa Rosa Creek watershed.

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A steady increase in the numbers of people choosing to live in the rural areas of the County is fueled in part by the existence of underlying antiquated subdivisions[2], of which there are over 3,500 in the unincorporated County area. Many of these parcels are capable of being developed through the process of obtaining certificates of compliance (legal documents that certify compliance of an underlying parcel with the California Subdivision Map Act). And while in 1977 approximately 80% of these parcels were farmed or grazed with only a small fraction of the parcels developed at that time, since the year 2000 over 600 of these parcels have been developed with homes (San Luis Obispo County 2009).

2.2.4 Rural to urban conversion

City and Regional Planning research indicates that there is a typical sequence to land use changes over time as rural lands are converted to urban uses (Briassoulis 2000). Portions of the lower Santa Rosa Creek watershed exhibit this shift, as large ranches have been subdivided and converted to dairy and row crops and urban land uses. This conversion can degrade the quality of watershed resources and it is often the degree and balance of disturbance in urban land uses versus rural that is of consequence. Said differently, rural land use development may impact watershed health in a dispersed manner whereas urban influences are more concentrated.

As rural lands are developed, shifting from grazing to intensified agriculture and/or urban uses, water consumption generally increases, rainfall runoff volume and velocity increase as impervious surfaces increase, groundwater recharge/infiltration decreases, bank erosion and channel incision may increase, and tributary and mainstem peak flow volumes, and therefore flood risk, increase during the rainy season. In the dry season, base flow is reduced as groundwater is pumped year-round.

Although urbanization in the Santa Rosa Creek watershed is limited to the relatively small community of Cambria and surrounding neighborhoods, several of the impacts associated with land use shift have been documented in the lower watershed. These include increased municipal water demand that can reduce instream flows (see Section 2.6), additional instream infrastructure that reduces habitat quality (see Section 2.7), and increased rainfall runoff and associated impacts to water quality and drainage (see Section 2.8). Urban development of the watershed has been limited by land use planning regulations and water supply (see Section 2.2.5 below), and is constrained to the downstream end of the watershed, where the ill effects associated with urbanization are limited to a small portion of the watershed. Changes in land use controls could, however, lift some of the current constraints to urbanization (see Section 2.2.5 below). It will be important to recognize and prevent or mitigate land use changes that could exacerbate the ill effects associated with urbanization or promote the expansion of such land use changes further up the watershed.

2.2.5 Land use controls

While a portion of the lower watershed has already been developed, outside of this area the pattern of rural to urban land use conversion is currently limited in the majority of the Santa Rosa Creek watershed. This is due to a variety of planning related factors, such as the Coastal Act, Local Coastal Program, Williamson Act, and agricultural and rural land use designations that limit development, and physical factors, such as the limited supply of water and road access to

[2] Underlying antiquated subdivisions are parcels created before modern land-use planning laws. These parcels underlay larger parcels created by the California Subdivision Map Act and they are antiquated because they were created before the Map Act was passed.

most of the watershed. Several of these land use control are, however, at risk of being lifted, which could increase the conversion of rural land uses to intensified agriculture and/or urban uses and, as described above, result in serious impacts to the ecological conditions of the watershed.

A major difference in land use controls within the two planning areas of the watershed is the resource protections provided by the California Coastal Act and the Local Coastal Program that apply only to the lower watershed in the North Coast Planning Area (see Figure 2-3). The Coastal Act requires protection of agricultural resources and environmentally sensitive habitat areas and provides an additional layer of development permit review by the California Coastal Commission. In addition, land use plans in the coastal zone must be consistent with the resource protection requirements of the Coastal Act and must be certified by the Coastal Commission. By contrast, the upper half of the watershed is not subjected to the same state agency scrutiny during the planning process or the development review process. Land uses are also tracked by the Coastal Commission during periodic reviews that provide additional data that are not available for inland portions of the upper Santa Rosa Creek watershed.

The geographic dividing line of the Santa Lucia Mountain ridge separates the development patterns in the upper Santa Rosa Creek watershed from other areas within the Adelaida Planning Area. While the majority of the planning area spreads east and south from the ridge to include land adjacent to the urban communities of Paso Robles, Templeton, Atascadero, Cayucos, and Morro Bay, the upper Santa Rosa Creek watershed is remote from urban communities other than Cambria and is connected to Cambria only by Santa Rosa Creek Road which at some points narrows to a single lane. Santa Rosa Creek Road is the only collector road in the watershed (Adelaida Planning area Circulation Map). Therefore, data representing the overall Adelaida Planning Area do not reflect the coastal influences, geographic conditions and development patterns that have occurred in the upper Santa Rosa Creek watershed and cannot be relied upon to show development trends in that area. The development projects completed between 2003 and 2008 in the Adelaida Planning Area (Table 2-1) do not represent the development that has occurred on the upper slopes of the Santa Rosa Creek watershed. For example, there are only two wineries in the Santa Rosa Creek watershed, while data for the Adelaida Planning Area show 36 new wineries completed between 2003 and 2008 (Table 2-1).

Development on the majority of privately-owned currently undeveloped parcels in the watershed is limited under Williamson Act contracts (Figure 2-4). The Williamson Act, the common name for the California Land Conservation Act of 1965, enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. In return, landowners receive property tax assessments which are much lower than normal because they are based upon farming and open space uses as opposed to full market value. If Williamson Act contracts are allowed to expire one of the primary land use controls in the watershed will be lifted, and large parcels, particularly in the Adelaida Planning Area where California Coastal Act and Local Coastal Program protections do not apply, may be at risk of subdivision and development.

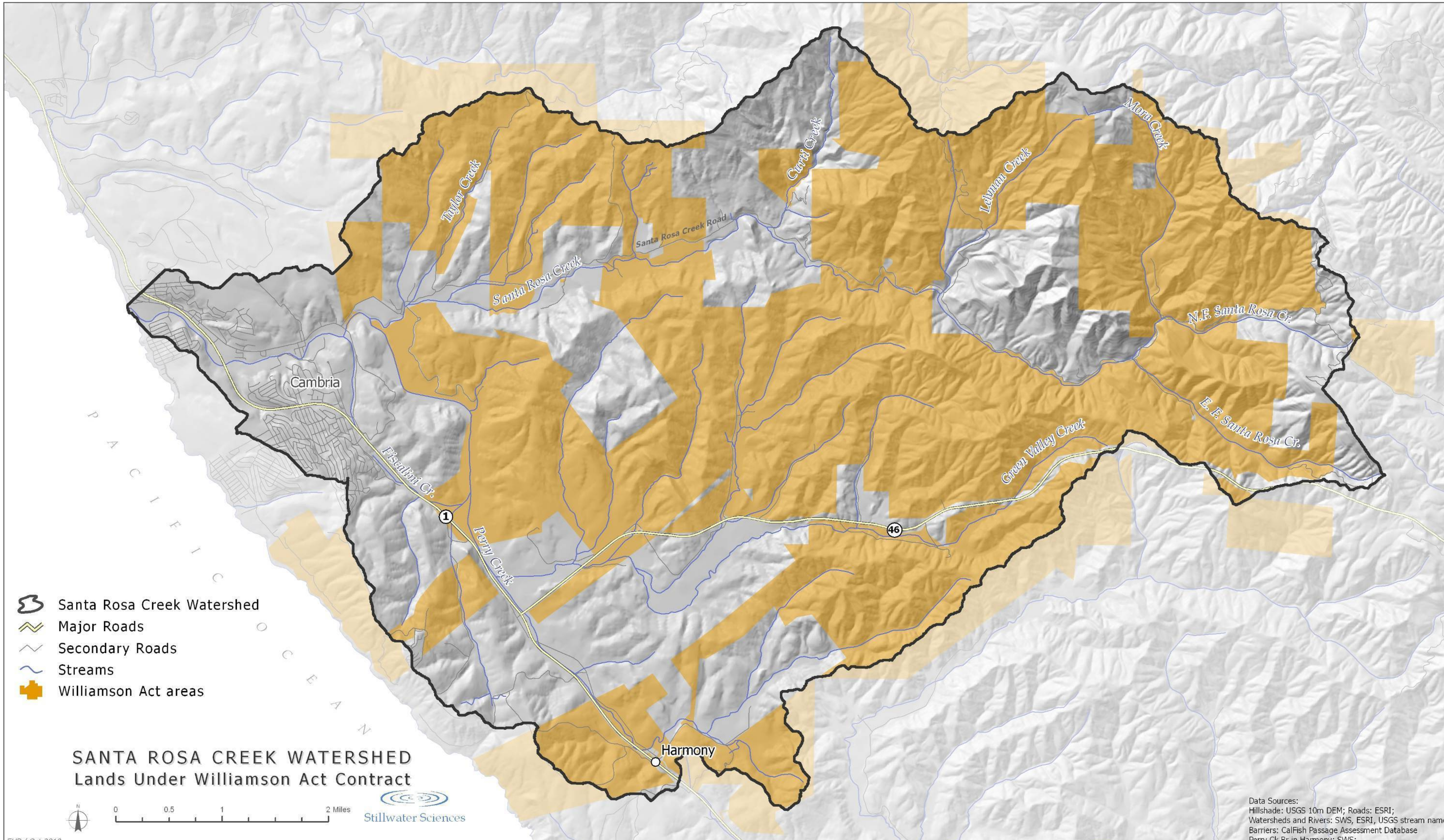

Figure 2-4. Land under Williamson Act contract within the Santa Rosa Creek watershed.

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The CCSD and U.S. Army Corp of Engineers (USACE) are currently assessing the feasibility of a seawater desalination plant at the mouth of Santa Rosa Creek. The desalination plant would improve water supply reliability in the CCSD service area, particularly in dry years, by augmenting the San Simeon and Santa Rosa Creek groundwater aquifers that are currently relied upon (CCSD 2008). At the December 9, 2011 California Coastal Commission hearing the USACE was unanimously denied a Coastal Consistency Determination by the Commission to conduct geo-technical drilling in the vicinity of the mean high tide line at the mouth of Santa Rosa Creek. The Commission determined that the proposed geo-technical study site was inappropriate because the mouth of Santa Rosa Creek and the associated lagoon are among the most protected and sensitive habitats on the Central Coast. If ultimately approved, however, a desalination plant could remove one of the key physical controls on population growth in the watershed and surrounding areas. The proposed desalination plant has the potential to produce unlimited amounts of water; however, as currently proposed it would produce 602 acre-feet of water per year. The plant would consist of subterranean seawater intake, pumping and pipeline facilities to transport the seawater to the desalination plant, reverse osmosis desalination treatment, a groundwater blending system, facilities to pump the treated water into the water supply distribution system, and disposal of desalination effluent into the ocean. The site currently being considered for intake and effluent disposal is the beach at the mouth of Santa Rosa Creek (CCSD 2008). Potential impacts related to construction and operation include: disturbance and mobilization of mercury, adverse impacts to protected species such as steelhead, California red-legged frog, and tidewater goby (California Coastal Commission 2010), and drawdown of water levels in the lagoon. To avoid influencing lagoon water levels, the beach wells must be constructed more than 500 feet from both the Santa Rosa and San Simeon creek lagoons (North Coast Engineering, Inc. 1993).

The growth-inducing impacts of a future water supply project such as a desalination plant and the additional water supply it will create, were analyzed in CCSD's Water Master Plan program-level Environmental Impact Report, which was certified by the CCSD Board of Directors on August 21, 2008 (R. Gresens, pers. comm., 2012). The CCSD operates a voluntary Buildout Reduction Program inside the town of Cambria, designed to reduce water demand by retiring and merging buildable lots. In addition, CCSD must also abide by conditions in San Luis Obispo County's (2008) North Coast Area Plan, which states that for any major public works water supply project to support new development within the CCSD service area "[t]he maximum service capacity of the project will not induce growth inconsistent with the protection of coastal resources and public access and recreation opportunities" and that "[t]he project shall assure that CCSD water withdrawals from Santa Rosa and San Simeon Creeks will be sufficiently limited to protect: (1) adequate instream flows necessary to support sensitive species and other riparian/wetland habitats within the reach of the streams affected by CCSD pumping; (2) underlying groundwater aquifers; and (3) agricultural resources." The North Coast Area Plan, however, anticipates that desalination will be a source of water for development outside of Cambria and, as such, the potential for growth-inducing impacts associated with a desalination plant or other major water supply project would primarily be outside of the current CCSD service area. By ordinance, CCSD accepts and processes applications for delivery of water outside of Cambria based on availability of water, which would notably increase if a desalination plant or other major water supply project becomes operational. In 2006, Measure P-06 was passed by CCSD-district voters which requires a majority vote of the CCSD electorate to extend potable water service outside of 2006 CCSD boundaries. Measure P-06 further requires an environmental review under the California Environmental Quality Act and an amendment to the Water Master Plan before potable water service is extended beyond 2006 CCSD boundaries.

2.3 Climate

Coastal watersheds along the western flank of the Coast Ranges experience a two-season Mediterranean-type climate, with wet cool winters and dry warm summers. The regional climate is controlled by the North Pacific High, a high pressure system resting over cold upwelling waters of the eastern Pacific, while the local climate is controlled by the watershed's topography and proximity to the ocean (Carle 2006). The Pacific High system deflects storms from reaching the California coast during summer months, resulting in dry westerly winds blowing over cold ocean water and often producing fog. In the Santa Rosa Creek watershed, this fog belt typically extends inland 8 miles from Cambria. During winter, the Pacific High retreats to the south resulting in high rainfall in California concentrated between November and April. Overall, the California coast experiences highly variable annual rainfall depending on each storm's frequency and magnitude on the landscape relief. Mean annual rainfall across the watershed varies between 21 and 37 in (53 and 94 cm), as reported by the U.S. Department of Agriculture (1971–2000) and San Luis Obispo County Division of Public Works (1954–2008) (Figure 2-5). A clear pattern of increased rainfall with elevation is expressed across the watershed, as the lowlands near Cambria, including much of Perry and Green Valley creeks, receive nearly half the rainfall received in the headwaters of Santa Rosa Creek.

Periodicity in the pattern of the wet/dry years in California is correlated to the El Niño–Southern Oscillation (ENSO) climatic phenomenon. ENSO is characterized by warming and cooling cycles (oscillations) in the waters of the eastern equatorial Pacific Ocean. Specifically, El Niño episodes are initially driven by abnormally low atmospheric pressures in the eastern Pacific, resulting in lower upwelling rates of cold ocean waters and, therefore, a persistence of warmer surface water temperatures (Kousky and Bell 2000). Ultimately, the warmer waters lead to increased precipitation along the eastern Pacific, extending up to California. ENSO cycles typically have a 1- to 1.5-year duration and 3- to 8-year recurrence interval. ENSO-induced climate change occurs on a multi-decadal time scale that is consistent with the recent shift from a relatively drier climate (averaged over the period 1944–1968) to a relatively wetter climate (averaged over the period 1969–1995) in North American's Pacific region (Inman and Jenkins 1999). The most recent El Niño events occurred in water years 2007 and 2010 (NOAA 2009a).

A long-term record of annual precipitation totals in San Luis Obispo County (SLO Cal Poly rain gauge #1.0) from 1870 to present day is presented in Figure 2-5. The precipitation record indicates periods of cumulative wetter and drier periods in the region, where most wet years coincide with large floods (see Section 2.6).

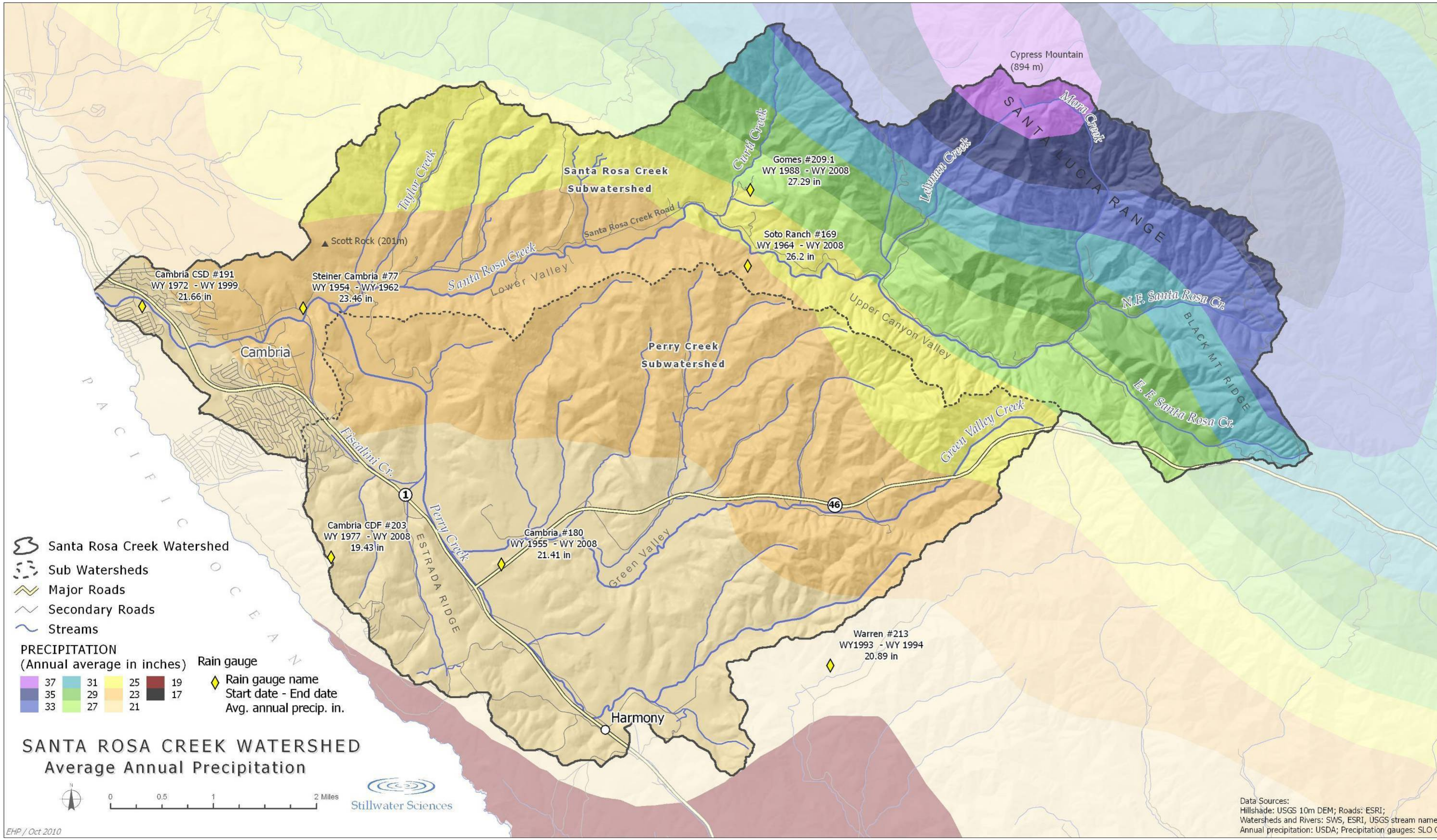

Figure 2-5. Distribution of average annual precipitation in the Santa Rosa Creek watershed. Precipitation contours represent the period of 1960–2001. Rain gauge stations representing various years of data shown for reference.

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In the future, the Santa Rosa Creek watershed is likely to be affected by changes in temperature, precipitation, and sea-level resulting from global warming. Predictions of climate change in California in the next century include warmer winters (by 5–6° F), slightly warmer summers (by 1–2° F), and increased winter precipitation (primarily as rain rather than snow), particularly in the mountains (Field et al. 1999). ENSO events may increase in intensity and/or frequency (Field et al. 1999). In central and southern California the change in precipitation timing is expected to lead to increased winter runoff, decreased summer stream flow, and changes in the frequency and/or intensity of severe storms, droughts, wildfires, and flooding. In addition, global climate change is expected to result in sea-level rise. Based on a set of climate scenarios prepared for the California Energy Commission, Cayan et al. (2009) project that, under medium to medium-high greenhouse gas emissions scenarios, mean sea level along the California coast will rise from 3–5 ft (1–1.4 m) by the year 2100. In the Santa Rosa Creek watershed, such a rise in sea-level would put new areas at risk of flooding, increase the likelihood and intensity of floods in areas that are already at risk, and accelerate shoreline recession due to erosion (Figure 2-6) (Heberger et al. 2009). Such predictions stress the importance of floodplain and coastal conservation, ecosystem restoration, and water conservation to increase the adaptability and resiliency of the watershed to respond to these changes, particularly when considered in conjunction with future land uses and human impacts to the watershed.

Figure 2-6. Predicted flood risk in 2100 in the Cambria area under a 1.4-m sea-level rise scenario. Light blue area is the current coastal base flood (approximate 100-year flood extent), dark blue area is the predicted coastal base flood under sea-level rise (current plus 1.4 m), yellow line is the predicted landward limit of erosion high hazard zone in 2100, and red line is Highway 1. Map used with permission from the Pacific Institute, Oakland, California.

2.4 Geology, Tectonics, and Soils

The Santa Rosa Creek watershed lies along the Santa Lucia Mountain range near the southern end of the geologically distinctive Coast Range geomorphic province. Orientated with the overall NW-SE trending grain of the California topography, the Santa Lucia range follows the southern Coast Range for 93 mi (150 km) between Monterey Bay to the north and the San Rafael Mountains to the south near Santa Barbara. The province resides within a tectonically active zone composed primarily of right-lateral strike-slip (horizontal sliding motion) faults separating the Pacific and North American plates. At the axis of this zone is the 600-mile-long (1,000-km-long) San Andreas Fault, which lies 37 mi (60 km) to the east of the Santa Rosa Creek watershed. Overall, this tectonically and geomorphically active province exhibits intermittent seismicity and asymmetrical drainages offset by faulting. Additionally, the presence of relatively weak rocks at higher elevations in the Santa Rosa Creek watershed has led to naturally high sediment delivery rates, or sediment yields, from those higher relief and steeper tributaries (see Section 2.5).

Much of the Coast Range province, and especially the Santa Rosa Creek watershed, is composed of old, weathered, and partially metamorphosed sedimentary rocks originally formed during the Mesozoic (200 to 100 million years ago [Ma]) and Cenozoic (65 to 25 Ma) eras (Chipping 1987). Today, the majority of the Santa Rosa Creek watershed is predominately (~50%) composed of Franciscan mélange: a mix of hard graywacke (sandstone) and weak, sheared argillite (silt/claystone) (Chipping 1987, Dibblee 2007a 2007b) (Figure 2-7). Following the complete subduction of the Farallon Plate beneath the North American Plate, the eventual transition to a transform (strike-slip) plate boundary began about 25 Ma with the gradual contact between the northwest-moving Pacific Plate and the southeast-moving North American Plate (Atwater and Molnar 1973). This transition marked a geologically brief period of coastal volcanism which locally produced the erosion-resistant Cambria Felsite rocks, as seen today at Scott Rock located east of Cambria near Taylor Creek (Dibblee 2007a). Other volcanic rocks formed during this period include the now highly weathered basalts and hardened tuffs (solidified volcanic ash) of the Obispo Formation that run along a northwest-trending band in the upper watershed. Terrestrial and marine sedimentary rocks formed during this period include a mix of hard, coarse-grained sandstones and weak, fine-grained shales.

The Coast Range orogeny, or mountain-building process, began during the late Pliocene and Pleistocene epochs (≤4 Ma) and continues today. Regional uplift has been driven by crustal convergence that occurs where subtle NW–SE trending bends along the active transform fault zones forcing materials in between the larger faults to "pile up," thereby creating the upland areas of the watershed. Obvious evidence of geologically recent uplift activity is the existence of Pleistocene marine terraces situated along the coastline and the lower watershed. Tectonic movement here may explain the watershed's unusual drainage pattern of being split in two primary halves—Santa Rosa Creek and Perry Creek sub-watersheds—where Perry and Green Valley creeks may have once flowed directly to the coast but were eventually "captured" by Santa Rosa Creek as uplift and transverse migration of the elevated landscape re-directed Perry and Green Valley creeks northward. Coincident with the Coast Range uplift period, the valley floors along Santa Rosa, Perry, and Green Valley creeks have accumulated unconsolidated alluvial and stream-terrace deposits as the uplifted landscape has eroded and delivered its sediments to the valley floors over time. It is within these sediments that the watershed's groundwater basin has developed, which currently serve as a primary water supply source to urban areas and land use activities in the watershed (see Section 2-6).

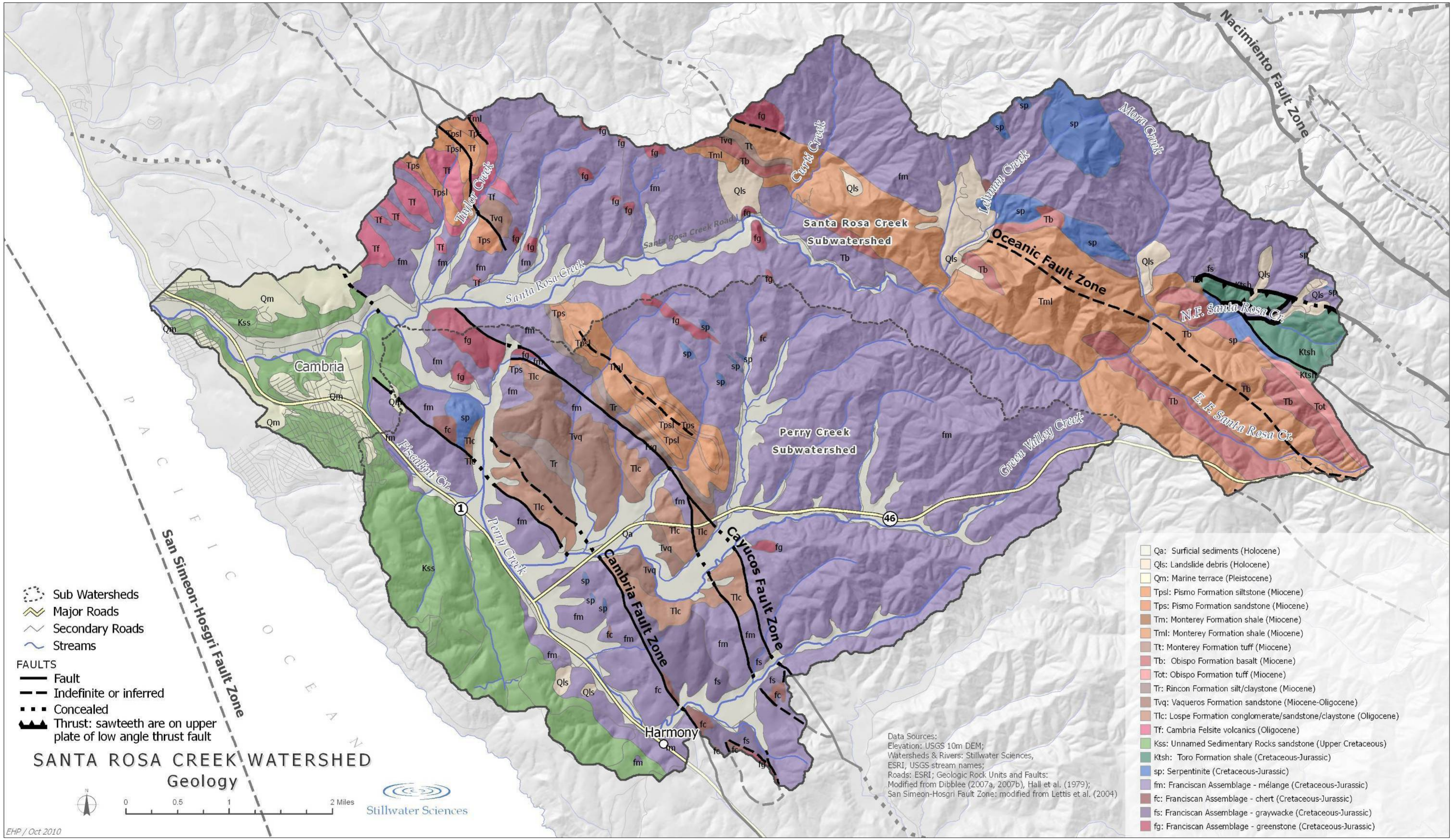

Figure 2-7. Santa Rosa Creek watershed geology.

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With continuous landscape uplift to drive hillslope processes and large areas of highly sheared metamorphic and sedimentary rock units now hundreds of meters above the valley bottoms, the Santa Rosa Creek watershed has geologic characteristics commonly associated with high rates of erosion. Field observations indicate that areas in the watershed displaying relatively high hillslope erosion are chiefly underlain by the fine-grained and easily eroded siltstone and mudstone of the Pismo (shale member), Monterey, Rincon, and Toro formations found traversing the watershed close to the two primary fault traces, and the highly fractured graywacke/argillite of the Franciscan mélange unit that is found throughout the watershed (Figure 2-7).

The sedimentary, metamorphic, and volcanic rocks of the Santa Rosa Creek watershed provide the parent material for much of the watershed's soils, and are one of the primary controls on soil texture and mineral content. As such, topographic form, rainfall runoff patterns, groundwater percolation rates, potential for erosion, and vegetation distribution are strongly influenced by geology. For this reason watershed geology, rather than soils, were used as the basis of the assessment of watershed geomorphology and hillslope sediment production estimates (see Section 2.5 for further discussion). Over 60 different soil types occur in the watershed, most of which are clay to sandy loams (NRCS 1977 and 1984). Additional details on watershed soils are summarized in TLCSLOC (2010).

2.5 Geomorphology

As all aquatic habitat is intimately linked to creek morphology and process, it follows that the habitat also responds to the flux created by sediment sources and storage sites within a watershed. They are particularly affected by changes away from "normal" conditions. For this reason, aquatic habitat is closely linked to geomorphic processes and the influence of human activity. The benefits and hazards of living near to a stream are also linked strongly to changing channel morphology and process: significant erosion of channel banks is often perceived as land loss by the owner, while sediment deposition raises channel bed elevations and makes the adjacent floodplain more prone to flooding. As such, understanding geomorphic processes and their alteration is also central to stream channel and watershed management in general.

A watershed-wide geomorphology study was conducted in 2009–2010 to provide information on the physical watershed and stream channel processes for the development of the watershed management plan. The study subdivided the lower 13 miles (22 km) of Santa Rosa Creek into upper, middle and lower reaches (Figure 2-8), which are referred to throughout this document[3]. The lower reaches begin at the river mouth (stream mile 0) and extend upstream to the confluence with Perry Creek (stream mile 3); the middle reaches extend from the Perry Creek confluence upstream to Mammoth Rock (stream mile 7); and the upper reaches extend from Mammoth Rock to stream mile 14. A detailed technical report of this study is presented in Appendix A, while the major findings have been summarized below.

From the chronology of watershed changes described in Section 2.1 and summarized in Figure 2-1, there are two time periods in recent history that likely had the greatest effect on watershed geomorphic processes: early land clearing in 1860–1880 and population growth, development, and road building from 1950–1990. Overall, the two periods both led to increased flashiness of streamflows, proportionally more rainfall entering the creek as runoff than from baseflow, and increased sediment entering stream channels, especially fine sediment. In comparison, it is likely that land clearing for lumber and agriculture created more extensive geomorphic impacts,

[3] D.W. Alley & Associates (2008) and Nelson et al. (2009) both used different reach delineations for their steelhead monitoring and habitat typing. Reach delineation differences are described in more detail in Section 2.10.1.

including the majority of the over 1,000 gullies still evident across the watershed (see Figure 2-8), whereas the more recent impact of road and urban development primarily impacted Green Valley Creek and the lower reaches of Perry and Santa Rosa creeks.

2.5.1 Sediment production, transfer, and storage

Sediment refers to rock- and soil-derived material that ranges in size from clay to boulder, and includes cobble, gravel, and sand. Coarse sediment refers to gravel-sized material and larger (>2 mm in diameter) and overall has the greatest influence on the morphology of a stream channel (e.g., providing grade control, and forming bar-pool morphology). Fine sediment refers to clay-, silt-, and sand-sized materials (<2 mm in diameter), which in excess can have detrimental affects on aquatic habitat conditions. As a geomorphic unit, a watershed serves to transport sediment from its place of origin to an eventual place of lasting storage. In so doing, a distinctive relief is developed in the watershed that reflects the balance between long-term processes of tectonic uplift and rates of erosion driven by physical, chemical, and biological factors. This balance is generally achieved through the medium of moving water. Sediment sources are those sites predominantly characterized by erosion and often have steep slopes. Sediment storage, particularly in a small coastal watershed such as Santa Rosa Creek, occurs mostly offshore as sediment-laden water exits the watershed, but it also occurs where sediments are deposited on floodplains (where the material is termed alluvium) and at breaks to gentler hillslope gradients (termed colluvium). Connecting sediment sources with their sites of long-term storage is a flux of sediment transport through the watershed, typically occurring on a time scale from years to centuries. The flux of sediment is intermittent and driven mostly by large rainfall or streamflow events, and so most such "short-term" sediment transfer occurs along the creek channel. The exact locations of the short-term sources and storage sites of sediment can, however, be influenced as strongly by human activities as by natural factors. A typical short-term sediment source is the erosion of alluvial stream banks, representing the re-mobilization of previously stored sediment, while short-term sediment storage often occurs on the channel bed in the form of a wave of "excess" sediment deposited after a flood event. Therefore, the typical transfer of sediment through a watershed involves a flux in which changes to the creek morphology is an integral part.

Present day Santa Rosa Creek watershed is characterized, as are most other watersheds, by a wide variety of sediment sources that potentially affect management decisions. The predominant sediment sources and stores in the Santa Rosa Creek watershed, and the dynamics of sediment transfer, are summarized in Table 2-2 and the various source locations mapped in Figure 2-8 (additional detail is also available in Appendix A). The very steep hillslopes in the headwaters of Santa Rosa Creek (and some tributaries to Green Valley Creek) have naturally high sediment yields, and it seems likely that, in geomorphic terms, the historically-noted steelhead populations in the watershed result in part from the habitat created by the delivery of very coarse sediment from the upper reaches of Santa Rosa Creek. The other predominant sediment sources in the watershed have resulted primarily from previous land and channel management, and include gullying, stream bank erosion, and road-related erosion. These processes primarily involve the erosion of the landscape's soils and thus supply primarily only fine sediment to watershed channels.

Historical land clearing for lumber and agriculture is likely responsible for the majority of the over 1,000 gullies still evident across the watershed (Table 2-2, Figure 2-8). Fine sediment yields from these features most likely increased substantially during and following land clearing in the late 1800s and early 1900s, but have probably been reduced closer to historical levels in recent decades (see "Fine Sediment Delivery" in Figure 2-1). This is because, with the exception of development in Cambria over the past several decades, land uses across the vast majority of the watershed have not changed considerably over the past half-century (see Section 2.1). Outside of Cambria's urban boundaries, contemporary views of the landscape are very similar to historical views from the early 1900s, and the number and location of gullies have not noticeably changed since 1937 (see Appendix A for additional detail). Streambank erosion in Santa Rosa Creek is exacerbated by channel incision, a deepening of the channel often resulting from perturbations to the watershed. Channel incision is assumed to have occurred quickly after initial land clearing activities began in the mid-19th century. Over time, channel incision eventually causes the mass instability of channel banks, which then become a source of fine sediment. More recently, channel meandering in the incised reaches has resulted in the erosion of high alluvial banks of the former floodplain (Figure 2-8). Over 250 instances of recorded road-related erosion features exist in the watershed (Figure 2-8), which effectively deliver predominately fine sediment to the channel network. Erosion is focused along cut and fill sections of Highway 46 and Santa Rosa Creek Road, and to a lesser extent Highway 1.

Coarse sediment (gravel and larger) delivered to the mainstem Santa Rosa Creek appears to be delivered primarily from Lehman and Curti creeks in the upper reaches, and from the tributary that runs adjacent to Main Street in the lower reach. Fine sediment (sand and silt) appears to be predominantly derived from tributary sources such as Curti Creek and Perry Creek, which delivers sediment to the lower reach, and local in-channel sources such as bank erosion in the middle reaches.

Table 2-2. Sediment sources, storage, and transfer dynamics in the Santa Rosa Creek watershed.

Location	Process/Description
Sediment Sources	
Landslides	Only 17 landslides are recorded in the areas of watershed without canopy cover, but they are individually high-yielding. Landslides are concentrated in high relief, steep-sided areas, primarily in the headwaters of Santa Rosa Creek. Landslides erode previously stored colluvium on hillslope swales and, potentially, weathered bedrock closer to the failure plane. Mixed-load sediments released as part of large deep-seated landslides, as mapped in geologic maps of the watershed (see Figure 2-7), may reside for years to centuries before eventually being completely delivered to the stream network.
Gullies and rills	Gullies and rills are numerous throughout the watershed. Over 1,000 gullies have been recorded and many have evidently been present since the late 19th century and so may be past their sediment production peak. These features primarily result in the production of fine sediments as they erode soil-mantled, moderately steep hillslopes and, because they are often connected directly to the stream network, a near 100% delivery ratio of sediment can be inferred. Gullying in the watershed is likely to have resulted in far higher volumes of fine sediment delivered to the channel network during and following their formation, which have likely been reduced closer to pre-development levels in recent decades.
High yielding Geomorphic Landscape Units	Areas of the watershed with the highest sediment yield potential are primarily situated on steep, grassland and barren hillslopes composed of weak rock. These areas result in the production of both coarse and fine sediments, but fine sediments are probably derived preferentially from the widespread Franciscan mélange terrain. Sediment delivery from these Geomorphic Landscape Units (GLUs) (see Figure 2-8 and Appendix A) is likely high given the steep hillslopes and confined and steep channels.
Creek incision	Channel incision in the major streams is assumed to have occurred quickly after initial land clearing activities began in the mid-19th century. Incision is widespread but focused in the middle reaches[c] of Santa Rosa Creek and the middle and upper reaches of Perry and Green Valley creeks. Incision initially releases channel bed sediments which may be relatively coarse.

Location	Process/Description
Bank erosion of high bluffs following incision	Over time, channel incision eventually causes the mass instability of channel banks of the former floodplain which then makes them a highly effective source of finer sediment as the channel widens. More recently, meander activity as the incised reaches recover their equilibrium has allowed erosion of high alluvial banks of the former floodplain, causing a net sediment supply biased towards fine sediment.
Road-related erosion	Over 250 instances of recorded road-related erosion features exist in the watershed. Erosion is focused along cut and fill sections of Highway 46 and Santa Rosa Creek Road (and to a lesser extent Highway 1). Because road drainage frequently serves channel road runoff from the road surface efficiently to the channel network, sediment (particularly fine sediment) is also delivered very effectively to the channel network.
Sediment Storage	
Lower Perry Creek in the vicinity of the former Estrada Lake	Historically, Estrada Lake at the downstream end of Perry Creek probably trapped all coarse and most fine sediments delivered by the contributing streams, meaning that few sediments from the Perry Creek sub-watershed ever reached Santa Rosa Creek. Subsequent draining of the lake to create a trapezoidal channel permitted the transport of sediment, especially fine sediment, from the Perry Creek sub-watershed into Santa Rosa Creek. Subsequent incision of the lowest reach of Perry Creek must have resulted in the remobilization of former lake sediment (i.e., fine, organic-rich sediment). The broad-bedded, low gradient ditch farther upstream still favors the deposition of coarse sediments before reaching Santa Rosa Creek, and a noticeable fining of bed material occurs on Santa Rosa Creek downstream of the Perry Creek confluence.
Water storage ponds	There are over 40 small water storage ponds throughout the watershed, with a greater proportion in the Perry Creek sub-watershed (Figure 2-8). They regulate 8% of the watershed area but are likely to have low sediment-trapping efficiencies, trapping primarily a small amount of coarser-grained sediments.
Channel bed in upper reaches	Field evidence indicates temporary storage of coarse sediments delivered from the steep, high relief tributary sub-watersheds (e.g., East Fork Santa Rosa and Curti creeks) into mainstem Santa Rosa Creek. Along the mainstem, there is also field evidence for the temporary storage of coarse material in channel and floodplain locations. Remobilization of the coarse sediment occurs during high flow events with material either wholly entrained or abraded into finer, more easily-transportable particles.
Channel bed in lower reaches	While lower gradient reaches are frequently characterized by finer sediment beds and sediment deposition, field evidence of short-term storage of fine material on the channel bed may reflect high rates of fine sediment supply to the lower reaches, especially from the Perry Creek sub-watershed.
Transfer Dynamics [a]	
Upper reaches	The upper reaches are very capable of mobilizing the median grain size (~2–3 in [~50–90 mm]) of the channel bed during even moderate flow events and the channel morphology rates as highly active. Fine sediment is transferred quickly from the reaches, whereas field evidence indicates the temporary storage and probable breakdown of very coarse material.
Middle reaches	Middle reaches are competent to transport the median grain size (~0.7–2 in [~20–50 mm]) of the channel bed during even moderate flow events and the channel morphology rates as highly. This stream power is borne out by increased sinuosity in these reaches since the early 20th century in which coarse sediment is deposited in the form of channel bars and larger volumes of fine sediment are derived from the high banks of the former floodplain surface.
Lower reaches	Lower reaches are competent to transport the median grain size (~0.2–1 in [~5–45 mm]) of the channel bed during even moderate flow events and the channel morphology rates as highly active. These reaches exhibit unusually high stream power for such low gradient reaches and may reflect bank protection which prevents the exchange of sediment from channel banks and prevents channel widening in response to flood events.

[a] See Figure 2-8 for locations of Santa Rosa Creek reaches.

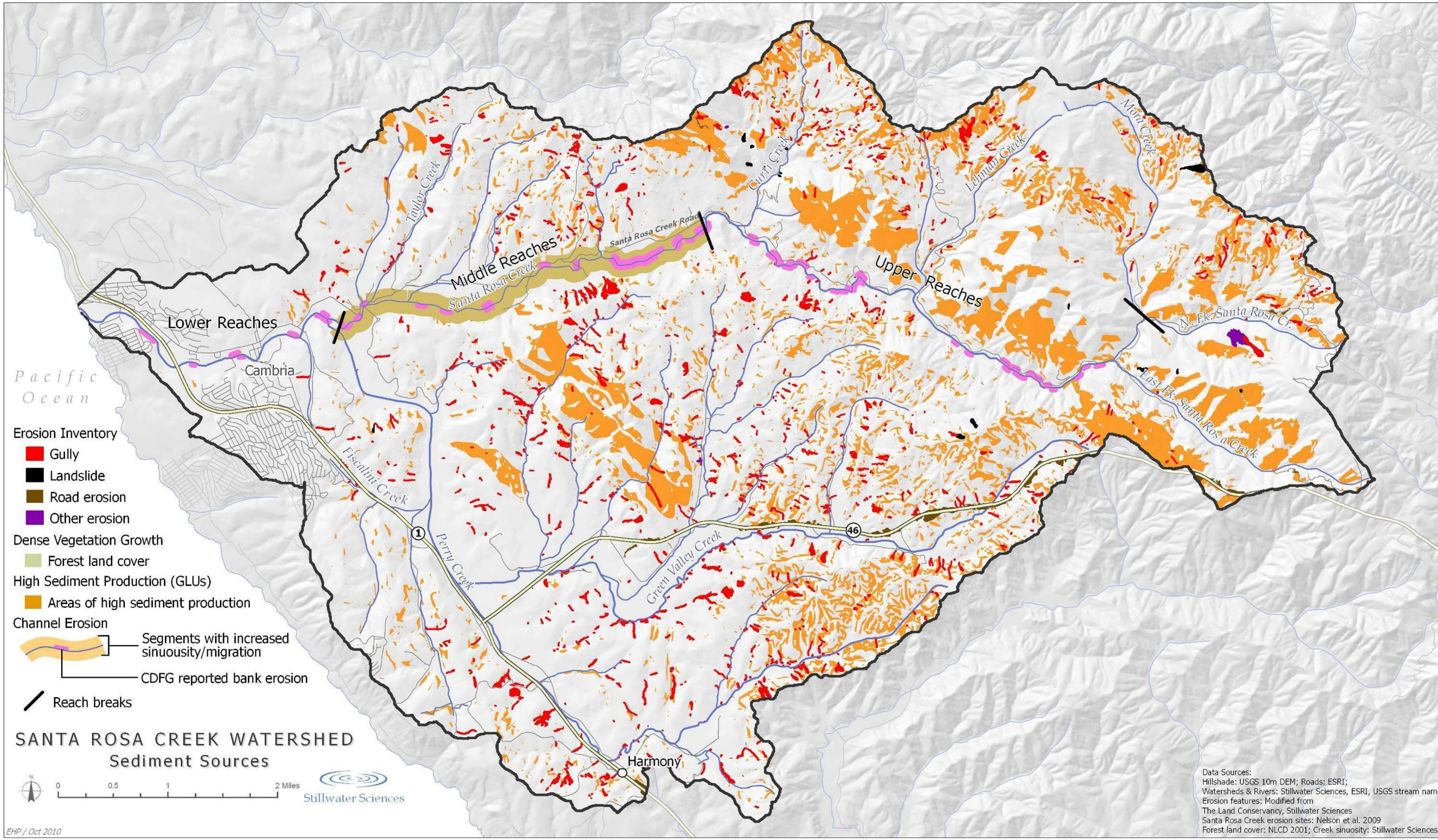

Figure 2-8. Sediment source and transfer areas in the Santa Rosa Creek watershed.

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2.5.2 Channel morphology

Understanding the character of the creek morphology and its sediment is a fundamental component in understanding how fluvial processes will affect the creek, the likely extent and availability of aquatic habitat, the extent of human impacts on the creek, and should be used to devise appropriate management actions into the future. Conditions in the upper, middle and lower reaches of Santa Rosa Creek, the Perry/Green Valley Creek sub-watershed, and lagoon are summarized below.

The upper reaches of Santa Rosa Creek are characteristic of a mountain river, with a steep, confined morphology and a boulder-cobble-gravel bed. Lehman and Curti creeks provide a relatively high supply of coarse to fine sediment to these reaches.

The middle reaches display the features of a classic alluvial channel, with a sinuous channel that meanders through deposited alluvium, and a cobble-gravel bed characterized by pool-riffle bedforms. The middle reaches transition from a highly incised reach with active bank erosion and high sediment input at its upstream extent, to a moderately incised and apparently less dynamic reach as the degree of channel confinement increases and bedrock control once again becomes an influence near the confluence with Perry Creek. Comparing aerial photographs from 1937 to 2007, there has been a significant increase in the sinuosity of the middle reaches (Figure 2-8). The increase in sinuosity of this incised reach is evidence that the channel is still recovering from the impact of land use change in the mid-19th century. Land clearing for lumber and agriculture changed rainfall-runoff dynamics by decreasing landscape surface roughness (i.e., vegetation removal), thereby increasing the stream power in the creek for a given rainfall intensity and duration (i.e., increased hydrograph “flashiness”). Stream bank erosion in the middle reaches is one of the primary sources of fine sediment in Santa Rosa Creek.

Examples of conditions in the upper, middle, and lower reaches of Santa Rosa Creek

Bedrock control returns at the junction with the lower reaches which have a sand-gravel bed and are moderately confined by terrain and development and show signs of aggradation before becoming tidally influenced near the low-gradient creek mouth (described in more detail below). Sediment delivered to the lower reaches from upstream Santa Rosa Creek, Perry Creek, and from local tributaries has resulted in a large amount of stored sediment in the reach. Banks are relatively stable, not least where extensive riprap protection exists.

Perry Creek enters Santa Rosa Creek approximately 2 mi (3 km) upstream of the Highway 1 Bridge and is the largest tributary. It is characterized by a moderately confined channel with finer bed sediment that flows approximately 10 mi (16 km) from the town of Harmony downstream to the confluence with Santa Rosa Creek. Lower Perry Creek was channelized from the former Estrada Lake and begins as a trapezoidal cut roughly paralleling Highway 1 while the lowest reach is incised into the organic-rich sediments of the former lake bed. The major tributary of Perry Creek is Green Valley Creek, which enters approximately 5 km upstream from Santa Rosa Creek confluence. Green Valley Creek originates in the steep, south-facing hillslopes along Highway 46, flows west through a confined alluvial valley, and enters Perry Creek in a broad alluvial zone near Highway 1. From limited field observation and available data, the upper reaches of mainstem Green Valley Creek appear somewhat similar to the upper reaches of Santa Rosa Creek in terms of valley confinement, but unlike Santa Rosa Creek, Green Valley develops a very wide alluvial valley through its middle and lower reaches. These reaches are highly incised and actively eroding their banks. Together, Green Valley and Perry creeks transport a mixed sediment load skewed toward finer sediment that includes silt/fine sand to fine cobbles, with the dominant sediment bed particle size ranging from coarse gravel in the upper reaches to fine gravel in the lower reaches. The Perry/Green Valley Creek sub-watershed is another of the primary sources of fine sediment in Santa Rosa Creek.


Perry/Green Valley Creek sub-watershed

The morphology of the coastal barrier lagoon at the mouth of Santa Rosa Creek is influenced by prevailing onshore currents and the effects of a rock island close offshore, by flows from Santa Rosa Creek, and by topographic constraints that are both geologic and a function of a landfill and riprap (at present-day Shamel Park). The upstream end of the lagoon is defined by the upstream extent of tidal influence, which is well below the Highway 1 Bridge. Overall, the lagoon responds largely to incoming streamflow including its pattern of seasonal breaching which is usually in response to overwash from ocean swells and to high flows from Santa Rosa Creek that overwhelm the capacity of the lagoon. The morphology of the lagoon has remained remarkably static since at least 1919, when the earliest USGS (1919) topographic maps and aerial photographs of the area are available (see Appendix A for additional detail). In a comparison of the lagoon over time, two main patterns are apparent: (1) the mouth has nearly always occupied its current position, on the north end of the beach adjacent to the marine terrace, with few exceptions (e.g., 1986); and (2) the amount of vegetation adjacent to the lower creek channel and lagoon has increased considerably since the earliest aerial photograph in 1937 (see Appendix A for additional details). It can be inferred from historical aerial photographs that neither net aggradation nor erosion has occurred during the past 70-plus years based on the following: (1) the lower stream channel and lagoon have maintained a relatively static position (i.e., no meandering or avulsions); and (2) the lower stream channel exhibits a similar, albeit transitory, bar and pool morphology. This has positive implications for the continued functionality of an ecologically-important lagoon.

2.6 Surface and Groundwater Hydrology

2.6.1 Hydrologic conditions

The climatic and hydrologic characteristics of the watershed produce a perennial flow regime along the majority of Santa Rosa Creek, while most tributaries, including Perry and Green Valley creeks, experience intermittent flows (Figure 2-9). Discharge has been measured over the past 50 years in both the upper (i.e., upstream of Mammoth Rock) and lower watershed (i.e., downstream of the Perry Creek confluence) by three gauges operating at different time periods (Table 2-3, Figure 2-9). During this time annual maximum flow has ranged by a factor of ~50 (60 to 3,350 cfs [1.7 to 95 $m^3 s^{-1}$]) in the upper watershed, and even more widely (<1 to <12,000 cfs [<0.03 to 340 $m^3 s^{-1}$]) in the lower watershed between water years (WY) 1962–1994, with the largest flow recorded at both locations occurring in WY 1969. The monthly streamflow patterns closely follow the seasonal precipitation patterns, where the highest flows occur in winter (Figure 2-10). In summer and fall, monthly average flows are often less than 5 cfs (0.14 $m^3 s^{-1}$), leaving many stream reaches dry, such as immediately downstream of Mammoth Rock where any surface water delivered from upstream reaches seeps down to the groundwater table (Figure 2-9).

The discussion of watershed hydrologic conditions in this section are informed by two stream gauges: one in the upper watershed (USGS 11142200) and one in the lower watershed at the Highway 1 Bridge crossing (SLO County Station 16). The active stream gauge at the Main Street Bridge crossing (SLO County Station 21) is not included because it was found to have large variations in reported annual maximum discharge, likely as a result of a lack of flow calibration. For consistency, this discussion focuses instead on the Highway 1 gauge in the lower watershed because it was used as part of a recent USGS groundwater recharge study conducted in the watershed (Yates and Van Konyenburg 1998).

Table 2-3. Stream gauges of Santa Rosa Creek.

Stream gauge ID	Stream gauge operator	Stream gauge location	Period of record (water years)
USGS 11142200	U.S. Geological Survey	0.4 mi (0.7 km) upstream of Curti Creek	1958–1972
SLO County Station 16	San Luis Obispo County Water Resources, Division of Public Works	Highway 1 Bridge	1976–1992
SLO County Station 21	San Luis Obispo County Water Resources, Division of Public Works	Main Street Bridge	1989–present

From the extended annual maximum flow data, the annual maximum discharge expected to be equaled or exceeded approximately once every 1.5 to 2 years (the statistical "bankfull" flow event) during this time period is approximately 760–1,100 cfs (21–30 $m^3 s^{-1}$) in the upper watershed and 1,800–2,700 cfs (50–78 $m^3 s^{-1}$) in the lower watershed. These "bankfull" flow events, which are geomorphically significant (see below), have the potential to occur in any month, but are more likely to occur in February or March (Figure 2-10).

Similar to other Coast Range watersheds, flood flows in Santa Rosa Creek typically increase, peak, and subside rapidly in response to high intensity rainfall. This hydrologic attribute is characteristic of a "flashy" hydrograph, whereby a rapid increase in discharge occurs over a relatively short time period with a quickly developed peak discharge in relation to normal baseflow (Ward 1978). Since 1958, large flood events have occurred in 1967, 1969, 1973, 1978, 1986, 1993, 1995, and 2005, frequently (but not always) corresponding with ENSO years (NOAA 2009b), which is consistent with an understanding that ENSO years in the Coast Ranges, especially south of 35ºN (Cambria is at 35.6ºN), are characterized by relatively high rainfall intensities, with rivers and streams exhibiting higher annual peak flows than they do in non-ENSO years (Cayan et al. 1999, Andrews et al. 2004).

Inundated floodplain during high flows

The Santa Rosa Valley groundwater basin underlies the Santa Rosa, Green Valley, and Perry creek valleys and is approximately 4,480 ac (7 mi^2) in size (Figure 2-9) (CDWR 2004). The groundwater storage capacity of the basin has been estimated at 24,700 ac-ft, although the actual volume is unknown and likely fluctuates in response to seasonal variations in rainfall and groundwater extraction (Yates and Van Konyenburg 1998, CDWR 2004). Groundwater levels in the basin are typically highest during the wet season, decline during the dry season, and then recover to higher levels in the following wet season. The groundwater basin is recharged primarily from seepage of surface flows in Santa Rosa Creek and its tributaries, deep percolation of precipitation, and residential/agricultural return flows (Yates and Van Konyenburg 1998). During dry periods, flows in Santa Rosa Creek can be insufficient to recharge the basin, which can lead to seawater intrusion and water quality degradation (Yates and Van Konyenburg 1998). Since the 1950’s there has been one temporary seawater intrusion event (in 1961), although there is not a good understanding of why this occurred (Yates and Van Konyenburg 1998).

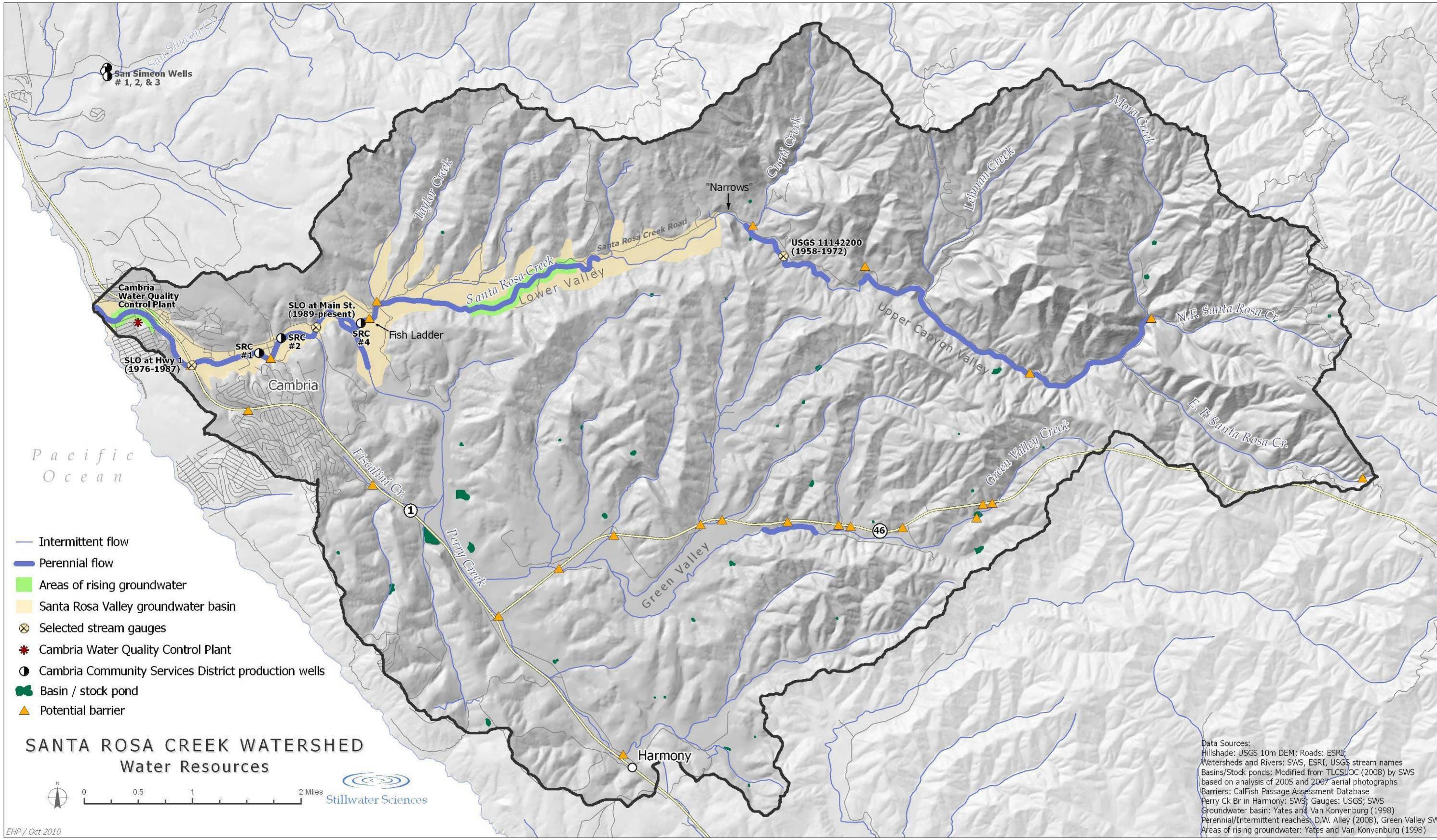

Figure 2-9. Water resources in the Santa Rosa Creek watershed. Perennial and intermittent streams, groundwater basin, and stream gauge locations are shown.

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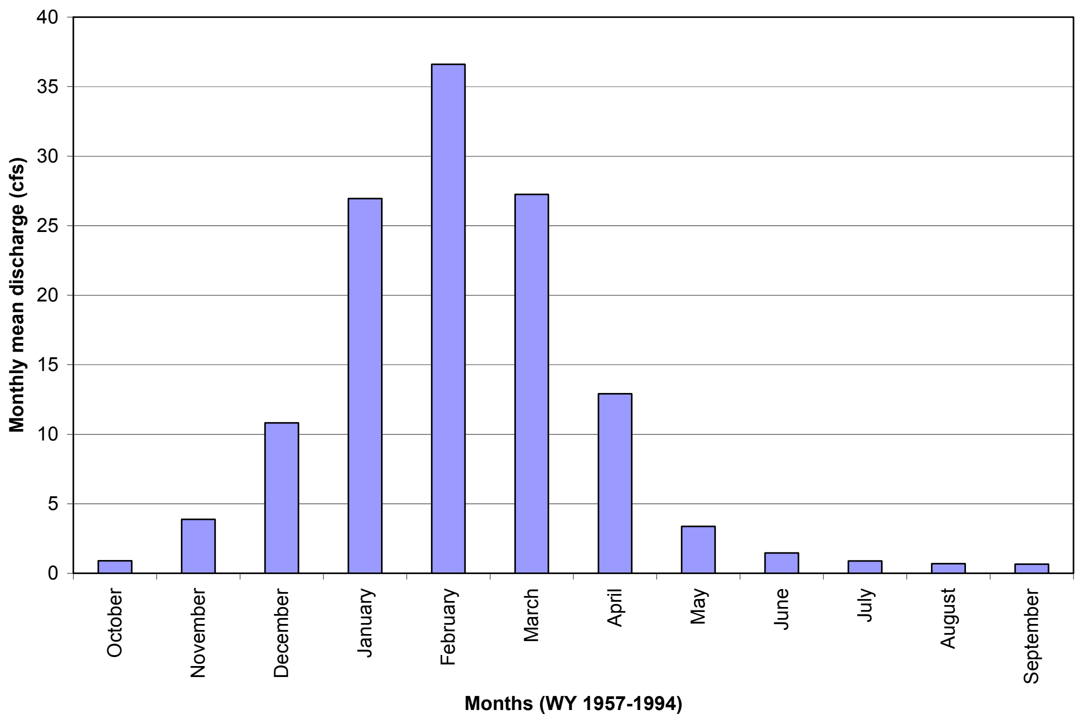

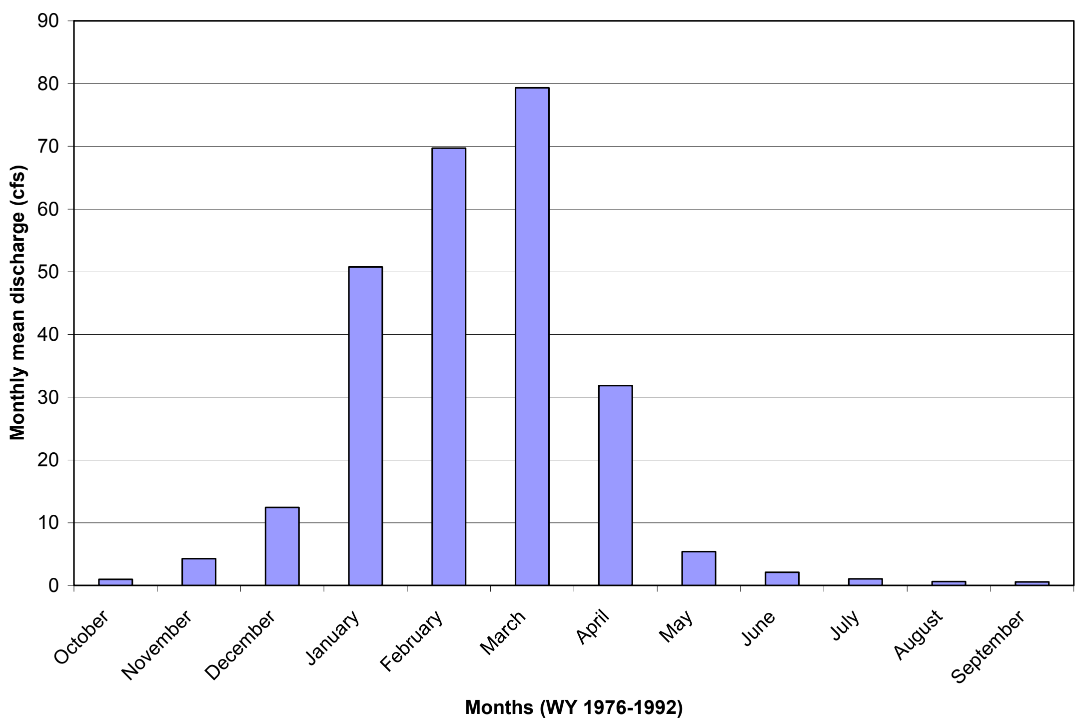

Figure 2-10. Monthly mean discharge for Santa Rosa Creek at Cambria based on USGS gauge 11142200 (from correlation with USGS gauge 11147070 to extend period beyond WY 1972 through 1994) (top) and SLO County Station 16 (bottom).

2.6.2 Groundwater extraction and surface water diversion

The urbanization time period between 1960 and the 1990s also represents an expansion of water use, primarily through groundwater pumping, to irrigate crops and provide drinking water to Cambria. The likely impact of groundwater extraction and limited surface water diversion has been an overall reduction in baseflow within Santa Rosa Creek, and potentially within Perry and Green Valley creeks. Until the San Simeon well field was established in 1979 (see Figure 2-9) to supplement municipal water demands in Cambria, the peak of groundwater extraction by CCSD for municipal water use in the Santa Rosa Creek watershed occurred in 1976 and totaled 520 acre-feet (CCSD 2009), or 3.6 times the total annual stream flow measured at the Highway 1 Bridge stream gauge (annual flow in 1976 = 144 acre-feet; 1976 was a dry water year) (Figure 2-11). Since 1979, annual extraction rates from the Santa Rosa wells have been strongly dependent on water year conditions, where rates peaked above 200 acre-feet during drought (or near-drought) years—1987, 1988, 1990, and 2008—and dropped close to zero during wet (or near-wet) years—1980, 1981, 1982, 1993, 1995, 1996, and 1998. Overall, extraction from the groundwater basin by CCSD has not exceeded the annual permitted limit of 518 acre-feet (CCSD 2008). In late 1990s, CCSD shut down its Santa Rosa wells (SRC-1 and SRC-2; see Figure 2-9) due to contamination risks from hydrocarbons from nearby leaking fuel tanks in Cambria. CCSD subsequently installed a new well (SRC-4) up-gradient of the fuel leak plume close to Coast Union High School and the confluence with Perry Creek (see Figure 2-9); it remains the sole municipal water production well in the watershed. Even with the San Simeon wells in place, the municipal water supply of Cambria has a severity rating of Level III (resource capacity has been met or exceeded) due to unreliability of the groundwater supply to meet existing demands, as designated in the 2011 San Luis Obispo County Draft Master Water Plan (Carollo 2011).

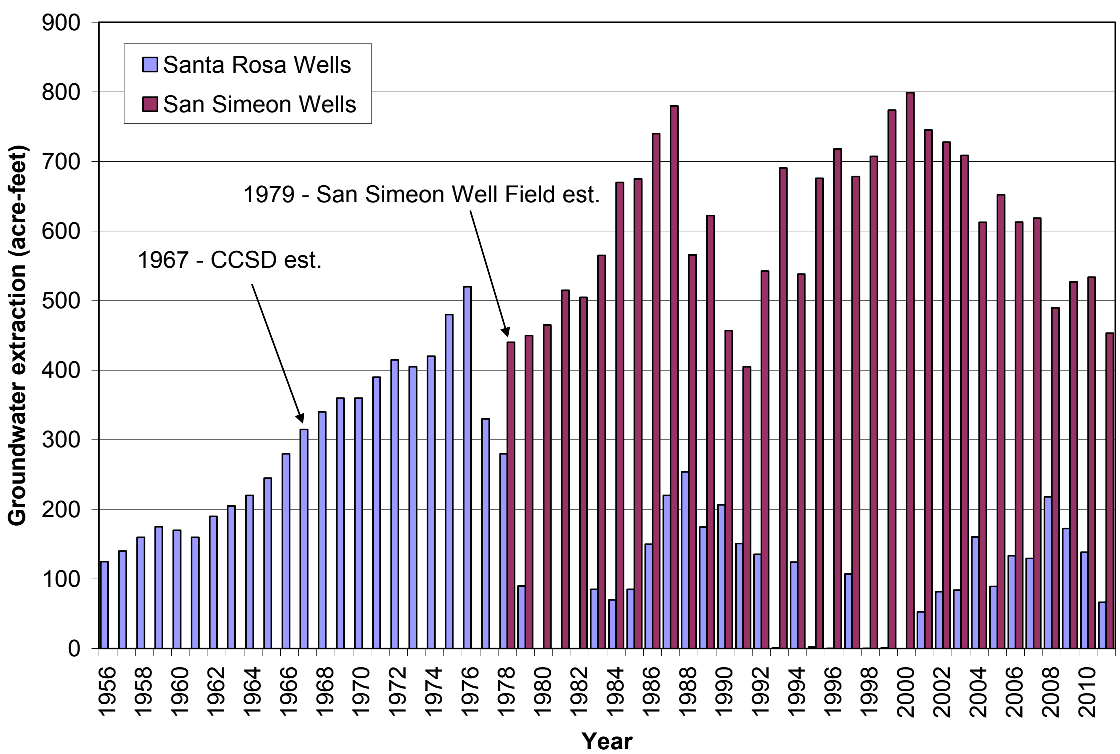

Figure 2-11. Annual groundwater extraction by CCSD from the Santa Rosa and San Simeon groundwater wells to provide Cambria water supply. Data from 1956–1988 provided by Yates and Van Konyenburg (1998) based on CCSD pumping records, and data from 1989–2011 provided by CCSD (2011). All years have recorded data.

Since the majority of municipal water is now supplied by the San Simeon wells (Figure 2-11), groundwater pumping in the Santa Rosa Creek watershed is primarily for private residential and/or agricultural use. Overall, the amount of groundwater extracted by entities other than CCSD is not well known. There are only few estimates of groundwater pumping by private entities available. USGS estimated that groundwater extracted by private entities for agricultural uses in 1988–1989 (after the establishment of the San Simeon wells) was approximately 3.5 times the amount pumped by the CCSD for municipal uses (Table 4 in Yates and Van Konyenburg 1998). The present-day amounts of urban and agricultural groundwater extraction are approximately equal (815 acre-feet per year [AFY] for urban, 830 AFY for agricultural) in the Cambria Water Planning Area, which includes Santa Rosa Creek, San Simeon Creek, Leffingwell Creek, and Villa Creek watersheds (ESA 2010). Agricultural pumping in the watershed typically peaks in the height of the growing season, usually July–August, and is close to zero in winter (Yates and Van Konyenburg 1998). Summer months also have the highest water demand due to increased occupancy and tourism in Cambria (San Luis Obispo County 2008).

Surface water diversion is limited in the watershed (for example, the recent update of the San Luis Obispo Water Master Plan makes no mention of surface water diversions in the Cambria Water Planning Area [Carollo 2011]), primarily because there is little to no instream flow during summer and fall when agricultural water demand is highest. Where surface diversions do occur, ditch pumps are generally employed (Yates and Van Konyenburg 1998). Ditch pumps have low yields and are, therefore, unlikely to significantly reduce surface water availability. The watershed does, however, host approximately 28 stock ponds, all situated on small, low-order tributaries. Taken together, these small ponds, which average 0.5–3.5 acre-feet in storage, intercept surface runoff from about 8% of the total watershed drainage area. In a given year, the amount of surface water intercepted by these ponds potentially ranges between 10 and 100 acre-feet based on their number and size. It is not known whether any of the ponds are supplemented with well water.

As discussed in Section 2.2, the CCSD and USACE are currently assessing the feasibility of a seawater desalination plant at the mouth of Santa Rosa Creek that would supplement the amount of municipal water currently being pumped from the San Simeon and Santa Rosa Creek aquifers, which is intended to improve the water supply reliability in the CCSD service area (CCSD 2008). There is the potential that, if desalinated water is ever used in place of pumped groundwater for the municipal water supply, the decreased extraction of groundwater from the Santa Rosa Creek aquifer could partially restore instream flows within Santa Rosa Creek. However, the extent to which, or even if, desalinated water may be used to replace the use of groundwater for the municipal water supply is unknown based on information available in CCSD (2008) and preliminary plans for the desalination plant. In addition, the majority of groundwater now pumped from the Santa Rosa Creek aquifer is by private entities for residential and/or agricultural water use. There is no indication that desalinated water would be used in place of privately pumped or diverted water from the watershed.

2.6.3 Lagoon hydrology

Similar to other lagoons along the California coast, the Santa Rosa Creek lagoon exhibits a "wet" and "dry" state during any given year, whereby winter and spring flows fill up the lagoon and the lack of flows during late summer and early fall often result in a dry lagoon. During the relatively wet year of 2005, D. W. Alley & Associates (2006) reported that the lagoon remained full throughout the summer. They also reported that lagoon water depth was predominantly controlled by streamflow and that tidal overwash and through-flow (i.e., subsurface flow through the sandbar) had a minimal effect. Flows into the lagoon during summer and fall are likely worsened by low stream flows resulting from excessive groundwater pumping and diversions (Rathbun et al. 1991, Yates and Van Konyenburg 1998, D. W. Alley & Associates 2006, 2008). From 1993 to 2007, summer and fall streamflows immediately upstream of the lagoon ranged from 0 cfs (1994 and 2007) to 2 cfs (2005), with a median of 0.4 cfs (D. W. Alley & Associates 2008). In some lower flow years such as 2003 and 2004, entire sections of the lower lagoon dried up, reducing the area of suitable steelhead rearing habitat (D. W. Alley & Associates 2008). Prior to its relocation farther upstream in 2001, a CCSD groundwater well was located at the upstream end of the lagoon. Groundwater pumping at this location had observable impacts on water levels in the lagoon (Elliott 1995), which have increased since the well was relocated. Depending upon the location, water extraction for the desalination plant proposed by CCSD and the U.S. Army Corps of Engineer's could also decrease water levels in the lagoon (e.g., if the extraction point is located in an area that is hydrologically connected with the lagoon). As such, the extraction point location is likely to be the subject of additional data collection and impact analysis. Low flows and water diversion may also contribute to extended periods of saltwater and freshwater stratification in the lagoon, which results in warmer temperatures and anoxic conditions along the bottom (where denser saltwater settles) (see Section 2.8).

The sandbar typically breaches after high rainfall and remains open for a week or more depending on streamflows; then the sandbar reforms to create the lagoon (M. Walgren, pers. comm., 2010). Often, high wave energy can also contribute to sandbar breaching. Reformation of the sandbar and closure of the lagoon occurs when lower stream discharges and lower-intensity wave action facilitate onshore sediment transport and deposition at the mouth. Lagoon closure can take weeks to months, depending on the stream discharge and wave conditions. While the sandbar is open, the lagoon drains and is subject to the tides. From 1993–2007 the median date of sandbar closure was May 27, with the earliest closure on March 15 in 2007, and the latest closure on July 13 in 1998 (D. W. Alley & Associates 2008). During these years, date of sandbar closure was positively and significantly related to rainfall in the preceding water year, although the relationship was not strong ($r^2 = 0.347$; $P = 0.0209$; n = 15).

Open sandbar at the lagoon

2.7 Infrastructure and Channel Modifications

Infrastructure involves man-made constructs such as dams, roads, and bridges, and facilities related to water diversion and return. Channel modifications include straightening channels, construction of levees for flood control purposes, and bed and/or bank revetments as protection against bank erosion. Generally, these modifications are related to the development of floodplains including routing of roads near stream channels.

2.7.1 Creek crossings and fish passage barriers

There are numerous creek crossings (i.e., bridges and culverts) along Highways 1 and 46 and Santa Rosa Creek Road that may locally influence the dynamics of sediment deposition and erosion and prevent or impede fish migration and movement. Bridges and other crossings frequently cause hydraulic constrictions during high flow, which promote local geomorphic changes including sediment deposition upstream of the structure and erosion of the bed and banks of the creek downstream of the structure as flow accelerates. Likewise, when crossing structures are not built to grade seamlessly with the channel bed, similar impacts are likely. Both causes may result in a significant "step" in the channel bed thereby disrupting geomorphic processes locally and impeding upstream fish passage.

Stream crossings and channel conditions in the Santa Rosa Creek watershed have been assessed by a number of entities to determine the extent to which they may limit fish migration and movement. The results of these assessments have been consolidated in the California Fish Passage Assessment Database (PAD)[4] (CalFish 2009). The potential barriers identified for the watershed in the PAD are summarized in Table 2-4 and mapped in Figure 2-12. The previous downstream-most barrier in the watershed, the Burton Street Bridge apron (PAD ID #707020) was modified in 2006 to provide fish passage under a wider range of flow conditions. In addition, the culverts and fish ladder at Ferrasci Road (PAD ID #700068) that were previously identified as a passage barrier were replaced with a free-spanning bridge in 2011. Without these two barriers, steelhead and other fish species, have unimpeded access to approximately 12 stream miles (19 km) on the mainstem creek between the ocean and East Fork Santa Rosa Creek, which presents the natural limit of anadromy.

Ferrasci Road crossing before (above) and after (below) replacement

There is a concentration of road drainage and crossing-related impacts along Green Valley Creek as part of the Highway 46 construction in the 1970s. The status of these creek crossings in impeding fish passage is largely unknown (Table 2-4), but it is possible that they exclude steelhead from nearly the entire Perry/Green Valley Creek sub-watershed (Figure 2-12). Perhaps the greatest geomorphic impact of these crossings has come from drainage modification approximately 3 mi (5 km) upstream from the junction of Highways 1 and 46. The increase in flow to Green Valley Creek at this location appears to have, at least in part, caused substantial downstream channel enlargement (i.e., bed incision and channel widening) in Green Valley Creek and erosion of the tributary channel downstream of the culvert. The impact appears to extend approximately 1 mi (2 km) downstream to where the channel gradient decreases, the channel width increases, and sediment deposition is observed to occur. Upstream of the road drainage and culvert, exposed bedrock and coarse bed material seem to be controlling the channel grade, thereby inhibiting channel enlargement due to the flow increase.

[4] While the PAD is not an error-proof database, many of the barriers identified in the Santa Rosa Creek watershed (Table 2-4 and Figure 2-10) have been previously field verified.

Table 2-4. Potential fish passage barriers in the Santa Rosa Creek watershed.

PAD ID No. [a]	Barrier location				Barrier description	Barrier status	Barrier priority	Information sources
	USGS-designated stream name	Unofficial stream name [b]	Station					
			mi	km				
712027	Unnamed	Unnamed tributary to Santa Rosa Creek	3.5	5.6	Culvert at Santa Rosa Creek Road crossing	Partial	Low	CCC, Greenspace
712044	Unnamed	Curti Creek	7.6	12.2	Culvert at Santa Rosa Creek Road crossing	Total	Low	CCC, Greenspace
712043	Unnamed	Unnamed tributary to Santa Rosa Creek	9.2	14.7	Culvert at Santa Rosa Creek Road crossing	Total	Low	CCC, Greenspace
712045	Unnamed	North Fork Santa Rosa Creek	12.6	20.2	Culvert at Santa Rosa Creek Road crossing	Total	Low	CCC, Greenspace
731782	Unnamed	Unnamed tributary	2.0	3.3	Culvert at Highway 1 crossing	Unknown	Medium	Caltrans
731365	Fiscalini Creek		6.0	9.6	Culvert at road crossing	Unknown	Medium	Caltrans
736678	Perry Creek		6.5	10.4	Highway 46 Bridge with potential passage constraints	Unknown	Medium	Caltrans
No ID	Perry Creek		8.3	13.4	Culvert at road crossing	Unknown	Medium	Caltrans
736483	Green Valley Creek		7.0	11.2	Highway 46 Bridge with potential passage constraints	Unknown	High	Caltrans
736475	Unnamed	Unnamed trib. to Green Valley Creek	7.5	12.1	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
736538	Unnamed	Unnamed trib. to Green Valley Creek	9.0	14.5	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
736487	Unnamed	Unnamed trib. to Green Valley Creek	10.0	16.0	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
736431	Unnamed	Unnamed trib. to Green Valley Creek	10.5	16.8	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
736457	Unnamed	Unnamed trib. to Green Valley Creek	10.6	17.0	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans

PAD ID No. [a]	Barrier location				Barrier description	Barrier status	Barrier priority	Information sources
	USGS-designated stream name	Unofficial stream name [b]	Station					
			mi	km				
736621	Unnamed	Unnamed trib. to Green Valley Creek	11.1	17.8	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
716213	Green Valley Creek		11.9	19.2	Unspecified	Unknown	Unspecified	CDWR
736625	Unnamed	Unnamed trib. to Green Valley Creek	12.0	19.4	Culvert at Highway 46 crossing	Unknown	Medium	Caltrans
736583	Green Valley Creek		12.1	19.5	Culvert at Highway 46 crossing	Unknown	High	Caltrans

[a] Data source: California Fish Passage Assessment Database (PAD) (CalFish 2009).
[b] To help identify unnamed tributaries on USGS topographic maps (USGS 1979a, 1979b) that are referred to elsewhere in this document unofficial tributary names from D.W. Alley & Associates (2008) are presented.

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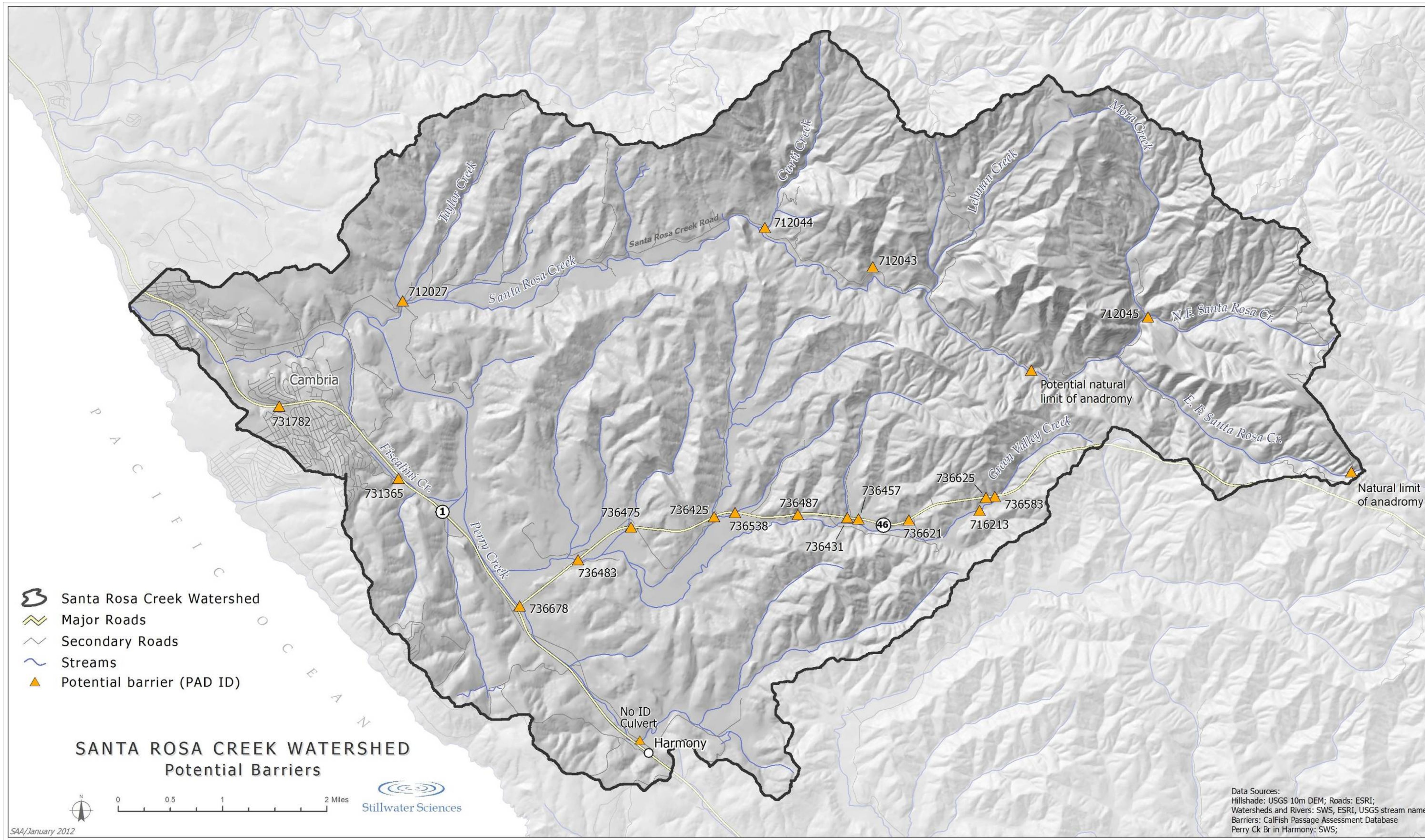

Figure 2-12. Potential fish passage barriers in the Santa Rosa Creek watershed (see Table 2-4 for details).

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2.7.2 Bank revetment and floodplain development

While no levees have been constructed along Santa Rosa Creek or its tributaries, there are numerous instances of bank revetment in the watershed, lining one or both banks of the creek (Nelson et al. 2009). The majority of riprap between the high school and old grammar school, which is composed primarily of boulder-size quarry rock, was reportedly installed immediately following the damaging floods of 1969 to repair banks that had eroded during the floods (D. Dunlap, pers. comm., 2009). In most instances, bank revetment is installed as a piecemeal solution to an on-going bank erosion concern that either threatens infrastructure or results in land loss. Unfortunately, bank revetment is also a symptomatic solution that does not account for the reason that high energy flow exists and is causing erosion. Therefore, bank revetments frequently cause flow to be deflected back across the channel resulting in further erosion downstream. The subsequent threat to downstream land and infrastructure promotes the continuing construction of further revetments and maintenance of existing revetments until such time that the channel is almost entirely revetted. Extensive revetment tends to cause channel incision, more rapid flows, channel bed armoring (i.e., coarse bed surface layer), and reduced topographic complexity of the channel bed resulting in significant reductions in habitat suitability for native aquatic organisms including salmonids.

In addition to in-channel structures, development along channel banks and the adjacent floodplain can have a significant impact on channel morphology. Floodplain development increases runoff associated with impervious area and increases channel confinement associated with bank hardening and structures built along channel banks, both of which have the potential to cause channel incision and/or widening due to increased flow velocities during high flow events. Since 1937, there has been concentrated development on the north bank (i.e., right bank) floodplain along Santa Rosa Creek from Highway 1 downstream. During the improvement of Highway 1 in the mid 1960's (bypass construction), many of the lower reaches of the channel were modified. In an effort to improve building conditions, an abandoned channel meander approximately 0.3 mi (0.5 km) downstream of the Highway 1 Bridge was filled-in sometime after 1937. These development features have undoubtedly played some role in controlling the current channel geomorphic character.

2.8 Water Quality

Surface water in the Santa Rosa Creek watershed has a number of beneficial uses, which are designated by Central Coast Regional Water Quality Control Board's (CCRWQCB) 1994 Basin Plan in order to inform water quality criteria (Table 2-5). A beneficial use is defined as the historical, present, and potential uses of water in the Basin as defined by the RWQCB. The intent is to ensure the continuance of beneficial uses and establish compatible water quality standards as well as the level of treatment necessary to maintain the standards.

Water quality monitoring by the CCRWQCB's Central Coast Ambient Monitoring Program (CCAMP) indicate that a number of water quality parameters occasionally exceed established criteria such that beneficial uses may no longer be supported in portions of the watershed at some times (CCRWQCB 2002). These include total dissolved solids (TDS), sulfates, sodium and chloride. In particular, a criterion for sulfate was exceeded 91% of the time on Santa Rosa Creek, at sites both upstream and downstream of Cambria. However, for all four of these parameters, the CCRWQCB acknowledged that because no upstream data exist it is unclear whether the elevated levels of these parameters are from anthropogenic sources and recommended that these parameters be evaluated throughout the watershed (CCRWQCB 2002).

Table 2-5. Beneficial uses of Santa Rosa Creek watershed surface waters.

Beneficial use	Estuary	Creek
Municipal and Domestic Supply (MUN)		X
Agricultural Supply (AGR)		X
Industrial Service Supply (IND)		X
Ground Water Recharge (GWR)	X	X
Freshwater Replenishment (FRSH)		X
Water Contact Recreation (REC-1)	X	X
Non-Contact Water Recreation (REC-2)	X	X
Commercial and Sport Fishing (COMM)	X	X
Warm Fresh Water Habitat (WARM)		X
Cold Fresh Water Habitat (COLD)	X	X
Estuarine Habitat (EST)	X	
Wildlife Habitat (WILD)	X	X
Preservation of Biological Habitats of Special Significance (BIOL)	X	
Rare, Threatened, or Endangered Species (RARE)	X	X
Migration of Aquatic Organisms (MIGR)	X	X
Spawning, Reproduction, and/or Early Development (SPWN)	X	X
Shellfish Harvesting (SHELL)	X	

Source: CCRWQCB (1994)

Additional monitoring by the CCRWQCB (Shwartzbart 1993), as well as CDFG (Nelson et al. 2009), and D. W. Alley & Associates (2008) identified a number of other water quality parameters that may be impairing instream conditions and potentially limiting the population of native aquatic species. These include temperature, dissolved oxygen (DO), and mercury, which are discussed in more detail below. In addition, development of this watershed management plan included a survey of benthic macroinvertebrates as a measure of overall water quality and stream health. The methods and results of this survey are also described below.

2.8.1 Temperature

Santa Rosa Creek is being considered for placement on the Clean Water Act 303d list of impaired waterbodies for temperature (CCRWQCB 2010). In streams such as Santa Rosa Creek with designated beneficial uses such as cold freshwater habitat (Table 2-5), objectives for water temperature are based, in part, on species-specific temperature tolerances (CCRWQCB 1994, SWRCB 1998). During their decision to recommend Santa Rosa Creek for placement on the 303(d) list, the CCRWQCB used 55–70°F (13–21°C), the optimal range for steelhead trout growth and other lifestages based on Moyle (1976), as their evaluation guideline (CCRWQCB 2010). However, some populations of steelhead have been shown to display local adaptation to higher water temperatures and there are many central California coast examples of steelhead surviving and growing well at water temperatures above 70°F (21ºC) (Moyle 2002, Spina 2007, Smith 1990, D. W. Alley & Associates 2008).

While there is still considerable uncertainty of what optimal temperatures for steelhead are in this region (A. Spina, pers. comm., 2010), available data for Santa Rosa Creek indicate that, in most years, summer water temperatures are suitable for successful steelhead rearing in the majority of stream reaches (see Section 3.4 for additional detail). A relatively intact riparian corridor in most reaches and the influence of coastal fog likely help moderate stream temperatures in Santa Rosa Creek. In 2004–2006, D. W. Alley & Associates (2008) recorded maximum daily summer (July to September 10) water temperatures ranging from 67–75°F (20–24°C) in the lower reaches (stream miles 0.5–2.9); 69–74°F (20–23°C) in the middle reaches (stream miles 3.4–4.2); and 64–71°F (18–22°C) at two sites in the upper reach (stream miles 9.6–10.1 and 11.5–12.4). In 2005, CDFG recorded maximum daily summer (June through October) water temperature at stream miles 0.6, 8.0, and 14.5 (Nelson et al. 2009). Temperatures ranged from 55–79°F (13–26°C) at stream mile 0.6, 50–71°F (10–22°C) at stream mile 8.0, and 51–70°F (11–21°C) at stream mile 14.5 (Nelson et al. 2009).

D. W. Alley & Associates (2008) recorded summer (July 10 through October) water temperatures at two locations in the lagoon—adjacent to the Moonstone Beach parking lot and to Shamel Park—in 2001, 2002, 2005, and 2006. In all four years, temperatures reached or exceeded 77°F (25°C) at one or both of the monitoring sites for some portion of the summer. While temperatures of this magnitude likely make the lagoon inhospitable for summer rearing, steelhead were observed using the lagoon in both 2001 and 2006 (D. W. Alley & Associates 2008). Low instream flows and water diversion likely contribute to extended periods of saltwater and freshwater stratification, with warmer temperatures and anoxic conditions along the bottom where denser saltwater settles.

2.8.2 Dissolved oxygen

Dissolved oxygen (DO) levels measured by the CCAMP suggest that it may be a potential water quality limiting factor and that beneficial uses may no longer be supported (CCRWQCB 2002). At DO levels <5–6 mg/l, stress can begin to effect fish and other organisms. At high temperatures, steelhead can survive DO concentrations as low as 1.5–2.0 mg/l for brief periods, though concentrations closer to 8–12 mg/L are normally required for growth (Moyle 2002).

D. W. Alley & Associates (2008) recorded DO levels in the lagoon for 14 years (1992–2005) and during that time DO levels rarely met the 5 mg/l criterion or the 2 mg/l lethal limit for steelhead. They concluded that a reduction in tidal overwash could help to reduce the low DO saline layer at the bottom of the lagoon (tidal overwash increases lagoon salinity which can result in higher salinity, higher temperature, and lower DO layer at the bottom of the lagoon) and an increase in lagoon depth from increased stream inflow and increased shading could help to prevent filamentous algae growth (D. W. Alley & Associates 2008). Further, they found that, while DO levels frequently failed to meet guidelines and likely restricted the activity of steelhead in the lagoon, they were likely less limiting than temperature to steelhead survival in the lagoon since steelhead could avoid the low DO zones in the saline layer at the bottom of the lagoon and in the vicinity of high density filamentous algae (D. W. Alley & Associates 2008).

2.8.3 Mercury

A 1993 CCRWQCB study documented elevated levels of mercury in stream sediment, and to a lesser extent in water, in and downstream of Curti Creek (Schwartzbart 1993). Cinnabar, the common ore of mercury, was historically mined at several locations in the watershed, most notably at the Oceanic Mine located in the Curti Creek sub-watershed. Active mining at the site began in 1865 and continued intermittently through the 1900s. Records during this time indicate that a total of over 38,000 flasks of mercury were produced from the Oceanic Mine, nearly equal to the production from all other mercury deposits in the County combined (CCRWCQB 1999). During peak production, ore was milled and processed into pure forms of mercury in a furnace located approximately ½-mile downhill from the mine (Eckel et al. 1941, as cited in CCRWQCB 1999). In 1964, the mine was sold to Buena Vista Mines, Inc., while the former mill site was sold to a different owner (Holcombe 1970, as cited in CCRWQCB 1999).

During a study of inactive mercury mines in San Luis Obispo County, the Central Coast Regional Water Quality Control Board documented iron-rich, red seepage from the mine, which reportedly pollutes and discolors Curti Creek for most of the downstream distance to Santa Rosa Creek, and the erosion of mercury-rich waste rock by Curti Creek at the former mill site (Schwartzbart 1993, CCRWQCB 1999). Stream sediment samples contained elevated mercury levels ranging between 1.095 to 8.48 mg/kg (ppm) downstream of the mine and former mill site (Schwartzbart 1993) (Table 2-6). These values exceed the concentrations above which adverse biological effects are expected to occur frequently in freshwater sediment (Buchman 2008).[5] Of the 49 inactive mines investigated during the study, the CCRWQCB concluded that Santa Rosa Creek was one of the most heavily metal-mined-impacted watersheds as a result of the Oceanic Mine former mill site (Schwartzbart 1993, CCRWQCB 1999). More recently, several sediment samples from lower Santa Rosa Creek have been tested for mercury (CCRWQCB 2002, L. Harkins and Sierra Club, unpubl. data, 2009). The results of all total mercury (THg) in sediment measurements taken in the watershed are summarized in Table 2-6 and sample points are mapped in Figure 2-13.

One sample point, HSC-4 in the lagoon, was analyzed for methyl mercury, the form of mercury that can bioaccumulate in living tissue, and was found to have 3 μg/kg (parts per billion), or 0.60% of THg (L. Harkins and Sierra Club, unpubl. data, 2009). Three-spined stickleback (*Gasterosteus aculeatus*) were collected in the lagoon by CCAMP in 1999 and 2001 and tested for mercury. The mercury concentration in the 1999 sample measured 0.318 ppm, while the 2001 sample measured 0.085 ppm; neither of which exceeded the CCRWQCB's (1994) 0.5 ppm criteria for mercury in aquatic organisms. Additional information is needed to more fully understand the magnitude of mercury methylation in the lagoon (which is the primary area in the watershed with the low dissolved oxygen conditions that facilitate the methylation process) and the extent to which mercury is being taken up by the aquatic foodweb.

CCRWQCB (1999) recommended that erosion control be implemented throughout the Ocean Mine area to stabilize the eroding mercury-rich waste rock at the former mill site. In addition, they determined that constructed wetlands could be a practical solution to retain and treat pollutants entering Curti Creek from the mine and former mill site. Remediation requirements from the CCRWQCB have been in place since 1997, however, no reclamation activities have been conducted at the mine or former mill site (CCRWQCB 1999).

[5] The following mercury levels in sediment are provided for reference:
0.08 mg/kg (ppm) = estimated pre-mining mercury levels in California stream sediments (SFBRWQCB 2008)
0.174 mg/kg (ppm) = mercury threshold effect level (TEL), the concentration above which adverse biological effects are expected to occur rarely, in freshwater sediment (Buchman 2008)
0.486 mg/kg (ppm) = mercury probable effect level (PEL), the concentration above which adverse biological effects are expected to occur frequently, in freshwater sediment (Buchman 2008)
20 mg/kg (ppm) = mercury hazardous waste limit

Table 2-6. Sediment mercury levels in Santa Rosa Creek watershed.

Sample point ID	Location	Date	Sediment THg (mg/kg) (ppm)
RB-SR-D1 [a]	Santa Rosa Creek upstream of Curti Creek	2/12/1992	0.192
RB-SR-C1 [a]	Curti Creek upstream of Oceanic Mine tributary	2/12/1992	0.511
RB-SR-A1 [a]	Tributary north of Oceanic Mine	2/12/1992	0.601
RB-SR-A2 [a]	Tributary at Oceanic Mine	2/12/1992	1.095/1.75 [d]
RB-FD-16 [a]	Tributary in vicinity of Oceanic Mine	5/19/1986	3 [e]
RB-SR-B [a]	Tributary south of Oceanic Mine	2/12/1992	6.79
RB-SR-C2 [a]	Tributary at Oceanic Mine just upstream of Curti Creek	2/12/1992	5.01
RB-SR-C3 [a]	Curti Ceek just downstream of Oceanic Mine tributary	2/12/1992	1.104
RB-SR-D2 [a]	Lower Curti Creek	2/12/1992	1.194/8.48 [d]
RB-SR-D3 [a]	Santa Rosa Creek downstream of Curti Creek	2/12/1992	0.161
HSC-1 [b]	Santa Rosa Creek 20 ft (6 m) upstream of Main Street Bridge	7/15/2009	0.12
HSC-2 [b]	Santa Rosa Creek at Creekside Reserve at Center St	7/15/2009	0.16
HSC-3 [b]	Santa Rosa Creek lagoon, 350 ft (106 m) upstream of bench at Shamel Park	10/12/2009	0.18
HSC-4 [b]	Santa Rosa Creek lagoon, at Shamel Park bench	10/12/2009	0.54
SWAMP-1 [c]	Mouth of Santa Rosa Creek	3/1/1998	0.55

[a] Source: Schwartzbart 1993
[b] Source: L. Harkins and Sierra Club, unpubl. data, 2009
[c] Source: CCRWQCB 2002
[d] Two measurements were taken at this sample point
[e] Another lab measured 41 mg/kg at this point

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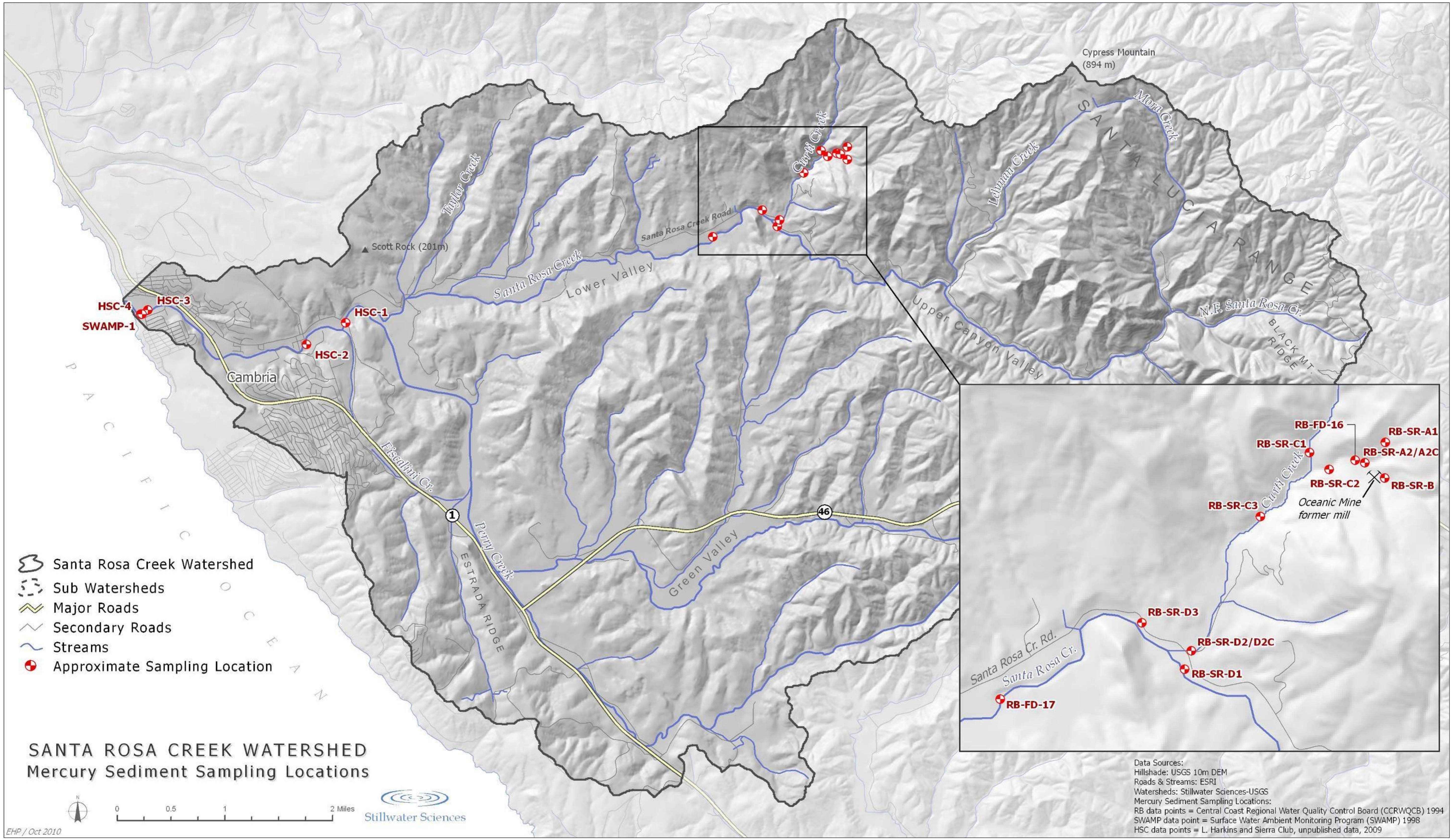

Figure 2-13. Mercury sample points in the Santa Rosa Creek watershed (see Table 2-6 for sampling entity and results).

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2.8.4 Benthic macroinvertebrates

Hydropsychid caddisflies

As a part of the development of this watershed management plan, the benthic macroinvertebrate population was sampled in lower Santa Rosa Creek to evaluate water quality and biological conditions of stream habitat in the watershed (Appendix B). Benthic macroinvertebrates are organisms that utilize the stream bed substrate as habitat. The distribution of benthic macroinvertebrates is dependent on seasonal weather variations (which influence water volume, velocity, and temperature), food availability, and water and habitat quality (Plotnikoff et al. 1997). Stream benthic macroinvertebrates respond to impacts related to pollution, sedimentation, and other changes in their habitat. The number, composition, and distribution of benthic macroinvertebrates can be a strong indicator of instream habitat quality. Benthic macroinvertebrates are also a primary food source for steelhead. Therefore, assessment of the benthic macroinvertebrate community can provide valuable insight into potential limiting factors for steelhead productivity.

In general, benthic macroinvertebrate diversity in Santa Rosa Creek is higher upstream, where the benthic macroinvertebrate assemblage is less tolerant of degraded conditions, and lower downstream, where the species assemblage is more tolerant of poor water quality conditions.

2.8.4.1 Sampling methods

On May 5, 6, and 7 of 2010, benthic macroinvertebrates were collected using an abridged version of the State Water Resource Control Board’s (SWRCB) Surface Water Ambient Monitoring Program (SWAMP) bioassessment protocol (Ode 2007) at seven sites along Santa Rosa Creek (Figure 2-14):

- Site 1 (stream mile 0.3)
- Site 2 (stream mile 1.0)
- Site 3 (stream mile 1.5)
- Site 4 (stream mile 1.8)
- Site 5 (stream mile 2.8)
- Site 6 (stream mile 3.3)
- Site 7 (stream mile 5.0)

Sampling sites were selected in part based on personal communications with Mary Adams of CCAMP and Jennifer Nelson of CDFG, both of whom have experience on Santa Rosa Creek. Physical accessibility and permission for access from landowners also played a role in site selection. Selected sampling sites reflect a variety of land uses and human influences, including urbanization, agriculture, and ranching. The four downstream-most sites are located within the town of Cambria.

Figure 2-14. Benthic macroinvertebrate sampling sites on Santa Rosa Creek.

Sampling took place at base flow conditions, at riffles no deeper than 2 ft, using the targeted riffle composite procedure (Ode 2007). A 450-ft reach of riffle habitat was defined at each site. Riffles are shallower stream habitats characterized by water that flows over and between rocks, creating mild to moderate water turbulence (Ode 2007). Riffles are commonly used for benthic macroinvertebrate sampling because they usually offer the highest diversity of benthic macroinvertebrate species (Ode 2007). Each 450-ft reach was randomly divided into eight transects, and sampling began at the lower-most transect and progressed upstream. At one location along each transect, a D-frame net with a mesh size of 0.5 micrometers was placed perpendicular to flow and flat on the substrate. Organisms in a 1-ft^2 sample area immediately upstream of the net were first removed from larger rocks and then the substrate within the sampling area was disturbed by hand for 60 seconds. Care was taken to ensure that all sample material flowed downstream and was captured by the net. Sample material from each transect was placed into a sample jar and preserved in 95% ethanol for lab analysis.

Water temperature, pH, dissolved oxygen, and velocity were measured at the downstream end of each reach using a digital Vernier LabQuest water quality meter. Wetted width of the stream, water depth, substrate, the presence of organic matter, and cobble embeddedness were measured and recorded at each transect. In addition, visual estimates and habitat scoring methods were used to assess the complexity of instream habitat, riparian vegetation, bank stability, and level of human influences at each transect.

2.8.4.2 Analysis and results

Transect samples were compiled for each site, sorted, and identified to 600 individual organisms per sample. Biometric values, including richness, composition, functional feeding group, and the Southern California Index of Biological Integrity (So Cal IBI), were calculated for each site. (Appendix B, Table 4.1 provides a list of all biometrics calculated, as well as a comparison of the results for Santa Rosa Creek with Coon Creek, San Luis Obispo County.) Each biometric is a characteristic of the benthic macroinvertebrate community that changes in a predictable way relative to a habitat stressor (Fore 1996). Biometrics are used as a diagnostic tool and are useful in evaluating stream health and for comparing conditions between sites, between sampling events, and with other streams.

Richness—Richness, or diversity, is the total number of individual benthic macroinvertebrate species in a sample. The more diverse a benthic macroinvertebrate assemblage, the greater the likelihood that the local habitat is also diverse and robust. Sites 2 and 3 had the lowest richness values (17 and 18 total species, respectively), while sites further upstream had greater richness (e.g., 25 to 29 total species) (Figure 2-15).

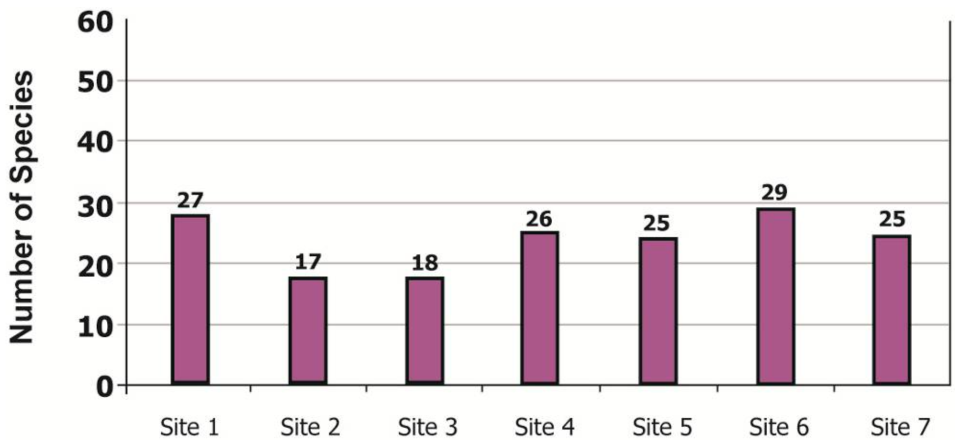

Figure 2-15. Benthic macroinvertebrate taxonomic richness at sampling sites on Santa Rosa Creek in 2010.

Composition—Composition is the percentage, or relative abundance, of particular taxa in a sample. The two composition metrics reported here are the sensitive EPT Index and the Dominant Taxa index. The sensitive EPT Index is the percentage of three pollution-sensitive orders of benthic macroinvertebrates: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The higher the percent of sensitive EPT in a sample, the greater the likelihood that local water quality is good. In general, downstream sites on Santa Rosa Creek had lower sensitive EPT Index values than upstream sites (Figure 2-16).

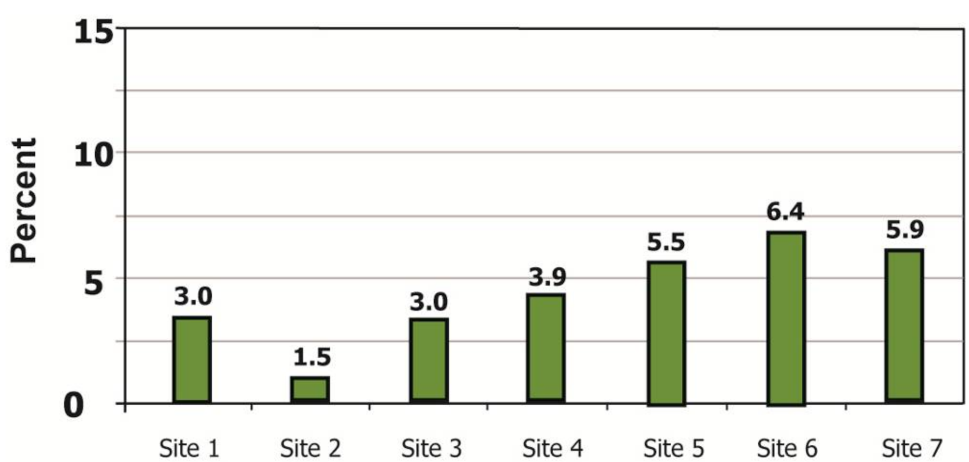

Figure 2-16. Benthic macroinvertebrate sensitive EPT Index values at sampling sites on Santa Rosa Creek in 2010.

The Dominant Taxa metric is the percentage of the third, second, and single most dominant benthic macroinvertebrate taxa in a sample. A stream with excellent water quality can support a greater number of taxa. If dominant taxa make up 40% or more of the total sample, it is an indication of instability in the macroinvertebrate community and that a stressor is present (MBNEP 2008). On Santa Rosa Creek, the three downstream-most sample sites had higher percentages of dominant taxa, indicating that a stressor is present (Figure 2-17).

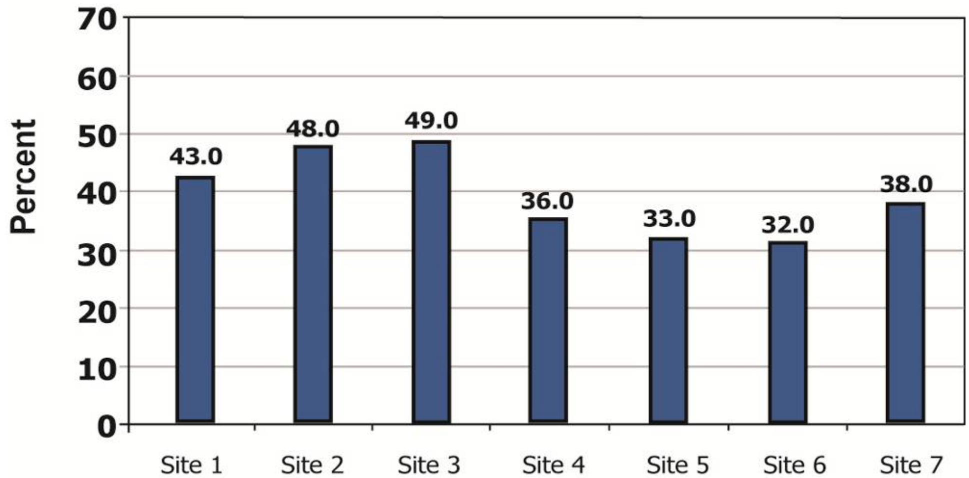

Figure 2-17. Percent of dominant benthic macroinvertebrate taxa at sampling sites on Santa Rosa Creek in 2010.

Functional Feeding Group—The functional feeding group metric is the proportion of taxa with different feeding strategies within a sample. Two types of functional feeding group metrics were calculated: the Scrappers Taxa metric and the Shredder Taxa metric. The Scrappers Taxa metric identifies the proportion of benthic macroinvertebrate taxa that graze upon periphyton. The greater the proportion of scrapper taxa, the higher the primary productivity at a sample location. On Santa Rosa Creek, downstream sites (e.g., Sites 1 through 4) had lower Scrapper Taxa values that upstream sites (e.g., Sites 5 through 7).

The Shredder Taxa metric is the percentage of benthic macroinvertebrate taxa that shred leaf litter. Higher proportions of shredder taxa indicate habitats with high retention of organic matter and food sources such as overhanging leaves and branches. On Santa Rosa Creek, Shredder Taxa values were much higher for Site 6 (3.1) and Site 7 (2.2), compared to Sites 3 and 4, where no shredder taxa where identified.

Southern California Index of Biotic Integrity—For each site, a standardized So Cal IBI score was determined. The So Cal IBI is a "condition" score that expresses the health of sites in a single qualitative number ranging from 0 to 100, with 0 representing an environment of very poor quality and low diversity and 100 being a very healthy environment with high diversity. The So Cal IBI is the sum of the following uncorrelated biometric values: (1) the number of Coleoptra (beetle) taxa; (2) the number of Ephemeroptera (mayflies), Plecoterea (stoneflies), and Trichoptera (caddisflies) (EPT) taxa; (3) the number of Predator taxa; (4) the percentage of sensitive individuals; (5) the percentage of Collector individuals; (6) the percentage of tolerant taxa; and (7) the percentage of non-insect taxa.

The So Cal IBI scores for the Santa Rosa Creek sites range from poor (34 at Site 2) to moderately good (63 at Site 6) (Figure 2-18). Site 2 (34) and Site 3 (37) exhibited the two lowest So Cal IBI scores, which suggest the likelihood of poor water quality at those sites. These sites are adjacent to the town of Cambria and, as such, experience higher levels of urban runoff. Urban runoff commonly contains higher levels of certain pollutants such as, but not limited to, heavy metals and petroleum-based pollutants, as compared to non-urban areas. These pollutants, along with physical changes to the riparian zone and stream channel that are common in urban areas, can affect the benthic macroinvertebrate community. The So Cal IBI score at Site 1, the most downstream site, is comparable to Sites 4 and 5, further upstream (Figure 2-18). The So Cal IBI scores suggest that the two most urban sampling sites, Sites 2 and 3, deserve a closer inspection of the potential influences on water quality in these areas and may warrant recommendations for land use best management practices to improve water quality in drainages leading to these sites. It should be noted however, that So Cal IBI scores can also be influenced by parameters other than water quality, such the size and quality of the riparian buffer. Thus, So Cal IBI scores should be utilized in conjunction with an understanding of local riparian conditions to guide management practices. The two upstream-most sites—Site 6 (63) and Site 7 (60)—exhibited moderately good water quality. These sites are not as affected by urban runoff but may be affected by adjacent lands uses of agriculture and ranching.

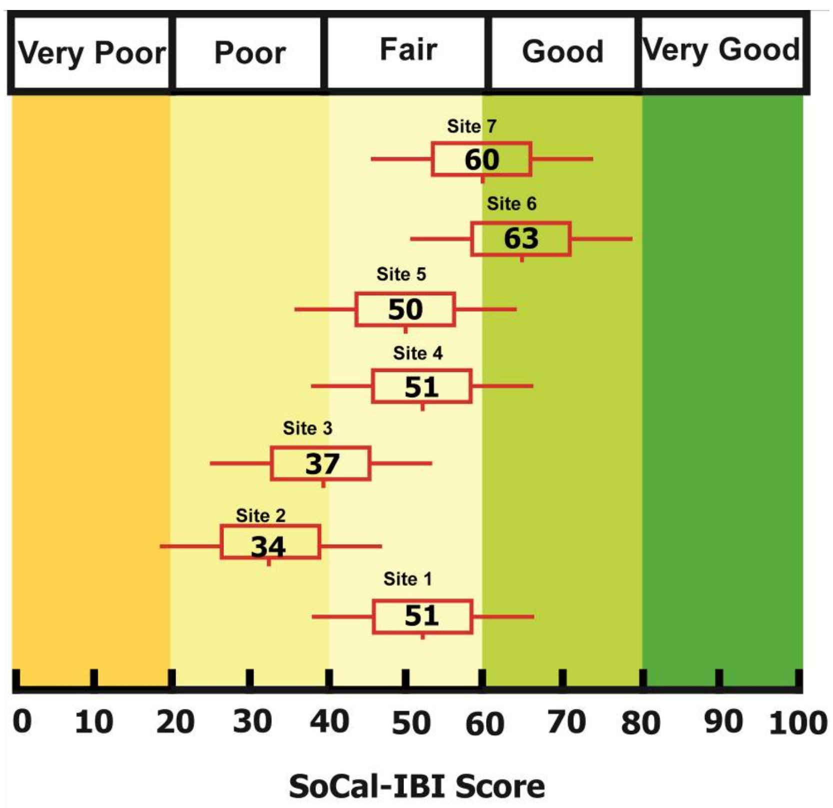

Figure 2-18. Southern California Index of Biological Integrity scores for benthic macroinvertebrate sampling sites on Santa Rosa Creek in 2010.

Another result of this study was to verify if the food supply in the Santa Rosa Creek is adequate to sustain populations of steelhead. The taxonomic lists for each site proved to have large populations of *Baetis* (mayflies) and *Simulium* (blackfly) populations, which are considered a valuable food source for steelhead (Appendix B).

The results in Appendix B can be used as a baseline for the establishment of a bio-monitoring program that tracks the impact of increased urbanization and other changes in land uses on the water quality of Santa Rosa Creek. In turn, repeated monitoring data can be useful in identifying areas that are in need of water quality improvement, and to help monitor the success of implemented restoration actions. Benthic macroinvertebrate sampling and analysis is increasingly recognized as an effective and efficient diagnostic tool for assessing water quality. The State of California is in the process of integrating benthic macroinvertebrate assessment into the water quality regulatory framework.

2.8.5 Storm water

2.8.5.1 First flush stormdrain monitoring

As a part of the development of this watershed management plan, water samples were collected in the late fall of 2010 to evaluate pollutants in the first stormwater runoff of the water year, or first flush, in the more urbanized portion of the watershed. The first flush is a unique opportunity to assess the quality of water entering creeks and streams as it carries materials, ranging from trash to road-way pollutants, which have accumulated on the landscape since the last rainfall. These constituents can be identified and analyzed in the lab, and can be used to guide the development of focused management actions to minimize the pollutants and/or prevent them from washing into waterways. Santa Rosa Creek 2010 first flush sampling sites are mapped in Figure 2-19 (sampling also occurred at the Burton Bridge and Bridge Street sites in 2011).

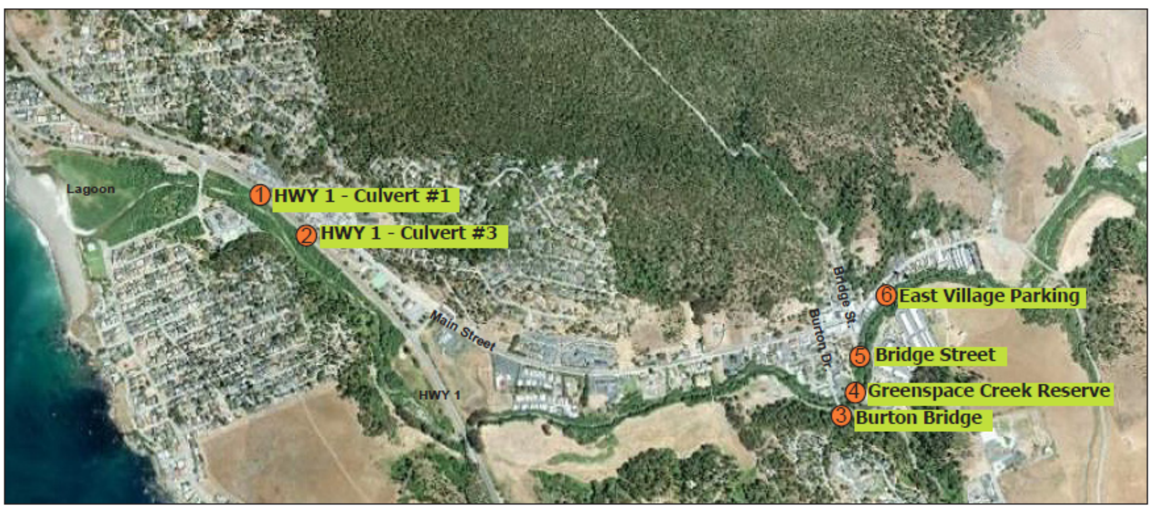

Figure 2-19. First flush sampling sites on lower Santa Rosa Creek.

Samples were collected using the Monterey Bay Sanctuary Citizen Watershed Monitoring Network's stormdrain monitoring protocol (Conrad et al. 2000). Water samples were collected directly from outfall pipes at all sample locations, except the Greenspace Creek Reserve, where samples were taken directly from the thalweg of the creek. Samples were collected in sterile Whirlpaks, stored in an ice chest, and transported to a lab for analysis at the earliest opportunity. Constituents identified in the Santa Rosa Creek first flush samples included total dissolved solids, nitrate, copper, zinc, and coliform bacteria (Table 2-7).

Table 2-7. 2010 first flush results for lower Santa Rosa Creek.

Analyte	Highway 1 Culvert #1	Highway 1 Culvert #3	Burton Bridge [a]	Greenspace Creek Reserve	Bridge Street [a]	East Village Parking	RWQCB attention level
Total Dissolved Solids (mg/L)	1,600	not detected	3,700 (80)	1,100	210 (400)	6,200	500
Nitrate as N (mg/L)	not detected	0.5	0.48	not detected	0.78	1.1	2.25
Copper (mg/L)	0.0095	0.031	0.05	0.0023	0.041 (0.73)	0.066	0.01
Zinc (mg/L)	0.04	0.075	0.15	not detected	0.18 (0.51)	0.21	0.01
Total Coliform (MPN/100 ml) [b]			(>1,600)		(>1,600)		100
Total Oil and Grease (mg/L)			(not detected)		(8)		n/a

[a] 2011 results, as available, are provided in parentheses.
[b] Total coliform is measured using the most probable number (MPN) index, which is the concentration of coliform bacteria in a sample expressed as the number of bacteria per 100 mL.

Total dissolved solids are all inorganic and organic substances that are smaller than 2 microns (0.0002 cm) in size. Total dissolved solids is not generally considered a primary pollutant but is used as an indicator of the presence of a broad array of chemical contaminants. Sources of total dissolved solids are agricultural and residential runoff (including pesticides), leaching of soil contamination, point source water pollution discharge from industrial or sewage treatment plants, and natural weathering and dissolution of rocks and soils. Total dissolved solids in the lower Santa Rosa Creek first flush samples are presented in Figure 2-20. Four of six sites exceeded the attention level set by the CCRWQCB (1994). An attention level is the concentration of a substance in a particular medium (water, soil, etc.) that may be of concern when exceeded (CCRWQCB 1994).

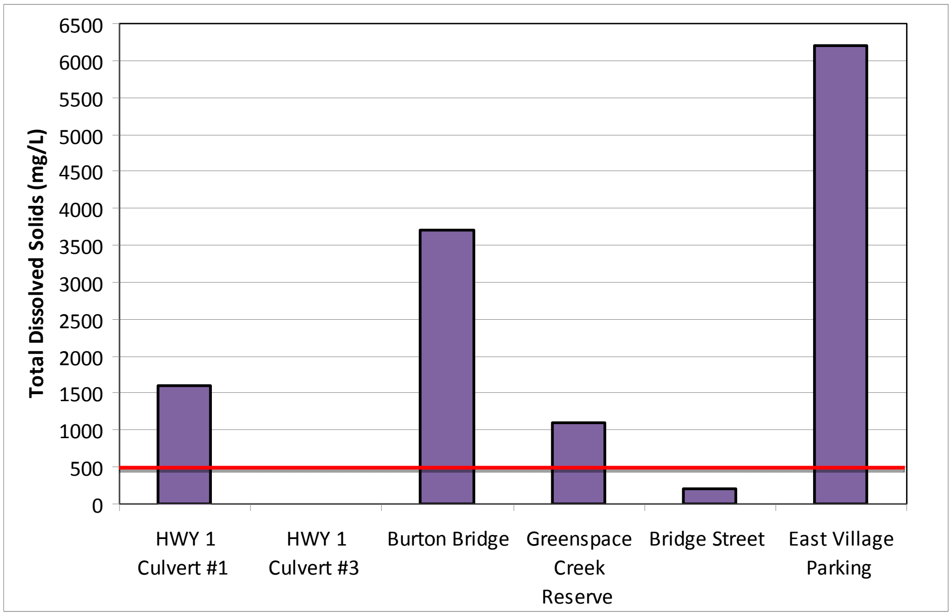

Figure 2-20. Total dissolved solids in 2010 lower Santa Rosa Creek first flush samples. The red line is 500 mg/L, the CCRWQCB (1994) attention level for total dissolved solids.

Nitrogen is a nutrient that acts as a fertilizer. When nutrient levels are high, excessive plant and algae growth can create water quality problems. Nitrogen enters water from human and animal waste, decomposing organic matter, and run-off of fertilizer from lawns and crops. Nitrate as nitrogen in the lower Santa Rosa Creek first flush samples is presented in Figure 2-21. While upstream sites have higher nitrate levels than downstream sites, none of the sites exceed the CCRWQCB (1994) attention level.

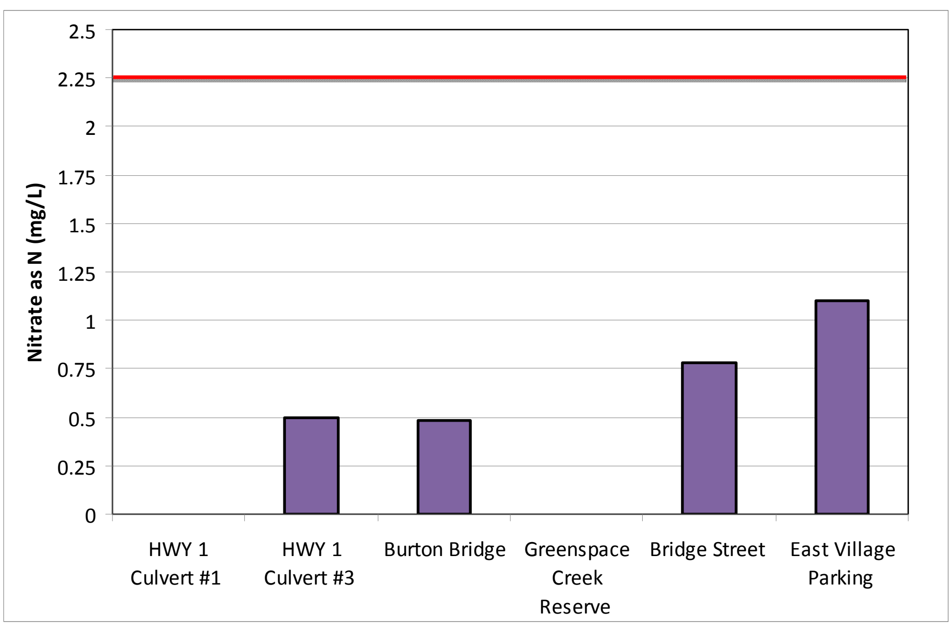

Figure 2-21. Nitrate as nitrogen in 2010 lower Santa Rosa Creek first flush samples. The red line is 2.25 mg/L, the CCRWQCB (1994) attention level for nitrate as nitrogen.

Metals such as copper and zinc may come from erosion of natural deposits, pesticides, industrial waste discharges, car brakes, agricultural waste, or corroding metal pipes and storage tanks. Trace metals can have direct toxic effects on aquatic plants and animals, and can bioaccumulate in aquatic species and have negative impacts throughout the food chain. Metals can also accumulate in sediment and be resuspended during storm events. Dissolved copper and zinc concentrations in the lower Santa Rosa Creek first flush samples are presented in Figures 2-22 and 2-23, respectively. The majority of sites on lower Santa Rosa Creek exceed CCRWQCB (1994) attention levels, but the attention levels are dependent on water hardness: copper and zinc are more toxic in softer water and less toxic in harder water (Ebrahimpour 2010). The Santa Rosa Creek results have not been adjusted for water hardness. Given the documented copper and zinc levels, a toxicity threshold that incorporates water hardness should be calculated.

Fecal coliform in the 2011 samples at the Bridge Street and Burton Bridge sites exceeded the limits of the lab test that was conducted. As such, it is not possible to determine if coliform levels in the creek exceeded the CCRWQCB (1994) attention level. However, the documented levels are high enough to suggest septic system or sewer leaks and fecal test should be conducted.

The first flush results represent an initial attempt at characterizing the types and quantities of pollutants in stormwater runoff in the more urban areas of the watershed. With additional resources a more robust first flush program could be initiated and conducted over time to more fully understand the trends in and degree of urban water quality influence on Santa Rosa Creek habitats and aquatic species.

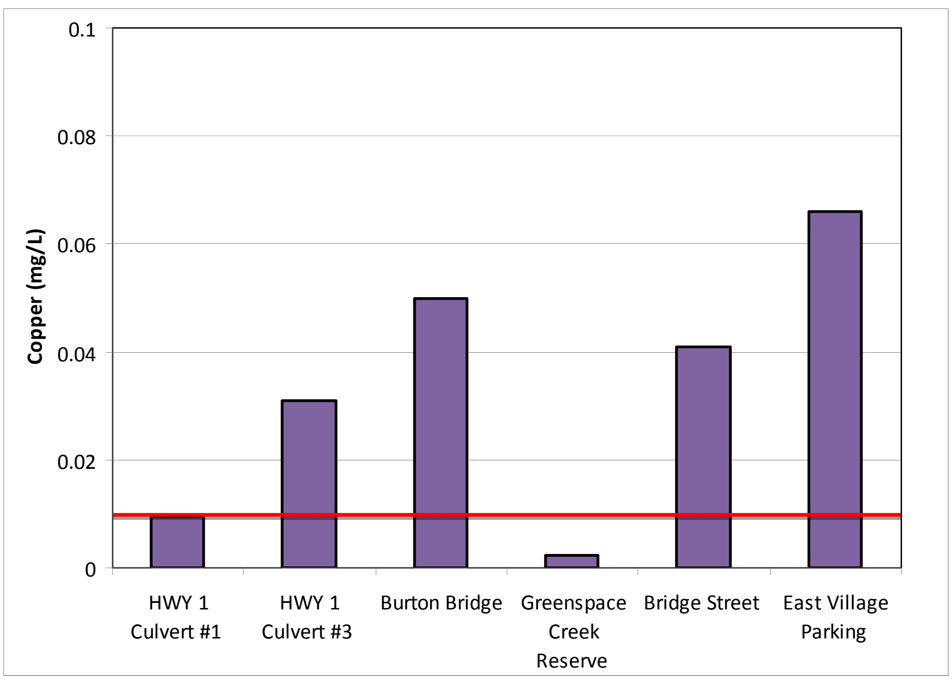

Figure 2-22. Dissolved copper in 2010 lower Santa Rosa Creek first flush samples. The red line is 0.01 mg/L, the CCRWQCB (1994) attention level for copper.

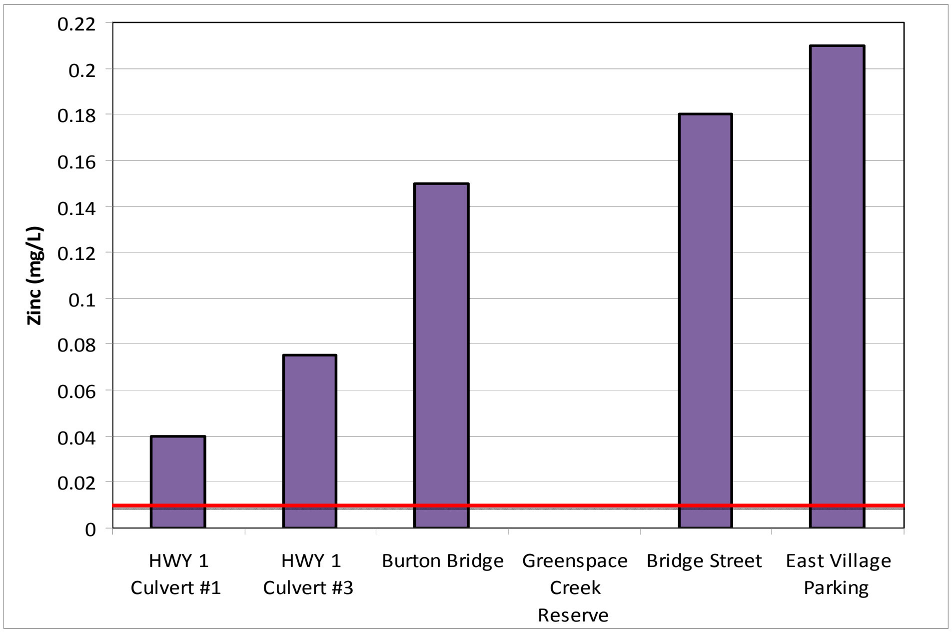

Figure 2-23. Dissolved zinc in 2010 lower Santa Rosa Creek first flush samples. The red line is 0.01 mg/L, the CCRWQCB (1994) attention level for copper.

2.8.5.2 Drainage-related erosion and flooding

Storm water related erosion, drainage problems, and flooding have been documented in a number of Cambria's residential neighborhoods. In 1999 an erosion and sediment study was commissioned for the Lodge Hill neighborhood after local residents, San Luis Obispo County staff, and local media documented storm water related drainage problems in the neighborhood (USDA NRCS 1999). While the study concluded that storm water erosion rates were not high enough to be a major source of sediment to nearby waterways and the Pacific Ocean, it documented steeply sloped unpaved roads, tire action from large vehicles, and construction sites with inadequate erosion control measures as sources of fine sediment during storm water flows (USDA NRCS 1999). The study report warned that without a coherent system of storm water management in the neighborhood, storm water drainage and erosion issues would worsen as more residences are constructed (USDA NRCS 1999). Study recommendations included developing a comprehensive master plan for built-out neighborhood conditions that incorporates a street drainage network, paved roads, and measures to address concentrated storm water flow and reduce impacts on forest resources (USDA NRCS 1999).

Flood damage to homes and businesses in March 2001 prompted San Luis Obispo County to commission another drainage study for additional Cambria neighborhoods (RMC 2004). The study found that the combination of steep topography in many Cambria neighborhoods, the lack of underground drainage facilities, and the location of many parcels below street grade results in localized poor drainage and flooding of some residences, buildings, and roadways during storm events (RMC 2004). Storm water-related flooding and erosion were found to be a result primarily of upslope concentrated flows entering downhill lots without any storm drain facilities. The study proposed a number of projects to capture storm water runoff from residential lots and roadways and convey it to a creek or to the ocean. Projects include paving roads with rolled asphalt berms, installing drop inlets or catch basins, and constructing roadside ditches and drainage channels (RMC 2004). Project implementation is likely to be the responsibility of individual property owners, developers, and/or a local entity, working in collaboration with the County Flood Control and Water Conservation District. The 2004 study noted that new development is expected to substantially increase storm water runoff in Cambria neighborhoods, particularly in Lodge Hill where many roads are unpaved, and that any proposed development in the Cambria area should be planned with drainage improvements.

Together the 1999 and 2004 drainage studies indicate that storm water is not being adequately planned for or managed in Cambria's residential neighborhoods. Although current rates of runoff and erosion from neighborhoods do not appear to be significantly affecting habitat conditions in Santa Rosa Creek, both studies warned that storm water issues can be expected to worsen if development continues in the Cambria area, unless meaningful steps are taken to plan for and address road- and home lot-related storm water runoff.

2.9 Vegetation

2.9.1 Vegetation types and distribution

The Santa Rosa Creek watershed is dominated (63% of watershed total) by grassland/herbaceous vegetation, much of which is used for cattle ranching and dairy cattle pasture (Homer et al. 2004) (Table 2-8, Figure 2-24). Throughout the watershed, scrub/shrub (coastal and chaparral) is found in steeper, upland areas and mixed-hardwood forest types, such as California bay tree (*Umbellularia californica*), occur in riparian areas. In the inland portions of the watershed, mixed-hardwood forest, such as coast live oak (*Quercus agrifolia*), and stands of evergreen forest occur on ungrazed hillslopes. Closer to the coast, stands of Monterey pine (*Pinus radiata*) evergreen forest occur near Cambria, and woody and emergent herbaceous wetland vegetation, such as willows (*Salix* spp.) are found primarily around the lagoon (Figure 2-24). While the National Landcover Dataset of 2001 (Homer et al. 2004) was used to generate the summary of data in Table 2-8 and map of vegetation in the watershed (Figure 2-24), the vegetation descriptions provided below are based, in part, on the compilation and description of multiple vegetation maps for the watershed by TLCSLOC (2010).

Table 2-8. Vegetation types in the Santa Rosa Creek watershed.[a]

Landcover/Vegetation type		Area (acres)	Area (hectares)	% of watershed area[b]
Grassland/Herbaceous		19,256	7,793	63
Scrub/Shrub		3,235	1,309	11
Mixed Forest		2,899	1,173	10
Developed	Open Space	1,951	790	6
	Low Intensity	409	165	1
	Medium Intensity	124	50	0.4
	High Intensity	3	1	0.01
Evergreen Forest		1,958	792	6
Cultivated Crops		360	146	1
Woody Wetlands		153	62	1
Pasture/Hay		37	14	0.1
Emergent Herbaceous Wetland		4	2	0.01

[a] Source: 2001 National Land Cover Data (Homer et al. 2004)
[b] Proportion of land cover category within the total watershed area determined in GIS.

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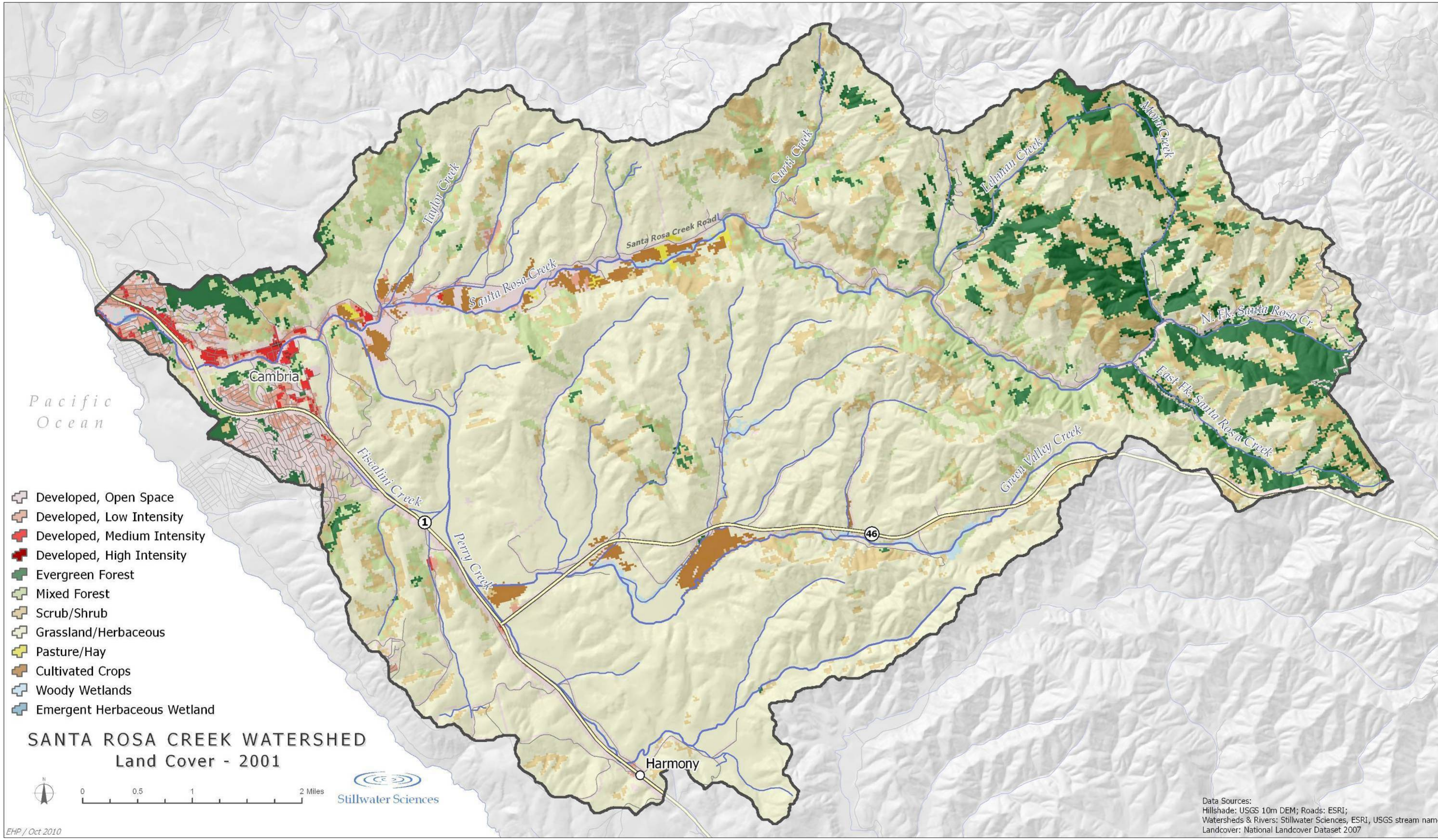

Figure 2-24. Vegetation/land cover types within the Santa Rosa Creek watershed.

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2.9.1.1 Grassland/Herbaceous

Grasslands dominate much of the watershed (Figure 2-24). Like most grasslands in California, those in the Santa Rosa Creek watershed are likely dominated by non-native grass species that are now considered naturalized (TLCSLOC 2010). For example, non-native wild oat (*Avena* spp.), soft chess (*Bromus hordeacous*), rip-gut brome (*B. diandrus*), and Italian ryegrass (*Lolium multiflorum*) are the dominant grass species in the Fiscalini Ranch Preserve (the old East-West Ranch), along with common weedy species such as filaree (*Erodium cicutarium*), vetch (*Vicia* sp.), black mustard (*Brassica nigra*), prickly lettuce (*Lactuca serriola*), storksbill (*Erodium botrys*), summer mustard (*Hirschfeldia incana*), milk thistle (*Silybum marianum*), wild radish (*Raphanus sativa*), mayweed (*Anthemis cotula*), Italian thistle (*Carduus pyncnocephalus*), coast morning glory *(Calystegia macrostegia* ssp*. cyclostegia*), and scarlet pimpernel (*Anagallis arvensis*) (Morro Group 2009). Despite being dominated by non-native species, grasslands in the Fiscalini Ranch Preserve have been documented to contain several native grasses and forbs that are indicative of native coastal prairie, such as California oat grass (*Danthonia californica*), hairgrass (*Deschampsia elongata*), purple needle grass (*Nassella pulchra*), sky lupine (*Lupinus nanus*), California poppy (*Eschscholzia californica*), tidy tips (*Layia platyglossa*), and California buttercup (*Ranunculus californicus*) (Ford and Hayes 2006, Morro Group 2009). Coastal prairie vegetation, which occurs in fog-influenced areas from the Oregon border to northern Santa Barbara County, is increasingly rare and endangered (Ford and Hayes 2006). Even though coastal prairie also tends to be dominated by non-native grasses, it supports a high diversity of native perennial grasses and forbs, many of which are endangered, threatened, or rare species, particularly when exposed to appropriate magnitudes and durations of cattle, goat, and/or sheep grazing and burning (Hayes and Holl 2003). Given the magnitude of coastal fog influence and cattle grazing in the watershed, it is quite likely that coastal prairie vegetation is supported in at least some areas mapped as grassland/herbaceous. As a result of this loss and the number of protected plant and animal species associated with this vegetation type, there is increasing interest and effort to preserve and maintain coastal prairie through land acquisition, and grazing and fire management.

2.9.1.2 Scrub/Shrub

Chaparral, coastal scrub, and coast mixed shrub occur in patches throughout the watershed (Figure 2-24). Chaparral and southern coastal scrub communities generally grow in dense thickets, and are dominated by drought-tolerant long-lived shrubs, such as manzanita (*Arctostaphylos* spp.), California sagebrush *(Artemisia californica*), sage *(Salvia* spp*.),* and coyote bush (*Baccharis pilularis*) (TLCSLOC 2010). These communities are also highly flammable and adapted to occasional disturbance by fire, which facilitates seed germination and regeneration of some dominant species. Like coastal prairie, these coastal scrub vegetation types are increasingly rare and endangered (Ford and Hayes 2006). As such, many coastal scrub and coastal prairie vegetation alliances are afforded protection by the State of California, either as CDFG-recognized special natural communities or as the host of state-protected plant and animal species (CDFG 2003a; Hillyard 2009).

Scrub/Shrub and Mixed Forest vegetation in the upper Santa Rosa Creek watershed

2.9.1.3 Mixed forest

Both coast live oak and blue oak woodlands are components of areas mapped as Mixed Forest in the Santa Rosa Creek watershed. Coast live oak woodlands can occur on more moist, often north-facing slopes or in drier, more exposed areas (TLCSLOC 2010). In moister areas, coast live oak (*Quercus agrifolia*) generally forms dense forests with California bay-laurel (*Umbellularia californica*), madrone (*Arbutus menziesii*), and big-leaf maple (*Acer macrophyllum*), with a variety of shade-tolerant understory plants (TLCSLOC 2010). In drier areas, coast live oak woodlands are characterized by sparsely scattered oaks among either shrubby or herbaceous understory plants, or integrated with grasslands (TLCSLOC 2010). Blue oak (*Q. douglasii*) woodlands occur in the warmer, drier eastern portion of the watershed.

Areas of Mixed Forest also include bands of riparian vegetation that occur along most of the larger channels in the watershed (Figure 2-24). CDFG (Nelson et al. 2009) noted abrupt changes in the composition and condition of riparian vegetation as one moves downstream:

> From the headwaters down to stream mile 7.8, the creek flows through a sinuous confined canyon where oaks, California bay and alder are the dominant tree species. Grasses, sedges and other herbaceous species comprised the understory. At stream mile 7.8, the creek abruptly discharges from the narrow canyon into a broad valley with a poorly defined creek channel, extensive gravel bars and flood plains, short, denuded stream banks and intermittent willow trees, mule fat and grasses. … From stream mile 6.5 downstream to stream mile 3, the valley floor is still broad, however the stream channel is incised. Riparian species include alder, willow, cottonwood, sycamore and a dense herbaceous understory. Downstream of this point the valley constricts somewhat and the town of Cambria surrounds the creek. Much of channel in this area is lined with rip rap and the riparian has been encroached upon by development. The native vegetation along the creek includes willow, poison oak, stinging nettle and blackberry, however extensive stands of non-native trees, shrubs and ivy dominate the riparian zone to the exclusion of native vegetation.

Riparian canopy conditions are further described in Section 2.9.4 below.

2.9.1.4 Evergreen forest

Much of the Evergreen forest mapped in the lower watershed is Monterey pine (*Pinus radiata*) (Figure 2-24). There are approximately 3,500 acres of Monterey pine forest in and around the community of Cambria (both within and outside the Santa Rosa Creek watershed), which constitutes approximately 17% of the remaining native Monterey pine forest in California and Baja California (Cambria Forest Committee 2002). In natural stands, Monterey pine forms a closed canopy forest with coast live oak, and toyon (*Heteromeles arbutifolia*), with various shrubs and herbs in the understory (Cambria Forest Committee 2002, TLCSLOC 2010). Approximately 1/3 of the Cambria Monterey pine forest intergrades with developed areas (Cambria Forest Committee 2002). The Cambria Forest Management Plan was developed in 2002 to guide conservation and management of the Cambria Monterey pine forest, in part as a response to continued threats to the forest by pine pitch canker disease and urban development. Monterey pine has also been planted extensively outside of its indigenous range, both in California and around the world.

Evergreen forest in the upper watershed is likely a mix of hardwoods, gray pine (*Pinus sabiniana*), and potentially Douglas fir (*Pseudotsuga douglasii*).

2.9.1.5 Woody and emergent herbaceous wetlands

During periods of low flow and when the sandbar at Moonstone Beach is closed, a seasonal lagoon forms at the downstream end of Santa Rosa Creek. The seasonal lagoon supports a fringe of riparian vegetation at its upstream end and wetland species, such as cattail (*Typha* spp.) that are tolerant of continuous inundation, along the water's edge. Small patches of salt marsh vegetation that are tolerant of the brackish water conditions closer to the ocean occur along the waters edge at the downstream end of the seasonal lagoon. Small patches of dune vegetation occur on the beach, outside of the seasonal lagoon inundation area (Z. Diggory, pers. obs., 2009).

2.9.2 Rare plant species and vegetation types

TLCSLOC (2010) identified special-status plant species with the potential to occur in the watershed using CDFG's California Natural Diversity Data Base (CNDDB) and the California Native Plant Society's (CNPS) Inventory of Rare and Endangered Plants online database. Queries of these databases, which included the Cambria and Cypress Mountain 7.5 minute quadrangles, identified 21 plant species with the potential to occur in the watershed that are listed by CNPS as rare, threatened, or endangered in California and elsewhere (CNPS List 1B). These are primarily perennial herb species, but also include five manzanita species and several other shrubs, as well as Monterey pine (TLCSLOC 2010). Of these, Cambria morning-glory (*Calystegia subacaulis* ssp. *episcopalism*), Obispo Indian paintbrush (*Castilleja densiflora* ssp. *obispoensis*), compact cobwebby thistle (*Cirsium occidentale* var. *compactum*), and Monterey pine (*Pinus radiata*) have been documented to occur in the watershed, specifically in the Fiscalini Ranch Preserve (Morro Group 2009).

As described earlier, Cambria supports a notable percentage of the remaining natural stands of Monterey pine in California and Baja California (Cambria Forest Committee 2002). Natural Monterey pine forests are recognized in the CNDDB as a special natural community (CDFG 2003a), and this population in particular is protected by the Coastal Commission as an Environmentally Sensitive Habitat Area (ESHA). In addition, the Fiscalini Ranch Preserve supports Valley Needlegrass Grassland vegetation, which is composed of purple needlegrass (*Nassella pulchra*), a native bunchgrass that was once an abundant component of the California grassland flora and is recognized in the CNDDB as a special natural community (CDFG 2003a, Morro Group 2009).

2.9.3 Non-native invasive plant species

Combined, over 200 non-native invasive plants observed or with the potential to occur in the Santa Rosa Creek watershed have been identified by CDFG (Nelson et al. 2009), TLCSLOC (2010), Morro Group (2009), and Cambria Forest Committee (2002). This includes the non-native grassland species described in Section 2.9.1. Several of these species are particularly troublesome as they are already widely distributed, are highly effective at replacing native vegetation, are known to disrupt and impair native habitat, or require aggressive treatment to control. These include:

- arundo/giant reed (*Arundo donax*)
- pampas grass (*Cortaderia selloana and/or C. jubata*)
- Scotch broom (*Cytisus scoparius)*
- cape ivy (*Delairea odorata*)
- eucalyptus (*Eucalyptus* sp.)
- French broom (*Genista monspessulana*)

During a survey of the lower 14 mi (22 km) of Santa Rosa Creek, CDFG noted the presence and general distribution of non-native plants in the riparian corridor (Nelson et al. 2009).
The greatest diversity of non-native invasive plants in the riparian corridor was found to occur in the lower 6 mi (10 km) of the creek, and at stream mile two specifically (Nelson et al. 2009). The residential and commercial land uses that occur close to the creek in this area are likely responsible for the intentional and/or accidental introduction of most of these plants, many of which are commonly found in gardens (e.g., palm trees, nasturtium, and periwinkle). With only two exceptions, no non-native plant species were observed between stream miles 11 and 14 (Nelson et al. 2009).

Eucalyptus, planted throughout California in the late 1800's for wharf construction and fence post production and to provide wind breaks, was recorded as relatively dense stands on the streambank in some locations. Eucalyptus often precludes the establishment and/or growth of understory species because of its allelopathic properties; oils in the leaves and bark that fall to the ground prevent or greatly reduce the ability of other plants to grow. CCSD is currently planning a eucalyptus removal project along the lower creek, downstream of the Highway 1 Bridge (B. Boer, pers. comm., 2010).

Cape ivy infestation near the lagoon

CDFG noted that "cape ivy was found from stream mile 10 downstream, but was most extensive in stream miles 5 and 6" (Nelson et al. 2009). In some areas, cape ivy was found to completely cover the streambank. In these and other cases, the extent of cape ivy is likely sufficient to preclude the establishment of native plants that would better shade the creek and help moderate stream temperatures as well as provide habitat for native wildlife species. Although Nelson et al. (2009) noted pampas grass in several areas in the lower 6 mi (9 km) of the creek, this was most likely jubata grass, which is easily confused with pampas grass but is more prevalent along the San Luis Obispo County coast (DiTomaso 2000). Large infestations of pampas grass and jubata grass threaten California's coastal ecosystems by crowding out native species, particularly in sensitive coastal dune areas.

Only one patch of arundo was recorded by CDFG, near stream mile 14 (Nelson et al. 2009). Arundo is a highly invasive species in central and southern California riparian environments and can rapidly displace native vegetation and alter riparian habitat conditions. This occurrence of arundo should be an extremely high priority for eradication to prevent it from spreading farther downstream.

In addition to cape ivy and pampas grass, the Cambria Forest Committee (2002) also noted that French broom and Scotch broom are the most abundant invasive species in the Cambria area, and the ones that will require the most aggressive treatments.

2.9.4 Riparian vegetation conditions

When of sufficient width and density, riparian vegetation performs many functions in natural river systems. It provides a buffer between the stream and adjacent land uses, reduces erosion, and filters runoff and nutrients, thereby reducing the delivery of fine sediment and pollutants to the stream. Riparian vegetation provides habitat for terrestrial wildlife and nesting birds, movement corridors for wildlife, and woody debris for instream habitat. Riparian canopy cover supplies leaf litter and terrestrial invertebrates for the aquatic foodweb and moderates stream temperatures by shading the channel and reducing near-stream windspeed (Poole and Berman 2001). The conservation and restoration of riparian vegetation, therefore, provides a relatively straightforward and cost-effective way for landowners and other watershed stakeholders to conserve and enhance myriad ecosystem conditions.

Following California statehood in 1850, Americans quickly settled the watershed and greatly increased the pace of land clearing, which was reportedly achieved by cutting and/or burning the native vegetation (Coffman 1995, D. Dunlap, pers. comm., 2009). Historical accounts from across the coastal region tell of coordinated efforts by land owners to clear valley-bottom forests along major rivers (Boughton et al. 2006), which was likely practiced along Santa Rosa, Perry, and Green Valley creek valleys. Historical illustrations of ranches in the watershed from the late 1800s and the earliest aerial photographs of the watershed in 1937 indicate only narrow strands of riparian vegetation along streams. Aerial photography taken in 2009 reveals a considerable increase in riparian vegetation extent and density compared with 1937 (Figure 2-5).

Outside of Cambria, the ability of riparian vegetation to recruit and grow is limited by cattle grazing in the riparian corridor, the effect of which is apparent in the denuded streambanks in much of the Perry/Green Valley Creek sub-watershed, and to some extent by groundwater conditions, such as in the middle reaches of Santa Rosa Creek. Encroaching riparian vegetation is also occasionally removed from the channel in wet water years in the vicinity of bridges and other public works by the San Luis Obispo County Public Works Department to reduce the risk of flooding (B. Boer, pers. comm., 2010).

While riparian vegetation extent has recovered since the 1930s, it is now limited by urban development and infrastructure, which limits the area where riparian vegetation can establish (see Figure 2-25) and is a source of non-native invasive plant species (see Section 2.9.3 above). Riparian canopy cover conditions on Santa Rosa Creek vary by reach and are strongly influenced by stream flow. Between 1994 and 2006, tree canopy closure (i.e., the percent of the channel covered by the riparian tree canopy) was measured every four years in the lower 13 mi (20 km) of Santa Rosa Creek in association with steelhead population and habitat surveys (D. W. Alley & Associates 2008). CDFG also measured riparian canopy density at approximately one-third of the habitat units mapped during a survey of steelhead in the lower 14 mi (22 km) of the creek (Nelson et al. 2009). Table 2-9 summarizes the results of the D. W. Alley & Associates (2008) tree canopy measurements.

Figure 2-25. Historical (1937) and current (2009) aerial photographs of riparian corridor conditions in the lower reach of Santa Rosa Creek and near the town of Cambria.

Table 2-9. Tree canopy closure in the lower 13 mi (20 km) of Santa Rosa Creek.[a]

Reach location (stream miles)	Tree canopy closure (percent) [b]				
	1994	1998	2002	2006	Average
0.5–2.9	n/a	33	42	27	34
2.9–3.4	n/a	40	54	42	45
3.4–4.2	44	36	53	42	44
4.2–7.9	44	32	33	24	33
7.9–9.6	57	34	55	44	48
9.6–10.1	72	63	67	58	65
10.1–11.2	63	63	77	67	68
11.2–11.5	52	70	80	85 [c]	72
11.5–12.4	59	71	77	70	69
12.4–13.0	59	70	74	68	68
Average	56	51	61	53	

[a] Source: D. W. Alley & Associates (2008). Values are estimated from Figure A18 and correspond with values reported in the text, with the exception of reaches 0b and 2 in 2002. The text reports these values as 61 and 54 percent, respectively.
[b] Measurements were taken in the fall and are estimated to be between 5 and 10 percent lower than during summer due to the onset of leaf-fall (D. W. Alley & Associates 2008).
[c] The Reach 5 sampling site was relocated into the upper portion of Reach 4 in 2006 (D. W. Alley & Associates 2008).

Tree canopy closure ranged from a low of 24% between stream miles 4.2–7.9 to a high of 85% between stream miles 11.2–11.5 (both in 2006), and varied by both reach and year (Table 2-9). The lower 8 mi (12 km) of the creek (reaches 0a–2), where the channel is widest, had consistently lower ranges and average canopy closure than in the upper reaches (Table 2-9). This is to be expected since higher levels of canopy closure are easier to maintain across narrower channels. This same pattern was observed by CDFG, who recorded canopy closures between 17% and 46% in the lower 8 mi (12 km) of the creek, and 23% to 57% in the upper 6 mi (9 km) (Nelson et al. 2009).

The lower 10 mi (16 km) of the creek experienced a decline in canopy closure between 1994 and 1998 in response to the March 1995 flood. D. W. Alley & Associates (2008) report that "[t]he entire riparian corridor, with all of its trees, was washed away for miles in the lower valley during that one storm flow. Many tree-less vertical banks were left afterwards, even in the straight-aways." Conversely, the canopy closure in the upper three reaches increased by approximately 10% between 1994 and 1998. By 2002, canopy closure had recovered to at least 1994-levels in most of the lower reaches. The high-flow event of 2005, which was a particularly wet year, likely contributed to the decline in canopy closure experienced in all reaches between 2002 and 2006.

The difference in canopy closure between the lower and upper reaches suggests that riparian vegetation is more effective at moderating stream temperatures in the upper reaches. This is demonstrated by the generally lower water temperature measured in the upper watershed by CDFG (see Section 2.8.1 above). The variation in canopy closure over the years, which appears to be driven largely by high-flow events, implies that the ability of riparian vegetation to shade the channel and effectively moderate stream temperatures also varies over time. In the years immediately following a scouring high-flow event, riparian vegetation is likely less effective at moderating stream temperatures and providing other ecosystem services, regaining its effectiveness as it re-grows. The typically more pronounced decline in canopy closure in the lower reaches of the creek following high-flow events further limits the ability of riparian vegetation to moderate stream temperatures in these reaches.

2.10 Wildlife

The diversity of vegetation types, as well as aquatic environments, in the Santa Rosa Creek watershed support a wide variety of habitat for a number of fish and wildlife species. TLCSLOC (2010) and Fiscalini Ranch Preserve final Master Environmental Impact Report (Morro Group 2009) both summarize the wildlife species that have been observed or are likely to occur in the habitat types found throughout the watershed. As the focal species of this watershed management plan, steelhead life history, habitat requirements, and population in the Santa Rosa Creek watershed is the primary focus of this section. In addition, this section summarizes other special-status species that occur in the watershed, with an emphasis on those species whose life history, habitat requirements, and population trends provide further insight into watershed conditions and the development of appropriate management and restoration action, as well as documented non-native invasive species.

2.10.1 Steelhead

Steelhead (*Oncorhynchus mykiss irideus*) found in the Santa Rosa Creek watershed belong to the South-Central California Coast Distinct Population Segment (DPS), which includes most streams in Monterey, San Benito, Santa Clara, Santa Cruz, and San Luis Obispo counties between the Pajaro (inclusive) and Santa Maria (exclusive) rivers (NMFS 1997, 2006). This DPS is listed as threatened under the federal Endangered Species Act (NMFS 1997, 2006), and is a CDFG species of special concern. The life history of south-central California coast steelhead and their population trends in Santa Rosa Creek are described below. As the focal species of this watershed management plan, factors limiting steelhead in the watershed are discussed in detail in Section 3.

2.10.1.1 Life history

Steelhead is the term commonly used for the anadromous life history form of *O. mykiss*, and rainbow trout is the term for the resident life history. Both steelhead and rainbow trout are expressed within the Santa Rosa Creek watershed (Nelson et al. 2009), although detailed information on the relative proportion of each life history type is not available. The relationship between anadromous and resident life history forms of this species is the subject of ongoing research. The two forms are capable of interbreeding and current evidence suggests that, under some conditions, either life history form can produce offspring that exhibit the alternate form (i.e., resident rainbow trout can produce anadromous progeny and vice-versa) (Burgner et al. 1992, Donohoe et al. 2008, Zimmerman et al. 2009), although in some watersheds the two life histories are distinct (e.g., Pearse et al. 2009).

Steelhead return to spawn in their natal stream, usually in their third or fourth year of life, with males typically returning to fresh water earlier than females (Shapovalov and Taft 1954, Behnke 1992). Adult steelhead are known to stray from their natal streams to spawn in nearby streams and, in more hydrologically variable streams of the central coast such as Santa Rosa Creek, straying is often more prevalent (Clemento et al. 2009, Pearse et al. 2009). Based on variability in life history timing, steelhead are broadly categorized into winter and summer reproductive ecotypes. Only the winter ecotype (winter-run) occurs in Santa Rosa Creek. Winter-run steelhead generally enter spawning streams from late fall through spring as sexually mature adults, and spawn in late winter or spring (Shapovalov and Taft 1954, Behnke 1992, Busby et al. 1996). Little data on steelhead spawning time exist for Santa Rosa Creek, although both spawning time and distribution within the watershed appear to be related to time and duration of sandbar opening at the Santa Rosa Creek lagoon and winter discharge (D. W. Alley & Associates 2008, Nelson et al. 2009). Peak spawning time for other steelhead populations in the South-Central California Coast ESU is generally between January and March (Busby et al. 1996).

Female steelhead construct redds in suitable gravels, often in pool tailouts, or in isolated gravel patches in cobble and boulder dominated streams (McEwan and Jackson 1996). Eggs incubate in redds for 3–14 weeks, depending on water temperatures (Shapovalov and Taft 1954, Moyle 2002). After hatching, alevins remain in the gravel for an additional two–five weeks while absorbing their yolk sacs, and then emerge in spring or early summer (Moyle 2002). After emergence in late-spring and summer, steelhead fry move to shallow-water, low-velocity habitat, such as stream margins and low-gradient riffles, and forage in open areas lacking instream cover (Hartman 1965, Fontaine 1988). As fry grow and improve their swimming abilities in the late summer and fall, they increasingly use areas with cover and show a preference for higher velocity, deeper mid-channel areas near the thalweg (the deepest part of the channel) (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). Juvenile steelhead occupy a wide range of habitats, using deep pools as well as higher-velocity riffle and run habitat (Bisson et al. 1982, Bisson et al. 1988). During periods of low temperatures and high flows that occur in winter months, steelhead prefer low-velocity pool habitat with large rocky substrate or woody debris for cover (Hartman 1965, Raleigh et al. 1984, Fontaine 1988).

Juvenile[6] steelhead in northern and central California typically spend one to two years in freshwater prior to smolting[7] and outmigration to the ocean (Shapovalov and Taft 1954). The duration of time they spend in fresh water appears to be related to growth rate, with larger, faster-growing members of a cohort smolting earlier (Hayes et al. 2008). Depending partly on growing conditions in their rearing habitat, steelhead may migrate downstream to estuaries as young-of-the-year (YOY) or may rear in streams for up to four years before outmigrating to the estuary and ocean (Shapovalov and Taft 1954). Some steelhead in the lower 8 mi of Santa Rosa Creek likely require only one year of growth before reaching smolt size (approximately 6–7 in [150–180 mm]), whereas most fish above stream mile 8 typically require two years depending on availability of food and streamflow (D. W. Alley & Associates 2008). Age data from scale analysis and corresponding length data from individuals collected in the lower 8 mi of Santa Rosa Creek indicate that many individuals reach 4–5 in (120–140 mm) fork length[8] by their first fall (D. W. Alley & Associates 2008).

There is very little data describing juvenile steelhead life history strategies expressed in Santa Rosa Creek. Limited outmigrant trapping in Santa Rosa Creek suggests some individuals rear in upstream reaches before outmigrating as smolt, and some migrate to the lower reaches and lagoon at smaller sizes/younger ages (D. W. Alley & Associates 2008, Nelson et al. 2009). A portion of Santa Rosa Creek juvenile steelhead appear to have historically reared in the lagoon prior to outmigration (Puckett 1970, as cited in Rathbun et al. 1991), and recent evidence suggests some individuals likely still do in some years (Nelson et al. 2009, Alley and Sherman 2006, D. W. Alley & Associates 2008). During summer and fall sampling in 2004, Alley and Sherman (2006) captured 101 and 69 juvenile steelhead (varying in size from approximately 1–4 in [35–94 mm]

[6] In this report juvenile steelhead refers to both young-of-the-year (YOY) and age 1+/2+, unless indicated separately. YOY are age 0+ individuals less than one year old that hatched the previous spring or early-summer and are the offspring of adults that spawned the previous winter or early-spring. Age 1+/2+ refers to all pre-smolt juveniles one year old or older. This report presents age-class-specific juvenile data from D. W. Alley & Associates (2008), who assigned age-classes based on site-specific divisions in the frequency distribution of steelhead standard-lengths (SL). Based on this sampling, YOY are likely to be between 3 and 6 months old, and age 1+/2+ are likely between 1.25 and 2.5 years old.

[7] Smolts are juvenile steelhead migrating to the ocean (i.e., smolting) that exhibiting silver coloration and have no parr marks.

[8] Fork length is measured from the tip of the snout to the fork, or middle, of the caudal (tail) fin

standard length[9]), respectively between Shamel Park and Windsor Bridge. Available water quality data also suggests that, at least in some years, conditions are suitable for steelhead rearing in the lagoon (see Section 3.5). In nearby San Luis Obispo Creek, many YOY steelhead that hatch in upper tributaries and reaches migrate downstream and rear in lower mainstem reaches prior to entering the ocean (Spina et al. 2005).

Smolt downstream migration in Santa Rosa Creek typically occurs from March through early June (D. W. Alley & Associates 2008). Trapping at Santa Rosa Creek stream mile 0.35 in 2005 revealed a peak in smolt capture from mid to late April (Nelson et al. 2009), which is consistent with that documented in nearby San Luis Obispo Creek (Spina et al. 2005). Steelhead exhibiting smolt coloration ranged from approximately 5–10 in (130–250 mm) fork length, with 6–7 in (150–180 mm) fork length being most common (Nelson et al. 2009).

2.10.1.2 Distribution and status

Annual estimates of adult escapement, the number of adults returning to spawn, are arguably the best measure of steelhead population trends (Gallagher and Gallagher 2005). Unfortunately, no actual adult steelhead escapement data are available for Santa Rosa Creek. Information on the historical adult steelhead population abundance in Santa Rosa Creek is largely anecdotal, but all available evidence points towards a decline. A study from 1969–1970 indicated that the adult steelhead run in the creek was approximately 600 individuals (Seldon 1972, as cited in Becker and Reining 2008). Based on CDFG unpublished reports and field logs, Rathbun et al. (1991) reported that steelhead were "abundant" in the Santa Rosa Creek drainage as recently as the early 1980's, but provided no adult population estimate. However, anecdotal fishermen reports indicated declines in the numbers of adult fish entering the creek between 1987 and 1991 (Rathbun et al. 1991). From 1988–1991, CDFG received only a few reports of spawning adults, and no steelhead were seen during a survey of the lower 2 miles of the creek in mid-July 1991 (Rathbun et al. 1991, Titus et al. 2006).

The apparent decline of the adult steelhead population is supported by more quantified juvenile population data. In 1972 the total juvenile population was estimate to be over 60,000 fish (Bailey 1973, as cited in Nelson 1994). An apparent population crash occurred between 1972 and 1978, when the juvenile population was estimated to be less than 10,000 (Knable 1978, as cited in Nelson 1994). The juvenile population in 1993 remained at just over 10,000 individuals (Nelson 1994). More recent population estimates (1998–2006) reported by D. W. Alley & Associates (2008), indicate an apparent rebound, with the juvenile population ranging from approximately 25,000 to 65,000. However, the different methodology used for these recent estimates makes it difficult to accurately compare them with the older estimates (Titus et al. 2006). Moreover, between 1998 and 2006 the abundance of both age 0+, also referred to as young-of-the-year (YOY), and age 1+/2+ juvenile steelhead in Santa Rosa Creek significantly declined (D. W. Alley & Associates 2008) (Figures 2-26 and 2-27).

[9] Standard length is measured from the tip of the snout to the anterior edge of the caudal fin (excludes caudal fin).

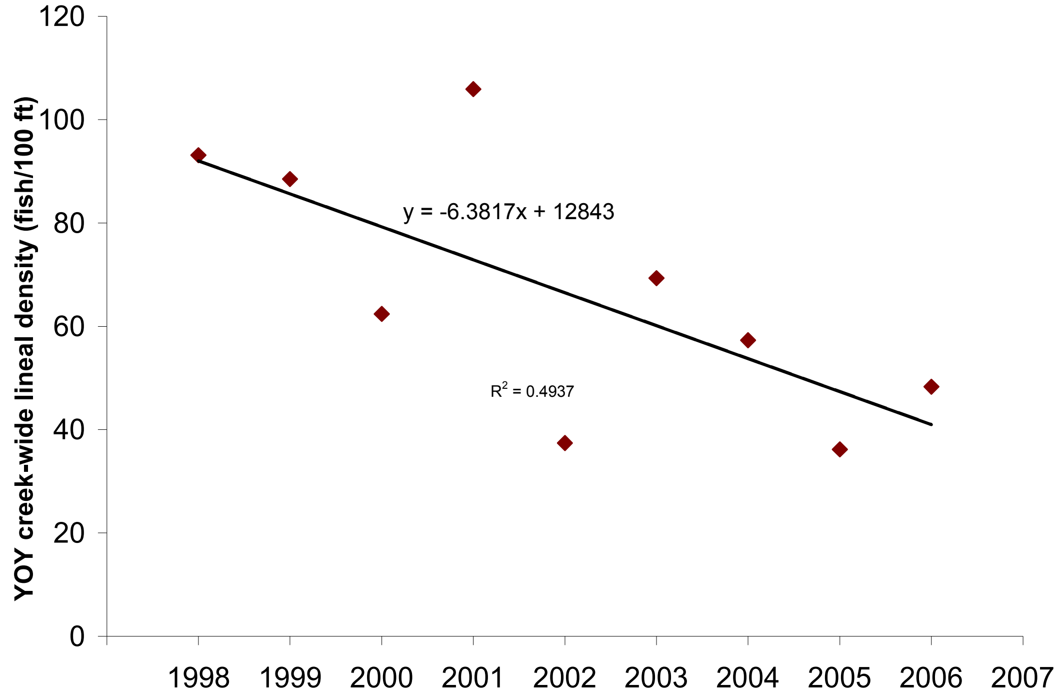

Figure 2-26. Lineal density (fish/100 ft) of YOY steelhead in Santa Rosa Creek from 1998 to 2006 (r^2 = 0.4937; *P* = 0.0348; n = 9). Data source: D. W. Alley and Associates (2007, Table 25a).

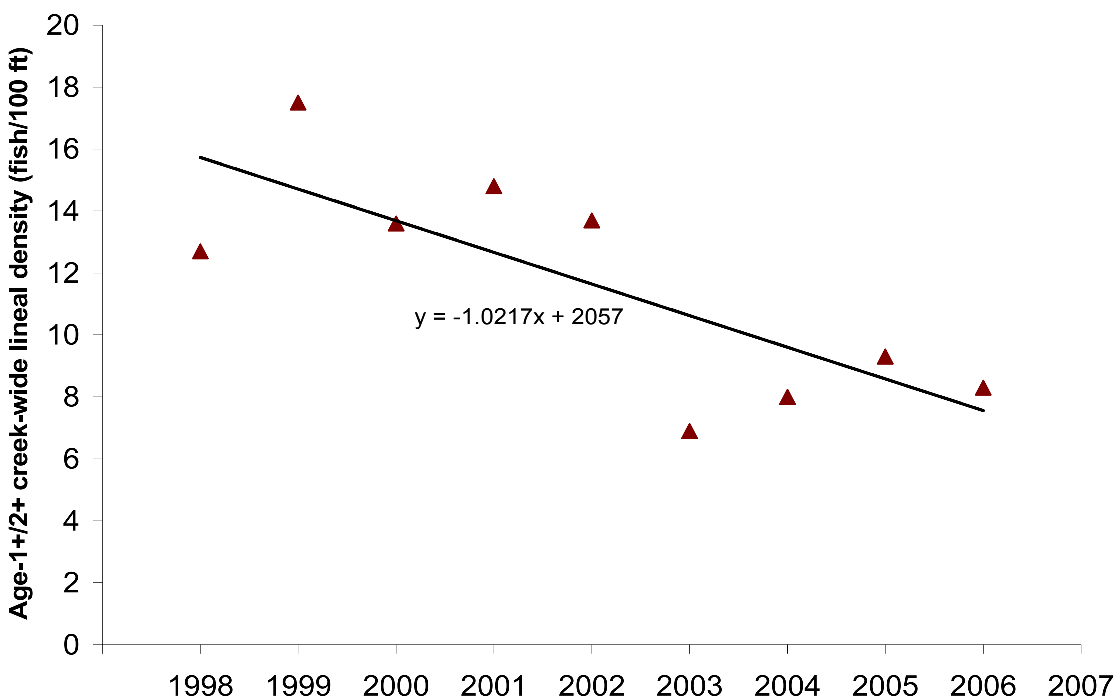

Figure 2-27. Lineal density (fish/100 ft) of age-1+/2+ steelhead in Santa Rosa Creek from 1998 to 2006 (r^2 = 0.592; *P* = 0.0154; n = 9). Data source: D. W. Alley & Associates (2007, Table 25a).

Juvenile steelhead densities are consistently higher in the upper reaches (approximately stream miles 8–13) than in the middle and lower reaches (approximately stream miles 0–8) of Santa Rosa Creek (D. W. Alley & Associates 2008, Nelson et al. 2009) (Figures 2-28 and 2-29).[10] The generally higher densities in the upper reaches suggest that a greater number of steelhead spawned there, that food availability and habitat quality are higher (and thus capable of supporting higher densities of fish), and/or that embryo and/or juvenile survival was higher in these reaches than in the lower watershed. In addition, the upper reaches are more likely to support some level of resident rainbow trout production due to water quality and habitat features, although this cannot be ascertained based on existing information. Habitat conditions vary considerably between the reaches, with the upper reaches generally containing larger substrates, less fine sediment, deeper pools, lower summer base flows, and more stream shading due to higher percentage of canopy closure, than the middle and lower reaches, which run through a marine terrace and are lower gradient and less confined (D. W. Alley & Associates 2008, Nelson et al. 2009).

Using average densities of juvenile steelhead from previous monitoring results, Titus et al. (2006) documented a statistically significant shift in the use between the upper (approximately stream miles 8–13) and lower reaches (approximately stream miles 0–8) over a 23-year period, with increasing use of the upper creek and decreasing use of the lower creek. These results suggest that the degraded physical habitat and reduced instream flows in the lower creek (see discussions in Section 3) have progressively rendered this area less and less suitable for rearing juveniles.

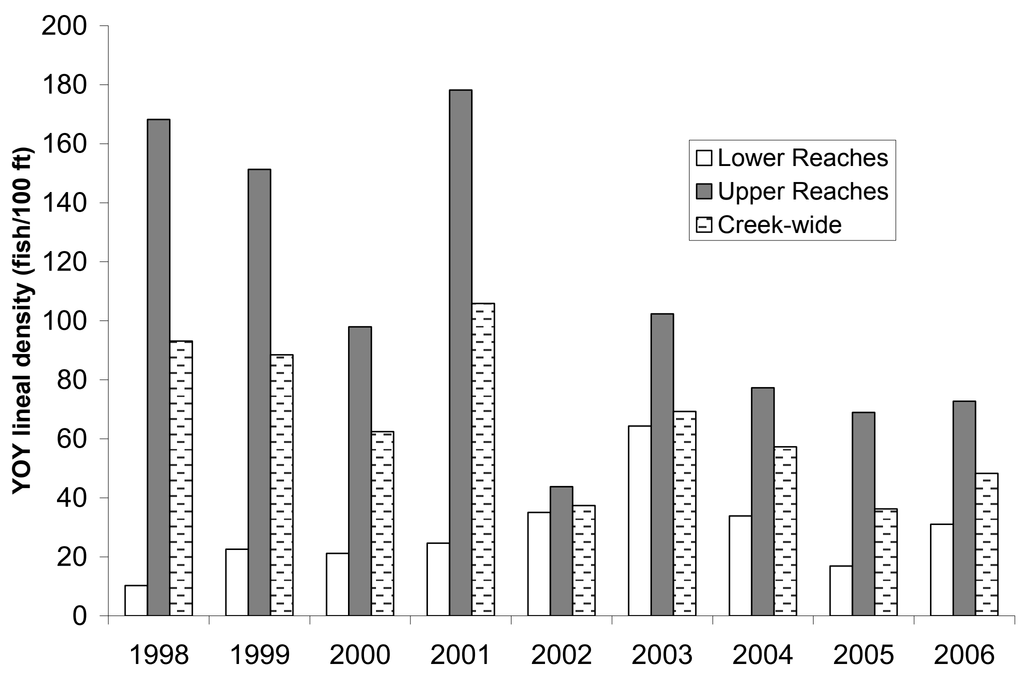

Figure 2-28. Mean lineal density of YOY steelhead at sample sites in the lower reaches (stream miles 0–8), upper reaches (stream miles 8–13), and creek-wide from 1998–2006. Data source: D. W. Alley & Associates (2007, Tables 26a and 26b).

[10] D. W. Alley & Associates (2008) and Nelson et al. (2009) used different reach delineations than those used and described previously in this document. These reports delineated lower reaches, also referred to as lower valley, from stream mile 0 to 8, and upper reaches, also referred to as upper canyon, from stream mile 8 to 13. These reach delineations are used when presenting data from D. W. Alley and Associates (2008) and Nelson et al. (2009).

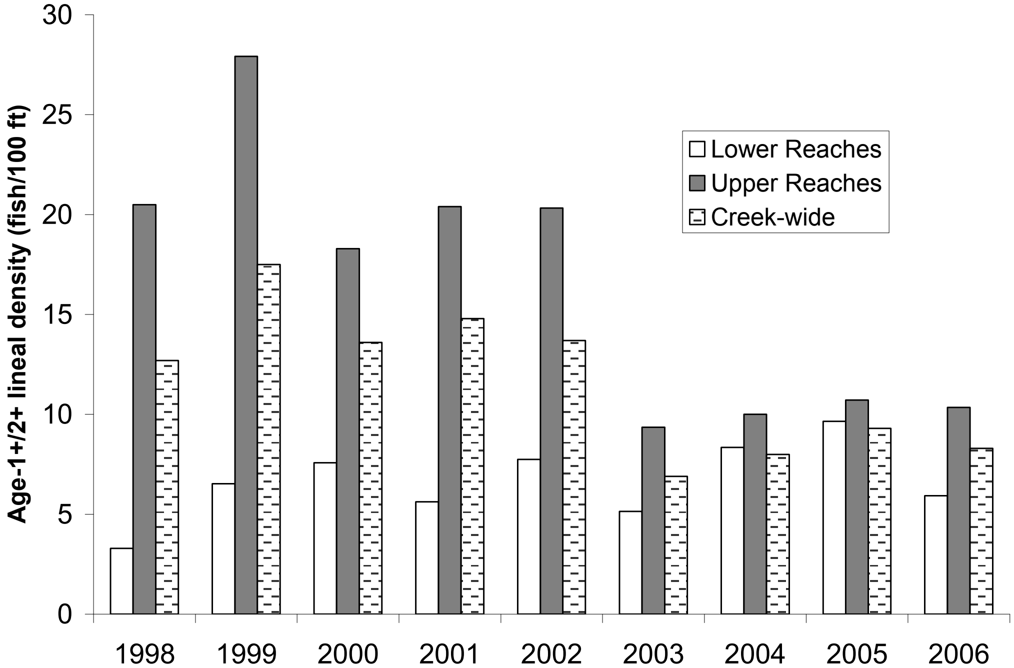

Figure 2-29. Mean lineal density of 1+/2+ steelhead at sample sites in the lower reaches (stream miles 0–8), upper reaches (stream miles 8–13), and creek-wide from 1998–2006. Data source: D. W. Alley & Associates (2007, Tables 26a and 26b).

Despite the evident decline in steelhead population since historical levels, compared to most other watersheds with populations in the DPS, Santa Rosa Creek contains a relatively high quantity of suitable spawning habitat and relatively high densities of juvenile steelhead have been observed in recent years (D. W. Alley & Associates 2008). For this reason, habitat restoration and continued monitoring of Santa Rosa Creek's steelhead population is considered important for the recovery of the DPS (NMFS 2007, CDFG 2010).

2.10.2 Other rare species

In addition to steelhead, TLCSLOC, Cambria Forest Management Plan, and Fiscalini Ranch Preserve final Master EIR all identified special-status wildlife species—those listed as threatened or endangered under either the federal or state Endangered Species Acts, or as a species of special concern (SC) by CDFG—with the potential to occur in the watershed (Cambria Forest Committee 2002, Morro Group 2009, TLCSLOC 2010). Of these, the following have been observed in the watershed (Rathbun et al. 1991, Nelson et al. 2009, D. W. Alley & Associates 2008, Morro Group 2009):

- Pacific (previously southwestern) pond turtle (*Actinemys marmorata*; SC)
- monarch butterfly (*Danaus plexippus*; CNDDB vulnerable species)
- tidewater goby (*Eucyclogobius newberryi*; federally endangered and SC)
- Monterey dusky-footed (Santa Lucia) woodrat (*Neotoma macrotis luciana*; SC)
- California red-legged frog (*Rana draytonii*; federally threatened and SC)
- American badger (*Taxidea taxus*; SC)
- two-striped gartersnake (*Thamnophis hammondii*; SC)

Pacific pond turtle, tidewater goby, California red-legged frog, and two-striped gartersnake have all been the subject of relatively recent surveys and reports in the Santa Rosa Creek watershed, as detailed below. The life history, habitat requirements, and population trends of these "umbrella species" provide additional insight, beyond that provided by steelhead, into the state of the watershed. In some cases, the habitat and life history requirements of these species are connected or overlap with those of steelhead and, as a result, appropriate management for steelhead is expected to benefit these species as well. In other cases, appropriate management for steelhead could conflict with the habitat and life history requirements of these other species. This section provides a brief overview of these species and their population trends in Santa Rosa Creek, and identifies potential synergies and/or conflict between these species and management for steelhead.

2.10.2.1 Pacific pond turtle

Pacific pond turtles inhabit fresh or brackish water characterized by areas of deep water, low flow velocities, moderate amounts of riparian vegetation, warm water and/or ample exposed basking sites, and underwater cover elements such as large woody debris and rocks (Jennings and Hayes 1994). In California, Pacific pond turtles are found from the Oregon border south to the border with Baja California, including the Central Valley and Sierra Nevada foothills, and along the Coast ranges (Stebbins 2003). The species has experienced population declines as conversion of wetland and riparian habitat to urban and agricultural use has accelerated (Jennings and Hayes 1994, Germano and Bury 2001). In addition, hatchlings and juveniles are vulnerable to predation by a variety of native and non-native mammals, birds, fish and amphibians (Moyle 1973, Holland 1985, both as cited in Rathbun et al. 1991).

Along major rivers, Pacific pond turtles are often concentrated in side channel and backwater areas. Turtles may move to off-channel habitats, such as oxbows, during periods of high flows (Holland 1994). While highly aquatic, Pacific pond turtles also spend time on land basking, over-wintering, nesting, and to seek refuge/cover, up to a reported 0.3–0.6 mi (0.5–1 km) away from aquatic habitats (Rathbun et al. 1992, Holland 1994, Reese and Welsh 1997, Rathbun et al. 2002). Egg-laying sites vary from sandy shoreline to forest soil types, though are generally located in grassy meadows, away from trees and shrubs (Rathbun et al. 1992, Holland 1994, Rathbun et al. 2002), with canopy cover commonly less than about 10% (Reese 1996). In an 8-year study of several creeks just north of Santa Rosa Creek, Pacific pond turtles left the drying creek beds in late summer for nearby woodland and coastal sage scrub habitat, and returned after winter floods, and females laid their eggs in sunny upland habitat, such as grazed pastures (Scott and Rathbun 2001, Rathbun et al. 2002).

Surveys of lower Santa Rosa Creek in the late 1970s consistently observed Pacific pond turtles hauled-out on logs in the lower end of the seasonal lagoon (D. Holland, unpubl. data, as cited in Rathbun et al. 1991). Since 1986, however, observations of Pacific pond turtles have decreased, and only two to three individuals were recorded downstream of the Highway 1 Bridge in 1991 (Rathbun et al. 1991). At least one Pacific pond turtle was captured in the lower 14 mi (22 km) of Santa Rosa Creek during CDFG's steelhead surveys in 2005 (Nelson et al. 2009). Rathbun et al. (1991) attribute this apparent decline to insufficient instream flows resulting from a combination of below-average precipitation that year and groundwater pumping in the lower reaches of the creek.

In general, management actions to enhance steelhead habitat should also benefit Pacific pond turtles. For example, actions to increase instream flow, enhance the riparian corridor, reduce fine sediment delivery to channels, and provide instream woody debris should improve aquatic habitat conditions for Pacific pond turtle. However, the conservation of upland scrub and grassland habitat adjacent to the creek is equally important for egg-laying, refuge, and basking habitat.

2.10.2.2 Tidewater goby

Tidewater goby is a small fish that inhabits coastal lagoons, marshes, estuaries, and lower stream reaches along the California coast from Del Norte County to San Diego County (Swift et al. 1989, Moyle 2002, USFWS 2005). The fish still occurs within this range, but at over half of the sites within the distribution, populations have been extirpated or are extremely small with uncertain long-term persistence (USFWS 2005). The decline in this species resulted in it being listed as federally endangered in 1994 (USFWS 1994). Tidewater gobies are an important part of estuarine food webs because they provide prey for larger fish, aquatic snakes, and piscivorous birds (Swenson and McCray 1996). Tidewater gobies are threatened by changes in water quality, degradation and loss of winter and summer habitat due to urbanization and sandbar breaching, and predation from invasive species.

During reproduction/spawning, juvenile, and adult life stages, tidewater goby appear to prefer shallow depths (20–100 cm [8–39 in]) near emergent vegetation at the fringe of large estuaries and within lagoon and tidal slough systems, though possibly deeper since most previous surveys did not effectively sample in deeper waters (Stillwater Sciences 2006a).

Tidewater gobies were documented as abundant in the Santa Rosa Creek lagoon in 1977, but subsequent surveys in the early to late 1980s documented only small numbers (Swift 1977, 1981, and Dudley 1988, as cited in Rathbun et al. 1991). As with other species in the lower creek, Rathbun et al. (1991) attributed this decline to a lack of instream flow from primarily agricultural and urban water use. D. W. Alley & Associates surveyed tidewater goby in Santa Rosa Creek lagoon from 1995 to 2007 and documented highly variable abundance (Alley and Sherman 2006, D. W. Alley & Associates 2008).

Habitat restoration may be mutually beneficial to steelhead and tidewater gobies. For example, enhancement of brackish marshes and lagoon habitat can increase steelhead rearing habitat while also providing year-round habitat for tidewater goby (Stillwater Sciences 2006a). However, the habitat requirements of the tidewater goby differ enough such that restoration for steelhead may not always be beneficial, and under some circumstances may be detrimental, to tidewater goby populations (Stillwater Sciences 2006a). Therefore, care must be taken when implementing actions to enhance steelhead habitat to minimize unintended consequences on tidewater goby habitat. Accurate predictions of the effect of restoration on both water depths and salinity dynamics are crucial in determining the long-term effect of restoration on tidewater goby habitat quality and extent (Stillwater Sciences 2006a).

2.10.2.3 California red-legged frog

California red-legged frogs are found in ephemeral or permanent bodies of water, including wetlands, natural and artificial ponds and reservoirs, wet meadows, lakes, and low-gradient, slow-moving stream reaches with permanent pools, primarily in coastal drainages along California's central coast. The frog's range covers Mendocino County to Baja California, with isolated remnant populations occurring in the Sierra foothills, from sea level to approximately 8,000 ft (2,440 m) (Stebbins 2003, Shaffer et al. 2004). They are considered extirpated from the foothills of the Sierra San Pedro Martir, the coastal plain of Baja California Norte, and the Central Valley region, which represents an approximate 70% reduction of its historical range (CDFG 2009, USFWS 2002). California red-legged frog populations are threatened within their remaining range by a variety of human-influenced impacts, including urban encroachment, altered hydrological regimes that are not suitable for their life history needs, introduction of exotic predators and competitors, contaminants including pesticides and fertilizers, and habitat fragmentation (USFWS 2002). It is a threatened species under the federal Endangered Species Act (USFWS 1996) and a California species of special concern.

California red-legged frog

California red-legged frog habitat is generally characterized by still or slow-moving water with deep pools (usually at least 2 ft [0.7 m], though frogs have been known to breed in shallower pools) and emergent and overhanging vegetation, usually cattails, rushes, or willows (Jennings and Hayes 1994). Although some adults may remain resident year-round at favorable breeding sites, others may disperse overland up to a mile or more (Fellers and Kleeman 2007). Movements may be along riparian corridors, but some individuals move directly from one site to another without apparent regard for topography or watershed corridors (Bulger et al. 2003). California red-legged frogs sometimes enter a dormant state during summer or in dry weather, finding cover in small mammal burrows, moist leaf litter, root wads, or cracks in the soil. California red-legged frog populations are likely to persist where multiple breeding and non-breeding aquatic areas are embedded within a matrix of upland dispersal habitat (USFWS 2002, Fellers and Kleeman 2007). In the study of several creeks north of Santa Rosa Creek, high spring flows were found to inhibit California red-legged frog breeding and eliminate egg masses in some creeks in some years (Scott and Rathbun 2001). In general frogs were always found in or very near water, but could be found farther upland in wet winters. Overhanging willow branches, bulrush/ cattails, exposed tree roots, and upland thickets were the most common cover types used by frogs during the study (Scott and Rathbun 2001).

Annual herpetological surveys of lower Santa Rosa Creek from the mid-1970s to 1989 consistently documented California red-legged frogs, but in decreasing numbers (Rathbun et al. 1991). In 1991, only two red-legged frogs—one dead—were observed in the creek between the Windsor Street bridge and Highway 1 bridge (Rathbun et al. 1991). An unspecified number of California red-legged frogs were captured in the lower 14 mi (22 km) of Santa Rosa Creek during CDFG's steelhead surveys in 2005 (Nelson et al. 2009). Rathbun et al. (1991) identified insufficient instream flow in lower Santa Rosa Creek, as a result of agricultural and urban water use, and a lack of adequate cover as the primary causes of the decline in red-legged frogs in this area.

In general, management actions to enhance steelhead habitat should also benefit California red-legged frogs, including increasing instream flows, enhancing riparian habitat, reducing fine sediment delivery to channels, providing instream woody debris and undercut banks for cover, and managing for non-native species (USFWS 2002). For California red-legged frog, it is also important to provide adequate connectivity between breeding, non-breeding, and dispersal habitats (Fellers and Kleeman 2007), as well as to conserve a well-distributed array of natural habitat elements in terrestrial areas upland from occupied aquatic sites (Bulger et al. 2003). Habitat for early life stages of steelhead tend to be similar for California red-legged frogs tadpoles, including low-velocity areas near streambanks.

2.10.2.4 Two-striped garter snake

The two-striped garter snake is generally found around pools, creeks, cattle tanks, and other water sources along the California coast from Monterey County to northern Baja California (Stebbins 2003). Two-striped garter snakes are threatened by a loss of wetland habitat, which has contributed to a reduction in their range. It is currently a California species of special concern.

Although generally considered an aquatic species, preferred retreat habitat is terrestrial, such as mammal burrows, crevices, and surface objects (Rathbun et al. 1993). Juveniles and adults feed primarily on small fish, fish eggs, tadpoles, frog metamorphs, and small invertebrates (Jennings and Hayes 1994). A study of several creeks just north of Santa Rosa Creek found that female two-striped garter snakes spent most of the year in various terrestrial habitats, either on the surface, under surface objects, or in animal burrows (Scott and Rathbun 2001). In the water, snakes were most often found among aquatic vegetation, cattails, bulrushes, and overhanging willow branches. Upland, snakes were often associated with grassy areas and small mammal borrows (Scott and Rathbun 2001).

Numerous two-striped garter snakes were observed in lower Santa Rosa Creek during surveys in the late 1970s, but none were observed in subsequent surveys (Rathbun et al. 1991). As with other aquatic species in the lower creek, Rathbun et al. (1991) attributed this decline to a lack of instream flow from primarily agricultural and urban water use, which is likely correlated with a decrease in aquatic prey species, such as small fish and frogs/tadpoles.

In general, management actions to enhance steelhead habitat should also benefit two-striped garter snakes. Primarily, actions to increase instream flow, enhance the riparian corridor, and reduce fine sediment delivery to streams should improve aquatic habitat conditions for two-striped garter snake by increasing their prey base. However, the conservation of upland habitats adjacent to the creek is equally important for refuge and basking.

2.10.3 Non-native, invasive wildlife species

While most non-native species are not particularly invasive or detrimental, some have no natural controls in their new environmental and are able to spread unchecked, causing significant and sometimes irreparable damage to native habitat and species. For example, non-native invasive species can prey on native species, out-compete native species for food and other resources, and/or degrade habitat for native species. While there has been no comprehensive survey for non-native invasive fish and wildlife species in the Santa Rosa Creek watershed, incidental observations during surveys for steelhead and other native species provide an indication of the primary non-native invasive species that occur in the watershed.

2.10.3.1 Aquatic species

Dr. Dan Holland (unpublished data, as cited in Rathbun et al. 1991), CDFG (Nelson 1994, Nelson et al. 2009), and D. W. Alley & Associates (2008) recorded the presence of several non-native aquatic species in creeks in the watershed. These include:

- brown bullhead catfish (*Ictalurus nebulosus*)
- green sunfish (*Lepomis cyanellus*)
- bluegill (*Lepomis macrochirus*)
- crayfish (*Pacifastacus leniusculus*)
- bullfrog (*Rana catesbeiana*)

Mosquitofish (*Gambusia affinis*) are also likely to occur in the creek and ponds in the watershed (G. Rathbun, pers. comm., 2010). Many of these non-native species have been documented to prey upon native species and are capable of continually dispersing into Santa Rosa Creek from the many stock ponds in the watershed. Preventing their further establishment and eradication has been identified as an important step in protecting native species populations in Santa Rosa Creek (Rathbun et al. 1991, D. W. Alley & Associates 2008, Nelson et al. 2009). Rathbun et al. (1991) implicated bullfrogs and bass in the extirpation of tidewater goby in nearby Old Creek (near the town of Cayucos) and noted that bluegill may be a serious predator of tidewater gobies and red-legged frog eggs in Santa Rosa Creek. Similarly, D. W. Alley & Associates (2008) identifies introduced non-native predators, such as centrarchids (bass family of fishes), bullfrog and possibly crayfish as one of the four major threats to tidewater goby in the watershed. In an assessment of steelhead habitat and limiting factors, Nelson et al. (2009) notes that while crayfish have been shown to consume salmonid eggs, the impact of their ubiquitous presence in Santa Rosa Creek is not understood and their eradication would be difficult at best. Nelson et al. (2009) were particularly disconcerted by the presence of bullfrogs and green sunfish, which can prey upon steelhead eggs and young-of-the-year, but are generally less common in small coastal streams like Santa Rosa Creek. They continued: "Given the warm water temperatures in the lower watershed both of these non-native species will thrive during the summer months. It is doubtful that the sunfish could withstand the higher winter flows, but the adult bullfrogs will move to higher ground during these flow events, re-occupying the creek when flows subside."

There have been no documented reports of Asian clam (*Corbicula fluminea*), a highly invasive aquatic invertebrate, in the Santa Rosa Creek watershed, but it has been documented in the Salinas River and in Lake Nacimiento by the USGS Nonindigenous Aquatic Species program (NAS 2010).

2.10.3.2 Terrestrial species

European starlings (*Sturnus vulgaris)* and brown-headed cowbirds (*Molothrus ater*) are both widespread non-native birds that can affect native bird populations and occur or are likely to occur in the Santa Rosa Creek watershed. European starlings are aggressive competitors for nest holes, often evicting native species, while brown-headed cowbirds are brood-parasites of many native bird species (i.e., they lay their eggs in the nests of native birds, who then raise the cowbird chicks often to the detriment of their own offspring) in riparian areas throughout California, especially those near agricultural lands. There have been no documented reports of brown-headed cowbirds in the Santa Rosa Creek watershed specifically, but high counts of the birds have consistently been recorded during the annual Christmas Day bird count in San Luis Obispo County (MCAS 2005, 2006). European starling populations appear, at least anecdotally, to be increasing in the watershed (R. Hawley, pers. comm., 2010).

Feral pigs (*Sus scrofa*) are known to occur and cause damage to creek channels and other areas in the watershed (S. Soto, pers. comm., 2010; G. Kendall, pers. comm., 2010; M. Smith, pers. comm., 2010). California's feral pig population likely started in San Benito and Monterey counties with escaped domestic swine brought over by Mexican settlers, who commonly released swine to forage in woodlands (Groves and Di Castri 1991, Kreith 2007). Since then feral pigs have been deliberately (and illegally) relocated elsewhere in the state for hunting (Kreith 2007). In the Santa Rosa Creek watershed, wild Russian boars and sows were brought in for hunting in the 1930's by a landowner to amuse his guests (D. Dunlap, pers. comm. 2010). Swine have the greatest reproductive capacity of all free-ranging, large mammals in the United States (Wood and Barrett 1979) and population expansion can occur rapidly. Feral pigs degrade ecosystems through predation and competitive impacts on native fauna, grazing on native plants, and physically altering habitat by rooting. Rooting creates large, disturbed areas that can lead to extensive erosion, displace native species, facilitate invasion by non-native, invasive plant species (Barrett 1977), and contribute to fine sediment delivery to waterways. Feral pig disturbance causes several million dollars in damages to crops, fencing, roads and trails annually in California, and, between 2002 and 2006, for over $275,000 in damages in San Luis Obispo County alone. Feral pig is regulated as a big game mammal by CDFG. Hunting is believed to have thinned the feral pig population in the Santa Rosa Creek watershed dramatically compared with levels in the 1960s through 1980s, but the population appears to be increasing again in the upper watershed (S. Soto, pers. comm., 2010; D. Dunlop, pers. comm., 2010).

2.11 Critical Issues

There are several issues that are impairing or have the potential to affect ecological conditions in the Santa Rosa Creek watershed and make obvious focal points for restoration and management planning. These issues are summarized below and include water quantity, water quality, fine sediment, non-native invasive species, and changes in land use. Several of these issues feature prominently in the steelhead limiting factors analysis (Section 3), and recommendations to address them are included in Section 4.

2.11.1 Water quantity

While the Santa Rosa Creek watershed, due to its climate and setting, likely experienced very low and intermittent flows in the late summer and fall on occasion under historical conditions, groundwater pumping and riparian water diversions are removing water that would otherwise be available to the stream channel (see Section 2.6). Since the establishment of the San Simeon well field in 1979, groundwater extraction in the Santa Rosa Creek watershed by CCSD for municipal use has ranged from 0 to just over 200 acre-feet annually. Through the early 1990s, the amount of groundwater and surface water extracted by private entities was estimated to be approximately 3.5 times the amount pumped by the CCSD. The precise effects of groundwater pumping and water diversion on the volume of instream flow are not currently known, but there is general consensus among the resource scientists who have surveyed the watershed that low instream flows have contributed to the decline of several special-status aquatic species in the watershed (Rathbun et al. 1991, D. W. Alley & Associates 2008, Nelson et al. 2009).

Reduced instream flows are particularly problematic in the intermittent reach of the creek and in the lagoon. In the intermittent reach of the creek (see Figure 2-8), where surface flows readily percolate into the subsurface, reduced instream flows constrain, and may entirely eliminate, connectivity between upstream and downstream habitat. The mechanisms for water loss in this reach, and thus for restoring flows, are not currently well understood. In the lowest reaches of the creek and in the lagoon, reduced instream flows limit the extent of aquatic habitat and likely contribute to elevated stream temperatures and low DO levels in the lagoon.

2.11.2 Water quality

In general, water quality in the middle and upper reaches of Santa Rosa Creek is good: relatively low summer stream temperatures and a diverse assemblage of benthic macroinvertebrates that are indicative of high water quality are maintained. As one moves downstream, however, water quality becomes increasingly reduced. Water temperatures begin to increase, and occasionally exceed CCRWQCB water quality criteria for temperature in the summer, in the downstream portion of the middle reach, most likely as a result of limited riparian canopy cover in some areas and low instream flows. Sites adjacent to the town of Cambria had the least diverse assemblages of benthic macroinvertebrates and exhibit generally poor water quality as a result of increased levels of urban runoff, riprap, concrete, and trash. Water quality criteria for temperature and DO are frequently exceeded in the lagoon, in part as a result of low instream flows.

Sediment samples downstream of the Oceanic Mine on Curti Creek, including several in the lagoon, indicate elevated levels of mercury in the watershed (Section 2.8.3). Mercury is delivered to the watershed primarily from the erosion of mercury-laden waste rock at the former mill site by Curti Creek. No actions have been implemented to control this delivery or remediate the mine or former mill site. While additional study is necessary to determine the extent of mercury bioaccumulation in the aquatic food chain, moderately elevated levels of methylmercury—the bioavailable form of mercury—were recently measured in the Santa Rosa Creek lagoon.

2.11.3 Fine sediment in the lower reaches

Historically, fine sediment production rates likely increased substantially during the late 1800s and early 1900s when land clearing activities initiated (e.g., logging, ranching, and urbanization). Changes in the rainfall-runoff dynamics caused by this land clearing created a flashier system that more effectively eroded previously stored sediment on the hillslopes creating numerous erosional features (e.g., gullies and landslides), and led to channel incision throughout the watershed, particularly in the middle reaches of Santa Rosa Creek and the middle and upper reaches of Perry and Green Valley creeks. Over time, the channel incision eventually drove the mass instability of channel banks, another significant source of fine sediment. Together, this increase in hillslope and bank erosion rates led to proportionally higher rates of fine sediment delivery (as opposed to coarse sediment delivery) to stream channels in the watershed.

During the past half century, high fine sediment production rates have been reduced for the following reasons: (1) land use activities and vegetation coverage remained largely unchanged; and (2) the supply of sediments stored on hillslopes is less available after significant volumes were previously evacuated. The number and size of gully and landslide features present in the early 20th century have not changed considerably in recent decades, further indicating that land use-induced erosion of the landscape has stabilized. Additionally, and perhaps more importantly, stored sediment in the Santa Rosa Creek channel bed is predominantly coarse-grained (fine gravels to coarse cobbles), with few accumulations of fine sediment in the middle and upper reaches. This signifies that present-day fine sediment yields to the channel, which are assumed to be greater than pre-settlement rates, are not overwhelming the transport capacity of the channel under the current flow regime. This ability of the channel to self-maintain a predominantly coarse-grained bed helps to provide suitable instream habitat. However, occurrences of bank erosion exacerbated by incised channel morphology, altered watershed hydrology, and road runoff continue to represent a significant fine sediment source that can limit habitat quantity and quality at the reach scale.

The downstream, low-gradient reaches of Perry and Green Valley creeks are very fine-grained indicating that these major tributaries transport a high fine-sediment load to the lower reaches of Santa Rosa Creek. In addition, stormwater runoff-related erosion from Cambria neighborhood roads and home lots may also contribute to fine sediment in the lower reaches of Santa Rosa Creek. While the much of this input of fine sediment is conveyed with relative ease out of the watershed, the instream habitat quantity and quality of lower Perry and Green Valley creeks are limited by their fine-grained channels and enough remains in the lower reaches of Santa Rosa Creek to embed coarser substrates (see Section 3 for additional details).

2.11.4 In-channel infrastructure

Although the two downstream-most barriers to fish migration and movement (i.e., Burton Street Bridge and Ferrasci Road crossing) have been corrected, close to 20 man-made (i.e., bridges and culverts) barriers have been identified in the watershed. Barriers that may impede access to potential steelhead spawning and rearing areas include several stream crossings on Perry and lower Green Valley creeks.

Culvert on Curti Creek

Streambank rip-rap placement in the lower reaches of Santa Rosa Creek may cause flow to be deflected back across the channel resulting in further erosion downstream and threatening downstream land and infrastructure. If continued, extensive rip-rap placement could cause channel incision, more rapid flows, channel bed armoring (i.e., coarse bed surface layer), and reduced topographic complexity of the channel bed resulting in significant reductions in habitat suitability for native aquatic organisms including salmonids.

2.11.5 Non-native invasive species

Stream surveys and other resource inventories have documented a variety of non-native invasive plant and animal species in the watershed. Several of these species are known predators of steelhead and other special-status aquatic species in the watershed, can alter and impair native habitat conditions, and/or have the ability to disperse and expand their distribution quickly. Relatively large infestations of some species, such as eucalyptus, cape ivy, crayfish, bullfrogs, and freshwater sunfishes, have already been reported. In addition, the currently limited distribution of some of the non-native invasive species documented in the watershed (e.g., arundo, pampas/jubata grass, and French broom) can quickly change since they are known to spread rapidly and can be difficult or problematic to control. For many non-native invasive species, early detection is important so that control measures can be undertaken before an infestation worsens and control becomes increasingly difficult.

2.11.6 Changes in land use

The subdivision of large parcels, population growth, and the proposed desalination plant all have important ramifications on the future condition of the Santa Rosa Creek watershed. In recent decades, fine sediment delivery to stream channels in the watershed has been reduced closer to pre-development levels primarily because land uses on high-yielding geomorphic landscape units have not changed over this time. The subdivision of large parcels is likely to result in land use changes in the smaller parcels. If these future land uses remove vegetation, change hillslope topography, or alter runoff patterns, there is the potential that gully and rill erosion could be reinitiated with a subsequent increase in fine sediment delivery to watershed stream channels. Retaining large parcels or otherwise conserving existing land uses, particularly in the upper watershed, could be a valuable tool in preventing the degradation of aquatic habitat throughout the watershed. In subdivided parcels, it will be important that land use changes are implemented in a way that reduces the potential for erosion and that associated increases in water demand are avoided.

The combination of San Luis Obispo County population growth and the proposed desalination plant to supplement the municipal water supply has the potential to increase the population and development in and around Cambria. This could further increase water demand and subsequently lead to impacts related to urban development that threaten aquatic habitat in the lower watershed (e.g., increased impervious surfaces, contaminated runoff, non-native invasive species introductions, and encroachment of floodplains and the riparian corridor). San Luis Obispo County's (2008) North Coast Plan restricts growth associated with any public works water supply project within the CCSD service area, stating: "[t]he maximum service capacity of the project will not induce growth inconsistent with the protection of coastal resources and public access and recreation opportunities," and that "[t]he project shall assure that CCSD water withdrawals from Santa Rosa and San Simeon Creeks will be sufficiently limited to protect: (1) adequate instream flows necessary to support sensitive species and other riparian/wetland habitats within the reach of the streams affected by CCSD pumping; (2) underlying groundwater aquifers; and (3) agricultural resources." Abiding by these restrictions by reducing groundwater pumping if the desalination plant is someday operational would minimize the potential effects of growth in Cambria on Santa Rosa Creek.

3 STEELHEAD LIMITING FACTORS ANALYSIS

The following limiting factors analysis describes seasonal and age class-specific habitat needs and discusses how habitat conditions in Santa Rosa Creek likely affect each steelhead freshwater life stage. The aim is to integrate the effects of habitat carrying capacity and density-independent mortality (i.e., sources of mortality such as water temperature or disease with effects that are not dependent on the density of the population) across the entire life cycle of steelhead to determine mechanisms regulating population growth. Determining the relative effect of each life stage on overall population dynamics then allows for the identification of the factors most limiting steelhead production in the watershed (i.e., limiting factors) (Section 3.6) and specific actions that can be taken to address these factors (Section 4).

A species' life history and available habitat are among the many factors that can influence the growth or decline of a population (i.e., population dynamics) (Figure 3-1). Individual growth rate, survival, outmigration size, outmigration timing, ocean survival, upstream migration, and spawning success can all influence population dynamics of the Santa Rosa Creek steelhead population. Central to this analysis of limiting factors, which draws primarily upon the recent monitoring work of CDFG (Nelson 1994, Nelson et al. 2009) and D. W. Alley & Associates (2007 and 2008), is that steelhead population dynamics in Santa Rosa Creek are defined by two major characteristics: (1) patterns of habitat use between the upper and lower reaches, and (2) annual variation in flow. As to the first point, most of the successful spawning and rearing of steelhead in Santa Rosa Creek occurs in the upper reaches of the watershed (upstream of stream mile 8), although individual growth rates in the lower reaches (downstream of stream mile 8) appear to be high. Secondly, nearly every pattern of steelhead distribution, habitat use, abundance, density, or growth within the watershed is related to significant annual variation in instream flow conditions (as influenced primarily by precipitation). The sections below summarize the current understanding of the Santa Rosa Creek steelhead population based on the information gathered to date, and describe preliminary hypotheses of the primary factors likely limiting steelhead production in the watershed.

Ideally this understanding of steelhead and limiting factors hypotheses will be tested through the recommendations in Section 4, such that preliminary hypotheses are accepted, rejected, or refined, based on new understanding of the system, and as new uncertainties are identified. The iterative process of hypothesis development, testing, and refinement provides an adaptive and efficient process for identifying restoration strategies and any additional priority studies for the conservation and support of steelhead.

3.1 Spawning Habitat

For anadromous steelhead populations (as well as other pacific salmon populations such as coho salmon), the average fecundity, the number of eggs in a female fish prior to spawning, is high relative to the amount of suitable juvenile rearing habitat usually available within a stream. Rather than being controlled by reproductive success, growth of anadromous populations tends to be limited by physical habitat constraints during the juvenile freshwater rearing stage. As described below this generally appears to be the case for Santa Rosa Creek as well, although spawning habitat quality in the lower reaches of Santa Rosa Creek, where fish can be restricted in dry winters, may become more limiting relative to juvenile habitat in some years.

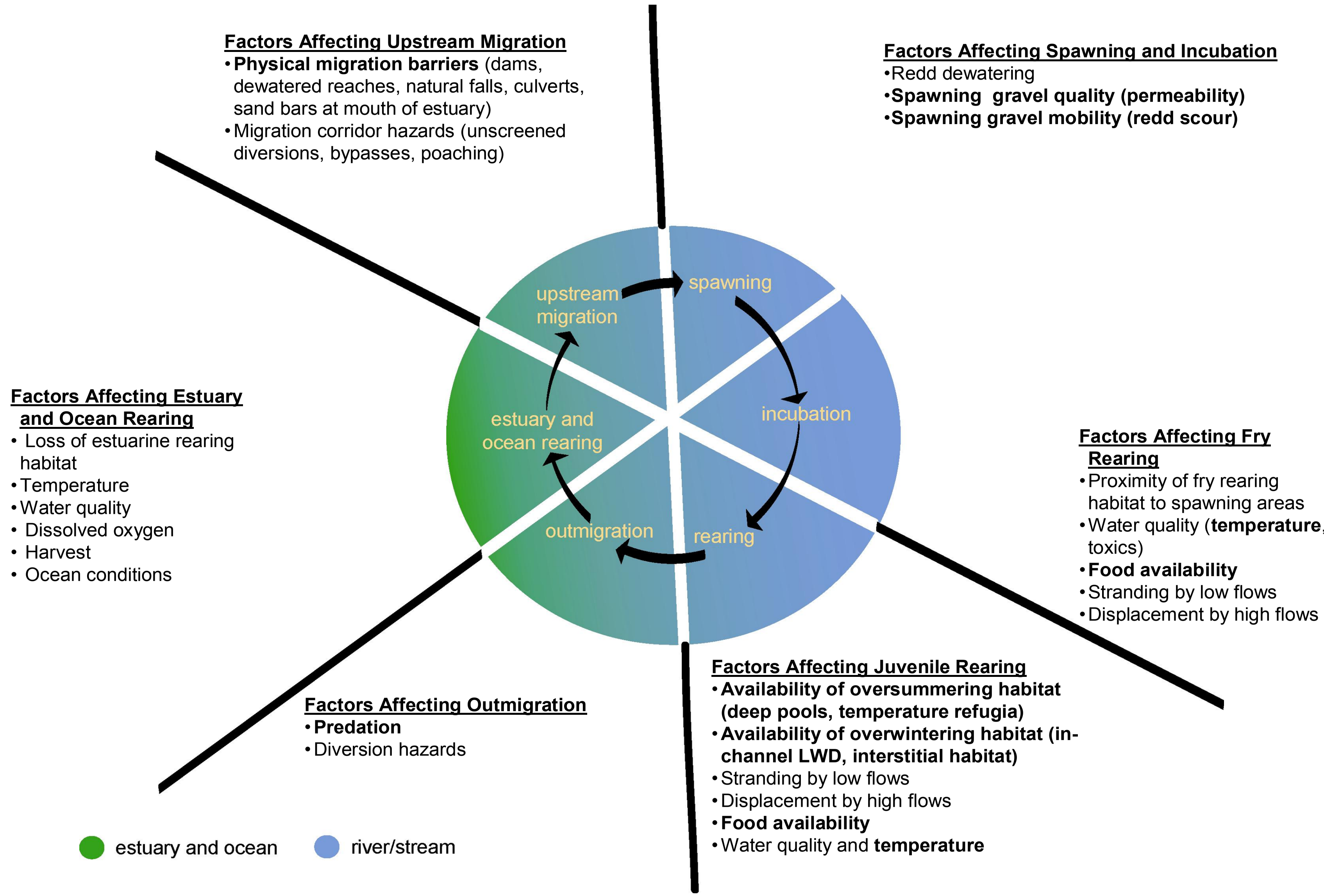

Figure 3-1. Steelhead life cycle with potential factors affecting each life stage.

3.1.1 Access to spawning habitat

CDFG surveys from the 1930s found no significant migration barriers to steelhead access in Santa Rosa Creek (Titus et al. 2006). Under current conditions several culverts and other man-made structures have been identified in the Santa Rosa Creek watershed that restrict the ability of migrating steelhead to access high quality upstream spawning habitat (see Section 2.7). Two of the furthest downstream barriers (Burton Street Bridge apron at stream mile 1.9 and Ferrasci Road crossing at stream mile 3.4) have recently been modified to allow fish passage under a wider range of flow conditions. Undersized and/or poorly placed culverts at road crossings likely limit steelhead access to potential spawning areas in Taylor and Curti creeks, and just as importantly, they disrupt the supply of coarse sediment and large woody debris that is necessary to create and maintain suitable rearing habitat (see Sections 3.2 and 3.3 below).

Nearly every road crossing in the Perry/Green Valley Creek sub-watershed has been identified as a potential fish passage barrier, but none have been assessed to determine if, why, or when a barrier to fish movement occurs (CalFish 2009; see Section 2.7). It is not known how often or in what capacity steelhead use reaches of the Perry/Green Valley Creek sub-watershed, or what condition those reaches are in (Nelson et al. 2009, Appendix A). Determining the potential for steelhead to access this sub-watershed would be an important first step towards understanding the relative importance of this sub-watershed for steelhead.

Low instream flows, which likely occurred naturally in drier years but are now exacerbated by groundwater pumping and water diversions, can also present barriers to fish movement on Santa Rosa Creek, particularly in the intermittent middle reaches (see Figure 2-8). Based on comparison of available flow data from the Main Street Bridge gauge (see Section 2.6) and steelhead passage requirements on lower Santa Rosa Creek (D. W. Alley & Associates 1993), it appears that when steelhead migration is initiated (as early as December) flows are typically adequate to allow migration, but that these flows are not continuously maintained throughout the entire upstream adult and downstream juvenile migration periods. It has also been suggested that in dry winters adult entrance into the lagoon and passage over shallow riffles can be constrained (Nelson 1994, Nelson et al. 2009, D. W. Alley & Associates 2007). Nelson et al. (2009) report that over one-half of the high-quality spawning locations are located upstream of stream mile 8, downstream of which the creek typically goes seasonally dry. During drier winters, this dry reach may significantly delay or prevent adult steelhead from accessing, and smolts from emigrating from, the upper reaches (Nelson et al. 2009).

Analyses of YOY steelhead capture data suggest that rainfall affects adult passage into the upper reaches of Santa Rosa Creek and drives the distribution of spawning and resulting YOY distribution (D. W. Alley & Associates 2007). Relative to the lower reaches, fall YOY densities were generally higher in the upper reaches in years with higher rainfall amounts during the previous year (D. W. Alley & Associates 2007, Nelson et al. 2009). Furthermore, the ratio of YOY steelhead densities in the upper reaches to lower reaches was positively correlated with rainfall in the preceding water year (Figure 3-2). These analyses suggest that during years with higher rainfall, such as 2005, a higher percentage of adults can migrate through the lagoon and lower reaches to access preferred spawning areas in the upper reaches (where greater numbers of YOY steelhead are produced), although the analyses did not specify whether this improved access is a result of longer sandbar breaching, the elimination of dry riffles, and/or improved flow conditions through or over structural barriers. A prolonged drought may prevent adult steelhead access to spawning grounds in the upper watershed for several consecutive years (Nelson et al. 2009).

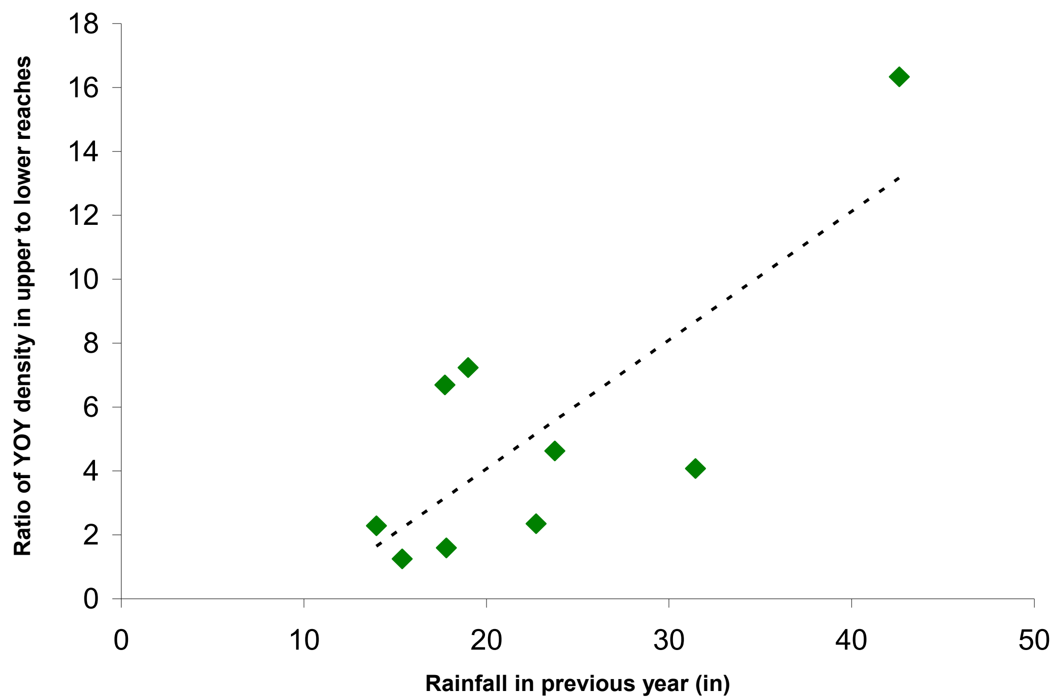

Figure 3-2. Ratio of YOY steelhead lineal density in upper to lower reaches versus rainfall in the previous water year (r^2 = 0.61; P = 0.0130; n = 9). Data sources: Nelson et al. (2009) and CCSD (http://www.cambriawqcp.org/).

In addition, lagoon sandbar formation and breaching patterns are speculated to affect adult steelhead migration in Santa Rosa Creek (D. W. Alley & Associates 2008, Nelson et al. 2009). In drier winters there can be insufficient instream flow to breach and/or maintain an open sandbar during adult migration, possibly preventing adults from entering the lagoon from the ocean, or resulting in a later or shorter run of steelhead (D. W. Alley & Associates 2008, Nelson et al. 2009). In addition, winter sandbar breaching can be influenced by ocean conditions. (Sandbar monitoring data for the Santa Rosa Creek lagoon were not available for this effort.)

In summary, structural and flow-related barriers to steelhead are likely a limiting factor for steelhead in dry years, when they may prevent steelhead from entering the lagoon and can restrict steelhead to the lower 3–7 mi (4–11 km) of the creek, where spawning and rearing habitat is of poorer quality (see discussions below).

3.1.2 Spawning habitat quantity

CDFG surveys from the 1930s described extensive steelhead spawning habitat in Santa Rosa Creek watershed (Titus et al. 2006). In 1960, CDFG noted that spawning areas were abundant and in good condition throughout the lower 7 mi (11 km) of the stream, and scattered in the next 4 mi (Titus et al. 2006). Recent surveys have also documented a substantial amount of steelhead spawning habitat throughout the watershed from stream mile 0.2–13 (Nelson et al. 2009, D. W. Alley & Associates 2008). Nelson et al. (2009) identified a total of 175 pool tail crests and 183 other potential spawning sites appropriate for steelhead spawning in the mainstem, and noted that suitable spawning habitat also likely exists in the lower, accessible reaches of Mora and Lehman Creeks and the East Fork of Santa Rosa Creek (see Figure 1-2). At this time it does not appear that spawning gravel quantity limits production of steelhead in the watershed.

3.1.3 Spawning habitat quality

On Santa Rosa Creek, spawning habitat quality is primarily controlled by the degree of spawning gravel embeddedness, since it appears that in most years flows are sufficient to prevent dewatering of redds during the incubation period and deliver adequate levels of dissolved oxygen to developing embryos (D. W. Alley & Associates 2008, Nelson et al. 2009). High levels of embeddedness, a measure of the degree to which cobbles and gravels are buried by fine sediments (i.e., silt and sand), reduces the ability of females to move cobble to construct redds, and the survival of developing eggs. The *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 2004) indicates that embeddedness of 25% or less is considered good spawning substrate for steelhead; however spawning habitat with embeddedness less than 50% is generally considered suitable (Nelson et al. 2009, NCRWQCB 2006). Excess fine sediments can also decrease egg-to-fry survival by filling interstitial spaces of the redd gravels and reducing oxygen delivery to developing embryos (Chapman 1988). Various studies indicate that as the percentage of fine sediments in spawning gravels exceeds 20–30%, dramatic reduction in embryo survival occurs (Chapman 1988, Reiser and White 1988, NCRWQCB 2006). Embeddedness values in Santa Rosa Creek range from 33–51% in runs (D. W. Alley & Associates 2008) to generally less than 25–50% in pool tail crests (Nelson et al. 2009)[11]. Spawning gravel embeddedness ratings higher than 50% are generally restricted to the lower reaches (Nelson et al. 2009).

Whereas spawning habitat appears to be suitable and not limiting production in the upper reach of Santa Rosa Creek, CDFG has identified a lack of suitable spawning substrates from excessive fine sediment deposition as one of the primary constraints to successful spawning in the lower reaches (Nelson 1994, Nelson et al. 2009). The lower reaches of a watershed are natural places for fine sediments to accumulate due to their lower gradients, and the Perry/Green Valley Creek sub-watershed, which joins Santa Rosa Creek at approximately stream mile 3, delivers a large supply of fine sediment directly to lower reaches of Santa Rosa Creek (see Section 2.5). Until 2011, the Ferrasci Road crossing may have, under a range of flow conditions, restricted spawning to the lower 3.5 mi (5.6 km) of the creek, while inadequate flows through the middle reaches may restrict spawning to the lower 7 mi (11 km) of the creek for a considerable portion of the spawning season during dry winters (Nelson et al. 2009). Under these circumstances, particularly if repeated over a number years, poor spawning habitat quality in the lower reaches likely limits the success of steelhead spawning and juvenile production. This is supported by the lower densities of fall YOY steelhead in the lower reaches when compared to the upper reaches (2-19), although it should be stressed that summer rearing habitat limitations may also be influencing this pattern. Notably, analysis of data from D. W. Alley & Associates (2007) indicated that YOY densities in the lower (stream miles 0–8) and upper (stream miles 8–13) reaches were not significantly correlated from 1998–2006, suggesting that YOY steelhead production—and the factors limiting it (e.g., spawning gravel quality)—differed between the upper and lower reaches within a given year.

Very little is known about the quality or access to spawning habitat in the Perry/Green Valley Creek sub-watershed. Presence of juvenile *O. mykiss* in Perry and Green Valley creeks (CDFG 2003b and USFS 1999, as cited in Becker and Reining 2008) indicates that at least some successful spawning occurred there, in spite of their apparently degraded condition (Yates and Van Konyenburg 1998, Appendix A), although it is not known if these juveniles were the progeny of anadromous steelhead or resident rainbow trout.

[11] It should be noted that a high degree of variability can result from embeddedness measures that are collected with different methods, calculations, or observers (Rowe et al. 2003).

3.2 Summer Rearing Habitat

The relatively extended freshwater rearing of steelhead has important consequences for the species' population dynamics. The maximum number of steelhead that a stream can support is limited by food and space through territorial behavior, and this territoriality is necessary to produce steelhead smolts that are large enough to have a reasonable chance of ocean survival. Therefore, the number of YOY fish that a reach of stream can support is typically small relative to the average fecundity of an adult female steelhead.

The habitat requirements for different age classes of juvenile steelhead are relatively similar, except that as fish grow they require more space for foraging and cover. YOY steelhead can use shallower and slower habitat with finer substrates (e.g., gravels) to meet their energetic demands and escape predators than age 1+/2+ steelhead, which, because of their larger size, have higher energetic demands and require deeper, more complex pools, and coarser substrate or large woody debris for cover while feeding (Hartman 1965, Fontaine 1988, Spina 2003). Spina (2003) found that, in a short reach of Santa Rosa Creek near stream mile 11, most YOY steelhead used shallower water (<0.4 m) than age 1+/2+ steelhead (>0.4 m) and considerably greater availability of shallow habitat. Due to the greater frequency of shallow habitat and because YOY steelhead can generally utilize habitat suitable for age 1+/2+ steelhead, but age 1+/2+ steelhead can not use the shallower, finer substrate habitat suitable for YOY, a stream reach supports far fewer age 1+/2+ than YOY individuals during summer. Between 1998 and 2006 creek-wide densities of YOY steelhead in the fall were between 2.7 and 10.0 times higher than age 1+/2+ densities (D. W. Alley & Associates 2008) (Figure 3-3). For this reason, it is unlikely that YOY steelhead summer rearing habitat limits steelhead production. In support of this hypothesis, D. W. Alley & Associates (2008) reported that fall YOY densities in Santa Rosa Creek were the highest of nine streams surveyed on the Central California Coast in 2006. As such, the following sections generally focus on rearing conditions for age 1+/2+ steelhead.

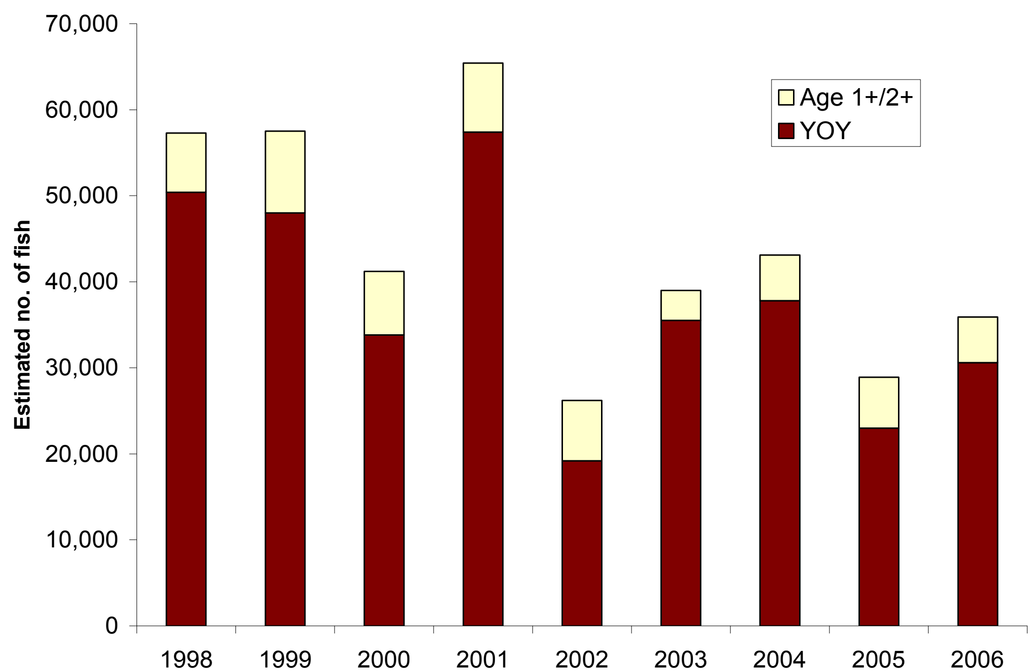

Figure 3-3. Creek-wide YOY and age 1+/2+ steelhead population estimates from 1998 to 2006. Data source: D. W. Alley & Associates (2007, Table 25a).

Juvenile steelhead carrying capacity is strongly influenced by instream flows during the summer, which influence overall rearing habitat area, the depth and volume of pool habitat, connectivity between habitat types, and water temperatures. Streamflow also dictates the quantity of drifting invertebrates that reach feeding steelhead, such that at higher summer flows steelhead can better maintain feeding rates that allow them to meet the metabolic demands of elevated summer water temperatures. Santa Rosa Creek likely experienced seasonally low flows, particularly during drought years, under natural conditions. However, due to groundwater pumping and water diversions, summer instream flows are chronically low compared to historic levels and are considered a critical factor limiting juvenile steelhead populations in Santa Rosa Creek (Yates and Van Konyenburg 1998, D. W. Alley & Associates 2008, Nelson et al. 2009). For example, in 2005, the wettest water year on record since 1998, discharge just downstream of Highway 1 was as low as 9 cfs by late May and was less than 2 cfs from late August until December (Nelson et al. 2009). During drier years, fall discharge measured by D. W. Alley & Associates (2008) was typically between 0.1 and 1 cfs at the downstream-most sampling site. While detailed analysis of how much flow is required to support steelhead summer rearing requirements (e.g., habitat connectivity, suitable stream temperatures, and invertebrate drift) in Santa Rosa Creek has not been conducted, it has been noted that instream flows are often inadequate to allow steelhead movement between habitat types in the late summer and fall (Rathbun et al. 1991, D. W. Alley & Associates 2007, Nelson et al. 2009). For example, flows in the mainstem Santa Rosa Creek go subsurface for approximately 0.5 mile (varying by year) near stream mile 7 during summer (D. W. Alley & Associates 2008, Nelson et al. 2009), eliminating rearing habitat and invertebrate drift in that reach and restricting it downstream.

In small coastal streams such as Santa Rosa Creek, pools are essential summer rearing habitat for age 1+/2+ juvenile steelhead (D. W. Alley & Associates 2008), although age 1+/2+ steelhead in Santa Rosa Creek have also been documented to utilize run habitat in the spring (Spina 2003). Pools must have sufficient depth, generally considered to be 2 ft (0.6 m), although this can depend on availability of escape cover and presence of predators and increases with fish size (Bjorrn and Reiser 1991, McEwan 2001, Spina 2003). In a 2,624-ft (800-m) reach of Santa Rosa Creek near stream mile 11, Spina (2003) documented age 1+/2+ individuals in water as shallow as 1 ft (0.4 m), but most individuals were in depths greater than 2 ft (0.6 m). Reductions in pool depth may adversely affect thermal and velocity refugia and reduce the potential to avoid predators. While recent surveys indicate pools comprise approximately one-third of habitat by stream length in the lower 13 mi (20 km) of Santa Rosa Creek, only about one-quarter were deep enough to be suitable rearing habitat for age 1+/2+ steelhead, and poor pool development has been cited as one of the primary limits on rearing habitat in Santa Rosa Creek (Rathbun et al. 1991; Nelson 1994; D. W. Alley & Associates 2007, 2008; Nelson et al. 2009). Substantially more pool habitat was located in the upper reaches above stream mile 8 than in the lower reaches from stream miles 0–8). Although pool filling as been attributed to fine sediment deposition (Nelson et al. 2009), the relatively high sediment-transporting capacity of the lower reaches of Santa Rosa Creek (see Section 2.5) suggests that poor pool development is likely due to the lack of large woody debris (see discussion below) and other elements that create and maintain pools (e.g., riparian tree roots), rather than solely infilling by fine sediment.

An important element of the pool habitat complexity required for juvenile steelhead rearing is escape cover. Also know as concealment cover or instream shelter, escape cover allows individuals to evade predators and, in the winter, to find refuge from high flows (Cunjak 1996, Spina 2003, D. W. Alley & Associates 2008). Escape cover in Santa Rosa Creek generally includes large, unembedded cobbles and boulders, undercut banks, large woody debris, and overhanging vegetation (D. W. Alley & Associates 2008, Nelson et al. 2009). Less than 20% of pools measured by Nelson et al. (2009) provided escape cover, and unembedded boulder/cobbles and large woody debris were in short supply. Large woody debris is a key habitat component for juvenile steelhead, not only because it provides escape cover, but because it increases overall habitat complexity, facilitates temporary sediment storage, and forms scour points that create and maintain the deeper pools needed by larger juvenile steelhead (Harmon et al. 1986). Both Nelson et al. (2009) and D. W. Alley & Associates (2008) report a paucity of large woody debris in Santa Rosa Creek, with large woody debris making up only about 3% of the cover. A lack of large woody debris is not uncommon in California Mediterranean-climate streams, where historical land clearing and development near streams has decreased the supply of large wood, and woody debris that does make it into the stream are frequently removed due to real and perceived threats to flood control and near-stream infrastructure (Opperman 2002). The lack of large woody debris in Santa Rosa Creek is speculated to restrict carrying capacity of oversummering age 1+/2+ steelhead, since it limits escape cover and prevents the scour formation and maintenance of deep pools (Nelson 1994, Spina 2003, D. W. Alley & Associates 2008, Nelson et al. 2009).

Based on the relatively high abundance of YOY steelhead in the fall, summer rearing habitat is not likely limiting this age class, which is supported by the fact that they can use shallower riffle and pool habitat than age 1+/2+. Based on low abundance of age 1+/2+ compared with YOY, infrequent pools, and groundwater extraction, physical rearing habitat required by age 1+/2+ (and larger YOY) steelhead is very likely limiting summer carrying capacity, and possibly smolt production, in Santa Rosa Creek. However, as discussed in detail below, limitations in winter habitat for age 0+ and age 1+ could also explain this pattern. In addition, the degree to which rearing habitat limits the population may be influenced by habitat conditions in the lagoon. In some cases, lagoons provide rearing habitat capable of supporting large numbers of juveniles that are likely in excess of the summer or winter carrying capacities of stream reaches (Smith 1990, Hayes et al. 2008, Sogar et al. 2009), although this has not been evaluated in the Santa Rosa watershed in recent years. As described in Section 3.5 below, in the 1970s, the juvenile steelhead population in the lagoon was quite large (Bailey 1973 and Puckett 1970, as cited in Rathbun et al. 1991), indicating that it was a suitable and significant rearing habitat for the steelhead population.

3.3 Overwintering Habitat

Overwintering steelhead may suffer elevated mortality when they are displaced (or “entrained”) by high winter flows. Discharge in the inherently flashy Santa Rosa Creek can range from 1 cfs to over 12,000 cfs (as in 1969 and 2005), with winter flood events over 5,500 cfs typically occurring once every five years (Appendix A). Refuge from such flood events requires that steelhead access deeper interstitial spaces in the substrate or other cover to avoid turbulent, high velocity conditions. In general, many of the habitat elements essential for successful summer rearing are also essential for winter rearing.

Because steelhead tend to spawn and rear in higher gradient stream reaches with more confined channels, they have less propensity than other species (e.g., coho salmon) for using off-channel slackwater habitat in winter, and a greater propensity for using in-channel cover provided by cobble and boulder substrates. As such, interstitial spaces in cobble or boulder substrate are considered to be the key attribute defining winter habitat suitability for juvenile steelhead (Hartman 1965, Chapman and Bjornn 1969, Meyer and Griffith 1997). Cobble-boulder rearing habitat is most likely to occur in step-pool channels of confined, higher gradient reaches (Montgomery and Buffington 1997). As described in Section 2.5, cobble-boulder dominated habitat is more common in the upper watershed, much of which is upstream of potential fish passage barriers, and median grain size decreases downstream in almost direct proportionality to drainage area.

Steelhead will use cover in the form of large woody debris or off-channel habitat when it is available, especially in low-gradient reaches where interstitial spaces among cobble and boulder are less abundant. Many of the stream surveys in the Santa Rosa Creek watershed indicate some level of substrate embeddedness by fine sediment (Rathbun et al. 1991, Nelson 1994, D. W. Alley & Associates 2008, Nelson et al. 2009). When embeddedness of cobbles and boulders is greater than about 25% it greatly restricts their utility as escape cover (D. W. Alley& Associates 2008). Nelson et al. (2009) reported that only 26% of pools in Santa Rosa Creek had small cobble, large cobble, or boulders as dominant substrate, with the remainder being comprised primarily of silt, sand, or gravel. Pool tail crest surveys indicated that most large cobbles and boulders were highly embedded, with only one of the 47 locations surveyed having an embeddedness value below 25%. Much of the geology underlying the watershed has moderate to very high erodibility (Section 2.4), so there is naturally a greater potential for fine sediment in the creek channels, and winter habitat in the form of interstitial space may be naturally less abundant than in other coastal streams. Further, there are many anthropogenic sources of fine sediment in the watershed (Nelson et al. 2009, Appendix A). In particular, the Perry/Green Valley Creek sub-watershed delivers a large supply of fine sediment, with no corresponding coarse sediment component, directly to lower 3 m (5 km) of Santa Rosa Creek (see Section 2.5). In this case large woody debris may be more important as winter habitat than in a stream system with naturally available unembedded substrate. However, as described previously, recent stream surveys indicate a lack of large woody debris within the watershed (Nelson et al. 2009, D. W. Alley & Associates 2008).

As with summer habitat, a reach of stream will typically support far fewer age 1+/2+ than YOY steelhead in the winter because YOY are smaller and can utilize a wider range of substrate for refuge. For this reason, in the winter, habitat may often become unsuitable for age 1+/2+ steelhead at lower magnitudes of sedimentation than for YOY. Substrate will become less suitable for both summer and winter rearing at higher levels of embeddedness, but it will often be more limiting in winter because refuge from entrainment during winter freshets requires that steelhead hide deeper within the substrate. As a result, in many watersheds—even those containing poor summer habitat—it has been observed that winter rearing habitat limits steelhead populations in other central California coastal streams such as Lagunitas Creek (Stillwater Sciences 2008), San Gregorio Creek (Stillwater Sciences 2009), and Upper Penitencia Creek (Stillwater Sciences 2006b).

The relatively low abundance of age 1+/2 steelhead observed in fall suggests that either summer rearing habitat or winter rearing habitat is limiting smolt production in Santa Rosa Creek. However, in the absence of an assessment of the juvenile steelhead population in both the fall and the following spring, it is not possible to directly determine whether winter habitat is limiting. Based on the observed relatively low quantity of unembedded cobble-boulder habitat and a paucity of large woody debris (Nelson et al. 2009, D. W. Alley & Associates 2008, Appendix A) it is possible that winter habitat is limiting. Overall, winter habitat is expected to be less important than summer habitat in dry years that lack high flow events and have reduced summer flows. In these years, individuals are less susceptible to entrainment in the winter, while pool habitat and feeding opportunities are expected to be more restricted in the summer.

Juvenile steelhead

3.4 Bioenergetics

Numerous studies have examined the relationships between water temperature, growth, and survival of juvenile steelhead. Results of these studies vary between study populations. Recent studies of more southern populations of steelhead indicate that they can continue to grow at higher water temperatures (Spina 2007, D. W. Alley & Associates 2008, Sogard et al. 2009, Bell et al., in review) and will tolerate short periods of temperatures, up to approximately 81–84°F (27°–29°C) (depending on acclimation temperature), that were previously considered lethal (Myrick 1998).

Available data for Santa Rosa Creek indicate that, in most years, summer water temperatures are suitable for successful steelhead rearing in the majority of stream reaches. Maximum temperatures in the summer and fall of 2004–2006 rarely exceeded 69°F (21°C), particularly in the upper reaches above stream mile 8 (D. W. Alley & Associates 2008, Nelson et al. 2009). Temperature suitability for steelhead rearing may occasionally be exceeded in the lower reaches (below stream mile 8) in drier years (in the summer and fall of 2004–2006, maximum daily water temperatures commonly exceeded 75°F (24°C), but rarely exceeded 77°F (25°C) [D. W. Alley & Associates 2008, Nelson et al. 2009]), but there is still considerable uncertainty of what optimal temperatures for steelhead are in this region (A. Spina, pers. comm., 2010).

Available data suggests that despite periods of unsuitable water temperature in lower Santa Rosa Creek, steelhead continue to grow, and at rates reported to be higher than in nearby San Simeon Creek (D. W. Alley & Associates 2008, Sogard et al. 2009). Fulton condition factors for YOY and age 1+/2+ individuals captured in the fall of 2005 by Nelson et al. (2009) varied considerably, but, within size classes, were actually higher in the warmer lower reaches than cooler, upper reaches. In addition, both Nelson et al. (2009) and D. W. Alley & Associates (2008) found that the size of YOY fish increased steadily in the downstream direction. Although it is not certain whether YOY growth was higher in downstream reaches, if individuals emerged and begin feeding earlier in the spring there, or if larger individuals actively migrated downstream, together these results do suggest that water temperatures were not excessive and/or sufficient food was available in the lower 8 mi (13 km) of the creek during steelhead rearing. Age data from scale analysis and corresponding length data from 2006 (which had a relatively wet spring) support the finding that juvenile steelhead in the lower 8 mi (13 km) of Santa Rosa Creek generally have relatively high growth rates in their first year, with many individuals reaching 5–6 in (130–160 mm) fork length by fall (D. W. Alley & Associates 2008). Above stream mile 8 however, length frequency data of juvenile steelhead captured in October and November 2005 do show a large number of relatively small (2–3 in [50–80 mm] fork length) YOY fish (Nelson et al. 2009). The relatively lower condition factors and generally smaller fish captured above stream mile 8 suggests that food availability may be limiting growth in these reaches compared to the lower 8 mi (13 km).

Overall it appears that water temperature generally does not hinder juvenile growth in Santa Rosa Creek, likely because of mostly suitable water temperatures, natural adaptations to higher temperature, and possibly because of high food availability. However, there appears to be an inconsistency between the observed growth rates and the relatively small smolt sizes observed by the limited spring outmigrant trapping data in Santa Rosa Creek. Based on the size range of YOY observed in the lower reach (5–6 in [130–160 mm] fork length) in fall, most smolts would be expected to be greater than 7 in (170 mm) by spring. Instead, the majority of smolts captured during spring outmigrant trapping in 2005 averaged 6.5 in (165 mm) fork length (Nelson et al. 2009). Several studies have shown a strong relationship between the size at which a steelhead smolt migrates to the ocean and the probability that it will return to spawn (Kabel and German

1967, Hume and Parkinson 1988, Ward et al. 1989, Bond et al. 2008). In one the most focused studies on marine survival in a central California coastal watershed, Bond et al. (2008) found that, in Scott Creek in Santa Cruz County, few returning adults were smaller than 6 in (150 mm) at ocean entry and the majority were larger than 8 in (200 mm). Similarly, Ward et al. (1989) found that only smolts greater than 7 in (170 mm) typically experienced relatively high marine survival (>10%). Assuming that size-dependent survival and ocean conditions experienced by the Santa Rosa Creek populations are similar to these other populations, it is possible that in some years (e.g., 2005) most smolts from Santa Rosa Creek have poor ocean survival due to their small size. As a comparison to other southern California watersheds, in the Santa Clara River smolts in 2009 averaged 7 in (185 mm) fork length (S. Howard, pers. comm., 2010); in the Santa Clara and Santa Ynez estuaries most smolts in 2007/2008 were greater than 7 in (170 mm) fork length (Kelley 2008), and in Topanga Creek nearly all smolts captured during spring 2009 were greater than 7 in (170 mm) (Bell et al. in review). Based on the 2005 outmigrant trapping results, there is the potential that relatively small smolt sizes in Santa Rosa Creek (and therefore poor ocean survival) are a potential limiting factor for the population. However, since outmigrant trapping occurred at stream mile 0.3, and there were growth opportunities in the riverine and lagoon habitat downstream of the trap, it is not clear if captured individuals continued to rear and grow in the lagoon before leaving for the ocean, as observed in other systems (Smith 1990, Hayes et al. 2008). The extremely high growth of some YOY—as indicated by annual growth rings on their scales—collected just upstream of the lagoon (D. W. Alley & Associates 2008), suggests that food resources are likely high in lower Santa Rosa Creek. Clearly, additional outmigrant trapping data, and determining growth opportunities and residency within the lower creek and lagoon, is critical to assessing if smolt outmigrant size is a limiting factor in Santa Rosa Creek.

3.5 Lagoon Habitat

Coastal lagoons are fed mostly by freshwater streamflow and are generally separated from the sea by a sandbar, except when that sandbar is breached during high-flow events or when sea water overwashes the sandbar. Lagoon rearing has been demonstrated to be critically important for other central California coast steelhead populations, with significantly higher growth rates and ocean survival by steelhead that reared in lagoons, even with lagoon water temperatures as high as 75°F (24°C) (Smith 1990, Hayes et al. 2008, Bond et al. 2008). While no studies of lagoon rearing, growth, and survival have been carried out in Santa Rosa Creek, these findings from other central California coast watersheds highlight the potential importance of the Santa Rosa Creek lagoon for steelhead rearing. Since larger smolts tend to have higher ocean survival, growth during lagoon rearing may increase ocean survival of steelhead smolts. It appears that if lagoons are well-mixed (i.e., not salinity stratified), or comprised of mostly freshwater, they can maintain a relatively cool, well-oxygenated, and food-rich environment that provides high quality habitat for juvenile steelhead (Smith 1990). This can potentially relax to some degree the density-dependent bottleneck occurring in stream habitat and provide a high growth environment and adjustment to a saline environment that improves ocean survival for both stream and lagoon reared fish. Conversely, when lagoons are highly saline, or salinity-stratified, they collect heat in the lower saltwater layer, have relatively lower dissolved oxygen levels, and typically have unsuitable conditions for rearing.


Full lagoon in winter

While very little historical or current data exist on the juvenile steelhead population in Santa Rosa Creek lagoon, what data are available suggests it has declined. In the 1970s, the juvenile steelhead population in the lagoon was estimated to be between 2,290 and 6,800 (Bailey 1973 and Puckett 1970, as cited in Rathbun et al. 1991), suggesting that it was a suitable and potentially important rearing habitat. By the 1980's it appears that little if any steelhead rearing occurred in the lagoon (Holland, unpubl. data, as cited in Rathbun et al. 1991). While ineffective at detecting juvenile steelhead, sampling for tidewater goby in the lagoon from 1993–2007 provides evidence that, in some years, both YOY and smolt-sized steelhead utilize the lagoon for rearing in the summer and fall. In summer and fall sampling in 2004, Alley and Sherman (2006) captured 101 and 69 juvenile steelhead, respectively between Shamel Park and the Windsor Bridge. No steelhead were captured in 2005, but visual observations of steelhead in the lagoon were made (Alley and Sherman 2006). Outmigrant trapping conducted in spring 2005 at stream mile 0.3 also suggests that a portion of the juvenile steelhead population likely migrates into the lagoon prior to smolting: numerous individuals measuring between 2 and 5 inches (50 and 140 mm) and having parr coloration were captured (Nelson et al. 2009). It is not clear whether these individuals were displaced due to limited carrying capacity in upstream reaches, or if they were preferentially exhibiting a lagoon rearing life history strategy.

It is unclear to what extent Santa Rosa Creek lagoon provides suitable conditions for juvenile rearing. While the lagoon may provide quality over-summering habitat in some years, it likely becomes too saline and warm for juvenile steelhead survival in others (D. W. Alley & Associates 2008). The quality of lagoon rearing habitat for steelhead is largely dependant on sandbar formation and maintenance, the amount of freshwater inflow, and water quality conditions. When sandbar breaching is delayed or cut short, either from inadequate instream flows or ocean conditions, adult steelhead are unable to enter the creek and spawn (they typically stray into other nearby creeks). The presence of smolt-sized individuals in Santa Rosa Creek lagoon after sandbar closure, suggests that outmigrating individuals may be "trapped" in the lagoon when the sandbar reforms early in the season (D. W. Alley & Associates 2006). Survival of smolts that rear in the lagoon is not known. Conversely, if the sandbar is breached artificially in the summer (natural breaching during the summer is rare), lagoon habitat can be rapidly reduced and become too saline for rearing steelhead. Fortunately, artificial breaching of the Santa Rosa Creek lagoon is not known to occur (M. Walgren, pers. comm., 2010).

Reduced instream flows limit the extent of lagoon habitat and affect the dynamics of lagoon formation, causing extended periods of saltwater and freshwater stratification that lead to thermal stratification, with warmer temperatures and anoxic conditions along the bottom that lower dissolved oxygen levels and reduce food supplies (Smith 1990, Capelli 1997). In some lower flow years such as 2003 and 2004, entire sections of the Santa Rosa Creek lagoon dried up, reducing the area of suitable steelhead rearing habitat (D. W. Alley & Associates 2008).

Water temperatures and DO levels in the lagoon, particularly at the bottom, can frequently exceed lethal limits for steelhead in the summer and fall (see Section 2.8.1). Although low DO may restrict the scope of steelhead activity in lagoon, D. W. Alley & Associates (2008) hypothesizes that low DO levels are less limiting than temperature to steelhead survival in the lagoon. The observed high water temperatures and low DO levels likely create seasonally unfavorable conditions for rearing steelhead and may limit smolt growth, survival, and production in the watershed in some years. Nonetheless, it is possible that the productive, food-rich lagoon allows juvenile steelhead to successfully rear in the lagoon, even when water temperatures reach moderately high levels for short periods. Overall, the lagoon habitat is predicted to be a crucial component of the life history of steelhead in Santa Rosa Creek and has the potential to increase the carrying capacity of the watershed, alleviating some of the limitations from poor habitat conditions in stream reaches and contributing to recovery of the population.

Although much of the above discussion describes stream and lagoon habitat separately, they are better viewed as connected habitat features. Just as upstream conditions such as freshwater inflow and sediment delivery affect lagoon characteristics, demographic processes such as immigration and emigration link steelhead population dynamics within stream and lagoon habitat. Thus, steelhead populations are typically limited by a combination of density-dependent processes occurring within stream reaches, and the degree to which seasonal rearing opportunities and water quality in lagoon habitat augment carrying capacity in the watershed. For example, if it is initially assumed that winter or summer habitat conditions limit the carrying capacity of stream reaches, it would then be assumed that the ability of lagoon habitat to support steelhead in excess of stream carrying capacity is dependent on the degree to which freshwater inflow interacts with, or displaces, saline water to prevent salinity stratification, which is affected by annual variability in timing of sandbar formation and amount of freshwater inflow.

Increasing winter carrying capacity for YOY steelhead may increase the abundance of juvenile fish until summer habitat for age 1+/2+ steelhead becomes limiting. After winters with high YOY survival, an age 1+/2+ summer habitat bottleneck may develop if pool habitat becomes limiting. However, behavioral emigration of “excess” age 1+/2+ steelhead surviving the winter could increase production if suitable habitat is available in the Santa Rosa Creek lagoon. Besides the ocean life stages, utilization of lagoon habitat is perhaps the least understood component of steelhead population dynamics and ecology in the watershed. For this reason, it is important to implement targeted studies describing the lagoon water quality and habitat conditions as they relate to juvenile steelhead use, growth, and survival.

3.6 Summary of Limiting Factors and Uncertainties

Based on historical evidence, the Santa Rosa Creek watershed supported a robust population of steelhead. There are many ecological characteristics of the watershed that continue to be relatively healthy compared to other streams in the region, and steelhead continue to persist in Santa Rosa Creek despite drastic declines in neighboring watersheds. These characteristics, including high quality habitat in the upper reaches (stream miles 8–13), moderate water temperatures, and an intact lagoon system, highlight the regional significance and potential of this watershed to protect and recover nearby steelhead populations.

A wide range of factors, however, affect the freshwater life stages of steelhead in Santa Rosa Creek. Rather than listing all elements that potentially influence the population (see D. W. Alley & Associates [2008] for a detailed discussion), the limiting factors analysis was used to generate the following hypotheses of the highest priority and most likely causes of the decline in steelhead abundance in the watershed. In turn, these hypotheses are the basis of several of the management and restoration recommendations in Section 4. Overall, the analysis results in the following hypotheses of high priority limiting factors in the watershed:

1. Restricted access to spawning habitat limits steelhead spawning and juvenile production. In dry water years the dry middle reaches can confine spawning adults to the lower reaches.
2. When confined to the lower reaches, steelhead spawning success is limited by poor quality spawning habitat. Potential spawning substrates in the lower reaches are embedded by fine sediment.

3. Low instream flows during the summer reduce summer rearing habitat for age 1+/2+ steelhead and limit the population, particularly during drier water years.
4. Inadequate large woody debris and to a lesser extent fine sediment filling of pools (primarily below Perry Creek), restrict formation and maintenance of complex summer rearing pool habitat for age 1+/2+ steelhead and limit the population.
5. Inadequate large woody debris, embeddedness of cobbles and boulders, and fine sediment filling of pools, limits the overwinter survival of YOY and age 1+/2+ steelhead, particularly during years with flood events.

In conducting the limiting factors analysis of steelhead in the Santa Rosa Creek several uncertainties and data gaps were identified. Filling these data gaps is fundamental to refining, and potentially eliminating, some of the limiting factor hypotheses posited above. These data gaps are the basis of several of the research recommendations in Section 4.

1. Given the uncertainty in recent escapement levels, adult trapping and/or detection in Santa Rosa Creek is needed to monitor annual population success and collect baseline data for the evaluation of population response to implemented restoration actions. Due to the difficulty in monitoring steelhead spawning in creeks with small steelhead populations and dispersed spawning habitat, CDFG recommends the use of traps, weirs, and/or video or sonar detection systems to provide an absolute count of migrating adults (Adams et al. 2011).
2. Juvenile population sampling (e.g., snorkel surveys) is needed in conjunction with fall sampling to differentiate overwinter from oversummer survival. This would need to be done over several years to help elucidate the dependence of winter and summer survival on variation in rainfall and stream flow.
3. A better understanding of residency timing, duration, and growth in the lagoon is needed to determine the suitability of the lagoon for rearing and the influence lagoon rearing has on smolt growth and ocean survival.

4 RECOMMENDATIONS

There are many ecological characteristics of the Santa Rosa Creek watershed that have not been as adversely impacted in terms of steelhead habitat requirements compared to other streams in the region—for example moderate stream temperatures and an intact lagoon system. However, based on the Watershed Synthesis, Steelhead Limiting Factors Analysis, Geomorphic Assessment (Appendix A), and benthic macroinvertebrate sampling (Appendix B), some watershed conditions have been degraded and will require restoration or enhancement to achieve significant protection and recovery of the steelhead population.

The primary objective of the recommendations provided in this section is to address the factors currently believed to be limiting the steelhead population. Additional objectives of these recommendations are to provide for the long-term protection of key ecosystem components that are intact, restore, or enhance ecosystem components that require it, and fill key gaps in the understanding of the watershed and steelhead population. Because there are a number of ways in which these objectives can be met, the recommendations have been organized based on their specific goal, resulting in eight categories. These goals are listed in order of their relative importance to steelhead habitat restoration:

- Increase Summer and Fall Instream Flows
- Restore the Riparian Corridor
- Reduce Fine Sediment Delivery to the Creek
- Conserve and Protect Open Spaces and Existing Land Uses
- Increase Woody Debris Supply and Retention
- Remove Barriers to Fish Passage
- Fill Key Data Gaps
- Reduce Mercury Supply

The recommendations serve as a guide to improving habitat conditions in the Santa Rosa Creek watershed for steelhead, based on identified limiting factors. If implemented, these actions will also benefit other aquatic and terrestrial species. In addition, they are compatible with current land uses in the watershed: reducing land erosion, maximizing efficient rural and urban water use, and conserving agricultural land use that has been part of this watershed for two centuries are compatible with many concerns voiced by stakeholders throughout the watershed planning process.

The recommendations have been developed to be implemented individually, although appropriate combinations and phasing are described, and on a voluntary basis, by or with the consent of willing landowners. They are not intended as prescriptions or requirements. Together, the full suite of recommendations presents multiple ways to address steelhead limiting factors and provides an integrated watershed management plan that will serve various local organizations and individuals for both the near- and long-term. As these are all voluntary actions, various funding sources are available to fund some or all of the recommendations described below (see Appendix D). One advantage of this plan is to serve as a document to support funding for restoration activities in the watershed.

4.1 Increase Summer and Fall Instream Flows

Insufficient instream flow during the summer and fall, as a result of groundwater extraction and riparian diversions, has been identified as the primary factor limiting summer rearing habitat and juvenile steelhead survival in the watershed (Rathbun et al. 1991, Nelson 1994, Yates and Van Konyenburg 1998, D. W. Alley & Associates 2008, Nelson et al. 2009). The recommendations below for increasing summer and fall instream flows include immediate actions, such as water conservation and constructing off-stream storage, as well as updating the water budget and identifying steelhead instream flow requirements, which are necessary to identify specific measures and locations that would be most effective in increasing summer and fall instream flows. These recommendations can be implemented to begin the process of reducing demand for surface and groundwater supplies in the summer and fall, and could also improve the quality and quantity of rearing habitat in the lagoon by increasing the amount and duration of freshwater inflow.

4.1.1 Implement water conservation and reuse strategies

To reduce the amount of water diverted from the stream and pumped from the groundwater basin, and potentially maintain summer and fall instream flows, it is recommended that municipal, domestic, agricultural, and recreational water conservation strategies, including water reuse, be implemented. It is further recommended that additional water conservation opportunities, such as using non-potable water for outdoor landscaping and irrigation, be pursued by CCSD. Per the San Luis Obispo County (2008) North Coast Area Plan, any new development resulting in increased water use should offset such an increase by retrofitting water fixtures, replacing irrigated landscaping with xeriscaping, or other verifiable actions to reduce water use. It is also recommended that water reuse, such as the direct reuse of sufficiently treated wastewater or groundwater replenishment with treated wastewater, be further evaluated in the Santa Rosa Creek watershed. A 2004 Recycled Water Master Plan prepared by CCSD estimated that approximately 50 acre-feet of water could potentially be provided through the use of recycled water, with no net increase in groundwater pumping (R. Gresens, pers. comm., 2012). Currently, Santa Rosa Creek watershed-derived municipal wastewater is treated and allowed to filter into the San Simeon Creek groundwater basin. Given the scarcity of water resources in the region, developing ways to retain and use this water in the watershed would be beneficial.

Local Resource Conservation District, Natural Resources Conservation Service, and Farm Bureau resources are available to assist rural residents and farmers in the watershed in implementing water conservation and reuse strategies. Examples of broad categories of voluntary on-farm and rural water conservation and reuse strategies include:

- Irrigation Management and Scheduling: The local Resource Conservation District's Mobile Irrigation Lab can provide on-site distribution uniformity evaluations of individual irrigation systems. Deciding when and how much water to apply to a field has a significant impact on the total amount of water used by the crop, water use efficiency, and irrigation efficiency. A number of different scheduling systems have been developed that can use either soil/plant- or atmosphere-based measurements to determine when to irrigate. Using a more scientific approach to irrigation scheduling has generally been shown to decrease the amount of water applied while improving yield.
- Tail Water Return Systems: To provide adequate water to the low end of the field, surface irrigation requires that a certain amount of water be spilled or drained off as tail water. Tail water return systems catch this runoff and pump the water back to the top of the field for reuse.

- Reduced Tillage and Cover Crops: The use of cover crops between crop rows or crop seasons and reducing soil tillage increases soil water storage capacity by capturing runoff and minimizing evaporation.
- Plant Species Options: Use drought tolerant forage and horticultural/landscaping plant species can help reduce water use.
- Keyline Design: Keyline design captures water at the highest possible elevation and spreads it outward toward drier ridges using plow lines and gravity, thereby reversing the natural concentration of water in valleys. Maximizing the distribution of water to drier ridges using precise plow lines that are slightly off-contour slows the movement of water and spreads it more uniformly, infiltrating it across the broadest possible area.

4.1.2 Construct off-stream closed water storage

Off-stream water storage of extracted groundwater and riparian diversions for domestic and agricultural uses, which would divert water during higher instream flow conditions in the winter and store it for use in the summer and fall, is one way of achieving additional instream flows for steelhead rearing and fall migration during dry water years. Water for off-stream storage would be diverted in winter only, with an elimination of spring, summer, and/or fall water rights. Off-stream closed water storage facilities (e.g., above-ground water tanks, cisterns, etc.) are maintained along several tributaries in the watershed; it is recommended that opportunities to increase their efficiency as well as to increase the number of facilities in strategic locations be pursued.


Storage tank in Santa Rosa Creek watershed

There have been several recent and successful efforts to increase summer and fall instream flows through water rights transfers and off-stream storage construction that may serve as a model for efforts in the Santa Rosa Creek watershed. In particular, the Mattole Headwaters Groundwater Management Plan 1.0 (Sanctuary Forest 2008) provides an example that, although from a northern California salmonid stream, is likely highly relevant to the Santa Rosa Creek watershed.

4.1.3 Purchase water rights from willing sellers for instream flows

California amended its Water Code in 1991 to allow for the purchase and transfer of water rights to instream flows. While water rights issues are technically and legally complex, and the effect of a single water rights claim on instream flows is typically not known, this could be a strategy for increasing summer and fall instream flows in Santa Rosa Creek. Water rights purchases would be based on willing sellers/donors. Purchased rights could be transferred to instream flows, with an entity such as CDFG or a land trust holding the right, or from a summer to winter diversion if off-stream storage is available (see recommendation above). Individual purchases and transfers will likely require significant research to understand the characteristics of the water right, assess second and third party impacts, and ensure the transfer is legitimate. If, based on this research, a purchase from a willing seller/donor is feasible and appropriate, an application for transfer would need to be prepared and finalized in accordance with SWRCB or governing agency specifications.

4.1.4 Conduct stream gauging and develop an updated water budget

Although Yates and Van Konyenburg (1998) provide insight into the effect of CCSD's municipal groundwater pumping and private groundwater pumping and water diversions on flow conditions in Santa Rosa Creek through the early 1990s, a more detailed and updated water budget is necessary to understand the effect of domestic and agricultural water extraction on instream flow levels, particularly during low-flow seasons. This level of understanding is important to identifying site-specific measures to increase instream flow levels and developing reasonable goals for minimum instream flow maintenance under a range of water-year types. Due to the technical and political complexities of developing an updated water budget, one option is that a sample set of private wells and surface water diversions be monitored and that the data be kept confidential. It is recommended that monitoring data be analyzed on an approximately annual basis to determine both the total amount of water pumped from the watershed and/or specific sub-watersheds during different water-year types and, in conjunction with instream flow measurements, the influence of groundwater pumping and surface water diversions on seasonal instream flow levels. An updated water budget would also contribute to the County's North Coast Area Plan requirement that any new development in Cambria not using a CCSD connection must assure no adverse impacts to Santa Rosa Creek (San Luis Obispo County 2008).

Currently there is no single consistent or accurate source of stream flow data in the watershed, which are necessary to provide useful and reliable data for an updated water budget. This is essential to understanding changes in watershed conditions, developing meaningful measures to increase instream flows, and monitoring the effectiveness of implemented actions. This could be done most efficiently by bringing the stream gauge at the Main Street Bridge up to current USGS-protocols for stream gauge operation and calibration. The primary requirement at present is for a campaign of flow measurements aimed at robustly calibrating the gauge during low and high flows. In addition to improving the gauge at Main Street Bridge, it is recommended that additional stream flow gauges be installed upstream of the lagoon to record flows that include all tributaries and in the vicinity of Mammoth Rock to record flows in the portion of the watershed with relatively consistent perennial flow.

4.1.5 Reduce future municipal groundwater pumping

Per the San Luis Obispo County (2008) North Coast Area Plan, if/when the proposed desalination plant is operational, it is recommended that CCSD water withdrawals from the Santa Rosa Creek aquifer be limited to help protect instream flows in the lower reaches of Santa Rosa Creek (i.e., those reaches affected by CCSD pumping), as well as the aquifer itself and agricultural resources. If planned and operated strategically, the proposed desalination plant could reduce the need for municipal groundwater pumping along Santa Rosa Creek and help to conserve instream flow in the summer and fall.

4.2 Restore the Riparian Corridor

Native riparian vegetation is fundamental to maintaining summer and winter rearing habitat elements that are likely limiting the steelhead population in Santa Rosa Creek. A functioning riparian corridor with overhanging vegetation moderates stream temperatures by shading the channel, provides a source of large woody debris and roots that interact with streamflows to force the development of pools for rearing habitat, and provides leaf litter for aquatic invertebrate, as well as terrestrial invertebrate, prey species. By providing these ecosystem benefits, riparian restoration will also improve steelhead rearing conditions in the lagoon by moderating water temperatures and contributing to the food supply. Riparian vegetation also reduces streambank erosion, filters fine sediment and nutrients from runoff, provides wildlife movement corridors, and prevents non-native invasive plant species from becoming established. The following recommendations to restore the riparian corridor, several of which overlap with previous recommendations by CDFG (Nelson 1994, Nelson et al. 2009), will enhance summer and winter steelhead rearing habitat elements, reduce streambank erosion and fine sediment supply, and help conserve more natural streambank conditions in the lower reaches.

4.2.1 Revegetate degraded streambanks

To facilitate and expedite the restoration of a dense, multi-storied riparian corridor that provides multiple ecosystem services and benefits, it is recommended that native riparian trees and shrubs be planted in suitable areas. Examples of suitable areas include reaches where cattle have been excluded or are otherwise unable to graze on revegetated plants, and in areas where natural recruitment of riparian vegetation is not expected to occur in the near-term, such as steeper streambanks, higher elevation benches, or in strategic locations in or around bank revetment. Active revegetation may also be suitable soon after non-native invasive plant removal efforts (see below) to quickly restore vegetative cover and minimize the potential for re-infestation.

Intact riparian vegetation in lower Santa Rosa Creek

While planting palettes need to be selected based on site-specific conditions (e.g., elevation above baseflow, soil type, and groundwater level), alder (*Alnus rubra*), willow (*Salix* spp.), cottonwood (*Populus* spp.), sycamore (*Platanus racemosa*), big-leaf maple (*Acer macrophyllum*), and mulefat (*Baccharis salicifolius*) are examples of native trees and shrubs that may be appropriate for revegetation on streambanks and in wetter areas. In some cases, such as in the middle reaches, steep streambanks may need to be graded before planting. In upland or drier areas, coast live oak (*Quercus agrifolia*), blue oak (*Q. douglasii*), madrone (*Arbutus menziesii*), manzanita (*Arctostaphylos* spp.), California sagebrush *(Artemisia californica*), sage *(Salvia* spp*.),* toyon (*Heteromeles arbutifolia*), and coyote bush (*Baccharis pilularis*) may be appropriate. To the greatest extent possible, planting stock should be collected from the Santa Rosa Creek watershed to maintain genetic integrity. Planting at the onset of the rainy season can greatly reduce and even eliminate the need for irrigation, particularly in areas where plant roots can be expected to reach groundwater quickly. The use of cuttings, particularly for willow, cottonwood, and mulefat, can be another way to reduce the cost of revegetation efforts.

4.2.2 Manage grazing to reduce impacts to the riparian corridor

Cattle currently graze on streambanks and access the stream channel in several reaches of Santa Rosa Creek, as well as throughout the lower Perry/Green Valley Creek sub-watershed (Nelson et al. 2009, Appendix A). Such grazing can have severe impacts on riparian and instream conditions, including denuded streambanks, increased water temperatures, increased streambank erosion, and water quality contamination (Armour et al. 1994, Belsky et al. 1999), to the extent that fish populations are impacted (Platts et al. 1985, Ohmart 1996). It is recommended that grazing in the Santa Rosa Creek watershed be managed to reduce impacts to the riparian corridor. This could include the installation of fencing to exclude cattle from streambanks and the channel, as previously recommended by CDFG (Nelson et al. 2009), or other practices to limit access and use of the riparian corridor by cattle, such as off-channel watering. Ideally these voluntary efforts would be focused on the denuded reaches of upper Santa Rosa Creek, the intermittent portion of the middle reach of Santa Rosa Creek, and in the Perry/Green Valley Creek sub-watershed. In the intermittent middle reach, where surface flow loss to groundwater may already limit the extent of riparian vegetation, cattle grazing is likely exacerbating streambank erosion and further preventing riparian vegetation to persist. In the Perry/Green Valley Creek sub-watershed, cattle grazing has denuded streambanks and is contributing to streambank erosion that supplies fine sediment to the lower reaches of Santa Rosa Creek.

4.2.3 Minimize the need for bank protection

While bank protection such as concrete, rip-rap, and gabion baskets can be necessary to protect infrastructure near the creek, particularly in emergency situations, it degrades riparian and instream habitat by precluding native vegetation and simplifying the channel, and, as observed on Santa Rosa Creek in the town of Cambria, often shifts the erosion upstream or downstream of the rip-rap or to the opposite bank (Nelson et al. 2009). Conserving and restoring streambanks and floodplains through the recommendations above will help minimize the need for bank protection by preventing development near the creek (that might subsequently require protection) and decreasing the erodibility of the banks. Where roads or buildings are threatened by streambank erosion, it is recommended that the potential to "train" the creek away from these areas be investigated as an alternative to hardened bank protection. For example, the bar opposite the eroding streambank could be manipulated (e.g., skimmed or cut) to direct flow closer to the middle of the channel and away from the eroding bank. The feasibility of such an approach is dependent upon site-specific conditions (e.g., access for heavy equipment, and the condition of upstream and downstream areas) and must be evaluated accordingly. However, it presents several significant benefits compared with hardened bank protection: it addresses the cause rather than just the symptom of bank erosion; and it conserves existing, and may even help improve, riparian and instream habitat conditions.

As previously recommended by CDFG, where bank protection is necessary, it is recommended that bio-engineering alternatives to rip-rap and other hard measures be implemented. Many of these alternatives are described in CDFG's California Salmonid Stream Habitat Restoration Manual (Flosi et al. 2004). Streambank soil bioengineering, for example, typically includes installing large woody debris and/or boulder structures and planting interstitial (i.e., exposed) bank surfaces with quick growing vegetation, such as willows. The exposed large woody debris, boulders, and planted vegetation dissipates flow velocities against the bank toe and bank surface, and planted vegetation physically holds bank substrates (silts and sands) in place, thus increasing bank strength. Exposed large woody debris and planted vegetation will, in turn, also contribute to over-summer and over-winter habitat improvements for steelhead by scouring pools and providing cover. Separate or in combination with soil bioengineering, a bio-fabric can be applied across the bank surface to shield the bank high flow velocities and holds bank soils in place, and/or steep streambanks can be re-contoured (i.e., re-shaping) to create a more gently-sloping profile and increase resistance at the bank toe. A more gently-sloping bank has a lighter load above the bank failure plane and is, therefore, better able to withstand toe scour and/or undercutting than a vertical bank.

4.2.4 Treat non-native invasive species

As described in the Watershed Synthesis, a number of non-native invasive plant species that have the potential to degrade riparian habitat by replacing native species and altering physical conditions have been documented in the Santa Rosa Creek riparian corridor. Several of these species, including several large-scale infestations of cape-ivy, isolated occurrences of arundo, pampas/jubata grass, eucalyptus, and French/Scotch broom are priorities for treatment efforts to promote the natural regeneration and growth of native vegetation and prevent further infestations. Removal of large areas of non-native vegetation is generally done in conjunction with riparian restoration so as to prevent the re-colonization of the area by non-native species.

However, the vast majority of the remaining watershed area has not been surveyed for non-native invasive species, where infestations can easily expand to downhill or downstream locations. For example, ponds in the Perry/Green Valley sub-watershed, which is largely un-surveyed, are likely a major source of bullfrogs to lower Santa Rosa Creek. Identifying small or recently established populations early on is important, since these are easier to control and/or eradicate. In addition, understanding broader patterns of non-native invasive plant distribution is important to increase the effectiveness of treatment measures and reduce the potential for later or downstream re-infestations. Therefore, it is recommended that the locations and populations of persistent non-native, invasive species in the riparian corridor be mapped and described. The inventory needs to conclude with a summary of identified species (in terms of their potential detriment to the ecosystem, rate of infestation, and methods of control) and priorities and designs for control measures.

Based on the non-native invasive species identified in the watershed, and the severity of their infestation, site-specific treatment methods need to be developed. Treatment methods should be selected that are appropriate for the site, minimize disturbance to adjacent natural areas, and do not result in unintended effects on non-target species. When appropriate, treatment methods should be implemented by trained and/or licensed crews. In some cases, non-native species can be discouraged and/or controlled by properly managed, targeted maintenance activities. For example, grazing practices can be managed to encourage and restore native species over non-native grasses and forbs.

4.3 Reduce Fine Sediment Delivery to the Creek

Summer and winter rearing habitat in the lower reaches (stream miles 0–3.5) of Santa Rosa Creek is partially degraded by excess fine sediment input. Fine sediment embeds larger substrates, limiting their use for spawning and as refuge from high flows, and can fill pool habitat that is used during both summer and winter rearing. The following recommendations focus on two of the most problematic sources of fine sediment identified in the Geomorphic Assessment (Appendix A): the Perry/Green Valley Creek sub-watershed and road-related streambank erosion. Fine sediment supply from excessive streambank erosion would be addressed through the riparian restoration recommendations made above. It is recommended that initial treatment of fine sediment sources, wherever they are conducted, be implemented as an adaptive management experiment, with monitoring to determine if treatments are effective at reducing substrate embeddedness and/or pool infilling.

In addition, it is recommended that fine sediment source treatments be conducted in coordination with other recommendations to improve winter rearing habitat in mainstem Santa Rosa Creek, further test the hypothesis that winter habitat is limiting steelhead production in the watershed, and assess the effectiveness of the actions. Based on the monitoring results of initial efforts, it can be determined whether to expand and/or revise treatment of fine sediment in the future. Remediating sources of fine sediment, particularly in the Perry/Green Valley Creek sub-watershed is also likely to increase the extent of rearing habitat in the lagoon by reducing the amount of aggradation.

4.3.1 Maintain roads to decrease hillslope and streambank erosion

San Luis Obispo County is responsible for the maintenance of Santa Rosa Creek Road and others in the watershed. Road-related runoff is the cause of much of the hillside and streambank erosion that is frequently observed in the watershed. Often, improperly placed ditches and culverts (or a lack thereof) concentrate winter runoff from roads where it can actively erode hillslopes or streambanks. Such erosion currently threatens Santa Rosa Creek Road at several locations. Road maintenance actions taken by the County would correct drainage features that currently concentrate runoff to unsuitable locations. It is recommended that culvert or ditch improvement or relocation be considered by the County at several locations (particularly where the road base is threatened) in the short-term, while out-sloping of roads (to discourage the concentration of runoff) may be more appropriate in the long-term.

Erosion at Santa Rosa Creek Road

4.3.2 Reduce and/or retain fine sediment delivery from the Perry/Green Valley Creek sub-watershed

Sediment delivered from the Perry/Green Valley Creek sub-watershed consists almost entirely of fine sediment (Appendix A). This supply is almost certainly a significant contributor to the lower quality spawning and rearing habitat conditions in the lower reaches of Santa Rosa Creek. Based on the Geomorphic Assessment (Appendix A) a number of measures are potentially appropriate to reduce fine sediment to and from the Perry/Green Valley Creek sub-watershed, including exclusion of cattle from stream channels, riparian corridor restoration, gully maintenance, and road infrastructure improvements to reduce sediment-laden runoff from roads. However, as survey access has previously been limited in this sub-watershed, it is recommended that a focused survey be conducted to identify specific fine sediment supply areas and site-appropriate remediation measures. Ideally this survey would also be used to identify measures that may be appropriate to retain fine sediment from the sub-watershed before it enters Santa Rosa Creek.

4.3.3 Implement Cambria drainage study recommendations

Both the 1999 and 2004 drainage studies conducted in Cambria's residential neighborhoods indicated that storm water is not being adequately planned for or managed, and warned that storm water issues can be expected to worsen if development continues in the Cambria area, unless meaningful steps are taken to plan for and address road- and home lot-related storm water runoff (USDA NRCS 1999, RMC 2004). These studies include detailed maps of problem areas, and recommend projects to improve storm water runoff capture and conveyance. It is recommended that these recommendations be implemented on a voluntary basis by existing property owners, and be required for newly proposed developments, either by the developer or coordinating local entity. The USDA NRCS (1999) report and maps are available for review at the Greenspace office: 4251 Bridge St, Cambria, CA 93428. The San Luis Obispo County Flood Control and Water Conservation District report and maps (RMC 2004) are available on-line: http://www.slocountydrainagestudies.org/

4.4 Conserve and Protect Open Spaces and Existing Land Uses

Conserving existing open space and land uses in the watershed will help address one of the critical issues in the watershed: the threat of land use change on fine sediment production, water demand, and the deleterious effects of urban development (e.g., increased impervious surfaces, contaminated runoff, non-native invasive species introductions, and encroachment of floodplains and the riparian corridor). This can be done via conservation easement, in which the current landowner retains ownership but is compensated for potential restrictions on land use, or fee-title purchase. If property with water rights is purchased, then these recommendations can also serve to increase summer and fall instream flows. Two focal areas for conservation efforts, to best protect aquatic habitat conditions in the watershed, are described below. TLCSLOC (2010) provides additional details on the conservation easement and fee-title purchase options that are relevant to landowners in the watershed.

4.4.1 Conserve undeveloped floodplains

Development near rivers and streams necessitates or facilitates many of the elements that degrade the riparian corridor and aquatic ecosystem, such as polluted runoff, increased runoff and decreased percolation from paved surfaces, rip-rap and other bank protection measures, decreased riparian vegetation, invasion by non-native species, and frequently levees to protect developed areas from high flow events. Floodplains also provide important habitat for a number of terrestrial and semi-aquatic species, such as Pacific pond turtle, California red-legged frog, and two-striped garter snake. To prevent further degradation of the Santa Rosa Creek riparian corridor and aquatic ecosystem, it is recommended that undeveloped floodplains, particularly along the lower creek where few remain and the middle reaches where the floodplains are undeveloped, be conserved and floodplain-compatible land uses maintained. For example, the left-bank floodplain between the Burton Street Bridge and Highway 1 is currently undeveloped and supports hiking trails and related recreational activities. Keeping infrastructure and/or more developed land uses away from the creek in this area will help conserve existing floodplain conditions and service, likely contribute to restoration efforts, and prevent further constraints on riparian and aquatic conditions in the future.

4.4.2 Conserve land uses in the upper watershed

The subdivision of large parcels, which are generally located in the upper watershed, is likely to result in land use changes in the subsequent smaller parcels. If these future land uses remove vegetation (both upslope and riparian), change hillslope topography, or alter runoff patterns, there is the potential that gully and rill erosion could be reinitiated with a subsequent increase in fine sediment delivery to watershed stream channels. Retaining large parcels or otherwise conserving existing land uses in the upper watershed would help prevent the degradation of aquatic habitat throughout the watershed.

4.5 Increase Woody Debris Supply and Retention

Lack of available summer and winter habitat was identified as a factor limiting the population of steelhead. Summer habitat for steelhead has been degraded in part by a disruption of the channel forming processes that form pools, including, but no limited to, a lack of woody debris that typically forms pools where steelhead and other aquatic species can over-summer, provides instream cover and protection from predators, and contributes to the food supply. This lack of woody debris also contributes to the degradation of winter habitat for steelhead. In addition to finding refuge from high flows in the interstitial spaces among cobbles and boulders, steelhead depend on the slower-water refuge areas provided by large woody debris, boulders and other instream cover, and undercut banks during high flow events. In Mediterranean-climate watersheds, large woody debris, which is generally composed of hardwoods such as bay, alder, sycamore, and willow trees greater than six inches in diameter at breast height, is frequently lacking as a result of overall riparian vegetation loss and its removal when it does enter streams (Opperman 2002).

Recommendations to restore the riparian corridor (Section 4.2) will, over time, help to increase the supply of natural large woody debris to the watershed. In conjunction with riparian restoration, education efforts are recommended to help landowners develop a complete understanding of the role large woody debris plays in the riparian ecosystem, and the measures that can be taken to avoid conflicts between large woody debris recruitment and retention and adjacent land uses due to the real and perceived threats from large woody debris on streambank infrastructure and flood risk. The combination of increased large woody debris supply and retention in stream channels contributes to restoring natural ecosystem function and providing long-term and sustainable summer and winter habitat for steelhead.

Riparian restoration is a long term action that will take upwards of a decade before the large woody debris it supplies begins to contribute to the improvement of summer and winter habitat conditions for steelhead. Since the lack of both over-summer and over-winter habitat may be limiting the steelhead population in the Santa Rosa Creek watershed, it is highly recommended that large woody debris in the stream be left where it is found or to manipulate its orientation in its current location. In other cases, it may be appropriate for large woody debris structures to be incorporated into other types of instream projects, such as bank stabilization projects (see Section 4.2.3). Riparian tree species that are native to the watershed, such as alder, bay, sycamore, and willows are appropriate and have been documented, particularly when in multiple log configurations, to effectively form pool habitat and provide instream cover (Opperman 2002). Any project in the watershed that incorporates large woody debris structures needs to be carefully and strategically planned and implemented to minimize unintended consequences on adjacent and/or downstream property, maximize the sustainability and effectiveness of the project in providing winter and summer habitat, and be consistent with the type of woody debris that would occur naturally in Santa Rosa Creek.

4.6 Remove Barriers to Fish Passage

Physical fish passage barriers can restrict adult and juvenile steelhead to the poorer quality spawning and rearing habitats in the lower reaches of Santa Rosa Creek, and may limit the steelhead population if/when this occurs in successive years. Culverts at Taylor and Curti creeks, and elsewhere, not only impede steelhead access to these tributaries, but they interrupt the supply of coarse sediment and large woody debris which is essential to maintaining suitable winter and summer rearing habitat for steelhead. Removal or modification of these culverts is recommended if there is sufficient quantity and quality steelhead habitat upstream. In addition to improving fish passage, sediment and large woody debris transport would be improved under the full range of flow conditions. Recommendations to determine additional actions that could be taken to improve passage conditions in the middle reaches of Santa Rosa Creek, and to assess the severity of potential passage barriers in the Perry/Green Valley Creek sub-watershed are included in Section 4.7 below.

4.7 Fill Key Data Gaps

The Watershed Synthesis and Steelhead Limiting Factors Analysis identified a number of key data gaps that limit the understanding of watershed conditions and processes, the identification of factors potentially limiting steelhead, and the ability to develop effective actions to enhance watershed conditions and address steelhead limiting factors. Ideally the results of the investigations described below will be used to test the hypotheses of steelhead limiting factors, such that hypotheses are accepted, rejected, or refined, based on new understanding of the system.

4.7.1 Monitor adult steelhead population

Adult returns are usually considered the best indicator of population status. However, there are currently no robust estimates of adult abundance in Santa Rosa Creek. Due to the difficulty in monitoring steelhead spawning in creeks with small steelhead populations and dispersed spawning habitat, CDFG recommends the use of traps, weirs, and/or video or sonar detection systems to provide an absolute count of migrating adults (Adams et al. 2011).

4.7.2 Identify steelhead instream flow requirements

While the recommendations in Section 4.1 above will contribute to the maintenance of summer and fall instream flows, better understanding the site-specific instream flow requirements for key steelhead life history stages is essential for developing and planning specific actions. Therefore, an analysis of how much flow is required to maintain adequate summer and fall rearing habitat for age 1+/2+ steelhead (e.g., passage over shallow riffles and connectivity between pools, and suitable water temperatures) and summer invertebrate production is recommended. The results of this assessment would refine the understanding of the specific locations and ways that instream flows limit the steelhead population and can be used to identify minimum instream flow goals in specific parts of the watershed that can then guide the type and number of actions taken to maintain summer and fall instream flows. In addition, this survey, if conducted in the winter can be used to identify minimum flow needs to facilitate migration over shallow riffles. The flows needed for both adult and juvenile steelhead migration have been identified for lower Santa Rosa Creek (D. W. Alley & Associates 1993), but the previous study did not include the intermittent portion of the middle reach situated upstream of the Perry Creek confluence, or upstream of Mammoth Rock where the stream is perennial most years (Figure 2-8). It is recommended that any identification of instream flow requirements be accompanied by an analysis of available stream flow data in order to evaluate the extent to which instream flow requirements for fish passage and/or summer and fall rearing habitat are or are not being met.

4.7.3 Assess lagoon habitat quality and steelhead smolt growth in and outside the lagoon

The degree to which steelhead use the lagoon for rearing, and that the lagoon contributes to steelhead growth, is uncertain (Nelson et al. 2009). As stated previously by CDFG, it is recommended that studies be implemented to document juvenile steelhead use of the lagoon to better understand the link between juvenile steelhead production/carrying capacity in the creek and lagoon, and evaluate steelhead growth patterns under a range of water-year types. These surveys would ideally include the timing and extent of steelhead use of the lagoon, timing and duration of emigration/immigration as related to sandbar closure and instream flow, growth rates in and upstream of the lagoon, and population estimates. Combined with strategic monitoring of water temperature, DO, and salinity under varying flow conditions, these studies can be used to evaluate the suitability of the lagoon for rearing under different water-year types and identify specific actions for enhancing lagoon quality and optimizing steelhead lagoon rearing.

4.7.4 Assess flows through the middle reaches of Santa Rosa Creek

These reaches (approximately stream mile 6.5 to 8) generally run dry each summer, restricting connectivity between steelhead rearing habitat, and, in dry winters, are hypothesized to impede upstream migration of spawning steelhead (Nelson et al. 2009). Due to the low gradient and position in the watershed, these reaches are the natural depositional area for sediments transported from the upper watershed and, in combination with land use changes, result in a wide, undefined floodway and highly pervious substrates. Additional survey work and analysis are recommended to better understand the natural vs. human factors controlling instream flows through these reaches and determine what, if any, other actions would be appropriate to increase the capacity of these reaches to maintain minimum instream flows in the summer and improve upstream migration conditions during dry winters.

4.7.5 Estimate juvenile steelhead abundance

There are currently extensive data on fall abundance of juvenile steelhead in Santa Rosa Creek. While fall abundance data is useful for understanding annual abundance trends, it does not allow the direct assessment of summer habitat limitations, which is a key step in understanding factors limiting the steelhead population in the watershed. Developing reach-specific abundance estimates in the early summer, in addition to the fall, would allow evaluation of both over-winter and over-summer survival of both YOY and older juveniles, and potentially help identify over-winter and/or over-summer habitat limiting factors that may be addressed through restoration. Ideally this would be conducted for several years to help understand the dependence of winter and summer survival on variations in water quantity and flow dynamics. It is recommended that any juvenile monitoring be done according to the protocols described in CDFG's recent California Coastal Salmonid Population Monitoring Strategy, Design, and Methods report (Adams et al. 2011).

4.7.6 Assess mercury uptake in the aquatic food chain

It is unknown to what extent or even if the high levels of mercury that have been detected in sediments in Curti and Santa Rosa creeks are accumulating in the aquatic food chain and/or potentially affecting steelhead populations. To better understand the degree of mercury contamination in the watershed and potentially garner funding for remediation efforts, it is recommended that a focused study of mercury be conducted in the watershed. A well designed study would include sites upstream of, at, and downstream of the mercury mine former mill site off of Curti Creek, as well as other known mercury mine locations in the watershed, to determine natural background levels of mercury and patterns of mercury contamination downstream. Such a study would also include water, sediment, and resident aquatic organism (e.g., benthic invertebrates and/or small resident fish) samples that are tested for total mercury and methylmercury.

4.7.7 Assess the Perry/Green Valley Creek sub-watershed

It is unknown if the Perry/Green Valley Creek sub-watershed is accessed or used by steelhead, or what the aquatic habitat conditions are like. Given the size of this sub-watershed and the potential for steelhead habitat, it is recommended that the assessment include, but not be limited to, geomorphic, hydrologic, and biological (e.g., aquatic habitat conditions, fish passage, and steelhead use) surveys. Knowing the limiting factors potential for steelhead in this sub-watershed would be an important first step towards understanding the relative importance of this sub-watershed for steelhead.

4.7.8 Continue and expand citizen water quality monitoring

The benthic macroinvertebrate and first flush sampling, which was done in coordination with the broader Monterey Bay Sanctuary Citizen Watershed Monitoring Network, conducted for the development of this Watershed Management Plan help characterize just one year of water quality conditions in lower Santa Rosa Creek. Multiple, and ideally continuous, years of sampling and additional sampling sites in the upper watershed, are needed to better understand temporal and spatial trends in water quality conditions. If and when temporal and spatial trends are recognized, these can be used to help identify emerging risks to water quality and aquatic species, pollutant sources, and, subsequently, appropriate best management practices to minimize or prevent pollutants from entering waterways.

4.8 Reduce Mercury Supply

Due to the high potential for mercury to affect human health and aquatic organisms and the fact that methlymercury—the most bio-available form of mercury—has been detected in the Santa Rosa Creek lagoon, it has been previously recommended that efforts be made to control known sources of mercury in the watershed. These recommendations include erosion control along Curti Creek to prevent mercury-laden sediment from being delivered to the creek and creation of treatment wetlands to retain and accumulate existing mercury in the system, need to be implemented to prevent further mercury contamination.

4.9 Summary of Recommendations

Table 4-1 summarizes the recommendations described above and the primary reason for their inclusion in the Watershed Management Plan (e.g., near-term steelhead habitat restoration, long-term watershed enhancement, etc.). The recommendations are listed in order of their relative importance to steelhead habitat restoration, but this ranking is not intended to limit the implementation of any recommendation. Appendix D describes a variety of sources of potential funding for implementation of the plan recommendations.

Table 4-1. Summary of recommendations.

Recommendation (Bolded text indicates actions that are of higher priority for steelhead habitat restoration)		**Included to Address:**		
		Near-term steelhead habitat restoration	**Long-term watershed enhancement**	**Key uncertainties**
4.1.1	**Implement water conservation and reuse strategies**	•	•	
4.1.2	**Construct off-stream closed water storage**	•	•	
4.1.3	**Purchase water rights from willing sellers for instream flows**	•	•	
4.1.4	**Conduct stream gauging and develop an updated water budget**		•	•
4.1.5	Reduce future municipal groundwater pumping			
4.2.2	**Revegetate degraded streambanks**		•	
4.2.1	**Manage grazing to reduce impacts to the riparian corridor**		•	
4.2.3	**Minimize the need for bank protection**		•	
4.2.4	Treat non-native invasive species		•	
4.3.1	**Maintain roads to decrease hillslope and streambank erosion**		•	
4.3.2	**Reduce and/or retain fine sediment delivery from the Perry/Green Valley Creek sub-watershed**		•	
4.3.3	Implement Cambria drainage study recommendations		•	
4.4.1	**Conserve undeveloped floodplains**		•	
4.4.2	**Conserve land uses in the upper watershed**			
4.5	**Increase woody debris supply and retention**	•	•	
4.6	**Remove barriers to fish passage**		•	
4.7.1	**Monitor adult steelhead population**			•
4.7.2	**Identify steelhead instream flow requirements**		•	•
4.7.3	**Assess lagoon habitat quality and steelhead smolt growth in and outside the lagoon**	•		•
4.7.4	Assess flows through the middle reaches of Santa Rosa Creek	•	•	
4.7.5	Estimate juvenile steelhead abundance			•
4.7.6	Assess mercury uptake in the aquatic food chain			•
4.7.7	Assess the Perry/Green Valley Creek sub-watershed			•
4.7.8	Continue and expand citizen water quality monitoring			•
4.8	Reduce mercury supply		•	

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6 REFERENCES

6.1 Printed Sources

Adams, P.B., L.B. Boydstun, S.P. Gallagher, M.K. Lacy, T. McDonald, and K.E. Shaffer. 2011. California Coastal Salmonid Population Monitoring: Strategy, Design, and Methods. State of California, The Natural Resources Agency, Department of Fish and Game, Fish Bulletin 180.

Andrews, E., R. Antweiler, P. Neiman, and F. Ralph. 2004. Influence of ENSO on flood frequency along the California Coast. Journal of Climate 17: 337–348.

Angel, M. 1883. History of San Luis Obispo County. Thompson and West, Oakland, California.

Armour, C. L., D. A. Duff, W. Elmore. 1994. The effects of livestock and grazing on Western riparian and stream ecosystems. Fisheries 19: 9–12.

Atwater, T., and P. Molnar. 1973. Relative motion of the Pacific and North American plates deduced from seafloor spreading in the Pacific, Indian, and South Pacific Oceans. Pages 136–148 *in* Kovach, R. L., and Nur, A., editors. Proceedings of the Conference on Tectonic Problems of the San Andreas Fault System. Volume 13. Stanford University Publications in Geological Sciences, California.

Bailey, R. 1973. An estimate of the standing crop of steelhead trout, Santa Rosa Creek, San Luis Obispo County, California. Natural Resources Management Department, California Polytechnic State University, San Luis Obispo, California.

Baker, G. 2003. Cambria. Hignell Book Printing, Canada.

Barrett, R.H. 1977. Wild pigs in California. Pages 111-113 in G.W. Wood, editor. Research and Management of Wild Hog Populations. Proceedings of a Symposium, B.W. Baruch Forest Science Institute, Georgetown, South Carolina.

Becker, G. S. and I. J. Reining. 2008. Steelhead/rainbow trout *(Oncorhynchus mykiss)* resources south of the Golden Gate, California. Cartography by D.A. Asbury. Center for Ecosystem Management and Restoration. Oakland, California.

Behnke, R. J. 1992. Rainbow trout of coastal basins. Native trout of western North America. American Fisheries Society Monograph 6.

Bell, E., S. Albers, and R. Dagit. *In review.* Implications of juvenile growth for a population of southern California steelhead (*Oncorhynchus mykiss*). California Fish and Game.

Belsky, A. J., A. Mamzke, S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the Western United States. Journal of Soil and Water Conservation 54: 419–431.

Bisson, P., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflows. Pages 62–73 *in* N. B. Armantrout, editor. Proceedings of the symposium on acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland.

Bisson, P. A., K. Sullivan, and J. L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead trout, and cutthroat trout in streams. Transactions of the American Fisheries Society 117: 262–273.

Bond, M. H., S. A. Hayes, C. V. Hanson, and R. B. MacFarlane. 2008. Marine survival of steelhead (*Oncorhynchus mykiss*) enhanced by a seasonally closed estuary. Canadian Journal of Fisheries and Aquatic Sciences 65: 2242–2252.

Boughton, D. A., P. B. Adams, E. Anderson, C. Fusaro, E.A. Keller, E. Kelley, L. Lentsch, J. Nielsen, K. Perry, H. Regan, J. Smith, C. Swift, L. Thompson, and F. Watson. 2006. Steelhead of the south-central/southern California coast: population characterization for recovery planning. NOAA Technical Memorandum.

Briassoulis, H. 2000. Analysis of land use change: theoretical and modeling approaches. *In* Loveridge, S. ed. The Web Book of Regional Science (www.rri.wvu.edu/regscweb.htm). West Virginia University Regional Research Institute, Morgantown, West Virginia.

Bulger, J. B., N. J. Scott, Jr., and R. B. Seymour. 2003. Terrestrial activity and conservation of adult California red-legged frogs (*Rana aurora draytonii*) in coastal forests and grasslands. Biological Conservation 110: 85–95.

Burgner, R. L., J. T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distribution and origins of steelhead trout (*Oncorhynchus mykiss*) in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission Bulletin 51.

Busby, P. J., T. C. Wainwright, and G. J. Bryant. 1996. Status review of west coast steelhead from Washington, Oregon and California. NOAA Technical Memorandum NMFS-NWFSC-27. National Marine Fisheries Service, Seattle, Washington.

CalFish. 2009. Passage Assessment Database (PAD), 2009. http://dnn.calfish.org/portals/2/Home/tabid/70/Default.aspx [Accessed September 2009].

California Coastal Commission. 2010. Final adopted consistency determination issued to the U.S. Army Corps of Engineers. May 13, 2010

Cambria Forest Committee. 2002. Cambria forest management plan. Cambria Forest Committee, Cambria, California. Available at: http://frap.cdf.ca.gov/pitch_canker/research/Cambria_Forest_Management_Plan_4_02.pdf

Capelli, M. H. 1997. Ventura River steelhead survey, Ventura County, California. Prepared for California Department of Fish and Game, Region 5.

Carle, D. 2006. Introduction to air in California. University of California Press, Berkeley, California.

Carollo. 2011. San Luis Obispo County Master Water Plan: Draft, August 2011. Prepared by Carollo, Inc., Fresno, California, for the San Luis Obispo County Flood Control and Water Conservation District, San Luis Obispo, California.

Cayan, D. R., K. T. Redmond, and L. G. Riddle. 1999. ENSO and hydrologic extremes in the western United States. Journal of Climate 12: 2881–2893.

CCRWQCB (Central Coast Regional Water Quality Control Board). 1994. Basin plan. California Regional Water Quality Control Board, Central Coast Region, San Luis Obispo, California.

CCRWQCB (Central Coast Regional Water Quality Control Board). 1999. Inactive metal mines in four San Luis Obispo County watersheds: surface water quality impacts and remedial options. California Regional Water Quality Control Board, Central Coast Region, San Luis Obispo, California.

CCRWQCB (Central Coast Regional Water Quality Control Board). 2002. 301 Estero Hydrologic Unit draft report. California Regional Water Quality Control Board, Central Coast Region, San Luis Obispo, California. http://www.ccamp.org/ccamp/documents/HU_310_Assessment_Report_DraftFinal.doc [Accessed July 2010].

CCRWQCB (Central Coast Regional Water Quality Control Board). 2010. Draft California 2010 integrated report (303(d) List/305(b) Report). California Regional Water Quality Control Board, Central Coast Region, San Luis Obispo, California.

CCSD (Cambria Community Services District). 2008. Water master plan program environmental impact report. Prepared by RBF Consulting for CCSD, Cambria, California.
CCSD (Cambria Community Services District). 2011. Water production report, 1988–2011. http://www.cambriacsd.org/cm/water_wastewater/well-levels.html [Accessed October 2011].

CDFG (California Department of Fish and Game). 2003a. List of California terrestrial natural communities recognized by the California Natural Diversity Database. Department of Fish and Game Biogeographic Data Branch, Vegetation Classification and Mapping Program. http://www.dfg.ca.gov/biogeodata/vegcamp/pdfs/natcomlist.pdf [Accessed December 2009].

CDFG (California Department of Fish and Game). 2003b. Field notes, Santa Rosa Creek, 1997–2003. Report by Dave Highland.

CDFG (California Department of Fish and Game). 2009. California natural diversity database. Electronic database. CDFG, Sacramento, California. http://www.dfg.ca.gov/biogeodata/cnddb/ [Accessed 2 July 2009].

CDFG (California Department of Fish and Game). 2010. Steelhead trout management tasks (coastal watersheds). Website. http://nrm.dfg.ca.gov/steelhead/steelhead_tasks.aspx [Accessed July 2010].

CDPH (California Department of Public Health). 2009. Public health assessment – Klau and Buena Vista mines, San Luis Obispo County, California, EPA Facility ID: CA1141190578, Public Comment Release. Prepared by CDPH under cooperation with the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. 117: 1–21.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams with special reference to food and feeding. Pages 153–176 *in* T. G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver, University of British Columbia, Vancouver, Canada.

Chipping, D. H. 1987. The geology of San Luis Obispo County, a brief description and field guide. California Polytechnic State University, San Luis Obispo, California.

Clemento, A. J., E. C. Anderson, D. Boughton, D. Girman, and J. C. Garza. 2009. Population genetic structure and ancestry of *Oncorhynchus mykiss* populations above and below dams in south-central California. Conservation Genetics 10:1321–1336.

Coffman, T. 1995. The Cambria forest. Coastal Heritage Press, Cambria, California.

Conrad, M. T., D. Meyers, J. Parke, S. Danner, L. Sheehan, S. Pufahl, E. Wendt, and T. Ish. 2000. Central Coast Regional Citizen Monitoring Guide. Prepared by the Monterey Bay Sanctuary Citizen Watershed Monitoring Network.

Cunjak, R. A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53(Suppl. 1): 267–282.

Dibblee, T. W. 2007a. Geologic map of the Cambria quadrangle, San Luis Obispo County, California. Edited by J. A. Minch. Scale 1:24,000. Dibblee Geological Foundation, Santa Barbara, California.

Dibblee, T. W. 2007b. Geologic map of the Cypress Mountain quadrangle, San Luis Obispo County, California. Edited by J. A. Minch. Scale 1:24,000. Dibblee Geological Foundation, Santa Barbara, California.

DiTomaso, J. M. 2000. *Cortaderia selloana*. *In* C.C. Bossard, J. M. Randall, and M, C. Hoshovsky, editors. Invasive plants of California wildlands. University of California Press, Berkeley, California.

Donohoe, C. J., P. B. Adams, and C. F. Royer. 2008. Influence of water chemistry and migratory distance on ability to distinguish progeny of sympatric resident and anadromous rainbow trout (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 65:1060–1075.

Dudley, T. 1988. Report to the County of San Luis Obispo on the aquatic and riparian biology associated with the Shame1 Park bank stabilization project. Department of Biological Sciences, University of California, Santa Barbara.

D. W. Alley & Associates. 1993. Passage requirements for steelhead in Santa Rosa Creek, San Luis Obispo County, California. Prepared by D. W. Alley & Associates for Cambria Community Services District, California.

D. W. Alley & Associates. 2006. Monitoring results for lower San Simeon and Santa Rosa Creeks, 2004–2005: Lagoon water quality, fishery resources and inflow near Cambria, San Luis Obispo County, California. Prepared by D. W. Alley & Associates for Cambria Community Services District, California.

D. W. Alley & Associates. 2007. Trends in Juvenile Steelhead Production in 1994–2006 for Santa Rosa Creek, San Luis Obispo County, California, with Habitat Analysis and an Index of Adult Returns. Prepared by D. W. Alley & Associates for Cambria Community Services District, California.

D. W. Alley & Associates. 2008. Santa Rosa Creek fishery summary, habitat conditions, watershed management guidelines, and enhancement goals. Prepared for The Land Conservancy of San Luis Obispo County, San Luis Obispo, California.

Ebrahimpour, M. 2010. Influence of water hardness on acute toxicity of copper and zinc on fish. Toxicological Indicators of Health 26(6): 361–365.

Eckel, E. B., R. G. Yate, and A. E. Granger. 1941. Quicksilver deposits in San Luis Obispo County and southwestern Monterey County, California. Department of the Interior, Strategic Minerals Investigation Bulletin 922-R. Washington, D. C.

Elliott, H. W. 1995. Relation of pool depth and groundwater elevation of Santa Rosa Creek in Santa Rosa Natural Preserve, San Simeon State Park, San Luis Obispo County: 1992–1994. Prepared by H. Woody Elliott, Associate State Park Resource Ecologist, California Department of Parks and Recreation, San Simeon District. 18 October 1995.

ESA. 2010. San Luis Obispo County water demand analysis methodology and results. Draft memorandum to Courtney Howard, San Luis Obispo County, Water Resources Advisory Committee, California from ESA, San Francisco, California. 11 January. http://www.slocountywater.org/site/Frequent_Downloads/Master_Water_Plan/pdf/Demand_Assessment.pdf [Accessed February 2010].

Everest, F. H., and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29: 91–100.

Fellers, G. M., and P. M. Kleeman. 2007. California red-legged frog (*Rana draytonii*) movement and habitat use: implications for conservation. Journal of Herpetology 41: 271–281.

Field, C.B., G.C. Daily, F.W. Davis, S. Gaines, P.A. Matson, J. Melack, and N.L. Miller. 1999. Confronting climate change in California: ecological impacts on the Golden State. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, DC.

Flosi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2004. California salmonid stream habitat restoration manual. Third Edition. Volume I. California Department of Fish and Game, Inland Fisheries Division.

Fontaine, B. L. 1988. An evaluation of the effectiveness of instream structures for steelhead trout rearing habitat in the Steamboat Creek basin. Master's thesis. Oregon State University, Corvallis.

Ford, L. D., and G. Hayes. 2006. Northern coastal scrub and coastal prairie. *In* M.G. Barbour, editor. Terrestrial vegetation of California. University of California Press, Berkeley, California.

Fore, L.S., J.R. Karr, and R.W. Wisseman. 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. Journal of the North American Benthological Society 15(2):212-231.

Gallagher, S. P., and C. M. Gallagher. 2005. Discrimination of Chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fisheries Management 25: 284–300.

Germano, J. D. and B. Bury. 2001. Western pond turtles (*Clemmys marmorata*) in the Central Valley of California: status and population structure. Transactions of the Western Section of the Wildlife Society 37:22–36.

Groves, R.H. and F. Di Castri. 1991. Biogeography of Mediterranean invasions. Cambridge University Press, Cambridge, Massachusetts.

Hamilton, G. 1974. Where the highway ends – Cambria, San Simeon and the ranchos. Padre Production, San Luis Obispo, California.

Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W., Lienkaemper, Cromac Jr., K., and K. W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15: 133–302.

Harris, R. R. 1874. Map of the county of San Luis Obispo, California. Scale 1:126,720.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 22: 1035–1081.

Hayes, G., and K. D. Holl. 2003. Site-specific responses of native and exotic species to disturbances in a mesic grassland community. Applied Vegetation Science 6: 235–244.

Hayes, S. A., M. H. Bond, C. V. Hanson, E. V. Freund, J. J. Smith, E. C. Anderson, A. J. Ammann, and R. B. MacFarlane. 2008. Steelhead growth in a small central California watershed, upstream and estuarine rearing patterns. Transactions of the American Fisheries Society 137: 114–128.

Heberger, M., H. Cooley, P. Herrera, P. H. Gleick, and E. Moore. 2009. The impacts of sea-level rise on the California Coast. A paper from the California Climate Change Center. Prepared by The Pacific Institute for the California Energy Commission, California Environmental Protection Agency, Metropolitan Transportation Commission, California Department of Transportation, and Ocean Protection Council. Available at: http://www.pacinst.org/reports/sea_level_rise/report.pdf

Hillyard, D. 2009. Regulatory framework and protection of coastal prairie. Ecology and conservation of California's coastal prairie, Elkhorn Slough Coastal Training Program, Moss Landing, California.

Holland, D. C. 1985. An ecological and quantitative study of the western pond turtle (*Clemmys marmorata*) in San Luis Obispo County, California. Master's thesis. California State University, Fresno.

Holland, D. C. 1994. The western pond turtle: habitat and history. Final Report. U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing 70: 829–840.

Hume, J. M. B., and E. A. Parkinson. 1988. Effects of size at and time of release on the survival and growth of steelhead fry stocked in streams. North American Journal of Fisheries Management 8: 50-57.

Inman, D., and S. Jenkins. 1999. Climate change and the episodicity of sediment flux of small California rivers. Journal of Geology 107: 251–270.

Jennings, M. R. and M. P.Hayes. 1994. Amphibian and reptile species of special concern in California. Final report submitted to the California Department of Fish and Game, Inland Fisheries Division.

Kabel, C. S., and E. R. German. 1967. Some aspects of stocking hatchery-reared steelhead and silver salmon. Marine Resources Administrative Report No. 67-3. California Department of Fish and Game.

Knable, A. 1978. Characteristics of steelhead rainbow trout streams, San Luis Obispo County, California. Natural Resources Management Department, California Polytechnic University, San Luis Obispo.

Kousky, V. E. and G. D. Bell. 2000. Causes, predictions, and outcomes of El Niño 1997–1998. Pages 28–48 *in* S. A. Changnon, editor. El Niño 1997–1998: the climate event of the century. Oxford University Press, New York.

Kreith, M. 2007. Wild pigs in California: the issues. AIC Issues Brief No. 33. Agricultural Issues Center, University of California, Davis.

Lannoo, M. J. 2005. Amphibian declines: the conservation status of United States species. University of California Press, Berkeley, CA.

MCAS (Morro Coast Audubon Society). 2005. 2004 Morro Bay Christmas bird count totals. Pacific Flyway 39: 8–9.

MCAS (Morro Coast Audubon Society). 2006. 2005 Morro Bay Christmas bird count totals. Pacific Flyway 408: 5–7.

McEwan, D. R. 2001. Central Valley steelhead. Pages 1-42 *in* R. L. Brown, editor. Fish Bulletin 179: Contributions 29 to the Biology of Central Valley Salmonids, vol. 1. California Department of Fish and Game, Sacramento, California.

McEwan, D., and T. A. Jackson. 1996. Steelhead restoration and management plan for California. Management Report. California Department of Fish and Game, Inland Fisheries Division, Sacramento.

Meyer, K. A., and J. S. Griffith . 1997. Effects of cobble-boulder substrate configuration on winter residency of juvenile rainbow trout. North American Journal of Fisheries Management 17: 77–84.

Montgomery, D. R., and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin 109: 596–611.

Morro Group (a division of SWCA Environmental Consultants). 2009. Fiscalini Ranch Preserve (SCH# 2006051092) final master environmental impact report. Prepared for Cambria Community Services District, Cambria, California.

Moyle, P. B. 1973. Effect of introduced bullfrogs (*Rana catebeiana*) on the native frogs of the San Joaquin Valley, California. Copeia 1973:18-22.

Moyle, P. B. 1976. Inland fishes of California. First edition. University of California Press, Berkeley.

Moyle, P. B. 2002. Inland fishes of California. Revised edition. University of California Press, Berkeley.

Myrick, C. A. 1998. Temperature, genetic, and ration effects on juvenile rainbow trout (*Oncorhynchus mykiss*) bioenergetics. Doctoral dissertation. University of California, Davis.

NCRWQCB (North Coast Regional Water Quality Control Board. 2006. Desired salmonid freshwater habitat conditions for sediment-related indices. California Regional Water Quality Control Board, North Coast Region, Santa Rosa, California.

Nelson, J. 1994. Summary of steelhead population and habitat sampling in Santa Rosa Creek, San Luis Obispo County, 1993. California Department of Fish and Game, Monterey, California.

Nelson, J., E. Baglivio, and T. Kahles. 2009. Santa Rosa Creek steelhead habitat and population survey, 2005. Prepared by California Department of Fish and Game and California Conservation Corps.

NMFS (National Marine Fisheries Service). 1997. Endangered and threatened species: listing of several evolutionary significant units (ESUs) of West Coast steelhead. Federal Register 62: 43937–43954.

NMFS (National Marine Fisheries Service). 2006. Endangered and threatened species: final listing determinations for 10 distinct population segments of West Coast steelhead. Federal Register 71: 834–862.

NMFS (National Marine Fisheries Service). 2007. Federal recovery outline for the distinct population segment of South-central California coast steelhead. NMFS Southwest Regional Office, Long Beach, California.

NOAA (National Oceanic and Atmospheric Administration). 2009a. El Niño/southern oscillation (ENSO) diagnostic discussion. Issued by the Climate Prediction Center: NOAA, National Weather Service, National Centers for Environmental Prediction.

NOAA (National Oceanic and Atmospheric Administration). 2009b. ENSO impacts: cold and warm episodes of by season. Climate Prediction Center: NOAA, National Weather Service, National Centers for Environmental Prediction, Camp Springs, Maryland.

North Coast Engineering, Inc. 1993. Preliminary site analysis and conceptual study, Cambria Community Services District Desalination Facility. Prepared for Cambria Community Services District, Cambria, California.

NRCS (Natural Resources Conservation Service). 1977. Soil survey of San Luis Obispo County, California, Paso Robles area. U.S. Department of Agriculture, Natural Resources Conservation Service (previously Soil Conservation Service).

NRCS (Natural Resources Conservation Service). 1984. Soil survey of San Luis Obispo County, California, coastal part. U.S. Department of Agriculture, Natural Resources Conservation Service (previously Soil Conservation Service).

Ode, P. R. 2007. Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

Ohmart, R. D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. Pages 245–279: P.R. Krausman, editor. Rangeland Wildlife. The Society for Range Management, Denver, Colorado.

Opperman, J. J. 2002. Anadromous fish habitat in California's Mediterranean-climate watersheds: influences of riparian vegetation, instream large woody debris, and watershed-scale land use. PhD dissertation, University of California, Berkeley.

Pearse, D. E., S. A. Hayes, M. H. Bond, C. V. Hanson, E. C. Anderson, R. B. MacFarlane, and J.C. Garza. 2009. Over the falls? Rapid evolution of ecotypic differentiation in steelhead/rainbow trout (*Oncorhynchus mykiss*). Journal of Heredity 100:515–525.

Platts, W. S., K. A. Gebhardt, W. L. Jackson. 1985. The effects of large storm events on basin-range riparian stream habitats. Pages 30–34 *in* R. R. Johnson, C. D. Ziebel, D. R. Patton, P. F. Folliott, and R. H. Hamre, editors. Riparian ecosystems and their management: reconciling conflicting uses. Proceedings of the First North American Riparian Conference, U.S. Forest Service General Technical Report Rm-120.

Plotnikoff, R.W. and S.I. Ehinger. 1997. Using invertebrates to assess the quality of Washington streams and to describe biological expectations. Washington State Department of Ecology, Ambient Monitoring Section. Publication No. 97-332. Olympia, Washington.

Poole, G.C. and C.H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27: 787–802.

Prunuske Chatham Inc. 1993. The lower Santa Rosa Creek enhancement plan. Prepared for Greenspace-the Cambria Land Trust, Cambria, California.

Puckett, L. 1970. Evaluation of the impact of summer trout fishing on juvenile steelhead inhabiting coastal lagoons. Prepared for State of California Region 3 Fisheries Management Office.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. FWS/OBS-82/10.60. U.S. Fish and Wildlife Service, Fort Collins, Colorado.

Rathbun, G. B., K. Worcester, D. Holland, and J. Martin. 1991. Status of declining reptiles, amphibians, and fishes in the lower Santa Rosa Creek, Cambria, California. Prepared for Greenspace-the Cambria Land Trust, Cambria, California.

Rathbun, G.B., M.R. Jennings, T.G. Murphey, and N.R. Siepel. 1993. Status and ecology of sensitive aquatic vertebrates in lower San Simeon and Pico Creeks, San Luis Obispo County, California. Final Report to California Department of Parks and Recreation, San Simeon, California.

Rathbun, G.B., N. Siepel, and D. Holland. 1992. Nesting behavior and movements of western pond turtles, *Clemmys marmorata*. The Southwestern Naturalist 37(3): 319–324.

Rathbun, G.B., N.J. Scott Jr., and T.G. Murphey. 2002. Terrestrial habitat use by Pacific pond turtles in a Mediterranean climate. The Southwestern Naturalist 47(2): 225–235.

Reese, D. A. and H. H. Welsh. 1997. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles. An International Conference, pp. 352-357 held 1997 by the New York Turtle and Tortoise Society.

Reese, D. A. 1996. Comparative demography and habitat use of western pond turtles in northern California: the effects of damming and related alterations. Unpublished doctoral dissertation. University of California, Berkeley.

Reiser, D.W. and R.G. White. 1988. Effects of two sediment-size classes on steelhead trout and Chinook salmon egg incubation and juvenile quality. North American Journal of Fisheries Management 8:432–437.

Rowe, M., D. Essig, B. Jessup. 2003. Guide to selection of sediment targets for use in Idaho TMDLs. Idaho Department of Environmental Quality, Pocatello, Idaho. http://www.deq.state.id.us/WATER/data_reports/surface_water/monitoring/sediment_targets_guide.pdf [Accessed July 2010].

RMC (Raines, Melton and Carella, Inc.). 2004. Cambria Drainage and Flood Control Study: Final Report. Prepared by RMC in association with Essex Environmental and Questa Engineering for San Luis Obispo County Flood Control and Water Conservation District, San Luis Obispo, California.

Sanctuary Forest, Inc. Mattole Flow Program. 2008. Mattole Headwaters Groundwater Management Plan 1.0. Available at: http://sanctuaryforest.org/cgi-files/0/pdfs/1224807707_Groundwater_mgmt_plan_v1.pdf

San Luis Obispo County. 1993. Coastal Zone Framework for Planning. San Luis Obispo County, San Luis Obispo, California.

San Luis Obispo County. 2008. North Coast Area Plan of the Land Use and Circulation Elements of the San Luis Obispo County General Plan. Revised August 2008. San Luis Obispo County, San Luis Obispo, California.

San Luis Obispo County. 2009. Conservation and open space element. Public review draft. File #LRP2006-0001. San Luis Obispo County, San Luis Obispo, California.

Schwartzbart, D. 1993. Surface water degradation by inactive metal mines in northwest San Luis Obispo County, California. California Regional Water Quality Control Board, Central Coast Region, San Luis Obispo, California.

Scott, N. J. Jr. and G. B. Rathbun. 2001. Biology of the aquatic vertebrates of coastal San Luis Obispo County, California: a study of the effects of highway bridge construction. Final report. U. S. Geological Survey, Western Ecological Research Center, Piedras Blancas Field Station. Prepared for California Department of Transportation, San Luis Obispo, California.

Seldon, M. M. 1972. Save our peninsula creeks committee. Today Decides Tomorrow. As cited in Becker, G. S. and I. J. Reining. 2008. Steelhead/rainbow trout *(Oncorhynchus mykiss)* resources south of the Golden Gate, California. Center for Ecosystem Management and Restoration. Oakland, California.

SFBRWQCB (San Francisco Bay Regional Water Quality Control Board). 2008. Guadalupe River watershed mercury total maximum daily load (TMDL) project. Staff report for proposed Basin Plan amendment. http://www.swrcb.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/guadalupe_river_mercury/C1_Guad_SR_Sep08.pdf

Shaffer, H. B., G. M. Fellers, S. R. Voss, J. C. Oliver, and G. B. Pauly. 2004. Species boundaries, phylogeography and conservation genetics of the red-legged frog (*Rana aurora/draytonii*) complex. Molecular Ecology 13: 2667–2677.

Shapovalov, L., and A. C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. Fish Bulletin 98. California Department of Fish and Game.

Smith, J. J. 1990. The effects of sandbar formation and inflows on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pornponio Creek Estuary/Lagoon systems, 1985–1989. Department of Biological Sciences, San Jose State University, San Jose, California.

Sogard, S.M., T.H. Williams, and H. Fish. 2009. Seasonal patterns of abundance, growth, and site fidelity of juvenile steelhead in a small coastal California stream. Transactions of the American Fisheries Society 138:549–563.

Spina, A. P. 2003. Habitat associations of steelhead trout near the southern extent of their range. California Fish and Game 89: 81–95.

Spina, A. P. 2007. Thermal ecology of juvenile steelhead in a warm-water environment. Environmental Biology of Fishes, DOI 10.1007/s10641-006-9103-7.

Spina, A. P., M. A. Allen, and M. Clarke. 2005. Downstream migration, rearing abundance, and pool habitat associations of juvenile steelhead in the lower main stem of a south-central California stream. North American Journal of Fisheries Management 25: 919–930.

Stebbins, R. C. 2003. Western reptiles and amphibians. Houghton Mifflin Company, Boston-New York.

Stillwater Sciences. 2004. Stevens Creek limiting factors analysis. Final Technical Report. Prepared by Stillwater Sciences, Berkeley, California for the Santa Clara Valley Urban Runoff Pollution Protection Program.

Stillwater Sciences. 2006a. Guidelines to evaluate, modify and develop estuarine restoration projects for tidewater goby habitat. Final Report. Prepared for U.S. Fish and Wildlife Service.

Stillwater Sciences. 2006b. Upper Penitencia Creek limiting factors analysis. Final Technical Report. Prepared by Stillwater Sciences, Berkeley, California for the Santa Clara Valley Urban Runoff Pollution Protection Program.

Stillwater Sciences. 2008. Lagunitas limiting factors analysis: limiting factors for coho salmon and steelhead. Final Report. Prepared by Stillwater Sciences, Berkeley, California for Marin Resources Conservation District, Point Reyes, California.

Stillwater Sciences. 2009. San Gregorio Creek watershed management plan. Draft report. Prepared for Natural Heritage Institute, San Francisco, California.

Sustainable Conservation. 2008. The Ponds Project: A summary and conclusions of a collaborative process for replacing summer stream diversions with winter diversions and off-stream storage ponds in San Mateo and northern Santa Cruz counties. Available at: http://www.suscon.org/ponds/pdfs/PondsProject_FINALReport_2-11-08.pdf

Swenson, R. O. and A. T. McCray. 1996. Feeding ecology of the tidewater goby. Transactions of the American Fisheries Society 125: 956–970.

Swift, C. C. 1977. Tidewater goby survey results. Los Angeles County Museum, Catalog No. 36667, 15 June 1977.

Swift, C. C. 1981. Tidewater goby survey results. Los Angeles County Museum, Catalog No. CCS81-21, 31 January 1981.

Swift, C. C. 1989. Tidewater goby survey results. Los Angeles County Museum, Catalog No. CCS89-22, 26 June 1989.

Swift, C. C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, *Eucyclobius newberryi* (Pisces: Gobiidae) of California. Los Angeles County Museum of Natural History Contributions in Science 404: 1–19.

SWRCB (State Water Resources Control Board). 1998. Water quality control plan for control of temperatures in the coastal and interstate waters and enclosed bays and estuaries of California. http://www.swrcb.ca.gov/water_issues/programs/ocean/docs/wqplans/thermpln.pdf [Accessed July 2010].

Titus, R. G., D. C. Erman, and W. M. Snider. 2006. History and status of steelhead in California coastal drainages south of San Francisco Bay. *In draft* for publication as a Department of Fish and Game, Fish Bulletin.

TLCSLOC (The Land Conservancy of San Luis Obispo County). 2010. Santa Rosa Creek watershed conservation plan. Prepared for the California Coastal Conservancy, Oakland, California.

U.S. Census Bureau. 2003. California: 2000, population and housing unit counts. U.S. Department of Commerce. http://www.census.gov/prod/cen2000/phc-3-6.pdf [Accessed July 2010].

U.S. Census Bureau. 2009. Resident Population and Apportionment of the U.S. House of Representatives, California. http://www.census.gov/dmd/www/resapport/states/california.pdf [Accessed November 2009].

USDA NRCS (USDA Natural Resources Conservation Service). 1999. Cambria Erosion and Sediment Study, Lodge Hill Study Area, Cambria, California. Prepared for the Upper Salinas/Las Tablas Resource Conservation District and San Luis Obispo County Planning Department by USDA Natural Resources Conservation Service Watershed Planning Services, Engineering and Resource Technology Staff.

USFS (U. S. Forest Service). 1999. Southern California mountains and foothills assessment: habitat and species conservation issues. USDA Forest Service.

USFWS (U.S. Fish and Wildlife Service). 1992. 90-day finding and commencement of status reviews for a petition to list the western pond turtle and California red-legged frog. Federal Register 57:45761.

USFWS (U.S. Fish and Wildlife Service). 1994. Endangered and threatened wildlife and plants: determination of endangered species status for the tidewater goby. Federal Register 59: 5,494–5,498.

USFWS (U.S. Fish and Wildlife Service). 1996. Endangered and threatened wildlife and plants: determination of threatened status for the California red-legged frog. Federal Register 61(101): 25,813–25,833.

USFWS (U.S. Fish and Wildlife Service). 2002. Recovery plan for the California red-legged frog (*Rana aurora draytonii*). USFWS, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2005. Recovery plan for the tidwater goby (*Eucyclogobius newberryi*). Prepared by USFWS, Pacific Region, Portland, Oregon.

USGS (U.S. Geological Survey). 1919. Topographic map of the San Simeon quadrangle, California. Scale 1:48,000.

USGS (U.S. Geological Survey). 1979a. Topographic map of the Cambria quadrangle, California. Scale 1:24,000.

USGS (U.S. Geological Survey). 1979b. Topographic map of the Cypress Mountain quadrangle, California. Scale 1:24,000.

USGS (U.S. Geological Survey). 2010. Nonindigenous Aquatic Species (NAS) database. Online database: http://nas.er.usgs.gov/queries/default.aspx [Accessed April 2010].

Ward, R. 1978. Floods: a geographical perspective. Macmillan, New York.

Ward, B. R., P. A. Slaney, A. R. Facchin, and R. W. Land. 1989. Size-biased survival in steelhead trout (*Oncorhynchus mykiss*): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46: 1853–1858.

Wood, C. W., and R. Barrett. 1979. Status of wild pigs in the United States. Wildlife Society Bulletin 7:237-246.

Yates, E. B. and K. M. Van Konyenburg. 1998. Hydrology, water quality, water budgets, and simulated responses to hydrologic changes in Santa Rosa and San Simeon Creek ground-water basins, San Luis Obispo County, California. U.S. Geological Survey Water Resources Investigations Report 98-4061.

Zimmerman, C. E., G. W. Edwards, K. Perry. 2009. Maternal origin and migratory history of steelhead and rainbow trout captured in rivers of the Central Valley, California. Transactions of the American Fisheries Society 138: 280–291.

6.2 Personal Communications

Boer, B. 2010. Resources and Facilities Supervisor, Cambria Community Services District. Personal communication with Z. Diggory, Ecologist, Stillwater Sciences.

Cambria Chamber of Commerce. 2009. Personal communication with G. Leverich, Geomorphologist, Stillwater Sciences.

Dunlap, D. 2009. Independent Cambria and Santa Rosa Creek watershed historian/Santa Rosa Creek Watershed Management Plan stakeholder. Personal communication with G. Leverich, Geomorphologist, Stillwater Sciences.

Dunlap, D. 2010. Independent Cambria and Santa Rosa Creek watershed historian/Santa Rosa Creek Watershed Management Plan stakeholder. Personal communication with R. Hawley, Executive Director, Greenspace – the Cambria Land Trust.

Gresens, R. C. 2012. District Engineer, Cambria Community Services District. Personal communication via peer review comments to R. Hawley, Executive Director, Greenspace – the Cambria Land Trust.

Hawley, R. 2010. Executive Director, Greenspace – the Cambria Land Trust. Personal communication with Z. Diggory, Ecologist, Stillwater Sciences.

Howard, S. 2010. Fisheries Biologist, United Water Conservation District. Personal communication with Ethan Bell, Fisheries Biologist, Stillwater Sciences.

Kendall, G. 2010. Cambria resident/Santa Rosa Creek Watershed Management Plan technical advisor. Personal communication with R. Hawley, Executive Director, Greenspace – the Cambria Land Trust.

Ochs, A. 2009. Volunteer researcher, San Luis Obispo County Historical Society. Personal communication with G. Leverich, Geomorphologist, Stillwater Sciences.

Rathbun, G. 2010. Honorary Fellow and Research Associate, California Academy of Sciences, Department of Ornithology and Mammalogy. Personal communication with Z. Diggory, Ecologist, Stillwater Sciences.

Smith, M. 2010. Cambria resident/Santa Rosa Creek Watershed Management Plan stakeholder. Personal communication with R. Hawley, Executive Director, Greenspace – the Cambria Land Trust.

Soto, S. 2010. Cambria resident/Santa Rosa Creek Watershed Management Plan stakeholder. Personal communication with R. Hawley, Executive Director, Greenspace – the Cambria Land Trust.

Spina, A. 2010. Fisheries Biologist, NOAA Fisheries Southwest Regional Office/Santa Rosa Creek Watershed Management Plan technical advisor. Personal communication via peer review comments to Z. Diggory, Ecologist, Stillwater Sciences.

Walgren, M. 2010. Environmental Scientist, California State Parks San Luis Obispo Coast District. Personal communication with Z. Diggory, Ecologist, Stillwater Sciences.

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Appendices

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Appendix A

Geomorphic Assessment of Santa Rosa Creek Watershed

(provided as separate document)

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Appendix B

Santa Rosa Creek BMI Sampling

(provided as separate document)

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Appendix C

Public Meeting Questionnaire

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Santa Rosa Creek Watershed
Tell Us What You Think

We greatly appreciate your assistance! Please, fill out this form as completely as you can and place in Public Comment Box before leaving. Then, take a raffle ticket and put one half in the bowl to be eligible for the drawing. (If you need more space for answers, please use the other side of the page.)

1. What are your concerns about the creek and watershed?

2. Do you know of an area in the creek that is in need of maintenance? *Example: bank stabilization, erosion, or trash pickups.*

3. Would you share any stories or historic photos you might have about steelhead or unusual occurrences that that have occurred related to Santa Rosa Creek? We can contact you if you prefer to provide contact info.

4. Please rank the following items in terms of your assessment of their importance with 1 as highest priority and 5 as lowest priority. There are two blank boxes to write in your own priorities.

	1	2	3	4	5
Improve water quality	1	2	3	4	5
Improve water quantity	1	2	3	4	5
Restore and protect riparian habitat for native plants and animals	1	2	3	4	5
Improve natural conditions for people living in the watershed	1	2	3	4	5
Foster community stewardship of, and education about, the watershed such as volunteering for projects	1	2	3	4	5
Reduce sediment delivery into the creek	1	2	3	4	5
	1	2	3	4	5

Contact Information (optional)

Name: ______________________________

Street Address: ______________________________

City: ____________________ Zip: ____________________

Phone ____
Email: ____
Interest Representing: ____

☐ Mailing List ☐ Volunteer Water Monitoring ☐ Special Events – creek clean up

Santa Rosa Creek Watershed
Compiled Questionnaire Information
Public Meeting January 19, 2010

1. What are your concerns about the creek and watershed?
   - Improving quality of resources through cooperation of community/landowners
   - Ag run-off, human caused pollution, illegal dumping, invasive species, sewage impacts
   - That it becomes a healthy system that supports wildlife and public enjoyment of the environment
   - Restore and maintain creek, tributaries and lagoon for steelhead and other wildlife
   - Deforestation, defoliation, top-soil erosion, earth subsidence, deterioration of air and water resources
   - Hope for cooperative effort that results in a healthy watershed
   - Balanced use between Santa Rosa and San Simeon Creeks
   - Use, pollution
   - Taking too much water out and loss of healthy habitat
   - Public health; maintain healthier habitat conditions; viability for diverse species; over-development
   - Sustainable management of water for environment and people; enhance the productivity of ecosystem services of SR Creek Watershed
   - Want more water flow and better water quality to support more wildlife
   - That there be enough water for all of us
   - Interfering with creek hydrology; desal; erosion
   - Steelhead; mercury
   - Sediment load/erosion; hydrologic roughness
   - Amount of overgrowth that has been allowed to remain along the banks; this is going to cause another flood when it all backs up behind Windsor Bridge
   - Overpopulation; building near the creek banks

2. Do you know of an area in the creek that is in need of maintenance? *Example: bank stabilization, erosion, or trash pickups.* If so, please indicate location.
   - Along Fiscalini Ranch Reserve; periodic trash pick up; invasive species removal along streambanks
   - Ferasci Bridge is a barrier to steelhead use; bridge should be reconstructed to allow passage
   - Maintenance is what degrades wildlands
   - Along Hwy. 1 to Burton Dr. trash, weeds, erosion near Hwy. 1 Bridge

- Burton Drive Bridge erosion under and around bridge; sediment falling from steep hillsides on Burton Dr. and increased grading activity on the Rodeo grounds

3. Would you share any stories or historic photos you might have about steelhead or unusual occurrences that that have occurred related to Santa Rosa Creek? We can contact you if you prefer to provide contact info.

   We may contact people who offered stories/photos directly.

4. Please rank the following items in terms of your assessment of their importance with 1 as high priority and 5 as low priority. First number is priority rank; second number is how many responded to that ranking.

Protect stream side archeological sites*	1/1	2	3	4	5
Improve water quality	1/14	2/4	3/1	4/1	5/0
Increase water quantity	1/9	2/5	3/4	4/2	5/0
Restore and protect riparian habitat for native plants and animals	1/11	2/6	3/2	4/0	5/2
Improve natural conditions for people living in the watershed for recreational activities	1/0	2/3	3/10	4/3	5/4
Increase education about the importance of the watershed	1/10	2/6	3/3	4/0	5/1
Foster community stewardship of the watershed such as through volunteering for projects	1/9	2/5	3/4	4/0	5/2
Reduce sediment delivery into the creek	1/12	2/1	3/5	4/2	5/0
Stop fire district campaign*	1/1	2	3	4	5
Monitor water quality (chemical) at least 4 times each year*	1/1	2	3	4	5
Clear sides of banks*	1/1	2	3	4	5
Steelhead enhancement*	1/1	2	3	4	5

*write-ins
Total submitted = 21

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Appendix D

Funding Resources

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California Department of Fish and Game Fisheries Restoration Grant Program (FRGP)

http://www.dfg.ca.gov/fish/Administration/Grants/FRGP/

FRGP was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California. This competitive grant program has invested over $180 million to support projects from sediment reduction to watershed education throughout coastal California. Contributing partners include the California Department of Fish and Game (CDFG), federal and local governments; tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners.

San Luis Obispo County Fish and Game Commission Fines Committee

Contact: Robert Cone (805) 781-5024

Each year as part of its budget process, the San Luis Obispo County Board of Supervisors approves a lump sum budget for the Fish and Game Fine Commission. The committee meets to develop a detailed listing of recommended projects for the coming fiscal year. The listing is then submitted to the Board for approval.

CalTrans Environmental Enhancement and Mitigation Program (EEM)

http://www.dot.ca.gov/hq/LocalPrograms/EEM/homepage.htm

EEM is provided by Streets and Highways Code Section 164.56 and authorizes the allocation of up to $10 million each year for grants to mitigate the environmental impacts of modified or new public transportation facilities.

San Luis Obispo Integrated Regional Water Management Plan (IRWMP)

http://www.slocountywater.org/site/Frequent%20Downloads/Integrated%20Regional%20Water%20Management%20Plan/index.htm

The Integrated Regional Water Management (IRWM) Program is intended to promote and practice integrated regional water management to ensure sustainable water uses, reliable water supplies, better water quality, environmental stewardship, efficient urban development, protection of agriculture, and a strong economy.

Wildlife Conservation Board Habitat Enhancement and Restoration Program (HERP)

http://www.wcb.ca.gov/HERP/grants.html

After the Wildlife Conservation Board (WCB) was created by the Wildlife Conservation Law of 1947, it was given the authority to acquire and restore California lands to protect wildlife values and to provide wildlife-oriented public access. The Habitat Enhancement and Restoration Program (HERP) was WCB's first program and incorporated all restoration projects until new restoration programs were first initiated in 1990. Over the last 20 years, there have been at least eight specific new programs added to the WCB's mandate that fund and target certain types of habitat restoration projects that historically fell under the HERP. While the program is not as active as it once was, it still effectively covers important habitat enhancement and restoration projects that fall outside the criteria of the other habitat restoration programs.

California State Coastal Conservancy
http://scc.ca.gov/category/grants/

To achieve its goals, the Coastal Conservancy may award grants to public agencies and nonprofit organizations that qualify under Section 501(c)(3) of the United States Internal Revenue Code and whose purposes are consistent with Division 21 of the California Public Resources Code (commencing with section 31000). Some examples of the kinds of projects the Coastal Conservancy may fund include trails and other public access to and along the coast, natural resource protection and restoration in the coastal zone or affecting coastal areas, restoration of coastal urban waterfronts, protection of coastal agricultural land, and resolution of land use conflicts.

U.S. Fish and Wildlife Service Fisheries Operational Needs System Database for National Fish Passage Program Funds
Contact: Donald Ratcliff (209) 334-2968 ext. 409

Millions of culverts, dikes, water diversions, dams, and other artificial barriers have been constructed to impound and redirect water for irrigation, flood control, electricity, drinking water, and transportation--all changing natural features of rivers and streams. In 1999, the U.S. Fish and Wildlife Service initiated the National Fish Passage Program to work with others to address this problem. The Program uses a voluntary, non-regulatory approach to remove and bypass barriers to aquatic species movement. The Program addresses the problem of passage barriers on a national level, working with local communities and partner agencies to restore natural flows and fish migration. The Program is administered by National and Regional Coordinators, and delivered by Regional Fish and Wildlife Management Assistance Offices.

U.S. Fish and Wildlife Service Partners in Fish and Wildlife Program
http://www.fws.gov/partners

The mission of the Partners Program is to efficiently achieve voluntary habitat restoration on private lands through financial and technical assistance for the benefit of Federal Trust Species.

National Oceanic and Atmospheric Administration (NOAA) Southwest Region
http://www.habitat.noaa.gov/funding/southwest.html

NOAA Restoration Center’s Community-based Restoration Program invests funding and technical expertise in high-priority habitat restoration projects that instill strong conservation values and engage citizens in hands-on activities. Through the program, NOAA, its partners, and thousands of volunteers are actively restoring coastal, marine, and migratory fish habitat across the nation. The NOAA Restoration Center staff helps to identify potential projects, strengthen the development and implementation of habitat restoration activities within communities, and generate long-term national and regional partnerships to support community-based restoration efforts across a wide geographic area.

Upper Salinas-Las Tablas Resource Conservation District
http://us-ltrcd.org/

The Upper Salinas-Las Tablas Resource Conservation District (RCD) serves the local community with its programs in watershed management, restoration, research and education and works with public and private landowners to conserve natural resources throughout the Upper Salinas River Watershed and surrounding environments. The RCD can coordinate with the USDA Natural Resources Conservation Service to bring cost-share programs to a project in order to make restoration projects cost effective.

Private Foundations

Fund For Wild Nature	http://www.fundwildnature.org/
Doris Duke Charitable Foundation Wildlife Action Opportunities Fund	http://www.wcs.org/wildlifeopportunity
Lindbergh Foundation	http://www.lindberghfoundation.org/
Disney Wildlife Conservation Fund	http://www.dwcf-rfp.com/
Waste Management	http://www.wm.com/community/giving.asp
Environmental Grantmakers Association	http://www.ega.org/funders/index.php
Acorn Foundation	http://www.commoncounsel.org/AcornFoundation
California Watershed Funding Database	http://www.calwatershedfunds.org/
Directory of Watershed Resources	http://www.efc.boisestate.edu/watershed/
Conservation grants	http://www.conservationgrants.com/water.htm
EPA Catalog of Federal Funding Sources for Watershed Protection	http://cfpub.epa.gov/fedfund/
Databases of Funding Opportunities	http://www.epa.gov/owow/funding/databases.html
Ben and Jerry's Foundation	http://www.benjerry.com/company/foundation/
Gordon and Betty Moore Foundation	http://www.moore.org/
Henry P. Kendall Foundation	http://www.kendall.org/index_flash.html
Rivers Foundation	http://riversfoundation.org/rfa/about/
Norcross Wildlife Foundation	http://www.norcrossws.org
Frost Foundation	http://www.frostfound.org/Pages/grantapp.html
Fish America	http://www.fishamerica.org/grants/index.html
American Rivers	http://www.americanrivers.org/our-work/restoring-rivers/dams/noaa-grants-program.html
Global Restoration Network	http://www.americanrivers.org/our-work/restoring-rivers/dams/noaa-grants-program.html
Trout Unlimited	http://www.tucalifornia.org