Garrapata Creek Watershed
Assessment and Restoration Plan

July 2006

Prepared for
The Garrapata Creek Watershed Community and
the California State Department of Fish and Game

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Prepared by
The Garrapata Creek Watershed Council

Cover: *Garrapata Creek Lagoon looking up canyon, Highway 1 bridge in the background.*
Photo: C. Kleissner, 2002

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Executive Summary

Framework and Guiding Questions

This Watershed Assessment and Restoration Plan assesses the overall condition and health of the Garrapata Creek Watershed. Based on this assessment, it identifies critical issues and limiting factors facing the watershed. The issues are framed primarily as they relate to anadromous steelhead trout (*Oncorhynchus mykiss*). Finally the Plan presents a set of recommendations to address the identified issues of concern.

The Garrapata Creek Watershed Council is a voluntary association of private and public landowners and managers who own property, live, and/or work in the watershed. The group developed this plan over a four-year period. Over 60 watershed stakeholders participated. These stakeholders conducted Watershed Council general membership and planning meetings, gathered data, supported scientists, located and obtained funding where needed, and participated in hands-on watershed informational activities, training, and clean-up events. Members of the Watershed Council, along with other watershed landowners, scientists, and agency representatives – including staff of the California Department of Fish and Game (CDFG) – assisted in the development of this Watershed Assessment and Restoration Plan.

Some of the council members met on a regular basis as the Planning Group to discuss, debate and develop the major sections of this document. Planning Group participants wrote portions of the plan in cooperation with the Technical Advisory Committee (TAC), who were contracted to address many of the science-based research needs identified by the Planning Group.

The planning process focused particularly on the following three questions:

- ***What are the major issues and concerns within the watershed?***
- ***What are the major issues impacting the creek and its tributaries?***
- ***Are there potential restoration projects that could be conducted to enhance and increase steelhead populations?***

The ultimate purpose of the plan is to identify activities and projects that could be undertaken by willing landowners to increase the population and distribution of steelhead trout and to enhance the riparian ecosystem. To accomplish this, the plan identifies a range of watershed impacts limiting steelhead trout now, and describes ways to improve them. It then prioritizes the suggested improvements by evaluating such criteria as their urgency, their feasibility, and their effectiveness - and by the risks of unintentional negative impacts.

Specific areas of assessment include: the watershed's hydrologic function, and sediment transport; geologic setting, road-produced sediment (erosion) issues; the current status of the steelhead population and distribution in the watershed; migration barriers to steelhead in the creeks; the Garrapata Lagoon and its function for steelhead; and the watershed's vegetation composition and the health of the riparian corridor. These assessment studies included field work in the majority of the watershed area. Instream conditions and fish passage barriers were assessed along all the anadromous reaches of Garrapata Creek and tributaries. Fisheries conditions were assessed at three sites in the lower and middle reaches of Garrapata Creek. Upslope erosion was assessed in over 70% of the total area of the watershed. Vegetation was assessed along much of the lower watershed and along locations throughout the upper watershed. This plan encompasses the most comprehensive assessment in the history of the watershed.

Limiting Factors Analysis

As originally stated, the purpose of this plan is to assess the overall condition of the Garrapata Creek Watershed and identify critical issues and limiting factors as they relate to steelhead. As supported by the assessments, the keystone limiting factors in the watershed are as follows:

- Sediment delivery to the streams from road erosion in the watershed is causing adverse conditions to Garrapata Creek and tributaries.
- Steelhead migration barriers in the lower reaches of Garrapata Creek and tributaries prevent fish from utilizing all of the habitat available for spawning and rearing.
- Non-native plant species invasion has restricted riparian habitat and has caused significant negative impacts, including the development of invasive monocultures that impedes the recruitment of native riparian species in the watershed.

Roads and Erosion

Given the impacts detailed in the Geomorphology, Hydrology, and Sedimentology section, the Upslope Road Assessment section, and the goal of improving anadromous fishery habitat, there is one major restoration opportunity that stands out above all others: reducing sediment delivery to the creeks from unpaved roads, especially in the Joshua Creek sub-watershed.

Recommended restoration activities to address sediment delivery to the creeks from road erosion are as follows:

a) Restoration of roads as recommended in PWA report. (Project is slated to begin in Summer 2006)
b) Better on-going road maintenance and practices.

Steelhead Migration Barriers

Given the impacts detailed in the Barrier Assessment section, the large and complete barriers to migration that define the limit of anadromy, have been in place for decades and due to their residence time have become stream gradient control features. Removal of these naturalized barriers would adversely impact the stability of the surrounding hillslopes, roads, and homes that are immediately adjacent to the creek. In addition, the release of stored sediment would likely have adverse impacts on spawning habitat and fish downstream, which could potentially take decades to restore. Likewise natural barriers in Joshua and Wildcat creeks define the limit of anadromy in those tributaries. However, barriers have been identified downstream of these natural features that can be modified or removed. Modification and/or removal should consider potential impacts of sediment release downstream in the design and planning of any project.

Recommended restoration activities to address steelhead migration barriers are as follows:

a) Modify/remove barriers in Garrapata Creek downstream of the barriers that define the limit of anadromy.
b) Modify/remove barriers in the lower reaches of Joshua and Wildcat Creeks downstream of natural barriers.

Riparian Habitat Enhancement and Non-native Plant Removal

Given the impacts detailed in the Watershed Vegetation and Riparian Resources section, there are a few specific locations where riparian habitat in the lower drainages is non-functional, or functionally at risk; proactive change, therefore, would be most beneficial in the lower watershed. Types of riparian enhancement projects range from massive in scope, to very small, site-specific efforts.

Recommended restoration activities for improving riparian habitat and maintaining watershed health can be prioritized as follows:

1. Control the spread of Cape ivy, eucalyptus, Monterey pine, vinca, pampas grass, sticky eupatorium and other invasive weeds, particularly in areas that support willow and alder vegetation. Provide disposal options to remove weed biomass.
2. In areas where stream banks are barren or unstable, revegetate with native species.
3. Clean up trash and provide disposal options.
4. Develop an information outreach campaign to maintain stewardship awareness for residents, and to introduce stewardship philosophy to new residents.
5. Assess feasibility of grant opportunities for larger-scale floodplain restoration that includes eucalyptus, pine and cypress removal.
6. Develop a strategy and action plan to assess need for action/restoration after high flows have caused erosion or bank failure.
7. Identify grant opportunities and conduct avian monitoring, both baseline and follow-up.
8. Identify opportunities to enhance habitat for California red-legged frog. Remove bullfrogs from pond habitats, if present.

Watershed Collaboration

While the intent of this plan was to provide a preliminary assessment of the watershed and generate a prioritized list of projects to address keystone issues affecting the steelhead fishery, it has become a great deal more, involving countless volunteer hours and input from the community regarding ideas for the watershed's future. The process of meeting collaboratively among stakeholders and regulatory agencies cannot be underestimated. This process is just as important as the document itself.

Introduction and Background

Background, Purpose and Need for the Plan

The Garrapata Creek Watershed Assessment and Restoration Plan focuses on upland, riparian, and instream issues that were originally identified by the Garrapata Creek Watershed Council Planning Group as being important in the watershed. The Plan includes historical information and existing conditions and identifies limiting factors and “keystone” problems affecting steelhead trout habitat in the watershed. It then identifies a range of watershed projects, and prioritizes them using criteria such as urgency, accessibility, and risks of unintentional impacts associated with remediation.

In the year 2000, it was determined that a plan was needed after residents and property owners in the Garrapata Creek Watershed began meetings to discuss various aspects of the watershed that pertained to both the residents and the environment. The Garrapata Creek Watershed Council (GCWC) was incorporated as a non-profit, tax-exempt, volunteer corporation in the spring of 2001. The Council is dedicated to improving and restoring watershed resources through community involvement, teamwork and education.

In 2002, the GCWC decided to develop a watershed-wide management plan for the Garrapata Creek Watershed. One reason for developing the plan was in order to jointly create a list of recognized issues and concerns in the watershed that are larger than any individual landowner can manage alone. Other reasons for developing the plan were to educate the watershed community, develop consensus among stakeholders, develop a non-regulatory (voluntary) approach to improving the watershed, identify and prioritize restoration projects and activities, and coordinate a simplified and affordable permitting process for these projects. Over 60 watershed stakeholders participated in the process. Interested watershed stakeholders conducted and attended Council general meetings, planning efforts, training, and other watershed activities. Participants of the GCWC Planning Group met on a monthly basis over the four-year period to determine issues of high priority in the watershed, to provide input and manage this project, and to focus on issues addressed by the Technical Advisory Committee (TAC).

The Planning Group used the following issues and concerns, which the council’s general membership generated, to identify issues to explore during this plan:

1. **Fish Habitat Issues**
    a) Fish migration barriers, log-jams
    b) Silt/sediment from roads impacting creeks and fish
    c) Lack of deep pools

2. **Road Issues**
    a) Road construction and design
    b) Road maintenance and upgrade

3. **Resource Imbalance Issues**
    a) Impassable log/debris jams
    b) Sudden oak death disease
    c) Fire suppression
    d) Trash and garbage in creek

4. **Invasive Species Management Issues**
    a) Riparian
    b) Upland

5. **Water Quality & Quantity Issues**
    a) Pollutants and excessive sediment in creeks
    b) Annual flow levels

6. **Public Policy Issues**
    a) Land-use policies that support beneficial watershed practices – such as fish habitat protection – on a watershed level.

Watershed Overview

Garrapata Creek is a small stream located 10 miles south of Carmel-by-the-Sea in coastal Monterey County, California. Garrapata Creek drains the western slope of the Santa Lucia Mountains (Fig. 1). The watershed drainage is approximately 10.7 square miles (27.5 square kilometers). The watershed includes two tributaries, Joshua and Wildcat Canyon Creeks. Joshua Creek, the northern most tributary is about 3.1 miles (5.0 kilometers) long and drains approximately 2.1 square miles (5.3 square kilometers). The headwaters originate near the northeastern-most portion of the basin and the confluence with Garrapata Creek is located 1.05 miles upstream of the mouth of the lagoon. Wildcat Canyon Creek also known as Wildcat Creek (located to the south of Joshua Creek) is about 3.9 miles (6.3 kilometers) long and drains approximately 2.9 square miles (7.5 square kilometers). The headwaters originate near the northeastern-most portion of the basin and the confluence with Garrapata Creek is located 2.4 miles upstream of the mouth of the lagoon. Mainstem Garrapata Creek is almost 8 miles in length (12.8 kilometers) and drains an area of over 5.7 square miles (14.7 square kilometers). The headwaters originate near the southeastern-most portion of the basin in the Los Padres National Forest. All three canyons are extremely steep over most of their length, making access to many parts (particularly in the upper watershed) extremely challenging and often dangerous. Mainstem Garrapata Creek and the two tributaries are perennial streams.

Garrapata Creek flows into the federally protected Pacific Ocean waters of the Monterey Bay National Marine Sanctuary.

Table 1: Some Physical Attributes of Garrapata Watershed

Drainage area	27.5 km^2 (10.7 mi^2)
Axial trend	270°
Length	7.7 km (4.8 mi)
Highest peak (Twin Peak)	1100 m (3610 ft)
General divide elevation	915 m (3000 ft)
Mouth elevation	Sea level at mouth of Garrapata Lagoon
Relief	915 m (3000 ft)
Average slope	12%
Approximate Strahler stream order	5th
Network geometry	Dendritic, but controlled by active faulting
Dominant stream types	Headwaters dominated by A, B Mid-slope dominated by B with sporadic waterfalls Lowland dominated by B with minor C (classification of Rosgen, 1994)[1]
Land-use	Wilderness, sparse residential, and light agriculture.
Vegetative Ecosystems	Dominated by chaparral, scrub, and oak/bay woodland. Local redwood forests near valley bottoms. Eucalyptus groves locally present. Cape Ivy is greatest non-native plant threat

[1] Dave Rosgen developed a simple stream classification system using letters. Type A is for steep, entrenched cascading or step-pool streams. Type B has Moderate steepness. Type C is low gradient, meandering stream with well-defined flood plans. (Rosgen 1994)

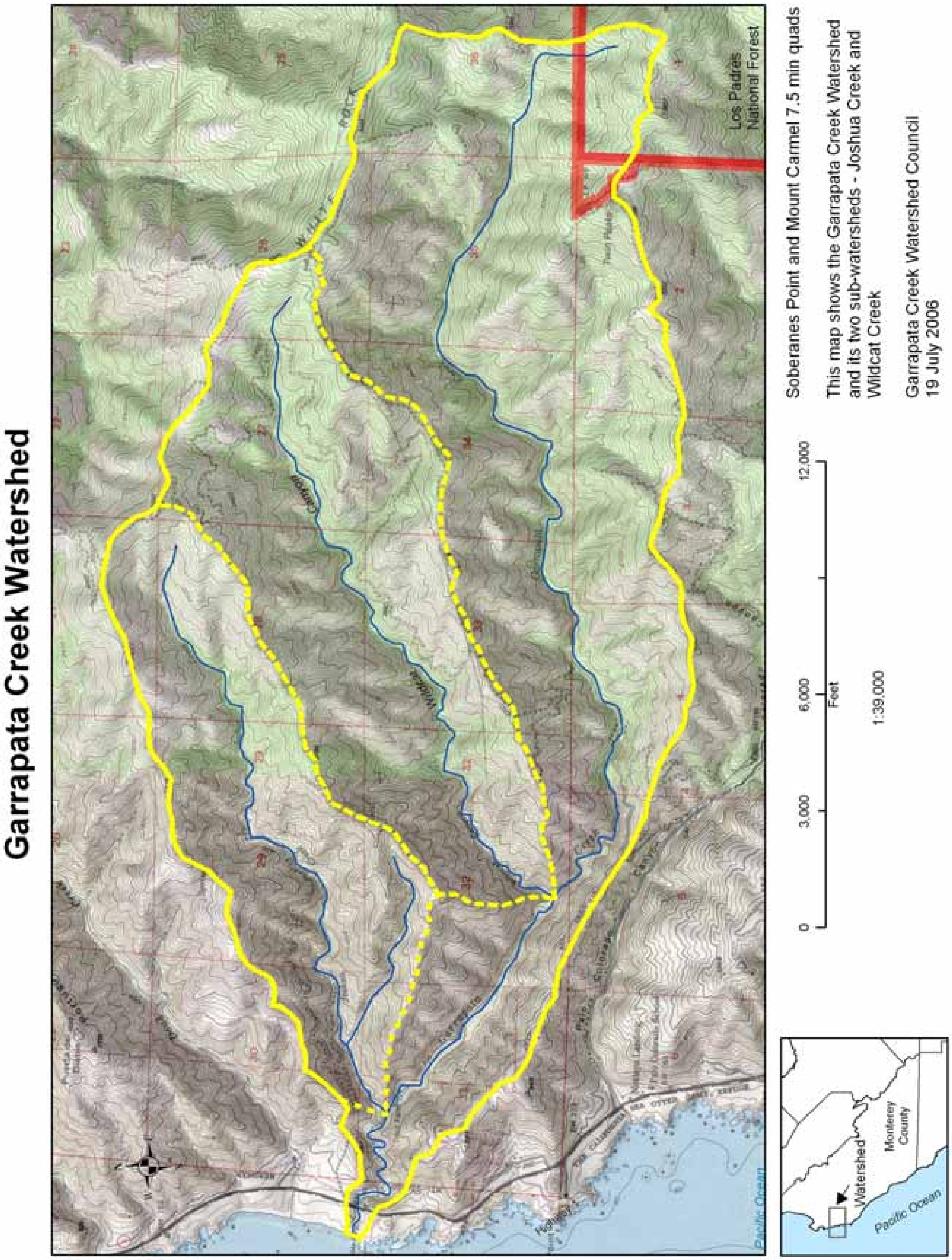

Figure 1: Garrapata Creek Watershed. Map: K. Ekelund, 2006

History of the Garrapata Creek Watershed

The Garrapata Creek Watershed supports a rich human history that includes well over 100 years of rural settlement and all the various attendant activities that relate to residential development and commercial use. Road construction, logging, land clearing, water extraction, grazing, commercial fish rearing, and small-scale agriculture occurred as homesteaders made claims to land in the watershed and established their homes and ranches. The vegetation history of the Garrapata Creek Watershed includes significant alterations due to human activity, as well as naturally induced episodic changes resulting from wildfires and floods.

Earliest European and American settlement in the watershed no doubt pre-dates the 1895 application found to operate a post office establishment – the Mungo Post Office – which was situated on the south side of Garrapata Creek about one-half mile from the coast road (Clark 1991). The Mungo Post Office may have been established to service the robust timber industry that sprang up throughout the Big Sur region at the close of the 1800's. Roads along approximately three miles of the lower creek area might be related to this early activity.

Several roads in the watershed including roads along much of the lower creek are known to be older than 100 years. Highway 1, which is the main route along the coast from Carmel south to the county line is more than 100 years old. Then known as the Coast Road, the highway was originally routed a short distance up the canyon, where it crossed the creek on a small bridge before turning back to the coast. A part of the old highway is now used as a driveway (Fig. 2). This road appears in a photograph taken around 1912 (Fig. 3) and can be compared to the current view (Fig. 4).

Figure 2: Lower watershed with Highway 1 and Garrapata Creek Bridge. Road in upper center is remnant of old coast road. Part of Garrapata Ridge is in the foreground. Note: Most roads in foreground drain away from creek.
Photo: D. Smith 2004

Figure 3: Garrapata Canyon in 1912.
Note: All vegetation had been scoured away
by the floods of 1911-1912.
Courtesy J. Norman and K. Phillips.

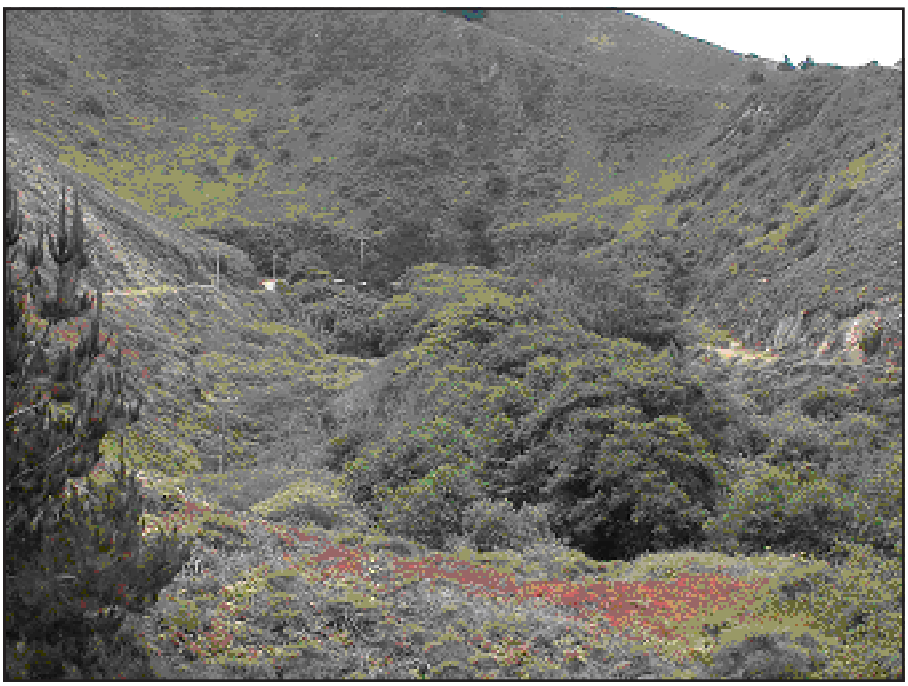

Figure 4: Same vantage point as Figure 3.
Note: Red Alder/Arroyo Willow Riparian habitat
Photo: N. Nedeff 2004.

The current Garrapata Creek Bridge was completed in 1931 (Figs. 5 and 6). A 1938 survey shows roads constructed along the south-facing slope of the Joshua Creek watershed.

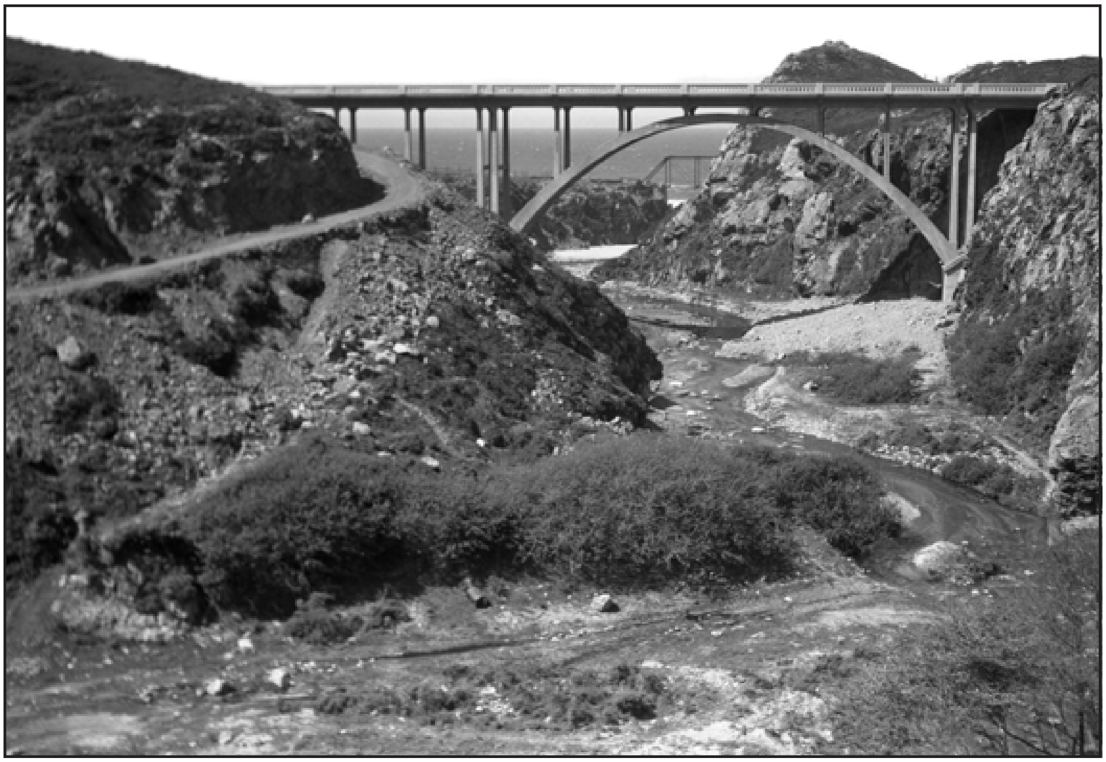

Figure 5: The new Highway 1 Bridge over Garrapata Canyon (old coast road bridge seen through new bridge). Riparian vegetation in this early 1930's view is very sparse, with discontinuous willow thickets found on exposed sand and gravel bars. Photograph courtesy Pat Hathaway and California Views Historical Photo Collection. This photograph should not be reproduced without the permission of Mr. Hathaway.

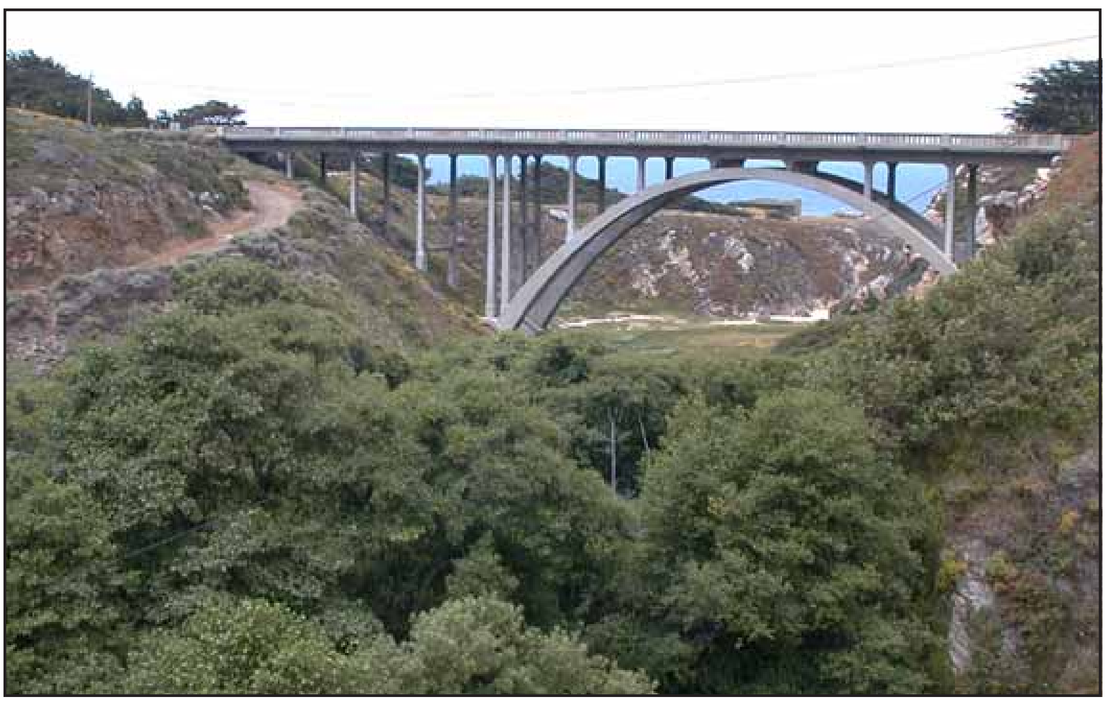

Figure 6: Same view as Figure 5. Photo: N. Nedeff July 2004.

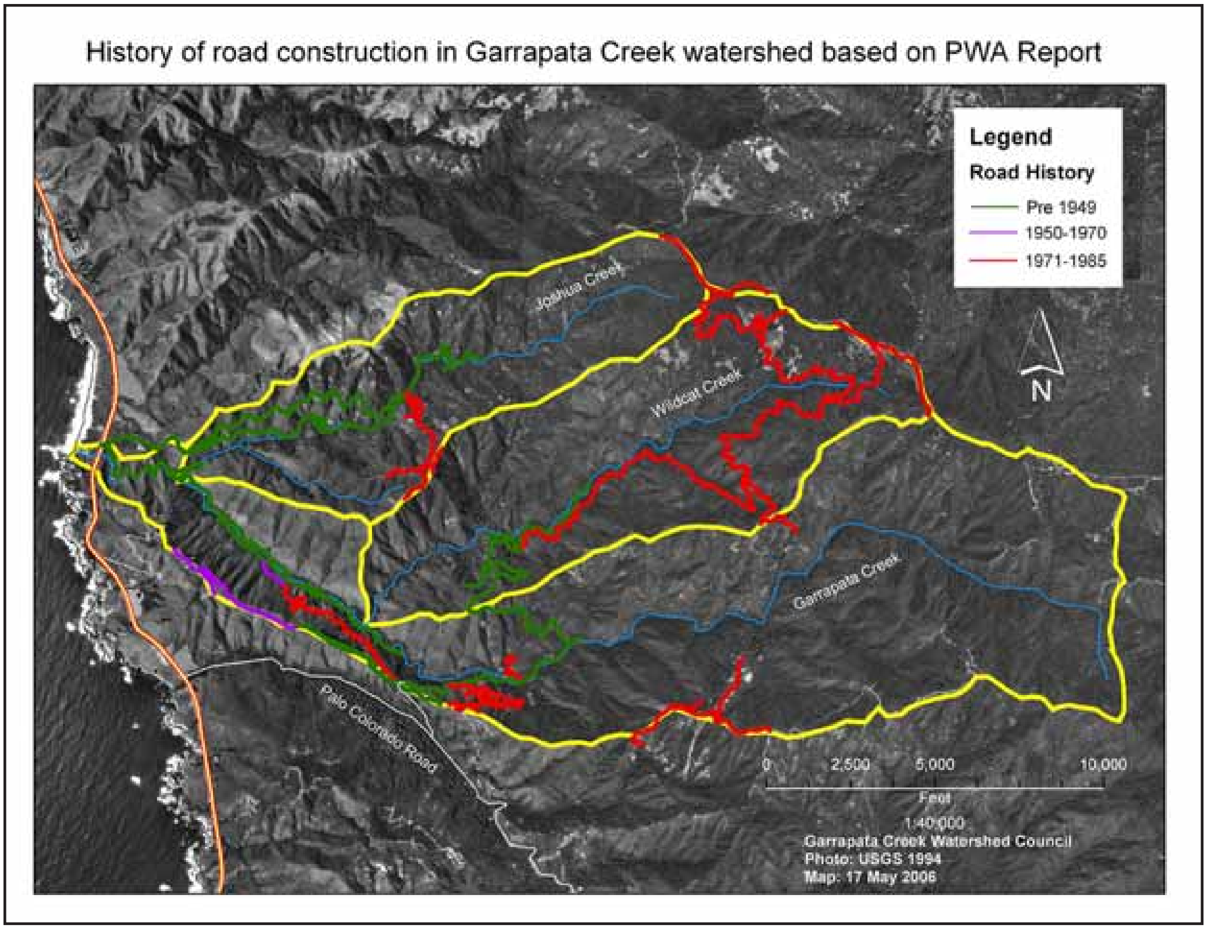

Figure 7: Road construction history based on 2003 PWA report. Map: Ken Ekelund, 2006

Aerial photos were used to document road construction history. Road construction was grouped as pre-1949, 1950-1970, 1971-1985 (Fig. 7). The first aerial photos from 1949 reveal limited logging and spur roads, which branched off a few existing main roads. Photos from 1970 show considerably more roads with construction on Garrapata Ridge and other locations. Most the roads that currently exist near the mouth of the creek near Highway 1 were in existence in the 1970 photos.

Between 1985 and 2000, additional spur roads that branch off pre-existing roads show up on the photos but could not be more specifically dated. The newer roads were mostly constructed for residential use including driveways and an alternate evacuation route for residents of Palo Colorado canyon to the south. Also during this time, jeep roads and firebreaks are seen along the ridge tops in the highest parts of the watershed.

Some of these later roads were on the Little Horse Ranch, part of what is now the Palo Corona Ranch owned by CDFG. A previous owner illegally constructed over 7 miles of roads in 1990 without the required county and state permits. The State Coastal Commission directed that all illegal roads be retired.

Background of Garrapata Creek Watershed Council

The GCWC was established in order for stakeholders – including landowners, residents and land managers – to participate in a cooperative and proactive effort to improve the health of the watershed. In addition to private land owners, several governmental agencies own land in the watershed including CDFG and the U.S. Forest Service. Monterey County Public Works Department which maintains the public portion of Garrapatos Road rounds out the stakeholders. Members have met on a regular basis since 2000 to discuss current issues in the watershed, plan for the future of the watershed, and learn appropriate conservation practices and activities they can apply on their own land. Members participated in over a dozen informational creek walks and several creek clean-up days where truckloads of human-caused debris was removed from the creek including household debris, pieces of vehicles including car batteries and household appliances.

Figure 8: Council creek cleanup day in 2004
Photo: B. Nelson, 2004

Watershed Council's Goals and Objectives

Working together, the Garrapata Creek Watershed Council is coordinating the efforts of local landowners and residents with multiple federal, state, and county agencies, and non-profit organizations. Through this effort the following goals have been identified:

- Educate the public about watersheds and their importance.
- Protect the natural, cultural, and historical resources of the Garrapata Creek Watershed.
- Encourage wise watershed stewardship in advance of resource degradation and regulatory action.
- Minimize water consumption by encouraging and educating people about conservation.
- Involve the local community to foster, develop, and coordinate a watershed approach to resource planning and management.
- Advise decision makers.

Existing Conditions

Topography

The Garrapata Creek Watershed drains the western slope of the Santa Lucia Mountains in the northern part of Big Sur. Big Sur is defined as the area from Mal Paso Creek in the Carmel Highlands to the county line in the south, from the coastline to the top of the coast ridge. The watershed divide rises to approximately 3445 feet (1050 meters) along the White Rock Ridge and to 3935 feet (1200 meters) at Twin Peak near the boundary of the Los Padres National Forest. The watershed drainage is approximately 10.7 square miles (27.5 square kilometers).

Climate

When asked what the weather was like in Big Sur, old-timer Hans Ewoldsen would reply, "Where do you mean?"

The Garrapata Creek Watershed is typical of the California central coastal region and has a Mediterranean climate marked by dry summers, rainy winters and relatively mild temperatures year round. The climate of the watershed is characterized by many distinct microclimates that are influenced greatly by both the North Pacific high-pressure cell and El Niño Southern Oscillation (ENSO) cycles.

Typically, the Garrapata Creek Watershed receives 90% of its annual rainfall between November and April of each year. The amount of rainfall from any particular storm will vary greatly based on location; the further from the ocean and the higher in elevation, the greater the amount of rain. Winter storms during the months of December - February tend to be the most severe. Winter storms also generate significant wind velocities, with some reaching over 100 mph along the ridge tops. Average annual rain amounts are not well documented for the upper watershed. Good records are available for several sites close to the ocean, with a general average of between 20-30 inches annually. One gage at the Glen Deven Ranch, which is located about at 800 feet above seas level and about 1.3 miles from the ocean, collected precipitation ranging from 14 to 72 inches in 24 years of record, with an average of 30 inches (74 cm). However, it is fair to estimate that annual totals for areas in the upper watershed and high elevations may be twice those at the coast.

In their book *The Natural History of Big Sur*, authors Paul Henson and Donald J. Usher write: "The North Pacific high is the most dominant influence on the climate of Big Sur. This giant, persistent high pressure is responsible for Big Sur's westerly winds and summer drought, as well as its summer fog. The absence of the high in winter allows Big Sur to receive its plentiful rainfall only this season."

While the North Pacific high is responsible for our average climate over time, it is the effects of the El Niño/Southern Oscillation (ENSO) that tend to bring the most dramatic weather events to the watershed. During a statistically high ENSO year, all of the averages for weather get thrown out the window. In past ENSO high years, summers have been virtually fog free, with day after day of beautiful weather. In ENSO high winters, storm after storm, backing up like a train from the Hawaiian Islands to the coast, dump huge amounts of rain and bring the highest recorded winds to the area. It is these ENSO years that cause long-lasting changes to the landscape, including landslides, dramatic changes in the location of the streambed, and new log jams from downed trees, to name a few.

In describing the average climate of the watershed it is best to use a model that divides the area into a number of microclimates to truly understand the dynamics. These microclimates fall into the following general categories:

1. Coastal — the area within roughly 800 meters of the shoreline. The coastal area is characterized by cooler temperatures in the summer, with more foggy days; breezy to windy weather is the norm. It receives the lowest total annual rainfall, as the dynamics that bring higher rainfall to the upper watershed are not present.

2. Canyon streambed — the area roughly 50-100 meters either side of the streambed. This microclimate in general is cool, moist far later into the summer, and almost always has a light to moderate breeze blowing either toward or away from the ocean. Rainfall will vary greatly with elevation, with the higher elevations receiving greater amounts.

3. South-facing slope — the canyon slopes roughly 500 or more meters from the coast that are south facing. This microclimate may appear in places to be almost desert-like in appearance. In summer time, temperatures commonly soar near or above 100 degrees. While it may receive similar amounts of rainfall as its north-facing counterpart, its moisture is quickly evaporated by the even cooler winter sun. For the sun lover it is second to none for sunny, hot days.

4. North-facing slope — the canyon slopes roughly 500 or more meters from the coast that are north facing. In the few places where one can clearly see both the south- and north-facing slopes from the canyon, the difference in microclimates is dramatic to say the least. The north-facing slopes contain the bulk of the redwoods, oaks and other trees of the watershed. Here the winter sun never rises above the ridgeline, leaving moisture ample time to saturate the slopes. Temperatures on any given day may vary as much as 50 degrees between the south- and north-facing slopes of the Garrapata Creek watershed. In summer, when winds trend from the north, the north-facing slopes may be hidden in fog, with temperatures in the mid to low 50's, while less than a mile away on the south-facing slopes the temperature may be near 100 degrees with sunny skies. The abundance of redwood trees further influence the climate by blocking out sunlight and keeping the area relatively mild year round.

5. Ridge tops — those areas within 50-100 meters of the ridge tops. This microclimate is a mixing zone for the previously described south- and north-facing slopes. It is generally warmer and drier than areas 100 meters below its northerly facing sides. It receives the strongest winds during winter storms and in higher elevations may receive twice the amount

of rain when compared to the coastal zone. Foggy days tend to be fewer than along the immediate coast and in the canyon bottoms. It is not unusual to look down from the upper watershed and see little islands in the fog that in fact are ridge tops.

In conclusion, the climate of the Garrapata Creek watershed is in reality a tapestry of many distinctly different and contrasting microclimates that are influenced greatly by both the North Pacific high and the ENSO cycles. Due to these microclimates it is difficult and most likely inaccurate to attribute any particular specific generalization to the total watershed. Instead it is important to always ask the same question that Hans Ewoldsen did so long ago, “Where do you mean?”

Land and Water Use

Current land use in the watershed consists mainly of low-density rural residential development and open space. Much of the land remains essentially undeveloped, though historical uses such as grazing and logging have certainly impacted the natural environment over most of the area.

Approximately 53% of the watershed is owned either by the California Department of Fish and Game or the U.S. Forest Service. Roughly 41% of the watershed was recently transferred from private to state ownership as part of the Palo Corona Ranch purchase. The California Department of Fish and Game now owns 51% of the watershed (the Palo Corona Ranch and the original Joshua Creek Ecological Reserve now collectively known as the Joshua Creek Ecological Reserve); another 2% is in federal ownership as part of the Los Padres National Forest. About 47% of the watershed is privately owned. These totals are reflected in the table below:

Table 2: Watershed Land Ownership

Type of Ownership	Number of Parcels	Percentage of Watershed Area
Public	23	53
Private	265	47
TOTAL	**288**	**100**

Private owners predominately use their property for private residences, either year-round or part-time. Current County Assessor records show 47 parcels as containing one or more residences, though it is not possible to state with authority how many of these are in use as permanent, year-round dwellings and how many are used intermittently. Twelve percent of the watershed consisting of 8 parcels belongs to The Big Sur Land Trust, a private non-profit organization with land conservation goals, while 1 parcel comprising 5% of the watershed belongs to the White Rock Gun Club, a private non-profit organization providing hunting and recreation opportunities for its members.

No registered commercial establishments presently exist in the watershed. As noted above, some lands have historically been used for grazing cattle and raising trout, and commercial logging activities have occurred as recently as the mid-1960’s. Currently these activities are not ongoing, though seasonal grazing sometimes occurs in the northern part of the watershed.

Public access is currently limited to two locations in the watershed. There is occasional low-tide access to the lagoon, located on private property, via Garrapata State Park beach. In addition, there is very limited access (with prior CDFG permission and notification to the Monterey Peninsula Regional Park District) to the upper watershed through the Palo Corona Ranch. It is however reasonable to assume that additional use of this second access will be sought as public access management plans for Palo Corona Ranch are developed.

The Garrapata Mutual Water Company is the only water company that delivers water outside of the watershed. Then called the Garrapata Water Company, it was officially recognized by the California Public Utilities Commission in 1962. The company has water rights to 35 acre feet per year from Garrapata Creek, and serves parcels on Garrapata Ridge and along a strip of land west of Highway 1 from the creek south to the Rocky Point Restaurant. Many of these latter customers are located outside the watershed. It is reported that about 40 customers are within the company service area. A State Water Resources Control Board ruling in 1999 (Decision 1639) established that the water is being drawn from the Garrapata Creek subterranean stream and is part of the stream and not groundwater as the company had contended in their 1998 petition. The diversion point is a shallow well in a layer of alluvium and is located on the north bank of the creek about 1500 feet upstream of the lagoon. Individual private wells and small water companies serve the remaining residences within the watershed.

Overall land use in the watershed is not expected to change in the foreseeable future because very stringent land use planning policies exist in this area, which will limit additional subdivision and restrict the allowable uses of land in many different ways. Currently only 8 parcels of record are larger than 80 acres (the general minimum size that would allow further subdivision). It is likely therefore that remodeling existing residences and building on existing legal lots of record are the most probable additional private land use activities. Development to support public recreational uses may be proposed for public lands. However, current regulations for development would suggest that all these activities may result in significant increases in road building and other impacts to the natural environment, since many current roads were created before current fire department standards were in effect and any development will be required to create or upgrade all infrastructure to current standards.

Of note in the consideration of land use within the watershed is an existing area called Garrapata Redwoods Estates located at the inland end of Garrapatos Road. This subdivision was reportedly created in the 1920's, and the resulting approximately 200 very small parcels averaging 3000 square feet (0.07 acres) were apparently awarded as premiums for newspaper subscriptions. Only a few of these lots are currently developed with private residences, roads and water systems. Most remain undeveloped, probably because of their small size, their remote and inaccessible locations, the steep terrain of the area, and current land use restrictions with respect to infrastructure. The eventual use and potential impacts of any further development that may be allowed in this area remain unknown since it is unique within the Big Sur Planning Area.

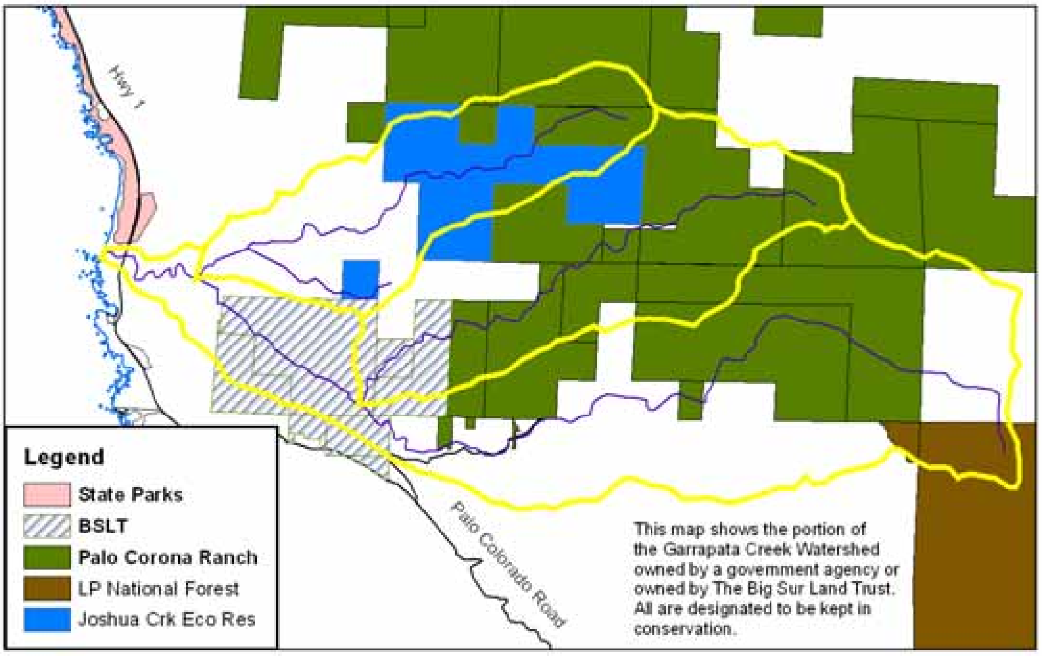

Figure 9: Public and Private ownership in Garrapata Creek watershed. Map: K. Ekelund, 2006

Geomorphology, Hydrology, and Sedimentology

Garrapata Creek can be described in terms of its physical shape and substrate (geomorphology), its hydrologic function (hydrology), and its role in transporting sediment (sedimentology). These three characteristics are discussed together because they are intimately related: Garrapata's water rushes down slope eroding the physical substrate to derive the sediment load carried by the creek. These issues are important because excess sediment has been identified as one "limiting factor" for steelhead populations. This section presents the results from several years of water and sediment monitoring. The monitoring effort has used a continuous recording pressure gauge on Garrapata Creek and Joshua Creek to quantify stream flow and a program of sediment sampling to quantify sediment flow. The results presented in this section include:

1) a description of the physical geology and geomorphology of the watershed,
2) estimates of the water budget for the watershed,
3) estimates of how much sediment is carried by Garrapata Creek and its tributaries, and
4) an assessment of probable sources of excess sediment.

Regional Geology

Geology is one of the fundamental variables controlling the physical condition and stability of a watershed. Rock type controls the soils, groundwater resources, erosion potential, landslide potential, ecosystem potential and both the land-use opportunities and liabilities. The Garrapata Creek Watershed dissects the Santa Lucia Mountains, which compose part of the much larger Salinian structural block. Based upon the rocks in the Salinian block, in Paleozoic time (400 million years ago) the block was located just south of the Sierra Nevada, where the Mojave

Desert is today (Mattinson and James, 1985). The Paleozoic rocks were deposited in a marine setting that was similar in geometry to the present eastern seaboard of North America. During Mesozoic time, those marine sediments were highly metamorphosed by heat from an enormous volume of magma that was generated below ancient volcanoes that lay near the present Sierra Nevada. The metamorphic rocks are present today as schist, marble, and gneiss in the Santa Lucia Range. Pico Blanco in Big Sur is “blanco” (white) because it is made of pale marble. The magma chambers cooled to form what is popularly called “granite”. The substrate in the Garrapata Watershed is entirely faulted and fractured granitic rocks with generally steep slopes (Figs. 10 and 11). The rock formation, which underlies approximately 99% of the Garrapata Watershed, is named the “hornblende-biotite-quartz diorite of Soberanes Point” (Rosenberg 2001). These are “granitic” igneous rocks that cooled at a depth of about 5 to 10 kilometers underground beneath an ancient volcanic region that existed about 100 million years ago. The rocks were geographically located south of the Sierra Nevada at that time.

The regional geology accounts for the natural erodability in the watershed. Most granitic rocks are not known for their “porosity” or value as a groundwater aquifer; however, the fractures and faults through the granitic rocks of the Garrapata Watershed allow them to store and transmit water in the groundwater system. The specific kind of granitic rocks underlying the watershed are classified as highly erodable by the county geologist (Fig. 12), explaining why road-cutting along steep slopes can lead to landslides and excess sediment in the streams located down slope.

The geologic history of the region is detailed, in Appendices A and B.

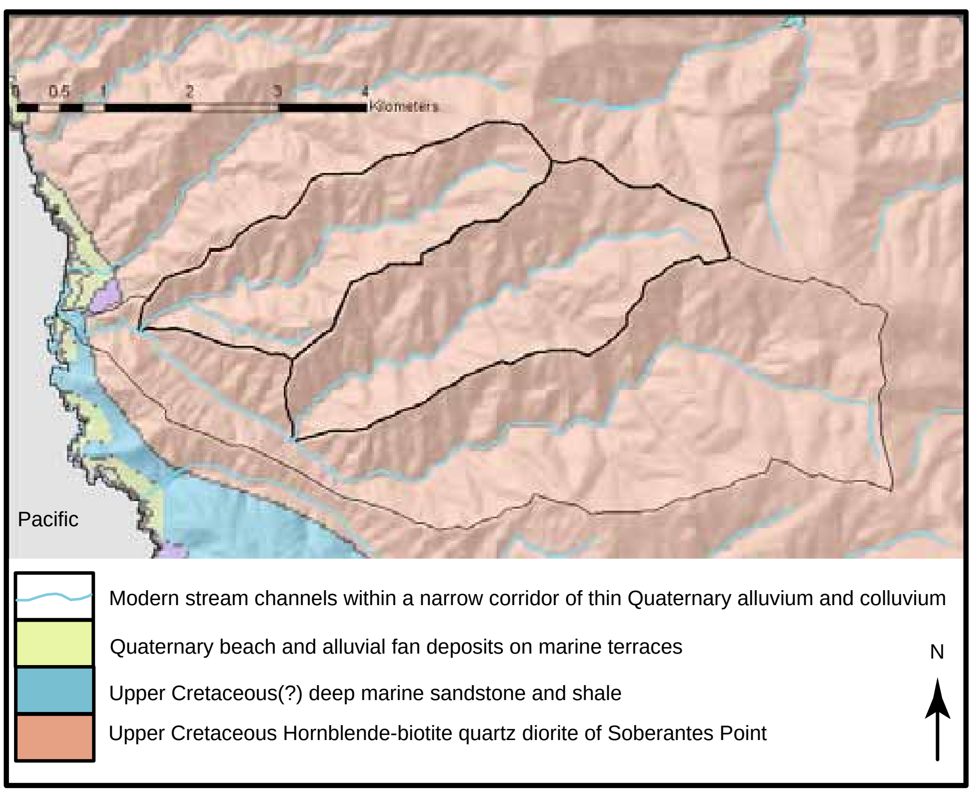

Figure 10: Regional Geology in Garrapata Creek Watershed area. The “pink” map symbol represents the “granitic” rocks in the watershed.
Data modified from Rosenberg (2001). Map: D. Smith, 2005

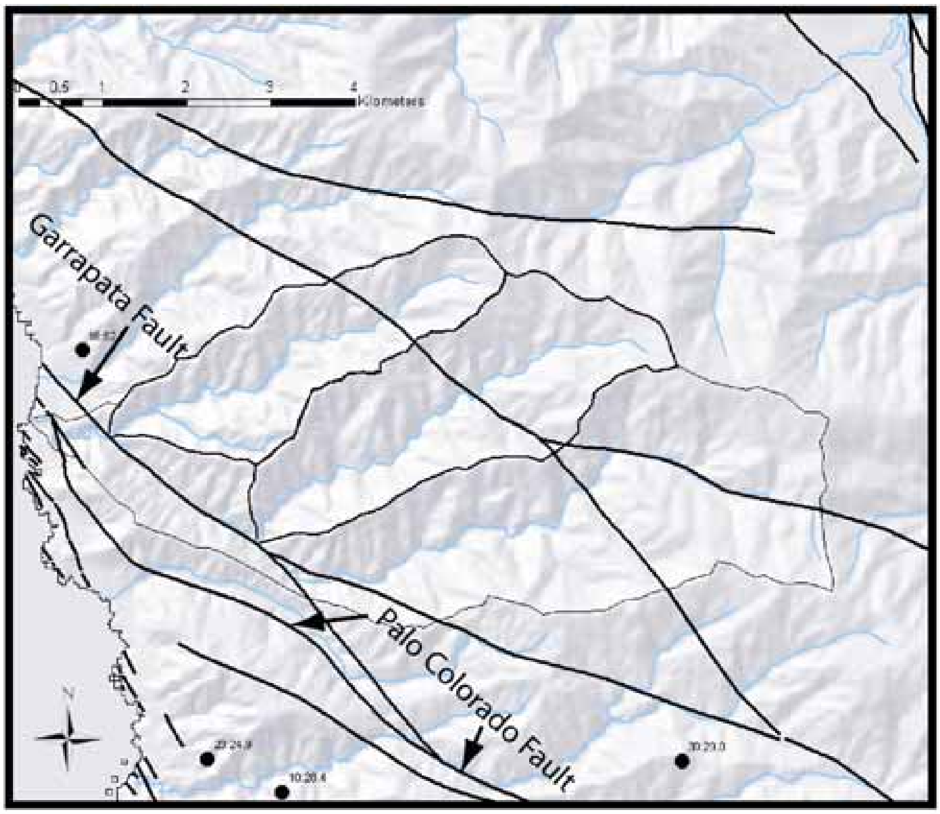

Figure 11: Regional faults that cut the Garrapata Watershed. Recent earthquake epicenters are shown as black dots. The two labeled faults are classified as active (modified from Rosenberg (2001). Map: D. Smith, 2005

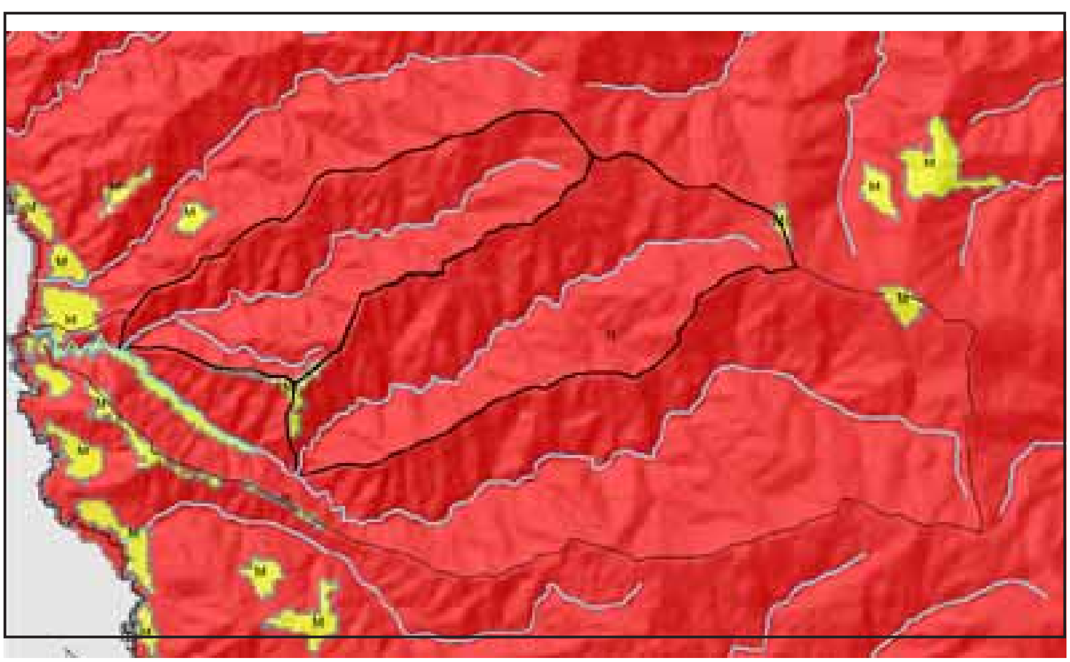

Figure 12: Erosion susceptibility in Garrapata Watershed. Red is high susceptibility, yellow is moderate susceptibility (Rosenberg, 2001). Map: D. Smith, 2005

Hydrology

Based upon a 24-year record of rainfall at the Glen Deven Ranch (Table 3), the average rainfall is 29.95 inches along the southern boundary of the watershed. Figure 13 shows the monthly averages of rainfall at the gauge, and Figure 14 is a plot of the annual mean rainfall. When a longer-term average rainfall is calculated based upon other local records, the 82-year average for Garrapata is approximately 28 inches.

Based upon the local record and a general knowledge of how rainfall values differ throughout the watershed, the average volume of rainfall entering the watershed is about 17,800 acre-feet/year. An "acre-foot" is a volume of water one foot deep covering an acre of land (or 325,851 gallons). On average about 77% of that water is either used by plants or lost to evaporation (evapo-transpiration). The remainder, 4025 acre-feet of stream flow per year, is what we measure at the gauges near the bottom of the watershed (Fig. 15). In general, the Garrapata Creek Watershed yields about 112 acre-feet of water from each inch of rainfall, but that value varies considerably from year to year.

Table 3: Monthly rainfall data from the Garrapata Watershed Gauge.

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total[2]
1982	4.16	8.43	3.51	9.05	3.73	10.22	5.1	0	0.75	0	0	1.92	46.87
1983	2.55	6.68	3.97	10.7	8.55	21.4	8.03	0.65	0	0	0.1	1.45	64.08
1984	0.85	9.3	7.75	0.95	3.35	1.4	0.35	0	0	0	0	0.1	24.05
1985	2.55	5.89	2.42	0.35	2.2	7.4	0.65	0	0	0.15	0	0.41	22.02
1986	1.7	5.46	2.1	3.15	10.77	7.7	0.66	0.58	0	0	0	1.29	33.41
1987	0	0.48	1.37	2.95	4.8	3.07	1.37	0.35	0	0	0.01	0	14.4
1988	1.52	2.97	6.05	3.22	1.79	0.52	3.69	0.95	0.35	0	0	0	21.06
1989	0	1.28	4.61	1.88	3.19	3.12	0.84	0.22	0	0	0	1.23	16.37
1990	2.52	1.67	0.15	4.3	2.99	1.25	1.55	0	0	0	0	0.12	14.55
1991	0.27	0.55	1.63	0.12	3.65	11.81	0.75	0.35	0.15	0	0	0	19.28
1992	1.76	0.1	4.2	2.35	12.1	5.45	0.38	0	0.25	0.25	0.06	0	26.9
1993	1.4	0.05	7.3	12.02	9.08	3.96	0.9	2	1.35	0	0	0.5	38.56
1994	0.4	0.8	2.2	3.59	5.5	1.2	3.75	1.35	0.1	0	0	0.35	19.24
1995	0.5	3.11	3.15	20.31	1.75	12.5	4.3	1.67	2.15	0.1	0	0	49.54
1996	0.1	0	4.75	7.3	9.62	3.5	1.6	2.05	0	0	0	0.22	29.14
1997	1.85	4.5	13.2	13.3	0.55	0.25	0.4	0.1	0.1	0	0.9	0	35.15
1998	0.85	10.1	3.6	15.55	24.1	5.8	6.15	4.7	0.5	0.2	0	0	71.55
1999	0.6	4.4	1.35	5.45	6.8	7.65	4.6	0	0	0	0.1	0.25	31.2
2000	0	0.5	0.75	10.85	13.45	0.95	2.3	0.7	0.75	0	0	0.5	30.75
2001	4.55	0.47	0.5	5.53	5.19	2.7	2.79	0	0.01	0	0	0.08	21.82
2002	0.28	3.69	4.08	0.83	1.72	2.25	0.43	0.42	0.04	0	0.05	0.04	13.83
2003	0	2.82	7.88	1.81	3	1.29	2.89	0.73	0	0.02	0	0.02	20.46
2004	0.19	0.97	1.88	5.84	7.31	0.93	0	0	0.28	0	0	0.17	17.57
2005	3.81	1.07	8.69	6.57	6.84	6.54	2.13	1.05	0.36	0.02	0	0	37.08
Monthly Avg	1.35	3.14	4.05	6.17	6.33	5.12	2.32	0.74	0.3	0.03	0.05	0.36	

[2] Annual Total

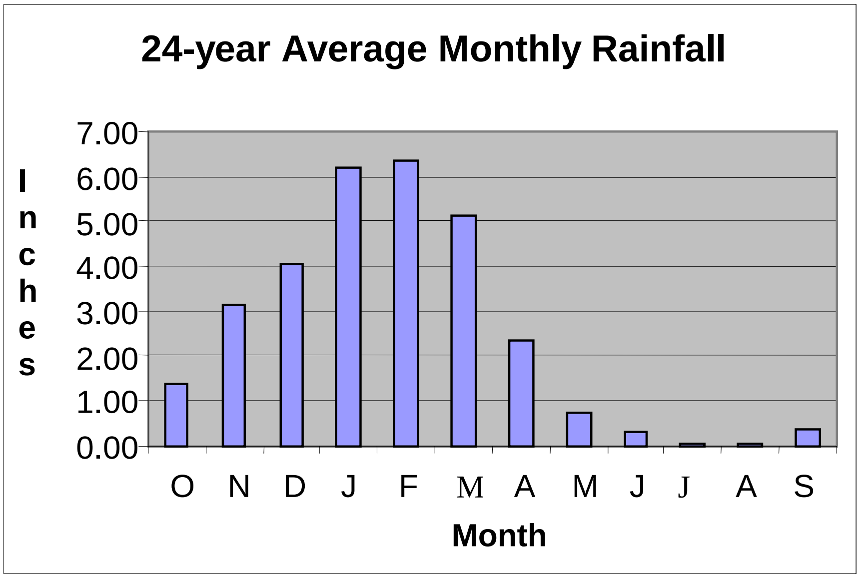

Figure 13: Average distribution of rain throughout the year.

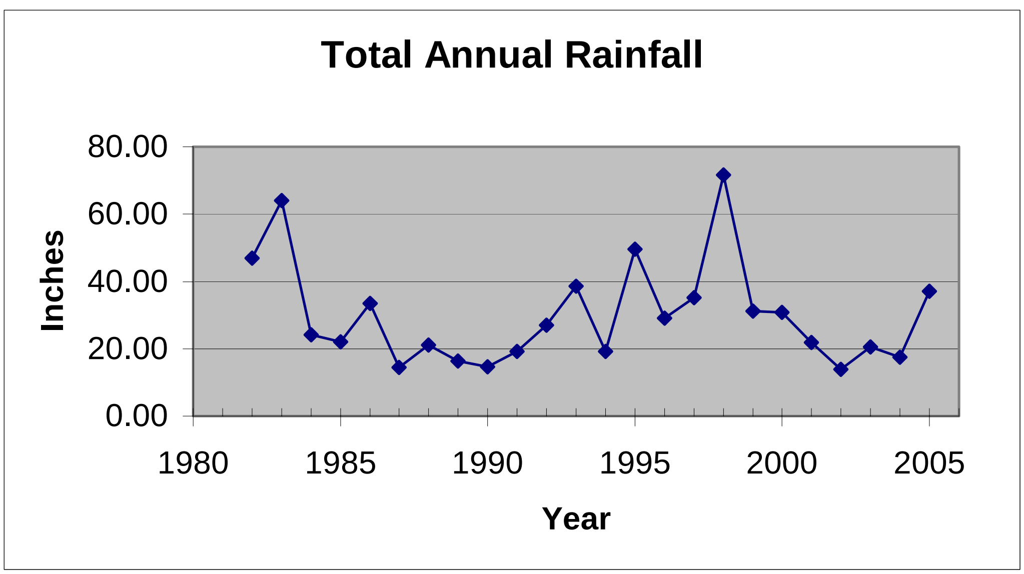

Figure 14: Total annual precipitation at the Garrapata rain gauge located at Glen Deven Ranch.

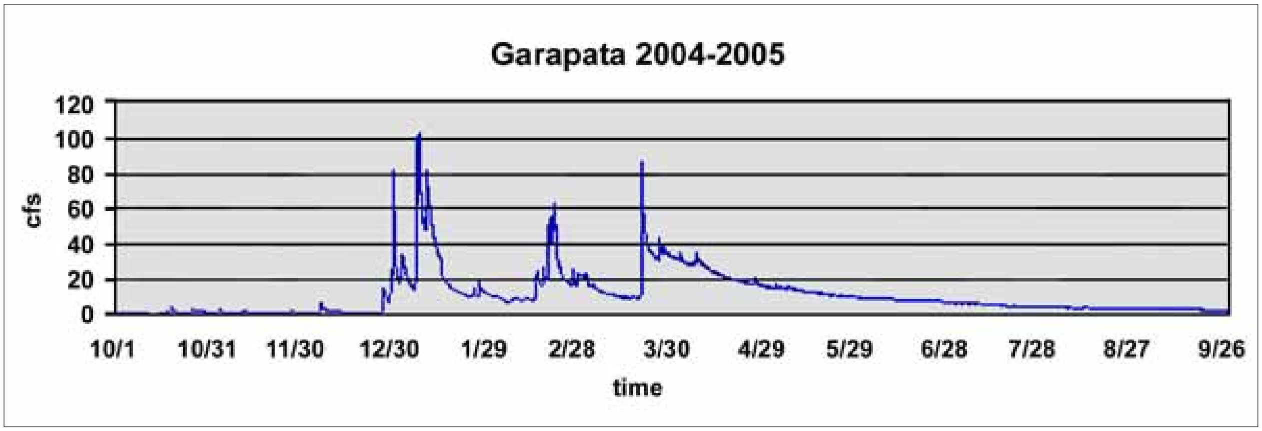

Figure 15: Example of annual stream discharge record for Garrapata Creek. "cfs" is "cubic feet per second." This record spans the "water year" from October 2004 through September 2005.

Given our data from the Garrapata gauge, we can estimate that the 2004 peak flow near 100 cfs represents the "5-year flood,"[3] and the two peaks near 80 cfs approximately represent the "2-year flood" (Fig. 15).

In summary, the Garrapata Creek Watershed yields enough water to keep the mainstem and tributaries flowing year round (e.g., Fig. 15). This is the case despite the fact that most of the rainfall occurs and "runs off" the land during the few storms between November and March. Flow during the rest of the year, when there are no rainfall and run-off events, is maintained by a granitic aquifer system that is charged with water during the winter and that then slowly "bleeds" flow to the streams through seeps and springs during the dry months. Water quantity is currently not a limiting factor for steelhead in Garrapata Creek.

Sedimentology

Excess fine sediment[4], including sand, silt, and clay can pose a significant environmental problem for steelhead. Among the negative impacts of sediment on steelhead are: gill abrasion, loss of visibility for feeding, loss of appropriate substrate for eggs, and infilling of pools which are critical refuge habitat during periods of high streamflow and where trout need to develop the speed to jump small waterfalls (Casagrande and Smith 2005).

Both suspended sediment (silt and clay) and bedload sediment (sand and gravel) were sampled on many occasions and analyzed at the CSUMB sediment labs. The samples allow us to calculate the rate at which the streams are transporting sediment at a variety of stream flow conditions.

We always expect more sediment to be transported by the stream (g/s or grams per second)

[3] A "5-year flood" means that there is a 1 in 5 chance of a flood of that magnitude in any given year, it is possible to have more than one flood of this magnitude in any given year.

[4] In this case, excess refers to a greater amount than would naturally occur in the creek; this is caused by poorly designed roads and cleared land that deliver fine sediment to the creek. For a discussion of the natural level of sediment refer to page 28.

when the stream is carrying more water (cfs or cubic feet per second). And, given equal watershed conditions, two streams will carry approximately the same amount of sediment at the same stream flow conditions. Figure 16 is a plot of sediment transport for a variety of stream flow levels for Garrapata Creek just upstream from the confluence with Joshua Creek, and for Joshua Creek also just upstream from its confluence with Garrapata Creek. The dots are the actual measured values and the lines represent mathematical functions that connect the dots for each stream.

The significantly steeper line in the Joshua Creek data clearly demonstrates that Joshua Creek has an excess of sediment when compared with Garrapata Creek (Fig. 16). Given a slight increase in stream flow in Joshua Creek, the sediment transport rate increases significantly. In contrast, Garrapata's sediment transport rate increases very gradually even at much higher flow rates. Visual inspection of both creeks supports these data.

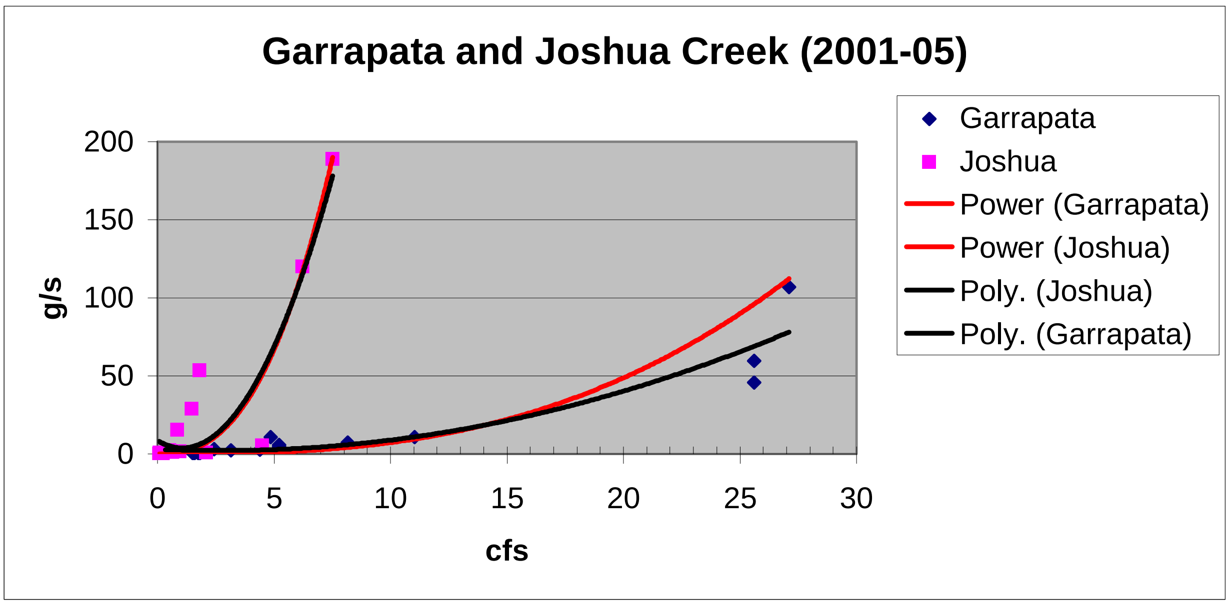

Figure 16: Sediment transport rates (grams per second) at different stream flow rates (cubic feet per second) for Garrapata and Joshua Creeks based upon samples taken between 2001 and 2005.

Another way to illustrate the great difference in sediment loads is to compare the amount of sediment flowing past a given point in each creek (Fig. 17). If Joshua Creek were unimpaired by sediment, its sediment pile (left pile in Fig. 17) would be much smaller than Garrapata's because Joshua Creek was flowing at a much lower rate that day.

Figure17: Bedload material collected on February 19, 2004.
Left pile is 5260 g collected from Joshua Creek.
Right pile is 710 grams collected from Garrapata Creek.
Sampling time for both creeks was 20 minutes.

Joshua Creek has been sediment impaired along its length (where we have had access to observe) in all but a few months during the five years of observation. In general, Garrapata has been relatively clear of excess sand, but sporadic slugs or waves of sediment have been observed at the monitoring point at the mouth of Wildcat Creek, and trapped behind logjams.

The soils of the Garrapata Creek Watershed are generally held in place by the very healthy and dense vegetation along its steep slopes. Because of the generally well-vegetated condition of the watershed, the natural sediment sources in the Garrapata Creek Watershed are mainly the very gradual erosion of the upper watershed and slopes. That natural background sediment inflow is increased on rare occasions by natural shallow landslides (soil slips) that carry wood and sediment to the channel and near-channel areas during intense rains or earthquakes.

The Garrapata Creek Watershed includes steep-sided valleys underlain by highly erodable granitic rock (Fig. 12). Valley walls like these cannot be de-vegetated and further steepened without an attendant substantial increase in erosion rates. Unfortunately, that is precisely the result when roads are cut or enlarged along the valley walls (see Appendix A for further information).

There are numerous examples of old logging roads, other abandoned road systems, and active roads (especially at stream crossings) that are delivering sediment into the creeks at above natural rates (Hagans and Kraemer 2003). Detailed aerial reconnaissance of the watershed revealed that the main sediment sources in the watershed are the roads cut along the southern slope of the Joshua Creek watershed where numerous landslides and sediment aprons are present (Figs. 18 and 19).

Figure 18: Sediment aprons shed from side-casted road cut material in Joshua Creek Watershed. Photo: D. Smith October 31, 2004.

Figure 19: Shallow soil slip and sediment aprons along the roads in Joshua Creek Watershed. Photo: D. Smith October 31, 2004.

The roads in Joshua Creek Watershed exhibit the classic erosion associated with road construction across steep slopes. Bare, unvegetated substrate exposed in scalloped road-cut scarps suggest that erosion is still a chronic problem, years after road construction. The light colored aprons beneath the roads are talus slopes shed from side-cast material and eroded from the cut side of the road. The talus aprons below the road show the path of sediment from the road system to the creek below. During heavy rainfall, the narrow, steep gullies or debris chutes, visible below the roads in the figures, likely route the loose sediment directly to the Joshua Creek channel.

Steep creeks like Garrapata and Joshua are known for their ability to quickly clean themselves of excess sediment during years with high flow events, as long as the sediment sources are not continuous and chronic (Smith et al. 2005, 2006).

In naturally steep, tectonically rising terrain like the Santa Lucia Range, high equilibrium slope angles are naturally maintained through gradual erosion and slope failure. In general, slopes in such regions are almost always near the threshold of failure. Grading for roads and building sites on steep slopes will locally increase the slope angle at the road cut and side cast material below the road (Fig. 19). Slopes that have been increased beyond the equilibrium angle will commonly be sites of chronic erosion and excess sediment in creeks long after the road is cut. For this reason, the roads of Joshua Creek will probably impact the creek environment in the foreseeable future.

The solution to excess sediment in Joshua Creek and elsewhere in the Garrapata Creek Watershed is to very carefully plan future roads, re-slope and decommission abandoned roads, and implement state-of-the-art drainage and erosion control measures on existing roads, including improved stream crossings.

Upslope Road Assessment

Road systems are now widely recognized throughout the Central Coast region as one of the most significant and easily controlled sources of accelerated erosion resulting in sediment delivery into the stream channel systems. Reducing accelerated erosion and sediment delivery to stream channel systems is a vital step toward long-term restoration of steelhead habitat and the eventual recovery of steelhead populations. Once human-caused erosion is reduced, future storm runoff can cleanse the streams of accumulated fine sediment rather than depositing more sediment.

A road assessment conducted in the Garrapata Creek Watershed during 2001- 2003 documents upslope erosion and provides a prioritized plan of action for erosion control and erosion prevention treatments. Such treatments, implemented in combination with better land management and road maintenance practices, can significantly help protect steelhead, restore our watershed and lower maintenance costs for landowners.

This report focused on erosion control because erosion prevention and "storm-proofing" of rural road systems can have an immediate benefit to the streams and aquatic habitat of the basin.

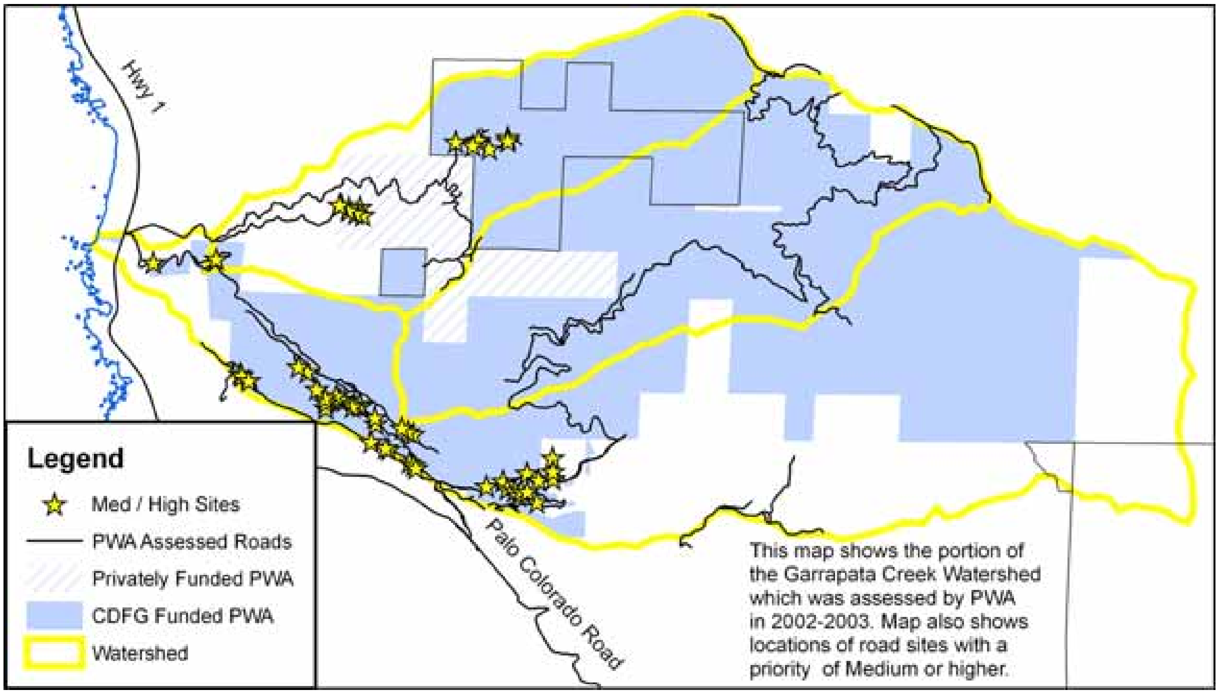

Figure 20: Area of watershed covered by PWA assessment.

The road assessment identified recognizable current and future sediment sources from roads within the watershed. The entire watershed was analyzed using historical air photos. Fieldwork was then conducted on parcels that had the written approval of the landowners (Fig. 20). The area covered amounted to approximately 70% of the total watershed and identified treatable current and future sediment sources from maintained, intentionally decommissioned, and abandoned roads within the watershed. (An additional 6% of the watershed area was funded privately, the results of which are not included in this plan.)

All roads within the study area were identified and dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. A total of 31.7 miles of road were built in the 50-year period covered by the air photo analysis, for a road density of approximately 3 miles of road per square mile of watershed area. Field inventories were subsequently conducted on the road systems identified during the air photo analysis. The result was an inventory of sediment sources where there is a potential for future sediment delivery to fish bearing portions of the stream. Sites were then identified as high, moderate and low treatment priority. The fieldwork identified future sediment sources from 137 sites, of which 87 sites were recommended for treatment on approximately 22 miles of roads in the watershed.

Erosion sites include locations where there is direct evidence that future erosion or mass wasting (landslides) could be expected to deliver sediment to a stream channel. Sites of past or future erosion were not inventoried unless there was a potential for additional future sediment delivery exceeding 10 yd^3 (enough to fill a large dump truck).

It was concluded that "Overall, sedimentation due to improper road grading and past logging practices was identified as the primary factor limiting steelhead production in the Garrapata

Creek drainage by filling pools and cementing spawning gravels" (Weaver 1990). Virtually all future road-related erosion and sediment delivery in the Garrapata Creek Watershed is expected to come from one of three sources:

1. The failure of landing and road fills[5] (through landsliding),
2. Erosion at or associated with stream crossings, and
3. Road surface and ditch erosion.

During the assessment, PWA identified high-yield roads and road segments. The report recommended specific treatments for these sites including "storm-proofing" (upgrading) or permanently decommissioning (closing) roads that are no longer needed. Seventy percent of the sites were recommended for "storm proofing" or upgrading, 16% of all the inventoried sites were recommended for decommissioning, and 14% of the sites were identified but not recommended for immediate treatment.

Prior Restoration Efforts in the Watershed

In addition to looking at roads that they had not previously studied, PWA returned to look at roads on the Little Horse Ranch (Figs. 21, 39, 40), part of the Palo Corona Ranch now owned by CDFG. A previous owner illegally constructed these roads in 1990 without the required county and state permits. The California Coastal Commission directed that all roads be retired.

As part of the settlement of this case, PWA developed and implemented a site-specific erosion control plan in 1991 to treat 7.7 miles of road impacted by the illegal road construction. The most effective treatment available for the bulk of the most severe areas was the direct removal of remaining unstable and potentially erodable soil material using mechanized earth moving equipment. In 2001-2002, PWA re-inventoried the decommissioned Little Horse Ranch road to learn more about the effectiveness of these treatments.

A total of 33 stream crossings from the 1991 project were re-evaluated 10 years after the recommended decommissioning treatments had been implemented. PWA estimated only 164 cubic yards of future erosion and sediment delivery is likely to occur at the 33 treated stream crossings. The sediment savings for removal of unstable fill over 7.7 miles of road was originally estimated at 18,665 cubic yards.

Based on their fieldwork in 2001-2002, PWA did not recommend including any sites on the Palo Corona Ranch including the former Little Horse Ranch for the road-upgrading project. Not only did none of the sites deliver sufficient sediment to warrant treatment but also access to any sites on the road decommissioned over 15 years ago would have required extensive new grading.

It may take many decades to completely assess the overall benefits of the 1990 decommissioning project. However, subjectively, an immediate benefit is apparent from field

[5] Road fill is the portion of the road made of material that was cut from the hill and placed on the outer portion of the road. Landing fill is similarly dirt that was moved to make an area to receive logs from above.

observations by PWA in 2001-2002 (see Appendix C) and by ecologist Nikki Nedeff in 2005 (see Appendix H). PWA noted that most of expected future erosion was stabilized by 1991 road decommissioning project; Nikki Nedeff's observed that the old road surfaces were largely revegetated and not producing large amounts of erosion. Additionally, lessons learned from 1990 project will substantially inform and improve future erosion control efforts in our area. (See Appendix C for further details.)

Figure 21: Portion of Little Horse Ranch road decommissioned in 1991 is seen near top of ridge. Photo: N. Nedeff, 2006

Biological Resources

Because of its limited development, the Garrapata Creek Watershed continues to support much of its native flora and fauna. In particular, the watershed is home to several rare species including, most notably for the purposes of this restoration plan, the federally listed steelhead trout. The following lists the special status species and habitats of special interest that exist in the watershed:

1. South/Central California Coast Steelhead Ecologically Significant Unit (*Oncorhynchus mykiss*): Federally Threatened. Confirmed in Garrapata Creek and Joshua Creek, and likely found in lower Wildcat Canyon.

2. Smith's blue butterfly (*Euphilotes enoptes smithi*): Federally Endangered. Requires host plant seacliff buckwheat (*Eriogonum parvifolium*), which is found in all coastal habitats near the Highway 1 corridor along Garrapata State Beach.

3. California red-legged frog (*Rana aurora draytonii*): Federally Threatened. The presence of the California red-legged frog has been confirmed along lower Garrapata Creek by Ken Ekelund, who observed an adult in February 2003 (Ekelund 2004). The frog was resting in standing water along the roadway fronting Garrapata Creek in the Glen Deven Ranch. The puddle originated as runoff from a spring on the southern side of the road upstream of the vehicular creek crossing. Although foothill yellow-legged frog (*Rana boylii*) has not been documented in the watershed, this species could be found in the upper reaches of Garrapata, Wildcat and Joshua Creeks. Foothill yellow-legged frog occurs in association with higher gradient, shady streamside habitats that are found in the upper watershed.

4. Central Maritime Chaparral and community indicators like Little Sur manzanita (*Arctostaphylos edmundsii* forma *edmindsii*): This highly restricted habitat occurs on the coastal bluffs near the mouth of Garrapata Canyon along the entry to the Garrapata Trout Farm.

Steelhead

Life Cycle

The Garrapata Creek Watershed supports a population of steelhead (*Oncorhynchus mykiss*) that is part of the California South Central Coast Evolutionary Significant Unit (ESU). Steelhead are anadromous fish that spawn and rear in fresh water streams and migrate to the ocean to grow to adult size (Fig. 22). They migrate to the ocean as juveniles where they spend one to four years. In the ocean, where food resources are abundant, steelhead can grow substantially, reaching nearly three feet in length. Adult steelhead usually return to their natal stream to spawn. Migration timing is based on winter storms, which bring the largest stream flows of the year. Steelhead are strong swimmers

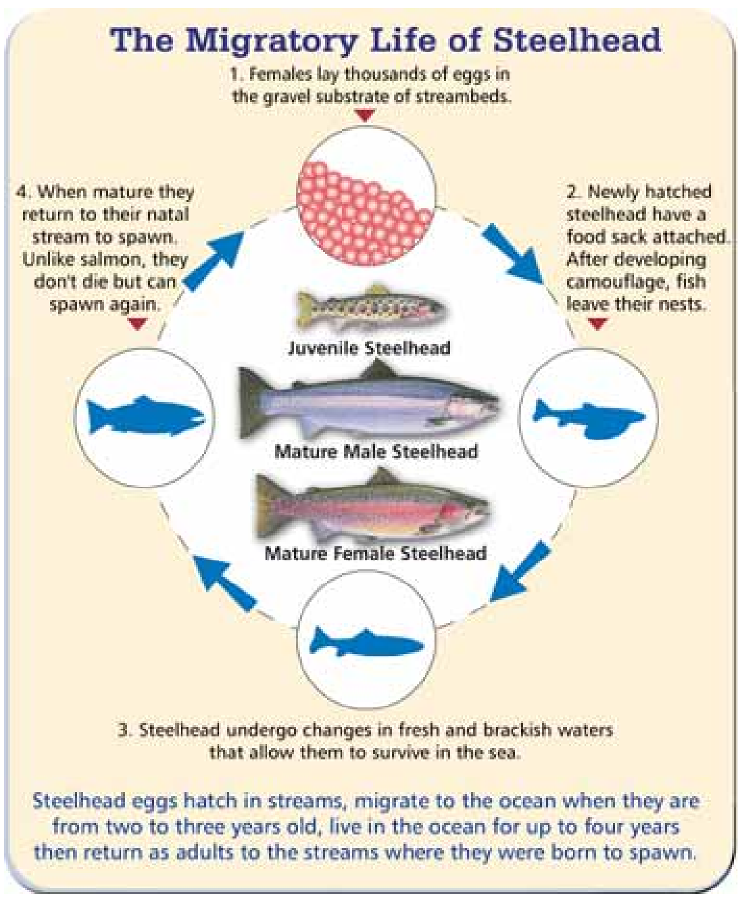

Figure 22: Steelhead lifecycle.

Figure 23: Recently emerged fry in creek margin on 14 May 2006
Photo: Ken Ekelund, 2006

and incredible jumpers – up to 10 feet – as they move upstream. Unlike other salmonids such as salmon, steelhead often do not die after spawning and may return to spawn in subsequent years.

During spawning, the adults swim upstream and look for abundant gravel in transition areas between pool and riffle habitats, called the pool tail. The female adult creates a depression in the gravel (called a "redd") using her tail, where she then deposits her eggs. Male adult steelhead, swim over the redd and quickly fertilizes the eggs. The female will then use her tail to immediately cover the eggs with gravel. The young, known as alevins, hatch in the gravel where they remain for several weeks. After absorbing their yolk sac, the alevins make their way through the gravel and sand to the surface and immediately find slower habitats near the stream's margin. These young steelhead – termed "fry" – are less than an inch in length (Fig. 23). Depending on watershed conditions, they can grow up to 3-4 inches in the first year. These juvenile fish may remain in the stream for up to two years before migrating downstream and to the ocean.

In the lagoon, juvenile steelhead can grow substantially as long as water quality and macroinvertebrate populations remain adequate. Here they swim in a mixed fresh and salt-water environment where they become acclimated to salt-water. During this period of rapid growth and salt acclimation, the juvenile steelhead often undergo smoltification, or the physiological transition to life in the ocean; smoltification can also occur in the stream habitats as well. After this transition period they are called smolts. When the first rains arrive and the stream flow increases enough to open the lagoon's sand bar, many smolts enter the ocean and remain there until they return as adults one to four years later.

Steelhead populations are in decline throughout much of their range – especially in their southern range in California. Anecdotal accounts from long-time residents of the watershed suggest that the population of steelhead was once considerably larger than it is at present. Concrete historic data are lacking, however both recent and historic land use practices (e.g., poor road construction and clear cut logging) have led to adverse conditions that are known to decrease steelhead populations on a watershed scale.

Current Status of Steelhead Populations

An assessment of steelhead trout (*Oncorhynchus mykiss)* was conducted to determine the distribution and relative abundance in lower Garrapata Creek. Three 100-meter stations, or sites, were sampled (Fig. 24), which were selected based on dominant riparian vegetation type (e.g. hardwood, mixed, and redwood), accessibility and how well the site represented the overall reach. At each site, stream habitat types were inventoried, a steelhead population estimate was obtained, and flow measurements were recorded at the upper and lower two sites.

Stream habitat conditions were assessed and inventoried at each of the three sites according to the methodology described in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). A Level Four classification of all distinct habitat units was used. At this level riffles are separated on the basis of water surface gradient; flatwater habitat is differentiated on the basis of depth and velocity; and pools are categorized based on either their location in the channel or the method of scour (i.e., boulder, bedrock, root wad, log, etc.) Once a unit is classified, mean width, length, and maximum depth are measured. Other parameters measured include instream shelter complexity and percentage of unit cover; primary and secondary substrate components; percent exposed substrate; percent total canopy and the percentage of canopy that is provided by deciduous and coniferous vegetation; dominate substrate on the right and left banks and the percent of the banks with vegetation coverage; depth and substrate embeddedness at the pool tail crest and comments regarding adjacent land use activities, eroded banks, barriers or impediments and diversions. The data were compiled and summarized utilizing the program habitat 8. (See Appendix D for a complete list of habitat measurements). Stream flow discharge was measured at sampling Sites 1 and 3.

Once appropriate locations within each reach were identified for sampling, a distance of approximately 100 meters was measured for sampling. Block seins were placed at the lower and upper ends of the unit to prevent egress for the sampling area and fish were sampled with a backpack electroshocker. Multiple passes (usually 2 passes) were made to ensure that all fish within the site were collected. In between passes, all fish were held in flow-through live cars to maximize water quality conditions and limit stress to the fish. At the end of each pass steelhead were measured for fork length and total length, and then weighed for “condition factor” (see Appendix D for discussion on condition factor). Other fish species captured included coast-range sculpin (*Cottus aleuticus*), and prickly sculpin (*Cottus asper*). These were identified and counted but not measured or weighed. All fish were re-distributed back into the sampling station once sampling was completed.

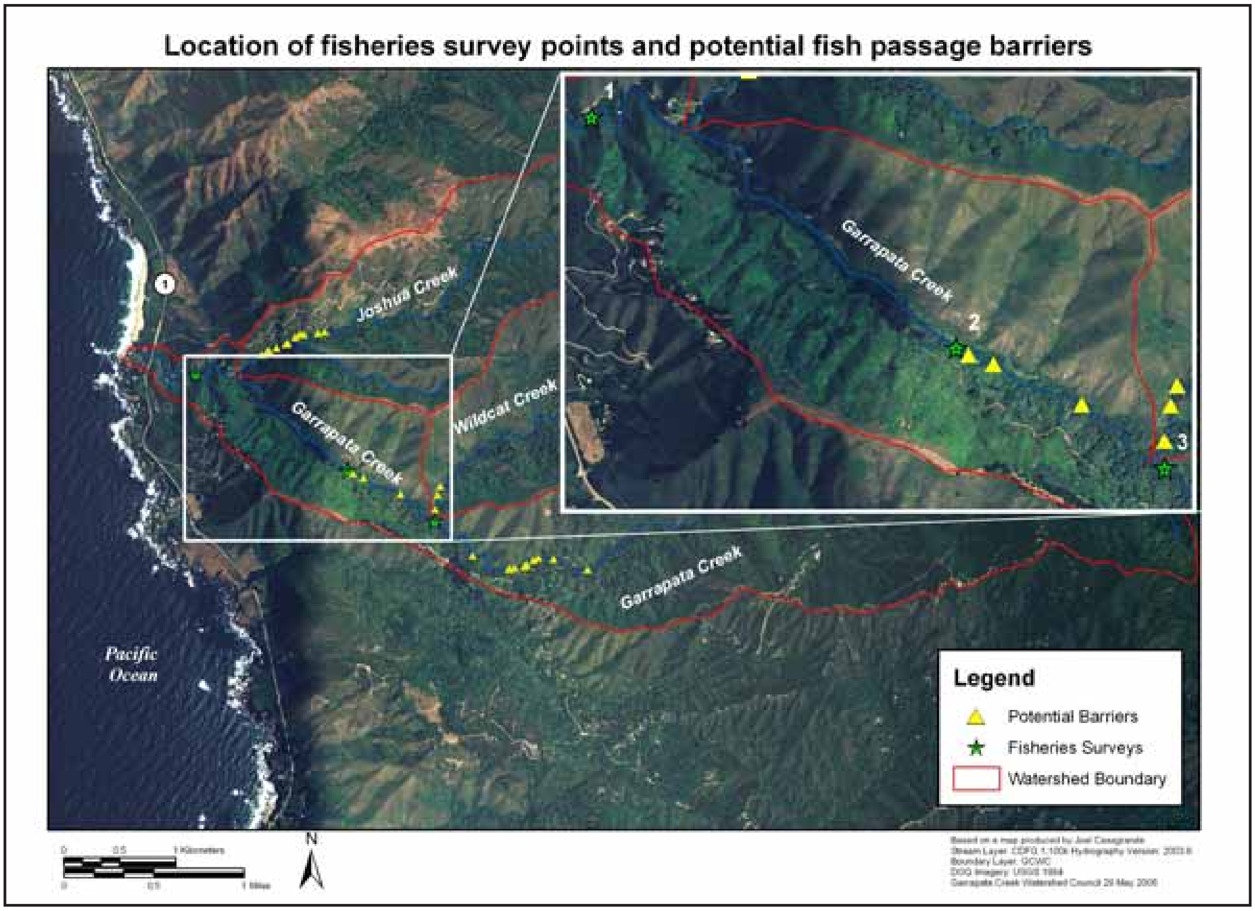

Figure 24: Garrapata Creek, barriers and Oct 2005 steelhead sampling locations. Map: K. Ekelund 2006

The location and results of the sampling are as follows**:**

- Site 1: Sites 1 was located approximately 0.92 miles upstream of the ocean in a low gradient section of stream (Fig. 25). The sampling site was 341 feet in length and included four mid-channel pools (35% of the total habitat), four low gradient riffles (33%), four runs (29%), and one high gradient riffle (2%). Stream vegetative canopy cover averaged 87% as willow and alder. Stream flow was 1.4 cfs and air and water temperatures were 59°F and 54°F respectively. No spawning substrate (e.g., gravel or small cobble) was located within the sampling area.

  At Site 1, total of 64 steelhead were captured. Age classes were defined by the following size classes: < 90 mm (3.6 in) fork length were considered to be young-of-the-year or age 0+, 91 to 165 mm (3.6-6.5 in) were age 1+, 166 to 250 mm (6.5 –9.8 in) were age 2+ (Fig. 26), and fish up to 350 mm (13.8 in) were the 3+ category. A majority of the fish at this site were either 0+ or 1+ fish (88%) however the frequency of larger fish was greater compared with other sites.

- Site 2: Site 2 was located approximately 2 miles upstream from the ocean in a moderate gradient reach (Fig. 27). This site was 310 feet in length and included two runs (50% of the length), two mid-channel pools (21%), two glides (19%), and one riffle (10%). Riparian

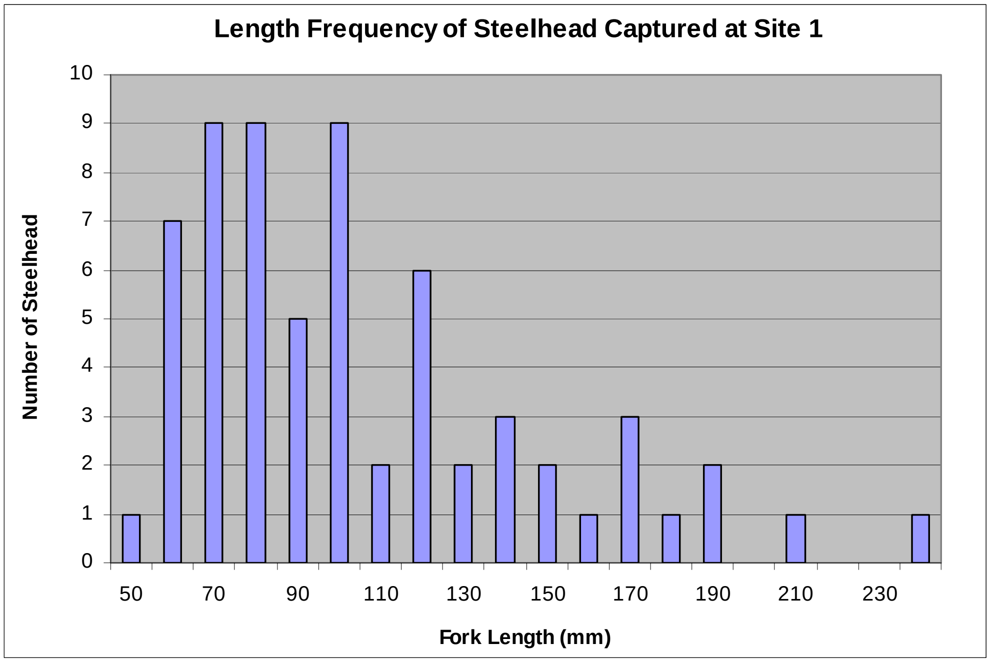

Figure 25: Fork length frequency of steelhead captured at Site 1 on Garrapata Creek on October 2005. Graph: CDFG

canopy cover averaged 66% and was dominated (70%) by hardwoods (alder, big leaf maple, and bay laurel) with 30% as conifers (redwood). Air and water temperatures at the time of the survey ranged from 64° to 68°F and 52° to 54°F, respectively. No suitable spawning areas were noted in Station 2.

At Site 2, a total of 42 steelhead were captured. Seventeen (40%) of the steelhead captured were considered age 0+, 21 (50%) were considered age 1+, and 4 (10%) steelhead were age 2+ (Fig. 27).

Figure 26: One of the larger juvenile steelhead surveyed measured 7.5 inches (~190 mm). Photo: Courtesy of CDFG (2005).

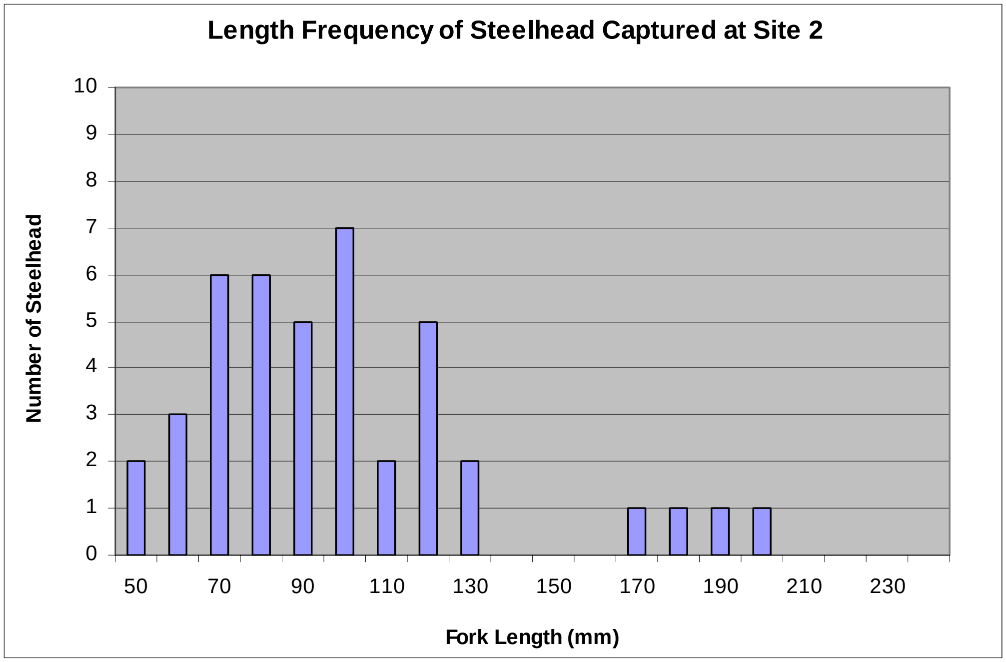

Figure 27: Length frequency distribution of steelhead captured at Site 2 on Garrapata Creek, October 2005. Graph: CDFG

- Site 3: Site 3 was located approximately 215 feet upstream of the confluence with Wildcat Creek, which enters Garrapata Creek approximately 2.7 miles upstream from the ocean. This site had a moderate stream gradient and was 305 feet in length. It included two runs (53% of the habitat) one high and three low gradient riffles (24%), two mid-channel pools (15%), and one step-pool (8%). Canopy cover averaged 84% and consisted of 80% conifers (redwood) and 20% hardwood (tanoak and big leaf maple). Air and water temperatures were 59°F and 52°F, respectively and stream flow discharge was 0.76 cfs. No suitable spawning areas were observed, and of the three sites, Site 3 had the greatest volume of fine sediments deposited within pools.

  At Site 3, a total of 36 steelhead were captured. Twenty-five (69%) were age 0+ with an average fork length of 68 mm (2.7 in), 9 (25%) were age 1+ with an average fork length of 111 mm (4.4 in), and 2 (6%) steelhead were age 2+ with a mean fork length of 182 mm (7.2 in) (Fig. 28).

Historically, very little quantitative population data has been collected for steelhead streams along the Central Coast. However, in 1990 sampling was conducted by CDFG at three locations within the anadromous reach of Garrapata Creek and one location on Wildcat Creek. It is unknown what type of habitat was sampled in 1990, but at that time densities of steelhead in the lower, middle and upper locations were 26, 1, and 13 trout per 150 feet, respectively. Corresponding mean fork lengths at each location were 107.2 mm (4.25 in), 163 mm 6.45 in), and 79.7 mm (3.2 in) (CDFG 1990).

Comparing current densities to the 1990 data, Site 2 had the most dramatic increase in steelhead density from 0.007 fish/ foot of stream in 1990 to 0.13 fish/foot in 2005. Densities at the lower site were almost the same with 0.17 fish/foot (1990) to 0.19 fish/foot (2005) and densities at the upper site also increased from 0.09 fish/foot to 0.12 fish/foot.

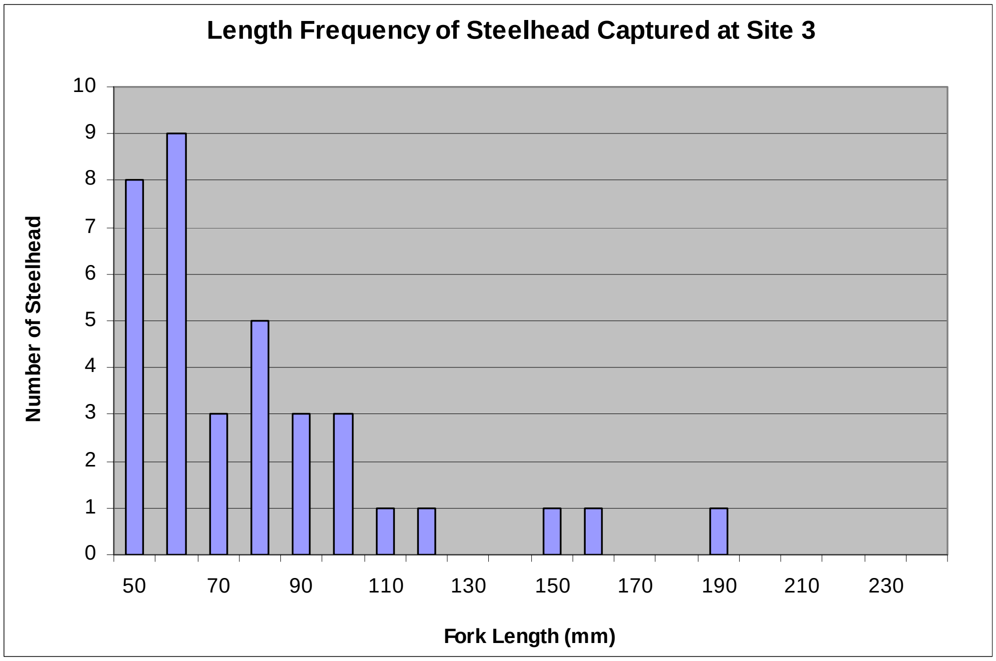

Figure 28: Length frequency distribution of steelhead captured at Site 3 on Garrapata Creek, October 2005. Graph: CDFG

Although habitat-typing data was not collected in 1990, their report did state that perennial flow was present and that excessive sedimentation was limiting spawning and rearing potential in the stream. Because the 1990 survey was conducted in the middle of a prolonged drought and because it is unknown what type of habitat was sampled, the 1990 data may not serve as the best “base line” to judge the current population.

Barrier Assessment

One of the primary objectives of the GCWC is to enhance anadromous steelhead trout (*Oncorhynchus mykiss*) populations and their distribution throughout the Garrapata Creek Watershed. Steelhead populations in the watershed are being adversely impacted by stream channel sedimentation (Smith et al. 2005) and limited access to spawning grounds due to passage barriers (log and debris jams) throughout the lower watershed (Titus et al. 2001).

The Watershed Institute was tasked by the GCWC to conduct an assessment of potential migration barriers to steelhead in the watershed, prioritize them for possible migration enhancement or removal, and make recommendations on how to improve passage at each migration impediment (Fig. 24). In addition, the location and size of near-channel sediment sources as well as general in-stream habitat conditions were noted.

Barriers to steelhead migration can be natural or man-made. Natural barriers include tall waterfalls or cascades, landslide debris piles, and occasionally logjams formed from naturally accrued large woody debris. In general, large woody debris is a critical component to riparian ecosystems because of its ability to create complex habitat features (such as pools, backwater areas, and undercut banks), diversify stream flow velocities, trap coarse sediments that are beneficial for spawning, and provide refuge habitat for other aquatic vertebrates such as the California red-legged frog (*Rana draytonii*) (Bisson et al. 1987; Naiman et al. 2002; Montgomery et al. 2003). However, in many watersheds, including the Garrapata Creek Watershed, excess wood from past logging and road construction activities can become trapped in narrow, confined sections of the creek, creating massive logjams. Larger and more durable tree species, such as coast redwood and other conifers, are not transported downstream as efficiently as the lighter and more brittle deciduous trees. Accumulations of large conifer logs typically form the most severe logjams.

Excess sediment from both road construction and natural processes accumulates behind the logs and other debris forming large "walls," or "debris jams." Sediment also fills in pools at the downstream side of the logjams. This can be problematic for the following reasons:

1) The removal or enhancement of debris jams could result in the release of a large volume of stored sediment to downstream spawning habitat, and in the Garrapata Creek Watershed the downstream and accessible stream sections are already stressed by excess sediments.

2) Many of the large debris jams have been in place for a long time and have since become significant grade control structures in the channels. Their removal or enhancement could jeopardize the stability of the surrounding canyon walls, putting roads, water systems and possibly some adjacent homes in danger.

3) Adult steelhead have the natural ability to leap over some impediments of heights up to 10 ft depending on a number of factors, most importantly the depth of the pool they launch from (Powers and Orsborn 1985). Deep pools provide the fish room to gain momentum they need to burst upward – the more room in the pool, the higher they jump and the better chance for a successful passage over the structure. If sediment has filled in such pools, relatively short impediments become increasingly difficult to successfully navigate over.

As mentioned above, not all accumulations of large woody debris are impassable to up-migrating adult steelhead, especially in wider sections of stream. In fact, passable accumulations of large woody debris are usually beneficial to steelhead because they produce pools and backwater areas used as refuge for both up-migrating adults as well as over-wintering juveniles trying to escape the harsh winter flows. Also, depending on the substrate size and origin, stream flows are sometimes able to scour under woody debris piles, creating a passage route for fish (Smith and Harden 2003).

In the summer of 2004, structures (i.e., logjams, debris jams, and natural waterfalls), in-stream habitat conditions and near-channel sediment sources were located and assessed by walking up the channel from the watershed's terminus at the Garrapata Lagoon.

Structures were assessed according to the following criteria:

- Size of structure (height – vertical; width – across channel; and length – upstream distance of accumulated debris),
- Presence and depth of leaping pool (Is there a pool located immediately downstream of log jam and if so how deep?),

- Number of possible migration routes (i.e., left bank, center, right bank, underneath, overtop),
- General substrate particle size beneath and downstream of the structure (i.e., sand, gravel, cobble, boulder, bedrock),
- Material characteristics (quantity, quality, and species of tree), and
- Estimated volume of stored sediment behind each logjam.

Structures were prioritized for restoration, or enhancement, as High, Medium, or Low based on the following criteria (excluding natural waterfalls):

- Structures that were downstream of large impassable logjams were given higher priority,
- Structures that would provide significant increases in upstream habitat were given higher priority over structures with limited or no upstream available habitat,
- Structures that were easily accessible and/or inexpensive to improve were given higher priority over inaccessible, larger, and therefore more costly barriers,
- Structures that were partial barriers and that would likely become barriers with the addition of more material were given higher priority over more easily passable structures or those that were complete barriers, and finally
- Structures with minimal fine sediment accumulations were given a higher priority over structures with high volumes of stored fine sediments.

For near-channel sediment sources, locations and characteristics for each occurrence were noted. We defined near-channel sediment sources as areas of exposed sediment (i.e., non-vegetated) within the active flood-prone channel width. Examples include landslides, exposed banks caused by lateral erosion, and exposed banks due to active vegetation removal. Where possible, estimates of the exposed or available sediment volume were made.

In Garrapata Creek, barriers to steelhead migration were assessed in the lower 5.9 km (3.6 mi), from the ocean to Garrapatos Road. Log and debris jams were assessed in Joshua Creek from its confluence with Garrapata Creek up to the natural migration limit – a natural waterfall > 12 m (40 ft) in height; and in Wildcat Creek we assessed all structures up to the natural limit to salmonid migration – a natural cascade/waterfall structure approximately 7-8 m (25-30 ft) in height located 0.3 km (0.2 mi) upstream from its confluence with Garrapata Creek.

Within the main stem of Garrapata Creek a total of 14 structures were observed and recorded as potential barriers to upstream migration. These structures consisted of log/debris jams and waterfalls. Some were passable depending on the flow levels in the creek. A significant logjam located approximately 4.5 km (2.8 mi) upstream from Garrapata Lagoon is the likely limit to anadromous steelhead in Garrapata Creek (Fig. 29). This logjam is followed by a series of three waterfalls and several larger impassable logjams less than 1 km (0.6 mi) upstream (Fig. 30).

Figure 29. This debris jam (gb04) is likely the limit to anadromous fish in Garrapata Creek. This is the backside of the debris pile looking downstream. Photo: J. Casagrande 11 August 2004. See Casagrande and Smith, 2005 for naming of each logjam.

Figure 30. This logjam (gb08) at approximately 3 meters tall is a significant barrier to migration on Garrapata Creek. Photo: J. Casagrande 11 August 2004.

In Joshua Creek, a total of 1.05 km (0.65 mi) of stream exists below a natural barrier (a 40+ ft waterfall). Several large log/debris jam structures were observed, most of which are impassable to steelhead (Fig. 31). These structures have significantly reduced access to spawning habitat in this sub-watershed.

In Wildcat Creek, a natural barrier exists approximately 0.32 km (0.20 mi) upstream from the Garrapata Creek confluence. Two logjams were observed in the channel and both structures are likely passable during higher flows. Fine sediment accumulation in the channel bed was present, however at lower quantities than Joshua and parts of Garrapata Creek. Spawning habitat was moderately suitable at best. Overall, in-channel conditions such as substrate size and habitat complexity (i.e., undercut banks and occurrence of deeper complex pools) were of higher quality.

Figure 31. This is large logjam on Joshua Creek (jb08) is a complete barrier to steelhead. Photo: J. Casagrande 3 June 2004.

In Garrapata and Joshua Creeks, sediment accumulation behind logjams was significant. Many of these logjams are now large grade control structures that form large steps in the channel. Although only surface sediments were observed, the accumulated material likely consists of a mixture of coarse and fine sediments. Downstream pools (those at the base of the debris jams) also had accumulations of fine sediments, some more extensive than others. The reduced downstream pool volume severely limits the ability of up-migrating adult steelhead to leap over the structures.

In the lower Garrapata Creek Watershed, no significant near-channel sediment sources were observed, although a few smaller sources were observed in both Garrapata and Joshua Creeks. These were caused by small landslides and exposed banks due to vegetation removal. Sedimentation of the stream channels in the lower watershed is the result of upstream sources. (For more details, please see Appendix E)

Lagoon Assessment

For many coastal watersheds, lagoons serve as important rearing habitat for juvenile steelhead prior to entering the ocean (Shapovalov and Taft 1954; Smith 1990; Martin 1996; Cannata 1998). With suitable water quality and habitat conditions, juvenile steelhead rearing in lagoon or estuarine habitats can grow substantially and therefore increase their chances for survival in the ocean (Holtby et al. 1990; Smith 1990). Suitable habitat conditions include cool to mild water temperatures, fresh to mildly brackish water, the presence of emergent vegetation, adequate depths to reduce avian predation, and most importantly, a robust macroinvertebrate community.

While coastal lagoons are common at the mouths of creeks of the Big Sur Coast, it is currently unknown what role Garrapata Lagoon plays in the life cycle of steelhead. To better understand this, and because few studies have been conducted on Central Coast lagoons, the Watershed Institute conducted an assessment of Garrapata Lagoon in the summer and fall of 2005. The primary objectives of this study were to document general habitat characteristics present in the lagoon, including seasonal changes in water quality conditions and macroinvertebrate communities, as well as attempt to document the use of the lagoon by juvenile steelhead.

The mouth of Garrapata Creek is a dynamic environment where energy of the stream is balanced by the energy of the ocean waves (Figs. 32 and 33). The two forces tend to push sand in different directions. Usually by the middle of summer, when the ocean’s energy and stream flow intensity have declined, sand replenishment along the beach is sufficient enough to form a partial sandbar across the mouth of Garrapata Creek. The result is a “coastal lagoon.”

Water quality conditions were monitored at six different sites, five in the lagoon area and one on lower Garrapata Creek. Monitoring occurred on eleven occasions between June 23rd and November 30th, 2005. Surface-to-depth profiles were collected for the following parameters: water temperature, dissolved oxygen concentration, and salinity (salt concentration) (Figs. 35-38). A secchi disk was used to determine clarity of the water (secchi depth).

The lagoon formed in mid to late July creating a small embayment approximately 0.25 acres in size. Stream flow entering the lagoon was perennial, which maintained a freshwater lens throughout the summer and fall and a partially opened sandbar. The water column in the lagoon remained brackish throughout the study period due to mixing of incoming stream flow and saltwater entering the lagoon. However, salt concentrations in the lagoon gradually increased during high wave events in October and November, but never reached oceanic concentrations due to the perennial supply of fresh water.

Density stratification of the water column, which is caused by the density differences between heavier saltwater and lighter freshwater, persisted throughout the year, especially in late summer and early fall. When a lagoon stratifies, it limits mixing of the water column. The bottom waters are unable to rise and cool during the evening and therefore retain their heat, causing the water column to become thermally stratified as well. Warmer temperatures increase decomposition rates of kelp and other organic debris; and as a result of the decomposition, dissolved oxygen concentrations are reduced, especially at the bottom of the lagoon.

In Garrapata Lagoon, thermal stratification was observed only in late August during a period of low wave energy and mild climate. At this time dissolved oxygen concentrations reached anoxic levels (i.e., no dissolved oxygen) on the bottom of the deeper portions of the lagoon. This was exacerbated by the decomposition of significant amounts of kelp that washed into the lagoon area in early summer prior to the formation of the lagoon embayment. Kelp continued to wash into the lagoon from wave overwash during high tide and wave events, especially in mid to late fall (Fig. 34).

Figure 32. Garrapata Creek Lagoon looking downstream.
The ocean is just out of view in the upper left corner. Photo: J. Casagrande 04 Aug 2005

Figure 33. Ocean waves frequently entered Garrapata Lagoon especially in fall. Photo: J. Casagrande 30 Nov 2005.

Figure 34. Large amounts of kelp enter the lagoon during wave events where it will then decompose and take up dissolved oxygen from the water leaving anoxic waters in place. Photo: J. Casagrande 12 Oct 2005.

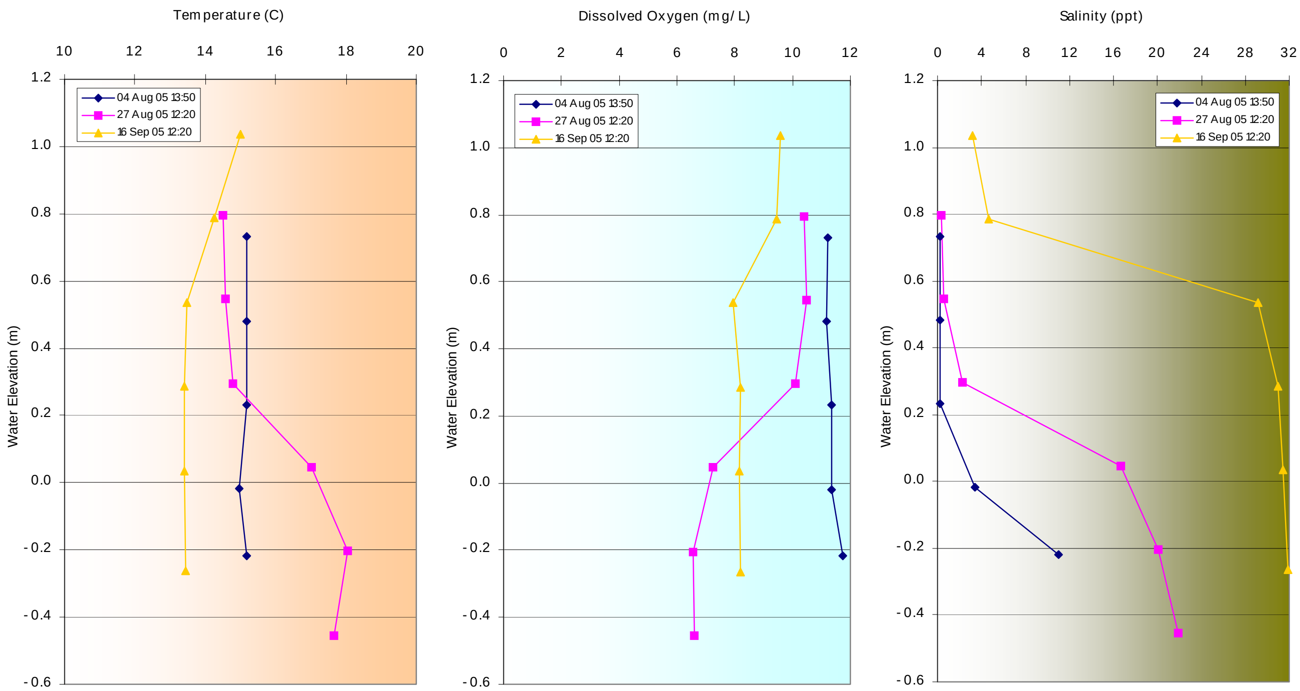

Figure 35. Summer water quality surface to depth profiles (temperature, dissolved oxygen, and salinity) from Site 3 in the Garrapata Lagoon.

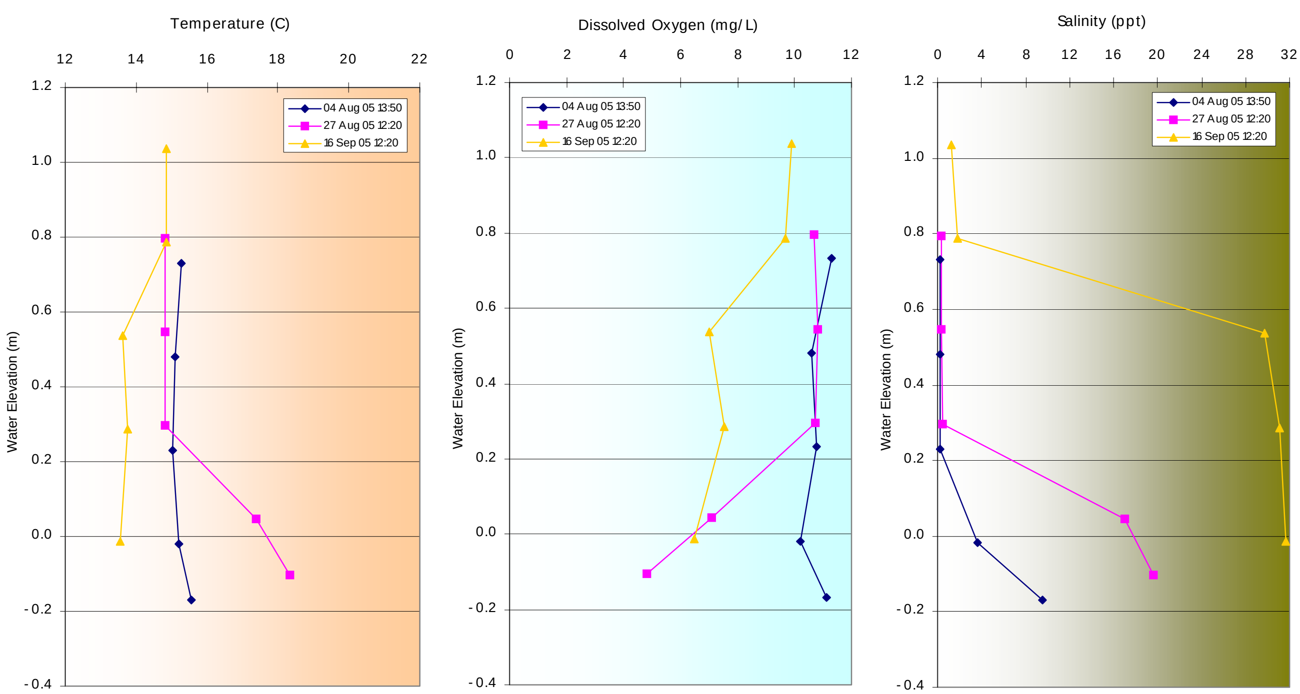

Figure 36. Summer water quality surface to depth profiles (temperature, dissolved oxygen, and salinity) from Site 4 in the Garrapata Lagoon.

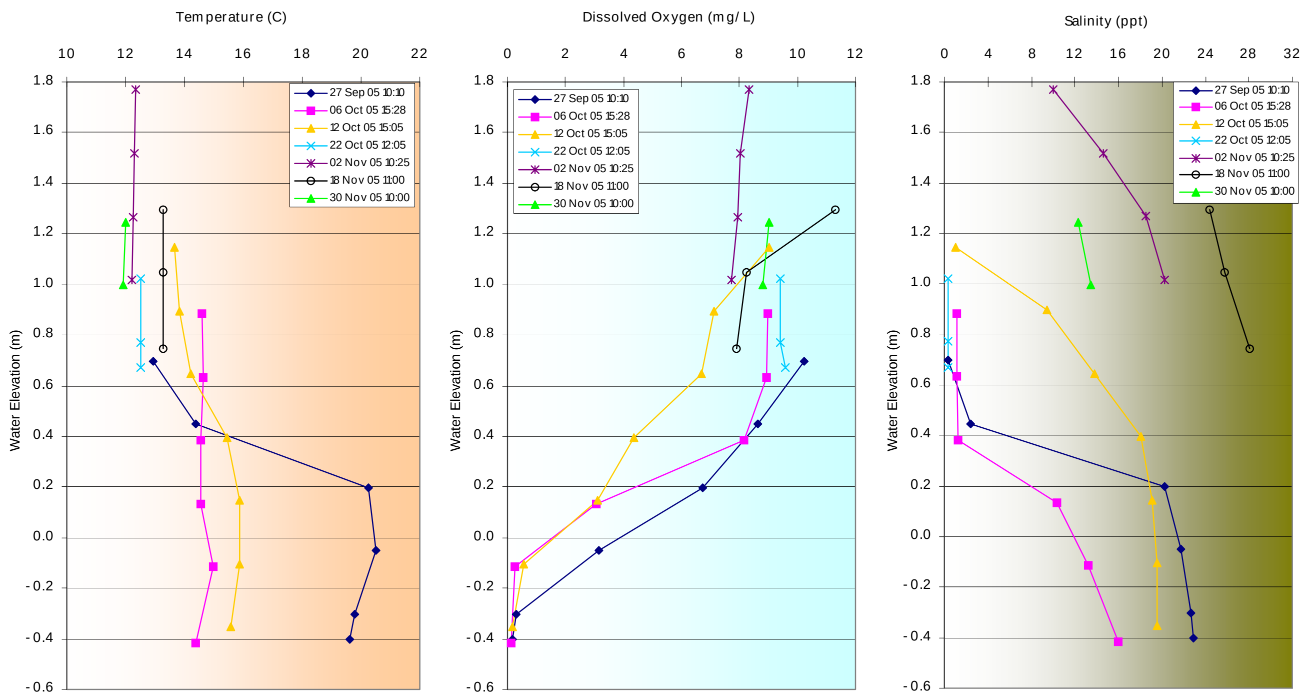

Figure 37. Fall water quality surface to depth profiles (temperature, dissolved oxygen, and salinity) from Site 3 in the Garrapata Lagoon.

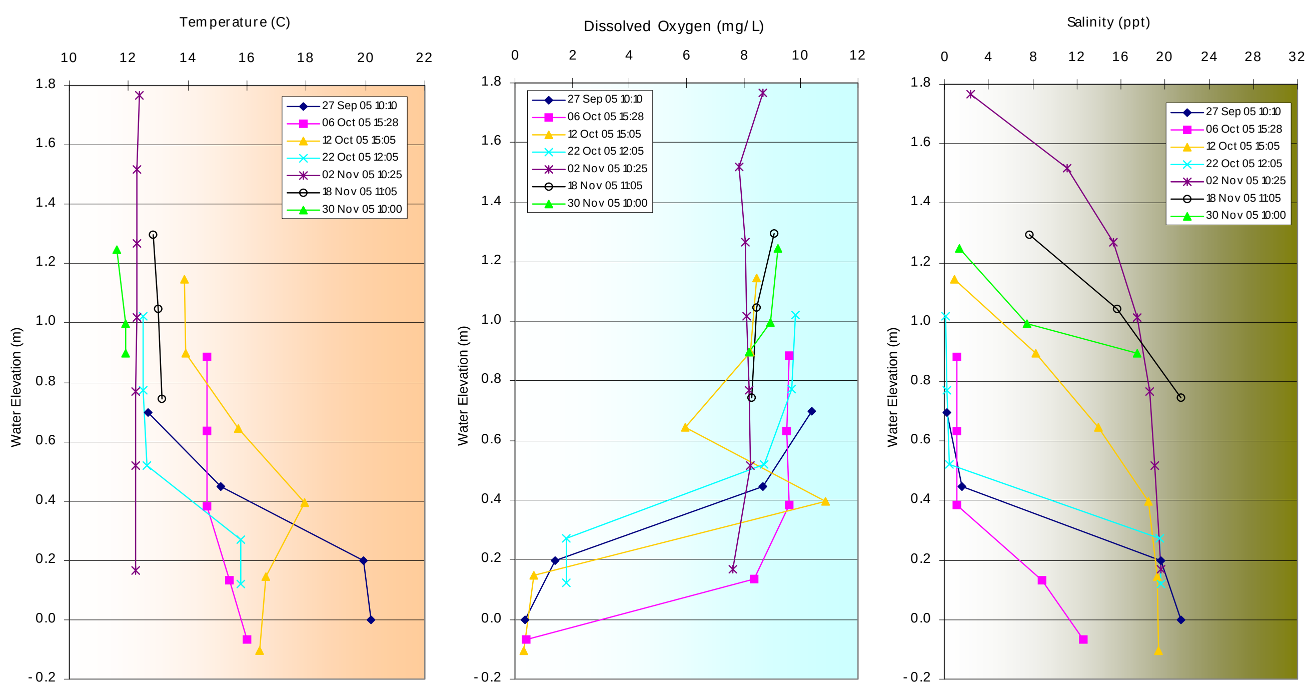

Figure 38. Fall water quality surface to depth profiles (temperature, dissolved oxygen, and salinity) from Site 4 in Garrapata Lagoon.

Water temperatures remained cool throughout the study period. Warmer temperatures (nearly 20ºC) occurred on the bottom of the lagoon, but only when the lagoon was stratified in late August. As density stratification became less dominant, bottom temperatures decreased. This also coincided with slightly cooler inflow from Garrapata Creek and increased wave overwash (i.e., cooler ocean water) in mid to late fall.

Macroinvertebrates are organisms that have no backbone, are large enough to be seen without a microscope, and that tend to live in or at the bottom of a body of water. Many macroinvertebrates are insect larvae, such as mayflies and black flies. Macroinvertebrates serve as an important food source for steelhead.

Water column and epibenthic (living on the surface of the lagoon bottom) macroinvertebrates were sampled on four occasions from early August to late November in Garrapata Lagoon. On all sampling dates, at least two sites, including the deepest, were assessed for presence and relative abundance of macroinvertebrate taxa. A net was used to spot check the lagoon by sweeping through the water column several times per site and dragging lightly along the substrate of the lagoon at each site.

Only four taxa were collected in the lagoon and creek inflow: two *Diptera taxa,* fly and midge larvae *(Tipulidae* and *Chironomidae*); a bristleworm, *Polychaeta* (*Spionidae*); and an isopod, *Gnorimosphaeroma* (*Sphaeromatidae*). Macroinvertebrates were consistently absent from the water column and only the epibenthic isopod was relatively abundant but only close to the stream inflow.

Several macroinvertebrate taxa typical of Central Coast lagoon and estuarine habitats were consistently absent from Garrapata Lagoon. These include the shrimp *Neomysis* (*Mysidae*) and two amphipods, *Eogammarus* (*Anisogammaridae*) and *Corophium* (*Corophiidae*). In addition to *Gnorimosphaeroma* and *Chironomidae,* these three taxa are all common food resources for steelhead and other fish species in the lagoon environment (Martin 1996).

Reasons for their consistent absence in Garrapata Lagoon are unclear. The methods used in this study to sample the macroinvertebrates were identical to those used in another recent lagoon study conducted by the Watershed Institute in the Carmel River Lagoon (Larson et al. 2005), in which these taxa were collected in abundance. The absence of these taxa could be linked to several environmental factors – either individually or in combination.

First, in winter and spring, the entire lagoon area was lotic, or flowing, with no impounded water. The lack of a perennial and calm embayment may be eliminating a source for colonization since these taxa generally do not use lotic environments.

Or, perhaps the lagoon is too dynamic. The relatively late lagoon formation, its small size, and consistent interaction with wave and tidal processes create an unstable environment that could reduce the ability for these taxa to become established.

Also, the lack of emergent vegetation could also be a contributing factor. A study conducted in Pescadero Lagoon, central California (Robinson 1993), showed that *Eogammarus*, *Chironomus,* and *Gnorimosphaeroma* were positively correlated with the site abundance of pondweed (*Potamogeton sp.*). Emergent aquatic plants were not present in Garrapata Lagoon at any time during this study. A brief period of anoxia on the lagoon bottom may have also impacted benthic species such as *Corophium*.

Finally, we suggest food chain dynamics as a possible cause. *Neomysis* abundance has been positively correlated with turbidity caused by phytoplankton and algae abundance (Robinson 1993). Although not sampled, the abundance of phytoplankton appeared to be minimal. Water clarity was assessed in the lagoon with a secchi disk as well as bank and underwater observations. Water clarity in the lagoon was excellent throughout the study period, suggesting a low abundance of phytoplankton, a critical food resource of *Neomysis*.

On two visits to the lagoon, underwater cameras were used to try to detect the presence of juvenile steelhead. On all visits, bank observations with polarized sunglasses were made prior to any other sampling. Observations for surface activity (i.e., feeding, etc.) were also noted during each visit.

Steelhead were not observed in the lagoon with any method. One juvenile coast-range sculpin (*Cottus aleuticus*) was collected in a net at the lagoon/creek confluence during invertebrate sampling.

Based on the data collected during the present study, it is likely that Garrapata Lagoon is not used by juvenile steelhead for rearing in most, if any, years. Habitat in the lagoon is limited, due primarily to: 1) a lack of impounded water for a large portion of the year (winter and spring), 2) a lack of diverse and abundant food resources, 3) lack of overhead cover (as depth and emergent aquatic plants), and 4) the overall unpredictable nature of the lagoon volume and water chemistry driven by random combinations of wave energy, tidal cycle, stream flow and sediment supply. The lagoon area may be used briefly, however, by juvenile steelhead for acclimation to saltwater during spring out-migration, especially if a protected embayment exists. (For the full report, please see Appendix F.)

Watershed Vegetation and Riparian Resources

This report describes the vegetation history and contemporary natural community composition in the Garrapata Creek Watershed, and focuses on riparian resources found along the three primary streams – Joshua Creek, Wildcat Canyon and Garrapata Creek.

Methods used for the examination of vegetation resources were descriptive in nature and not quantitative. The protocol for assessing riparian function loosely followed the "Properly Functioning Condition" analysis techniques recommended by federal agencies that consider hydrology, vegetation and geomorphic processes (erosion and deposition) to determine how well riparian systems are working. Accordingly, the Riparian Area Management Handbook (U.S. 1998) defines riparian and wetland habitat as being in proper functioning condition when adequate vegetation, landform, or large wood is present to:

- Dissipate stream energy associated with high waterflow, thereby reducing erosion and improving water quality;
- Filter sediment, capture bedload, and aid floodplain development;
- Improve flood-water retention and ground-water recharge;
- Develop diverse ponding and channel characteristics to provide habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding and other uses;
- Support greater biodiversity.

All lower reaches of Joshua Creek, Wildcat Canyon and Garrapata Creek, including the estuary/lagoon, were traversed on foot until private property access constraints and/or physical barriers were encountered. The uppermost watershed areas of all three drainages were surveyed on foot using vehicular routes on the CDFG Palo Corona - Little Horse property. Field survey pursuant to this project was conducted in October of 2003; March, July, August and November of 2004; and October, November and December of 2005.

Tanbark oak trees occur as scattered elements in redwood and mixed evergreen forest, and the extraction of tanbark trees involved numerous cable networks and skid trails for livestock that helped harvest this resource. Roads, landings and haul trails were built to facilitate timbering activities. Some road networks were crudely dug excavations; while others were elaborate systems of cribbing with inlaid timbers that created roadbeds perched high above steep canyon streams.

Old growth redwood stumps occur along most of Joshua Creek and Wildcat Canyon, including the upper headwaters in what is now the CDFG Joshua Creek Ecological Reserve. Stumps also occur in the lower and middle reaches of Garrapata Canyon. Most of the contemporary redwood forest in all drainages of the watershed is second and third-growth.

The history of logging activities in the Garrapata Creek Watershed underscores the significance of how substantially portions of the landscape had been altered in past decades. In addition to timber operations and homesteading activities, e.g., the stone hearth in lower Wildcat Canyon, commercial activities like livestock grazing and fish-rearing have occurred in scattered parts of the watershed. Cattle drives from ranches deep in Big Sur country made their way north along the coast and inevitably grazed areas of the lower watershed on their march to markets in Monterey and Salinas (Post 2003).

The contemporary landscape bears only reminders of the history of large-scale anthropogenic disturbances. Today there does not appear to be logging or large-scale grazing in the watershed, and clearing is generally limited to the patchwork of rural residential home sites concentrated in the lower watershed and the PG&E right-of-way in upper Garrapata Canyon. Vegetative indicators of past historic activities can be noted in the presence of atypical plants that have naturalized over large areas of the riparian corridor, including blue gum eucalyptus (*Eucalyptus globulus*), Monterey pine (*Pinus radiata*), Monterey cypress (*Cupressus macrocarpa*) and periwinkle (*Vinca major*). When located outside of their natural range, these species and many others are typically considered domestic plantings associated with historic home sites.

In addition to past landscape alterations brought about by human activities, the watershed has been subjected to natural episodes of change that occur with variable periodicity. The region has a fire history that begs to be documented and the watershed has experienced vegetation changes resulting from landslides and slumps. Of particular importance to riparian vegetation is the episodic disturbance brought about by flooding, which uproots vegetation, transports woody debris, veneers banks and floodplains with fresh sediment, and restarts the ecological clock for riparian processes.

As previously discussed, Figure 3 is a historical photograph depicting the mouth of Garrapata Canyon in 1912; Figure 4 is the same view in 2004. At the time the 1912 photograph was taken, a bridge over Garrapata Creek was situated upstream of the current Highway 1 alignment. Note the complete lack of riparian vegetation and the extent of barren cobble bars on the floodplain south (right) of the old bridge. Note also the steep switchbacks that descend to the canyon from the saddle above the bridge on the south side. There were huge floods documented along the Central Coast in 1911 and again in 1914, and it is likely that Garrapata Creek suffered substantial flooding and erosion during these episodic high flow events. Logging activities that destabilized upstream slopes may have contributed to the massive erosion that stripped all vegetation from the banks of the creek.

Vegetation Communities in Watershed

The Garrapata Creek Watershed is a classic mosaic of coastal and inland vegetation types typical of Pacific slope watersheds in central California. In a transect from the upper watershed divides to the estuary/lagoon at the mouth of Garrapata Creek, the natural communities in the watershed reflect bedrock, tectonics, soil, aspect, moisture, fire, land use and marine influences.

Uplands: Upper watershed vegetation in Joshua, Wildcat and Garrapata canyons is remarkably similar – the vegetation is a patchwork of differing habitat types that reflect edaphic (soil) differences, fire histories and microclimate conditions. Sunny, exposed, generally south-facing slopes are mantled with chamise-dominated Chaparral; with patches of mesic Canyon live oak/Bay forest tucked into the folds of narrow drainages. Floristically diverse Mixed Chaparral usually occurs on south slopes in inland areas of the watershed, particularly on higher elevation CDFG lands. Most all north-facing slopes support Mixed Evergreen Forest, with a few unique groves of enormous madrone (*Arbutus menziesii*) and canyon live oak (*Quercus chrysolepis*) in the highest elevation areas of the Wildcat Canyon drainage. Most narrow drainage bottoms support linear Canyon Riparian Communities that snake their way along increasingly steep gradients towards watershed divides.

As one moves towards the coast and the omnipresent marine influence of persistent coastal fog, Chaparral vegetation gives way to Northern Coastal Scrub and occasional patches of rare Central Maritime Chaparral, which is found on marine terraces in the Highway 1 corridor. Closest to the coast, the bluffs and dunes at the mouth of Garrapata Canyon host uncommon communities noteworthy in their own right for their floristic composition and vegetative complexity.

Large tracts of Grassland ecosystems occur on the northern margin of the watershed along the northern edge of Joshua Creek. Although dominated by introduced annual species and forbs, the Joshua divide includes notably large patches of native, perennial grasses and both perennial and annual wildflower species. The eastern edge of the Wildcat Canyon drainage has a few small, but distinctive patches of Grassland that are also notable for their composition of native, perennial species. Other areas of Grassland ecosystems in the watershed tend to be very small, widely scattered, and composed primarily of introduced, annual species and weedy forbs.

Figure 39: Decommissioned roadbed in upper Wildcat Canyon. This stretch of road does not appear to have had noticeable “treatment” related to road decommissioning, however the simple act of ripping the compacted roadbed could have led to invasion of weedy annuals, as is depicted in this photograph. Photo: N. Nedeff October 2005.

As is typical of watershed vegetation, the most extensive coverage of specific natural community types occurs in the upper watershed areas, with the most restricted plant community distribution at the narrow mouth of Garrapata Creek.

Figure 40: Upper portion of restored roadway traverses through dense mixed chaparral and small groves of coast live oak and canyon live oak woodland. The saddle on the right side of the photograph separates the Wildcat Canyon and Joshua Creek watershed basins. Photo: N. Nedeff October 2005.

Riparian: By definition, Riparian vegetation is associated with the margins of streams and is restricted to the narrow belt of land influenced directly by stream flow. High water tables in the alluvium fringing streams in the Garrapata Creek Watershed sustain riparian species, which otherwise could not survive in the seasonally arid climate of central California.

Riparian vegetation in the Garrapata Creek Watershed is a floristically diverse collection of moisture-dependent plants in habitats that are influenced by physical aspects of the watershed and related biological processes. Riparian natural communities in the watershed run the gamut from coastal forms that are pruned and stunted by salty winds at the mouth of the mainstem, to narrow, linear habitats restricted to the seasonally damp folds of the Chaparral-covered watershed divides.

Lower Watershed Riparian: The lower reaches of the Garrapata Creek Watershed support a collection of riparian habitat types that include several species of willow (*Salix*) as dominant or co-dominant taxa.

The following natural communities occur along lower Garrapata Creek and the lowest portion of Joshua Creek where the mainstem canyon bottom is relatively wide and floodplain development has created appropriate habitat for riparian vegetation recruitment:

- Central arroyo willow
- Red willow/arroyo willow
- Red alder/arroyo willow

Each of these streamside communities includes varying proportions of arroyo willow (*Salix lasiolepis*), which occurs in pure stands, as well as with other riparian species as a co-dominant.

Arroyo willow is usually a relatively small tree that can grow in very shrubby forms. Occasionally, arroyo willow will occur with red willow (*Salix laevigata*), a willow species that can attain tree heights of 15 to 40 feet, or more under favorable conditions. Leaves of the red willow are noticeably larger and more linear than those of arroyo willow and generally taper to a fine point.

Both arroyo and red willows can occur with red alder (*Alnus rubra*) in the lower watershed. Red alder is a pioneering colonizer along the banks of streams in the watershed and often the relative dates of large flow events can be determined by the even age of alder trees that occur in dense stands. Alders require constant high water tables and usually cannot grow where their shallow roots fail to reach abundant moisture. Shifting stream channels, channel incision, or drops in water table levels result in alder mortality, and thus the presence of dead alders may provide clues to lowering groundwater or the geomorphic history at particular sites in the watershed.

Typical understory plants in various phases of willow/alder habitat in the lower Garrapata Creek Watershed include creek dogwood (*Cornus sericea* ssp. *occidentalis*), which is also called western red dogwood, thimbleberry (*Rubus parviflorus*), California blackberry (*R. ursinus*), mugwort (*Artemisia douglasiana*), chain fern (*Woodwardia fimbriata*), shield fern (*Polystichum californicum*), wood rose (*Rosa gymnocarpa*) and wood mint (*Stachys bullata*). Occasionally, damp cobbles or fine soils adjacent to the active channel support patches of liverwort (*Conocephalum* sp.), and areas of slow moving water are choked with watercress (*Rorippa nasturtium-aquaticum*).

The lower watershed riparian habitat is composed of areas where open canopies and abundant light create dense, shrubby stands dominated by arroyo willow; however, there are quite different areas where tall canopies of mature red alder and naturalized blue gum eucalyptus (*Eucalyptus globulus*), Monterey pine (*Pinus radiata*) and Monterey cypress (*Cupressus macrocarpa*) create structurally simple plant associations with understories dominated by low, tangled vines of blackberry and non-native species. The "natural communities" throughout the lower reaches of the Garrapata Creek Watershed are mostly compromised by invasive species - weed-free habitat is relatively hard to find.

Redwood-riparian forest is a phase of adjacent redwood-dominated habitat restricted to the edges of perennial stream reaches of Joshua, Wildcat and Garrapata creeks. The riparian phase of the adjacent redwood forest occurs where canyon bottoms narrow and stream gradients increase in steepness. Shaded by dense canopies that open up ever so slightly where divided by stream courses, the redwood-riparian communities of the Garrapata Creek Watershed include many species found in the neighboring redwood forest, but also include species unique to streamside habitats.

Redwood, tanbark oak, big-leaved maple and bay usually provide the overstory above redwood sorrel and widely scattered shrubs. Vegetation lining the banks of Joshua, Wildcat and Garrapata Creeks tends to be discontinuous and is either confined to areas above steep banks, or floodplain terraces immediately adjacent to the active channels in each drainage. The shrub component of the redwood-riparian forest can include coffeeberry, thimbleberry, sticky monkey flower, canyon gooseberry (*Ribes menziesii*), Santa Lucia gooseberry (*R. sericeum*), creambush (*Holodiscus discolor*), elk clover (*Aralia californica*) and osoberry (*Oemleria cerasiformis*).

A variety of fern species generally grow in separated locations along stream banks, with chain fern and shield fern found with five-finger fern (*Adiantum aleuticum*), lady fern (*Athyrium felix-femina*), western bracken (*Pteridium aquilinum*), sword fern (*Polystichum munitum*), wood fern (*Dryopteris arguta*) and occasionally maidenhair fern (*Adiantum jordanii*). Common, although not ever abundant, herbaceous species include sedges (*Carex* spp.), vanilla grass (*Hierochloe occidentalis*), stinging nettle (*Urtica dioica* ssp. *holosericea*), crimson columbine (*Aquilegia formosa*), boykinia (*Boykinia elata*), and the lovely leopard lily (*Lilium pardalinum*). Western colt's foot (*Petasites palmatus*) is found growing in both coarse cobble, as well as fine sediments. Colt's foot can be partially submerged adjacent to active channels and also higher on floodplains above bankfull stage.

Canyon Riparian: As one moves up in elevation above the zone where redwood dominates the canopy, canyons become increasingly narrow and v-shaped stream valleys are constrained by bedrock-controlled topography. Canyon riparian habitat is restricted to the narrow canyon bottoms that usually support seasonal flow. This moisture-dependent habitat thins out as elevation and steepness increase throughout the watershed and the diversity of riparian or wetland obligate species lowers as the number of upland types increases. Fog and the supplemental moisture from fogdrip become negligible. Big-leaved maple (*Acer macrophyllum*), occasional sycamore (*Platanus racemosa*), poison oak and blackberry typify canyon riparian communities until elevations increase and mesic habitat grades into upland types of canyon live oak/bay or mixed chaparral. Often the only noticeable indicator of a canyon riparian habitat will be an occasional maple or a solitary sycamore in an otherwise evergreen canopy. (For the full report, please see Appendices G and H.)

Figure 41: Redwood riparian habitat along middle reaches of Garrapata Creek. Note the relatively wide floodplain, which is unvegetated and covered with a thick layer of redwood duff. Photo: N. Nedeff March 2004.

Conclusions

In general, the Garrapata Creek Watershed and most reaches of Garrapata Creek, Wildcat Canyon and Joshua Creek have good quality riparian habitat in “Properly Functioning Condition” (U.S., BLM 1998). There is adequate cover to protect banks and dissipate stream energy during high flows, as well as to provide habitat for terrestrial and aquatic species. Of concern is the predominance of weedy species in the immediate riparian corridor, particularly in the lower Garrapata and Joshua drainages. Also of concern is the relatively high sediment load carried by Joshua Creek, which tends to cause stream flows to destabilize immature riparian vegetation on continuously active bars and floodplains. When given a chance to mature, riparian vegetation will capture sediment and promote floodplain development.

The presence and cover of several weedy species is problematic in the lower watershed. Weeds may control recruitment sites and perpetuate a non-native riparian environment. In addition, food webs in river systems can be damaged for native aquatic organisms when weedy cover takes hold. Linked energy flows between riparian vegetation and the production of detritus and invertebrate food resources for salmonids can be disrupted by changes in associated riparian vegetation (Power and Dietrich 2002). Research described in the literature confirms that red alder in particular, provides abundant invertebrate and detritus input to streams, thus supporting fish biomass in a manner that cannot be provided by non-native riparian vegetation (Wipfli 2004). The dominance of floodplain areas by eucalyptus, Monterey pine and cypress could lead to decreased habitat values for steelhead trout and a variety of riparian obligate species.

In the Garrapata Creek Watershed, the biologically limiting factor for riparian vegetation appears to be a combination of weed dominance and/or human activities (clearing, dumping of trash, road maintenance). Despite the concern for high sediment loads in the Joshua drainage, sediment issues in most other portions of the watershed are not critical limiting factors for riparian vegetation. In fact, the deposition of sediment can enhance riparian plant recruitment.

The presence of large wood is generally a beneficial element in the riparian corridor. Diverse structure provides instream habitat value. Although the large logjams that restrict fish passage in Garrapata Creek are a limiting feature for steelhead, the barriers have trapped a significant amount of load and reduced downstream sediment accumulation in pools and areas of slower water flow. The stream has adjusted to a new “toe of bank” created by accumulated sediment behind the logjams and riparian vegetation growth on these adjusted topographic features has promoted bank stability upstream.

In several areas of the watershed, the potential width of the riparian zone – edge of bank through floodplain or zone of stream influence – is constricted by home sites, roads, artificial ponds, and areas of cleared land. Floodplain constrictions limit water movement during high flow events and often lead to concentrated flow areas where bank erosion is facilitated.

Restoration Recommendations and Implementation

Limiting Factors Analysis

As originally stated, the purpose of this plan is to assess the overall condition of the Garrapata Creek Watershed and identify critical issues and limiting factors as they relate to steelhead. Not surprisingly, the Planning Group's original list of issues and concerns include the limiting factors identified as keystone problems in the watershed. As supported by the assessments the limiting factors in the watershed are as follows:

- Sediment delivery to the streams from road erosion
- Steelhead migration barriers
- Non-native plant species invasion and lack of riparian vegetation

Roads and Erosion

Given the impacts detailed in the geomorphology and hydrology section, the close examination by PWA of road conditions in the watershed, and the goal of improving anadromous fishery habitat, **there is one major restoration opportunity that stands out above all others: *reducing sediment delivery to the creeks from unpaved roads, especially in the Joshua Creek sub-watershed.***

In general, the sediment would be reduced: 1) if much of the road surfaces are outsloped and rolling dips installed, 2) culverts are properly sized and maintained, 3) side-cast road material is stabilized by vegetation or appropriate geo-textiles, 4) road-cuts are stabilized and 5) the excavated material is end-hauled to an area that would not deliver the sediment to the creeks instead of the usual practice of side-casting the material over the edge of the road.

It should be noted that based upon the estimates of highly mobile bed-load sediment and an understanding of the sediment transport capacity of Joshua Creek, the channel would be clear of the pool-filling sand and silt in less than two years if all sediment sources in Joshua Creek were suddenly stopped.

Recommended restoration activities to address sediment delivery to the creeks from road erosion are as follows:

> ***a) Restoration of roads as recommended in PWA report. (Project slated to begin in Summer 2006.)***
> ***b) Better on-going road maintenance and practices.***

Steelhead Migration Barriers

Table 4 shows the prioritization for restoration of all assessed barrier structures in the watershed.

In Garrapata Creek, the large and complete barriers to migration have been in place for decades and have since become stream gradient control features. Their removal would likely jeopardize the stability of the surrounding hillslopes, roads, and homes that are immediately adjacent to the creek. In addition, the release of a substantial load of stored sediment would likely have adverse impacts on spawning habitat and fish downstream, which could potentially take decades to restore. Efforts in Garrapata Creek should therefore be focused on improving structures downstream of the larger impassable barriers.

Table 4: Benefits and costs to modification and level of suggested priority of structure improvement.

Structure ID	**Distance from ocean (m)**	**Upstream of impassable barrier?** (+ easily accessible, - inaccessible)	**Accessible for enhancement** (+ accessible; - not accessible)	**Labor/effort required** (+ minimal labor required; - high labor required)	**Upstream Habitat Availability** (+ habitat available; - limited habitat)	**Sediment Storage** (+ low sediment storage; - high sediment storage)	**Priority**
Garrapata Creek							
gb01	2982	+	+	+	+	+	High
gb02	3089	+	+	+	+	+	High
gb03	3485	+	+	+	+	+	High
gb04	4529	+	+	+	+	-	High
gb05	5015	+	-	+/-	-	+	Medium
gb06	5024	+/-	-	+	-	+	Medium
gb08	5167	+/-	-	-	-	-	Low
gjb09	5181	-	-	+	-	-	Low
gb10	5197	-	-	+	-	-	Low
gb11	5280	-	-	-	-	-	Low
gb12	5330	-	+	+	-	-	Low
gb13	5482	-	+	+	+	-	Low
gb14	5846	-	+	-	unknown	+	Low
Joshua Creek							
jb01	364	+	+	+	-	+	High
jb02	427	+	+	+	+/-	-	High
jb03	447	+	+	+	-	+	High
jb04	524	+	+	+	-	+	High
jb05	621	+	+	+	-	-	Medium
jb06	642	+/-	-	+	-	-	Medium
jb07	745	+/-	-	-	-	-	Low
jb08	799	-	-	-	-	-	Low
jb09	841	-	-	-	-	-	Low
jb10	979	-	-	-	-	-	Low
Wildcat Creek							
wb01	88	+	+	+	+	+	High
wb02	226	+	+	+	+	+	High

Note: Labor required for improvement of structures includes: distance and accessibility to the structure, materials need to improve (i.e. heavy machinery, saws, and number of people). Structure gb07 is not shown because it is a natural waterfall with no improvements needed.

In Joshua Creek, the amount of potential spawning habitat is naturally limited due to a natural barrier located 0.65 miles (1.05 km) upstream from the confluence with Garrapata Creek. The removal or enhancement of the larger debris jams would be costly economically due to the limited accessibility to the sub-watershed and the amount and size of debris material to be removed. More importantly, the sediment released from these obstructions could smother downstream spawning habitat in Garrapata Creek, where debris jams are not present and sedimentation is not as severe. ***Efforts should be focused on improving high priority barriers in the lower reaches of Joshua Creek and those in lower reaches of Garrapata and Wildcat creeks.***

Barriers on Wildcat Creek are easily accessible on foot through The Big Sur Land Trust property (Glen Deven Ranch). The better accessibility, limited number of debris jams, their lower cost for enhancement, lack of impassable structures downstream, and the minimal volume of accumulated fine sediment, increases Wildcat Creek's priority for enhancement. Although the amount of spawning habitat in this sub-watershed is naturally limited (only 0.3 km (.2 mile) of stream below a natural barrier), the stream is presently accessible to steelhead. Therefore ***the two structures observed in Wildcat Creek were given High priority for improvement.***

Cautions

The most critical objective for the GCWC is to reduce sediment loading into the stream channels of the Garrapata Creek Watershed. Any major debris jam enhancement projects in the watershed should be done after the primary sediment source(s) have been located and steps have been taken to reduce their sediment yields. Modifications of any structures would result in the release of some volume of sediment downstream. This would further impact channel substrate conditions in the lower watershed currently used by steelhead for spawning and rearing. Therefore, the cumulative impacts of barrier modification to downstream habitat should be considered. All modification or enhancement project(s) implemented should be done over an extended period of time to ensure that sediments are slowly released downstream.

Finally, the presence of large woody debris in streams is critical for healthy riparian ecosystems. The habitat complexity it provides in streams is an essential habitat component for both steelhead and California red-legged frogs. Therefore it is strongly recommended that any large woody debris removed from log or debris jams during enhancement or restoration projects be used on site or in other areas of the watershed to improve stable habitat complexity for these species.

Riparian Habitat Enhancement and Non-native Plant Removal

Regarding riparian habitat and upland natural communities in the Garrapata Creek Watershed, most physical and biological processes remain intact. Upper watershed areas of Garrapata Creek, Joshua Creek and Wildcat Canyon are largely untrammeled today and will continue to persist in conserved status through public ownership. The challenge will be proper stewardship given the remote location.

There are a few specific locations where riparian habitat in the lower drainages is non-functional, or functionally at risk; proactive change, therefore, would be most beneficial in the lower watershed. Types of riparian enhancement projects range from massive in scope, to very small, site-specific efforts.

Riparian community function would be improved by removing non-native trees to enhance floodplain habitat values; the elimination of eucalyptus, Monterey pine and Monterey cypress from the lower Garrapata Creek Watershed should be encouraged. Riparian community function could be dramatically enhanced from the Glen Deven Ranch downstream to the mouth of the canyon (including the lower Joshua area), although the effort to accomplish the changes required would be significant and would result in localized short-term habitat disruption.

These invasive species will increase in cover and density through time and should be controlled to the extent feasible. As the non-native component of the lower watershed riparian habitat increases, riparian function will decrease and eventually come close to failure. As red alder is replaced by non-native vegetation, the input of beneficial detritus and invertebrates used by steelhead will diminish and aquatic habitat will degrade.

The same recommendation for elimination and control applies to the increasingly pervasive Cape ivy, which likely cannot be completely removed from the watershed without the introduction of biological control agents. Cape ivy would be extremely difficult to eliminate from the watershed, yet its spread can be controlled, or at least slowed by manual and chemical agents. Even small advances in restoring native habitat by removing Cape ivy can result in significant benefits to wildlife and plant resources.

Pragmatic efforts to restore riparian function include relatively small projects involving revegetation of eroding banks, restoring cleared areas, and keeping livestock outside the riparian corridor. Limiting the spread of invasive weeds like vinca (*Vinca major*), panic veldt grass (*Ehrharta erecta*), pampas grass (*Cortaderia jubata*) and sticky eupatorium (*Ageratina adenophora*) helps to maintain the character and function of native ecosystems and will benefit native wildlife species.

Recommended restoration activities for improving riparian habitat and maintaining watershed health can be prioritized as follows:

1. Control the spread of Cape ivy, eucalyptus, Monterey pine, vinca, pampas grass, sticky eupatorium and other invasive weeds, particularly in areas that support willow and alder vegetation. Provide disposal options to remove weed biomass.
2. In areas where streambanks are barren or unstable - revegetate with native species.
3. Clean up trash and provide disposal options.
4. Develop an information outreach campaign to maintain stewardship awareness for residents, and to introduce stewardship philosophy to new residents.
5. Assess feasibility of grant opportunities for larger-scale floodplain restoration that includes eucalyptus, pine and cypress removal.
6. Develop a strategy and action plan to assess need for action/restoration after high flows have caused erosion or bank failure.
7. Identify grant opportunities and conduct avian monitoring, both baseline and follow-up.
8. Identify opportunities to enhance habitat for California red-legged frog. Remove bullfrogs from pond habitats, if present.

Future Recommended Studies and Monitoring

Monitoring of Steelhead and Habitat Conditions

Since Garrapata Creek has baseline data on the steelhead population for drought conditions and for a normal water year (CDFG 1990 and 2005) as well as habitat typing data (McKnight 2002), it would be valuable to continue similar sampling every three to five years. Since steelhead populations can be so variable from year to year, the sampling could be habitat based whereby certain habitat features are measured annually against some standard that has been identified.

If fish population sampling is repeated at some time interval, there are two different sampling strategies that could be employed. For both strategies, channel typing would need to be conducted and the habitat would need to be re-typed at CDFG Level Four (See Flosi et al, 1998). Level Four habitat typing provides more information on the scouring elements of pools, riffle gradient and substrate composition of the flatwater units.

If the long term goal of sampling is to obtain population estimates from fixed transects that are representative of a reach, as was done for this assessment, then transects would be chosen based on the prevalent habitat in the different channel types. At some defined time interval, the same transects would be sampled and the results from each transect compared from year to year. This would provide relative abundance of steelhead within the transect sites and would suggest changes in watershed conditions.

If the goal of sampling is to obtain a population estimate of the entire stream or watershed, then a complete and detailed habitat assessment and inventory would be required for the entire watershed (or the area below impassable barriers). This would be followed by fish sampling in each of the habitat types encountered during the habitat inventory and then extrapolations of the two data sets would be used to generate an estimated population for the "anadromous portion" of the watershed. For a more detailed discussion of this see Appendix D.

If monitoring is a long-term goal in the watershed, it is recommended that fish population sampling be done every five years and to pick habitat features such as percentage of fines in spawning areas and pools, or biological studies such as macro-invertebrate analysis, to measure annually.

Data Gaps

The following areas have been identified as "data gaps" requiring additional information:

- **Sediment Sources and Sediment Load**: Support sporadic sediment monitoring program in order to evaluate natural and anthropogenic changes in amount of sediment reaching creeks. These data will be invaluable when it is time to monitor the changes in sediment load associated with restoration efforts. More information is needed on sediment sources in Joshua Creek.

- **Water Use**: Maintain existing gauges to assess water resource quantity through time. Continued monitoring of flow data will be invaluable when it comes time to monitor the positive impacts of watershed restoration. The gauge data will be used to both detail changes in water quantity and sediment flow.

- **Lagoon**: Although a preliminary study has been conducted on the lagoon, continued monitoring will help to better understand how small lagoons, such as Garrapata, are utilized by steelhead and other aquatic organisms.

Additional Activities:

In addition, the following topics or issues have been identified for further consideration and possible action:

- Riparian areas: Establish permanent monitoring stations, including cross-section monitoring stations; collect information on baseline riparian conditions and revisit periodically.
- Development of a Garrapata Creek Watershed water budget: This will include assessing variables such as input of water from upslope sources/springs, surface runoff, well use, evapotranspiration rates, etc.
- Assess the specific condition of riparian vegetation in vicinity of large wells.
- Document annual water extraction from wells and in-stream diversions.
- Conduct Habitat Typing using CDFG protocols throughout the watershed.
- Document macroinvertebrate communities (indicators of water quality) and monitor periodically.
- Document avian species and monitor periodically (can be indicators of riparian condition).
- Inventory for California red-legged frog, tiger salamander, Smith’s blue butterfly, foothill yellow-legged frog.
- Accurately map vegetation types in the watershed (Monterey County maps are too general).
- Continue riparian assessment in parts of upper watershed that is currently inaccessible due to terrain and private property issues.
- Research historic land use, logging, settlement, fire history, and history of the Trout Farm.
- Repeat steelhead survey every five years (as noted above in the fisheries survey report).

Benefits to Landowners and Community

Through the development of the Garrapata Creek Watershed Assessment and Restoration Plan, the landowners and community members living within the watershed have gained new perspectives about the issues, concerns and resource needs of the creek and its tributaries. Much has been learned about the habitat needs of the steelhead. Benefits of this education and awareness process are both immediate and long term.

With the data and information included in this plan, landowners will now be able to assess and implement projects that benefit not only their own property but the environment as well. Projects such as road upgrade and maintenance and non-native plant removal ensure the landowner's full control over his/her property, while at the same time protecting habitat for steelhead and helping to restore watershed health. When residents think at the watershed-level they see that what happens on other lands in the watershed impacts their land. Working cooperatively, with willing landowners they can implement the recommendations of this plan.

Watershed Activities Completed

Actions have already been initiated to address several of the issues outlined above. The GCWC takes a holistic watershed approach to addressing degradation of the creek from siltation, pollution, and invasive, non-native plant species. Council members have been instrumental and active in conducting watershed-wide trash and debris clean-ups, including the removal of parts of abandoned vehicles, parts of houses and other industrial and household trash from the creek. The GCWC has also hosted a number of educational workshops, work sessions and seminars for stakeholders on a variety of topics including: exotic plant identification and removal, drought tolerant landscape techniques, road design and maintenance, and best management conservation practices. The GCWC produced several educational newsletters covering topics related to watershed management and monitoring.

Specific activities of the GCWC to date include:

- Conducting an average of two general meetings per year, including presentations on the natural history of steelhead, invasive plants, water conservation, roads and their impacts on the watershed.
- Purchasing and installing a stream flow gauge. Collecting in-stream flow data for over four years.
- Creating a Geographic Information System (GIS) database to map the location of prominent features such as stream crossings and steelhead migration barriers.
- Creating a Watershed Newsletter to give updates and provide information to help landowners manage their lands better.
- Organizing field trips, including over a dozen creek walks, to educate residents about the creek.
- Organizing creek cleanup and invasive plant removal days where residents removed harmful material and trash and cleared several areas of Cape ivy.

- Sponsoring two meetings of the Monterey County Watershed Information Exchange, whose goal is to educate and increase the level of community-based watershed activity throughout Monterey County.
- Facilitating an inventory of road sites with active and potential erosion and sediment delivery. A roads assessment involving willing landowners in the watershed (encompassing about 70% of the watershed area) was completed in March 2003 by the CDFG-funded PWA watershed upslope erosion assessment. A follow-on grant from CDFG and the California Coastal Conservancy secured funding to implement the most cost-efficient treatment sites identified in the PWA report.

Conclusions

While the Garrapata Creek Watershed has been impacted by various human activities, there is much that can be done to restore and improve watershed health. This assessment and restoration plan for Garrapata Creek and its watershed has focused on critical issues related to steelhead and invasive plant species, both as indicators of overall watershed health and as important restoration goals. When implemented, the recommendations of this restoration plan will result in improved fisheries habitat, water quality, and overall watershed health. Specific recommendations include reducing sediment loading through better road management, improving fish migration, eliminating or reducing non-native plant species, and re-vegetating and stabilizing creek banks with native vegetation.

While this plan provides detailed recommendations regarding most, but not all, of the GCWC Planning Group's issues and concerns, it represents an important step towards developing and implementing prioritized restoration projects that address keystone limiting factors in the watershed. There is, however, clearly more work to be done. Watershed management is as much a people process as it is a science of restoring the natural and human-impacted landscape. Creatively addressing the needs of the community requires vigorous and continuous community dialogue. To develop and implement a complete and truly operational watershed management plan requires continuing dialogue with the stakeholders that began with the formation of the Garrapata Creek Watershed Council in 2000. While the success of that dialogue is clearly evident in the development of this plan, the next step is to implement these prioritized recommendations.

While the intent of this plan was to provide a preliminary assessment of the watershed and generate a prioritized list of projects to address keystone issues affecting the steelhead fishery, it has become a great deal more, involving countless volunteer hours and input from the community regarding ideas for the watershed's future. The process of meeting collaboratively among stakeholders and regulatory agencies cannot be underestimated. This process is just as important as the document itself.

Finally, many communities along the Central Coast and Big Sur area face similar watershed issues as those in our watershed. We hope the Garrapata Creek Watershed effort can serve as a model for other watersheds in the region.

We look forward to addressing critical watershed issues, keeping in mind the need to preserve and enhance the watershed resources within the limits imposed by past human modifications and the current needs of the community. It is hoped that efforts will continue to move forward to protect and enhance the creek's resources for generations to come.

Glossary of Terms

acre-foot	The volume of water that covers an acre of land to the depth of one foot (or 325, 851 gallons).
alevins	Newly hatched steelhead, which stay in the gravel until their yoke sacs are absorbed
anadromous	Migrating up rivers and creeks from the ocean to breed in fresh water.
anthropogenic	Human-induced
CDFG	California Department of Fish and Game
cfs	Cubic Feet per Second. (1 cfs flow equals 1.98 acre-feet per day)
fry	The name of juvenile steelhead after they emerge from the redd (or nest).
g/s	Grams per second
macroinvertebrate	Organisms with no backbones that can be seen without a microscope.
redd	Depression in gravel where steelhead and other salmonids deposit and fertilize eggs (i.e. nest).
riparian	Pertaining to anything connected with or near the banks of a stream or lake.
smolt	Juvenile steelhead that has undergone physiological changes (e.g. gills, color, etc.) in preparation for life in the ocean.
steelhead	The anadromous (or ocean-going) form of rainbow trout.
watershed	An area of land draining into a river/creek system.
YOY	Young of the Year, a term for steelhead and other salmonids in their first year of life.

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Jonathan Berkey was the Restoration Plan Coordinator and did much of the editing for this plan.

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Looking down Wildcat Canyon; a fog-shrouded Garrapata Ridge in the distance.
Photo: N. Nedeff