Redwood Creek Erosion Hazard Assessment
Summary Report

Inter-Agency Agreement No. 113311H124

Prepared for U.S. Fish and Wildlife Service

By
Redwood National and State Parks

August 7, 2003

Executive Summary

This report presents the results of road assessments recently completed in the 105,000-acre upper Redwood Creek watershed. The USF&WS, JITW program provided funds for the purpose of data management and on the ground assessment review for a portion of the upper watershed assessments that covered about 11,000 acres (11%) of the upper Redwood Creek watershed. The work provided for data integrity and management needed to produce this report and future reports that will layout plans that improve and protect habitat for anadromous salmonids by preventing or controlling erosion and sedimentation in the project area.

There are about 1,133 miles of road in the upper Redwood Creek watershed. Since 1996, nine assessment projects have been completed, evaluating 685 miles, or 60 percent of all roads in the upper watershed. A tenth and final assessment of 67 miles of road is underway that will raise the total miles assessed to about 752 miles, or 66 percent of all roads in the upper watershed. The assessments were funded primarily by California Department of Fish and Game SB 271 grants, with contributions from private landowners, Redwood National and State Parks (RNSP), and U.S. Fish and Wildlife Service Jobs-in-the-Woods Program (USF&WS, JITW).

This report summarizes in detail the findings related to 434 miles of road from the most recent road assessments, completed since 1999, where methods included collection of more detailed information. Data from the road assessments completed between 1996 and 1999 are included in various analyses when the data are known to be reliable.

Of the 434 miles of roads recently assessed, 41 percent were driveable, 52 percent were not driveable and the driveable status for 7 percent of the roads is unknown. Twenty-two percent of the road mileage was maintained, 68 percent was not maintained and the maintenance status for about 9 percent of the roads is unknown.

The total potential sediment yield from the 434 miles recently assessed is about 1,448,000 yds^3 or 3,400 yds^3/mile of road evaluated. Fluvial sites (stream crossings, gullies, etc.) account for 44 percent, landslide sites (road fill, landing fill, swale, etc.) account for 43 percent, and road surface erosion accounts for 13 percent of the total potential sediment yield.

We have reliable sediment yield data for 528 miles of roads. The total potential sediment yield from these 528 miles of roads is about 1,690,000 yds^3, or 3,200 yds^3 per mile of road. Fluvial sites account for 47 percent, landslide sites account for 42 percent and road surface erosion accounts for 11 percent of the total potential sediment yield.

The total potential sediment yield from the 528 miles of road represents a potential sediment input of 2,535,000 tons into Redwood Creek, equivalent to nearly three times its annual sediment load. If the relationship of roads to potential sediment yield holds true for the 50 percent of roads for which we do not have data, the total potential sediment yield could be more than five million tons, or six times the annual sediment load of Redwood Creek.

There were 1,717 stream crossings evaluated on the 434 miles of recently assessed roads. Twelve crossings were on fish bearing streams, or Class I watercourses. Two of the crossings may be migration barriers. One is scheduled for decommission in summer 2003, and the other should be evaluated further to determine whether treatment is needed. Excluding bridges and fords, 68 percent of the crossings had diversion potentials, 39 percent had medium to high culvert plug potentials, 85 percent of the culverts were undersized for the 100-year storm, and 18 percent of the crossings, referred to as "critical" crossings, had all three attributes. Critical crossings are most likely to divert a stream from its natural watercourse, because each critical crossing has a diversion potential, undersized culvert and at least medium plug potential.

Specific treatment costs were estimated as part of the recent assessments and total $13.8 million for 434 miles of road. Roads proposed for decommission total $6.3 million for 144 miles ($43,700/mile). Roads proposed for upgrade total $7.5 million for 202 miles ($37,200/mile). Proposed treatment are based on field conditions and, in some cases, landowner comments, but are not intended to obligate a landowner to a specific treatment of their roads. When extending the unit costs over *all* roads (both privately and publicly owned) in the upper watershed for which costs have not been estimated, the total treatment cost is estimated at about $37 million.

Three analysis methods using assessment results are provided as examples of how erosion control and prevention treatments can be prioritized. Sub-watersheds that consistently rank high in the analyses are Coyote, Dolly Varden, Headwaters East, Headwaters West, Johnson Prairie, Joplin, Lacks, Lake Prairie, Lee, Panther, Pilchuck, Powerline, Timbo, Tom and Wiregrass creeks. Lacks Creek has the highest total potential sediment yield (197,200 yds^3) but it is also the largest sub-watershed. Lacks Creek also contains the highest number of anadromous salmonid species. Lee Creek has the highest total potential sediment yield normalized by sub-watershed area (42,000 yds^3/mi^2) and mile of road evaluated (6,020 yds^3/mi.).

The riparian corridor along Redwood Creek has changed significantly since the advent of timber harvest. Once dominated by coniferous forests, today about 60 percent of the riparian corridor is dominated by hardwood forests. The greatest restoration opportunities likely exist in the reaches upstream of Highway 299, especially along the inner gorge. Riparian restoration opportunities exist through conifer planting and/or release, especially where Douglas-fir is established below hardwood canopies. Conservation easements for riparian corridors, especially for the inner gorge of Redwood Creek, could be established with willing landowners.

Preface

This report contains information previously reported in “Upper Redwood Creek Watershed Road Assessment Summary Report” (Bundros, et. al., 2003) prepared for California Department of Fish and Game. The earlier document contains additional information omitted from this report including more detailed cost estimates for erosion control implementation, additional watershed information on road density, landslide history and channel erosion, a watershed improvement plan, and additional maps and tables. This current report, prepared for U.S. Fish and Wildlife Service Jobs-in-the-Woods Program, contains a new section on monitoring and a description of the budget specific to Project 3 which was funded by the JITW Program.

Acknowledgements

The road assessments would not have been possible without the generous funding by U.S. Fish and Wildlife Jobs-in-the-Woods Program, California Department of Fish and Game SB 271 grants, landowner contributions and funding by the National Park Service.

The project would also not have been possible without private landowner cooperation. The private landowners in Redwood Creek were willing landowners who worked in partnership by providing access to their lands, funding, opinions and perspectives, and an optimistic outlook of improving watershed conditions. It is our hope that the report information is used appropriately and private landowners in Redwood Creek are never penalized for their trusting cooperation.

The road assessments in Projects 1, 2, 3 and 5 were managed by Mitch Farro of Pacific Coast Fish, Wildlife and Wetlands Restoration Association. We are grateful to Mr. Farro for his leadership role in Redwood Creek, as the projects would not have occurred without his involvement. Pacific Watershed Associates provided invaluable technical oversight, training and quality control during this work as a sub-contractor to PCFWWRA. We are extremely grateful to Randy Lew who provided consistent quality control. Most importantly, we acknowledge the field crews who worked so diligently under sometimes adverse field conditions. They are dedicated and highly skilled, and did an outstanding job.

Finally, we would like to acknowledge very talented GIS staff at RNSP. Without their dedication to resource assessments, quality spatial data and endless system maintenance, some of the analyses and most of the graphics contained in this report would not have been possible. We also thank Dr. Mary Ann Madej and Vicki Ozaki for their critical review and contributions of the original report.

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Introduction

In the watershed analysis for Redwood Creek (RNSP 1997), erosion and sedimentation from roads on private lands in the upper two-thirds of the watershed (upper watershed) were identified as major causes of the loss of aquatic and riparian habitats, and the decline of salmonid populations. The Redwood Creek Watershed Analysis, the Total Maximum Daily Load for Redwood Creek (U.S. Environmental Protection Agency (EPA), 1998), and the Draft Redwood Creek Water Quality Attainment Strategy for Sediment (California North Coast Regional Water Quality Control Board, 1998) all recommend road assessments that identify potential sediment sources, and plans that contain prioritized erosion control and prevention treatments.

In 1995 and 2000, Memorandums of Understanding (MOUs) between the National Park Service (NPS) and individual private landowners were signed and stated that the NPS and private landowners will "...voluntarily cooperate to identify, prioritize, and correct, where economically feasible, potential sediment sources in the Redwood Creek basin." These MOUs provide the framework for successful cooperative erosion control and prevention efforts on private lands in the upper watershed.

Road assessments began in 1996 and by 1998, 125 miles of road were evaluated. In 1999, the landowners, the NPS and Pacific Coast Fish, Wildlife and Wetlands Restoration Association (PCFWWRA) agreed to undertake a road assessment in the 26,000-acre Park Protection Zone (Project 1, Figure 1). This arrangement of cooperators provided a model for future projects, which led to three subsequent road assessment projects in the watershed (Projects 2, 3 and 5, Figure 1). Project areas were kept to a reasonable size and included groups of sub-watersheds tied together by geography, geomorphology or ownership patterns. Approximately 434 miles of roads were assessed in these four projects.

Since 1996, ten assessment projects have been completed or are underway (Table 1). These projects have been managed by Redwood National and State Parks (RNSP), Natural Resources Management Corporation (NRM), PCFWWRA, and Humboldt County. In 2003, a final project area (Project 7) will be completed, covering about 67 miles. Upon completion, about 752 miles of roads will have been assessed in the watershed. This is about 66 percent of the total 1,133 miles of road in the upper watershed. The remaining 34 percent of roads are owned by landowners who have either not replied or have declined our invitation to participate.

This report presents the results of the assessments in Projects 1, 2, 3 and 5 completed by PCFWWRA in partnership with RNSP. These projects, while funded and implemented separately, included overlap of many functions including logistics planning, database and GIS development and maintenance and data analysis. For this reason, the report describes methods and presents results for all 4 areas. We also present data from other assessments completed in the watershed and estimate the potential yield volumes and treatment costs for all roads in the upper watershed. Various analysis methods are presented that prioritize treatments.

Funding for Projects 1, 2, 3 and 5 was provided as shown in Table 2.

Figure 1.

Table 1. Road assessments in upper Redwood Creek watershed

Project	Sub-watersheds	Field Crew	Year(s)	Assessment Area (acres)	Total Road Miles in Project	Miles Evaluated
Project 96	Garrett Creek	RNSP	1996	Note 1	16.1	11.2
Project 97	Bradford Ck., etc	NRM	1996	7,040	90.6	31.2
Project 0	Lake Prairie and Headwaters	RNSP	1996	19,193	98.5	82.6
Project 1	Park Protection Zone (PPZ)	PCFWWRA	1999 - 00	25,641	222.3	186.8
Project 2	Dolly Varden Ck. to Lupton Ck.	PCFWWRA	2001 - 02	16,985	197.9	131.5
Project 3	Noisy Ck. to Smokehouse Ck.	PCFWWRA	2000 - 01	11,914	156.4	108.6
Project 5	Stover Creek	PCFWWRA	2001	1,592	18.5	6.8
Project 4	Roaring Gulch – Minor	NRM	1999 - 00	16,471	182.3	95.6
Project 6	County Roads	Humboldt County	2000	Note 2	Note 3	31.0[4]
Project 7	Captain – Simon, High Pr.	PCFWWRA	2003	6,063	150.0	0[5]
Totals[7]				**104,899**	**1132.6**	**685.4[6]**

Table notes:
1 Project 96 in Garrett Creek is a small area completely within Project 1. The area for Project 96 is not shown for simplicity of summing columns.
2 The area for the County roads is not easily described by an area measurement because county roads cross through other projects.
3 The total mileage for County roads is counted in other projects because County roads cross through other projects.
4 The miles of County roads that were assessed are counted independently from other projects because the assessment data are not yet contained in our GIS.
5 Project 7 has 67 miles currently in progress that will be completed in 2003. This will bring total roads assessed in all projects to 752 miles or 66% of all road mileage.
6 RNSP GIS currently contains information and data for 655 miles. It does not include the county road assessment of 31 miles nor all 67 miles in Project 7.
7 Totals may differ slightly from those shown in other tables due to rounding.

Table 2. Funding contributions for Projects 1, 2, 3 and 5.

Source	Funding
California Dept. of Fish and Game	$ 471,896
RNSP	102,400
U.S. Fish & Wildlife Service, Jobs-In-the-Woods Program	31,981
Simpson Resource Company	20,000
Barnum Timber Company	1,500
Kahn Properties	1,500
Total	$ 629,277

Description of Study Area

Watershed Description

Redwood Creek drains a 285 square mile watershed located in the Coast Range of Northern California. The watershed is steep and mountainous, located within a tectonically active area with relatively rapid uplift. Weak, pervasively sheared rocks underlie the watershed. Mean annual watershed-wide precipitation averages about 80 inches. The combination of steep terrain, weak underlying geology and soils, and moderately high precipitation contribute to naturally high erosion rates and susceptibility to accelerated erosion.

The watershed is unusually long and narrow, and has a very large number of small tributary sub-watersheds. There are no major tributary forks to Redwood Creek above Prairie Creek. Most tributaries are characteristically low-order and high gradient streams. Their channels are, in general, deeply incised, and steep hillslopes adjacent to channels are particularly landslide prone (Pitlick, 1982).

Land use

The major land use in the watershed during the past 60 years has been ranching and timber production. Historically, roughly 82 percent of the Redwood Creek watershed supported old-growth coniferous forests. Harvesting of the coastal redwood forests in portions of the lower Redwood Creek watershed began in the latter half of the 1800s. Mechanized timber harvesting established throughout the watershed by the late 1930s. Timber harvesting and associated road construction accelerated in the watershed in the late 1940s to 1950s in the Douglas-fir dominated upper watershed. During the 1960s timber harvest became most concentrated in the lower watershed, and logging continued steadily there until the expansion of Redwood National Park in 1978. By 1978, about 81 percent of the original forest in the watershed had been logged (Best, 1984).

Road construction history

The earliest roads in the Redwood Creek watershed coincided with settlement in the mid-1800s. New roads were continually built as settlement and ranching expanded. A rapid rise in road construction occurred along with increased timber harvest activities in the mid-1900s.

Road construction history for the Redwood Creek watershed was researched by RNSP in 1992-93 using stereo aerial photography. Photos were analyzed for photo years 1958, 1962, 1970, 1978 and 1992. Subsequently, photo year 1998 has been interpreted from digital orthophoto coverage. Road construction information after 1998 is from approved timber harvest plans. Some of these roads were verified by field crews during road assessments.

There are about 1,133 miles of roads in the upper watershed of which 1,040 miles are on private lands. About 61 percent of the road mileage was constructed before 1962, 88 percent was constructed before 1978, and 95 percent was constructed by 1992. Figure 2 shows the cumulative road mileage in the upper watershed since 1958.

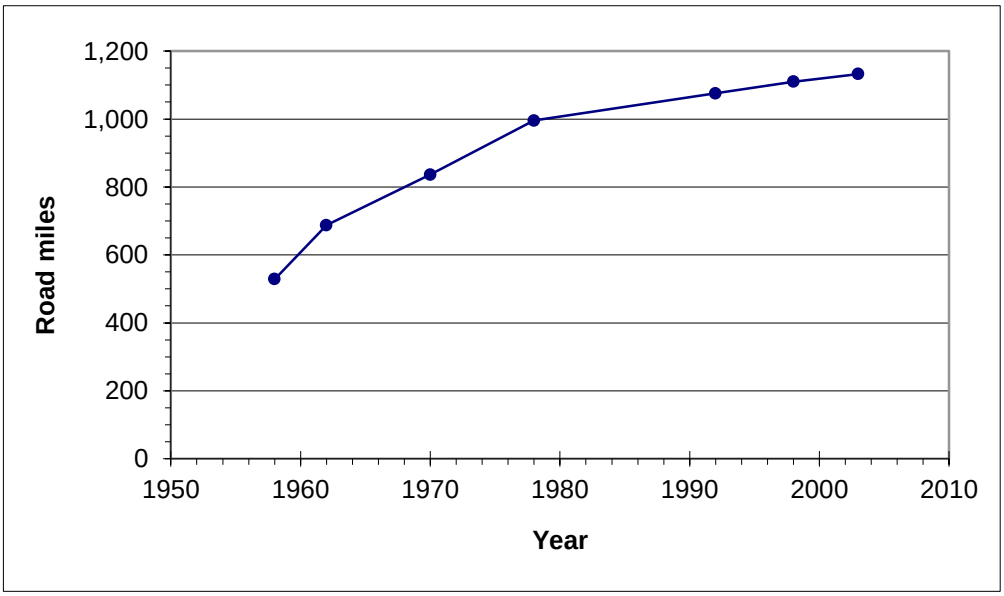


Figure 2. Road construction history since 1958 for upper Redwood Creek watershed.

The California Department of Forestry and Fire Protection (CDF) regulates forest practices on private lands. Timber harvest regulation by the state began in 1945, but was not fully implemented until the passage of the Z'berg-Nejedly Forest Practice Act of 1973. The first substantive erosion control rules for logging roads appeared in 1983.

The early history of forest practice rules is important to keep in mind when considering the road construction history in the Redwood Creek watershed. By 1983, more than 1,000 miles of roads in the upper watershed had been built to inadequate standards. More than 88 percent of the roads in existence today were built before forest practice rules had been fully implemented. This, in part, explains the legacy road conditions present in the watershed today.

Road density

Logging roads contribute sediment to streams by erosion of unpaved surfaces, cutbanks, and sidecast, and from gullies and landslides. Each process contributes a different size class of sediment, and each size class has potentially damaging effects on salmonid habitat and water quality. The average road density in the Redwood Creek watershed is nearly 7 miles per square mile. We do not know what road density is appropriate for Redwood Creek, but we believe the current road density is too high, and poses a significant risk to salmonids and water quality.

Methods and Materials

Previous Road Assessments in Redwood Creek

Several road assessments have been completed in the Redwood Creek watershed over the past decade. Most of data that are consistent with current assessment methods are used in some of the analyses in this report.

Redwood National and State Parks assessed about 250 miles of park roads in lower Redwood Creek in the early 1990s (RNSP, 1996). The data were collected for planning treatments on the parks' abandoned road system. These data are not used in this report because most of the park roads have been treated and this report focuses on lands in the upper watershed.

Pilot road assessments in the upper watershed were completed in the early- to mid-1990s. These were on Bureau of Land Management (BLM) lands in Lacks Creek performed by RNSP in 1992, and on private lands in the eastern headwaters of the watershed by NRM in 1996-97. These pilot projects were of small scope and used assessment methods sufficient to develop treatment plans and contracts for implementing work shortly after completion of the assessment. Both projects had treatments completed within one year of the respective assessment. Since most sites have already been treated, data from these assessments are not contained within out database.

Two moderately sized pilot road assessments were completed in the upper watershed by RNSP in 1996-97. These two projects, Project 96 and Project 0, evaluated about 94 miles of privately owned roads and were the first two assessments to occur following the signing of the MOUs between the NPS and private landowners. Data from these projects are contained in our database and are used in most analyses in this report.

Natural Resources Management Corporation completed a SB 271 grant funded assessment in the eastern portion of the watershed between Moon and Minor Creeks in 1999 (Project 97). The assessment methods were different enough from the methods used by PCFWWRA and RNSP that the data are difficult to analyze together. The NRM data are contained within our database, but have been excluded from analyses in this report that use potential sediment yield volume.

Road Treatments Subsequent to Road Assessments

Landowners in Redwood Creek have performed road upgrades and decommissions subsequent to some of the road assessments described in this report. These projects have been completed both individually and in partnership with RNSP, California Department of Fish and Game (DFG), USFWS, and others. RNSP records show that about 18 miles of roads have been decommissioned and 27 miles have been upgraded since 1995, but the records are incomplete. Many more miles of roads have been upgraded in conjunction with timber harvest plans and some landowners have upgraded roads as part of their road management programs. Our records also show that more than $1.1 million has been spent to upgrade and decommission roads in the upper watershed over that past 10 years. Again, this does not include work that has been

completed through timber harvest plans or as part of landowner road management programs. An additional $1.2 million is now secured for road treatments in 2003 through 2005. These projects will decommission and upgrade about 10 miles of highest priority roads. Project funds have come from the following sources: SB 271, 49%; Landowners, 22%; USFWS (Jobs-in-the-Woods), 13%; Clean Water Act, Section 319h, 11%; and RNSP, 5%.

While a significant amount of work has been completed we do not have enough information to fully describe what has been done. Because of this, we have not included the subsequent work in our tables or analyses, nor are they shown on the maps. Instead, we show and analyze the data that were collected at the time of the initial assessments. We will work with landowners to acquire information on upgraded and decommissioned roads so that we can better describe landowner efforts to reduce erosion and sedimentation from existing roads in a future report.

Current Road Assessment

This section describes the details of the road assessments recently completed in Projects 1, 2, 3 and 5 performed jointly by RNSP and PCFWWRA. The U.S. Fish-and Wildlife Service Jobs-in-the-Woods Program provided funds for Project 3.

Assessment fieldwork

Road assessment fieldwork for Projects 1, 2, 3 and 5 began in June 1999, and concluded in February 2002. Field crews walked all roads to identify and evaluate existing and potential erosion sites. This included sites where sediment would likely be delivered to a stream channel and all ditch relief culverts (DRC). For each assessment site, a data form was filled out, and the site was located and mapped on 1:6,000 1997 aerial photography. Each site was flagged and marked with an orange aluminum tag for locating in the future.

The field form (Appendix A), when completed, contains basic information about the type, nature, and location of each potential erosion site on a road. A form was also completed for each DRC along a road, even if the DRC had no potential erosion. The field form is organized in five sections as follows: general site information, fluvial site, landslide site, treatments, and fill and future erosion volumes. The form guides the field crew as they document the critical information needed to describe the potential erosion site. The crew then prescribes needed erosion control or prevention treatments, and surveys the sites to quantify volumes.

The form allows a detailed tape and clinometer survey of a site to be recorded. The survey is used to estimate potential erosion volumes and excavation volumes necessary for treatments (e.g., excavation volumes for decommissions, culvert replacements, etc.). Recommended treatments and needed equipment and labor are also recorded. The crew also provides a written description and simple sketch of each site.

All field crew members were previously trained by Pacific Watershed Associates (PWA) and had completed numerous road assessments prior to starting the Redwood Creek assessments. PWA and RNSP provided additional training on issues specific to Redwood Creek immediately before work began in the watershed. The crews worked in teams of two. For quality control, each

assessment site was field reviewed by an experienced geologist from PWA. In addition, about 20 percent of the sites were field checked by experienced geologists from RNSP.

Volume calculations and limitations

As used in this report, "site potential yield" and "site potential erosion" are synonymous with "future yield" and "future erosion" (respectively) found on the assessment form (Appendix A). Site potential yield is the amount of sediment that is reasonably expected to be delivered to a watercourse if site failure occurs.

Fluvial sites

Site potential yield at a stream crossing is estimated from tape and clinometer surveys of the crossing fill. The field crew surveys a profile through the stream crossing that follows a straight line and approximates the center of the stream valley. The profile begins in the undisturbed or stable channel above the crossing, extends downstream across the roadway and down the fillslope to the channel below the crossing. When drafted, an accurate profile survey reveals the original channel grade through the crossing. The site potential yield is estimated by assuming that, on average, a stream will eventually erode the crossing to its original channel grade and width, and will erode sideslopes to a 1:1 (100%) slope.

For stream crossings where decommission is proposed, the surveyed profile is used in combination with cross-section surveys to determine the fill volume in the crossing. The fill volume is the amount of fill that would be excavated from the crossing to expose the original or near original stream bed, with a channel width similar to the channel and valley width above and below the crossing. The default design uses 2:1 sideslopes (50%) for calculating the estimated fill volume. The actual crossing excavation will be influenced by bedrock and stumps, which guide the final excavation and reveal original, pre-road conditions.

The estimated *site potential yield* is generally always less than the estimated *fill volume* of a stream crossing. Field observations of eroded stream crossings have shown that road fill within a crossing typically erodes a void similar to a gully through the fill and not all road fill within a crossing will be eroded. The eroded gully can be of any shape, but generally, by assuming 1:1 side slopes, the volume is estimated using a consistent method and represents a typical average volume.

For stream crossings where upgrade is proposed, the surveyed profile provides a means for determining proper culvert placement on channel grade, length of culvert needed and, where appropriate, the length of downspout needed. The volume of fill that must be excavated and replaced during a culvert upgrade can also be determined from the surveys.

Fluvial erosion at ditch relief culvert outlets, springs and along road reaches is estimated by assuming reasonable dimensions of a gully that could potentially form or enlarge at the site.

Stream diversions – Site potential yield from stream diversions was not estimated during the assessments. Stream diversions can cause a substantial amount of erosion and sedimentation, but estimating the potential yield from future, hillslope gully erosion would be speculative and most likely incorrect.

Landslide sites

Estimates for site potential yield at a landslide site were determined by delineating the boundaries of the future landslide, calculating the volume of the material and then estimating the percent of the volume that was expected to reach a stream. The site potential yield generally includes only the erosion volume directly associated with the road prism. For most landslide sites, the yield does not include the volume of material that can erode downslope from a road when road failures occur, nor the volume associated with larger landslide features that can extend far upslope or downslope from the road. Field crews measured only that portion of the landslide mass that could be directly associated with the road prism. There were two situations where the yield included more than just the road prism. These sites were: 1) deep seated landslides where the road mass likely initiated a failure that incorporated native ground, and; 2) landslide sites where 'extreme erosion' had been identified and quantified. Other than these two exceptions, the total volume associated with a large landslide that may or may not be exacerbated by a road was not quantified as part of this assessment. Because volume calculations for most landslide sites are based only on the road prism, volume and yield estimates for potential landslide erosion are likely conservative.

Culvert diameter sizing

Recommended culvert diameters were sized using two methods and choosing the larger of the two results. The first method used field evidence including natural channel cross-sectional area and existing culvert rust line. The second method used standard published runoff equations.

In the first method, channel cross-sectional area (average channel width x average channel depth) for the 100-year storm was estimated in the field as part of the assessment and was reported on the assessment form. The crew then made a field decision on the adequacy of the existing culvert diameter by comparing the channel cross-sectional area to the existing culvert inlet area. If determined undersized, the field crew recommended a larger culvert diameter equal to the channel cross-sectional area. The culvert rust line was also used to determine whether or not a culvert was undersized. A rust line that exceeded 50 percent of the circumference was used as a criterion indicating an undersized culvert.

The second culvert sizing method was an office exercise that estimated 100-year discharge based on Waanenen and Crippen (1977) for drainage areas 80 acres and greater, and the rational method (Dunne and Leopold, 1978) for drainage areas less than 80 acres.

There are inherent errors in both the field and the office methods when sizing culvert diameters. In the field, errors occur when estimating the channel dimensions of the 100-year storm discharge. In the office, errors occur when delineating drainage areas from topographic maps. We used a 10-meter digital elevation model (DEM) produced by RNSP as a base for delineating drainage areas.

During project level planning, the recommended culvert diameter should be evaluated in the field prior to finalizing a culvert replacement. Results from both the initial field call and the office determination should be used in combination with other field evidence to correctly determine culvert size.

Database and GIS

All data collected as part of the road assessments are contained in a relational database using Microsoft Access™ 97. All GIS data are maintained in ESRI ArcInfo™.

We maintain a single database that contains the data from all assessments for which data are available. Data that are not contained in the database are Project 97, Project 6 (county roads) and Project 7 data (Table 1). Project 97 was completed by NRM and we do not have those data. Project 6 was completed as part of a five-county assessment and will be included in the database in the near future. Project 7 is underway and will use the same methods and form as the current road assessments (Projects 1, 2, 3 and 5). Those data will be included in the watershed-wide database and future analyses.

Results and Discussion

Projects 1, 2, 3 and 5 contain approximately 595 total road miles of which approximately 434 miles of roads were assessed. The 161 miles not assessed were mostly roads on land where access was denied. A small amount of the roads identified on maps were not found in the field.

Driveability and Maintenance Status

Of the 434 miles evaluated, about 181 miles of roads were driveable by a standard 4WD vehicle and about 222 miles were not driveable. The driveability was not documented for about 31 miles of road. Road driveability is summarized in Table 3.

Table 3. Driveability of all assessed roads in Projects 1, 2, 3 and 5.

Driveability	*Miles*	% of Total Assessed Miles
Driveable	181	41%
Not driveable	222	52%
Unknown	31	7%
Total Assessed in Projects 1, 2, 3 and 5	434	100%

Table notes: Totals may differ slightly from those shown in other tables due to rounding. Driveability is as documented at the time of assessment.

The road maintenance level was also documented during the assessment. Field crews described roads as maintained, unmaintained, or decommissioned. Maintained roads are roads that show evidence of recent maintenance, including cleaning of culvert inlets, trash racks, and inboard ditches, grading, rolling dip or waterbar reconstruction, brushing, culvert replacement, or reconstruction of fills. Roads identified as unmaintained lacked obvious maintenance to culverts and ditches, and vegetation was encroaching the road and road surface. The road may or may not have been driveable. Decommissioned roads were roads blocked to vehicular access. Fills

and culverts had been removed from stream crossings, unstable fills pulled-back, and permanent road drainage provided by outsloping, rolling dips or cross-road drains. There were also partially decommissioned roads where not all of the crossing fill had been removed from stream crossings, culverts remained, and potential sediment yield was documented. There were about 97 miles of maintained roads, 296 miles of unmaintained roads, and about 1 mile of decommissioned or partially decommissioned road. The status was not documented for about 39 miles of roads. Table 4 summarizes these data.

Table 4. Maintenance status of all assessed roads in Projects 1, 2, 3 and 5.

Maintenance Status	*Miles*	*% of Total Assessed Miles*
Maintained	97	22%
Unmaintained	296	68%
Decommissioned	0.3	0%
Partially Decommissioned	0.8	0%
Unknown status	39	9%
Total assessed in Projects 1, 2, 3 and 5	434	100%

Table notes: Totals may differ slightly from those shown in other tables due to rounding. Status is as documented at the time of assessment.

Prescribed Road Treatments

Roads were assessed on 26 separate ownerships. As field crews conducted the assessment, sites were assigned a treatment type of decommission, upgrade or maintain. The larger industrial timberland owners provided lists of roads that could be prescribed for decommission during the assessment. Accordingly, all sites on roads assessed were prescribed for either decommission or upgrade based on landowners' guidance or field conditions that clearly showed a road had been located in a geomorphically unstable setting. Approximately 144 miles (33%) of roads were prescribed as decommission, 207 miles (48%) as upgrade and 83 miles (19%) of roads currently need no treatments other than routine maintenance. Road treatment prescription are summarized in Table 5.

Table 5. Road treatments prescribed for Projects 1, 2, 3 and 5.

Prescribed Treatment	Miles Prescribed for Treatment	% of Total
Decommission	144	33%
Upgrade	207	48%
Maintain	83	19%
Totals	434	100%

The treatment type assigned to each site by the field crews was purely a 'call' that guided the type of information collected at the site. It was not meant to reflect a commitment or obligation by the landowner to treat the road as prescribed. While we encourage road decommissioning to reduce the road density in the upper Redwood Creek watershed, the landowner will ultimately decide how a road will be treated.

Regardless of the prescription assigned at the time of the assessment, the basic information gathered during the assessment can still be used if prescriptions change. For example, if the landowner decides they would like to upgrade a road that had been prescribed as decommission, the basic information gathered during the assessment can be adjusted to provide an estimate of the needed work. Similarly, for roads that had been prescribed as upgrade, the data can be re-worked for decommission treatments. This second scenario requires additional time in the field to determine such things as: where to store spoils, how to haul spoils, estimating equipment production rates for more complex excavations, etc. In both cases, the information from the original road assessment must be ground-truthed and a budget developed for the specific project.

Potential Sediment Yield

For each site in the assessment, the *site potential yield* was measured in the field. It is the volume of material that can potentially erode and be delivered to a stream during a large storm from the erosion site. An *extreme potential yield* was also estimated in the field, but only where the potential for an extreme erosional event (e.g., a debris torrent initiating at a stream crossing) was identified at a site. The extreme potential yield is larger than the site potential yield. In this report, *potential sediment yield* is the larger of *site potential yield* or the *extreme potential yield* for each site. For example, a stream crossing has a site potential yield of 500 cubic yards. The stream crossing also has the potential to debris torrent down a steep slope, which would yield an estimated 2,500 cubic yards of sediment during an extreme erosional event. In this example, the *potential sediment yield* is 2,500 cubic yards. If the stream crossing did not have an *extreme potential yield* (did not have debris torrent potential), then the *potential sediment yield* would be simply the *site potential yield* of 500 cubic yards.

A total of 3,359 sites were evaluated in the field. Sites were categorized into two groups based on the dominant erosional process at the site. Fluvial sites generally included haul road and skid road crossings, DRCs, road reaches, springs. Landslide sites generally included debris slides and deep-seated features. There were 2,663 fluvial erosion sites and 694 landslide sites. Site locations are shown on maps in Appendix C. General site information is summarized in Table 6.

Fluvial erosion sites

The 2,664 fluvial sites can potentially deliver nearly 647,000 yds^3 of sediment to streams. About 93 percent of the sediment is from stream crossings. The remainder is from skid trails and gully erosion from ditch relief culverts, and along road reaches. Potential sediment yield from stream diversions was not estimated, but can be significant. Data for fluvial erosion sites are summarized in Table 7.

Table 6. Potential sediment yield for Projects 1, 2, 3 and 5.

	No. of Sites	Erosion Volume[1] (yds^3)	Site Potential Yield (yds^3)	Extreme Potential Yield[2] (yds^3)	Potential Sediment Yield [3] (yds^3)	% of No. of Sites	% of Pot. Sediment Yield
Sites Inventoried	3,359	1,652,892	944,666	582,250	1,296,324	100%	100%
All Sites with no yield	401	5	0	500	500	12%	0%
All Sites, Yield > 0	2958	1,652,887	944,666	581,750	1,295,824	88%	100%
M-H Sites, Yield > 0	1942	1,140,482	724,300	459,750	1,006,268	58%	78%
All Fluvial Sites	2,663	594,460	593,912	87,250	647,071	79%	50%
All Landslide Sites	694	1,058,432	350,754	495,000	649,253	21%	50%
Field Prescriptions							
Decommission	1,416	1,017,266	471,242	404,250	714,270	42%	55%
Upgrade	1,584	631,455	469,392	174,500	574,566	47%	44%
Maintain	359	4,171	4,032	3,500	7,488	11%	1%

Table notes:
[1] Erosion Volume is that amount of sediment that can potentially erode from a site. Not all sediment eroded will be delivered to a stream.
[2] Only 372 of 2,958 sites with site potential yield greater than 0 had an extreme potential yield.
[3] Potential Sediment Yield is the greater of the site potential yield and the extreme potential yield for each site then summed for all sites. It is not the sum of the two columns "Site Potential Yield" and "Extreme Potential Yield".
Totals may differ slightly from those shown in other tables due to rounding.

Table 7. Selected information for fluvial erosion sites in Projects 1, 2, 3 and 5.

	All Urgency Sites		Medium to High Urgency Sites			
Fluvial Features, Yield>0	No. of Sites	Potential Sediment Yield (yds^3)	No. of Sites	Potential Sediment Yield (yds^3)	% of No. of Sites	% of Pot. Sediment Yield
Road Crossings	1,710	604,700	1,166	473,800	68%	78%
DRC and Swale	338	22,400	134	18,500	40%	82%
DRC, no sediment delivery	380	0	0	0	0%	0%
Road Reaches	125	5,400	62	2,890	50%	54%
Skid Trail Crossings	91	14,100	65	10,840	71%	77%
Totals	2,644[1]	646,600	1,427	506,100	54%	78%

Table notes:
[1] The total number of sites does not equal the number of fluvial sites shown in Table 6 due to some sites being counted in more than one fluvial feature type.
Totals may differ slightly from those shown in other tables due to rounding.

Fish passage at stream crossings

In Projects 1, 2, 3 and 5 there were 12 Class I (fish bearing) stream crossings (Table 8). Of those, two crossings *may* be partial or complete barriers for fish at some life stage. Of these two,

one is currently targeted for decommission and is included in a SB 271 funded project scheduled for summer 2003. The other *potential* fish barrier site is on the Dolly Varden Road in Cashmere Creek about 2,400 feet from the confluence with Redwood Creek. Fish were seen at the crossing at the time of the inventory. The stream was not assessed to determine whether the fish were resident or anadromous, or if the crossing was truly a barrier and to what degree. However, the bridge logs are collapsing into the channel and substantial sediment is stored within and upstream of the large diameter redwood logs.

Table 8. Status of Class I stream crossings in Projects 1, 2, 3 and 5.
Shaded sites are potential barriers.

Site ID	Road	Location	Type	Urgency	Comment
2017021	O-Line	Mainstem Panther	Bridge	Low	Landowner recently replaced undersized culvert with Bridge.
2052028	1300	Mainstem Panther at Redwood Creek	Removed bridge	Low	Landowner removed bridge. Abutments and sill remain. DFG and others proposing to manipulate the sediments downstream of sill to improve fish access.
2053025	1305	Mainstem Joplin	Blown-out	Low	Culvert blown-out to original grade.
2064050	LC4000	Tributary to Lacks	Blown-out	Medium	"King's Crossing". Culvert blown-out.
2073007	RC-1	Mainstem Lacks	Bridge	Low	Bridge.
2078004	LC-11	Mainstem Lacks	Ford	Low	Ford immediately above bridge.
4036001	K&K West	Redwood Creek	Removed bridge	Low	Landowner removed bridge across Redwood Creek.
4037223	Dolly Varden	Cashmere	Old log bridge	Med-High	Failing Humboldt-Bridge **may be barrier. Need to Replace.**
4037269	Dolly Varden	Mainstem N. F. Dolly Varden	Old log bridge	Med-High	Failing Humboldt-Bridge **may be barrier**. SB 271 scheduled for decommission in 2003.
5038016	UPR-10	Mainstem Windy	Bridge	Med-High	Bridge seriously constricting channel. **Need to Replace.**
5044018	L2000-CN	Noisy	Bridge	Med	Bridge condition is OK. Road drainage treatments are medium urgency.
5101003	N950	Noisy	Fill crossing	Low	Low volume, low gradient fill crossing.

Treatments at all Class I stream crossings should be designed to meet fish passage guidelines.

Landslide erosion sites

The 694 landslide sites can potentially deliver over 649,000 yds^3 of sediment to streams. About 86 percent of the sediment is associated with road reaches and landings. The remainder is associated with other locations not restricted to the road or landing prism. About 77 percent of the potential sediment yield from landslides is at medium to high urgency sites. Data for landslide erosion sites are summarized in Table 9.

Table 9. Selected information for landslide erosion sites in Projects 1, 2, 3 and 5.

Landslide Features, Yield>0	All-Urgency Sites		Medium to-High Urgency Sites			
	No. of Sites	Potential Sediment Yield (yds^3)[3]	No. of Sites	Potential Sediment Yield (yds^3)[3]	% of No. of Sites	% of Potential Sediment Yield
Roads	496	322,000	377	268,900	76%	84%
Landings	104	101,800	80	88,000	77%	86%
Road-Hillslope	82	182,400	54	133,800	66%	73%
Hillslope	12	43,100	4	9,500	33%	22%
Totals	694	649,300	515	500,200	74%	77%

Table notes
Totals may differ slightly from those shown in other tables due to rounding.

Road drainage and surface erosion

Proper road surface drainage is essential to any road system. When properly configured by ditch relief culverts, outsloped road surfaces and/or rolling dips, road surface drainage distributes surface runoff uniformly along a road, and prevents concentrated surface runoff that can lead to sheet, rill and gully erosion. Reducing the amount of road surface and inboard ditch that drains directly to streams reduces chronic fine sediment delivery to streams.

Field crews evaluated the road surface drainage as they performed road assessments for Projects 1, 2, 3, and 5. They noted the number, frequency and conditions of ditch relief culverts, the need for inboard ditch repair, and considered where outsloping road surfaces might be appropriate. They also measured the length of road surfaces and inboard ditches that drained directly to stream crossings. Of the 434 miles of road evaluated, 234 miles (54%) of inboard ditches or road surfaces drained directly to streams.

A simple calculation with reasonable assumptions can estimate the level of sediment delivery due to road-stream connectivity. For example, if the combined road and ditch width is 20 feet and their surfaces are lowered, on average, by two inches over 234 miles in a 10-year period, surface erosion would deliver roughly 152,500 yds^3 of fine sediment to project area streams, averaging 15,250 yds^3 annually. By no means is this meant to reflect what will actually occur, but the estimated volume of fine sediment in this example shows the relative importance of disconnecting road and inboard ditch surfaces from streams. Table 10 summarizes the three general categories of potential sediment sources for all roads assessed in Projects 1, 2, 3, and 5. The potential sediment delivery from medium to high urgency sites is about 1,158,800 yds^3, averaging about 2,700 yds^3 per mile. Fluvial sites account for 45 percent of the volume, landslides account for about 43 percent and road surface erosion about 13 percent.

Table 10. Summary of potential sediment sources from 434 miles in Projects 1, 2, 3 and 5.

Sediment Source	Potential Sediment Yield All Urgency Sites (yds^3)	% of Total Potential Sediment Yield (all urgency)	Potential Sediment Yield (Medium to High Urgency) (yds^3)	% of Potential Sediment Yield (Medium to High Urgency)	Average Pot. Sediment Yield from Med to High Sites (yds^3 / mi.)	Average Pot. Sediment Yield from all Sites (yds^3 / mi.)
Fluvial sites	646,600	45%	506,100	44%	1,200	1,500
Landslide sites	649,300	45%	500,200	43%	1,200	1,500
Road surfaces[1]	152,500	10%	152,500	13%	400	400
Totals	1,448,400	100%	1,158,800	100%	2,700	3,400

Table notes

[1] Volume is only an estimate based on length of roads and/or ditches connected to streams.

[2] Totals do not sum equally and may differ slightly from those shown in other tables due to rounding.

Road Treatment Costs

Costs were calculated for all work identified during the field assessments in Projects 1, 2, 3 and 5. Costs have been determined separately for each of the two road treatment types – decommission and upgrade. They are strictly a scope of costs for Projects 1, 2, 3 and 5. Actual costs will vary based upon final field evaluations at the project level and the landowner's decision to upgrade or decommission a road.

Site specific costs were calculated first for each site evaluated based on equipment and labor needs identified on the field form. Other costs associated with treatments, such as equipment mobilization, road opening and rebuilding, road drainage treatments, culvert materials, and mulching were summed for the entire assessment area. Additional costs for project layout, coordination, supervision and reporting were added as an aggregate amount to the total project cost.

All costs described above are listed and summed in Table 11 to calculate the total estimated cost for treating sites identified in Projects 1, 2, 3 and 5.

Excluding routine road maintenance, the total estimated cost to treat roads prescribed for decommission is $6.3 million, averaging about $43,700 per mile of road. For decommission roads, costs are calculated for all sites and all treatment urgency levels. It is anticipated that all sites along a decommissioned road would be treated when cost-effective to do so.

For roads prescribed as upgrade, the total estimated treatment cost is $7.5 million, averaging about $36,300 per mile of road. Costs for upgrade sites are only calculated for medium to high urgency sites. Treatments at lower urgency sites are likely not critical, so limited funds would be spent most effectively treating higher urgency sites.

Table 11. Estimated road treatment costs for all evaluated sites in Projects 1, 2, 3 and 5.

Item	Decommission	Upgrade	Maintain	Totals
Miles prescribed for treatment	144	207	83	434
Site specific treatments	$ 3,537,900	$ 3,217,500	0	$ 6,755,400
Mobilization	$ 39,600	$ 34,700	0	$ 74,300
Equipment and labor logistics	$ 707,900	$ 652,300		$ 1,360,200
Road opening and rebuilding	$ 176,900	$ 32,200	0	$ 209,100
Road drainage	$ 175,300	$ 558,500	0	$ 733,800
Culvert materials	$ 0	$ 1,221,600	0	$ 1,221,600
Mulch	$ 207,600	$ 64,700	0	$ 272,300
Layout, coordination, supervision and reporting (30% of above costs)	$ 1,452,600	$ 1,734,500		$ 3,188,100
Totals	$ 6,299,900	$ 7,516,200		$13,815,300
Average treatment cost per mile	$ 43,700	$ 36,300	0	$ 31,800

Compiled Results from all Completed Assessments

This section summarizes data from all road assessments completed since 1996 in the upper Redwood Creek watershed that are contained in our database. As shown in Table 12, about 685 miles (61%) of the 1,133 miles of roads in the upper watershed have been evaluated. However, our database contains data for 623 miles. We do not have data for 31 miles of roads in Project 97, 31 miles of roads in the Humboldt County assessment and 67 miles of roads in Project 7 which is currently in progress.

Road Conditions for all Completed Assessments

Road maintenance status and driveability were recorded during most road assessments and is summarized in Tables 13 and 14 (respectively) and shown in Appendix D. Driveability and maintenance status is as documented at the time of assessment.

Table 12. Projects, road miles and data use for assessment projects in the upper Redwood Creek watershed.

Project	Total	Public	Private	Evaluated	%Evaluated	Data in Database	Volume Data Used in Report
Project 96	16.1	0.0	16.1	11.2	70%	Yes	Yes
Project 97	90.6	12.9	77.7	31.2	34%	No	NA
Project 0	98.5	8.1	90.4	82.6	84%	Yes	Yes
Project 1	222.3	15.0	207.3	186.8	84%	Yes	Yes
Project 2	197.9	10.5	187.4	131.5	66%	Yes	Yes
Project 3	156.4	4.7	151.7	108.6	69%	Yes	Yes
Project 4	182.3	19.8	162.4	95.6	52%	Yes	No
Project 5	18.5	1.9	16.6	6.8	37%	Yes	Yes
County Roads	Note[1]	note[1]	note[1]	31.0[2]	100%	No	NA
Project 7	150.0	15.7	134.4	0	0%	No	NA
Totals	1,132.6	88.5	1,044.1	685.4	61%	623.2 mi.	527.6 mi.

Table notes

[1] County road mileage is not shown because it is included within other projects as defined in our GIS.

[2] County road mileage is shown because it is not included within other projects in our database.

Totals may differ slightly from those shown in other tables due to rounding.

Table 13. Driveability of assessed roads contained within the database.

Driveability	*Miles*	% of Total Assessed Miles
Driveable	311	50%
Not Driveable	279	45%
Unknown	33	5%
Total Assessed in Projects 0, 1, 2, 3, 4, 5, and 96	623	100%

Table note: Totals may differ slightly from those shown in other tables due to rounding

Table 14. Maintenance status of assessed roads.

Maintenance Status	*Miles*	*% of Total Assessed Miles*
Maintained	198	32%
Unmaintained	373	60%
Decommissioned	6	1%
Partially decommissioned	2	0%
Unknown Status	44	7%
Total Assessed in Projects 0, 1, 2, 3, 4, 5, and 96	623	100%

Table note: Totals may differ slightly from those shown in other tables due to rounding

Potential Sediment Yield for all Completed Assessments

Potential sediment yield data for all evaluated sites in Projects 0, 1, 2, 3, 5, and 96 are summarized in Table 15. Project 4 is not included because we feel the volumes are inaccurate. The county roads project, Project 7, and Project 97 are omitted because we do not have the data. Table 15 does not include potential sediment yield from road surface erosion.

Road drainage and surface erosion

Road drainage and surface erosion was not measured in Projects 0 and 96, but was measured in Projects 1, 2, 3 and 5. We discussed the potential sediment yield for Projects 1, 2, 3 and 5 earlier in this report. The assessments in those projects found 55 percent of the road length was connected to streams by inboard ditch. We can assume this value holds generally true for areas where connectivity was not measured because the areas where measurements were made are well distributed across the watershed and reflect road connectivity across diverse terrain, ownership and road age. Based on this assumption, we compute the road surface erosion for the 528 miles of roads assessed in Projects 0, 1, 2, 3, 5 and 96.

Table 15. Potential sediment yield for Projects 0, 1, 2, 3, 5 and 96.

	No. of Sites	Erosion Volume (yds^3)	Site Potential Yield[2] (yds^3)	Extreme Potential Yield (yds^3)	Potential Sediment Yield (yds^3)[4]	% of No. of Sites	% of Potential Sediment Yield
Sites Inventoried	3,973	1,866,700	1,111,000	653,000	1,500,000	100%	100%
All Sites with No Yield	518	0	0	500	500	14%	0%
All Sites, Yield > 0	3,973	1,866,700	1,111,000	653,000	1,500,000	86%	100%
M-H Sites, Yield > 0	2,152	1,277,500	832,600	518,500	1,144,900	86%	76%
All Fluvial Sites	3,198	732,000	722,500	130,000	797,100	80%	53%
All Landslide Sites	775	1,134,700	388,500	523,000	702,900	20%	47%
Field Call for Treatment							
Decommission	1,517	1,087,700	519,200	429,600	774,200	38%	52%
Upgrade	1,728	668,600	501,100	191,300	615,400	44%	41%
Maintain	728	110,400	90,700	32,100	110,200	18%	7%
Totals	3,973	1,866,700	1,111,000	653,000	1,499,800	100%	100%

Table note: Totals may differ slightly from those shown in other tables due to rounding

If we assume the combined road and ditch width is 20 feet and their surfaces are lowered, on average, by two inches over 290 miles (55% of 528 miles) in a 10-year period, surface erosion would yield roughly 189,000 yds^3 of fine sediment to project area streams, averaging 18,900 yds^3 annually. As in the surface erosion discussion for Projects 1, 2, 3 and 5, this does not mean it will actually occur, but it is an example that shows the relative importance of disconnecting road and inboard ditch surfaces from streams.

Summary of total potential sediment yield for all completed assessments

The total potential sediment yield for the 528 miles of assessed roads in Projects 0, 1, 2, 3, 5, and 96 is about 1,690,000 yds^3. Fluvial sites account for about 797,000 yds^3 (47%), landslide sites account for about 703,000 yds^3 (42%), and road surface erosion accounts for about 189,000 yds^3

(11%). Table 16 summarizes the three general categories of potential sediment sources from assessed roads in Projects 0, 1, 2, 3, 5 and 96.

Table 16. Total potential sediment yield and sources for 528 miles of assessed roads in Projects 0, 1, 2, 3, 5 and 96.

Sediment Source	Total Potential Sediment Yield - All Urgency Sites (yds^3)	Total Potential Sediment Yield per Mile for 528 Miles (yds^3/mile)	% of Total Potential Sediment Yield from Roads
Fluvial sites	797,000	1,510	47%
Landslide sites	702,900	1,330	42%
Road surfaces[1]	189,000	360	11%
Totals	1,689,900	3,200	100%

Table notes
[1]Volume is only an estimate based on length of roads and/or ditches connected to streams.
[2] Totals may differ slightly from those shown in other tables due to rounding.

Potential Sediment Yield for ALL Upper Watershed Roads

We have estimated the potential sediment yield for 528 miles of roads assessed in the upper watershed. If we assume the assessed roads are representative of all roads within the upper watershed, we can apply the values across all roads to estimate the total potential sediment yield from all roads in the upper watershed. The sum of all sediment sources from all roads is estimated at about 3,200 yds^3 per mile of road resulting in approximately 3,630,000 yds^3 of sediment with potential delivery to streams. These data are summarized in Table 17.

Table 17. Estimated total potential sediment yield and sources for 1,133 miles of roads in the upper Redwood Creek watershed.

Sediment Source	Yield Per Mile (yds^3/mile)	Total Estimated Potential Sediment Yield From Roads (yds^3)
Fluvial Sites	1,510	1,710,000
Landslide Sites	1,330	1,510,000
Road Surfaces	360	410,000
Totals	3,200	3,630,000

Road Treatment Costs for ALL Upper Watershed Roads

Treatment costs have been estimated for Projects 1, 2, 3 and 5 where the overall average for upgrade and decommission is roughly $40,000 per mile. About 20 percent of the roads are being maintained in these projects and do not require upgrade or decommission treatments. If we assume that ALL roads in the upper watershed would have proportionately similar treatment needs and costs as those in Projects 1, 2, 3 and 5, the total treatment costs for all roads in the upper watershed can be estimated as follows:

1,163 total miles x 80% (require treatment) = 930 miles require treatments

930 miles requiring treatment x $40,000 per mile = $37 million

For privately owned roads only we calculate the following:

1,044 privately owned miles x 80% (require treatment) = 835 miles

835 privately owned miles requiring treatment x $40,000 per mile = $33.4 million

Treatment Priorities

This section provides examples of how treatment priorities can be established based on results of road assessments in the upper Redwood Creek watershed. Establishing treatment priorities is important because erosion control and prevention treatments are expensive, and the funds available for this type of work are limited. Establishing priorities helps determine where the greatest benefit can be achieved so that limited funds are spent wisely.

We present three different analysis methods that can be used to prioritize treatments. Each method analyzes road assessment data differently and at a different scale. The first method uses database queries. It first ranks individual roads and then ranks individual sub-watersheds. The second method identifies areas in the watershed that have a high density of potential sediment yield using a Geographic Information System (GIS) spatial analysis. The third method ranks sub-watersheds using a numeric risk analysis that is performed twice. First, the analysis ranks sub-watersheds based on the likelihood for and magnitude of erosion, or *resource threat*. The analysis is repeated a second time using anadromous salmonids as the *resource at risk*. The strength and weakness of each method are described. The section ends with a discussion of stream diversions and what we refer to as "critical" crossings.

Prioritizing Roads and Sub-Watersheds Using Database Queries

Databases are an efficient way to store and analyze road assessment data. They allow a user to ask questions through the construction of database "queries." Once constructed, queries retrieve information quickly and the results can be exported to other applications such as spreadsheets for further analysis. The method presented in the following discussion relies on database queries that characterize individual roads and or sub-watersheds so that treatment priorities can be established. Unlike other methods described in this section, database queries are based on *treatment urgency* instead of *erosion potential*.

Roads

This method establishes a treatment priority for individual whole *roads* using database queries and data from Projects 1, 2, 3 and 5. All other projects were omitted because field crews did not prescribe detailed treatments nor estimate treatment costs. Roads that contained sites with medium, medium to high, and high treatment urgencies were summarized based on: 1) potential

yield (volume of sediment that can enter a stream) from the entire road; 2) potential yield per mile of road evaluated, and; 3) treatment cost-effectiveness (the cost per cubic yard to prevent sediment from entering a stream). Each road was then ranked by each criterion. Tables B-1, B-2, and B-3 (Appendix B) rank each road by each criterion. Table 18 below lists the roads that appear in all or at least two of the tables when considering the top 30 ranked roads in each table.

The 1250, 1440, K&K East and LC5000 roads each ranked in the top 30 roads in all three tables. These roads have relatively high potential sediment yield, high yield per mile of road, and high treatment cost-effectiveness. Also in the top 30, are 12 roads that showed up in both Table B-2 and Table B-3. They are characterized by high potential sediment yield per mile of road, and high treatment cost-effectiveness. These are the 800G, 1250, 1440, 1433, K&K East, LC5000, LC5005, O-10, PR1106, PP1110, R2100 and R3351 roads. Ten roads showed up in both Table B-1 and Table B-2, meaning they each have high potential sediment yield, and sediment yield per mile of road. They are the 809, 1250, 1440, 1500, 1550, 1555, Dolly Varden, K&K East, LC5000 and R3800.

An interesting side note is that high treatment urgencies were identified for the most of the sites on the 1250, K&K East and Dolly Varden early in the assessments. The 1250 road was recently decommissioned and the K&K East and Dolly Varden roads are scheduled for decommissioning in 2003 and 2004.

Sub-watersheds

This method ranks individual *sub-watersheds* using database queries and data from Projects 0, 1, 2, 3, 5 and 96. Project 4 was omitted because we believe the volumes are inaccurate. The analysis presents basic information for each sub-watershed, and lists the total potential sediment yield per mile of road (yds^3/mile) and treatment cost-effectiveness ($/$yd^3$) for each sub-watershed. The query evaluates sites with medium to high erosion potentials, and sorts the results on the potential sediment yield per mile of road evaluated during the assessment.

Table 18. Highest ranked roads based on total potential sediment yield, yield per mile and/or treatment cost-effectiveness. These roads consistently appear in the top 30 roads when roads are ranked by either potential sediment yield, yield per mile of road or treatment cost-effectiveness.

Road Name	Length (mi)	Total no. of sites	Total no. M to H sites	Potential Sediment Yield all sites (yds^3)	For Medium to High Urgency Sites			
					Potential Sediment Yield (yds^3)	Potential Sediment Yield per mile (yds^3 / mi)	Total cost	Cost/yard "saved"
809	1.8	15	13	16,032	12,510	6,989	$98,155	$7.85
1250	1.4	14	14	17,922	17,922	12,801	$31,845	$1.78
1433	0.5	7	7	3,978	3,978	7,800	$7,480	$1.88
1440	1.5	18	15	15,155	14,588	9,726	$20,105	$1.38
1500	2.5	38	23	28,842	22,753	9,287	$78,990	$3.47
1550	0.6	9	9	11,244	11,244	17,848	$52,370	$4.66
1555	0.8	10	9	8,406	8,339	10,170	$112,475	$13.49
800G	0.3	2	2	3,726	3,726	12,420	$7,700	$2.07
Dolly Varden	14.7	159	137	129,082	122,842	8,385	$950,850	$7.74
K&K East	2.2	47	36	41,880	38,940	18,112	$79,705	$2.05
LC5000	2.3	26	21	23,659	23,089	10,172	$37,895	$1.64
LC5005	0.5	3	1	7,074	3,500	7,292	$5,610	$1.60
O-10	0.1	4	2	8,000	5,000	45,455	$1,980	$0.40
PP1110	0.5	8	5	9,346	7,061	13,845	$13,640	$1.93
PR1106	0.6	5	5	10,417	10,417	17,960	$20,075	$1.93
R2100	0.2	2	2	1,557	1,557	7,414	$3,080	$1.98
R3351	0.1	1	1	750	750	6,818	$660	$0.88
R3800	0.9	11	10	9,796	9,796	11,235	$35,585	$3.64

Table note: Costs above include only heavy equipment costs for site specific treatments and laborers for culvert installations. Costs do not include equipment mobilization, road opening, heavy equipment requirements for road drainage treatments, culvert materials costs, mulch and seeding costs, project layout, coordination, oversight, report preparation, or overhead.

Table 19 shows the query results and ranks each sub-watershed by the total potential sediment yield per mile of road from medium to high erosion potential sites evaluated in each sub-watershed. Potential sediment yield per mile ranged from 122 yds^3/mile in Monroe Flat to 6,020 yds^3/mile of road in Lee Creek. Potential sediment yield averaged 1,745 yds^3/mile and treatment cost-effectiveness ($/$yd^3$) averaged $6.82/$yd^3$.

Also from the Table 19, Lacks Creek has the highest potential sediment yield, equal to about 197,200 yds^3. Lacks Creek is more than twice the size of the next largest sub-watershed, so the fact that it has the largest total potential yield is no surprise. Also, there are seven sub-watersheds where yield exceeds 20,000 yds^3/$mile^2$. They also have some of the highest yields per mile of road assessed. It is interesting to note that one of the smallest sub-watersheds, Jena Creek, had the highest treatment costs. This might be partly explained by the fact that only 47 percent of the roads in Jena Creek have been evaluated.

It is unlikely that treatment priorities can be established with only this type of analysis. The ranking of roads and sub-watersheds is most useful during a decision making process that considers all available information.

Table 19. Sub-watersheds ranked by total potential sediment yield per mile of road.
Data are from Projects 0, 1, 2, 3, 5, and 96 for sites with medium to high erosion potentials. The average potential sediment yield is 1,745 yds^3/mile. Treatment cost-effectiveness ($cost/yd^3$) is not available when shown as "$0.00".

Watershed	Acres	Roads			Total Potential Sediment Yield (yds^3)	Potential Sediment Yield/mi^2 (yds^3/mi^2)	Potential Sediment Yield/mile (yds^3/mi)	Cost/Yd^3 ($/$yd^3$)
		Total (mi)	Evaluated (%)	Density (mi/mi^2)				
Lee	292	3.2	100%	7.0	19,264	42,261	6,020	$5.88
Headwaters_W	179	1.8	55%	6.3	8,914	31,843	5,036	$0.00
Tom	259	2.7	93%	6.6	10,899	26,920	4,097	$0.00
Wiregrass	1,153	9.5	93%	5.3	35,631	19,771	3,759	$5.49
Joplin	441	4.7	90%	6.8	17,290	25,110	3,671	$2.59
Headwaters_E	114	1.3	82%	7.1	4,401	24,733	3,465	$0.00
Johnson Prairie	386	2.2	87%	3.6	7,338	12,179	3,351	$8.36
Toss-Up	1,709	15.2	97%	5.7	47,414	17,760	3,113	$9.13
Pilchuck	1,086	7.2	88%	4.3	21,449	12,643	2,975	$7.11
Dolly Varden	2,151	28.8	90%	8.6	76,148	22,660	2,641	$7.99
Coyote	5,043	36.2	62%	4.6	89,850	11,402	2,480	$4.27
Timbo	229	4.0	90%	11.3	9,899	27,632	2,450	$6.06
Lake Prairie	2,144	27.7	68%	8.3	66,193	19,763	2,389	$0.01
Lacks	10,977	91.6	81%	5.3	197,193	11,497	2,154	$3.03
Garcia	905	10.1	80%	7.1	20,627	14,581	2,046	$6.58
Loin	601	6.1	43%	6.5	12,515	13,328	2,042	$5.94
Powerline	408	4.6	91%	7.2	9,256	14,515	2,030	$5.09
Panther	3,800	40.0	92%	6.7	74,343	12,522	1,859	$2.74
June	125	0.9	100%	4.7	1,694	8,701	1,841	$10.42
Stover	544	5.4	49%	6.3	9,885	11,621	1,834	$12.21
Smokehouse	426	5.8	74%	8.7	9,210	13,850	1,599	$5.60
Burley	255	3.3	91%	8.2	5,089	12,789	1,566	$1.23
George	699	7.4	99%	6.7	11,297	10,349	1,537	$5.18
Twin Lakes	811	10.0	90%	7.9	14,604	11,523	1,457	$1.08
Headwaters_M	1,688	16.3	59%	6.2	19,219	7,289	1,179	$0.00
Fern Prairie	509	6.5	72%	8.2	7,310	9,194	1,126	$8.98
Lupton	3,329	44.1	52%	8.5	37,573	7,224	852	$6.85
Snow Camp	773	8.6	63%	7.1	6,262	5,182	726	$5.53
Jena	246	4.1	47%	10.7	2,715	7,061	661	$13.45
Ayers	242	3.9	97%	10.2	2,234	5,901	577	$0.00
Garrett	2,643	22.2	62%	5.4	12,705	3,076	572	$6.68
Cashmere	861	10.3	68%	7.6	5,554	4,130	542	$12.20
Pardee	1,985	27.4	59%	8.8	12,560	4,050	458	$4.40
Christmas Prairie	455	6.9	71%	9.7	3,033	4,267	440	$11.45
Marquette	492	6.3	77%	8.2	2,747	3,572	436	$5.69
Noisy	4,030	49.0	67%	7.8	20,392	3,239	416	$7.47
Cool Springs	737	9.7	44%	8.4	3,592	3,118	370	$4.72
Six Rivers	741	9.1	58%	7.8	3,056	2,640	337	$0.00
Santa Fe	530	9.2	43%	11.1	3,003	3,625	328	$10.37
Debris Torrent	129	1.8	98%	9.1	559	2,770	305	$12.66
Monroe Flat	189	1.8	55%	6.2	223	755	122	$0.00

Prioritizing Areas within the Watershed Using a GIS Spatial Analysis

This method establishes a treatment priority for *areas* in the watershed using a GIS spatial analysis and data from Projects 0, 1, 2, 3, 5 and 96. Project 4 data were not used because we believe the potential erosion volumes are inaccurate. Rather than focusing on a specific road, this method analyzes potential sediment yield throughout the watershed and characterizes discrete areas by the concentration or *density* of potential sediment yield. The spatial analysis ignores sub-watershed boundaries.

The analysis uses both numeric and spatial data. Numeric data are the potential sediment yield values for sites as estimated by the field crews, and the spatial data comes from a GIS point coverage for each site evaluated during the assessment. Because each point represents the location of each site, the analysis can evaluate the potential sediment yield of one site in relation to the potential sediment yield of sites that surround it.

Using GIS and the data sources described above, the density or "hot spots" of potential sediment yield per square mile throughout the upper Redwood Creek watershed was computed. Simply stated, an analysis tool found in GIS software can scan and analyze a contiguous area using a moving one square mile circular "window." As the window sweeps across the landscape, it notes the potential sediment yield at each site location and adds to it the yield associated to neighboring sites if they are within one square mile of the site being evaluated. The results of this analysis are shown in Figure 3. The darkest colors represent the areas that contain the highest density of potential sediment yield, suggesting another possible treatment priority.

Prioritizing Sub-Watersheds Using Risk Analyses

This method establishes treatment priorities using a numeric risk analysis and data from Projects 0, 1, 2, 3, 5, and 96. Rather than analyzing a specific road or broad contiguous area, this method ranks each *sub-watershed* based on specific criteria. Only major sites such as crossings, landings and road reaches with medium to high erosion potentials (likelihood of failure) were considered, because it simplifies the analysis, and these sites represent the bulk of the potential sediment yield. The analysis is performed twice. It first ranks sub-watersheds based on the likelihood for and magnitude of potential erosion which we call *resource threat*. Then it integrates anadromous salmonids into the analysis that considers salmonids as the *resource at risk*.

Resource threat

In this analysis, risk is defined by resource threat, or the likelihood for and magnitude of erosion in each sub-watershed. The resource threat for each sub-watershed considers three criteria: 1) the potential sediment yield from each site; 2) the slope steepness at each site, and; 3) the number of critical crossings on each road. Resource threat was computed as follows:

Resource Threat = Yield + CXing + Steepness

where, for each sub-watershed:

Yield is the potential sediment yield,

CXing is the number of critical crossings (defined below), and
Steepness is the average hillslope steepness of sites evaluated.

Weighted values were assigned to each criterion based on the actual range of values for each one and then normalized, if needed, to ensure each criterion had equal importance in the analysis. The weighted values were then summed to create a final score for each sub-watershed. The highest scores identify the sub-watersheds at greatest risk from erosion and suggest another treatment priority.

Yield

In the formula for risk, *Yield* describes the total potential sediment yield in each sub-watershed. It integrates nicely into a risk analysis, because it quantifies the amount of sediment that can potentially impact aquatic habitat and water quality. Yield is expressed in cubic yards per square mile of sub-watershed area (yds^3/mi^2).

In this analysis, *potential sediment yield* is always the larger of *site potential yield* or the *extreme potential yield* for each site. The site potential yield was estimated for each site in the field, and represents the volume of material that can potentially erode and be delivered to a stream during a large storm. The extreme potential yield was estimated in the field where the potential for an extreme erosional event (e.g., a debris torrent initiating at a stream crossing) was identified at a site. It is larger than the site potential yield where the possibility for an extreme event had not been identified. The potential sediment yield for all sites in a sub-watershed was summed and then divided by the sub-watershed drainage area. A weighting value was then assigned to each sub-watershed based on the following actual range of total potential sediment yield:

Range of Potential Sediment Yields (yds^3/mi^2)	Sub-watershed Weight Value
0 – 5,000	1
5,001 – 10,000	3
10,001 – 15,000	5
15,001 – 20,000	7
>20,001	9

Table C-1 (Appendix C) ranks each sub-watershed by total potential sediment yield. Potential sediment yield ranged from 755 $yds^3/mile^2$ in Monroe Flat to 42,261 $yds^3/mile^2$ in Lee Creek. Monroe Flat was the only sub-watershed that had a potential sediment yield of less than 2,600 $yds^3/mile^2$. Seven sub-watersheds had potential sediment yields greater than 20,000 $yds^3/mile^2$. The average yield was 12,367 $yds^3/mile^2$, and the median was 11,497 $yds^3/mile^2$. Only sites that had medium to high erosion potentials were considered, because low sites were considered relatively stable.

Critical crossings

In the formula for risk, critical crossings (CXings) are road-stream crossings that are the most likely crossings to divert streams from their natural watercourses. They have a diversion potential, an undersized culvert, and a medium to high plug potential. Critical crossings are included in the analysis because of the significant risk they represent to a sub-watershed. The

Figure 3 – remove this page, insert figure 3 Sediment Yield hot spots

potential sediment yield from a critical crossing cannot be measured before failure occurs. However, studies performed in Redwood Creek show that stream diversions can lead to significant gully and landslide erosion (Best and others, 1995;Weaver and Hagans, 1987).

Critical crossings are expressed as the number of critical crossings per mile of road evaluated in each sub-watershed (#cxings/mile). Diversion and plug potential were evaluated in the field. Culvert diameter sizing was based on field evaluations and the use of standard discharge formulas for the 100-year storm. For each sub-watershed, the number of critical crossings was summed then divided by the total length of roads evaluated. The following weighting values were then assigned to each sub-watershed based on the following actual range of critical crossings per mile of road:

Range of Critical Crossings (#cxings/mile)	Sub-Watershed Weight Value
<0.50	1
0.51 - 0.80	3
0.81 - 1.20	5
1.21 - 1.60	7
>1.61	9

Table C-2 (Appendix C) ranks each sub-watershed by the number of critical crossings per mile. Critical crossings ranged from 0.2 crossings/mile (n=1) in Marquette Creek to 6.3 crossings/mile (n=12) in Johnson Prairie. The mean was 1.1 crossings/mile and the median was 0.9 crossings/mile.

Steepness

In the formula for risk, *Steepness* describes the average hillslope steepness of the sites evaluated in each sub-watershed. It integrates well into a risk analysis because sites located on steeper hillslopes are more likely to fail. Steepness includes only the major sites such as crossings, landings, and road reaches with medium to high erosion potentials. The steepness at each site was determined by GIS using a 10-meter digital elevation model (DEM) for the Redwood Creek watershed (Figure C-1, Appendix C). A weighting value was then assigned to the hillslope steepness at each site based on the following range of steepness:

Range of Steepness, %	Steepness Weight Value
0 – 30	1
31 – 40	3
41 – 50	5
51 – 65	7
>65	9

The weighted values for all sites in a sub-watershed were summed and then divided by the number of sites in the sub-watershed. This produced an average weighted hillslope steepness for all sites evaluated in each sub-watershed. The average weighted site steepness for each sub-

watershed was then normalized to the highest weighting value to give site steepness equal importance in the analysis. Table C-3 (Appendix C) ranks each sub-watershed by site steepness. Normalized site steepness ranged from 1.7 (n=1) in Monroe Flat to 9.0 (n=31) in Pilchuck Creek.

In the final step, the normalized values for potential sediment yield, critical crossings and site steepness for each sub-watershed were summed, creating a final score for each sub-watershed. The results are shown in Figure 4 and Table 20 and suggest that 11 sub-watersheds rank high or very high based on the potential resource threat. Joplin, Lee and Timbo creeks have the highest resource threat. The results are in general agreement with the spatial analysis for potential sediment yield density.

Resource threat and resource at risk

This analysis uses the same methods as the risk analysis performed above, but now introduces anadromous salmonids in each sub-watershed as the resource at risk. It adds a biological element to the previous analysis that defined risk only in terms of the likelihood for and magnitude of potential erosion, or resource threat. In this analysis risk is defined as follows:

Risk = Resource Threat + Resource at Risk

Resource Threat was defined in the previous analysis. *Resource at Risk* is the number of anadromous salmonid species observed in each sub-watershed, normalized to the highest weighting value for other ranking criteria. Salmonid distribution information for the Redwood Creek watershed is from documented stream surveys performed since 1965 and is shown in Figure F-2 (Appendix C). Table F-4 ranks each sub-watershed by the number of anadromous salmonid species observed in each sub-watershed.

Risk analysis results are shown in Figure 5 and Table 21. Some of the sub-watersheds previously ranked as medium moved up to a higher ranking because they supported salmonid populations. For example, Lacks and Pilchuck creeks moved up to the high ranking from a medium ranking that had been based only on resource threat. The sub-watersheds at greatest risk are a combination of sub-watersheds that support salmonids and those that do not. In the latter case, resource threat still dominated in the risk analysis.

FIGURE 4

Table 20. Sub-watersheds ranked by resource threat.
Includes Projects 0, 1, 2, 3, 5, and 96, but not the sub-watersheds in which less than 40 percent of the roads had been evaluated. Includes sites with medium to high erosion potentials.

Sub-Watershed	Area (ac)	% Road Eval.	Normalized Values for			Total Score	Sub-Watershed Rank
			Potential Sediment Yield	Critical Crossings	Site Steepness		
Timbo	229	90%	9	7	7.0	23.0	Very High
Joplin	441	90%	9	7	6.1	22.1	Very High
Lee	292	100%	9	5	8.0	22.0	Very High
Powerline	408	91%	5	9	6.6	20.6	High
Tom	259	93%	9	9	2.4	20.4	High
Dolly Varden	2,151	90%	9	5	4.9	18.9	High
Wiregrass	1,153	93%	7	5	6.6	18.6	High
Coyote	5,043	62%	5	7	6.2	18.2	High
Headwaters_W	179	55%	9	5	4.1	18.1	High
Johnson Prairie	386	87%	5	9	4.1	18.1	High
Headwaters_E	114	82%	9	5	3.5	17.5	High
Panther	3,800	92%	5	5	6.8	16.8	Medium
Lake Prairie	2,144	68%	7	3	6.8	16.8	Medium
June	125	100%	3	5	8.7	16.7	Medium
Burley	255	91%	5	9	2.5	16.5	Medium
Toss-Up	1,709	97%	7	3	6.3	16.3	Medium
Cashmere	861	68%	1	9	5.9	15.9	Medium
Garcia	905	80%	5	3	7.6	15.6	Medium
Pilchuck	1,086	88%	5	1	9.0	15.0	Medium
Lacks	10,977	81%	5	3	6.9	14.9	Medium
George	699	99%	5	5	4.7	14.7	Medium
Stover	544	49%	5	5	4.4	14.4	Medium
Loin	601	43%	5	3	6.1	14.1	Medium
Ayers	242	97%	3	3	7.7	13.7	Medium
Cool Springs	737	44%	1	5	7.0	13.0	Medium
Debris Torrent	129	98%	1	5	6.6	12.6	Medium
Garrett	2,643	62%	1	7	4.5	12.5	Medium
Snow Camp	773	63%	3	5	4.3	12.3	Medium
Monroe Flat	189	55%	1	9	1.7	11.7	Medium
Jena	246	47%	3	5	2.7	10.7	Low
Twin Lakes	811	90%	5	1	4.7	10.7	Low
Lupton	3,329	52%	3	3	4.6	10.6	Low
Smokehouse	426	74%	5	3	2.1	10.1	Low
Pardee	1,985	59%	1	3	6.1	10.1	Low
Fern Prairie	509	72%	3	3	3.5	9.5	Low
Christmas Prairie	455	71%	1	3	4.9	8.9	Low
Headwaters_M	1,688	59%	3	1	4.7	8.7	Low
Noisy	4,030	67%	1	3	3.8	7.8	Low
Six Rivers	741	58%	1	3	3.5	7.5	Low
Santa Fe	530	43%	1	3	3.3	7.3	Low
Marquette	492	77%	1	1	4.5	6.5	Very Low

FIGURE 5

Table 21. Sub-watersheds ranked by resource threat and resource at risk.
Includes Projects 0, 1, 2, 3, 5, and 96, but not the sub-watersheds in which less than 40 percent of the roads had been evaluated. Includes sites with medium to high erosion potentials.

Sub-Watershed	Area (ac)	% Roads Eval.	Normalized Values for				Total Score	Sub-Watershed Rank
			Potential Sediment Yield	Critical Crossings	Site Steepness	Fish # of Species		
Coyote	5,043	62%	5	7	6.2	6.8	25.0	Very High
Lacks	10,977	81%	5	3	6.9	9.0	23.9	Very High
Dolly Varden	2,151	90%	9	5	4.9	4.5	23.4	High
Timbo	229	90%	9	7	7.0	0.0	23.0	High
Joplin	441	90%	9	7	6.1	0.0	22.1	High
Lee	292	100%	9	5	8.0	0.0	22.0	High
Panther	3,800	92%	5	5	6.8	4.5	21.3	High
Wiregrass	1,153	93%	7	5	6.6	2.3	20.9	High
Powerline	408	91%	5	9	6.6	0.0	20.6	High
Tom	259	93%	9	9	2.4	0.0	20.4	High
Pilchuck	1,086	88%	5	1	9.0	4.5	19.5	High
Lake Prairie	2,144	68%	7	3	6.8	2.3	19.0	High
Toss-Up	1,709	97%	7	3	6.3	2.3	18.6	Medium
Cashmere	861	68%	1	9	5.9	2.3	18.2	Medium
Headwaters_W	179	55%	9	5	4.1	0.0	18.1	Medium
Johnson Prairie	386	87%	5	9	4.1	0.0	18.1	Medium
Garcia	905	80%	5	3	7.6	2.3	17.8	Medium
Headwaters_E	114	82%	9	5	3.5	0.0	17.5	Medium
June	125	100%	3	5	8.7	0.0	16.7	Medium
Burley	255	91%	5	9	2.5	0.0	16.5	Medium
Loin	601	43%	5	3	6.1	2.3	16.3	Medium
Garrett	2,643	62%	1	7	4.5	2.3	14.7	Medium
George	699	99%	5	5	4.7	0.0	14.7	Medium
Snow Camp	773	63%	3	5	4.3	2.3	14.6	Medium
Stover	544	49%	5	5	4.4	0.0	14.4	Medium
Ayers	242	97%	3	3	7.7	0.0	13.7	Medium
Jena	246	47%	3	5	2.7	2.3	13.0	Low
Cool Springs	737	44%	1	5	7.0	0.0	13.0	Low
Twin Lakes	811	90%	5	1	4.7	2.3	12.9	Low
Lupton	3,329	52%	3	3	4.6	2.3	12.8	Low
Debris Torrent	129	98%	1	5	6.6	0.0	12.6	Low
Smokehouse	426	74%	5	3	2.1	2.3	12.3	Low
Pardee	1,985	59%	1	3	6.1	2.3	12.3	Low
Monroe Flat	189	55%	1	9	1.7	0.0	11.7	Low
Noisy	4,030	67%	1	3	3.8	2.3	10.1	Low
Six Rivers	741	58%	1	3	3.5	2.3	9.7	Low
Santa Fe	530	43%	1	3	3.3	2.3	9.6	Low
Fern Prairie	509	72%	3	3	3.5	0.0	9.5	Low
Christmas Prairie	455	71%	1	3	4.9	0.0	8.9	Very Low
Headwaters_M	1,688	59%	3	1	4.7	0.0	8.7	Very Low
Marquette	492	77%	1	1	4.5	0.0	6.5	Very Low

Discussion

We have presented three examples of different analysis methods that can be used to prioritize erosion control and prevention treatments in the Redwood Creek watershed. Each method works at a different scale, and has its strength and weakness.

The first analysis method ranked individual roads and then sub-watersheds using database queries. Road queries ranked individual roads based on: 1) total potential sediment yield for the entire road; 2) total potential sediment yield per mile of road, and; 3) treatment cost-effectiveness. Sub-watershed queries ranked sub-watersheds by total potential sediment yield per mile of road. This simple analysis characterizes each road and sub-watershed by potential sediment yield and cost-effectiveness, and requires no sophisticated use of databases or GIS. Analysis results are most useful when all roads are controlled by a single landowner. Its utility diminishes when roads cross multiple ownership or sub-watershed boundaries, because the analysis lacks spatial reference.

The second method identified areas of high potential sediment yield density or "hot spots" using a GIS spatial analysis. The analysis is blind to sub-watershed boundaries. Its ability to highlight discrete areas containing a potentially high cumulative potential sediment yield is its greatest strength. The spatial reference provided in this analysis is well suited to establishing treatment priorities at all planning scales. A disadvantage to this method is that it does not consider what percentage of an area has been evaluated. Thus, the analysis can miss areas of high potential sediment yield density if adjacent areas have not been fully evaluated.

The third analysis method ranked sub-watersheds by performing two separate risk analyses. The first analysis was based only on resource threat (the likelihood for and the magnitude of potential erosion), and the second integrated the resource at risk (anadromous salmonids) into the analysis. Depicting the risk to salmonid populations at a watershed scale is perhaps the greatest strength of this analysis that integrates specific site information such as potential sediment yield and critical crossings, with watershed attributes such as hillslope steepness and salmonids. A disadvantage to this method is that it is based on sub-watershed boundaries and, therefore, does not evaluate interfluves between sub-watersheds. Interfluves tend to have the highest road densities and deliver sediment directly to Redwood Creek. Like the spatial analysis, the risk analysis is also sensitive to how much of a sub-watershed has been assessed, so the percentage of roads and/or the number of sites evaluated in each sub-watershed must be considered when reviewing the analysis results. We also believe DEMs tend to underestimate hillslope steepness, especially in streamside areas. Underestimating steepness in these areas could reduce the resource threat at individual sites and perhaps the sub-watershed ranking.

The "best" prioritization method would probably use a combination of the analyses presented in this report, and would depend on the scale and objectives of the planning effort. For example, a smaller landowner willing to implement an erosion control and prevention project might use database queries in combination with the spatial analysis to prioritize work on their land. If the protection of sub-watersheds that supports the greatest number of salmonid species is the objective, then the numeric risk analysis that integrates salmonid information would be

appropriate in combination with the database query that considers treatment cost-effectiveness. The spatial analysis could also help pinpoint priority areas within the sub-watershed.

Another objective might consider the main channel of Redwood Creek and its importance to fisheries in the watershed. Outside of the Prairie Creek sub-watershed, the main channel of Redwood Creek represents about 70 percent of all accessible anadromous salmonid habitat in the Redwood Creek watershed (California Resources Agency, 2002). Thus, a watershed-wide planning effort that sets sediment reduction to the main channel of Redwood Creek as its primary objective could appropriately use the numeric risk analysis based resource threat in combination with other analyses, such as the "hot spots" presented in this report.

Regardless of which method is used to establish treatment priorities, it is important to remember that some landowners are more able and willing to implement erosion control and prevention work than others, and the logistics of a project can complicate "priorities." In other words, the most effective erosion control and prevention strategy for the Redwood Creek watershed should be flexible and acknowledge the challenging nature of implementing projects across a large landscape with multiple owners.

Finally, the assessment data and analyses in this report reflect the ground conditions that existed at the time of the road assessment. Some landowners have implemented significant erosion control and prevention projects in Redwood Creek since the assessments were completed. However, we do not have enough information at this time to describe all of the work that has been completed. We hope to inventory all work completed to date and report the findings in a subsequent report that, in collaboration with private landowners and other partners, also presents an erosion control and prevention strategy for the Redwood Creek watershed.

A Note on Stream Diversions and Critical Crossings

The prevention of stream diversions is perhaps the most cost-effective erosion control and prevention treatment. Based on our observations in the Redwood Creek watershed, stream diversions can cause severe gully erosion that often leads to significant landslide erosion. Studies performed in the Redwood Creek watershed have shown that: 1) stream diversions can account for a significant portion of a sediment budget during large storms; 2) the erosion volume from diversions can far exceed the volume contained in the crossings from which the streams diverted, and; 3) stream diversions are preventable (Weaver and Hagans, 1987; Best and others, 1995).

Stream crossings that are especially prone to diversions are those we refer to as "critical" crossings. These crossings have a diversion potential, an undersized culvert, and at least a medium plug potential, and are the most likely crossings to cause a stream diversion during a large storm. Excluding bridges and fords, 2,335 stream crossings were evaluated in projects for which we have data. Of these crossings, 1,421 crossings (60%) had diversion potentials, 1,893 (81%) crossings had undersized culverts for the 100-year storm, and 979 (42%) crossings had medium to high plug potential at the time of the road assessment. There were 488 (20%) critical crossings that had all three attributes.

Stream crossings with diversion potentials, especially critical crossings, pose a significant threat to salmonid habitat and water quality. Thus, it seems logical that stream crossings with diversion potentials should be treated as soon as possible. To identify areas where the concentration of critical crossings might be high, we performed a GIS spatial analysis that computed the density of critical crossings per square mile across all of the project areas. The results of this analysis are shown in Figure 6. The darkest colors represent potential "hot spots" of crossings that are at the greatest risk.

Redwood Creek Riparian Conditions and Restoration Opportunities

Introduction

Riparian vegetation along fish bearing streams is intimately linked to stream channel processes, water quality and aquatic habitat. Riparian vegetation can retard movement of sediment and water, and increase bank stability. It can shade the channel providing cool water temperatures and provide the source for large woody debris (LWD) that stores in-channel sediment and influences important aquatic habitats such as pools and riffles. In this section, we describe how riparian conditions have changed along Redwood Creek, and what restoration opportunities exist for the riparian corridor. The discussion is based on uncompleted graduate work performed in 1997 by Stacy Urner under the direction of Dr. Mary Ann Madej of the U.S. Geological Survey, and field mapping performed by RNSP staff during the summer of 2002.

Methods

The graduate study performed by Stacy Urner looked at how the composition of riparian vegetation along the mainstem of Redwood Creek changed from 1948 to 1997. The study is still in progress and must be considered draft until completed. Urner documented the changes in overstory riparian composition through analysis of sequential aerial photographs of the Redwood Creek watershed at a scale of 1:24,000, 1:20,000, 1:12,000 and 1:6,000. Aerial photographs were reviewed for several dates that bracketed periods of intense timber harvest and large floods: 1948, 1958, 1966, 1978, 1992 and 1997. For each photo year, both the left and right channel banks were mapped. Among other attributes, the dominant riparian vegetation type, either conifer or hardwood, was recorded on a mylar overlay map. The mapped zone on each side of the channel was 165 feet wide in areas upstream of Highway 299 where Douglas-fir is the dominant riparian conifer, and was 240 feet wide downstream of Highway 299 where redwood generally becomes the dominant riparian conifer. The channel length (left and right banks) dominated by each riparian species for each year that aerial photos were reviewed was entered into a GIS on routed hydrography for the entire length of Redwood Creek. Limited field work was performed in the summer of 1998 during which time aerial mapping was confirmed and the presence of understory conifers was noted. The analysis procedure was developed by

Washington's Forest Practice Board (1995) and modified slightly for the Redwood Creek watershed.

Park staff field mapped riparian vegetation along eight miles of Redwood Creek in the summer of 2002, from Lake Prairie Creek to Noisy Creek. The purpose was to compare Urner's aerial photograph riparian mapping to actual riparian vegetation in this sample reach. Base strip maps (1:2,400 scale) were developed from scanned 1997 air photos overlain with mylar. The riparian vegetation on both the left and right sides of Redwood Creek, within the first 200 feet (approximate) from the channel, was recorded on the mylar. Mapping was performed primarily from the channel, occasionally entering the riparian forests to verify vegetation species and tree diameters. Tree diameters were estimated visually. Vegetation categories were developed in the field as new combinations were observed. The narrow ribbon of alder that occupied nearly the entire length of this reach was ignored unless it continued upslope into the 200-foot wide riparian zones. Where they existed, recruitable Douglas-fir greater than 16 inches in diameter were also mapped. The channel length (left and right banks) dominated by each vegetation type was entered into GIS on routed hydrography for the length of the sample reach.

Results

Figure 7 shows the cutting history and subsequent hardwood growth (average for left and right banks) in the Redwood Creek riparian corridor based on Urner's 1997 air photo analysis. The earliest complete set of air photos that were available are dated 1948, and by this time 8 percent of the coniferous forest in the watershed had been cut mostly from upper hillslope areas, representing 6 percent of the Redwood Creek watershed area (Best, 1995).

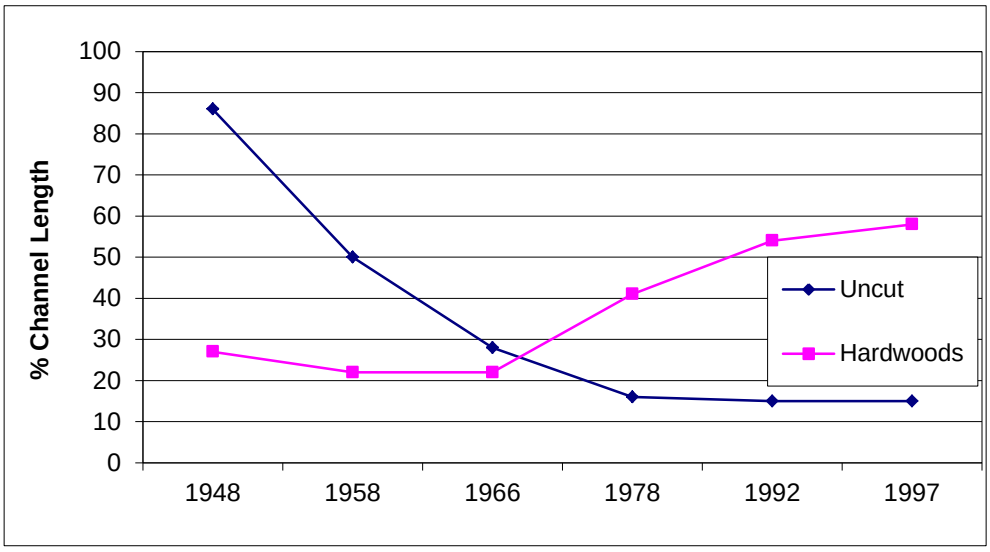


Figure 7. Timber harvest history and hardwood growth in riparian along Redwood Creek.

Most logging occurred after 1940, so it is assumed that most of the channel length was uncut and conifer-dominated before 1948. A partial set of 1936 photos supports this assumption, especially in areas upstream of state Highway 299 where a closed conifer-dominated canopy was common.

Figure 6 – critical crossings- remove this page and insert

Timber harvest along the mainstem of Redwood Creek, in particular its inner gorge, accelerated in the early 1960s (Best, 1995).

Urner (in progress) grouped the riparian vegetation along Redwood Creek into three general categories. The general categories and mapping results are shown below in Table 22.

Table 22. Riparian vegetation along Redwood Creek mapped from aerial photographs.

Vegetation	Left Bank		Right Bank	
	(mi.)	(%)	(mi.)	(%)
Conifer	21.0	34	26.0	42
Hardwood	37.8	62	33.5	54
Brush/grass	2.4	4	2.5	4
	61.2	100	62.0	100

For the entire length of Redwood Creek, 62 percent of the riparian along the left bank and 54 percent of the riparian along the right bank is dominated by hardwood species. Maps showing the riparian vegetation along the entire length of Redwood Creek are in Appendix H.

The 2002 field mapping recorded the riparian vegetation within the first 200 feet (approximate) on each side of Redwood Creek. The vegetation was grouped into eight classes: alder, alder with Douglas-fir understory (DFU), hardwood, hardwood with DFU, mixed conifer and hardwood, old (>24 inches dbh) Douglas-fir, young (up to 16 inches dbh) Douglas-fir, and brush/grass. The results of field mapping the eight-mile sample reach are shown in Table 23.

Table 23. Riparian vegetation along field mapped sample reach.

Vegetation	Left Bank		Right Bank	
	(mi.)	(%)	(mi.)	(%)
Alder	2.2	27	0.9	11
Alder w/ DFU	1.3	15	1.0	13
Hardwood	1.2	14	2.0	24
Hardwood w/ DFU	0.3	4	0.6	7
Mixed conifer/hardwood	1.7	20	2.1	26
Old Douglas-fir	0.5	6	0.6	7
Young Douglas-fir	1.0	12	0.6	7
Brush/grass	0.0	0	0.4	4
Totals	8.2	100	8.2	100

Because the sample reach was field mapped with the use of enlarged aerial photos as base maps, the riparian vegetation could be mapped with greater detail than in Urner's aerial photograph interpretation. The main channel is also confined by steep valley walls in most of the sample reach that allowed the riparian corridor to be described mostly from the main channel. The mixed conifer/hardwood class describes a stand when both conifers and hardwoods shared the overstory canopy, and conifers represented at least 20-25 percent of the stand. Where a Douglas-fir understory existed, there was considerable variation in its density and height.

Table 24 compares 1997 aerial photo mapping with 2002 field mapping of the sample riparian reach between Lake Prairie Creek and Noisy Creek. Because the air photo mapping grouped riparian trees into only two classes – conifers or hardwoods, the 2002 field mapping data were generalized to fit the general categories used by Urner so that results could be compared.

Table 24. Comparison of aerial photo and field mapping of sample riparian reach.

Vegetation	1997 Aerial Photo Mapping				2002 Field Mapping			
	Left Bank		Right Bank		Left Bank		Right Bank	
	(mi.)	(%)	(mi.)	(%)	(mi.)	(%)	(mi.)	(%)
Conifers	2.4	29%	2.0	24%	1.5	18%	1.2	15%
Hardwoods	5.8	71%	6.2	76%	5.0	61%	4.5	55%
Mixed	NA	NA	NA	NA	1.7	20%	2.1	26%
Brush/Grass	0.0	0%	0.0	0%	0.0	0%	0.4	4%
Totals	8.2	100%	8.2	100%	8.2	100%	8.2	100%

It is impossible to compare the 1997 mapping directly to the 2002 mapping because only the 2002 mapping used a mixed conifer/hardwood class to group riparian trees. It is necessary to distribute the 2002 mixed conifer/hardwood class amongst the conifer and/or hardwood classes if a comparison is to be made. Mixed conifer/hardwood stands field mapped in 2002 must have been previously grouped into either the conifer or hardwood classes in the 1997 air photo survey. Further, it is reasonable to assume that the mixed conifer/hardwood class could have been evenly distributed (not intentionally, but by chance) into the conifer or hardwood classes in the 1997 survey. By evenly distributing the 2002 mixed conifer/hardwood class to the 2002 conifer and hardwoods classes, the 2002 results for conifer and hardwood classes agree fairly well with the 1997 air photo survey.

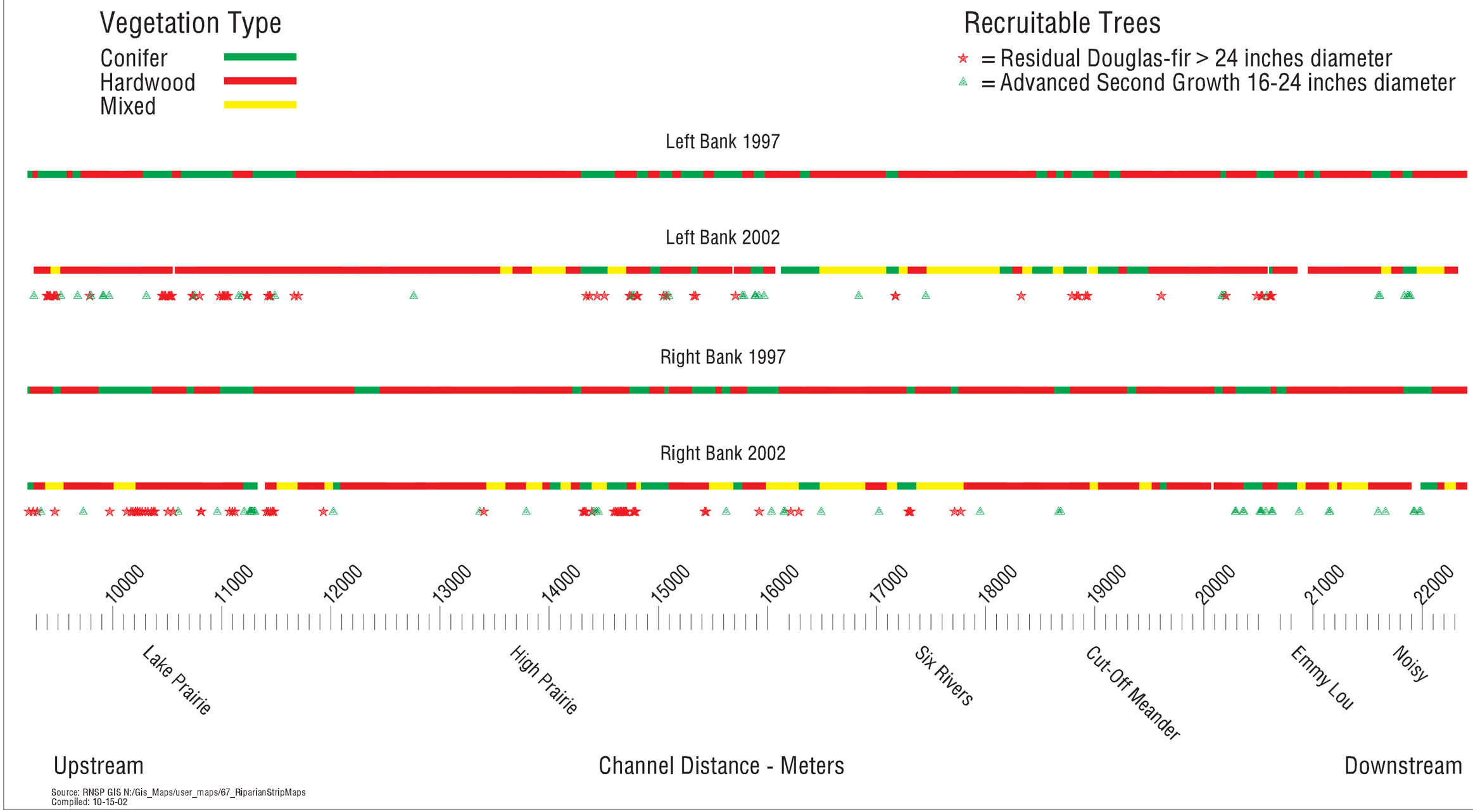
When interpreting vegetation type from aerial photographs, hardwood forests can be misinterpreted as coniferous forests if conifer residuals are scattered throughout a forest stand. Among other attributes, our eyes tend to focus on tree tops and crown spread when interpreting forest types from air photos. Thus, scattered residuals can misrepresent the actual forest type in air photos, because of their height and broad crowns. This appears to account for some of the discrepancy between the 1997 air photo mapping and the 2002 field mapping. Figure 8 is a strip map of the riparian vegetation along the sample reach. It compares the 1997 and 2002 mapping for the left and right banks, and shows the largest conifers field mapped in 2002 that we believed could recruit (were within reach) to Redwood Creek. In several areas where 1997 mapping recorded more coniferous riparian than the 2002 mapping, hardwood stands containing residual conifers appear to have been misinterpreted as coniferous forest stands. The sample reach represents about 40 percent of the total channel length upstream of Highway 299. Given the discussion above, we believe the 1997 air photo mapping reasonably describes the riparian vegetation along Redwood Creek upstream of Highway 299.

The riparian corridor along the mainstem of Redwood Creek has been altered significantly since 1948. Today, species composition favors hardwoods and, where they exist, conifer stands are relatively young and do not currently contain the size (length and diameter) of trees needed for functional and stable in-channel LWD. Additionally and as observed during the 2002 field mapping of the sample reach, existing in-channel LWD was very scarce, and pools lacked

FIGURE 8

Riparian Vegetation of Sample Reach, Upper Redwood Creek Watershed

Left and Right Banks



Source: RNSP GIS N:/Gis_Maps/user_maps/67_RiparianStripMaps
Compiled: 10-15-02

Figure 8. Riparian vegetation of sample reach.

complexity and cover. Similar observations regarding existing riparian vegetation and size classes, recruitable LWD, existing in-channel LWD and pool complexity were made by the California Department of Fish and Game as part of the North Coast Watershed Assessment Program (California Resources Agency, 2002).

Riparian Restoration Opportunities

Riparian restoration is likely to be most cost-effective where a conifer understory already exists below a hardwood canopy. Such areas were recorded by the field mapping along the sample reach described above. In the hardwood stands evaluated in the sample reach, 32 percent of the left bank stands and 36 percent of the right bank hardwood stands contained a Douglas-fir understory of varied height and density. This accounted for about 1.6 miles of riparian on each side of Redwood Creek or a combined total of 58 acres, assuming a 150-foot wide zone. If this relation of conifer understory to hardwood stands holds true over the entire length of Redwood Creek, then restoration opportunities in the form of conifer release might be available along roughly 12 miles on each side of Redwood Creek, totaling roughly 590 acres. Scott Bauer from the California Conservation Corps estimates that conifer release by felling hardwoods to the ground would cost about $95-$150/acre (personal comm., 2003). Bill Blackwell from Sierra Pacific Industries estimates girdling hardwoods would cost about $70-$150/acre. He believes girdling would reduce the loss of understory conifers from felling operations (personal comm., 2003). Adding an additional 30 percent for poor access, long hikes and steep terrain to the highest estimates, conifer release could average about $195/acre. Therefore, treating the riparian corridor along Redwood Creek using conifer release methods would cost about $115,000.

Conclusions

The Redwood Creek watershed is somewhat unique from other north coastal California watersheds. It is relatively small (180,000 acres) and a national and state park occupies the lower-third of the watershed. Most of the land upstream of the park is used almost exclusively for ranching and forest products, and is mostly owned by a relatively small number of large landowners which makes watershed-scale planning feasible. There are no major water diversions in the watershed, and the only developed municipality is the town of Orick, located along the lowermost reach of Redwood Creek. The partnerships that have formed around the common objective of sediment reduction from logging roads is also unique. They have spawned collaborative efforts that will ultimately improve and maintain salmonid habitat in Redwood Creek, and protect the downstream public trust resources in Redwood National and State Parks.

There are about 1,130 miles of road in the upper Redwood Creek watershed. Of those, about 1,040 miles are on private lands and most are used for forest management. All of the assessments completed to date have evaluated about 685 miles (60 percent) of all roads. An additional 67 miles of road are being evaluated in 2003. Upon completion, about 67 percent of

the roads in the upper watershed will have been evaluated. About 88 percent of the private land roads were built before forest practice regulations had been fully implemented.

PCFWWRA assessed 434 miles of roads and the estimated total treatment cost is $13.8 million. Road decommission has been prescribed for 144 miles of road ($6.3 million, or $43,700/mile) and road upgrade has been prescribed for 207 miles of road ($7.5 million, or $36,300/mile). Extending unit costs to remaining roads only on private lands, the estimated total cost to treat all roads in the watershed is about $33.4 million.

Volume data are complete for about 530 miles of road which is about 50 percent of all roads in the upper watershed. Based on these data for evaluated sites, the total potential sediment yield is about 1,690,000 yds^3 for all roads in the upper watershed, averaging about 3,200 yds^3 per mile of road. Fluvial sites (crossings, gullies, relief culverts, etc.) account for 47 percent, landslide sites (roads and landings) account for 42 percent, and road surface erosion accounts for 11 percent of the total potential sediment yield.

The total potential sediment yield from 530 miles of road is about 1,690,000 yds^3 (Table 16). If we assume a bulk density of 1.5 tons/yd^3, this suggests that the sediment yield estimates from the road assessments represent a potential sediment input of 2,535,000 tons into the Redwood Creek channel network. Average annual suspended sediment yield for Redwood Creek at Orick (based on records from 1971 to 1999) is 884,000 tons/year (personal comm., Madej, 2003). Thus, removing the sediment potential of 2,535,000 tons from road-related problems is the equivalent of saving nearly three times the annual sediment load of Redwood Creek. If the relationship of roads to potential sediment yield holds true for the 50 percent of the remaining roads for which we have no data, then the total potential sediment yield could be as high as five million tons, six times the annual sediment load of Redwood Creek.

We believe the values for total potential sediment yield are conservative and represent a minimum value. Extreme erosion potentials are difficult to estimate, and we know that road assessments do not capture the full risk of stream diversions, landslides or debris torrents originating at roads. For example in the January 1997 storm, 135 debris torrents occurred in the Redwood Creek basin, contributing an estimated 430,000 yds^3 (645,000 tons) of sediment to streams (personal comm., Madej, 2003). Of these torrents, 97 were associated with roads which implies the large volume of sediment input might have been preventable if roads had been decommissioned or upgraded. Also, we have observed offsite landsliding caused along stream channels that have filled rapidly by torrent deposits. This volume is not included in yield estimates when sites are evaluated because doing so would be highly speculative.

There are three to seven stream crossings per mile of road, averaging four crossings per mile on all roads evaluated. Stream crossings with diversion potentials represent a significant sediment threat to watershed resources, because they often lead to deep hillslope gully erosion that can initiate landslide erosion. Of the 2,335 stream crossings evaluated in all project areas, 1,421 crossings (60%) had diversion potentials that can divert a stream from its natural watercourse. We estimate there are 488 (20%) critical crossings that are most likely to divert streamflow, because each critical crossing has a diversion potential, undersized culvert and at least medium plug potential. The potential yield for stream diversions was not estimated during the

assessment, but we know from past experience in the Redwood Creek watershed that potential yield from stream diversions during large storms can be significant. The potential sediment yield from future stream diversions is predictably high and preventable with proper crossing design and/or critical dip placement. Stream crossings with diversion potentials should be treated as soon as possible. We estimate there are 4,000-5,000 stream crossings in the upper watershed.

Forest road construction standards have improved greatly over the past years, but continued improvements are needed. In particular, stream crossing standards should reflect the shear number of crossings that exist and the significant risk they pose to salmonids and water quality. Stream crossing standards should emphasize properly sized and installed culverts, minimum fills, grade breaks or critical dips, and properly compacted fills. Roads and inboard ditches should be disconnected from streams.

The high number of unmaintained roads in the upper Redwood Creek watershed most likely reflect legacy roads built during the initial watershed entry when there was little concern for proper road design and construction, and hillslope stability. Of all roads evaluated, about 60 percent of the road mileage was unmaintained and 32 percent was maintained at the time of the assessment. We have no data for about 7 percent of the road mileage, and about 1 percent had been decommissioned at the time of the assessment. Unmaintained roads contained about 70 percent of all sites evaluated and accounted for 80 percent of the potential sediment yield. Maintained roads contained about 30 percent of all sites and represented 20 percent the future potential sediment yield. The potential impacts associated with roads do not disappear with time. Clearly, roads should be maintained into perpetuity or they should be permanently or temporarily decommissioned.

Common sense suggests that road density in Redwood Creek is too high. The effects of roads have been well documented in scientific literature. Roads act as first-order streams that convey water directly to larger streams (Wemple and others, 1996). Roads have been associated with increases in peak discharges for small and larger watersheds (Jones and Grant, 1996). Roads can increase landslide risk through increased pore water pressure caused by soil compaction during road construction (Keppeler and Brown, 1998). Roads and harvest rates in heavily managed sub-watersheds have been associated with high turbidity levels (Klein, in progress). Significant increases in fine sediment have been observed once road area exceeds 3 percent of the basin area (Cederholm and Reid, 1987). We do not know what an appropriate road density would be for Redwood Creek or its sub-watersheds, but we believe an average road density of less than 5 miles/mile^2 would be a reasonable starting point.

The riparian corridor along Redwood Creek has changed significantly since the advent of timber harvest. Once dominated by coniferous forests that provided shade and a source of large woody debris, today an estimated 60 percent of the riparian corridor is dominated mostly by hardwood forests. Outside of the Prairie Creek sub-watershed, the main channel of Redwood Creek represents about 70 percent of all accessible anadromous salmonid habitat in the Redwood Creek watershed (California Resources Agency, 2002). The hardwood dominated riparian corridor is likely the result of timber harvests that occurred during an earlier period in which the relationships between riparian forests, in-channel large woody debris, aquatic and salmonid habitat, and water quality was not well understood.

Riparian restoration opportunities exist through conifer planting and/or release, especially where Douglas-fir is established below hardwood canopies. The greatest restoration opportunities might exist in the reaches upstream of Highway 299 where the active channel is commonly less than 100 feet wide, well within the growth potential of Douglas-fir that could provide channel spanning structure. Larger conifers in this reach could add channel and pool complexity, provide over-winter habitat, and better survive the larger floods because root masses would still be attached. Planning for future timber harvests along Redwood Creek and its higher order tributaries should continue to fully evaluate existing riparian conditions and the supply of recruitable large woody debris. Conservation easements, especially for the inner gorge of Redwood Creek, upstream of Highway 299, could also be arranged with willing landowners.

We have presented several methods that can be used to prioritize erosion control and prevention treatments in the Redwood Creek watershed. When considering the results from three analyses, 14 out of 41 sub-watersheds ranked consistently high in at least two of the three analyses selected for this comparison. Eight sub-watersheds ranked high in all three analyses. They were Coyote, Dolly Varden, Joplin, Lee, Powerline, Timbo, Tom and Wiregrass creeks. Seven sub-watersheds ranked high in at least two out three analyses, and included Headwaters East, Headwaters West, Johnson Prairie, Lacks, Lake Prairie, Panther, and Pilchuck creeks. Lacks Creek has the highest potential sediment yield (197,200 yds^3) but it is also the largest sub-watershed in the Redwood Creek watershed. Lack Creek also contains the highest number of anadromous salmonid species. Lee Creek had the highest potential sediment yield normalized by sub-watershed area (42,000 yds^3/mi^2) and miles of road evaluated (6,020 yds^3/mi.).

Regardless of how erosion control and prevention treatments are prioritized in the Redwood Creek watershed, it is important to remember that ground conditions change, some landowners are more able and willing to implement erosion control and prevention work than others, and logistics can complicate “priorities." The most effective erosion control and prevention strategy for the Redwood Creek watershed should be flexible and recognize the challenging nature of implementing projects across a large landscape with multiple owners.

Monitoring

Restoration Implementation

The parks are pro-actively working with private landowners, using the assessment results to prepare implementation projects. RNSP is monitoring the progress of the implementation projects to best assure the completion of the erosion control treatments of all roads in the upper basin within the next 10-15 years.

The parks have developed a component of the road assessment database that records completed work for each identified erosion potential site. RNSP records currently show that about 18 miles of roads have been decommissioned and 27 miles have been upgraded since 1995, but the

records are incomplete. Many more miles of roads have been upgraded or decommissioned in conjunction with timber harvest plans and some landowners have treated roads as part of their road management programs.

RNSP is currently working with the landowners to compile all treatment work completed subsequent to the road assessments. The parks and landowners have agreed to record all site specific work accomplishments on a jointly developed form. All data are being stored in the RNSP database for future analysis.

Our records also show that more than $1.1 million has been spent to upgrade and decommission roads in the upper watershed over that past 10 years. Again, this does not include work that has been completed through timber harvest plans or as part of landowner road management programs. An additional $1.2 million is now secured for road treatments in 2003 through 2005. These projects will decommission and upgrade about 10 miles of highest priority roads. Project funds have come from the following sources: SB 271, 49%; Landowners, 22%; USFWS, JITW, 13%; Clean Water Act, Section 319h, 11%; and RNSP, 5%.

Photo points

All implementation projects completed in partnership with RNSP are photo documented with before and after photography of selected, representative work sites. The photographs are taken from monumented photo-points and traditionally are reoccupied for two subsequent years following completion of work. Selected work sites may be re-photographed in later years as access and revegetation allows.

Budget

No major property was purchased for the project. There were no cost overruns. Grant funds made available from USFWS, JITW were expended except for $2 left unspent. All cost share contributions either met or exceeded original estimates. The exceeded amounts were provided by the National Park Service. The budget for Project 3 is shown in Table 25.

Table 25. Budget worksheet showing estimated budget and actual expenses incurred for Project 3.

			Funding Request	Other Federal funds	Other Non-Federal Cost share Cash	Total Estimated Budget	Total Actual Expenses Incurred	Actual USFWS-JITW Expenses	Difference Requested - Actual
1) Personnel (wages):	**#Hours**	**Hourly Rate**							
Project Manager	750	20.00	0	2,500	12,500	15,000	15,000	0	0
Survey Crews	2,920	14.50	0	10,000	32,340	42,340	42,340	0	0
Phys. Sci. Tech	1,569[1]	15.10	23,691			23,691	22,742	22,742	949
(data management and field reviews)									
Staff Benefits			8,292	1,650	9,102	19,044	19,991	9,239	<947>
Subtotal Personnel			**31,983**	**14,150**	**53,942**	**100,075**	**100,073**	**31,981**	**2**
2) Sub-contractors	**#Hours**	**Hourly Rate**							
Geologist (100% field review)	603	38.76	0	0	23,370	23,370	23,370	0	0
Subtotal Personnel			**0**	**0**	**23,370**	**23,370**	**23,370**	**0**	**0**
3) Materials and Supplies									
-- none --			0	0	0	0	0	0	0
Subtotal materials and Supplies			**0**	**0**	**0**	**0**	**0**	**0**	**0**
4) Operating Expenses ---	**#Units**	**Cost/Unit**							
Mileage/Trans.	17,400 mi.[2]	.24/mi.	0	1,350	4,989	6,339	6,339	0	0
Trans. 4X4 quad,	50 days [3]	$50/day	0	500	2,500	3,000	3,000	0	0
Travel perdiem	60 days [4]	$40/day	0	1,200	2,400	3,600	3,600	0	0
Materials and supplies			0	700	1,911	2,611	2,611	0	0
Insurance			0	250	750	1,000	1,000	0	0
Administrative			0	1,850	7,986	9,836	9,836	0	0
Subtotal Operating Expenses			**0**	**5,850**	**20,536**	**20,536**	**26,386**	**0**	**0**
Total Direct Costs			**31,983**	**14,150**	**77,312**	**123,445**	**121,708**	**31,981**	**2**
Totals			**31,983**	**20,000[5]**	**97,848[6]**	**149,831**	**148,094**	**31,981**	**2**

Table notes:

[1] Actual Physical Science Technician hours were 1433, with an average hourly rate of $15.87.

[2,3,4] Typographical errors in proposal budget: mileage # units should have read 26,412 mi.; Trans. 4X4 quad should have read 60 days; Travel perdiem should have read 90 days.

[5] Other Federal funds: RNSP provided $20,000 cash.

[6] Other Non-Federal Cost Share: California SB271 grant = $87,848; Simpson Resource Company = $10,000.

Costs for Project Manager, Survey Crews, a portion of Staff Benefits, and all Operating Expenses were incurred by Pacific Coast Fish, Wildlife and Wetlands Restoration Association (PCFWWRA). RNSP provided $20,000 to PCFWWRA for a portion of those costs.

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Glossary

Culvert - a metal, plastic or concrete pipe set below the road surface. Is used to pass streamflow from upslope of the road to downslope of the road. Culverts can also be placed to drain springs and inboard ditch flow from the inside to the outside of the road, beyond the outer edge of the road fill, or fillslope.

Class I watercourse crossing – a fish bearing stream as defined by the California Forest Practice Rules.

Cost-effectiveness – the cost per unit volume of sediment to prevent it from entering a stream, commonly expressed as $/yd^3$ "saved".

Critical crossing – a haul road or skid road crossing at a stream channel that possesses all three of the following characteristics: a diversion potential, an undersized culvert and medium to high plug potential.

Critical dip – a broad rolling dip located at a stream crossing that returns streamflow to its natural watercourse if the crossing culvert plugs and streamflow overtops the road. It is a broad, gentle, permanent dip (low spot) across the road surface that allows passage of vehicles, logging trucks and standard logging equipment. They are generally maintenance-free.

Cross-road drain - a deep, abrupt ditch constructed across a road to drain water from the road surface and/or inboard ditch. Generally, not drivable and placed at frequent intervals (approx. every 50 - 100 feet) on permanently closed roads. Compare to *rolling dip.*

Delivery – the percentage of erosion volume that is actually delivered to a stream. It is used to calculate *yield*. Stream crossings usually have a 100% delivery. For landslides the percent delivery can be between 0 and 100%. Some landslides fail and deliver to a hillslope or terrace bench with no delivery to streams (0%). Many landslides deliver 100% directly to stream channels.

Diversion – a condition originating at a stream crossing, where stream flow overtops the road and flows down a road, inboard ditch, or skid trail instead of re-entering its natural watercourse. Stream diversions can cause significant gully and landslide erosion.

Diversion potential – normally associated with stream crossings that have continuous road grades through the crossing which allow a stream to flow down a road if the crossing culvert plugs and streamflow overtops the road. The crossing is not the low point of the road as the road passes over the stream channel. Existing diversion potentials can be corrected by installing well-constructed *critical dips* at the crossing so that streamflow returns immediately to its stream channel if diversion occurs. Proper crossing construction (grade-breaks, critical dips, minimum fill, properly sized culverts) can prevent diversions.

Decommission – the process of removing road fill or reshaping a road such that erosion and sedimentation are minimized. A decommissioned road has all culverts removed, all road fill at stream crossings fully excavated and permanent, self-maintaining road surface drainage provided by a combination of outsloping, rolling dips or cross road drains. A road may be permanently or temporarily decommissioned.

Ditch relief culvert (DRC) – a drainage structure that intercepts and conveys water from the inside edge of the road to the outside edge of the road.

Downspout – normally culvert material bolted and secured to the culvert outlet that conveys water down a fillslope to undisturbed ground to prevent surface erosion. Downspouts may be either full-round or half-round.

Erosion potential (EP) – the subjective and relative ranking of the likelihood, not magnitude, of erosion at a site during the next major storm. Expressed as "high", "medium" or "low."

Erosion volume – is the amount of material that could eroded from a site. It is expressed in cubic yards and 0-100 percent may reach a stream. Is used with *delivery* to calculate *yield*.

Extreme erosion potential (EEP) – A subjective assessment of the capability of a potential erosion site to erode significantly more volume than the estimated potential erosion volume. Expressed as "yes" or "no." It characterizes a worst case scenario that identifies the potential for an unusually large magnitude failure. An example would be a stream diversion that could obliterate inboard ditches, relief pipes, and other crossings during a major storm, or a stream crossing or landing that could fail catastrophically, scouring hillslopes or channels below.

Extreme potential yield – The volume of sediment that would be delivered to a stream by a site failing under the extreme erosion potential scenario. Expressed in cubic yards.

Fluvial erosion – erosion caused by flowing water. Includes erosion at stream channels, gullies and rills. Compare to landslide erosion, which does not include erosion by flowing water.

Ford – a stream crossing that requires a vehicle to drive across and through a stream channel bed. There is no fill or drainage structure in a ford crossing.

Inboard ditch – a ditch along the inside edge of the road that collects and conveys road surface runoff and spring discharge. The ditch usually conveys runoff to the next culvert or drainage structure down the road.

Landing – a location where logs are collected and loaded onto trucks for transport. Landings are typically located along haul roads.

Landslide erosion – erosion associated with mass movement of soil or hillslope. Types of landslides are debris slides, torrents, earthflows, slumps, rock falls and others. Compare to fluvial erosion, which is erosion by flowing water.

Maintained road – a road that shows evidence of recent maintenance, including cleaning of culvert inlets, trash racks, and inboard ditches, grading, rolling dip or waterbar reconstruction, brushing, culvert replacement, or reconstruction of fills. Compare to *unmaintained road*.

Outslope – a road surface that is shaped to slant toward the outside (downslope side) edge of a road. The slanted surface naturally disperses surface runoff. A road that is outsloped may or may not be drivable depending on the intent of treatment. Outsloped road may or may not have an inboard ditch.

Outsloping – the act of changing a flat or insloped road to an outsloped road. For erosion control treatments, substantial fill is removed from the outer edge of the road prism, and spread and shaped along the inside edge of the road, typically against the cutbank. For surface drainage on active roads, the road surface has a mild outslope that is driveable by logging trucks and forms a relatively maintenance-free road surface that disperses road surface runoff.

Potential sediment yield – the larger of the *site potential yield* and the *extreme potential yield* (if one exists) for a site. Expressed in cubic yards.

Road upgrade – improving a road to current road building standards with the intent of reducing erosion from roads. Upgrading includes; replacing rusted, plugged and undersized culverts, reshaping roads for proper drainage, constructing critical dips at crossings to prevent stream diversions, pulling back steeply perched road or landing fill that can enter a stream, reducing road fill volumes at stream crossings and others.

Rolling dip - a broad, shallow, gentle dip (low point) in the road surface that collects road surface runoff and conveys it to the outer edge of the road. It can also drain an inboard ditch.

Site potential yield - the expected volume of material that would be delivered to a stream from a single erosion site expressed in cubic yards. It is computed by multiplying the *erosion volume* at a site by the percentage *delivery* to the stream (e.g. 800 yds^3 erosion volume x 80% delivery = 640 yds^3 site potential yield). Compare to *extreme potential yield* and *potential sediment yield*.

Skid trail crossing - a point where a tractor skid trail crosses a defined stream channel. A drainage structure may or may not be present.

Stream crossing – the point where a road crosses a defined stream channel. The crossing may be composed of road fill without a drainage structure or may be composed of buried logs (Humboldt crossing), a culvert, a ford, or a bridge.

Stream diversion - a condition where streamflow has been diverted from its natural watercourse.

Unmaintained road – a road that lacks obvious maintenance to culverts, ditches and road surface. Culverts may be partially or completely plugged, badly rusted or crushed, outlet flow uncontrolled across fillslope or other deficiencies present. Ditches may lack cleaning and vegetation may be encroaching the road and road surface. The road may or may not be drivable.

Upgrade – improving a road to current road building standards with the intent of reducing erosion from roads. Upgrading includes; replacing rusted, plugged and undersized culverts, reshaping roads for proper drainage, constructing critical dips at crossings to prevent stream diversions, pulling back steeply perched road or landing fill that can enter a stream, reducing road fill volumes at stream crossings and others.

Urgency or treatment urgency – a subjective and relative assessment of the need to treat a site to prevent erosion. Identified as low, medium or high. A low urgency site typically would survive an average winter storm with little threat of experiencing or causing erosion. A medium urgency site may experience erosion during an average winter if left untreated. A high urgency site would likely erode or cause erosion during an average winter if left untreated.

Waterbar – a shallow ditch or berm constructed across a road or skid trail that drains the road surface and/or inboard ditch. It is not a permanent structure as they tend to break down with any type of use, including wildlife tramping. They are insufficient to prevent stream diversions at crossings.

Yield – the amount of sediment that reaches a stream channel. It is express in cubic yards and may be 1-100 percent of the *erosion volume*.

APPENDIX A

REDWOOD CREEK BASIN ROAD ASSESSMENT FORM

Reviewed by : _____
ID No.: _____

REDWOOD CREEK BASIN ROAD INVENTORY FORM
Redwood National and State Parks / Pacific Watershed Associates
Version 5/6/00

Check _____
ASAP _____

SECTION I: GENERAL SITE INFORMATION

Road Name:_____ Site # _____ Date:_____ By:

Watershed:_____ Ownership _____Year built:

Quad ID:_____ Photo#_____ Photo date:

Current road condition: Drivable [Maintained Abandoned Decommissioned]

The road surface is: [Native Rocked Paved]

Proposed Treatment: [Maintain Upgrade Decommission]

SECTION II: FLUVIAL SITE (CROSSINGS, RELIEF CULVERTS, GULLY, ETC.)

***FEATURE**:* [Stream crossing Skid Xing ***Ditch/road relief Road reach] Spring

***EROSIONAL PROCESS**:* None Gully Streambnk/channel eros. Collapsing Fill failure

***DRAINAGE STRUCTURE**:* Bridge ***Culvert:** *metal *concrete *plastic

Humboldt Fill Ford Armored fill Pulled

Critical dip@xing? **Y N** Left ditch/road length_____ft. Right ditch/road length_____ft.

***DIVERSION POTENTIAL**:* DP? **Y N** Now diverted Past diverted Rd grade_____%

CONDITION OF FILL: Intact removed_____% washed-out_____%

***CULVERT INLET INFORMATION**:*

***Diameter_____in. Headwall height_____in. Rust line: width_____ in. depth_____ in.

Upstream channel: width_____ft; depth_____ft; grade_____%

Stream class: **I, II, III, or IV** Sediment transport: **H M L**

Does culvert look undersized? **Y M N** Plug potential: **H M L**

***Inlet condition:** OK Rust/holes Band separation Trash rack Drop inlet

***crushed_____% ***plugged_____%

CULVERT OUTLET INFORMATION:

***Condition:** OK Rust/holes Functional downspout %crushed_____% Shotgun

Fish-outlet drop: now _____ ft. @bankfull_____ ft. Culvert grade_____%

Pool dim.: length_____ft. depth_____ft. @bankfull: length_____ft. depth_____ft.

Comments:

SECTION III: LANDSLIDE SITE

***FEATURE**:* Swale Road fill Landing fill Cutbank Hillslope

***PROCESS**:* Slow, deep seated Fast, shallow debris slide Will it debris torrent? **Y M N**

***SETTING**:* Streamside (<55%) Inner gorge (>55%) Headwall Break-in-slope Hillslope

Distance to stream_____ft. Slope_____%

ACTIVITY: Failed in past? : **Y N** %failed_____%

***ASSOCIATION(S)**:* Road related Water onto feature Spring Stream undercutting

SECTION IV: TREATMENTS (Circle all that apply)

Critical dip@xing Install culvert Replace culvert New culv: dia._____in. len_____ft.

Drop inlet Flared inlet Trash rack Remove sed@CMP inlet Brush inlet

Reconstruct fill Excavate fill Ford Bridge Other None

Armor fillslope: @inlet _____ft^2; Downstream face_____ft^2 Downspout_____ft.

Armored fill: sill height_____ft. sill width_____ft. Check culvert size

********** URGENCY: **H M L** COMPLEXITY: **H M L** **********

ROAD REACH TREATMENTS

Clear/est. IBD_____ft. Remove IBD_____ft. Rock road_____ft^2. Remove berm_____ft.

Rolling dips: # _____ OS w/out IBD_____ft. OS w/IBD_____ft. Inslope road_____ft.

Cross-road drains # _____ Ditch relief culvert #_____, _____ ft.

SECTION V: FILL AND FUTURE EROSION VOLUMES

Dimensions of landslide or gully: length:_____ft. width:_____ ft. depth:_____ft.
(Use Comment Section below to record dimensions of complex features)

Future erosion volume:_____yd^3 %delivery:_____% Future yield:_____yds^3

Erosion Potential: **H M L** Potential for Extreme Erosion? **Y N**

Is the treatment likely to control or prevent erosion?: **Y M N**

Extreme Erosion Potential Volume (yds^3): [<500, 500-1000, 1K-2K, 2K-5K, >5K]

3	EXCAVATION VOLUMES	3	EQUIPMENT HOURS	COMMENT ON TREATMENT:
	Total excavated (yds^3):		Excavatror (hrs):	
	Vol. put back in (yds^3):		Dozer (hrs):	
	Vol. removed (yds^3):		Dump truck (hrs):	
	Vol. stockpiled (yds^3):		Grader (hrs):	
	Vol. endhauled (yds^3):		Backhoe (hrs):	
	Dist. endhauled (ft):		Labor (hrs):	
	Exca. prod. rate (yds^3/hr):		Other:	

Stream Profile through Crossing (begin at top of crossing)

Xing type: 1, 2, 3, 4 (circle one)

Angle (deg) (up+, dn-)	Distance (feet)	Code (UES, TOP, IBR, OBR, BOT, XS1, XS2 ….LES)	Comments
0	*0*	*UES, TRN*	*in natural channel*

Cross Section(s) (begin on left side of crossing)

XS#	Angle (deg)	Distance (feet)	Code (LRP, LEC, CLP,REC,RRP)	Comments
1	*0*	*0*	*LRP, TRN*	*Base of cutbank*

Site sketch - ***Site No. :*** .

Design Results	
Decommission vol. (2:1)	
Erosion vol. (1:1)	
Culvert add/repl. vol. (1:1)	
Humboldt crossing (1:1)	
Culvert length needed	

APPENDIX B

TREATMENT PRIORITIES FOR ROADS USING THREE DIFFERENT CRITERIA

Table B-1: Roads in Projects 1, 2, 3 and 5 prioritized by total potential sediment yield from medium to high treatment urgency sites.

Table B-2: Roads in Projects 1, 2, 3 and 5 prioritized by total potential sediment yield per mile from medium to high treatment urgency sites.

Table B-3: Roads in Projects 1, 2, 3 and 5 prioritized by site specific cost/yard “saved” from medium to high treatment urgency sites.

APPENDIX C

SUB-WATERSHED RANKING AND CRITERIA

Table C-1. Sub-watershed ranking by potential sediment yield

Table C-2. Sub-watershed ranking by critical crossings

Table C-3. Sub-watershed ranking by slope steepness

Table C-4: Sub-watershed ranking by the number of salmonid species observed in each sub-watershed

Figure C-1. Slope steepness upper Redwood Creek watershed

Figure C-2. Anadromous salmonid distribution by sub-watershed, upper Redwood Creek watershed

APPENDIX C

SUB-WATERSHED RANKING

Table C-1. Sub-watersheds ranked by total potential sediment yield.
Table C-2. Sub-watersheds ranked by critical crossings.
Table C-3. Sub-watersheds ranked by average weighted site steepness.
Table C-4. Sub-watersheds ranked by the number of salmonid species.

Figure C-1. Slope steepness upper Redwood Creek.
Figure C-2. Anadromous salmonid distribution by sub-watershed, upper Redwood Creek watershed.

Table C-1. Sub-watersheds ranked by total potential sediment yield per square mile. Includes Projects 0, 1, 2, 3, 5, and 96, and only major sites such as crossings, landings and road reaches with medium to high erosion potential. Does not include sub-watersheds in which less than 40 percent of the roads had been evaluated.

Sub-Watershed	Acres	%Road Evaluated	Total Potential Sediment Yield		Normalized Value
			(yds^3)	(yds^3/mi)	
Lee	292	100%	19,264	42,261	9
Headwaters_W	179	55%	8,914	31,843	9
Timbo	229	90%	9,899	27,632	9
Tom	259	93%	10,899	26,920	9
Joplin	441	90%	17,290	25,110	9
Headwaters_E	114	82%	4,401	24,733	9
Dolly Varden	2,151	90%	76,148	22,660	9
Wiregrass	1,153	93%	35,631	19,771	7
Lake Prairie	2,144	68%	66,193	19,763	7
Toss-Up	1,709	97%	47,414	17,760	7
Garcia	905	80%	20,627	14,581	5
Powerline	408	91%	9,256	14,515	5
Smokehouse	426	74%	9,210	13,850	5
Loin	601	43%	12,515	13,328	5
Burley	255	91%	5,089	12,789	5
Pilchuck	1,086	88%	21,449	12,643	5
Panther	3,800	92%	74,343	12,522	5
Johnson Prairie	386	87%	7,338	12,179	5
Stover	544	49%	9,885	11,621	5
Twin Lakes	811	90%	14,604	11,523	5
Lacks	10,977	81%	197,193	11,497	5
Coyote	5,043	62%	89,850	11,402	5
George	699	99%	11,297	10,349	5
Fern Prairie	509	72%	7,310	9,194	3
June	125	100%	1,694	8,701	3
Headwaters_M	1,688	59%	19,219	7,289	3
Lupton	3,329	52%	37,573	7,224	3
Jena	246	47%	2,715	7,061	3
Ayers	242	97%	2,234	5,901	3
Snow Camp	773	63%	6,262	5,182	3
Christmas Prairie	455	71%	3,033	4,267	1
Cashmere	861	68%	5,554	4,130	1
Pardee	1,985	59%	12,560	4,050	1
Santa Fe	530	43%	3,003	3,625	1
Marquette	492	77%	2,747	3,572	1
Noisy	4,030	67%	20,392	3,239	1
Cool Springs	737	44%	3,592	3,118	1
Garrett	2,643	62%	12,705	3,076	1
Debris Torrent	129	98%	559	2,770	1
Six Rivers	741	58%	3,056	2,640	1
Monroe Flat	189	55%	223	755	1

Table C-2. Sub-watersheds ranked by critical crossings.
Includes Projects 0, 1, 2, 3, 5, and 96. Includes sites with low-high erosion potential. Does not include sub-watersheds in which less than 40 percent of the roads had been evaluated. Critical crossings have a diversion potential, an undersized culvert, and a medium-high plug potential.

Sub-Watershed	Miles			#CXs	#CXs/Mile	Normalized Value
	Total	Evaluated	%Evaluated			
Johnson Prairie	2.2	1.9	87%	12	6.3	9
Burley	3.3	3.0	91%	7	2.4	9
Powerline	4.6	4.2	91%	9	2.2	9
Tom	2.7	2.5	93%	4	1.6	9
Garrett	22.2	13.8	62%	20	1.5	7
Coyote	36.2	22.3	62%	32	1.4	7
Joplin	4.7	4.2	90%	6	1.4	7
Timbo	4.0	3.6	90%	5	1.4	7
George	7.4	7.3	99%	9	1.2	5
Stover	5.4	2.7	49%	3	1.1	5
Debris Torrent	1.8	1.8	98%	2	1.1	5
June	0.9	0.9	100%	1	1.1	5
Jena	4.1	1.9	47%	2	1.0	5
Headwaters_W	1.8	1.0	55%	1	1.0	5
Wiregrass	9.5	8.8	93%	9	1.0	5
Headwaters_E	1.3	1.0	82%	1	1.0	5
Lee	3.2	3.2	100%	3	0.9	5
Cool Springs	9.7	4.3	44%	4	0.9	5
Dolly Varden	28.8	26.0	90%	24	0.9	5
Snow Camp	8.6	5.5	63%	5	0.9	5
Panther	40.0	36.7	92%	33	0.9	5
Lacks	91.6	74.5	81%	62	0.8	3
Christmas Prairie	6.9	4.9	71%	4	0.8	3
Six Rivers	9.1	5.3	58%	4	0.8	3
Loin	6.1	2.6	43%	2	0.8	3
Pardee	27.4	16.2	59%	12	0.7	3
Smokehouse	5.8	4.3	74%	3	0.7	3
Lupton	44.1	22.8	52%	15	0.7	3
Fern Prairie	6.5	4.7	72%	3	0.6	3
Garcia	10.1	8.1	80%	5	0.6	3
Ayers	3.9	3.8	97%	2	0.5	3
Noisy	49.0	32.7	67%	17	0.5	3
Santa Fe	9.2	4.0	43%	2	0.5	3
Lake Prairie	27.7	18.8	68%	9	0.5	3
Toss-Up	15.2	14.7	97%	7	0.5	3
Pilchuck	7.2	6.3	88%	2	0.3	1
Headwaters_M	16.3	9.6	59%	3	0.3	1
Twin Lakes	10.0	9.0	90%	2	0.2	1
Marquette	6.3	4.9	77%	1	0.2	1

Table C-3. Sub-watersheds ranked by average weighted site steepness.
Includes Projects 0, 1, 2, 3, 5, and 96, and only major sites such as crossings, landings, and road reaches sites with medium to high erosion potential. Does not include sub-watersheds in which less than 40 percent of the roads had been evaluated. Slope steepness was normalized at the highest weighting value, in this case 9, to give it equal importance with other ranking criteria.

Sub-Watershed	Total Miles	Percent Evaluated	#Sites	Sum of Weighted Steepness	Average Weighted Steepness	Normalized Value
Pilchuck	7.2	88%	31	161	5.2	9.0
June	0.9	100%	4	20	5.0	8.7
Lee	3.2	100%	16	74	4.6	8.0
Ayers	3.9	97%	7	31	4.4	7.7
Garcia	10.1	80%	22	96	4.4	7.6
Timbo	4.0	90%	21	85	4.1	7.0
Cool Springs	9.7	44%	8	32	4.0	7.0
Lacks	91.6	81%	340	1,344	4.0	6.9
Panther	40.0	92%	79	309	3.9	6.8
Lake Prairie	27.7	68%	58	226	3.9	6.8
Wiregrass	9.5	93%	47	179	3.8	6.6
Debris Torrent	1.8	98%	5	19	3.8	6.6
Powerline	4.6	91%	26	98	3.8	6.6
Toss-Up	15.2	97%	90	328	3.6	6.3
Coyote	36.2	62%	132	474	3.6	6.2
Joplin	4.7	90%	19	67	3.5	6.1
Loin	6.1	43%	20	70	3.5	6.1
Pardee	27.4	59%	45	157	3.5	6.1
Cashmere	10.3	68%	15	51	3.4	5.9
Christmas Prairie	6.9	71%	10	28	2.8	4.9
Dolly Varden	28.8	90%	116	324	2.8	4.9
George	7.4	99%	20	54	2.7	4.7
Twin Lakes	10.0	90%	19	51	2.7	4.7
Headwaters_M	16.3	59%	37	99	2.7	4.7
Lupton	44.1	52%	95	249	2.6	4.6
Marquette	6.3	77%	15	39	2.6	4.5
Garrett	22.2	62%	24	62	2.6	4.5
Stover	5.4	49%	18	46	2.6	4.4
Snow Camp	8.6	63%	23	57	2.5	4.3
Headwaters_W	1.8	55%	6	14	2.3	4.1
Johnson Prairie	2.2	87%	18	42	2.3	4.1
Noisy	49.0	67%	64	140	2.2	3.8
Headwaters_E	1.3	82%	2	4	2.0	3.5
Fern Prairie	6.5	72%	18	36	2.0	3.5
Six Rivers	9.1	58%	12	24	2.0	3.5
Santa Fe	9.2	43%	13	25	1.9	3.3
Jena	4.1	47%	7	11	1.6	2.7
Burley	3.3	91%	13	19	1.5	2.5
Tom	2.7	93%	10	14	1.4	2.4
Smokehouse	5.8	74%	20	24	1.2	2.1
Monroe Flat	1.8	55%	1	1	1.0	1.7

Table C-4. Sub-watersheds ranked by the number of salmonid species.
Includes Projects 0, 1, 2, 3, 5, and 96. The number of salmonid species found in each sub-watershed has been normalized on the largest weighting value, in this case 9, so that salmonids are given equal importance with other sub-watershed ranking criteria.

Sub-Watershed	Acres	Number of Species	Normalized Value
Lacks	10,977	4	9.0
Coyote	5,043	3	6.8
Dolly Varden	2,151	2	4.5
High Prairie	3,476	2	4.5
Panther	3,800	2	4.5
Pilchuck	1,086	2	4.5
Cashmere	861	1	2.3
Garcia	905	1	2.3
Garrett	2,643	1	2.3
Jena	246	1	2.3
Lake Prairie	2,144	1	2.3
Loin	601	1	2.3
Lupton	3,329	1	2.3
Noisy	4,030	1	2.3
Pardee	1,985	1	2.3
Santa Fe	530	1	2.3
Six Rivers	741	1	2.3
Smokehouse	426	1	2.3
Snow Camp	773	1	2.3
Toss-Up	1,709	1	2.3
Twin Lakes	811	1	2.3
Windy	1,118	1	2.3
Wiregrass	1,153	1	2.3
Ayers	242	0	0.0
Burley	255	0	0.0
Christmas Prairie	455	0	0.0
Cool Springs	737	0	0.0
Debris Torrent	129	0	0.0
Fern Prairie	509	0	0.0
George	699	0	0.0
Headwaters_E	114	0	0.0
Headwaters_M	1,688	0	0.0
Headwaters_W	179	0	0.0
Johnson Prairie	386	0	0.0
Joplin	441	0	0.0
June	125	0	0.0
Lee	292	0	0.0
Marquette	492	0	0.0
Monroe Flat	189	0	0.0
Powerline	408	0	0.0
Stover	544	0	0.0
Timbo	229	0	0.0
Tom	259	0	0.0

Slope Steepness

Upper Redwood Creek Watershed

Coyote
Bridge
Johnson Prairie
Devils
Garrett
Joplin
Monroe Flat
Stover
Panther
George
Lacks
Dolly Varden
Lee
Garcia
Cashmere
Moon
Pilchuck
Toss-Up
June
Minor
Wiregrass
Loin
Santa Fe
Sweathouse
Greenpoint
Captain
Lupton
Windy
Fern Prairie
Squirrel Tail
Christmas Prairie
Emmy Lou
Jena
Cut-Off Meander
Gunrack
Noisy
Simon
Cool Springs
Six Rivers
Minon
Ayers
High Prairie
Upper Panther
Lake Prairie
Bradford
Pardee
Marquette
Last Gap
Timbo
Powerline
Lineament
Snow Camp
Smokehouse
Twin Lakes
Burley
Tom
Headwaters_E
Headwaters_W
Headwaters_M

N
W
E
S

Slope Steepness

- 0 - 30%
- 31 - 50%
- 51 - 65%
- > 65%
- Roads
- Streams (1:24k)
- Watershed divides
- RNSP Boundary

Slope is presented here as calculated from a 10-meter drainage-enforced digital elevation model created in-house at RNSP.

SCALE 1:133,000

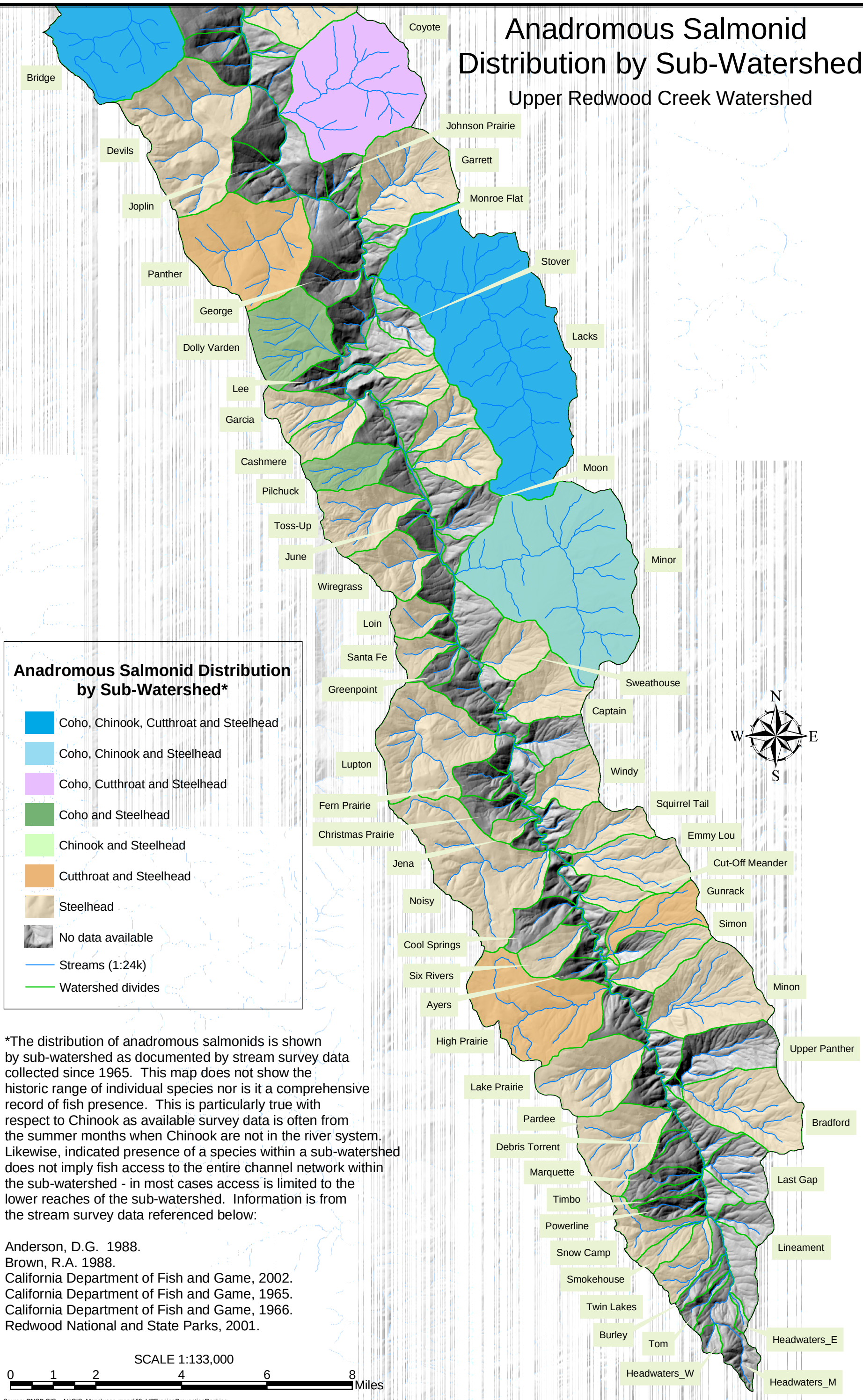
0 1.25 2.5 5 7.5 10 Miles

Source: RNSP GIS - N:\GIS_Maps\user_maps\60_UBErosionPreventionRanking
Compiled: February, 2003

Figure C-1. Slope Steepness

Anadromous Salmonid Distribution by Sub-Watershed

Upper Redwood Creek Watershed



Anadromous Salmonid Distribution by Sub-Watershed*

- Coho, Chinook, Cutthroat and Steelhead
- Coho, Chinook and Steelhead
- Coho, Cutthroat and Steelhead
- Coho and Steelhead
- Chinook and Steelhead
- Cutthroat and Steelhead
- Steelhead
- No data available
- Streams (1:24k)
- Watershed divides

*The distribution of anadromous salmonids is shown by sub-watershed as documented by stream survey data collected since 1965. This map does not show the historic range of individual species nor is it a comprehensive record of fish presence. This is particularly true with respect to Chinook as available survey data is often from the summer months when Chinook are not in the river system. Likewise, indicated presence of a species within a sub-watershed does not imply fish access to the entire channel network within the sub-watershed - in most cases access is limited to the lower reaches of the sub-watershed. Information is from the stream survey data referenced below:

Anderson, D.G. 1988.
Brown, R.A. 1988.
California Department of Fish and Game, 2002.
California Department of Fish and Game, 1965.
California Department of Fish and Game, 1966.
Redwood National and State Parks, 2001.

SCALE 1:133,000

0 1 2 4 6 8 Miles

Source: RNSP GIS - N:\GIS_Maps\user_maps\60_UBErosionPreventionRanking
Compiled: February, 2003

Figure C-2. Anadromous salmonid distribution by sub-watershed