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Watershed Assessment and Erosion Prevention Planning Project for the Garrapata Creek Watershed, Monterey County, California

prepared for

California Department of Fish and Game

by

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Background

Garrapata Creek is a small coastal stream located 10 miles south of Carmel in Monterey County, California. Garrapata Creek and its two tributaries, Joshua and Wildcat Creek, flow year round (Figure 1). Hydrologist reports have estimated the annual flow at around 5,000 acre-feet per year. The watershed, which is approximately 10.4 square miles in area, is located in a rural region of coastal Monterey County in an area with light development. The watershed encompasses primarily privately owned land (both large ranch parcels and smaller residential parcels) with a few large tracks owned by the State of California and the U.S. Forest Service. Although the watershed is still impacted by past logging activities, there are no current logging operations under way or planned. Abandoned roads, developed during past land use activities, are still a common part of the landscape. Such old road systems, common on the Palo Corona and other large properties, are known to represent existing and potentially important sources of erosion and sediment delivery to the stream system (PWA, 1990).

CDFG survey reports indicate that sedimentation of decomposed granite was a pollution problem throughout much of the stream in the early 1990s, with filling of pools and cementing of spawning gravels. Overall, sedimentation due to logging and improper road grading was identified as the primary factor limiting steelhead production in the Garrapata Creek drainage. An analysis of uncontrolled, poor road grading activities conducted on ranch lands in the middle and upper watershed in 1990 confirms the conclusion that sedimentation rates from such activities are high (PWA, 1990).

Fish population and distribution data is extremely limited. Three CDFG surveys are known, including a brief survey in February, 1981, a 1990 survey along 6.7 miles of Garrapata Creek and Wildcat Canyon Creek (including four mark-and-recapture reaches), and a more recent (1998) electrofishing survey of a short reach of lower Garrapata Creek. In the earliest survey, CDFG biologists did not regard the stream as a probable salmonid production area. In sampling of four 150 foot reaches in 1990, biologists documented winter steelhead populations in both Garrapata Creek (three reaches) and Wildcat Canyon (one reach). Finally, CDFG biologists conducting fish population sampling in November 1998 found 18 steelhead in a 100 foot reach in the lower part of the watershed, approximately 0.25 miles from the creek mouth. Limited population data suggests that spawning conditions may be suitable, but rearing conditions may be limiting (Marty Gingras, CDFG, personal communication). This may include water quantity and/or water quality (sediment) limitations in the watershed, especially in the lower basin.

The Garrapata Creek Watershed Council (GCWC) is a working watershed group recently formed in response to the need for stakeholders, which include landowners, residents and land managers, to participate in a cooperative and proactive effort to improve the condition of the watershed by

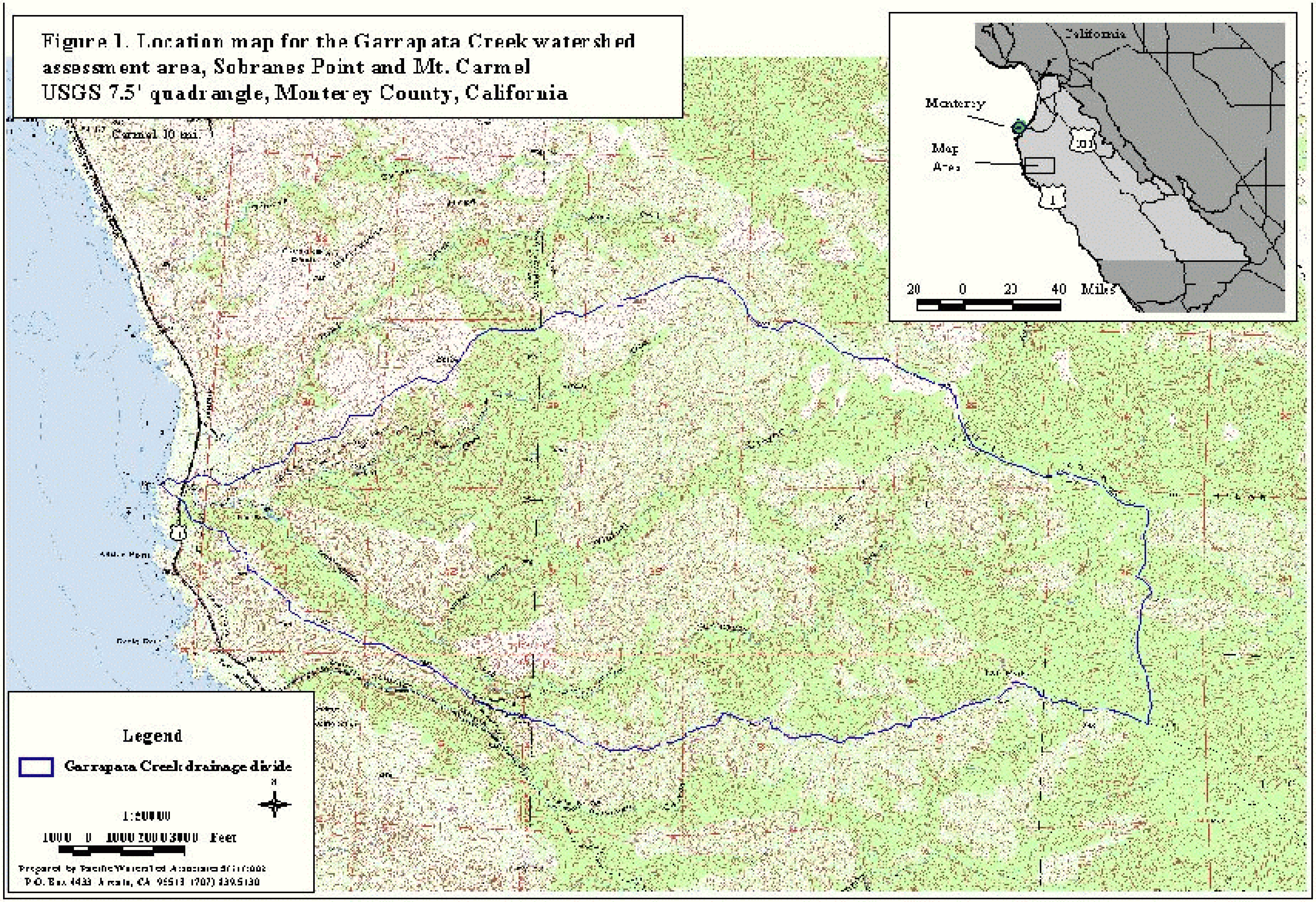

Figure 1. Location map for the Garrapata Creek watershed assessment area, Sobranes Point and Mt. Carmel USGS 7.5' quadrangle, Monterey County, California

working together locally and with multiple federal, state and county agencies. The GCWC was formed to take a large-scale (watershed level) approach to address stakeholder concerns about degradation of the creek from siltation, pollution and invasive, non-native plant species. Prior to formation of the GCWC, several founding members were very active in removing abandoned cars, parts of houses and other industrial and household trash from the creek. The first major accomplishment of the GCWC was the approval and execution of a CDFG funded watershed erosion assessment (Contract # P00304039) which inventoried sites of active and potential erosion and sediment delivery.

Garrapata Creek Watershed Assessment and Implementation

Perhaps the most important element needed for long term restoration of salmon habitat, and the eventual recovery of salmonid populations in Garrapata Creek, is the reduction of accelerated erosion and sediment delivery to the channel system. This report describes the watershed assessment and inventory process that was employed in the Garrapata Creek watershed assessment. It also serves as a prioritized plan-of-action for cost-effective erosion control and erosion prevention treatments for the Garrapata Creek project area. When treatments are implemented in combination with protective land use and road maintenance practices, the proposed projects will contribute to the long term protection and improvement of salmonid habitat. The implementation of erosion control and erosion prevention work is an important step towards protecting and restoring watersheds and their anadromous fisheries (especially where sediment input is a limiting or potentially limiting factor to fisheries production, as is thought to be the case for the Garrapata Creek watershed).

Road systems are now widely recognized throughout the northcoast region as one of the most significant, and the most easily controlled, sources of sediment production and delivery to stream channels. The Garrapata Creek Watershed is underlain by decomposed, steep and potentially unstable geologic substrate, and both field observations and aerial photo analysis suggests that roads have been a significant source of accelerated sediment production in the watershed (PWA, 1990). In the Garrapata Creek Watershed, as elsewhere, excess sediment input to stream channels during large magnitude rainfall events is perhaps one of the most significant factors affecting salmonid populations.

Unlike many watershed improvement and restoration activities, erosion prevention and "storm-proofing" of rural road systems has an immediate benefit to the streams and aquatic habitat of the basin. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion, and that future storm runoff can cleanse the streams of accumulated coarse and fine sediment, rather than depositing additional sediment from managed areas. Sites targeted for immediate implementation in the project area have been identified as high, moderate and low priority sites for treatment so that fill failures, stream crossing washouts and stream diversions do not continue to degrade the stream system.

The sediment source inventory for the Garrapata Creek Watershed, funded through a SB 271 restoration grant, has recently been completed. Among other things, this assessment identified all recognizable current and future sediment sources from roads on lands within the watershed assessment area. The primary objective of these road decommissioning and upgrading projects is to implement cost-effective erosion control and erosion prevention work on priority sites that were identified as a part of this inventory.

Project Description

A sediment source inventory for the Garrapata Creek watershed area was funded through a DFG watershed inventory and restoration planning project ("Garrapata Creek Watershed Erosion Inventory and Restoration Planning Project" CDF&G Contract # P00304039). The majority of the watershed was analyzed using historical air photos and a complete field inventory. Among other things, the assessment identified treatable current and future sediment sources from decommissioned, abandoned and maintained roads within the Garrapata Creek assessment area.

In the first phase of the Garrapata Creek inventory project, all roads within the study area were identified and age dated from historic aerial photography. Aerial photographs were analyzed to identify the location and approximate date of road construction. Each road identified was mapped on mylar overlays on the most revealing aerial photos for which there was complete coverage of the basin. Photo periods were pre-1949, 1950-1969, 1970-1984, and 1985-2000. PWA developed a composite map of the road systems in the Garrapata Creek watershed **(Map 1)**. The base maps, updated through analysis of aerial photos, depicts the primary road network in the watershed.

The second phase of the project involved a complete field inventory of the road systems identified during the air photo analysis. Technically, this assessment is neither an erosion inventory nor a road maintenance inventory. Rather, it is a sediment source inventory of sites where there is a potential for future sediment delivery to the stream system that could impact fish bearing streams in the watershed. All roads, including both maintained, decommissioned and abandoned routes, were walked and inspected by trained personnel and all existing and potential sediment delivery sites were identified. Sites, as defined in this assessment, include locations where there is direct evidence that future erosion or mass wasting could be expected to deliver sediment to a stream channel. Sites of past erosion were not inventoried unless there was a potential for additional future sediment delivery exceeding 10 yds^3. Similarly, sites of future erosion that were not expected to deliver sediment to a stream channel were not included in the inventory.

Two different methods of field inventory were employed during this assessment. The first method was conducted on several landowners properties using the standard Pacific Watershed Associates inventory methods and analysis. The majority of the assessment was located in the lower watershed. During Part 1 of the assessment 11.9 miles of road were inventoried and 104 sites were identified and written up as sediment source sites. The second method was conducted on the Palo Corona Ranch reviewing the erosion prevention treatments and post excavation adjustments from a road decommissioning project completed in 1991. Part 2 on the Palo Corona Ranch, assessed 10.4 miles of road and identified 33 sites as sediment sources. The combined field inventories identified future sediment sources from 137 sites, of which 87 sites are recommended for treatment on approximately 22 miles of abandoned logging roads, decommissioned roads and rural residential roads in the watershed.

Land Use History

Road construction and harvesting in the Garrapata Creek watershed began prior to the 1950s, with a main trunk road built along approximately 3 miles of the main channel of Garrapata Creek. Other 1950 roads were constructed along the south facing slope of the Joshua Creek watershed. Highway 1 was also established at this time as the main coastal road between Monterey and San Luis Obispo. The first aerial photos reveal limited logging and spur roads which branched off these main routes.

Road construction continued in 1970 along the north-facing slope of the mainstem of Garrapata Creek. Most the road construction existed near the mouth of the creek near Highway 1. Between 1985 and 2000, additional spur roads branched off pre-existing roads. These roads were mostly for residential use including driveways and alternate evacuation routes for residents of Palo Colorado. During this time jeep roads and fire breaks were constructed along the ridge tops in the highest ar3as of the watershed. The most recent roads were newly constructed in 1990 but were removed instantaneously during emergency control work on the Palo Corona Ranch (Little Horse Ranch).

Map 1 depicts the general road construction history for the Garrapata Creek Watershed, as derived from an analysis of aerial photography. A total of 31.7 miles of road have been built in the 50 year period covered by the air photo analysis, for a road density of approximately 3 mi/mi^2.

Assessment Overview

Inventoried sites generally consisted of stream crossings, potential and existing landslides related to the road system, gullies below ditch relief culverts and long sections of uncontrolled road and ditch surface runoff which currently discharge to the stream system. For each treated, existing or potential erosion source that was identified, a database form was filled out and the site was mapped on a mylar overlay over a 1:12,000 scale aerial photograph. The database field form for both inventory methods (Figure 1) contained questions regarding the site location, the nature and magnitude of existing and potential erosion problems, the likelihood of erosion or slope failure and recommended treatments to eliminate the site as a future source of sediment delivery.

The erosion potential (and potential for sediment delivery) was estimated for each major problem site or potential problem site. Estimates of the future expected volume of sediment to be eroded and delivered to streams was also estimated at each site. The data provides quantitative estimates of how much material could be eroded and delivered in the future, if no erosion control or erosion prevention work is performed. In a number of locations, especially at stream diversion sites, actual sediment loss could easily exceed field predictions. All sites were assigned a treatment priority, based on their potential to deliver deleterious quantities of sediment to stream channels in the watershed and the cost-effectiveness of the proposed treatment.

In addition to the database information, tape and clinometer surveys were completed on virtually all stream crossings. These surveys included a longitudinal profile of the stream crossing through the road prism, as well as two or more cross sections. The survey data was entered into a computer program that calculates the volume of fill in the crossing. The survey allows for an accurate and repeatable quantification of future erosion volumes (assuming the stream crossing was to washout during a future storm), decommissioning volumes (assuming the road was to be closed) and/or excavation volumes that would be required to complete a variety of road upgrading and erosion prevention treatments (e.g., culvert installation, culvert replacement, complete excavation, etc.).

The primary emphasis of the erosion prevention plan be to treat existing and potential sediment sources identified along 12.67 miles of inner gorge, mid-slope and ridgetop roads located throughout the watershed. All roads proposed for treatment are prioritized and currently threaten to deliver eroded sediment to Garrapata Creek if they are left untreated. A number of sites in the upper watershed have already been decommisssioned, others have failed in the past and many are currently eroding. The remaining sites show signs of pending and potential failure and sediment delivery.

Treatments along these unstable and/or high yield roads will be accomplished by permanently decommissioning (closing as on the Palo Corona Ranch) and “storm proofing” (upgrading) the reaches identified in the site location maps. These projects are carried out to "storm-proof" road systems (through road closure or road upgrades) and prevent or minimize accelerated sediment yield to stream channels during future large storms. Old, unneeded roads, decommissioned roads and high impact roads have been identified during the watershed sediment source assessment. A total of 7.7 miles of these roads were decommissioned in 1991 on the Palo Corona Ranch. For the current project, road upgrading comprises 70% of the current project, while only 16% of the sites have been recommended for decommissioning. The remaining 14% of inventoried sites have been recommended for no treatment.

This decommissioning and upgrading implementation plan is primarily aimed at old, abandoned and maintained high risk roads located within riparian, inner gorge, stream-side, mid-slope, and ridgetop areas. These roads have been identified as the most common and important human-caused sources of sediment in the watershed. Roads are also the most easily treated sediment source. Eighty seven (87) recommendations for site-specific treatments have been prepared. Only those sites identified in the assessment that are both likely to yield sediment to a stream channel if left untreated and can cost-effectively be treated to prevent or control future sediment yield are being discussed for implementation.

General heavy equipment treatments for *road decommissioning and road upgrading* have been tested, described and evaluated (Harr and Nichols, 1993; Weaver and others, 1987; Weaver and Sonnevil, 1984; Weaver and Hagans, 1994). Decommissioning essentially involves “reverse road construction,” except that full topographic obliteration of the road bed is not normally required to accomplish cost-effective sediment prevention goals. In order to protect the aquatic ecosystem, our goal is to “hydrologically” decommission the roads; that is, to minimize the adverse effect of the road on natural hillslope processes and watershed hydrology.

Only in relatively few instances does “hydrologic decommissioning” have to include full recontouring of the original road bed. Typically, potential problem areas along a road are isolated to a few locations (perhaps 10% to 20% of the road network to be decommissioned) where stream crossings need to be excavated, unstable landing and road sidecast needs to be removed before it fails, or roads cross potentially unstable terrain and the entire prism needs to be removed. Most of the remaining road surface simply needs permanently improved surface drainage, using decompaction, road drains and/or partial outsloping.

Successfully decommissioning most roads will cost a fraction of complete or total topographic road obliteration, and can be significantly less expensive than road upgrading. Costs are highly dependent on the frequency and nature of the potential erosion problems along the alignment. Specific treatments and costs for the Garrapata Creek decommissioning project are included on the attached data tables.

Maintained roads will be "storm proofed" or upgraded for the 100 year storm event to minimize the risk of episodic erosion and sediment delivery. Storm-proofing techniques entail: 1) upgrading stream crossings by eliminating stream diversion potentials and upgrading culvert sizes; 2) removing unstable sidecast and fill material from steep slopes, headwater swales and along approaches to deeply incised stream channels where failures could result in sediment delivery; and 3) applying surface drainage techniques to disperse road surface runoff and disconnect road surface drainage from the stream channel network.

Specific details and drawings for each sediment treatment site are not included with this report, but will be available for field review and evaluation typical plan view diagrams are included. For each site proposed for treatment, there is a detailed field data form describing site conditions, risk of future erosion, and details of the proposed treatment. For all stream crossing sites, we have prepared sketch maps, as well as cross sections and profile surveys and design drawings for each proposed excavation or upgrade.

The specific erosion prevention plan for each site recommended for treatment includes the recommended treatment prescription, treatment specifications, needed materials and equipment (including heavy equipment), estimated equipment times (hours), needed labor, estimated costs to complete the project and a quantitative evaluation of treatment cost-effectiveness. This implementation information, as well as the expected benefit (in yds^3 "saved" from entering the stream system) have been detailed in the attached treatment tables. All proposed treatments for specific sites have be discussed with the landowner or land manager to ensure they are in conformance with existing or future management plans for the properties.

Virtually all future road-related erosion and sediment delivery in the Garrapata Creek watershed is expected to come from three sources: 1) the failure of road and landing fills (landsliding), 2) erosion at or associated with stream crossings (from several possible causes), and 3) road surface and ditch erosion. Treatments along these unstable and/or high yield roads will be accomplished by permanently decommissioning (closing) or "storm-proofing" (upgrading) the sites identified on the site location map (Map 2). These projects are carried out to "storm-proof" road systems (through road closure or road upgrades) and prevent or minimize accelerated sediment yield tto stream channels during future large magnitude storms. Old, unneeded roads and high impact roads have been identified during the watershed sediment source assessment, and 16% (n=16) of all the inventoried sites in Part 1 have been recommended for decommissioning. Road "storm proofing" on upgrade roads comprise 70% (n=71) of the project. Sites that were identified but not recommended for treatment total 14 sites or 14% of the inventoried sites. For Part 1, the basic data for the cooperators of the Garrapata Creek watershed sediment source investigation and erosion prevention plan are included and detailed in attached data tables 1-5.

Part 1: Maintained and Abandoned Road Assessment

The primary emphasis of the Garrapata Creek watershed assessment and erosion prevention planning project is to prioritize and prescribe treatments for existing and potential sediment sources identified along 11.9 miles of maintained and abandoned roads in the watershed. All roads proposed for treatment are prioritized and currently threaten to deliver eroded sediment to Garrapata Creek and its tributaries if they are left untreated. A number of sites have already failed and some are currently eroding. A number of sites show signs of pending and potential failure and sediment delivery.

Inventoried road-related erosion sites fell into one of three categories: 1) upgrade sites- defined as sites on maintained roads that are to be retained for homeowner access and land management; 2) decommission sites- defined as sites exhibiting the potential for future sediment delivery that have been recommended for either temporary or permanent closure and; 3) maintenance sites- defined as sites exhibiting wear and erosion of the road network which do not deliver sediment to the stream system. The majority of inventoried roads and sites are planned for upgrading.

Inventory Results

A total of **101** sites with sediment delivery were identified in this assessment (Map 2). These sites were identified as having a high, high-moderate, moderate, moderate-low or low risk of future erosion to the Garrapata Creek watershed. Sites include **49** stream crossings, **24** future landslides, and **33** miscellaneous "other" sites. Of the **101** inventoried sites, **92** have been recommended for erosion prevention treatment. In addition, 5.1 miles (89%) of the 5.7 miles of roads identified in the Garrapata Creek assessment area are "hydrologically connected" and currently deliver fine sediment and runoff to streams. Percents, volumes and other numbers in this report refer to point sites and road drainage treatments for all recommended treatment priorities.

Stream crossings - Forty nine stream crossings were identified in the field with **14** being culverted fill crossings, **31** unculverted fills, **2** bridges and 2 wet ford crossings (Table 1). Total future erosion and sediment delivery from stream crossing sites is approximately 3,933 yds^3 if erosion prevention measures are not undertaken.

Four road design conditions indicate a high potential for future erosion at stream crossings. These include: 1) undersized culverts (the culvert is too small for the 100-year design storm flow), 2) culverts that are prone to plugging with sediment or organic debris, 3) stream crossings with no drainage structures (fill crossings) and 4) stream crossings with a diversion potential. The worst scenario is for the culvert to plug and the stream to wash out or the stream to divert down the road in a major storm.

These road and stream crossing conditions are easily recognizable in the field and have been inventoried in the Garrapata Creek watershed assessment area.The most significant problem from stream crossings inventoried on roads in the Garrapata Creek watershed arise from stream crossings with a diversion potential. Of the 36 stream crossings recommended for treatment, 28 have a diversion potential and 10 are currently diverted (Table 1).

Landslides- Only those landslide sites with a potential for sediment delivery to a stream channel were inventoried. A total of 24 potential landslides were identified with a potential for future sediment delivery to the stream channels. Potential landslides account for approximately 23% of the inventoried sites in the assessment area (Table 1). Potential landslides are expected to deliver nearly 2,577 yds^3 of sediment to Garrapata Creek and its tributaries in the future. Correcting or preventing potential landslides associated with the road is relatively straightfoward, and involves the excavation of potentially unstable road fill and sidecast material.

Table 1. Site classification and sediment yield from all inventoried sites recommended for treatment on the maintained and abandoned roads in the Garrapata Creek watershed assessment area, Monterey County, California.

Site Type	Number of sites or road miles	Number of sites or road miles to treat	Future delivery (yds^3)	Stream crossings w/ a diversion potential (#)	Streams currently diverted (#)	Stream culverts likely to plug (plug potential rating = high or moderate)
Stream crossings	49	36	3,933	28	10	7
Other	28	28	928	-	-	-
Landslides	24	23	2,577	-	-	-
Total (all sites)	101	87	7,438	28	10	7
Persistent surface erosion[1]	5.7	5.1	14,865	-	-	-
Totals	**101**	**87**	**22,303**	**28**	**10**	7

[1] Assumes 25' wide road prism and cutbank contributing area, and 0.2' of road/cutbank surface lowering per decade for 3 decades.

There are a number of potential landslide sites located in the assessment area that did not, or will not, deliver sediment to streams. These sites were not inventoried using data sheet due to the lack of expected sediment delivery to a stream channel. They are generally shallow and of small volume, or located far enough away from an active stream such that delivery is unlikely to occur. All landslide sites with the potential for sediment delivery were inventoried using a data sheet.

"Other" sites - Twenty eight "other" sites were identified for future sediment yield to stream channels. "Other" sites include road surface drainage problems and ditch relief culverts. These sites are mainly excessive road/ditch drainage that concentrate flow and cause ditch relief culvert outlet gullies and hillslope gullies that deliver to a stream channel. Approximately 928 yds^3 of future sediment delivery is expected to occur associated with these 33 "other" sites. Together, these sites represent approximately 4% of the total predicted sediment delivery from future road-related erosion.

Chronic road surface runoff- Concentrated road surface runoff can generate fine sediment which can negatively impact general stream health and fish habitat. A total of 5.7 miles of the roadbed, ditch and cutbank currently persistently deliver fine sediment and runoff to stream channels (Table 1).

Cutbank, road bed and ditch erosional processes are predicted to yield 14,865 yds^3 (67%) of sediment to nearby streams over the next three decades, if road drainage practices remain the same. This will occur through a combination of 1) cutbank erosion delivering sediment to the ditch triggered by dry ravel, surface lowering, cutbank landslides and brushing/grading practices, 2) inboard ditch erosion and sediment transport, 3) direct impact and wearing down of the road surface, and 4) erosion of the road surface during wet weather periods. Relatively simple treatments can be applied to upgrade and decommissioned road systems to "disconnect" surface drainage and prevent this eroded fine sediment from entering stream channels prevent material from entering stream channels. These include installing a series or combination of road surface treatments such as rolling dips, cross road drains, insloping, outsloping, berm removal, and/or additional ditch relief culverts to disperse runoff.

Treatment Priority

The watershed assessment of future or potential erosion and sediment delivery sites is designed to provide information which can be used to identify and prioritize erosion prevention and erosion control and road decommissioning activities in the watershed. Not all of the sites that have been recommended for treatment have the same priority, and some can be treated more cost effectively than others. Treatment priorities are evaluated on the basis of several factors and conditions associated with each potential erosion site:

1) the expected volume and rate of sediment to be delivered to streams (yds^3),
2) the potential or "likelihood" for future erosion (high, moderate, low),
3) the "urgency" of treating the site (treatment immediacy - high, moderate, low)
4) the ease and cost of accessing the site for treatments, and
5) recommended treatments, logistics and costs.

The ***erosion potential*** of a site is a professional evaluation of the likelihood that erosion will occur during a future storm event. Erosion potential is an estimate of the potential for additional erosion, based field observations of a number of local site conditions. Erosion potential was evaluated for each site in the Garrapata Creek Watershed, and expressed as "High", "Moderate" or "Low." The evaluation of erosion potential is a subjective estimate of the probability of erosion, and not an estimate of how much erosion is likely to occur. It is based on the age and nature of direct physical indicators and evidence of pending instability or erosion. The likelihood of erosion (erosion potential) and the volume of sediment expected to enter a stream channel from future erosion (sediment delivery) play significant roles in determining the treatment priority of each inventoried site (see "treatment immediacy," below). Field indicators that are evaluated in determining the potential for sediment delivery include such factors as slope steepness, slope shape, distance to the stream channel, soil moisture and evaluation of erosion process. The quicker the rate and larger the potential future contribution of sediment to a stream, the more important it becomes to closely evaluate its potential for cost-effective treatment.

Table 2 outlines the treatment immediacy for all 87 inventoried sites with future sediment delivery along roads in the Garrapata Creek watershed. Altogether, five sites were identified as having a high treatment immediacy with a potential sediment delivery of approximately 2,775 yds^3. Nine sites were listed with a moderate-high treatment immediacy and these account for up to 61 yds^3. Thirty-seven sites were listed with a moderate treatment immediacy and these account for 7,139 yds^3. Twenty-six sites were listed with a low - moderate treatment immediacy these and account for up to 7,405 yds^3. Ten sites were listed with a low treatment immediacy and account for approximately 2,123 yds^3 of potential sediment delivery to the stream channel network.

Table 2. Treatment priorities for all 87 inventoried sediment sources recommended for treatment in the Garrapata Creek watershed assessment area, Monterey County, California.

Treatment Priority	Upgrade sites (# and site #)	Decommission sites (# and site #)	Problem	Future sediment delivery (yds^3)
High	**4** (site #: 51, 54, 55, 58)	**1** (site #: 83)	5 stream crossings	2,775
Moderate High	**8** (site #: 5, 7, 24, 25, 27, 50, 56, 59)	**1** (site #: 84)	2 stream crossings, 6 landslides, 1 other	2,861
Moderate	**29** (site #: 4, 8.1, 11, 23.1, 31, 32, 33, 35, 36, 37, 38, 39, 41, 42, 44, 45, 47, 48, 52, 53, 57, 62, 65, 74, 78, 89, 92, 120, 121)	**8** (site #: 16, 17, 20, 21, 23.2, 81, 82, 85)	11 stream crossings, 11 landslides, 15 other	7,139
Moderate Low	**21** (site #: 1, 6, 7.1, 8, 10, 12, 13, 14, 26, 34, 40, 43, 46, 49, 61, 63, 66, 68, 70, 72, 90)	**5** (site #: 15, 18, 19, 22, 23)	12 stream crossings, 5 landslides, 9 other	7,405
Low	**9** (site #: 2, 9, 60, 67, 69, 71, 73, 79, 91)	**1** (site #: 64)	6 stream crossings, 1 landslide, 3 other	2,123

Total	**71**	**16**	**36 stream crossings, 23 landslides, 28 other**	**23,303**

Treatment immediacy (treatment priority) is a professional evaluation of how important it is to "quickly" perform erosion control or erosion prevention work. It is also categorized as either "High", "Moderate",or "Low" and represents both the severity of the problem and urgency of addressing the threat of sediment delivery to downstream salmonid habitat. An evaluation of treatment immediacy considers erosion potential, future erosion and delivery volumes, the rate of erosion, the value or sensitivity of downstream resources being protected, and treatability, as well as, in some cases, whether or not there is potential for an extremely large erosion event occurring at the site (larger than field evidence might at first suggest). If mass movement, culvert failure or sediment delivery is imminent, even in an average winter, then treatment immediacy might be judged "High". Treatment immediacy is a summary, professional assessment of a site's need for immediate treatment. Generally, sites that are likely to erode or fail in a normal winter, and that are expected to deliver significant quantities of sediment to a stream channel, are rated as having a high treatment immediacy or priority.

One other factor influencing a site's treatment priority is the difficulty (cost and environmental impact) of reaching the site with the necessary equipment to effectively treat the potential erosion. Many sites found on abandoned or unmaintained roads require brushing and tree removal to provide access to the site(s). Abandoned roads require minor road rebuilding of washed out stream crossings and/or existing landslides in order to reach potential work sites farther out the alignment. Road reconstruction adds to the overall cost of erosion control work and reduces project cost-effectiveness. Potential work sites with lower cost-effectiveness, in turn may be of relatively lower priority. However, just because a road is abandoned and/or overgrown with vegetation is not sufficient reason to discount its need for assessment and potential treatment. Treatments on heavily overgrown, abandoned roads may still be both beneficial and cost-effective.

Evaluating Treatment Cost-Effectiveness

Treatment priorities are developed from the above factors, as well as from the estimated cost-effectiveness of the proposed erosion control or erosion prevention treatment. Cost-effectiveness is determined by dividing the cost ($) of accessing and treating a site, by the volume of sediment prevented from being *delivered* to local stream channels. For example, if it would cost $2000 to develop access and treat an eroding stream crossing that would have delivered 150 yds^3 (had it been left to erode), the predicted cost-effectiveness would be $13/yds^3 ($2000/150 yds^3).

To be considered for priority treatment a site should typically exhibit: 1) potential for sediment delivery to a stream channel (with the potential for transport to a fish-bearing stream), 2) a high or moderate treatment immediacy and 3) a good cost-effectiveness value relative to sites in the watershed. Treatment cost-effectiveness analysis is often applied to a group of sites (rather than on a single site-by-site basis) so that only the most cost-effective groups of sites or projects are undertaken. During road decommissioning, groups of sites are usually considered together since there will only be one opportunity to treat potential sediment sources along the road. In this case, cost-effectiveness may be calculated for entire roads or road reaches that fall into logical treatment units.

Cost-effectiveness can be used as a tool to prioritize potential treatment sites throughout a sub-watershed (Weaver and Sonnevil, 1984; Weaver and others, 1987). It assures that the greatest benefit is received for the limited funding that is typically available for protection and restoration projects. Sites, or groups of sites, that have poor cost-effectiveness values relative to sites in the watershed, or are judged to have a lower erosion potential or treatment immediacy, or low sediment delivery volumes, are less likely to be treated as part of the primary watershed protection and "erosion-proofing" program. However, these sites should be addressed during future road reconstruction (when access is reopened into areas for future management activities), or when heavy equipment is performing routine maintenance or restoration at nearby, higher priority sites.

Types of Prescribed Heavy Equipment Erosion Prevention Treatments

Roads can be storm-proofed by one of two methods including upgrading or decommissioning (closure). Upgraded roads are kept open and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate or withstand the 100-year storm. In contrast, properly decommissioned roads such as those on the Palo Corona Ranch, are closed and no longer require maintenance. Generic treatments for decommissioning roads and landings range from mild outsloping or simple cross-road drain construction, to full road decommissioning (closure), including the excavation of unstable and potentially unstable sidecast materials, road fills, and all stream crossing fills.

Road upgrading involves a variety of treatments used to make a road more resilient to large storms and flood flows. Erosion prevention work is recommended for several existing roads that are located in stable locations yet have potential for future sediment delivery. The most important of include stream crossings upgrading (especially culvert up-sizing to accommodate the 100-year storm flow and debris in transport, and to eliminate stream diversion potential), removal of unstable sidecast and fill materials from steep slopes, and the application of drainage techniques include berm removal, road outsloping, rolling dip construction, installation of bems, cleaning and cutting ditch and/or the installation of ditch relief culverts. When rolling dips are to be constructed on rock-suraced roads, itemized costs include 10 yds^3 of road rock per rolling dip to resurface the road**.**

Table 3 lists the specific treatments for all inventoried sites recommended for erosion prevention work in the Garrapata Creek assessment area. Recommended erosion prevention work includes decommissioning abandoned roads that have future sediment delivery and need road surface drainage improvements. Decommissioning consists of excavation filled stream crossingsm restoring altered channels to their natural channel gradients and contouring stream banks back to the natural hillslope gradient. Decommsissioning roads also includes cutting off the road drainage by utilizing different road surface treatments such as ripping and installing frequent cross road drains.

Labor intensive (hand labor) erosion control treatments are often needed on sites where heavy equipment has been used to perform road decommissioning and road upgrading. Hand labor is used to stabilize and revegetate soils exposed by heavy equipment operations. Only the most effective and cost-effective labor techniques have been prescribed. These include mulching, seeding and planting. Hand labor is used to attach downspouts and install stream crossing pipes compact stream crossing backfill around a newly installed stream crossing culvert and assist with other heavy equipment operations. In general, heavy equipment will perform most of the significant erosion prevention and erosion control work in drainage basins and along road networks.

Table 3. Recommended treatments along all inventoried roads in the Garrapata Creek watershed assessment area, Monterey County, California.

Treatment	No.	Comment	Treatment	No.	Comment
Critical dip	10	To prevent stream diversions	Inslope road	5	Inslope 485 feet of road to improve road surface drainage
Install CMP	4	Install a CMP at an unculverted fill	Outslope road	11	Outslope 4,228 feet of road to improve road surface drainage
Replace CMP	7	Upgrade an undersized CMP	Install rolling dips	113	Install rolling dips to improve road drainage
Install bridge	2	Install bridge and replace undersized CMP	Install berm drain	30	Install berm drain to rolling dip outlet
Install flared inlet	4	Install flared inlet to increase culvert capacity	Install ditch relief CMP	10	Install ditch relief culverts to improve road surface drainage
Excavate and remove soil	45	Typically fillslope & crossing excavations; excavate a total of 9,007 yds^3	Clean/cut ditch	1	Clean/cut 90 feet of ditch
Down spouts	5	Installed to protect the outlet fillslope from erosion	Cross road drains	49	Install cross road drains to improve road drainage
Wet crossing	7	Install 2 fords and 5 armored fill crossings using 160 yds^3 rip-rap	Rock road surface	134	Rock road surface using 1,617 yds^3 road rock
Clean CMP	1	Remove debris and/or sediment from CMP inlet	Reconstruct fill	1	Re-construct fill using an engineered design
Remove berm	8	Remove 3,213 feet of berm to improve road surface drainage	Other	4	Miscellaneous treatments
			No treatment recommended	14	

It is estimated that erosion prevention work will require the excavation of approximately 8,967 yds^3 at 19 stream crossing sites, 22 landslide sites and 2 “other” erosion sites (Table 3). Approximately 55%

of the volume is a result of excavating (decommissioning) crossings on abandoned roads, 45% of the volume is a result of excavating future landslides and approximately 45% of the volume excavated is associated with future landslides. Other miscellaneous treatments for inventoried sites on roads in the Garrapata Creek watershed assessment area will include a variety of road surface treatments (such as constructing rolling dips, critical dips, cross road drains, berm removal, road insloping and road outsloping) and installing additional ditch relief culverts to lessen erosion and fine sediment delivery from the road surface during wet winter months. Each treatment site has an individual data form which outlines the problem(s) and describes in detail the recommended treatment(s) and the estimated heavy equipment and labor requirements necessary at each site.

Equipment Needs

Table 4 list the expected heavy equipment and labor requirements, by treatment immediacy, to treat all the specific inventoried sites as well as the 5.1 miles of contributing (connected) road surfaces and ditches which contribute persistent road surface erosion and sediment delivery within the assessment area. Treatments for the 87 sites recommended for treatment in the Garrapata Creek watershed will require approximately 300 hours of excavator time, 397 hours of dozer time, 11 hours of grader time and 3 hours of backhoe time to complete all prescribed upgrading, erosion control and erosion prevention work (Table 4). Approximately 303 dump truck hours are needed for endhauling excess spoil. Dump truck times for road rocking following construction of rolling dips are included with rock costs. Two hundred and twenty four hours (224) of labor is necessary for installing new culverts, and other miscellaneous tasks, and 49 hours (not included in Table 4) are for mulching and planting activities. The remaining equipment hours apply to prescribed road opening costs (see Table 5)**.**

Labor Intensive Needs

Many potential work sites will need mulching, seeding and/or tree planting following erosion prevention work. These include fillslopes at stream crossings where fill is excavated or new culverts are installed, at spoil disposal sites and at fillslope excavations. Costs have been included for laborers to seed and mulch approximately 3.6 acres of ground following heavy equipment work along the Garrapata Creek watershed road system. Weed free straw mulch will be applied at 70 bales/acre.

Cost Estimate for Treating Inventoried Sites

Table 5 summarizes the necessary costs by equipment types for the 87 controllable sites with future sediment delivery. The estimate includes costs for seed and mulch, new culverts, landslide excavations, stream crossing decommissioning, as well as rock necessary for road surfacing at rolling dips and other road upgrade locations. "Treatment hours" represent direct equipment times for erosion control work but does not include time needed for conferences with equipment operators or additional costs for unseen complications. These additional times are accounted for as "logistics" and are added to the total equipment hours to determine the total project cost (Table 5).

Total operating costs for the project are estimated at approximately $396,586 to treat the 87 recommended sites with future sediment delivery and to significantly reduce sediment yield from the 5.1 miles of road feeding sediment annually to streams. The average cost effectiveness value of the project is $17.80 per cubic yard of sediment prevented from entering Garrapata Creek and its tributaries.

Costs in Table 5 assume that the work will be accomplished during two summers work periods using one equipment team. The cost estimate includes layout, coordination, monitoring, technical oversight and reporting hours for a professional to work with equipment operators to insure the plan is cost effectively implemented, as proposed, and treatments are installed or constructed properly and according to specifications.

Table 4. Estimated heavy equipment and labor requirements for treatment of all inventoried sites with future sediment delivery, Garrapata Creek assessment area, Monterey County, California.

Treatment Immediacy	Site (#)	Excavated Volume (yds^3)	Excavator (hrs)	Dozer (hrs)	Dump Trucks (hrs)	Grader (hrs)	Backhoe (hrs)	Labor (hrs)
High, High/Moderate	14	4,718	122	142	209	2	0	63
Moderate, Low/Moderate	63	5,111	146	214	85	7	3	133
Low	10	288	32	41	9	3	0	28
Total	**87**	**10,177**	**300**	**397**	**303**	**12**	**3**	**224**

Conclusion

The expected benefit of completing the erosion control and erosion prevention work lies in the reduction of long term sediment delivery to Garrapata Creek, an important steelhead trout stream. A critical first-step in the overall risk-reduction process is the development of a watershed plan. After several meetings and a formal presentation of preliminary findings, all the property owners involved in the assessment agreed to move forward with the second phase of this project. On May 18, 2002 The Garrapata Creek Watershed Council and PWA submitted the Garrapata Creek Watershed Restoration Implementation Project to CDFG for SB 271 grant approval, including all 87 treatment sites on the cooperating landowners' property. In developing this plan, all roads in an ownership or sub-watershed were considered for either decommissioning or upgrading, depending upon the risk of erosion and sediment delivery to streams, as well as future management needs. The property owners will continue to pursue funding for this erosion prevention work.

Good land stewardship requires that roads either be upgraded and maintained, or intentionally closed ("put-to-bed"). The old practice of abandoning roads, by either installing barriers to traffic (logs, "tank traps" or gates) or simply letting them naturally revegetate, is no longer considered acceptable. These roads typically continue to fail and erode for decades following abandonment. The proper word for proactive road closure is "decommissioning".

Decommissioning may be either permanent or temporary, but the treatments are largely the same. Properly decommissioned roads such as those on the Palo Corona Ranch, no longer require maintenance and are no longer sources of accelerated erosion and sediment delivery to a watershed's streams. The impacts of reopening old, abandoned roads so that they can be correctly decommissioned has been evaluated on a case-by-case basis, but the benefits (large reductions in long term erosion) almost always far outweigh the negative effects (small, short-term increases in erosion from bare soil areas).

Table 5. Estimated logistic requirements and costs for road-related erosion control and erosion prevention work on all inventoried sites with future sediment delivery in the Garrapata Creek watershed assessment area, Monterey County, California.

Cost Category[1]		Cost Rate[2] ($/hr)	Estimated Project Times			Total Estimated Costs[5] ($)
			Treatment[3] (hours)	Logistics[4] (hours)	Total (hours)	
Move-in; move-out[6] (Low Boy expenses)	Excavator	100	8	--	8	800
	Dozer	100	8	--	8	800
Road opening costs[7]	Excavator	165	6	--	6	990
Heavy Equipment requirements for site specific treatments	Excavator	165	258	77	335	55,275
	Dozer	140	259	78	337	47,180
	Dump Truck	75	303	91	394	29,550
	Backhoe	85	3	1	4	340
	Water truck	90	32	10	42	3,780
Heavy Equipment requirements for road drainage treatments	Excavator	165	42	13	55	9,075
	Dozer	140	138	41	179	25,060
	Grader	90	11	3	14	1,260
	Water truck	90	28	8	36	3,240
Laborers[8]		30	273	82	355	14,200
Rock Costs: (includes trucking for 2,507 yds^3 of road rock and 160 yds^3 of rip-rap sized rock)						106,689
Culvert materials costs (280' of 18", 315' of 24", 130' of 30", 225' of 36", 120' of 42"; Costs included for couplers, elbows, flared inlets and flume drains)						26,740
Mulch, seed and planting materials for 3.1 acres of disturbed ground[9]						1,607
2 Bridges (50', Engineered)[10]						40,000
Layout, Coordination, Supervision, and Reporting[11]		50	--	--	600	30,000
Total Estimated Costs						**$396,586**
Potential sediment savings: 22,303						
Overall project cost-effectiveness: $17.80 spent per cubic yard saved						

[1] Costs for tools and miscellaneous materials have not been included in this table. Costs for administration and contracting are variable and have not been included.

[2] Costs listed for heavy equipment include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[3] Treatment times include all equipment hours expended on excavations and work directly associated with erosion prevention and erosion control at all the sites.

[4] Logistic times for heavy equipment (30%) include all equipment hours expended for opening access to sites on maintained and abandoned roads, travel time for equipment to move from site-to-site, and conference times with equipment operators at each site to convey treatment prescriptions and strategies. Logistic times for laborers (30%) includes estimated daily travel time to project area.

[5] Total estimated project costs listed are averages based on private sector equipment rental and labor rates.

[6] Lowboy hauling for tractor and excavator, 4 hours round trip for two (2) crews to two areas within the Garrapata Creek watershed. Costs assume 2 hauls each for two pieces of equipment (one to move in and one to move out).

[7] Road opening costs are applied to roads that are currently abandoned and not driveable.

[8] An additional 49 hours of labor time is included for straw mulch and seeding activities.

[9] Seed costs equal $6/pound for erosion control seed. Seed costs based on 50# of erosion control seed per acre. Straw costs include 50 bales required per acre at $5 per bale. Sixteen hours of labor are required per acre of straw mulching. Does not include additional seed and mulch required on decommissioned road surfaces within the Water/Lake Protection Zones.

[10] Cost for the bridges are engineer's estimates from the local private sector. "I" beam construction; engineer certified

[11] Supervision time includes detailed layout (flagging, etc) prior to equipment arrival, training of equipment operators, supervision during equipment operations, supervision of labor work and post-project documentation and reporting). Supervision times based on 30% of the total excavator time for site specific treatments and 30% of the dozer time for road drainage treatments plus 1 week prior and 1 week post project implementation.

Currently unused, unmaintained and/or abandoned roads in the assessment area were recommended for either upgrading or permanent decommissioning. Three miles of roads are to be permanently closed by fully excavating stream crossings, excavating unstable road fill, decompacting road surfaces and installing road surface drainage structures. We have held discussions with landowners in the assessment area to discuss which roads represent good candidates for permanent decommissioning. All of these have been proposed for treatment over a two year period.

Road upgrading consists of a variety of techniques employed to "erosion-proof" and to "storm-proof" a road and prevent unnecessary future erosion and sedimentation. Erosion-proofing and storm-proofing typically consists of stabilizing slopes and upgrading drainage structures so that the road is capable of withstanding both annual winter rainfall and runoff, as well as a large magnitude storm events, without failing or delivering excessive sediment to the stream system. The goal of road upgrading is to strictly minimize the contributions of fine sediment from roads and ditches to stream channels, as well as to minimize the risk of serious erosion and sediment yield when large magnitude, infrequent storms and floods occur.

Part 2: 1991 Road Decommissioning Assessment

Roads on the Palo Corona Ranch were illegally re-constructed in 1990 without using required state or federal permitting. Pacific Watershed Associates (PWA) developed a site specific erosion control plan in 1990 to treat 7.7 miles of road impacted by the illegal road construction. A plan was written addressing existing and potential erosion problems that threatened to deliver sediment to local stream channels. The road decommissioning project was designed to protect and improve salmonid habitat through controlling and preventing road-related erosion on several inner gorge slopes of Wildcat Creek, a tributary to Garrapata Creek. The primary objective of the project was to implement cost-effective erosion control and erosion prevention work on high priority roads that were identified as a part of the comprehensive watershed assessment and inventory project for the basin. The most effective treatment available for the bulk of the most severe areas was the direct removal of remaining unstable, potentially erodible soil material using mechanized earth moving equipment.

Location

The 5,000 acre Palo Corona Ranch is located in steep coastal mountains roughly 10 miles south of Carmel, California. Most of the property is confined to three watershed areas: upper Doud Creek, upper Joshua Creek and Wildcat Creek. Most of the road system that received the erosion control and erosion prevention work is in the Wildcat Creek basin. Elevations range from approximately 1,000 feet in the lower portion of Wildcat Canyon to nearly 3,500 feet in the headwaters of the same basin and along ridge roads in two other watersheds.

Project Description

In 1990, PWA identified all sediment sources and developed an erosion control and erosion prevention plan for the 7.7 mile road system on what was previously known as Little Horse Ranch. The specific goal of the detailed mapping was to identify all locations where on-going or potential erosion threatened to deliver sediment to stream systems that could adversely affect on-site or downstream aquatic resources.

The main erosional processes of concern included mass soil movement of unstable sidecast material along road segments on steep slopes, as well as fluvial erosion (rain drop erosion, rill erosion and gully erosion) of soil material that had been pushed into stream channels or sidecast onto steep slopes adjacent to stream channels.

An implementation plan, *A Working Plan for Emergency Erosion Control and Erosion Prevention for Roads on the Little Horse Ranch.* (PWA 1990), was written for the County of Monterey. Overall recommendations for road reaches, as well as site-specific treatment prescriptions, were prepared for each road proposed for decommissioning. The report also included treatment specifications, needed materials and equipment, and estimated equipment times (hours), needed labor, and estimated costs to complete this project. The basic plan of action described a relatively straightforward approach for restoration. Where soil material generated from recent grading activities threatened to enter local stream channels, prescriptions called for 1) removal of whatever unstable material was still within reasonable reach of the existing road bed, 2) replacement in a nearby, stable location where it would not enter a channel and 3) protection of the bare soil areas that were exposed by these operations.

For the 2001-2002 Garrapata Creek Watershed Assessment and Erosion Prevention Planning project, PWA re-inventoried sites on the 7.7 miles of decommissioned road. The assessment included all recently (1991) decommissioned stream crossings, road reaches and swales related to the restored road system in the upper Wildcat sub-basin. For each treated work site that was identified, a database form was filled out and the site was mapped on a mylar overlay over a 1:12,000 scale aerial photograph

1991 Implementation

The 1991 Palo Corona road decommissioning project was conducted and administered by an outside construction and excavating business. Erosion control work was employed to remove unstable material and decommission the roads in the Garrapata Creek watershed and the Doud Creek watershed. On-the-ground implementation (road decommissioning) work was completed during summer flow periods when impacts to water quality would be minimal. All data reported in this report only refers to decommissioning work conducted in the Garrapata Creek watershed and its tributaries (Wildcat Creek).

Almost all roads and spurs that were decommissioned were located along the steep inner gorges of Class 2 and Class 3 stream channels. Roads ranged from upper and mid-slope areas throughout the watershed. Each road that was treated showed evidence of substantial past erosion, as well as considerable future potential for erosion and sediment delivery (PWA 1990).

Treatments were carried out in 1991 using a hydraulic excavator and bulldozer. A single excavator and tractor crew treated all 7.7 miles of road and decommissioned a total of 33 stream crossings. The excavator was used to: 1) open access to each site (brushing and filling of gullies), 2) excavate soil and organic debris (logs and chunks of wood) from the stream crossings, 3) place small volumes of excavated spoil on stable slopes near the decommissioned stream crossing, 4) decompact (rip) the road bed between stream crossing locations (especially if fill was to be stored on the old surface), 5) outslope the old road bed between sites, 6) mulch the treated road with logs, limbs and brush and 7) construct waterbars and cross-road drains on the decommissioned road. The bulldozer was used to help store the spoil locally, on stable portions of the old road surface, within about 500 feet to the stream crossing being excavated.

Review and Assessment of Decommissioned Roads

The field inventory form contained questions regarding the site location, the nature of decommissioned stream crossings, outsloped road reaches and excavated swales. Quantitative of post excavation erosion and the potential future volume of sediment to be eroded and delivered to streams was developed for each decommissioned stream crossing.

Inventoried road-related erosion sites fell into one of three assessment categories: 1) decommissioned stream crossings with evidence of future erosion- defined as sites on previously decommissioned roads that were not completely excavated and have remaining fill and evidence of future erosion; 2) decommissioned stream crossings with no evidence of future erosion- defined as sites that were treated properly, have all road fill removed from the stream crossing and are exhibiting no potential for future sediment delivery and; 3) decommissioned swale crossings- defined as excavated draws with no surface runoff, streambed or stream banks and no potential for future delivery.

Assessment Results

A total of 33 stream crossings were re-evaluated ten years after the recommended decommissioning treatments had been implemented. Obvious recent erosion was documented at each site. Future erosion from all stream crossings and swales along the decommissioned road were mapped and estimated in the field. The inventory determined post excavation volumes and future erosion volumes at 33 stream crossings, 49 swale crossings and 42 road reaches (Table 6).

Stream crossing adjustment occurred after in-stream decommissioned work was employed at all restored stream crossings. The post excavation adjustments ranged from 1 to 60 yds^3 of erosion and sediment delivery. Past erosion from stream channel adjustments at the decade old restored stream crossing sites totaled approximately 336 yds^3 (Table 6). Ten years after decommissioning work, during the field inventory field crews estimated 164 yds^3 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 yds^3.

The 1990 erosion control plan written by PWA estimated one season of work would require to excavate the stream crossings and steep unstable road fillslopes using heavy equipment. It was estimated that approximately 22,176 yds^3 of sidecast fill would be removed from 7.7 miles of road (Table 6). The original inventory (1990) identified treatments for 124 sites with potential sediment delivery in the Garrapata Creek watershed. Stream crossing excavation volumes at 33 stream crossings were determined to be 6,325 yds^3, or 29% of the total excavation work. During the initial 1990 assessment, unstable road fill along road reaches and swales were identified at 91 locations and determined to be 15,851 yds^3 or 71% of the total fill volume to be removed (Table 6). The initial heavy equipment estimated approximately 95 hours of excavator and 150 hours of dozer time to complete all prescribed road decommissioning, erosion control and erosion prevention work The majority of stream crossings and fillslopes excavations appeared to have been completed properly.

A properly excavated stream crossing has all road fill removed in a straight line or slightly concave profile at the elevation of the original natural channel. In essence, the original channel bed and side slopes are exhumed by the excavation. Any fill remaining within the excavated stream crossing would experience bank failures and downcutting through the remaining, erodible road fill. A proper stream crossing excavation also has the newly excavated stream banks removed to a gentle, stable hillslope grade. We found that stream crossings with stream banks excavated and sloped back at a ratio 2:1 (50%) showed little sign of post-excavation side-slope adjustment.

Conclusion

The implementation of erosion control and erosion prevention work on this decommissioned road project was an important step to protecting and restoring the Wildcat and Garrapata Creek watersheds and their anadromous fisheries. The road decommissioning and erosion prevention and stormproofing work has had an immediate benefit to the watershed's streams and aquatic habitat. It helps ensure that the biological productivity of the watershed's streams is not impacted by future human-caused erosion, and that future runoff can cleanse the streams of accumulated coarse and fine sediment rather than depositing additional sediment from managed areas. The decommissioning work completed on this project is a significant step toward realization of long term salmon habitat protection and improvement in the Garrapata Creek drainage.

Table 6. Past and potential sediment delivery from all decommissioned sites on 7.7 miles of road on the Palo Corona Ranch, Garrapata Creek watershed, Monterey County, California.

Site type	Number of sites or reaches treated	Total volume excavated (yds^3)	Post excavation delivery (yds^3)	Future delivery (yds^3)	Sediment savings
Stream crossings	33	6,325	336	164	5,545
Swales	49	0	5	5	0
Road reaches	42	15,851	0	0	13,120
Totals	124	22,176	341	169	18,665

The purpose of the 1991 road decommissioning project was to permanently reduce the amount of anthropogenic sediment that could have been delivered to Garrapata Creek and its tributaries from this poorly built road. It is estimated that over 22,000 yds^3 of material was excavated in this restoration project. In the initial inventory, it was estimated that approximately 18,665 yds^3 of sediment had a high potential to deliver to Garrapata Creek if it was not treated. Because of the effective treatments that were applied, less than 350 yds^3 of eroded sediment has been delivered in the last decade from the treated sites (Table 6).

With the extensive restoration of these 7.7 miles of road, a significant amount of sediment that once threatened this stream no longer poses a threat. It will take years to completely assess the overall benefits of the decommissioning project, but the immediate benefit of removing over 22,000 yds^3 of material, and preventing the delivery of over 18,000 yds^3 to the Garrapata Creek system should become apparent over the next several decades.

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