

Redwood Creek Assessment Implementation Summary



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Assessment Implementation Summary

Preface to this Summary

This summary provides key findings and recommendations from the NCWAP Redwood Creek Watershed Assessment. Therefore, goals, methods, and analytic tools and systems are only briefly discussed. Likewise, the basin's contextual background, history, and the conditions of its geology, hydrology, vegetation, stream systems, water quality, and land uses are only briefly summarized here. The complete Redwood Creek Watershed Assessment Report and its appendices should be consulted for detailed multidisciplinary discussions and the synthesis of findings and recommendations.

Assessment Report Structure and Usage Guide

The complete Redwood Creek Assessment has seven main sections:

- Executive Summary
- Program Introduction and Overview
 - Six guiding assessment questions (see page 6)
 - Four strategic program goals (see page 7)
- Assessment Strategy and General Methods
- Redwood Creek Basin Profile and Synthesis
- Subbasin Profiles and Syntheses
 - Estuary Subbasin
 - Prairie Creek Subbasin
 - Lower Subbasin
 - Middle Subbasin
 - Upper Subbasin
- Redwood Creek Basin in the Regional Context
 - Summary of Conditions
 - Propensity for Improvement
 - Limitations of this Assessment
- Appendices
 - Glossary
 - List of Abbreviations
 - Bibliography
 - Spatial Data and Geographic Information System

The elements of the five subbasin profile sections are:

- Overview
- Disciplinary findings and analyses
- Listing of issues raised by the assessment
- Watershed and tributary analysis and results
- Synthesis of information with Integrated Analysis (IA)
- Ecosystem Management Decision Support (EMDS) limiting factors analysis
- Refugia rating analysis and results
- Responses to the assessment questions and subbasin recommendations

- Subbasin conclusions

Of interest to many readers are the recommendations associated with specific locations in the basin with which they are familiar or in which they have ownership. In the report, basin and subbasin maps are provided at the beginning of each of the five profile sections to help them locate points of interest. In addition, refugia rating system results are presented. The refugia rating designation provides insight into the level of management needed to improve watershed conditions and increase the value of stream habitat for anadromous salmonids. Discussion concerning the development of the refugia rating system is in the Methods Section of the Redwood Creek Report.

Watershed improvement recommendations are summarized at the end of each subbasin section in the Redwood Creek Assessment report and are as spatially specific as possible. Following the tributary recommendation tables and discussion, six guiding assessment questions are answered. The assessment questions and their responses at the basin and subbasin scales are also in the Redwood Creek Assessment Report. The reader will find responses to question six in this Implementation Summary, including tributary improvement recommendations and general watershed improvement activities. Responses to question six highlight key improvement recommendations in five general categories:

- Flow and water quality improvement activities;
- Erosion and sediment delivery reduction activities;
- Riparian and stream habitat improvement activities;
- Supplemental fish rescue and rearing activities;
- Education, research, and monitoring activities.

California's Large Scale Watershed Assessment Program

In 2000, the California Legislature established its first large scale watershed assessment program, the North Coast Watershed Assessment Program (NCWAP), composed of a multi-disciplinary team from the Resources Agency and the departments of Fish and Game (CDFG), Forestry and Fire Protection (CDF), Conservation/California Geologic Survey (DOC/CGS), and Water Resources (DWR), in conjunction with the North Coast Regional Water Quality Control Board (NCRWQCB) and the State Water Resources Control Board. The program's intent was to provide a consistent body of information on North Coast watersheds for use by landowners, agencies, stakeholders, and collaborative watershed groups. Due to California's General Fund reductions in 2003, that program was eliminated as a multi-agency effort, but CDFG has continued their large scale watershed assessment activities through the Coastal Watershed Planning and Assessment Program (CWPAP). The resultant assessment products should facilitate actions to create positive change in watershed conditions in the North Coast. The assessments are guided by six logical assessment questions at basin, subbasin, and tributary scales:

1. **What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?**
2. **What are the current salmonid habitat conditions? How do these conditions compare to desired conditions?**
3. **What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?**
4. **How has land use affected these natural processes?**
5. **Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?**
6. **What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?**

To help answer these questions, the basin assessment was designed to meet these strategic program goals:

- Organize and provide existing information and develop baseline data to help evaluate the effectiveness of various resource protection programs over time;
- Provide assessment information to help focus watershed improvement programs, and assist landowners, local watershed groups, and individuals to develop successful projects;
- Provide assessment information to help focus cooperative interagency, nonprofit, and private sector approaches to protect the best watersheds and streams through watershed stewardship, conservation easements, and other incentive programs;
- Provide assessment information to help landowners and reviewing agencies implement laws and regulatory codes such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

General Assessment Approach

Each of the assessment program's participating departments developed data collection and analysis methods used in their discipline's basin assessments. They also developed a number of tools for the interdisciplinary synthesis of collected information. These included models, maps, and matrices for integrating information on basin, subbasin, and stream reach scales to explore linkages among watershed processes, conditions, and land use. These tools provided a framework for identifying watershed refugia areas and factors limiting salmonid productivity, as well as providing a basis for understanding the potential for cumulative impacts from natural and man caused disturbances. The resulting information provided guidance for developing restoration, management, and conservation recommendations. The general steps in the large-scale assessment include:

- Form multi-disciplinary basin assessment team;
- Conduct scoping and outreach workshops with landowners and interested parties;
- Determine logical subbasin assessment scales. Large basins usually have too much variance in physical, biological, and/or cultural attributes to generalize about their conditions. Logical subbasin demarcation provides large common sub-areas for conducting assessments, and reporting findings and recommendations applicable across a subbasin area;
- Collect and organize existing data and information according to discipline;
- Identify data gaps needed to further develop the assessment;
- Collect necessary field data;
- Analyze and report intra-disciplinary information as appendices to the basin report;
- Conduct Integrated Analysis (IA). Through the use of a series of IA Tables, multidisciplinary data and information are related to one another. The IA Tables follow these processes and their products (drivers) as they route through the watershed and help explain the conditions (responses) they cause. The IA process also helps identify watershed condition trends;
- Conduct limiting factors analysis (LFA). The Ecological Management Decision Support system (EMDS) is used, along with expert analysis and local input, to evaluate factors affecting fish at the tributary scale;
- Conduct tributary scale refugia rating analysis. The tributary ratings are determined by combining the results of air photo analyses, EMDS, and data in the CDFG tributary reports by a multi-disciplinary, team of expert analysts;

- Develop conclusions and recommendations for watershed and stream improvement activities. The recommendations are provided as answers to guiding assessment question six;
- Facilitate monitoring of conditions in cooperation with the CDFG coastal monitoring team.

Subbasin Scale

The complexity of large basins makes it difficult to speak about them concerning watershed assessment and recommendation issues in other than very general terms. In order to be more specific and useful to planners, managers, and landowners, it is useful to subdivide the larger basin into smaller subbasin units whose size is determined by the commonality of many watershed attributes. Variation in subbasins is a product of natural and human factors. Variables that can distinguish subbasins include differences in elevation, geology, soil types, aspect orientation, climate, vegetation, fauna, human population, land use, and other social-economic considerations.

Redwood Creek Basin Profile

Overview

Redwood Creek flows into the ocean near the town of Orick, approximately 35 miles north of Eureka, in northern Humboldt County, California. The basin contains approximately 285 square miles (about 180,000 acres) of mostly forested and mountainous terrain. The elongate shaped basin extends in a south-easterly direction for approximately 65 miles from Prairie Creek to the headwaters of Redwood Creek and averages only about 6 miles wide (Figure 1). Elevation ranges from sea level near the town of Orick up to 5,200 feet at headwaters near Board Camp Mountain, located at the south-east end of the basin. There are approximately 500 miles of Perennial (blue line streams indicated on USGS maps) streams within the basin and many more miles of intermittent stream channels. Approximately 122 miles of stream habitat are accessible to anadromous salmonids.

As a result of high water temperatures and large sediment inputs to stream channels, Redwood Creek Basin is listed as impaired by sedimentation/siltation and temperature under Section 303(d) of the federal Clean Water Act. Therefore, the Redwood Creek Basin falls under jurisdiction of state and federal TMDL programs.

There are four primary factors that dominate watershed processes linked to stream conditions in the basin 1) the geology and relatively weak lithology make lands of the Redwood Creek Basin naturally susceptible to erosional process; 2) winter storm events and high stream flows 3) land management activities that accelerate erosional processes; and 4) land management that alters near stream forest characteristics. Furthermore there are spatial and temporal scale factors (Ziemer 2004). Cumulative effects from these primary factors and scale issues are complex and are largely responsible for the status of stream conditions throughout most of the Redwood Creek Basin.

During the flood of 1964, these factors interacted, resulting in a large disturbance to the basin. The 1964 flood and associated hillslope and streambank erosion left Redwood Creek in a severely damaged condition and without much suitable anadromous salmonid habitat (Fisk et al 1966). A large proportion of the erosion was associated with an extensive road network, skid trails, and timber harvesting (Janda et al. 1978 and Weaver et al. 1995). Less drastic erosion occurred during moderate storms in 1972, 1975, and again in 1997 (Madej 2001). The present widened condition of the upper mainstem of Redwood Creek channel and the aggraded and simplified channel in the lower mainstem are examples of legacy impacts from the 1964 flood and affects from more recent storms (Madej and Ozaki 1996). How the basin will respond to the next large flood event is viewed with uncertainty.

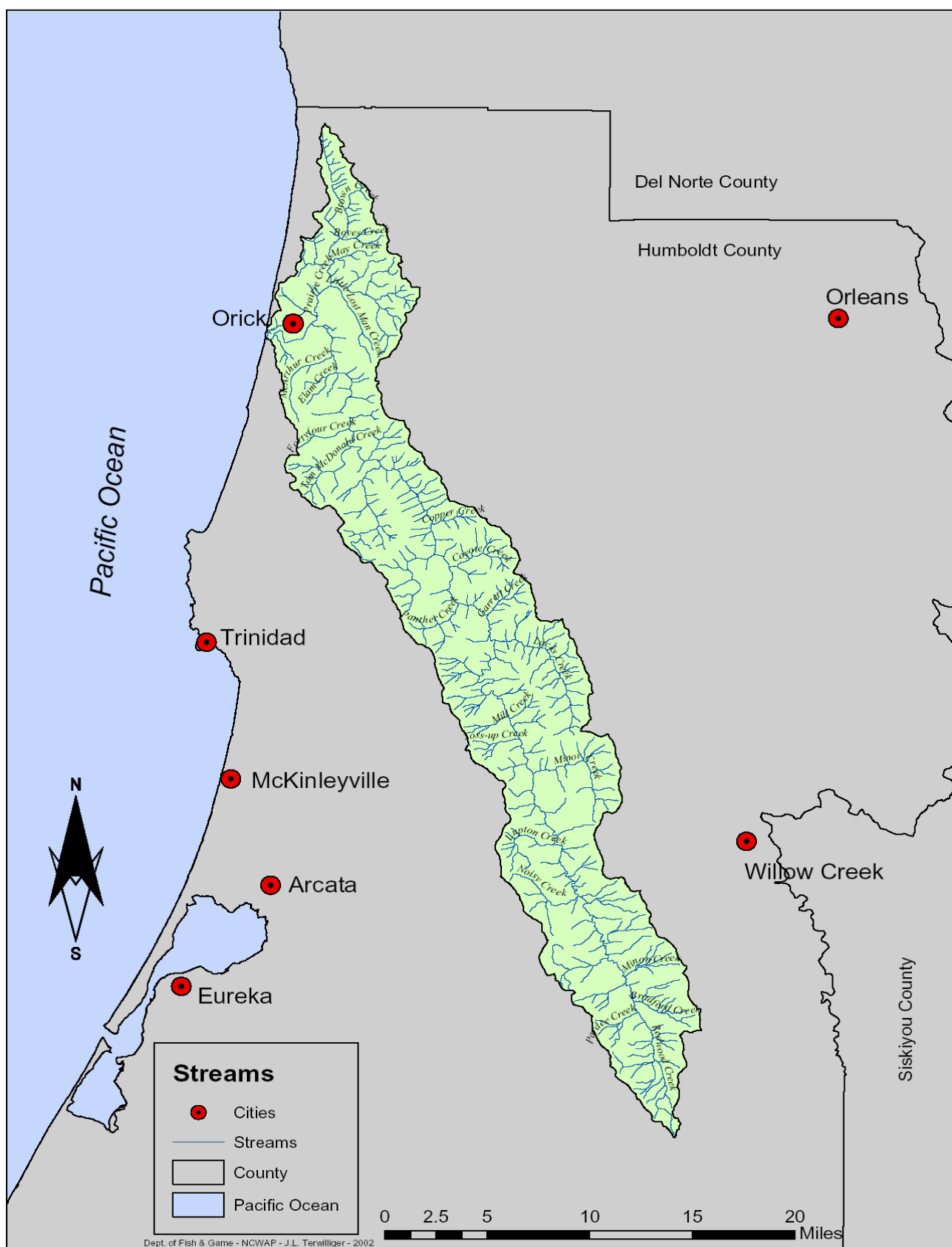


Figure 1. Redwood Creek basin and stream network.

Redwood Creek Assessment Subbasins

For the purpose of the NCWAP study of Redwood Creek, the basin was divided into five subbasins (Figure 2). The five subbasins in Redwood Creek were designated based on geography, historical classification by Redwood National and State Park (RNSP), geology, climate patterns, and land use (Table 1). They conform to CalWater 2.2 Planning Watershed boundaries when possible and 22 planning watersheds as defined by the CalWater 2.2 system.

Estuary Subbasin: The Estuary Subbasin includes the drainage of Redwood Creek below the confluence with Prairie Creek, including Strawberry Creek, Sand Cache Creek and Dorrance Creek. Features of the subbasin include the estuary, pasture lands, and the town of Orick.

Prairie Creek Subbasin: The Prairie Creek Subbasin contains all of Prairie Creek watershed except for a small portion of Skunk Cabbage Creek. The Prairie Creek watershed is hydrologically distinct and joins Redwood Creek approximately at river mile 3.5. Ninety-eight percent of the Prairie Creek subbasin is managed by RNSP.

Lower Subbasin: The Lower Redwood Creek Subbasin includes the area above the confluence of Redwood and Prairie Creeks to the confluence of Redwood and Devil's Creeks including Devil's Creek. The Lower Redwood Creek Subbasin is managed by RNSP.

Middle Subbasin: Middle Redwood Creek Subbasin includes the area above the confluence of Redwood/Devil's Creeks excluding Devil's Creek up to the confluence of Redwood and Lupton Creeks, including Lupton Creek. The Middle Redwood Creek subbasin includes the Park Protection Zone, Redwood Valley, and ends at the valley confinement just upstream of State Highway 299 crossing. This subbasin is predominantly managed for timber production and some cattle grazing.

Upper Subbasin: The Upper Redwood Creek Subbasin is defined as the area above but not including Lupton Creek and covers the same area as the CalWater 2.2 Lake Prairie Hydrologic Area. This subbasin has the highest relief and greatest proportion of natural prairies. This subbasin is predominantly managed for timber production and also has the greatest number of individual private ownerships per square mile of all Redwood Creek subbasins.

Table 1. Redwood Creek Subbasin attribute summary.

	Estuary Subbasin	Prairie Creek Subbasin	Lower Subbasin	Middle Subbasin	Upper Subbasin	Total
Square Miles	5.36	39.59	69.51	100.14	67.72	282.33
Total Acres	3,429	25,339	44,488	64,088	43,344	180,689
Private Acres	2,007	463	275	57,843	40,640	101,282
Federal Acres	1,422	18,247	44,212	5,838	2,240	71,960
State Acres	0	6,629	0	0	0	6,630
Principal Communities	Orick			Redwood Valley		
Predominant Land Use	Livestock Grazing	Park Land	Park Land	Timber Production	Timber Production	
Predominant Vegetation Type	Pasture Land	Redwood Forest	Redwood Forest	Douglas-fir Forest	Hardwood Douglas-fir Forest	
Anadromous Fish Stream Miles	5	24	28	42	23	122

	Estuary Subbasin	Prairie Creek Subbasin	Lower Subbasin	Middle Subbasin	Upper Subbasin	Total
Lowest Elevation	0	26	26	325	866	
Highest Elevation	1,243	2,270	1,286	4,091	5,322	

Geology

Faulting dominates the geomorphology of the Redwood Creek basin. The basin is situated in a tectonically active and geologically complex area, with some of the highest rates of uplift, and seismic activity in North America (Cashman et al. 1995; Merritts 1996). The basin's elongate shape is largely controlled by the Grogan fault which Redwood Creek follows for most of its length. Many of the basin's tributary streams flow through narrow and incised canyons. Hillslopes adjacent to these stream channels are among the steepest in the basin and are highly susceptible to mass wasting processes.

Most of the bedrock underlying the Redwood Creek basin has been broken and sheared by tectonic action making it relatively weak, easily weathered, and when saturated by heavy rainfall, the landscape becomes naturally susceptible to landsliding and other erosional processes. Redwood Creek Schist predominates to the west of the Grogan Fault. Schist rocks are metamorphic and are formed when sedimentary rocks are subjected to enough heat and pressure to melt and re-crystallize some or all mineral components. This can also occur locally when rocks are crushed as a result of faulting. East of the fault is mostly underlain by rocks of the Incoherent Unit of Coyote Creek and the Coherent Unit of Lacks Creek. The incoherent unit of Coyote Creek is relatively weak, pervasively sheared shale containing isolated intact blocks of sandstone/shale and other exotic rocks and forms the lower, earth flow-dominated slopes close to Redwood Creek. The coherent unit of Lacks Creek is a hard, competent parcel of interbedded sandstone and shale (turbidites). It stands steeply and creates rugged topography forming debris slide amphitheaters.

Approximately 75% of the Redwood Creek Basin shows signs of high landslide potential. The presence of logging roads and other land use activities have accelerated erosion rates throughout much of the basin. A study of 358 landslides that occurred in the Redwood Creek basin during the 1997 storm season found the volume of sediment generated from landslides in logged areas has been much greater than from unlogged areas (Madej, U.S Geological Survey 2001, written communication). Erosion associated with land use should be expected to continue unless proposed projects and existing problem sites are carefully evaluated and mitigated from a slope stability and potential sediment production perspective.

Climate

The climate of the Redwood Creek Basin varies from moderate seasons along the coastal area to the more extreme seasons common to the inland region. In the lower portion of the basin, extending some ten to twenty miles inland, the predominant influence on the climate is the moist marine air mass, which is moved inland by the prevailing onshore winds. Fog is a dominant climatic feature along the coast, generally occurring daily in the summer and frequently throughout the year. This oceanic influence has a great moderating effect on the climate of the coastal areas over most of the year. Temperatures in the coastal area of the Redwood Creek Basin vary only slightly, with a seasonal difference of only ten to fifteen degrees Fahrenheit. For example, mean temperatures at Redwood Park are 47° F in January and 59° F in June. The inland portion of the basin is separated from the oceanic influence both by elevation and intervening ridges, so that it is not strongly influenced by the marine air mass. Higher elevations and inland region tend to be relatively fog free.

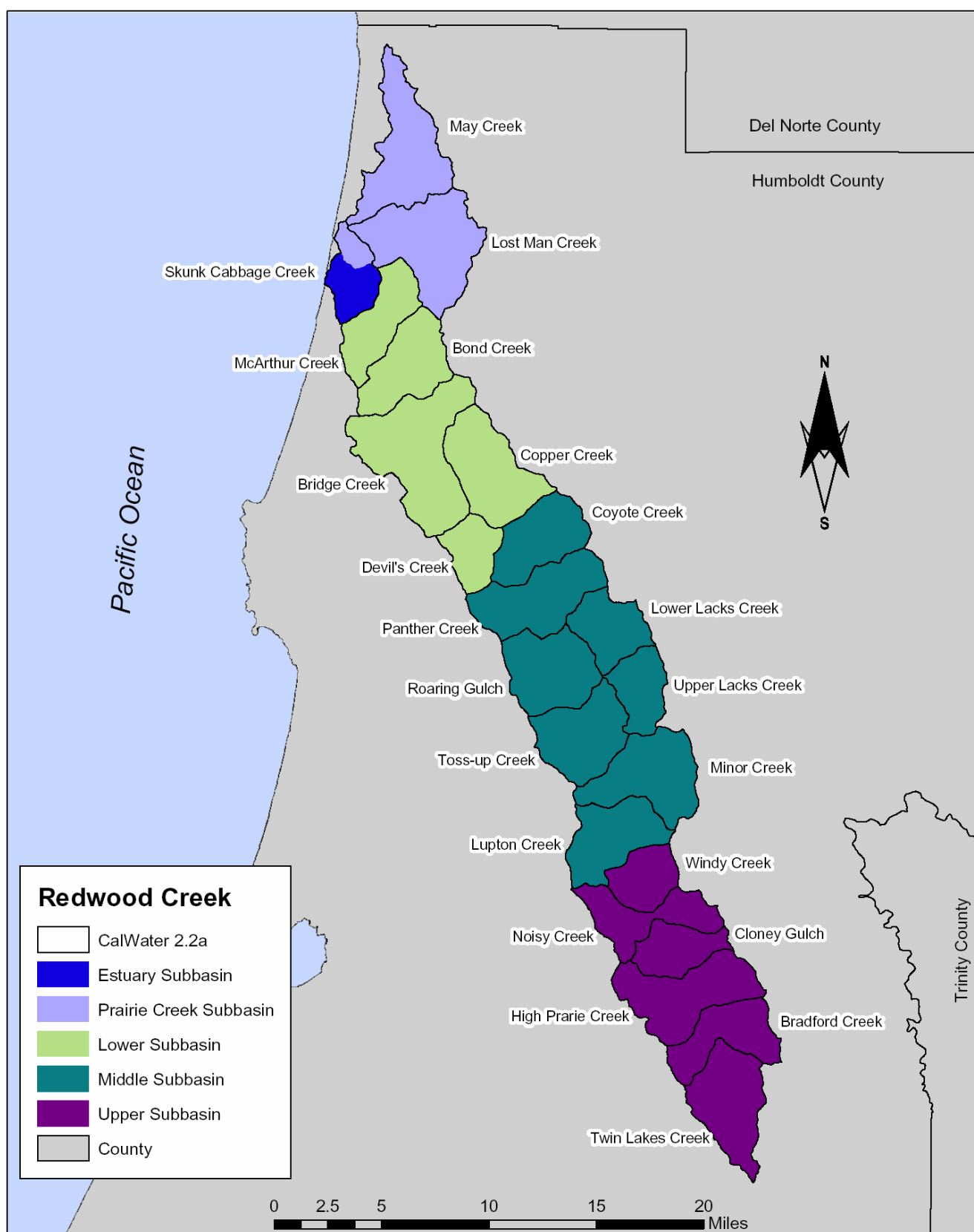


Figure 2. The five subbasins of the Redwood Creek basin and their planning watersheds.

Temperatures of the inland regions range from below freezing to above 100° F. Precipitation within the Redwood basin is characterized by profuse rainfall during the winter. Across the basin, annual precipitation ranges in amount from 32 inches at lower elevations to 98 inches at the headwaters. Precipitation falls mostly during the winter and spring. Average rainfall is approximately 70 to 80 inches per year, with frequent snow above 1600 feet during winter months. The headwaters region of the Redwood Creek basin can accumulate fairly large snow pack and this may have an effect on high flow events given the right conditions as occurred in December 1964. However, it is very difficult to quantify the runoff rate of the snow pack during rain-on-snow events.

Vegetation

Vegetation in the watershed varies from redwood forest along the lower portion of the drainage to Douglas-fir, intermixed with oak woodlands and hardwoods, to ponderosa and Jeffery pine stands along the upper elevations. Areas of grasslands are also found along the main ridge tops and south facing slopes of the watershed. Redwood Creek drainage currently has about 24,000 acres (13 percent of area) in old-growth coniferous forests. Most of the remaining old growth forest is in publicly owned lands in Redwood National and State Parks (RNSP). Prior to the harvesting of timber within the Redwood Creek basin, 82 percent (150,000 of 181,000 acres of the drainage) supported mature coniferous forests. The remainder of the watershed supports prairie grasslands (9 percent) and oak woodlands (9 percent) (Best 1984).

Land Use

Major land uses in the basin include public parkland in the lower basin and private forestland in the upper portion of the basin. Eight large land owners own approximately 90% of the private lands in the basin which are mostly managed for timber production. Large scale timber harvesting in the basin began in the early 1950s, although harvests also occurred in the early 1900's. Fifty-five percent of the coniferous timber was cut by 1966 and by 1992, over 80 percent (123,000 acres) of the timber lands were harvested at least once. Small rural developments and livestock grazing also are a land use on the basin.

Approximately 40 percent of the Redwood Creek Basin is managed by RNSP. The park lands include 98 percent of the Prairie Creek watershed and approximately the lower third of the Redwood Creek watershed. The RNSP management strategies include: 1) perpetuation of the redwood forest and associated ecosystems as prime resources; 2) perpetuate ongoing natural influences on the basis of natural values and visitor use; and 3) protect threatened and endangered species and species of special concern (USDOI 1999).

There are approximately 2,000 miles of roads within the basin of Redwood Creek. The vast majority of the roads were constructed during the initial timber harvest period of the 1950s. This road system was identified as a major source of sediment delivered to stream channels. The road-decommissioning program within the National Park has treated or removed 214 miles of roads since the program began in 1978. Road assessment for the entire Redwood Creek basin has been completed or is nearing completion. As of 2002, assessment work in Lupton Creek, Noisy Creek, Pardee Creek, Toss Up Creek and Roaring Gulch planning watersheds has been funded. With the funding and implementation assessment program, roughly 90% of the private lands in Redwood Creek will have been inventoried.

Water Quality

Thirty years of water chemistry data collected 1958-1988 by USGS and USEPA characterizes Redwood Creek as a moderately hard water, moderately oligotrophic stream. Most water chemistry parameters were within optimal ranges for human consumption. However, the basin is listed as sediment and temperature impaired under Section 303(d) of the federal Clean Water Act, and hence falls under jurisdiction of the state and federal TMDL programs. High water temperature and excessive sediment loads may have deleterious effects to anadromous salmonids.

The maximum weekly average temperatures (MWATs) collected in mainstem Redwood Creek from 1994 to 2001 range from 67-72° F. While the tributaries were generally much cooler with MWATs in the 54-68° F

range. The mainstem reaches, especially in the Upper and Middle subbasins, experience the highest MWAT temperatures due to wide aggraded channels with little to no canopy cover and a northwest southeast aspect.

Throughout the basin, cool tributary inflows help to ameliorate increases in lower mainstem temperatures, and in some cases, locally lower mainstem temperatures. Localized patches of cool water refugia located at tributary confluences with the mainstem may be used by salmonids during warm summer months, when adjacent water is too warm for suitable habitat. Summer temperature refuge sites in the mainstem Redwood Creek are also located in thermally stratified pools where concentrations of cool intragravel flows maintain cool bottom water (Ozaki 1988). Overall, the headwaters area of Redwood Creek, mainstem tributaries and the streams in the Prairie Creek Subbasin provide the coolest water temperature and hence the best water quality conditions for summer rearing salmonids.

Sediment composition samples collected from various sites along the mainstem Redwood Creek do not sustain mean particle sizes (D_{50} at $>37\text{mm}$) set by US EPA minimum TMDL targets. Excessive levels of fine sediments have infiltrated the channel bed, and accumulations of coarse and fine sediments have filled pools. In addition, the extended duration of highly turbid flows attributed to elevated levels of suspended sediments has been noted in Redwood Creek (Van Kirk 1994 and Klein 2001).

Salmonid Fishery Resources

The Redwood Creek Basin supports populations of Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead trout (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and other valuable fisheries resources. There are approximately 65 miles of Redwood Creek mainstem and 60 miles of tributary streams accessible to anadromous salmonids within the Redwood Creek basin (Table 2 and Attachment 1). These fish are traditionally important as food and they provide an important sport fishery to local residents and visitors to the Redwood Creek area. The presence of anadromous salmonid stocks also has substantial ecologic and natural resource values. The sport fishery still provides an important source of recreation and revenues to the local economy, but because of a decline in stocks and changes in regulations, fishing is no longer as popular in Redwood Creek as it was in the past.

In 1960, the USFWS estimated spawner escapement of 5,000 Chinook, 2,000 coho, and 10,000 steelhead to Redwood Creek basin (USFWS 1960). These numbers were derived from data collected from other streams and applied to Redwood Creek. They were meant to provide only the general magnitude of anadromous fish runs and are not indicative of the larger runs of prior years (USFWS 1960; CDFG 1965; RNSP 2000). A recent estimate of the size of anadromous salmonid populations of the Redwood Creek Basin has not been determined. However, a review of past fisheries studies, anecdotal information and data collected for this assessment indicates that the present populations are less abundant and less widely distributed compared to their historic presence. The review of information also suggests that salmonid populations were already in decline by 1960 but populations fell sharply in the years following the December 1964 flood event.

Summer steelhead, sea run coastal cutthroat, coho and Chinook salmon have likely suffered widespread declines due to their sensitivity to degradation of specific habitat factors necessary to complete the freshwater and/or estuarine phase of their life cycle. Because steelhead tolerate a wider range of habitat conditions than the other anadromous species, they are more widely distributed in the basin and have persisted in streams where other species have declined or are now rarely observed.

Table 2. Estimated number of stream miles accessible to anadromous salmonids in each of the Redwood Creek subbasins (Adapted from Brown 1988).

Subbasin	Mainstem Miles Accessible To Anadromous Salmonids	Tributary Miles Accessible To Anadromous Salmonids
Estuary	3.5	1.5
Prairie Creek	NA	24

Lower	19	9.5
Middle	24	19
Upper	19	5.5

Fish Habitat and Watershed Relationships

The present habitat problems observed in most streams of the Redwood Creek basin are typically related to excessive sediment inputs to stream channels and the harvests of nearstream forests. The large sediment loads have caused several adverse changes to aquatic habitats needed by anadromous salmonids including: channel aggradation, stream bank erosion, widened channels, increased width to depth ratios, filling of pools, loss of riparian shade, increased water temperature, loss of channel diversity, loss of stream connectivity, impediments to spawning migrations and prolonged high turbidity levels. The negative impacts from excessive sediments in some cases are elevated by the general lack of instream large wood debris (LWD) needed for pool scour and sediment routing processes. LWD also plays an important role as instream shelter for fish and is also noted for its importance as a source and for storage of organic matter and nutrients contributing to stream productivity (Bilby and Bison 1998).

As a result of timber harvests and stream bank erosion, there is a low potential for near term LWD input to most anadromous reaches of the Middle and Upper subbasins. In the Middle and Upper subbasins, over 75 percent of the area within a 300 foot buffer width along anadromous salmonid bearing reaches is composed of trees that average less than 24 inches diameter at breast height (DBH) and 35 percent of the area has trees that average less than 12 inches DBH. Fox (1994) suggested that for streams ranging from 20 to 45 feet channel width, key individual LWD pieces should be 22 to 25 inches in diameter and 32 to 59 feet long. For a channel the size of mainstem Redwood Creek, the size of functional LWD is much larger. Based on these data, it appears that near term LWD recruitment to streams may fall short of what is needed for channel maintenance, instream cover for fish and nutrient cycles.

Much of the mainstem Redwood Creek salmonids habitat is impaired by warm water temperature. Most of the increase in mainstem Redwood Creek water temperature occurs within the upper subbasin. Here, large storm runoff lead to stream bank erosion, loss of riparian vegetation and consequently a loss of shade over the water and increased channel width (Madej and Ozaki 1996). At present, the widened channel does not receive beneficial shade from riparian vegetation that existed prior to the 1964 flood and the water warms quickly along this reach during hot summer days.

Most tributaries provide cool water temperatures, although the reduction of shade and air temperature moderating effects from mature near stream forests has likely led to an increase in water temperature along lower Lacks and Minor creeks and other tributary reaches.

Stream Reach Condition EMDS Results and Limiting Factors

The Ecosystem Manage Decision Support (EMDS) system was used in the assessment of the Redwood Creek Basin. The EMDS software synthesizes a variety of environmental data, but requires that a custom hierarchical model (termed ‘knowledge base’) be built to evaluate ecosystem conditions. Models are fed data stored in a Geographic Information System (GIS – ArcView™) to perform the spatial assessments of watershed conditions and facilitate rendering the results into maps and tables. Further details explaining how the EMDS system works and how it was used for this assessment can be found in the Methods section of the Redwood Creek Basin Assessment report.

The EMDS suitability criteria used to evaluate instream habitat factors were developed for coarse level stream assessments and were adapted from target values presented in Flosi et. al (1998) and broad review of other reference literature. Due to the wide range of geology, topography and diverse stream channel characteristics which occur within the North Coast region, there are streams that require more detailed interpretation and explanation of results than can be simply generated by EMDS criteria or tributary survey target values. For example, some of the smaller fish-bearing stream channels may not have the stream power to scour pools of the depth and frequency considered to be high value, or “primary,” pools by target values, or to be fully suitable according to EMDS. Therefore, some streams may not have the inherent ability to attain conditions that meet the suitability criteria or target values, specifically for pool depth.

Summary results of the EMDS show that the percent reach length of deep pool habitat was generally in the unsuitable range at all survey sites across the Redwood Creek basin (Table 3). Although the streams of the Middle Subbasin received the great majority of stream habitat assessment for assessment, it is likely that streams of the Upper and Lower Subbasins have similar salmonid habitat limiting factors. Water temperature was not included in the EMDS assessment.

A lack of pools containing suitable escape cover and shelter complexity was also identified as a limiting stream habitat factor throughout the watershed. Much of the shelter complexity in forested streams is provided by LWD which appeared in low abundance in Redwood Creek streams according to stream habitat surveys. Large wood debris, a major pool-forming and shelter element, was often lacking or clumped into debris jams rather than dispersed randomly through stream channels. Large debris jams associated with debris torrents impedes fish passage during spawning migrations in the lower reaches of some tributary streams.

An additional factor affecting salmonid production is the large reduction in area and habitat quality of the estuary/lagoon. Flood control modifications, levees, sediment accumulations and conversion of wetlands and riparian areas to pasture are all involved with a large decline of estuarine habitat utility for salmonids. The present condition of the estuary/lagoon is considered a major limiting factor to the production of anadromous salmonids of the Redwood Creek basin.

Table 3. Generalized results from EMDS stream reach evaluations, summarized by subbasins.

The stream habitat components are categorized with respect to suitability for anadromous salmonid production. The scores represent a range from fully suitable conditions to fully unsuitable conditions. Factors that received plus scores (+, ++, +++) should be considered to support anadromous salmonids and minus scores (-,--,---) should be considered as limiting factors to anadromous salmonid production.

Subbasin	Canopy Density	Pool Quality	% Reach in Deep Pools	Pool Shelter	Embed-dedness
Prairie Creek Subbasin					
10 tributary sample sites	+++	-	--	+	+
Lower Redwood Subbasin					
3 tributary sample sites	++	--	--	-	--
6 Redwood Creek mainstem sample sites	--	--	---	--	+
Middle Redwood Subbasin					
16 tributary surveys	++	--	--	--	+
Redwood Creek mainstem survey	--	--	-	---	-
Upper Redwood Subbasin					
2 tributary surveys	++	--	---	--	+
Redwood Creek mainstem survey	-	--	---	--	-

Refugia Areas

The NCWAP interdisciplinary team identified and characterized refugia habitat by using criteria developed for North Coast watersheds. These criteria consider the status of watershed and stream ecosystem processes, stream habitat conditions, the presence and status of fishery resources, land uses, land ownership, potential risks from human activities, and other factors that may affect stream refugia quality. A detailed discussion of refugia habitat categories is presented in the Redwood Creek Basin Assessment Report

Most of the streams of Redwood Creek Basin fit into the potential refugia class based on the status of watershed conditions, salmonid habitat and salmonid populations (Table 4 and Figure 3). The majority of streams support populations of anadromous salmonids, although 2001 fish numbers appear lower compared to past assessments of fishery status.

Table 4. Refugia designations for streams of the Redwood Creek basin.

Subbasin	High Quality Refugia	High Potential Refugia	Potential Refugia	Low Quality Habitat	Critical Contributing Areas	Passage Barrier Limited	Other
Estuary			Redwood Creek Strawberry Creek		Redwood Creek		Dorance Creek Sand Cache Creek
Prairie Creek	Prairie Creek Lost Man Creek Little Lost Man Creek Streelow Creek Godwood Creek	Brown Creek	May Creek Boyes Creek				Skunk Cabbage Creek
Lower Redwood Creek		Bridge Creek Emerald Creek (Harry Wier) Tom McDonald Creek Copper Creek Bond Creek Coyote Creek	Mc Arthur Creek Elam Creek Forty Four Creek Redwood Creek		Devils Creek Forty Four Creek Hayes Creek Slide Creek Bond Creek		Miller Creek Dolason Creek
Middle Redwood Creek		Dolly Varden Creek (Karen)	Lacks Creek Minor Creek Panther Creek Wiregrass Creek Beaver Creek Molasses Creek Mill Creek Captain Creek Sweathouse Creek Lupton Creek	Toss Up Creek Pilchuck Creek	Dolly Varden Creek (Karen)	Beaver Creek	Garcia Creek Cashmere Creek Lion Creek
Upper Redwood Creek		Simion Creek	Redwood Creek Minon Creek Fern Prairie Creek Lake Prairie Creek			Lake Prairie Creek	High Prairie Creek Noisy Creek

Summary of In-Stream and Riparian Zone Recommendations

The instream conditions were considered in need of improvement to increase salmonid populations. Addressing limiting habitat factors with the strategies identified below and implementing the following

recommendations should increase the refugia rating for Redwood Creek basin streams and promote the production of anadromous salmonids.

The following recommendations were derived from the analysis and interpretation of data generated from randomly selected sample reaches in the Prairie Creek and Lower subbasins, CDFG stream surveys conducted in the Middle and Upper subbasins, and reviews of biologic studies, physical conditions of the Redwood Creek Basin. The stream surveys and sample reaches were limited to anadromous salmonid bearing stream reaches and therefore do not include observations of all watershed factors that are acting on the stream such as roads, riparian canopy and eroding stream banks located further upstream.

The most frequently listed recommendation category across the subbasins is to improve instream habitat factors followed by erosion/sediment and riparian/temperature treatments (Table 5 and Table 6). In some cases, improving watershed conditions may need to be addressed before successful instream treatment, or riparian restoration activity for fish. This means that habitat improvements often need to be prioritized to obtain efficient results.

In general, implementation of projects that involve erosion and sediment reduction by treating roads and failing stream banks, near stream vegetation improvements, and warm stream temperature precede the instream recommendations for pool development and spawning gravel projects. One of the main mechanisms for reducing water temperatures and increasing LWD recruitment to streams is to promote the growth of conifers in the riparian and near stream forest zone to a size large enough to function as channel forming elements and develop cool microclimates along watercourses. Water temperature improvement often results from improving near stream forest function, reducing sediment delivery, pool development and by increasing the exchange between intragravel and surface flows. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant. Fish passage problems, especially in situations where favorable stream habitat reaches are separated by a man-caused feature (e.g., culvert), are usually a treatment priority.

Additional considerations must enter into the decision process before these general recommendations are developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistic considerations that enter into a recommendation's subsequent ranking for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of the candidate work sites. Biological considerations are made based upon the potential for benefits to single or multiple fishery stocks. Cost benefit and project feasibility are also factors in project selection for design and development. Recommendations that may be applied across the Redwood Creek basin are provided below. Recommendations specific to Subbasins are found in the subbasin sections that follow.

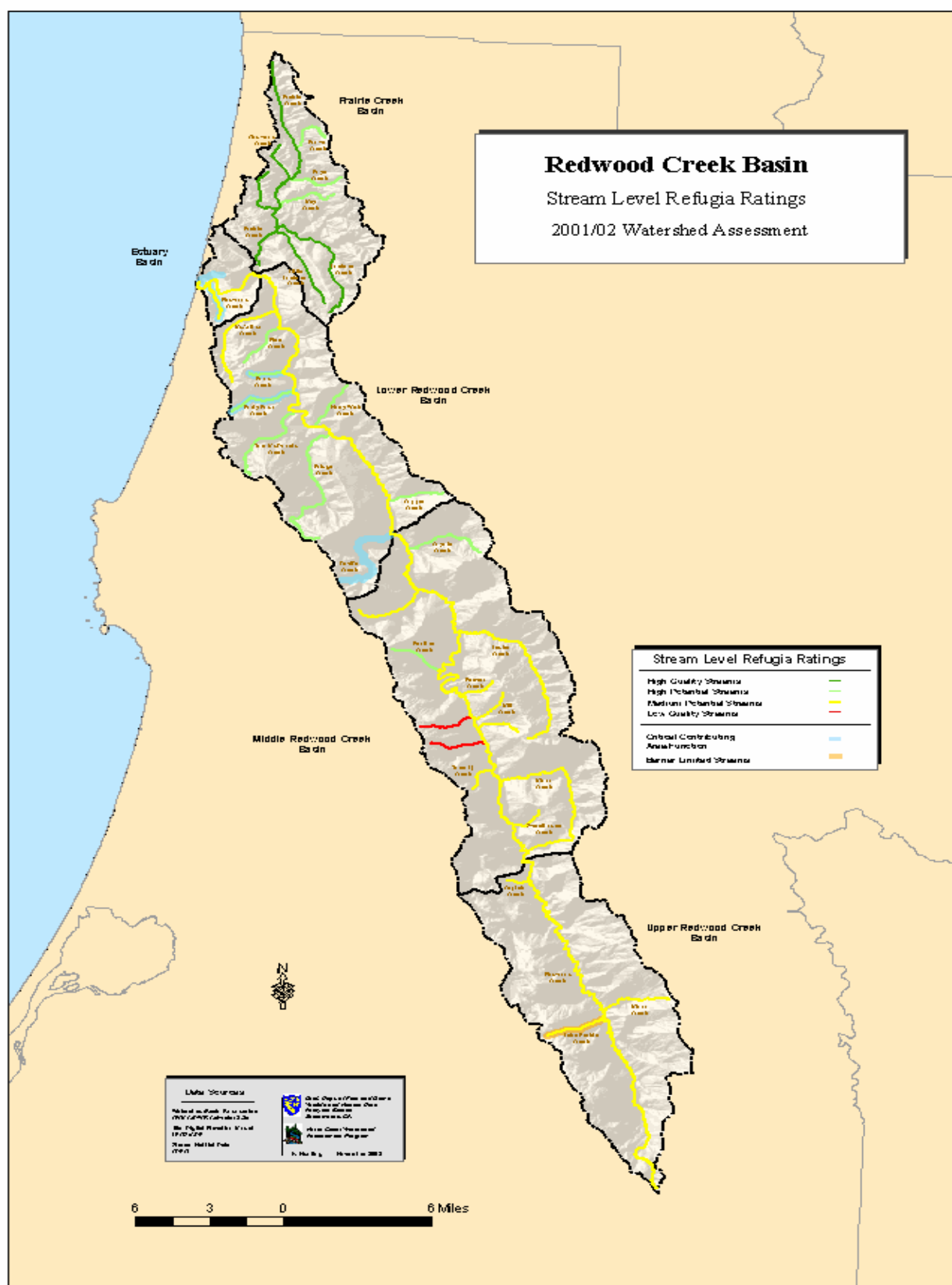


Figure 3. Refugia designations for streams of the Redwood Creek basin.

It is important to note that without management strategies that promote restoring integrity to watershed ecosystem process by addressing root causes of problems, instream improvement projects will likely be short-lived patches on the environment. It also may be necessary to provide additional protection beyond the minimum requirements of current watershed management practices to aid in the reestablishment of desirable functions of riparian and aquatic ecosystems. To maintain and increase the fish populations of the Redwood Creek depends in part on identifying limiting factors, and linking them to watershed processes and the management activities that act on those processes. Management activities and habitat improvement projects that address the links or root causes between land use and processes and habitat condition should receive high priority for implementation.

Table 5. Prioritization of steps to address limiting factors.

Tributaries and sections of mainstem Redwood Creek were assigned prioritized treatment recommendations for addressing limiting factors. The total number of treatments ranked 1,2, or 3 for each tributary or mainstem reach of the Middle and Upper subbasins basins is shown. The recommendations for sample sites located in the Prairie Creek and Lower Redwood Creek subbasins were determined only at the subbasin scale.

SUBBASIN	TEMP	POOL	COVER	BANK	ROADS	CANOPY	SPAWNING GRAVEL	LDA	LIVE-STOCK	ACCESS
Prairie Creek Subbasin Sample Sites (N=9)		1	1				1			
Lower Subbasin Tributary Sample Sites (N=3)		1	1	1			1			
Lower Subbasin Redwood Creek Sampling Sites (N=6)	1	1				1				
Middle Subbasin Tributary surveys (N= 16)	3	14	15	6	1	2	4	1		2
Middle Subbasin Mainstem Redwood Creek survey (N= 1)	1	1	1							
Upper Subbasin Tributary surveys (N = 2)		2	2	2						
Upper Subbasin Mainstem Redwood Creek survey (N = 1)	1	1		1						

Key to fields: Temp = summer water temperatures seem to be above optimum for salmon and steelhead; Pool = pools are below target values in quantity and/or quality; Cover = escape cover is below target values; Bank = streambanks are failing and yielding fine sediment into the stream; Roads = fine sediment is entering the stream from the road system; Canopy = shade canopy is below target values; Spawning Gravel = spawning gravel is deficient in quality and/or quantity; LDA = log debris accumulations are retaining large amounts of gravel and could need modification; Livestock = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; Access = there are human made barriers to fish migration in the stream.

Table 6. Top three ranking recommendation categories by number of tributaries and mainstem reaches in the Redwood Creek Basin.

Basin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	11
Riparian / Water Temp	Canopy / Temp	9

Instream Habitat	Pool / Cover	41
Gravel / Substrate	Spawning Gravel / LDA	7
Other	Livestock / Barrier	2

Responses to Assessment Question Six:

What habitat improvement and other activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Barriers to Fish Passage

- Modify potential barriers such as culverts, perched deltas or boulder and/or debris accumulations that may impede upstream fish passage into tributary streams for spawning.

Flow and Water Quality Improvement Activities:

- Water flow or water quality does not appear to be an issue at this time over most of the basin. However, fish habitat requirements and channel maintenance flows should be considered prior to any water development projects including riparian diversions and small domestic water use;
- In order to help reduce water temperature in tributaries and the mainstem, ensure that near stream forest management encourages growth and retention of conifers sufficient for providing shade and cool micro climate benefits to stream and riparian zones;
- Timber harvests or other land use should be conducted in a manner that does not increase peak flows, accelerate runoff rates, or deliver excessive sediment to stream channels;
- Consider using willow baffles or other applicable methods to promote effective shading from riparian trees and to reduce the channel width along reaches of Redwood Creek.

Erosion and Sediment Delivery Reduction Activities:

- Since timber harvesting and other land use can cause disturbances that may contribute to slope instability, management on slopes with high landslide potential and/or on lands adjacent to streams should first involve a risk assessment or be avoided. Determination of appropriate practices should be made through the use of the CGS landslide and landslide potential maps, in conjunction with site-based geological examinations by licensed and appropriately trained geologists;
- For timber management on steep and/or potentially unstable slopes (in many cases, slopes greater than 35%) we recommend use of lower impact silvicultural prescriptions to maintain vegetative cover and the use of cable or helicopter yarding to reduce the potential for erosion and sediment production, which can result in sediment accumulation in Redwood Creek.
- Landowners should continue road erosion hazard surveys throughout the basin and use this information to set priorities for road removals and upgrades, and implement these improvements as rapidly as private and public funding allow. Roads located on unstable slopes and roads near streams should receive high priority for survey and upgrades and decommissioning projects;
- Consider avoidance or mitigation for risks of excessive erosion when planning, building or removing roads in or near deep-seated landslides and earthflows;
- If new roads need to be constructed, they should not be located near the valley bottom where they may pose a high risk of generating sediment delivery to streams. Consider locating roads along ridge tops;

- The use of fire for site preparation purposes should be minimized on schist soils during warm, dry periods (late summer and fall).

Riparian and Stream Habitat Improvement Activities:

- Implement management that will promote mature characteristics in the riparian corridor along mainstem Redwood Creek;
- Where current near stream forest canopy is strongly dominated by hardwoods and site conditions are appropriate, land managers should consider cautious thinning of hardwoods from below to hasten the development of denser and more extensive coniferous canopy component;
- To address the lack of large woody debris in many tributary channels and along the mainstem, management should promote retention and growth of near stream conifers and allow natural recruitment of LWD to stream channels;
- Where near stream conifers are not large enough to function as naturally occurring scour elements, consider importing LWD from nearby hillslopes for placement in locations and orientations where it will provide beneficial habitat elements and will not accelerate adverse bank erosion;
- Add combinations of boulders and LWD to increase shelter complexity to cool water patches located in Redwood Creek. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from springs, seeps and tributary flows;
- For timber harvest plans in the Upper and Middle subbasins, consider additional measures to increase function of watercourse protection zones when justified by lack of large conifers to provide shade and microclimate, lack of instream LWD, and low LWD loading potential;
- Consider the use of conservation easements or other management strategies for the purpose of maximizing potential benefits to aquatic habitats from near stream forest protection along the middle and upper reaches of Redwood Creek;
- Consider limiting cattle access in streams where their presence has caused significant bank erosion and impaired growth of vegetation;
- Prescribed fire use within the Redwood Creek basin could reduce adverse impacts to watercourses and wet areas. Regular use of prescribed fire could reduce fuels so that catastrophic fires are less likely to occur.

Monitoring, Education and Research Activities:

- Utilize CalVeg GIS layers to locate areas where coniferous trees are too small to provide beneficial functions of LWD loading. These areas should be considered for LWD addition to stream channels to retain and promote desirable pool characteristics, sediment routing and other channel maintenance processes;
- Monitoring for temperature by land owners and responsible agencies should continue at current and additional sites to extend trend lines and track changes that may impact salmonids and water quality or that may indicate recovery of instream habitat conditions. The establishment of trend lines from these data will aid in future studies, validate improvements from forest and stream recovery and will be helpful for habitat improvement project effectiveness monitoring;
- Monitoring suspended and in-channel stored sediments by sampling sediment size distribution, turbidity, V*, photo points, etc. should be continued, and tracking of streambed levels with stream channel cross sections should be continued by responsible agencies and landowners;

- A long-term, concerted monitoring effort among the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations of Redwood Creek. Efforts should include annual spawner surveys, weir counts, summer steelhead dive counts and monitoring juvenile populations;
- Biological monitoring, particularly for aquatic insects and aquatic food web dynamics, will be an important addition to monitoring efforts in the Redwood Creek Basin;
- Ensure that CEQA-compliant environmental assessment is conducted prior to issuance of the Fish and Game Code 1603 streambed alteration permits and Corps of Engineers or NOAA Fisheries permitting requirements are complete for significant projects on streams of Redwood Creek.
- CDFG stream habitat surveys provide information only for reaches accessible to anadromous salmonids. Additional surveys above the limits to anadromy would be helpful to identify additional sediment delivery sites that may benefit from erosion control treatments.

Redwood Creek Estuary

Introduction

The Estuary Subbasin is located within the Skunk Cabbage Creek Planning Watershed. The subbasin includes the drainage area of the 3.5 mile reach of Redwood Creek located between the confluence of Prairie Creek and the ocean, the lower reach of Strawberry Creek, and Sand Cache and Dorrance creeks. The lower reaches of Sand Cache and Dorrance creeks form the north slough channels (Figure 4). The tidal inlet or creek mouth is located approximately three miles west of the town of Orick. Other features in the subbasin are pasture lands and flood control levees (Table 8).

Table 7. Estuary Subbasin features, Redwood Creek.

Square Miles	5.4
Total Acreage	3,430
Private Acres	2,010
Federal Acres	1,420
State Acres	0
Principal Communities	Orick

Predominant Land Use	Livestock grazing
Predominant Vegetation Type	Pasture / Ag Land
Miles of Anadromous Stream	~5
Low Elevation (feet)	0
High Elevation (feet)	1,243

The Redwood Creek estuary seasonally alternates between an open estuary and a closed coastal lagoon. The estuary usually remains open from the first substantial rains in the fall through the early summer season (D. Anderson, RNSP, personal communication). In early summer, a sand bar forms across estuary mouth creating a coastal lagoon. Although there are ecologic differences between the estuary and lagoon, both extend approximately 1.5 miles upstream from the mouth of Redwood Creek. The sandbar usually breeches during the onset of the first fall rains, opening the creek to tidal mixing of freshwater and marine water masses in the estuarine channel.

Like many estuaries along California's coast, the Redwood Creek estuary/lagoon plays an important role as anadromous salmonid habitat. The estuary/lagoon is important habitat for anadromous salmonids because it provides adults access to freshwater spawning grounds and offers valuable juvenile rearing habitat. However, over the last century, the estuary/lagoon has undergone several modifications that have reduced its ability to support salmonids. In terms of salmonid juvenile rearing and adult holding habitat, the present conditions of the estuary/lagoon are far from desired conditions that historically existed. In most years, less than 10% of the juvenile Chinook salmon and juvenile steelhead rearing in the lagoon survive through the summer to the fall season (Anderson 2000 and 2001). The impaired condition of the estuary likely contributes to the low salmonid survival rate.

The modifications to the estuary include flood control levees, removal of riparian forests, and pasture land development. Together these modifications reduced the size, volume and biologic productivity and changed circulation patterns in the estuary/lagoon. The overall size and tidal prism of the estuary/lagoon has been reduced by 50-75 % by the combined effects from channel modifications, the levee system and sedimentation (Ricks 1983). Sediment accumulations derived from marine sources have become excessive in the lower embayment and sloughs. The main channel is aggraded with sediments conveyed from upstream source areas.

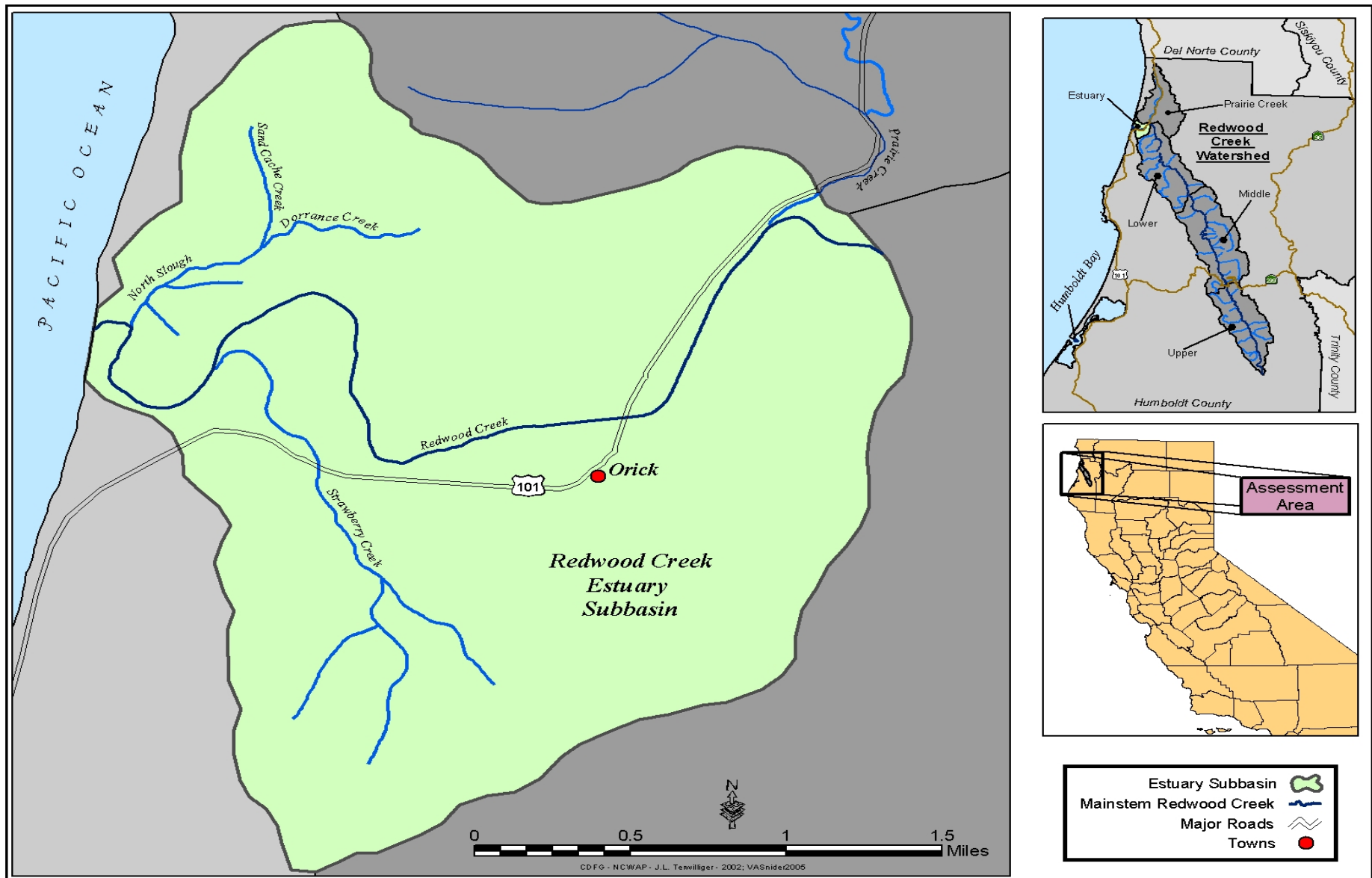


Figure 4. Estuary Subbasin.

A great amount of work has been done by RNSP, private landowners, public agencies (Humboldt County, California Coastal Conservancy, Army Corps of Engineers, and Department of Fish and Game), and interested parties to develop plans and alternatives to improve habitat conditions in the estuary/lagoon. RNSP and others have developed management alternatives to improve the estuarine habitat. Some of the ideas can be found in the *General Management Plan for Redwood National and State Parks* (RNSP 2000) and *Hydraulic Analysis of Alternative Levee Configurations for Lower Redwood Creek* (Moffatt and Nichol 2003). Planning also includes protecting Highway 101, the Town of Orick and addressing needs and concerns of landowners of the estuary project area. The objectives of any estuarine restoration project should promote restoring estuarine ecosystem integrity by increasing the area of the lower embayment and lower river channel while also increasing depths, shelter, and connectivity and circulation between the main channel and slough channels, and re-establishing riparian forest. The proposed alternatives include widening the levees to 2 to 3 times the historical channel width and shortening the extent of the levees to exclude the lowermost channel reach. Alternatives also include efforts to purchase land within the project area and should consider conservation easement strategies.

Response to Assessment Question Six:

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Flow and Water Quality Improvement Activities:

- Increase tidal prism by restoring tidal and riverine flow, channel depth, and increasing tidal connectivity between the main channel and slough channels;
- Work to restore natural drainage patterns from adjacent wetlands to sloughs and main channel;
- Any new project or modifications to the levee system may consider cross draining culverts through any flood control structure to drain water from wetlands into sloughs or main channel;
- Increase circulation between the lagoon, Strawberry Creek and sloughs to help mix water and increase dissolved oxygen levels;
- Modify or relocate logs and debris that contribute to blocking tidal connectivity between the embayment and the north slough channel;
- Prevent or reduce cattle waste from entering stream and slough channels;
- Develop a shade corridor of riparian trees along main estuarine channel and along lower Strawberry Creek to help cool water;
- Remove exotic vegetation from within the Strawberry Creek channel;
- Land managers should work to reduce the temperature of water flowing into the Estuary Subbasin. To accomplish this, they should maintain and/or establish adequate streamside protection zones to reduce solar radiation and moderate air temperatures into Redwood Creek and its tributaries throughout the Redwood Creek basin;
- Digging of any artificial channel through the beach sand berm that would result in an uncontrolled breach should be discouraged;
- Any controlled breach should be performed as an option and in coordination with the expert judgment of RNSP staff and CDFG to preserve natural resources;
- The goal of any controlled breach project must be to maintain the volume in the lagoon to best support the anadromous fisheries while considering land owner concerns.

Erosion and Sediment Delivery Reduction Activities:

- Reduce inputs of sands by tidal currents to the embayment and north slough by modifying levee configuration or removing levees altogether;
- Use levee set back and reconfiguration or removal strategies to increase transport rates of excessive amounts of sediment that are stored between the levees and balance the transport of future sediment from upstream sources through the estuary to desirable levels;
- Consider strategies to reduce bank erosion related to cattle on lower Strawberry Creek (see riparian and instream habitat improvement activities below);
- Land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with all land use activities throughout the basin to reduce sediment delivery to lowermost Redwood Creek and the estuary.

Riparian and Instream Habitat Improvement Activities:

- The use of levee set backs, reconfiguration, or levee removal strategies to develop a wider flood plain that restores natural sinuosity, improves connectivity with sloughs and adjacent wetlands, and that allows the development of an effective zone of riparian vegetation will contribute to a large improvement to the estuarine ecosystem;
- Improvements to the estuary/lagoon environment that result in increasing the juvenile salmonid carrying capacity during the summer months is likely the most beneficial project for Redwood Creek's Chinook population;
- Where feasible, develop or improve riparian vegetation function along the banks of Redwood Creek, Strawberry Creek, and slough channels;
- Work to restore natural drainage patterns within adjacent wetlands and the subbasin
- Increase off-channel and rearing habitat by improving conditions of sloughs and tributaries (Strawberry, Dorrance and Sand Cache creeks);
- Where feasible add LWD to develop habitat diversity in the main channel and to increase shelter complexity for salmonids;
- Leave large wood in estuarine channels, on the beach, and on stream banks for potential recruitment into the estuary;
- Re-establish a corridor of riparian vegetation to lower Strawberry Creek and restore riparian function in areas where vegetation removal or significant cattle impacts have been noted. This may require temporary fencing the riparian zone to prevent cattle and deer from grazing on seedlings and trampling growing trees.

Education, Research and Monitoring Activities:

- Work should continue by Redwood National and State Parks (RNSP), private landowners, agencies, and interested parties to investigate and implement strategies to improve habitat conditions of the estuary by modifying the levees system while protecting Highway 101 and the town of Orick;
- Utilize National Wetlands Inventory maps and soils maps to help delineate historic wetland areas for planning estuary restoration projects;

- RNSP, DFG, RWQCB should continue and expand existing monitoring of anadromous salmonid populations to include some winter and spring fish sampling;
- Water temperature and dissolved oxygen monitoring in the lagoon and sloughs should continue;
- Monitoring water quality in the lagoon should be expanded to include nutrient levels (ammonia, nitrates, nitrates) that may be elevated from runoff from cattle pastures;
- Work with USACE, Redwood National and State Parks, and Humboldt County Department of Public Works to modify levees and levee maintenance manuals to be consistent with habitat requirements of salmonids and a properly functioning estuarine ecosystem.

Subbasin Conclusions

Restoration efforts that move conditions and processes of the Redwood Creek estuary ecosystem towards historic status should receive high priority. Improvements to the estuary/lagoon environment that result in increasing the juvenile salmonid carrying capacity during the summer months is likely the most beneficial project to for Redwood Creek's Chinook population and will benefit other fish and wildlife resources of Redwood Creek.

Prairie Creek Subbasin

Introduction

The Prairie Creek Subbasin includes the May Creek and Lost Man Creek planning watersheds and a large portion of the Skunk Cabbage Creek planning watershed. Prairie Creek joins Redwood Creek at approximately river mile 3.5 mile and drains approximately 40 square miles of the northwestern portion of the Redwood Creek basin (Figure 5). Most of the Prairie Creek Subbasin (98%) is in public lands managed by the Redwood National and State Parks (RNSP) (Table 8). The RNSP is part of a World Heritage Site and is part of the California Coast Range Biosphere Reserve, designations that reflect worldwide recognition of the parks' natural resources as irreplaceable. However, prior to acquisition by the RNSP, approximately half of the Prairie Creek subbasin endured timber harvest activity which has led to long term impacts to anadromous stream habitat.

Table 8. Prairie Creek Subbasin features.

Square Miles	39.59
Total Acreage	25,339
Private Acres	463
Federal Acres	18,247
State Acres	6,629
Predominant Land Use	Park Land
Predominant Vegetation Type	Redwood Forest
Miles of Anadromous Stream	24
Low Elevation (feet)	26
High Elevation (feet)	2,270

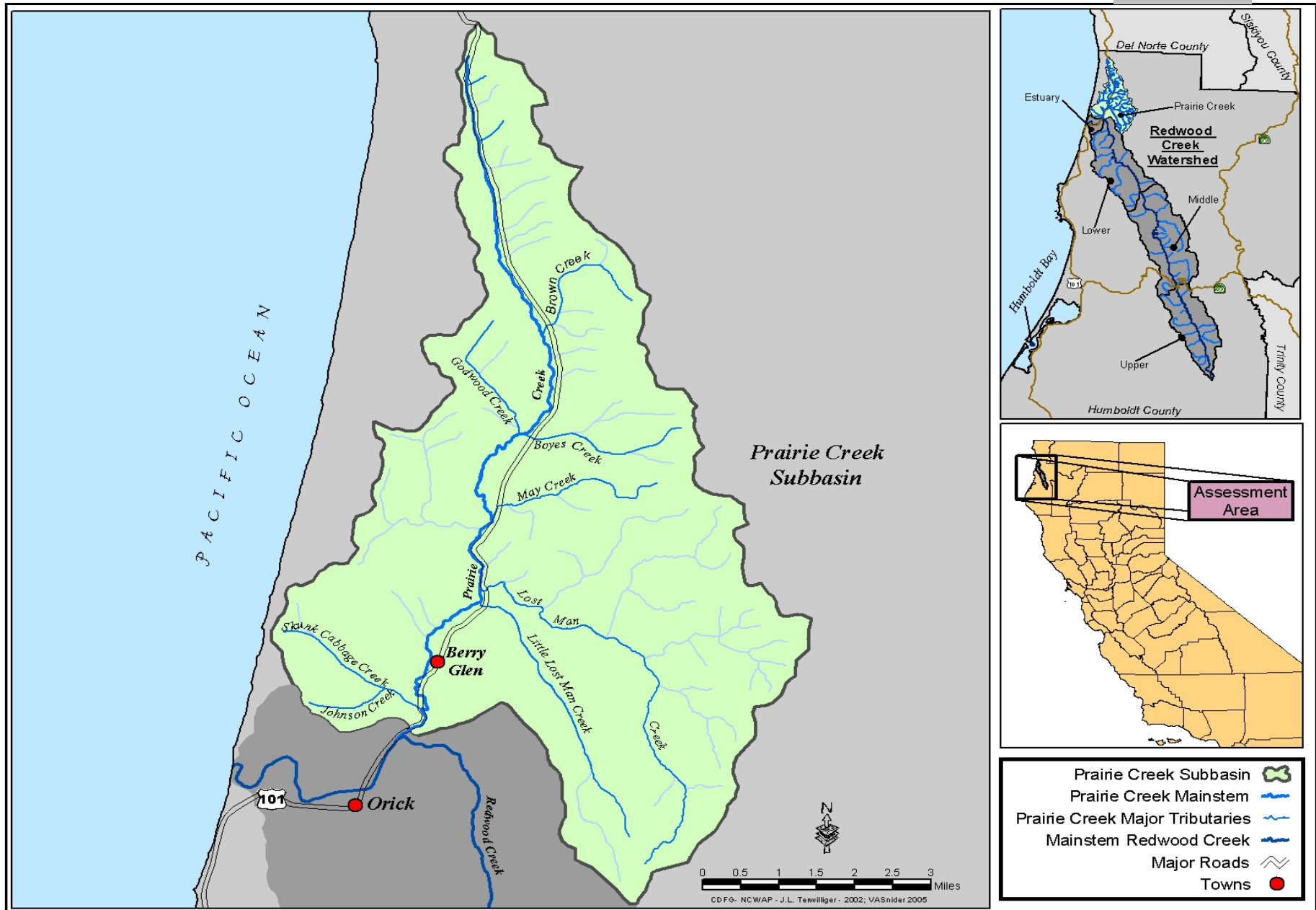


Figure 5. Prairie Creek Subbasin and its tributaries.

Prairie Creek and its eight major tributary streams support populations of Chinook salmon, coho salmon, steelhead, and coastal cutthroat trout. It is believed that presently the Prairie Creek Subbasin provides the most coho salmon habitat and supports the largest coho population of all subbasins in Redwood Creek. Recent counts of spawning Chinook and coho show an increase from the low numbers observed in the early 1980s. However, a review of available information concludes that salmonid populations have declined well below historic levels of abundance.

Stream Reach Condition, EMDS Evaluations, and Limiting Factors

Overall, stream conditions in the Prairie Creek Subbasin varied among sampling sites. Sites located in the upper reach of Prairie Creek, and Godwood Creek offer some of the highest quality fisheries habitat within the Redwood Creek basin. These watersheds are relatively undisturbed and retain old growth forest characteristics. Sites in disturbed portions of Lost Man, Boyes and Brown creeks were less favorable for supporting salmonids. Water temperatures (MWATs) recently collected from Little Lost Man, Lost Man, and Prairie creeks were all suitable for rearing salmonids and ranged from 57 to 60° F.

Factors that received negative scores by the EMDS should be considered as limiting factors anadromous salmonid production in the Prairie Creek Subbasin (Table 9). The lack of deep pools was the habitat factor most often identified by EMDS that may limit salmonid production. Often, these shallow pool conditions were found in low gradient reaches within small watersheds that lack sufficient discharge to deeply scour the channel. For example, some of the smaller fish-bearing stream channels (Godwood Creek, Prairie Creek Site 6), may not have the stream power to scour pools of the depth and frequency considered to be of high value, to be fully suitable according to EMDS. However, these streams are still important because of other desirable features that support valuable fishery resources.

Table 9. Summary of the results from the Prairie Creek Subbasin EMDS stream reach evaluation.

The stream habitat components are categorized with respect to suitability for anadromous salmonid production. The scores represent a range from fully suitable conditions to fully unsuitable conditions. Factors that received plus scores(+, ++, +++) should be considered to support anadromous salmonids and minus scores (-,--,---) should be considered as limiting factors to anadromous salmonid production at the sampling sites in Prairie Creek Subbasin.*

Stream	Reach Length (ft)	Reach number	Canopy Density	Pool Depth	Pool Shelter	Embeddedness
Lost Man Creek Site 5	844	1	+	---	--	-
Lost Man Creek Site 23	962	2	+++	---	+	--
Lost Man Creek Site 15	634	3	+++	---	-	-
Lost Man Tributary Site 13	474	1	+++	---	+++	--
May Creek Site 19	449	1	+++	---	--	++
Boyes Creek Site 11	508	1	+++	---	--	-
Brown Creek Site 10	512	1	+++	---	--	--
Prairie Creek Site 3	568	1	+	+++	--	+++
Prairie	544	2	++	---	-	+

Stream	Reach Length (ft)	Reach number	Canopy Density	Pool Depth	Pool Shelter	Embeddedness
Creek Site 6						
Godwood Creek	1701	1	+++	---	-	++
Godwood Creek	12,858	2	+++	---	+	+

Refugia Areas

The high quality and high potential refugia designation for streams of the Prairie Creek Subbasin were largely based on the known presence and production of Chinook and coho salmon and cutthroat and steelhead trout, overall habitat conditions, and the protection provided against future risk to habitat under RNSP management goals (Table 10). It is believed that Lost Man, Brown, Boyes, and May creeks will increase to high habitat quality with time and/or proper management activities. Management activities that address limiting factors presented in Table 9 will promote the advancement of these streams to the high quality refugia category.

Table 10. Anadromous salmonid refugia designations for streams of the Prairie Creek Subbasin.

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Potential	Low Quality	Passage Barrier Limited	Critical Contributing Area/Function	Data Limited
Prairie Creek	X						
Lost Man Creek		X			X		
Little Lost Man Creek	X						
Brown Creek		X					
Boyes Creek		X					
Streelaw Creek	X						
Godwood Creek	X						
Skunk Cabbage		X					X
May Creek		X			X		

Response to Assessment Question Six :

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Flow and Water Quality Improvement Activities:

- Ensure that adequate streamside protection measures are used to reduce solar radiation and to moderate air temperatures in order to reduce heat inputs to the lower reach of Prairie Creek and to maintain good water temperature in Lost Man Creek and upper reaches of other tributary streams;

Erosion and Sediment Delivery Reduction Activities:

- Continue road assessments and upgrades or removal of roads, especially in the Lost Man Creek planning watershed;
- Consider bank stabilization projects in the Lost Man Creek and May Creek planning watersheds;
- Work with Caltrans to reduce sediment input potential to streams from Highway 101 activities.

Riparian and Instream Habitat Improvement Activities:

- Ensure that any land management activities include protection and preservation of stream and riparian habitats and maintain or improve ecological integrity within the subbasin;
- Restore riparian function in areas where vegetation removal or significant cattle impacts have been noted in lower Prairie Creek;
- Consider modifying debris accumulations in Lost Man Creek to facilitate fish passage;
- Consider adding pool enhancement elements (e.g. LWD) to increase the number of pools or deepen existing pools and add shelter complexity in Lost Man Creek, May Creek, Brown Creek and Boyes Creek.

Supplemental Fish Rescue and Rearing Activities:

- The use of Prairie Creek hatchery may be considered to supplement fishery resources of Redwood Creek if populations fail to respond to current management strategies.

Education, Research and Monitoring Activities:

- Perform stream surveys throughout Lost Man Creek, Brown Creek, May Creek, Brown Creek and other streams in the subbasin to identify potential sites for improving habitat with restoration techniques;
- The wide range of habitat conditions within the watershed provides an opportunity to monitor channel and salmonid habitat recovery rates using habitat improvement treatments within a variety of channel types and conditions;
- Humboldt State University and RNSP should continue and expand their salmonid population and continuous temperature monitoring tasks in the Prairie Creek subbasin. This includes the use of fish counting weirs, spawner and redd surveys and juvenile population studies;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations of Redwood Creek;
- Water temperature monitoring should occur at the confluence of Prairie Creek and the mainstem to determine the effects of colder Prairie Creek water on the mainstem and estuary;
- Caltrans should continue to monitor sediment delivery from the Highway 101 bypass.

Subbasin Conclusions

The Prairie Creek subbasin provides important spawning and rearing habitat for anadromous salmonids. The subbasin is composed of both near pristine stream reaches and streams disturbed by land use. Timber harvest activities, road and highway construction, have had long lasting adverse impacts to anadromous salmonid stream habitat in portions of the Prairie Creek Subbasin. Physical factors including debris jams and sediment inputs that impair anadromous salmonid habitats are mostly linked to these past land use activities. In contrast, the undisturbed areas of the subbasin generally maintain desirable conditions for anadromous salmonids. Overall, the best stream habitat of the subbasin was observed at locations that received the least amount of land disturbance.

While over half of the Prairie Creek Subbasin falls within the high to very high mass wasting potential category, historically active landslide features account for less than 1.5 percent of the subbasin area. A relatively small amount compared to the other Redwood Creek subbasins. Nearly all of the active landslides were observed in the Lost Man Creek Planning Watershed, where the most timber harvesting and road construction has occurred. Streams in the areas of past timber harvests were lower in habitat quality than streams in near pristine areas of the subbasin.

The Prairie Creek Subbasin contains the most high quality refugia habitat in the Redwood Creek Basin. The maintenance and protection of natural resources and refugia habitat provided by RNSP is important to the recovery and expansion of anadromous salmonid populations of the Redwood Creek basin. As such, the Prairie Creek Subbasin provides an excellent opportunity for planning and implementing management plans to maintain and improve stream habitat conditions and to strengthen anadromous stocks of Redwood Creek.

Lower Subbasin

Introduction

The Lower Subbasin includes the area above the confluence of Redwood and Prairie creeks upstream to the confluence of Redwood and Devil's creeks including Devil's Creek watershed (Figure 6). Until 1978, much of the Lower Subbasin was under private ownership and was managed for timber production. The lower Subbasin is now 99 % in public ownership (Table 11). These lands were brought under Redwood National and State Park management in 1978 when the Park expanded its boundaries to include an additional 48,000 acres in the Lower Subbasin. The Lower Subbasin includes the planning watersheds of McArthur Creek, Bond Creek, Bridge Creek, Copper Creek and Devils Creek.

Table 11. Lower Subbasin features.

Square Miles	69.51
Total Acreage	44,488
Private Acres	275
Public Acres	44,212
Principal Communities	none
Predominant Land Use	Park Land
Predominant Vegetation Type	Redwood Forest
Miles of Anadromous Stream	26
Low Elevation	~10 ft.
High Elevation	1,286

The lower reach of Redwood Creek is straight and follows the Grogan fault zone downstream between the confluences of Devil's Creek and Dolason Creek. Streamside landslides are abundant along this reach within the fault zone. Below the mouth of Dolason Creek, the course of Redwood Creek veers westward into the Redwood Creek Schist. Below Bridge Creek, this wider and flatter reach contains large stream bars and some terraces, including the terrace of the Tall Trees Grove in Redwood National and State Parks. Downstream, the main stem makes its final westward bend toward the ocean.

The Lower Subbasin supports populations of Chinook salmon, coho salmon, steelhead, and coastal cutthroat and other valuable fishery resources. The entire lower reach of Redwood Creek (17 miles) is used by anadromous salmonids for upstream and downstream migrations and is also used for seasonal spawning and rearing habitat.

Problems with fish habitat of the lower Redwood Creek mainstem are generally related to excessive erosion, aggraded channels and warm water temperature delivered from upstream. Excessive amounts of stored sediments contribute to a simplified channel which exhibits a lack of deep pools, inadequate shelter complexity, a widened channel with an increased width to depth ratio, elevated water temperature, and reduced summer surface flows.

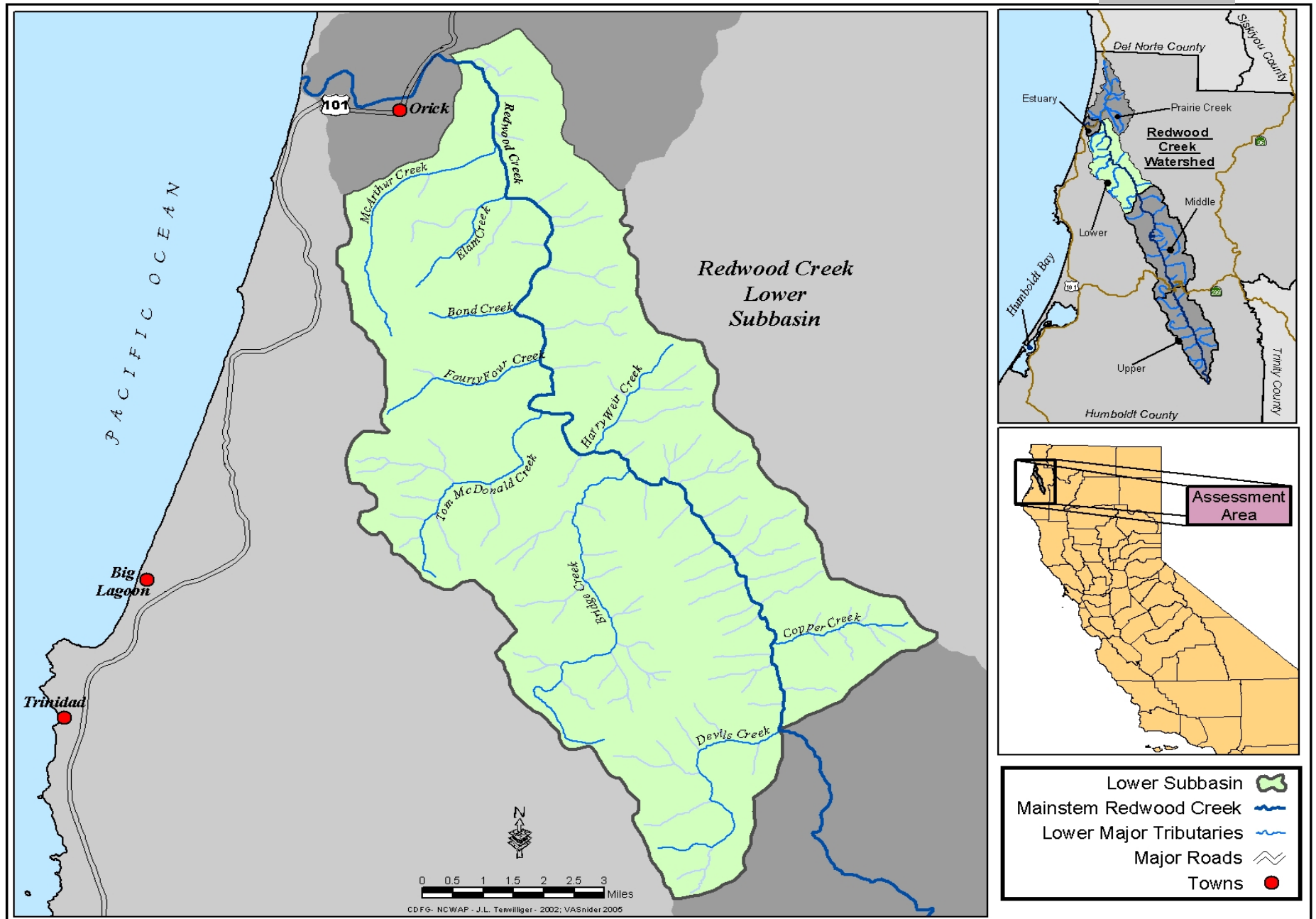


Figure 6.. Lower Subbasin.

The most important tributary streams (based on amount of available habitat) in the Lower Subbasin for anadromous salmonids are Bridge, Emerald (Harry Weir), Tom McDonald, and McArthur Creeks. These four creeks comprise approximately 78% of the nine miles of tributary stream habitat available to anadromous salmonids in the lower subbasin. In the tributary streams, fish habitat is lacking in deep, complex pools, but water temperature is generally suitable for summer rearing habitat.

Stream Reach Condition, EMDS Evaluations, and Limiting Factors

The overall reach condition of the sample sites located in the lower subbasin were all rated “somewhat unsuitable” for salmonid production by EMDS (Table 12). The somewhat unsuitable rating for stream condition is largely due to the lack of deep, complex pools observed from the tributary sites (Elam, Bridge, and Forty-four Creeks) and lack of deep, complex pools and lack riparian canopy density affecting the lower mainstem Redwood Creek sites. Site 7 on Redwood Creek was completely dry during the time of sample surveys in late September 2001, so no habitat data was collected from this site.

The average embeddedness ratings for the five measured sample sites in Redwood Creek and three tributary sample sites located in the Lower Subbasin indicate that overall pool tail spawning substrate contains more than the desirable levels of fine sediment for successful salmonid spawning. Although, site 14 located on Redwood Creek received a “fully suitable” evaluation by EMDS, the result was due to only one pool tail measured in the sample reach. Pool tail substrate at Sites 22 and 18 located on Redwood Creek were generally 25-50 percent embedded with fines which places them into the for the EMDS “undetermined” evaluation category. All tributary sites evaluated to “moderately unsuitable” for pool tail embeddedness.

Table 12. Summary of results from the Lower Subbasin EMDS stream reach evaluation.

The stream habitat components are categorized with respect to suitability for anadromous salmonid production. The scores represent a range from fully suitable conditions to fully unsuitable conditions. Factors that received plus scores(+, ++, +++) should be considered to support anadromous salmonids and minus scores (-,--,---) should be considered as limiting factors to anadromous salmonid production at the sampling sites in Prairie Creek Subbasin. These overall scores provide a general overview of current stream conditions and may be used to identify limiting factors and focus on areas for habitat improvement strategies.*

Stream	Reach Length (ft)	Reach Condition	Canopy Density	Pool Quality	Residual Pool Depth	Pool Shelter	Embeddedness
Elam Creek site24	513	-	+++	--	--	-	--
Forty-Four Creek Site 2	597	-	+++	--	---	-	---
Bridge Creek Site 8	1373	-	++	--	---	0	--
Redwood Creek Site 7	1500	* ¹	*	*	*	*	*
Redwood Creek Site 22	2065	-	---	--	---	--	0
Redwood Creek Site 14	1819	-	---	--	---	--	+++
Redwood Creek Site 4	1608	-	--	---	---	---	--
Redwood Creek Site 18	1566	-	---	--	---	--	0
Redwood Creek Site 17	1508	-	---	---	---	---	-

¹ Dry reach

Canopy density evaluations were “fully suitable” at the Elam Creek and Forty-Four Creek sites. On the mainstem Redwood Creek, canopy density was generally unsuitable for providing shade benefits to salmonid habitat. The wide channel of the mainstem Redwood Creek and the historical harvest of streamside conifers (Urner and Madej 1998) have prevented the riparian canopy from providing shade on large areas of the stream. In addition, changes in tree species composition, seral stage, and canopy structure adjacent to the tributaries and mainstem Redwood Creek associated with past timber harvest also may adversely affect stream habitat conditions. In some cases hardwoods strongly dominant the riparian forest and inhibit the re-growth of conifers. A mix of conifers and hardwood species is desired for to achieve the largest benefits to the stream habitat.

Refugia Areas

The majority of fish bearing tributary streams of the lower subbasin received designations as high potential refugia habitat or critical contributing areas (Table 13). The high quality refugia designations were based on the presence of more than one species of anadromous salmonid in the watershed, low risk from future human caused disturbance, relatively favorable fish habitat conditions, and propensity for improvement. The critical contributing areas are known to contribute cool water to the lower reach of the mainstem. Redwood Creek received a potential refugia designation as problems with water temperature, habitat structure, and the likelihood of improvement potential lowered its refugia value. Management activities that address limiting factors presented in Table 12 will help promote the advancement of these streams to the higher quality refugia category.

Table 13. Anadromous salmonid refugia designations for streams of the Lower Subbasin.

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Potential	Low Quality	Passage Barrier Limited	Critical Contributing Area/Function	Data Limited
Bridge Creek		X					
Emerald Creek (Harry Weir)		X					
Tom McDonald		X					
McArthur Creek			X				
Copper Creek		X					
Elam Creek		X					
Cloquet Creek							X
Devils Creek						X	
Forty-Four Creek		X				X	
Hayes Creek						X	
Bond Creek		X				X	
Slide Creek						X	
Dolason Creek							X
Miller Creek							X
Redwood Creek			X				

Response to Assessment Question Six:

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Barriers to Fish Passage

- Modify potential barriers such as deltas or boulder and/or debris accumulations that may impede upstream fish passage into tributary streams for spawning.

Flow and Water Quality Improvement Activities:

- Ensure that adequate streamside protection measures are used to promote near stream forest growth to reduce solar radiation and to moderate air temperatures along stream corridors. This will reduce heat inputs to Redwood Creek and its tributaries and help to keep water cool.

Erosion and Sediment Delivery Reduction Activities:

- Any reduction of sediment from upstream sources will benefit the lower mainstem Redwood Creek;
- RNSP should continue efforts such as road improvements in the Lower Subbasin (e.g., upgrading crossings, rocking native surface roads, outslipping, ensuring surface drainage does not flow directly into watercourses, etc.) and decommissioning (e.g., removing unstable fills, removing drainage structures and fills, restoring natural contours, blocking vehicle access, etc.).
- Sediment sources from eroding stream banks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to Elam, Bridge, and Forty-four creeks.

Riparian and Habitat Improvement Activities:

- Land managers should use tree planting, thinning from below, and other vegetation management techniques to promote the development of large near stream conifers along mainstem Redwood Creek, Bridge Creek or other stream reaches with a low coniferous component in the riparian zone;
- Strategically add wood into pools and flatwater units to increase pool depth and overall shelter complexity in Bridge, Elam, Forty-four creeks and other streams within the subbasin that lack deep complex pools;
- Consider adding shelter complexity with wood and large boulders to existing cool temperature refuge sites on Redwood Creek, and lower reaches of tributary sites. This could be done even on a temporary basis using small woody debris to provide escape cover for juvenile salmonids during summer season. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from tributary flows at Bridge Creek or near springs, and seeps;

Education, Research and Monitoring Activities:

- Perform stream habitat surveys in tributaries throughout the Lower Subbasin to identify excessive erosion areas, assess salmonid stream habitat, identify deltas or boulder and/or debris accumulations that may impede passage for spawning, and to identify potential sites for improving habitat with restoration techniques;
- The range of habitat conditions within the Lower Subbasin provides an opportunity to monitor channel and salmonid habitat recovery rates using habitat improvement treatments within a variety of channel types and conditions;
- Monitoring for in-channel sediment (e.g., sediment size distribution, turbidity, V^* , photo points, etc.) should be increased and tracking of streambed levels (i.e., stream channel cross sections) should be continued along the mainstem reach of lower Redwood Creek;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations in Lower Subbasin streams;
- Land managers and responsible agencies should increase continuous temperature monitoring efforts along the mainstem and at additional tributary locations to determine the impact of cold-water inputs from tributary and ground water sources.

Subbasin Conclusions

The lower mainstem of Redwood Creek is an important migratory route for anadromous salmonids as it provides access to Lower Subbasin tributaries and upstream spawning areas. The mainstem also may serve as spawning habitat for Chinook salmon during low water years. Juvenile use of the lower mainstem Redwood Creek is limited by high water temperature and lack of channel diversity and complexity.

Present conditions of the lower Redwood Creek mainstem are largely related to excessive sediments, the aggraded and widened channel along the lower reach, and a reduction of riparian forest values. The main channel of Redwood Creek often threads through the center of large gravel deposits during summer base flows, which isolates the stream from benefits of a riparian corridor. The majority of sediment delivery is transported from the Upper and Middle subbasins.

Lower subbasin tributary streams provide important salmonid spawning and year round rearing habitat. The three Lower Subbasin tributary sample sites were typically lacking in deep pools with adequate shelter complexity. Spawning gravels were moderately to highly embedded in fine sediments, which is considered unfavorable for successful incubation salmonid eggs. Water temperature is generally suitable in the tributaries for summer rearing habitat.

The Lower Subbasin offers opportunities for both implementing and effectiveness monitoring of stream and riparian habitat improvement activities. Further surveys are needed to assess conditions of Lower Subbasin tributaries. However, based on the survey sample sites, stream habitat improvement activities for Lower subbasin streams include reducing sediment inputs by stabilizing stream bank and hillslope erosion, increasing depth and complexity to existing pool habitats, promoting riparian conifer growth, and adding shelter complexity to cool water refuge sites.

Middle Subbasin

Introduction

The Middle Subbasin includes the area above the confluence of Redwood and Devil's creeks, up to the confluence of Redwood and Lupton creeks, including the Lupton Creek watershed (Figure 7). The predominant land use in the Middle Subbasin is timber production with some livestock grazing in Redwood Valley. The Middle Subbasin includes the following Planning Watersheds:

Coyote Creek	Panther Creek	Lower Lacks Creek	Upper Lacks Creek
Roaring Gulch	Toss-up Creek	Minor Creek	Lupton Creek

Main features within the Middle Subbasin include coniferous forestland, the Park Protection Zone, and rural developments in Redwood Valley. The Park Protection Zone was established on private lands in 1978 and includes private lands within Coyote (not within RNSP boundary), Panther, and Upper and Lower Lacks Planning Watersheds. There is a long history of timber harvest in the subbasin, with a sharp peak in acres harvested in the 1980s, when about half of the forested area was harvested. Approximately 2,300 acres in the Lacks Creek watershed is managed by the BLM as late successional reserves. Other notable features of the subbasin are presented in Table 14.

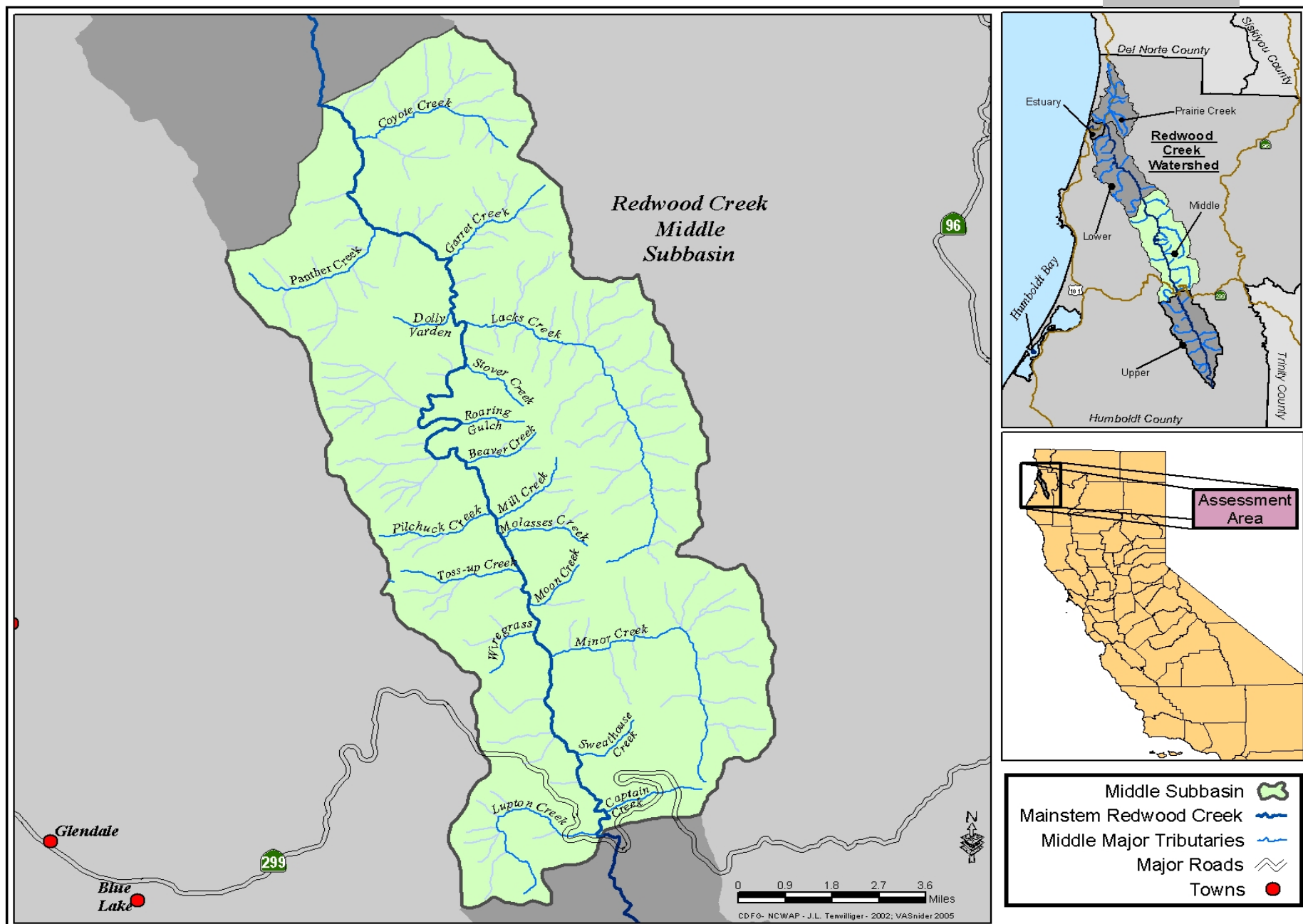


Figure 7.. Middle Subbasin and its tributaries.

Table 14. Middle Subbasin features.

Square Miles	100.14
Total Acreage	64,088
Private Acres	57,843
Federal Acres	5,838
State Acres	0
Principal Communities	Redwood Valley
Predominant Land Use	Timber production and livestock grazing
Predominant Vegetation Type	Douglas-fir forest/ hardwoods
Miles of Anadromous Stream	43.0
Low Elevation (feet)	325
High Elevation (feet)	4,091

Approximately 24 miles of mainstem Redwood Creek and 19 miles of tributary channel are accessible to anadromous salmonids within the subbasin. The streams of the Middle subbasin support populations of Chinook and coho salmon, steelhead and coastal cutthroat trout. Coho have been found at low abundance during past CDFG surveys of Coyote, Dolly Varden (Karen), Pilchuck, Minor and Redwood creeks, although they were not observed in Middle Subbasin tributaries during 2001 surveys. The summer steelhead that rely on deep, cool and sheltered pools for holding habitat over summer and fall seasons may be the most threatened of all salmonid stocks of the Redwood Basin.

Stream Reach Condition, EMDS Evaluations, and Limiting Factors

Results from the EMDS evaluations show that along the majority of streams of the Middle Subbasin the streamside canopy cover (canopy density) over the tributaries was in suitable condition, pools were in short supply or in poor quality to support fish and cobble embeddedness ratings were generally mixed (Table 15). Water temperatures in tributaries were generally suitable to sustain anadromous salmonids over the summer season. However, the lower reaches of Lacks and Minor Creeks have temperatures (MWATs of 65 or more) above desirable levels for sustaining healthy salmonids.

A closer review of the data shows that the great majority of the shade canopy was formed by broadleaf trees, and that the small fraction of conifer tress providing shade is considerably less than would be expected from forest streams (See data in Redwood Creek Assessment Report). There is a loss from benefits from a desirable nearstream forest provided by conifers such as LWD loading potential and moderating air temperature is lacking along most Middle Subbasin tributary streams. The entire length of the mainstem Redwood Creek in the Middle Subbasin is deficient in streamside canopy cover. The lack of mature conifers, the wide channel and the aspect of the channel account for the shortfall in shade over the mainstem.

Table 15. Summary of the results from the Middle Subbasin EMDS stream reach evaluation.

These scores provide a general overview of current stream conditions and may be used to identify limiting habitat factors to anadromous salmonid production and to focus on areas for habitat improvements. The scores represent a range from fully suitable conditions to fully unsuitable conditions. Factors that received plus scores(+, ++, +++) should be considered to support anadromous salmonids and minus scores (-,--,---) should be considered as limiting factors to anadromous salmonid production at the sampling sites in Prairie Creek Subbasin.*

Subbasin and Reach	Reach Length	Canopy Density	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Redwood Middle Basin						
Beaver Creek	2608	+++	---	---	---	+
Captain Creek	2360	++	---	---	---	++

Subbasin and Reach	Reach Length	Canopy Density	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Coyote Creek	13379	++	--	--	--	++
Dolly Varden Creek	5833	+++	-	0	-	-
Fern Prairie Creek	852	+++	---	---	---	0
Garrett Creek	4779	+++	---	---	---	-
Lacks Creek	24262	+	--	---	--	++
Lupton Creek	3832	+++	--	-	---	-
Mill Creek	2788	+++	--	---	--	-
Minor Creek	14418	++	--	--	--	+
Molasses Creek	2556	+++	---	---	---	++
Panther Creek	14589	+++	--	---	-	-
Pilchuck Creek	1617	---	---	---	---	0
Sweathouse Creek	1859	+++	---	---	---	--
Toss up Creek	5462	+++	--	---	--	-
Wiregrass Creek	2000	+++	--	---	--	++
Mid Basin Tribs Wt. Ave.	103194	++	--	--	--	+
Redwood Creek Mid 1	12002	--	--	-	---	+
Redwood Creek Mid 2	19919	---	-	+	---	-
Redwood Creek Mid 3	32044	---	0	+++	---	--
Redwood Creek Mid 4	28724	---	---	---	---	--
Redwood Creek Mid 5	29406	---	---	---	---	-
Redwood Creek Mid Wt. Ave	130520	--	--	-	---	-

The lack of deep and well sheltered pools was a factor identified by EMDS that may limit anadromous salmonid production in tributaries of the Middle Subbasin. The pools of tributary streams were generally too shallow or except for reaches of Coyote Creek and Minor Creek. Some streams (eg. Panther, Toss Up, Wiregrass, Pilchuck, Lupton and Dolly Varden creeks) had good numbers of pools, but the pools are small and do not compose much of the channel length or they may be less than the desirable depth. The mainstem shows mixed results for pool depths. Redwood Creek reaches 2 and 3 evaluated to suitable pool depths by the EMDS while the pools of reaches 1, 4, and 6 were considered too shallow to be suitable.

Pool shelter ratings were generally unsuitable according to EMDS for both mainstem and tributary streams, although reaches of Coyote, Lacks, and Minor creeks show some suitable pools shelter conditions. The most common shelter element was usually composed of boulders. This indicates a general shortage of LWD in pool habitat compared to what may be expected from coniferous forest streams.

The spawning substrate embeddedness evaluations were generally mixed between suitable and unsuitable condition both tributary streams and the mainstem Redwood Creek. Recent spawning surveys and trapping studies have shown that in most years from 1999 – 2003, portions of the mainstem Redwood Creek and some tributaries are providing suitable spawning habitat for Chinook salmon. The recent spawning success may be attributed to the presence of suitable spawning gravels, the Chinook's ability to select suitable spawning habitat, and to favorable flow conditions over most recent years.

Refugia Areas

Most of the streams of the Middle Subbasin fit into the potential refugia class based on the status of watershed conditions, salmonid habitat and salmonid populations (Table 16). The majority of streams support populations of anadromous salmonids, although 2001 fish numbers appear low compared to past surveys. Addressing limiting habitat factors with the strategies identified in table III-67 should elevate the refugia rating for Middle Subbasin streams.

Table 16. Anadromous salmonid refugia designations for streams of the Middle Subbasin

Stream	Refugia Categories:				Other Categories:		
	High Quality	High Potential	Potential	Low Quality	Passage Barrier Limited	Critical Contributing Area/Function	Data Limited
Lacks Creek			X				
Minor Creek			X				
Coyote Creek		X					
Panther Creek			X				
Dolly Varden Creek (Karen)		X			X	X	
Wiregrass Creek			X				
Garcia Creek							X
Toss Up Creek				X			
Garrett Creek							
Lupton Creek					X	X	
Sweathouse Creek			X				
Mill Creek			X				
Molasses Creek			X				
Captain Creek			X				
Beaver Creek			X		X		
Pilchuck Creek				X			
Cashmere Creek							X
Roaring Gulch							X
Loin Creek							X
Santa Fe Creek							X
Redwood Creek			X				

Stream Habitat Improvement Recommendations

The most frequently listed recommendation category across the basin is to improve instream habitat factors (pool frequency, depth, and shelter complexity), followed by erosion/sediment and riparian/temperature treatments (Tables 17 and 18). In a few streams large debris and/or sediment accumulations may need to be modified to increase fish passage. Since much of the upper reaches have suitable water temperature, a priority should be give to extending the cool water temperatures to the lower reaches of Lacks and Minor creeks and to the confluences with redwood creek. A reduction in temperature will likely occur as the result of increasing pool frequency and depth, controlling erosion and increasing the coniferous component of the riparian zone.

Table 17 Prioritization of steps to address limiting factors.

The first four recommendations for treatment to address limiting factors on tributaries and sections of mainstem Redwood Creek are shown. The total number of treatments ranked 1,2, or 3 for each tributary or mainstem reach of the Middle Subbasin are summed.

SUBBASIN	SURVEY LENGTH (feet)	TEMP	POOL	COVER	BANK	ROADS	CANOPY	SPAWNING GRAVEL	LDA	LIVE-STOCK	ACCESS
Middle Subbasin Tributaries (N= 16)	103,194	3	14	15	6	1	2	4	2		2
Lacks Creek	24,262	4	2	1	3	5	6	7			
Minor Creek	14,418	5	3	1	2	6	4	7			
Coyote Creek	11,282		5	1	2	3	4				
Panther Creek	14,504		4	3		5		6	1		2
Wiregrass Creek	2,000		2	1		3	4				
Dolly Varden Creek	5,968		1	3		4	5		2		
Toss Up Creek	5,462		3	1	2	4	5	6			
Garrett Creek	4,779		4	1	2	3		5			
Lupton Creek	3,832		4	1	5	2	6	7	8		3
Sweathouse Creek	1,611		2	1	6	3	5	4			
Pilchuck Creek	1,617		2	1	5	4		3			
Mill Creek	2,788		1	2		4	3	5			
Molasses Creek	2,556		1	2	5	4	3				
Captain Creek	2,360	1	4	3		5	4	7	6		2
Beaver Creek	2,731		2	3	6	4	5	7			1
Redwood Creek	24 miles	1	4	2	5	6	3	7			
Middle Subbasin Mainstem Redwood Creek (N= 1)	130,520	1	3	2	4		1				

Key to fields: Temp = summer water temperatures seem to be above optimum for salmon and steelhead; Pool = pools are below target values in quantity and/or quality; Cover = escape cover is below target values; Bank = streambanks are failing and yielding fine sediment into the stream; Roads = fine sediment is entering the stream from the road system; Canopy = shade canopy is below target values; Spawning Gravel = spawning gravel is deficient in quality and/or quantity; LDA = log debris accumulations are retaining large amounts of gravel and could need modification; Livestock = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; Access = there are human made barriers to fish migration in the stream.

Table 18. Top Three ranking recommendation categories by number of tributaries and mainstem reaches in the Middle Subbasin.

Basin Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	11
Riparian / Water Temp	Canopy / Temp	9
Instream Habitat	Pool / Cover	41
Gravel / Substrate	Spawning Gravel / LDA	7
Other	Livestock / Barrier	2

In general, the recommendations that involve erosion and sediment reduction by treating roads and failing stream banks, near stream vegetation improvements, and reducing temperature precede the instream recommendations for pool development and spawning gravel projects. The recommendations presented in Tables 18 and 19 were developed from CDFG stream surveys, so roads located outside the stream zone or roads above anadromous reaches may be under represented in the recommendations for sediment reduction. A considerable amount of road surveys have been conducted in the Middle Subbasin. The recommendations for treatments provided by the survey should be considered before proceeding with instream activities.

Water temperature improvement often results from improving near stream vegetation function and reducing sediment delivery in upstream and fish bearing reaches. The Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant. Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), or debris jams are usually a treatment priority.

Response to Assessment Question Six:

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Barriers to Fish Passage

- Investigate improving fish passage through 500 foot long culvert under HWY 299 on Lupton Creek;
- Consider modifying large debris accumulations that may impede fish passage on Panther Creek and other tributaries. (This was done by Green Diamond and the California Conservation Corps in 2004)
- Modify sediment deltas or boulder accumulations that impede upstream migration into tributaries. Impediments are located at the confluence of Panther Creek and other tributaries.

Flow and Water Quality Improvement Activities:

- Reducing water temperature is essential to improve anadromous salmonid habitat in the Middle Subbasin. A long term goal should be to reduce water temperature in the middle reach of Redwood Creek and the lower reaches of Coyote, Minor, and Lacks creeks;
- Work to extend the cool water temperatures from the upper to the lower reaches of Lacks and Minor creeks and on to the confluences with Redwood Creek. A reduction in temperature will likely occur as the result of increasing pool frequency and depth, controlling erosion and promoting growth of the coniferous component of the near stream shade canopy;
- Where current streamside canopy is insufficient, nearstream conifer forests need to be developed and retained along Redwood Creek in the Middle Subbasin to help increase shade canopy and to moderate air temperatures. This may require more than the minimum protection provided by Forest Practice Rules;
- Managers should explore methods to develop cool water refuge sites on Redwood Creek and the lower reaches of Lacks, and Minor creeks. Methods should include using pool enhancement elements, and increasing connectivity to ground water sources.

Erosion and Sediment Delivery Reduction Activities:

- Upgrade or decommission roads in accordance with existing or future road assessment surveys. This work should be done especially on older roads built below current standards located on unstable slopes and roads near streams in Upper and Lower Lacks, Minor, Lupton, Panther, and Coyote and Roaring Gulch planning watersheds;
- Identify locations for stream bank and hillslope stabilization projects along tributary streams of the Upper and Lower Lacks, Minor, Lupton, Panther, and Coyote, Toss Up and Roaring Gulch Planning Watersheds;
- For timber management in Lacks, Minor, Coyote and other planning watersheds, with active landslides or on steep and/or potentially unstable slopes (slopes $\geq 35\%$) we recommend the use of lower impact silvicultural prescriptions to maintain vegetative cover, root strength, and the use of

cable systems or helicopter yarding to reduce the potential for mass wasting and sediment production, which can result in sediment delivery to all tributaries and Redwood Creek;

- Timberland managers should decrease the use of tractor or ground lead yarding on all slopes steeper than 35 percent (19 degrees); and use fully suspended (skyline) cable or helicopter yarding on steep and unstable slopes of the Middle Subbasin;
- Continue efforts such as road improvements (e.g., upgrading crossings, rocking native surface roads, out sloping, ensuring surface drainage does not flow directly into watercourses, etc.) and decommissioning (e.g., removing unstable fills, removing drainage structures and fills, restoring natural contours, blocking vehicle access, etc.) throughout the Middle Subbasin to reduce sediment delivery to Redwood Creek and its tributaries;

Riparian and Stream Habitat Improvement Activities:

- Land managers should consider tree planting, thinning from below, and other vegetation management techniques to promote the development of large near stream conifers along mainstem Redwood Creek, lower Lacks Creek, Lower Minor Creek, Molasses, and Coyote Creeks and other stream reaches with a low coniferous component in the riparian zone;
- Consider adding shelter complexity with wood and large boulders to existing cool temperature refuge sites on Redwood Creek, lower Lacks and Minor creeks. This could be done even on a temporary basis using small woody debris to provide escape cover for juvenile salmonids during summer season. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from tributary flows like Panther Creek or springs, and seeps;
- Add wood into pools and flatwater units to increase shelter complexity especially where the average size of near stream conifers is less than 2 feet DBH in Redwood, Lacks, Minor, Lupton, Panther, Coyote and Molasses creeks;
- Add pool enhancement elements to increase the number of pools in Redwood, Lacks, Minor, Lupton, Molasses, Panther, Mill and Beaver creeks;
- Deepen and increase the size of existing pools by strategically adding LWD in Dolly Varden, Toss Up, Garret, Lupton, and in lower reach of Coyote Creek.

Education, Research and Monitoring Activities:

- Water temperature monitoring should continue at the current locations in the Middle Subbasin streams to monitor trends in temperature as effects from aggradation, degradation, channel widening, and riparian condition adjust through time;
- Identify potential perched deltas or boulder and/or debris accumulations that may impede passage for spawning into Panther Creek and other Middle Basin tributaries;
- Formal stream reach surveys were not done for LWD; however observations of crews and findings regarding pool complexity indicate that there is limited instream LWD. Formal survey for LWD loadings could be done to verify these observations;
- A long term, concerted monitoring effort by the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations in the Middle Subbasin mainstem and tributaries;
- Summer steelhead dive counts should be conducted on an annual basis on the middle reach of mainstem Redwood Creek and in the lower reach of Lacks and Minor creeks;

- Continue monitoring juvenile fish population trends such as downstream trapping operations on mainstem Redwood Creek;
- Investigate effects to fish and fish habitat from construction and operations of Chezum dam and any other seasonal dams in the Middle Subbasin;

Subbasin Conclusions

Middle Subbasin streams provide important spawning and rearing habitat for anadromous salmonids. Steelhead and coastal cutthroat predominate in the tributary streams year round while Chinook depend on the mainstem for spawning habitat and temporary juvenile rearing. Coho once noted as present in some tributaries were not observed during 2001 surveys. Summer steelhead

The mainstem Redwood Creek has slowly adjusted from destructive impacts related to the 1964 flood and other recent winter storm events. Sediments are moving from the active channel to downstream reaches, and an increase in channel structure has formed. However, this has not occurred without setbacks related to moderate storm events.

High water temperature is likely the most limiting factor to salmonid production in mainstem Redwood Creek. The high water temperature is in part related to the lack of shade over the water along middle and upper mainstem reaches. Other factors affecting salmonids production in the mainstem are lack of pools and instream shelter complexity. Tributary streams generally provide good water temperature, except in lower reaches of Lacks and Minor creeks. Tributaries also showed a lack of deep pool habitat and instream shelter complexity.

The Middle Subbasin offers opportunities for developing and implementing watershed, stream and riparian habitat improvement activities. Watershed management strategies aimed at reducing erosion and developing functional near stream forests will help address landscape issues. Stream habitat improvement activities should focus on increasing depth and complexity to existing pool habitats, and adding shelter complexity to cool water refuge sites. This will help to reduce water temperature, increase bank stability, provide a source of LWD and reduce sediment inputs to stream channels.

Upper Subbasin

Introduction

The Upper Subbasin drains approximately 68 square miles and includes the land and waterways from the confluence of Lupton Creek upstream to the headwaters of Redwood Creek (Table 19, Figure 8). Approximately 19 miles of mainstem, 21 miles of blue line tributary stream channel drain the surrounding landscape. This subbasin has the highest relief and greatest proportion of natural prairies of all Redwood Creek subbasins. The predominant land use is timber production, but the Upper Subbasin also has the most area in the Redwood Creek basin in small land ownerships. The Upper Subbasin includes the following Planning Watersheds:

Windy Creek	Noisy Creek	Cloney Gulch
High Prairie Creek	Bradford Creek	Twin Lakes Creek

The upper main stem of Redwood Creek lies within a narrow channel that follows the trace of the Grogan Fault zone. Abundant streamside landslides flank the narrow mainstem channel, or inner gorge. The storm and flood of 1964 caused massive debris jams and sediment accumulations in the main channel. Aerial

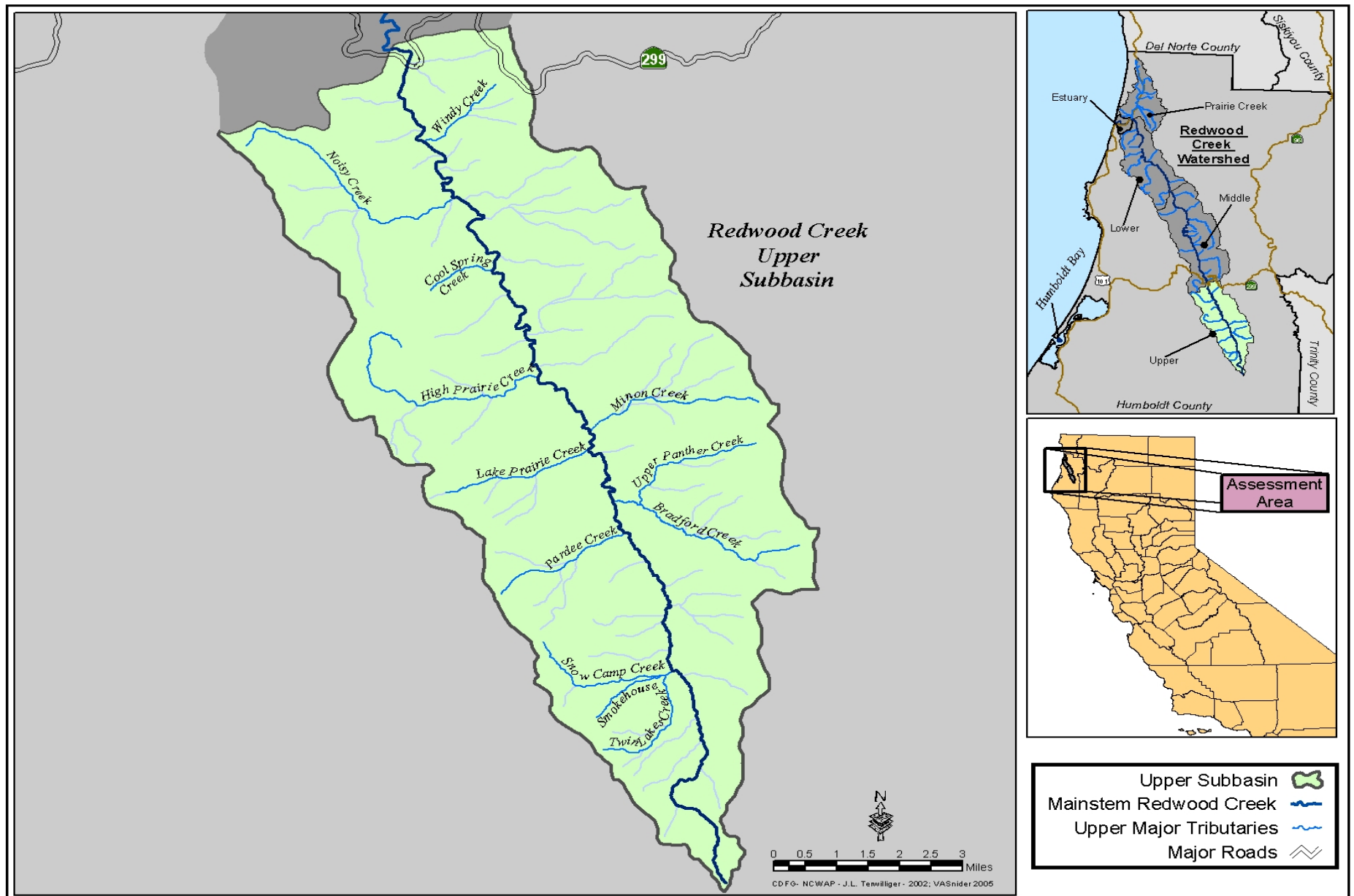


Figure 8. Upper Subbasin and its tributaries.

photos from 1965 show the banks of the mainstem significantly eroded, the channel widened and aggraded with active sediment. Riparian trees that once shaded the mainstem were lost as the banks eroded.

The Upper Subbasin supports populations of Chinook salmon, steelhead, and coastal cutthroat. Although the mainstem provides access to suitable habitat for coho salmon, there is no recent account of their presence in the Upper Subbasin.

Table 19. Upper Subbasin features.

Square Miles	67.72
Total Acreage	43,344
Private Acres	40,640
Federal Acres	2,240
State Acres	0
Principal Communities	None
Predominant Land Use	Timber Production
Predominant Vegetation Type	Hardwoods / Douglas-fir Forest
Miles of Anadromous Stream	23.0
Low Elevation (feet)	866
High Elevation (feet)	5,322
Fish Species	steelhead coastal cutthroat trout
	Chinook salmon Coho Salmon? Pacific lamprey

The Upper Subbasin was severely affected by the 1964 flood. Channel-bed elevations increased in response to excessive sediment inputs, the capacity of the channel to convey peak flows was reduced, and the channel adjusted its width to accommodate flood peaks by eroding its banks and widening the channel. The problems associated with channel widening have long term and far reaching adverse effects to stream temperature and channel conditions throughout the Redwood Creek basin. The channel more than doubled in width and the shade benefits of riparian vegetation and moderating air temperatures from near stream forests were lost leading to increased water temperatures.

Excessive erosion continues to be a problem in the Upper subbasin. The Upper Subbasin has begun to yield more suspended sediment to the mainstem of Redwood Creek than the middle and lower subbasins combined. A comparison of photo years 1984 and 2000 showed that the mainstem of Redwood Creek retained much of its sediment in the Twin Lakes Creek and Noisy Creek planning watersheds. During the preceding 16 years, five tributaries in the subbasin deteriorated by gaining elevated sediment: Noisy, High Prairie, Minon, Snowcamp, and Twin Lakes Creeks.

Stream Reach Condition, EMDS Evaluations, and Limiting Factors

The favorable stream temperatures (MWAT of 65° F at Minon Creek) of the upper mainstem reach, above Minon Creek, helps create some of the best mainstem juvenile steelhead rearing habitat in the basin. Downstream of Minon Creek, the water warms, and by the time it reaches the O’kane gauging station near the Highway 299 Bridge, the water has a MWAT of 71.

The overall reach condition of the surveyed stream reaches located in the upper subbasin were mostly rated “somewhat unsuitable” for salmonid production by EMDS (Table 20). The somewhat unsuitable rating for stream condition is largely due to the lack of deep, complex pools observed from the tributary and lack of deep, complex pools and lack riparian canopy density affecting the stream observed from the upper mainstem of Redwood Creek. In contrast, canopy density generally evaluated as suitable and pool tail substrate embeddedness was often in suitable condition to support anadromous salmonids in Minon Creek. Canopy density and pool tail substrate embeddedness was generally unsuitable in the mainstem Redwood Creek. Based on EMDS evaluations of shelter ratings, conditions were generally unsuitable in survey reaches of the Upper Subbasin.

Table 20. Summary of the results from the upper subbasin EMDS stream reach evaluation.

The stream habitat components are categorized with respect to suitability for anadromous salmonid production. The scores* represent a range from fully suitable conditions to fully unsuitable conditions. Factors that received plus scores(+, ++, +++) should be considered to support anadromous salmonids and minus scores (-,--,---) should be considered as limiting factors to anadromous salmonid production at the sampling sites in Prairie Creek Subbasin. These overall scores provide a general overview of current stream conditions and may be used to identify limiting factors and focus on areas for habitat improvement strategies.

Stream	Reach Length (ft)	Reach number	Reach Condition	Canopy Density	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Fern Prairie Creek	852	1	-	+++	---	---	---	0
Redwood Creek (lower)	8425	1		---	---	---	---	+
Upper Redwood Ck	13996	2	-	-	--	---	---	-
Minon Creek	1101	1	-	++	---	---	---	+
Minon Creek	1784	2	-	+++	---	---	---	++
Minon Creek	3294	3	-	+++	--	---	--	0

Refugia Areas

The upper reach of mainstem Redwood Creek (above Minon creek) provides some of the best refuge type habitat of the entire mainstem. This reach provides the coolest water of all Redwood Creek, but lacks in the number of deep, complex pools considered favorable for anadromous salmonid habitat. The reach below Minon Creek is currently warmer than considered desirable for salmonids. However, the potential for water cooling along this reach by increasing the shade canopy. Simon, Minon and Fern Prairie creeks were also classed as potential refuge based on the cool water temperature and fair condition of the stream habitat. Lake Prairie Creek is passage barrier limited as a large debris jam exists at the mouth of the creek. Most of the tributary streams could not be assigned into a refugia class because of data limitations. Addressing limiting habitat factors with the strategies identified in Table 22 should elevate the refugia rating for Upper Subbasin streams.

Table 21. Anadromous salmonid refugia designations for streams of the Upper Subbasin

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Potential	Low Quality	Passage Barrier Limited	Critical Contributing Area/Function	Data Limited
Minon Creek			X				
Fern Prairie Creek			X				
Bradford/Up. Panther Creek							X

Noisy Creek							X
Gunrack Creek							X
High Prairie Creek							X
Lake Prairie Creek					X		
Emmy Lou Creek							X
Windy Creek							X
Squirrel Tail Creek							X
Snowcamp/Smokehouse Creek							X
Pardee Creek							X
Simon Creek		X					
Cut-off Meander Creek							X
Jena Creek							X
Xmas Prairie Creek							X
Redwood Creek			X				

Response to Assessment Question Six:

What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Barriers to Fish Passage

- Modify sediment deltas or boulder and/or debris accumulations that impede upstream migration into tributaries. Barriers are located at the confluence of Lake Prairie Creek. Consider building step pools in the lower reaches where sediment accumulations may restrict or delay access to migrating salmonids.

Flow and Water Quality Improvement Activities:

- Maintaining good water temperatures in tributaries and in the upper reach of Redwood Creek is essential to maintain good condition of salmonid habitat in the Upper Subbasin.
- To help preserve and extend the benefits of cool water flowing from the headwater reach of Redwood Creek, a high priority should be placed on re-establishing riparian shade and reducing the channel width along the upper reach of Redwood Creek;
- Adequate nearstream conifer forests need to be developed and/or maintained along Redwood Creek in the Middle Subbasin to help increase shade canopy and to moderate air temperatures. This may require more than the minimum protection provided by Forest Practice Rules;

- Reducing water temperature in Redwood Creek at the O’Kane Bridge Gauging station is essential to improve anadromous salmonid habitat in the Upper Subbasin and will provide benefits to downstream reaches;
- In the reach of Redwood Creek below Minon Creek, consider tree planting and other vegetation management techniques to hasten the development of denser and more extensive near stream forest and riparian canopy.

Riparian and Instream Improvement Activities:

- In appropriate locations along the upper reach of mainstem Redwood Creek, consider installing willow baffles or other habitat structure to help establish shade over water and to encourage channel width reduction;
- The riparian corridor along the upper reach of Redwood Creek should be managed to encourage growth of coniferous trees to help maintain cool water temperatures, provide large woody debris (LWD) recruitment, add stability to banks, moderate sediment delivery, and provide nutrient inputs;
- Design and engineer pool enhancement structures to increase the number of pools or increase the size, deepen, or add shelter complexity to existing pools in Redwood Creek and Minon Creek and other tributaries;
- Consider adding shelter complexity with wood and large boulders to existing cool temperature refuge sites on upper Redwood Creek. This could be done even on a temporary basis using small woody debris to provide escape cover for juvenile salmonids during summer season. The cool patches may be located in temperature stratified pools or adjacent cool water inputs from tributary flows, springs, and seeps;
- To address the lack of large woody debris in Redwood Creek and Minon Creek, we encourage recruitment of large woody debris through allowing near stream conifers to grow to large sizes and consider direct placement of large woody debris in stream channels, especially where the average size of near stream conifers is less than 2 feet DBH. Land managers should consider cautious thinning from below in riparian areas to hasten the development of large riparian conifers;
- Consider the use of conservation easements along the upper reach of Redwood Creek to protect valuable riparian and near stream forest from development or timber harvests.

Erosion and Sediment Delivery Reduction Activities:

- Upgrade or decommission roads in accordance with existing or future road assessment surveys, especially roads located on unstable slopes and roads near streams. These are found throughout the subbasin but are most frequent in Windy Creek, Twin Lakes Creek, Bradford Creek, and High Prairie Creek Planning Watersheds;
- Consider bank stabilization projects in tributary streams throughout the Upper Subbasin;
- Throughout the Upper Subbasin, timberland managers should decrease the use of tractor yarding on slopes steeper than 35 percent (19 degrees); rather, use full suspension cable or helicopter yarding on steep and unstable slopes;

Education, Research and Monitoring Activities:

- Monitoring for temperature should continue at the current locations to observe changes in temperature as effects from mainstem fluvial conditions, such as aggradation, degradation, channel widening, and riparian function adjust through time.

- Monitoring for in-channel sediment (e.g., sediment size distribution, turbidity, V^* , photo points, etc.) should be increased and tracking of streambed levels (i.e., stream channel cross sections) should be continued at upper Redwood Creek study sites;
- A long term, concerted monitoring effort between the land owners, interested parties and responsible agencies is needed to determine the status and trends of anadromous fish populations of upper Redwood Creek.
- Summer steelhead dive counts should be conducted on an annual basis along the upper reach of mainstem Redwood Creek.

Subbasin Conclusions

The Upper Subbasin is important habitat for anadromous salmonids. High water temperature is likely the most limiting factor to salmonid production in the upper mainstem Redwood Creek. The lack of deep and complex pool habitat were identified as potential limiting factors in tributary streams.

Watershed management strategies aimed at reducing erosion and developing functional near stream forests will help address landscape issues. Opportunities to improve stream habitat conditions should focus on preserving cool water flowing from the headwaters reach of Redwood Creek re-establishing riparian shade and reducing the channel width along mainstem Redwood Creek in the Upper Subbasin. The riparian corridor should be managed to encourage growth of coniferous trees to help maintain cool water temperatures, provide large woody debris (LWD) recruitment, add stability to banks, moderate sediment delivery, and provide nutrient inputs. Restoration projects such as tree planting and adding LWD to stream channels may increase the rate of recovery. The Middle Subbasin offers opportunities for developing and implementing watershed, stream and riparian habitat improvement activities. Stream habitat improvement activities should focus on increasing depth and complexity to existing pool habitats, and adding shelter complexity to cool water refuge sites. This will help to reduce water temperature, increase bank stability, provide a source of LWD and reduce sediment inputs to stream channels.

Propensity for Improvement in the Redwood Creek Basin

Advantages

Redwood Creek Basin has several advantages for planning and implementing successful salmonid habitat improvement activities that include:

- Approximately 40 percent of the basin is managed by RNSP to preserve natural resource values;
- There are relatively few land owners to coordinate projects at the subbasin and subbasin scales;
- Redwood Creek Land Owners Association is working to solve watershed problems.

Challenges

The Redwood Creek Basin also has some challenges confronting efforts to improve watershed and fish habitat conditions, and increase anadromous fish populations:

- Without a watershed wide cooperative land-base, treatment options are limited. In some cases this can remove some key areas from consideration of project development;
- Current reduced levels of coho salmon populations limit re-colonization potential into improved or expanded habitat conditions.

Redwood Creek Basin Conclusion

The results from this assessment indicate that patches of suitable salmonid refugia areas exist within each of the Redwood Creek subbasins. The streams located in the undisturbed portion of the Prairie Creek Subbasin provide some of the best salmonid habitat in the Redwood Creek Basin due to the combination of beneficial riparian vegetation, cool water temperature, desirable pool characteristics, instream shelter and good spawning habitat. However, there are also sites in the Prairie Creek Subbasin that are lacking in one or more important factors and stream conditions over much of the Redwood Creek Basin are below standards for preferred salmonid habitat, particularly in the mainstem Redwood Creek. Salmonid production in the Lower, Middle and Upper subbasins may be limited by a single factor or combination of high water temperature, poor pool characteristics, poor spawning habitat, or lack of instream shelter. Many tributaries across the basin have cool water temperatures but may lack the combination of structural components that create the habitat diversity and complexity needed by salmonids to support viable populations. In addition, the estuary/lagoon, in its current condition, also acts as a significant bottleneck to salmonid production.

Significant factors effecting salmonid habitat are erosion and associated sediment inputs to streams. Excessive quantities of sediment enter stream channels during flood events when heavy rains and storm runoff erode the basin's unstable mountainous terrain. Change in riparian and near stream forest composition and function associated with timber harvest has also played a role in degrading channel conditions and altering channel maintenance processes.

Excessive sediment loads in Redwood Creek streams have contributed to stream bank erosion, channel widening, loss of habitat diversity, a loss of riparian shade, and an increase in water temperature. Much of the erosion is linked to timber harvest and other land use activities including the extensive road network across the basin. Because approximately 75% of the Redwood Creek Basin shows signs of high potential for landsliding, erosion associated with land use should be expected to continue unless proposed projects and existing problem sites are carefully evaluated and mitigated from a slope stability and potential sediment production perspective. Since timber harvesting and other land use can cause disturbances that may contribute to slope instability, management on slopes with high levels of relative landslide potential should first involve a risk assessment, mitigated appropriately to non-significant erosion potential, or be avoided.

A considerable amount of restoration work has been done on the watershed, on both the public parklands and private lands. Road removal and stabilization and improvement of existing roads and stream crossings, and improving fish passage have been a major focus of this work. Working together, the major landowners on the Redwood Creek Basin recently have completed assessment work to identify erosion related problems with the roads throughout the watershed. The landowners are now working to implement the road improvement recommendations produced through the road assessments.

General trends in the watershed are toward the improvement of a number of the factors that currently are limiting salmonids. Recovery appears to be occurring in terms of declining sediment in most channels and increasing tree growth in riparian areas. Still, expected impacts from another large flood event are viewed with uncertainty. However, if stream and riparian habitats continue to move towards pre disturbance conditions, anadromous salmonid populations will likely respond by increasing in numbers and distribution across the watershed. Although coho salmon and summer steelhead populations have the greatest challenges ahead due to their low abundance in the basin and specific habitat requirements. Poor habitat conditions of the estuary/lagoon will likely impede juvenile Chinook survival until major actions are taken to restore historic ecosystem processes in the Redwood Creek estuary/lagoon.

The potential for anadromous salmonid populations to increase in abundance and distribution throughout the basin should increase by implementing watershed management strategies that reduce excessive sediment inputs, retain and encourage growth of near stream forests and their function in the aquatic ecosystem, and improve instream and estuarine habitats. The likelihood that any North Coast basin will react in a responsive manner to management improvements and restoration efforts is a function of existing watershed conditions. In addition, the status of processes influencing watershed condition will affect the success of watershed

improvement activities. A good knowledge base of these current watershed conditions and processes is essential for successful watershed improvement. Acquiring this knowledge requires property access. Access is a requirement to design, implement, monitor, and evaluate suitable improvement projects. Thus, systematic improvement project development is dependent upon the cooperative attitude of resource agencies, watershed groups and individuals, and landowners and managers.

The Redwood Creek assessment has considered a great deal of available information regarding watershed conditions and processes in the basin. This long assessment process has identified problems and made recommendations to address them while considering the advantages and challenges of conducting watershed improvement programs. After considering these problems, recommendations, advantages and challenges, the Redwood Creek Basin is an excellent candidate for a successful long-term, programmatic watershed improvement effort. According to the current refugia analysis, the Prairie Creek watershed contains high quality fishery refugia. Other subbasins have a high potential to improve. Reaching that goal is dependent upon the formation of a well organized and thoughtful improvement program founded on broad based community support for the effort.

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Attachment 1. Anadromous salmonid species found in Redwood Creek and its tributaries. (Adapted from Brown 1988).

Subbasin	Streams	Steelhead	Cutthroat	Chinook	Coho
Estuary Subbasin	Redwood Creek	x	x	x	x
	Strawberry Creek	x	x		x
Prairie Creek Subbasin	Prairie Creek	x	x	x	x
	Skunk Cabbage Creek	x	x		x
	Little Lost Man Creek	x	x	x	x
	Lost Man Creek	x	x	x	x
	Streelow Creek	x	x		x
	May Creek	x	x		x
	Godwood Creek	x	x	x	x
	Boyes Creek	x	x	x	x
	Brown Creek	x	x	x	x
Lower Subbasin	Hayes Creek	x	x		
	McArthur Creek	x	x		x
	Elam Creek	x	x		
	Bond Creek	x	x		
	Cloquet Creek	x	x		
	Miller Creek	x			
	Forty Four Creek	x	x		
	Tom McDonald Creek	x	x	x	x
	Harry Wier (Emerald) Creek	x	x		x
	Bridge Creek	x	x	x	x
	Dolason Creek	x			
	Copper Creek	x			
	Devils Creek	x			
	Redwood Creek	x	x	x	x
Middle Subbasin	Coyote Creek	x	x		x
	Panther Creek	x	x		x
	Garrett Creek	x			
	Lacks Creek	x	x	x	x
	Karen Creek	x			x
	Roaring Gulch	x			

	Garcia Creek	x			
	Cashmere Creek	x			
	Beaver Creek	x			
	Pilchuck Creek	x			x
	Mill Creek	x			
	Molasses Creek	x			
	Toss-up Creek	x			
	Wiregrass Creek	x			
	Minor Creek	x		x	x
	Loin Creek	x			
	Santa Fe Creek	x			
	Sweathouse Creek	x			
	Captain Creek	x			
	Lupton Creek	x			
	Redwood Creek	x	x	x	x
Upper Subbasin	Windy Creek	x			
	Jena Creek	x			
	Noisy Creek	x			
	Squirrel Trail Creek	x			
	Emmy Lou Creek	x			
	Cut-off Meander	x			
	Six Rivers Creek	x			
	Gunrack Creek	x			
	Simion Creek	x			
	High Prairie Creek	x	x		
	Minon Creek	x			
	Lake Prairie Creek	x			
	Upper Panther/Bradford Creek	x			
	Pardee Creek	x			
	Snowcamp/Smokehouse/ Twin Lakes	x			
	Redwood Creek	x	x	x	x