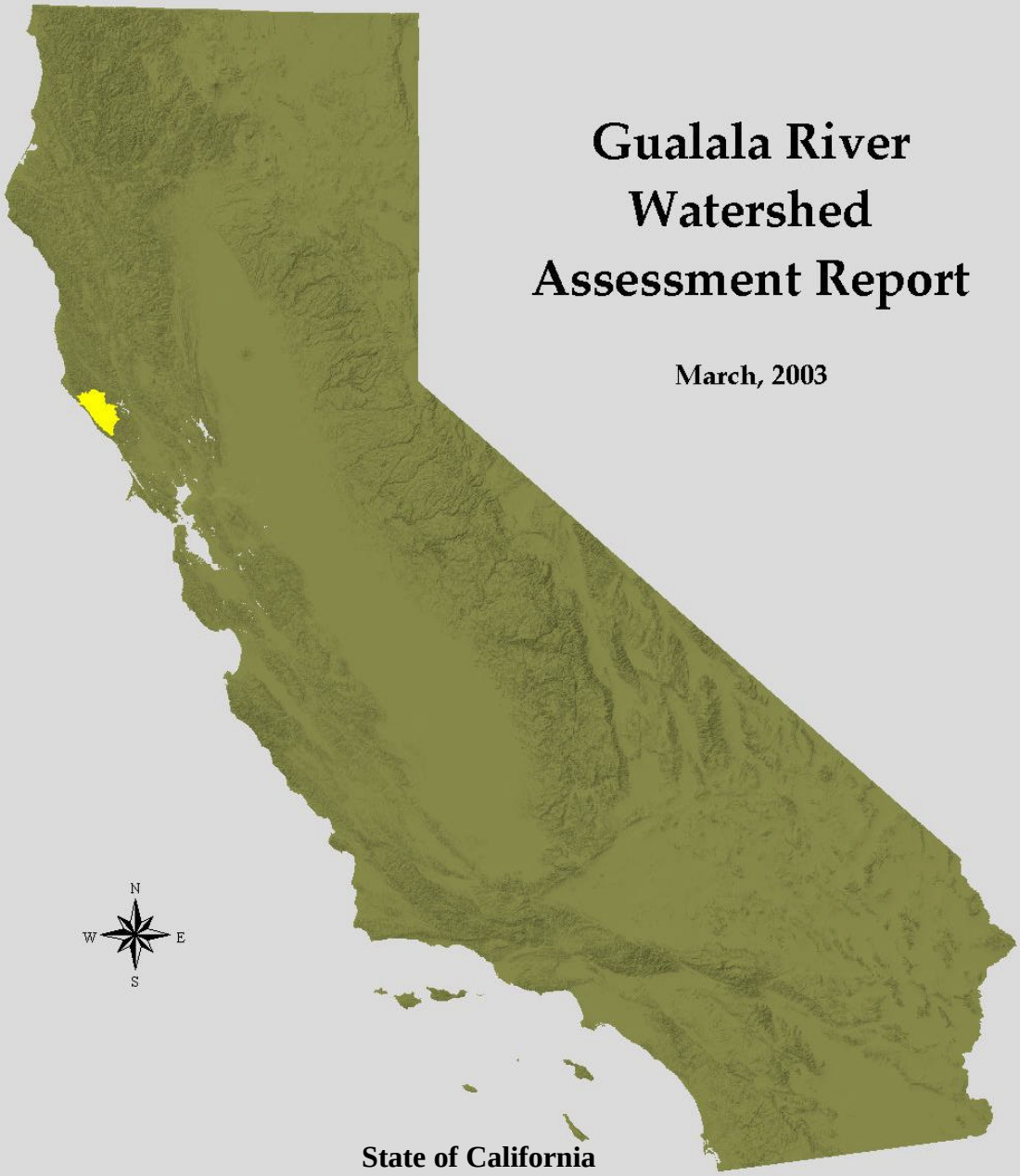
North Coast Watershed Assessment Program



Gualala River Watershed Assessment Report

March, 2003

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California Environmental Protection Agency
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NCWAP Reports

NCWAP's main products are basin level assessment reports for each subject watershed. These reports consist of an integrative synthesis report and a number of discipline oriented appendices. A limited number of these synthesis reports and appendices were produced in printed media for program cooperators, stakeholder groups, and program partners. Printed reports were also distributed to most major libraries. Printed documents are not currently available to the public; however the entire synthesis report document, including appendices and maps, is available on a compact disk (CD) in PDF format or via the NCWAP website www.ncwatershed.ca.gov. The NCWAP watershed assessment reports are currently available for the Gualala River, Mattole River, and Redwood Creek watersheds. Other reports will become available over time. CDs containing the reports, appendices, and maps may be requested from:

California Department of Fish and Game
Wildlife and Habitat Data Analysis Branch
1807 13th Street, Suite 202
Sacramento, CA 95814
(916) 324-9265

Klamath Resource Information System CDs and Website

The Institute for Fisheries Resources (IFR) has produced Klamath Resource Information System (KRIS) projects for six North Coast watersheds. KRIS is a custom software program capable of managing watershed datasets, tables, charts, photos and maps. There are currently KRIS products for the Noyo, Big, Ten Mile, Gualala, and Mattole rivers, and Redwood Creek; they are available via the IFR website (www.krisweb.com). These products may also be requested on Compact Disc from:

Department of Forestry and Fire Protection
Fire and Resource Assessment Program
1920 20th Street
Sacramento, CA 95815
(916) 227-2651
frap@fire.ca.gov

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Executive Summary

Gualala River Watershed Assessment

North Coast Watershed Assessment Program

The North Coast Watershed Assessment Program (NCWAP) is an interagency effort between the California Resources Agency and the California Environmental Protection Agency (CalEPA), established to provide a consistent body of information on North Coast watersheds for use by landowners, stakeholders, and collaborative watershed groups. The program's work is intended to provide answers to the following assessment questions at the basin and subbasin scales in California's North Coast watersheds:

- What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?
- What are the current salmonid habitat conditions? How do these conditions compare to desired conditions?
- What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?
- How has land use affected these natural processes?
- Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead trout production?
- 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 watershed assessments met these strategic program goals:

- Organize and provide existing information and develop limited 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. This will help guide support programs, like CDFG's Fishery Restoration Grants Program, toward those watersheds and project types that can efficiently and effectively improve freshwater habitat and lead to improved salmonid populations;
- 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 agencies better implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

The program was established by the California Resources Agency and the California Environmental Protection Agency, and developed by the Departments of Fish and Game (CDFG), Forestry and Fire Protection (CDF), Conservation/California Geological Survey (CGS), Water Resources (DWR), and by the North Coast Regional Water Quality Control Board (NCRWQCB) and State Water Resources Control Board. The Institute for Fisheries Resources (IFR) is also a partner and participant in this program.

Salmonids, Habitat, and Land Use Relationships

There are several factors necessary for the successful completion of an anadromous salmonid's life history. In the freshwater phase of the life history, stream connectivity, stream condition, and riparian function are essential for survival. Stream connectivity describes the absence of barriers to the free instream movement of adult and juvenile salmonids. Stream condition includes several factors: adequate stream flow, suitable water quality, suitable steam temperature, and complex habitat. Adequate instream flow during low flow periods is essential for good summer time stream connectivity, and is necessary to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries. Three important aspects of water quality for anadromous salmonids are water temperature, turbidity, and sediment load. Habitat complexity for salmonids is created by a combination of deep pools, riffles, and flatwater habitat types.

Geology, climate, watershed hydrologic responses, and erosion events interact to shape freshwater salmonid habitats in the Gualala River Watershed. "In the absence of major disturbance, these processes produce small, but virtually continuous changes in variability and diversity against which the manager must judge the modifications produced by nature and human activity. Major disruption of these interactions can drastically alter habitat conditions" (Swanston, 1991). Major watershed disruptions can be caused by catastrophic events, such as the 1955 and 1964 floods. They can also be created over time by multiple small natural and / or human disturbances.

Naiman and others (1992) offer the perspective that "Several aspects of disturbance regimes are important to the functioning of biological communities in mountain watersheds. Unfortunately, knowledge of natural disturbance regimes is limited because of the length of time required for the processes to operate (100-1,000 years) and therefore to be observed by humans, and because recent use has altered the disturbance regimes in ways not fully understood." They go on to conclude, "Therefore, the type, intensity, and frequency of erosional events and their spatial distribution across the landscape are important considerations to understanding the relationships between geomorphic process, form, and ecological functioning of watersheds. The temporal and spatial scales at which these processes occur, however, complicate their study. Our minimal knowledge of natural disturbance regimes limits our understanding of the functioning of ecologically healthy watersheds over long periods and large spatial scales, thus precluding accurate environmental assessments of the long-term effects of land use in watersheds in the coastal ecoregion."

A functional riparian zone helps to control the amount of sunlight reaching the stream, and provides vegetative litter and invertebrate fall. These contribute to the production of food for the aquatic community, including salmonids. Tree roots and other vegetative cover provide stream bank cohesion and buffer impacts from adjacent uplands. Near stream vegetation eventually provides large woody debris and complexity to the stream (Flosi et al. 1998).

A main component of the North Coast Watershed Assessment Program (NCWAP) is the analysis of these stream and watershed factors in order to identify whether any of them are at a level that limits production of anadromous salmonids in North Coast watersheds. A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population. This limiting factors analysis (LFA) provides a means to evaluate the status of key environmental factors that affect anadromous salmonid life history. This information will be useful to identify the underlying causes of stream habitat deficiencies and help reveal if there is a linkage to watershed processes and land use activities.

The Gualala River Watershed

WATERSHED DESCRIPTION

The Gualala River drains 298 square miles along the coast of southern Mendocino and northern Sonoma counties (Figure ES-1). The river enters the Pacific Ocean near the town of Gualala, 114 miles north of San Francisco and 17 miles south of Point Arena. The Gualala River Watershed is elongated, running over 32 miles long in a north/south direction, with an average width of 14 miles. Elevations vary from sea level to 2,602 feet at Gube Mountain and terrain is most mountainous in the northern and eastern parts of the watershed. A long history of movement along the San Andreas Fault and the Tombs Creek Fault has been a dominant force in shaping of the watershed.

The climate is influenced by fog near the coast with seasonal temperatures ranging from 40 to 60 degrees Fahrenheit (F), and the interior areas of the watershed ranging from below freezing to over 90 F.

A rainfall/runoff hydrology predominates in the Gualala River Watershed, with minimal snow accumulation. Detention time and time of concentration of rainfall are reduced by steep slopes and high rainfall amounts, causing stream levels to rise quickly in response to rainfall. Alterations of the landscape can change the hydrologic curves, flood frequencies and peaks within the subbasins of the Gualala River Watershed. However, affects on unit discharge hydrographs due to changes in land use or geomorphology within the watershed can not be directly assessed with existing data. Precipitation in the watershed is highly seasonal, most precipitation occurring October through April. Average annual precipitation ranges from 33 inches at the lower elevations near the Pacific Ocean to 63 inches at the higher elevations in the southeastern upper watershed. Coastal conifer forests of redwood and Douglas fir occupy the northwestern, southwestern and central portions of the watershed, while oak-woodland and grassland cover many slopes in the interior. Coho salmon naturally inhabited the streams flowing from coniferous forest, but were likely sub-dominant to steelhead trout in interior areas due to the more open nature of the channels, less suitable habitat, and naturally warmer stream temperatures. The interior is largely grassland with scattered oaks. Surface waters in this area generally lack shade and are warmed with abundant sunshine and warmer air temperatures.

Current fish species include coho (silver) salmon (H. Alden, pers. comm. 2002, CDFG unpub. 2002), steelhead trout, pacific lamprey, roach, coastrange sculpin, prickly sculpin, riffle sculpin (R. Kaye, pers. comm. 2002) and three-spine stickleback. Above impassable barriers, resident populations of rainbow trout exist (Cox 1989). Species inhabiting the coastal lagoon/estuary include starry flounder, staghorn sculpin (Brown 1986) and Pacific herring (R. Kaye, pers. comm. 2002).

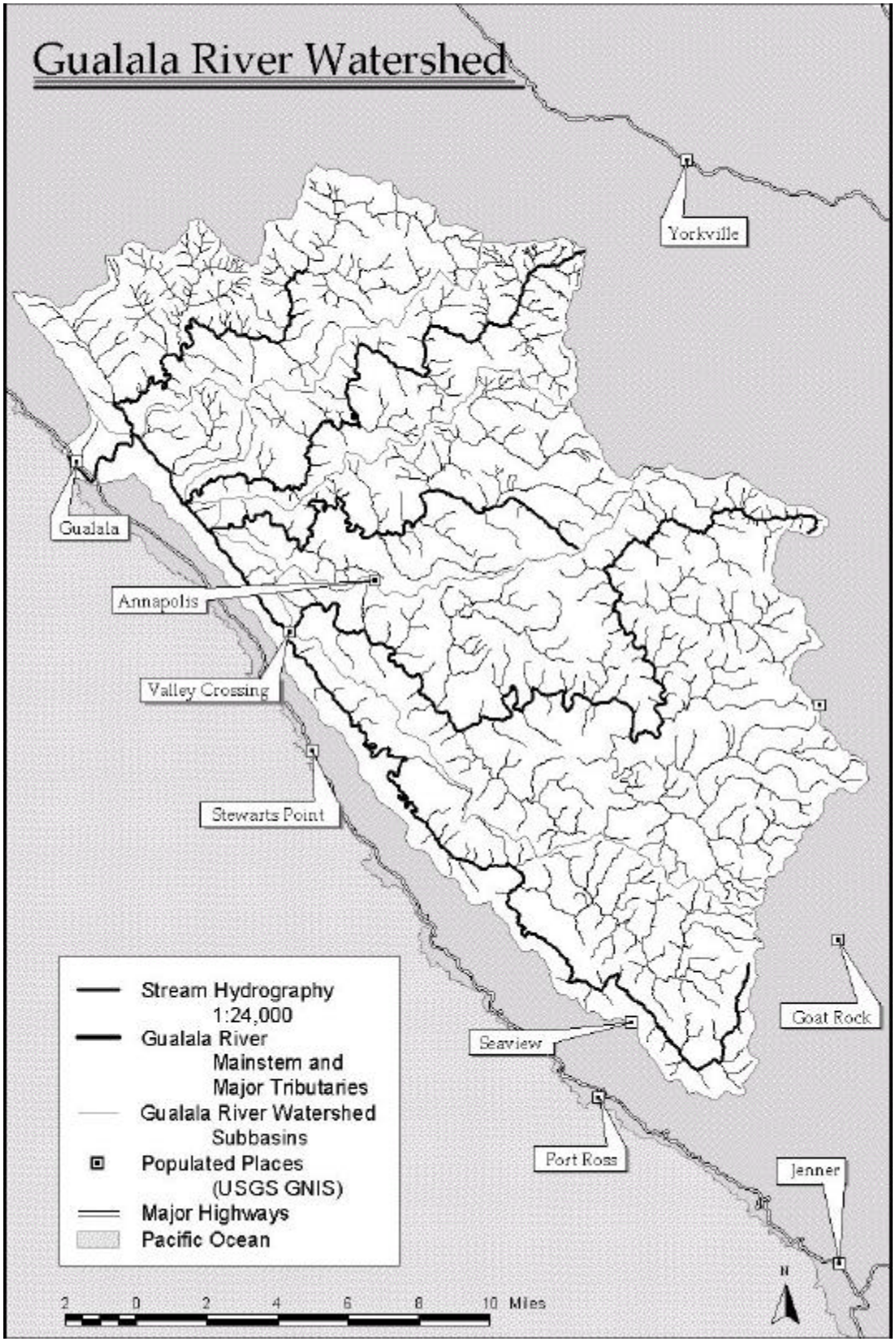


Figure ES-1
Gualala River Watershed Streams and Towns

Historic anecdotal accounts cite eulachon in the estuary and Sacramento sucker in the mainstems of both Buckeye Creek and the Wheatfield Fork (Higgins 1997). Snyder (1907) did not observe Sacramento suckers on the Wheatfield Fork. Juvenile Chinook (king) salmon specimens were caught prior to 1945, indicating that they were present at that time (D. Fong pers. comm.). It is unknown if eulachon, Sacramento sucker or Chinook salmon inhabit the watershed today.

Salmonid population data is limited for the watershed. Limited fish surveys combined with anecdotal evidence suggests that coho salmon and steelhead trout populations were large and experienced a decline prior to the 1960s. After World War II ended in 1945, the Gualala River became a popular place to fish for coho salmon, steelhead trout, and possibly chinook salmon, based on the 200-300 percent increase in fishing pressure (Taft 1946). The increased fishing pressure indicated that the coho salmon and steelhead trout populations were large in the 1940s. Length frequencies of fish captured in 1952 electrofishing in the North Fork showed a healthy condition (Kimsey 1952). Bruer (1953) wrote that there were millions of young steelhead trout and coho salmon in the Gualala River Watershed.

Fish stocking began in 1969, and over the next 30 years 347,780 hatchery coho salmon were stocked throughout the Gualala River Watershed. Even with the extensive planting, coho salmon had not been consistently observed, except in the North Fork Subbasin. Electrofishing data from 2001 indicated that coho salmon were not detected and possibly may be extirpated from the watershed (Coho Salmon Status Review 2001). In September of 2002, young-of-the-year coho salmon were observed in the North Fork Subbasin during snorkel surveys on Dry Creek, a tributary to the North Fork, and in two sites on the Little North Fork and Doty Creek during electrofishing surveys.

Although accurate coho salmon population estimates were never conducted, stream surveys indicated that the coho salmon population began to decline prior to the 1960s. Stream surveys from 1964 recommended stocking coho salmon to reestablish a viable self-supporting run in streams with pre-existing populations. This stocking indicated a shift from the large, fishable population of the 1940s toward the need to reestablish a viable population in the 1960s, further establishing that the coho salmon population declined during the 1950s. By 1956, adverse logging conditions and past improper practices had done considerable damage to the headwaters (Fisher 1957).

The distribution of coho salmon has changed substantially over the past 32 years in the watershed. Coho salmon were known to inhabit four of the five subbasins, some 10-15 tributaries. Currently, coho young-of-the-year are observed in the North Fork Subbasin only.

Starting in the 1940s and continuing today, steelhead trout have been actively fished on the Gualala River. In 1945, a summer juvenile steelhead trout closure was ordered to protect juvenile salmonids. This closure remained in effect until 1982. Bruer (1953) stated that the Gualala River was a prime steelhead trout and coho salmon stream and should be used to provide recreation for hundreds of anglers. By 1956, the Gualala River continued to sustain a good steelhead trout population despite the damage to the headwaters. Fishing pressure continued to increase through the early 1970s. In spite of the increased pressure, the steelhead trout catch was less than in the 1950s, probably due to smaller steelhead trout populations. During the 1970s, CDFG efforts focused on a program to enhance sport fishing, and began planting steelhead trout in 1970. By 1990, 426,290 had been planted.

Steelhead trout young-of-the-year and older were observed in all ten of the tributaries electrofished in September 2001. During the 2001 fishing season, local angler and long time Gualala CDFG Warden Ken Hofer reported that the steelhead trout run was the largest seen in over seven years.

The steelhead trout distribution does not appear to have changed over the past 37 years. This conclusion is based on comparison between stream surveys from 1964 and 1970, and the habitat inventory and electrofishing surveys of 2001. No data exist to confirm the steelhead trout distribution prior to the mid 1950s-60s logging era. Slash and log jams located in both tributaries and headwater areas were well documented in the 1964 and 1970 stream surveys. This logging debris caused barriers to fish passage and may have reduced steelhead trout distribution from its potential pre-logging range.

The Gualala River Watershed Council (GRWC), in collaboration with local landowners, has obtained funding to conduct stream surveys, road assessment and restoration, revegetation, instream habitat improvement, public education, and monitoring. Data on water temperatures, large woody debris, and other characteristics from the GRWC and other cooperators were helpful in this assessment.

GENERAL GUALALA RIVER WATERSHED ISSUES

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala residents and constituents. **The following general concerns were expressed as potential factors affecting the Gualala River Watershed and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.**

- Filling of the estuary since the turn of the century due to sediment from logging
- The extent to which the estuary functions in sustaining salmonids, and what factors may be limiting its functions
- Excessive extraction of water during low flow periods, including the recent proposal to extract large volumes of wintertime flows and transport the water to Southern California
- Abandoned roads, new road construction, and road maintenance issues related to landsliding and sediment input
- High water temperatures and low shade canopy density, as well as the density and diversity of the riparian zone
- Herbicides used on industrial timberlands and agricultural operations
- Location and conduct of timber harvest operations
- Best management practices required by current forest practice rules are reducing forestry impacts to insignificance
- Sub-division construction, grazing, feral pigs, and land use conversions
- Current logging practices on steep unstable slopes and near streams, especially regarding contributions of sediment to an already impaired system
- Sediment as a limiting factor for salmonids due to pool filling, aggradation, and small-sized spawning substrate
- Reduced instream large wood and limited large woody debris recruitment potential from past stream clearance projects and tree removal
- Absence of salmonid information, low fish densities, or absences of fish

- Impacts of invasive and exotic plants and wildlife on the watershed conditions; Pampas grass was mentioned as one of the prominent problem species.

General Assessment Methods

The NCWAP assessment is a science and history based assessment of watershed conditions. The assembled data were used to document current conditions and to infer trends and relationships between processes and conditions where possible. Establishing scientific certainty or proof of cause and effect was more limited due to fragmentary background data. While this limited our comparisons with recent data, collected under new methods and standards, this report provides a substantial body of pertinent information and conclusions. Current conditions were assessed to the extent possible with the resources available, using current standards of sampling, interpretation, and quality control. The synthesis of information resulted in the interpretation of current conditions and trends derived from aerial photos, satellite images, and field data. An Ecological Management Decision Support (EMDS) knowledge base was developed to identify relationships and to map the distribution of conditions suitable for salmonids. A logical outcome of the synthesis was the identification of limiting factors and subsequent management and instream recommendations for watershed protection and improvement.

METHODS

Each of NCWAP's participating departments developed data collection and analysis methods used in the assessments. They also developed a number of tools for interdisciplinary synthesis of the collected information. These include models, maps, and matrices for integrating information on basin, subbasin, and stream reach scales to explore linkages among watershed processes, conditions and use. These tools provided a framework for identifying watershed refugia areas and factors limiting salmonid productivity, as well as understanding the potential for cumulative impacts from natural and man caused impacts. This information provided the basis for developing restoration, management and conservation recommendations.

The Gualala NCWAP Team considered concerns and questions raised in scoping sessions with watershed residents, landowners, interested stakeholder groups, agencies, and other scientists. They then compiled existing information and data, and identified data gaps to focus additional data collection. This report describes data collection and analysis methods used by each of NCWAP's participating departments, and for identifying limiting factors for salmonids.

The CDFG identified the need for habitat inventories for the Gualala River Watershed. CDFG biologists used the standard channel, stream, and biological sampling methods contained within the CDFG's California Salmonid Stream Habitat Restoration Manual (Floss, et al. 1998) to survey over 100 miles of streams in the watershed in 2001. Prior to the NCWAP effort only 15 miles of habitat inventory survey existed. Electrofishing surveys occurred in conjunction with the habitat inventories. This data lead to the development of the limiting factor analysis, refugia identification, and EMDS Model stream Reach Model. CDFG, CDF and CGS co-developed a map of potential restoration sites.

While descriptive narratives about the land use history of the watershed existed, little of that was both site specific and quantitative in nature. CDF mapping included: 1) historical road networks (1945 – 1968) to compare with maps of current roads, 2) riparian canopy cover changes over time, and 3) timberstand and rangeland change detections as a function of area.

Evaluating the geology, relative slope stability and fluvial geomorphic characteristics within the Gualala River Watershed was a critical element in the assessment of current watershed conditions, the relative impact of past land-use practices (turn of the 20th century, mid-20th-century, and recent past of 1991-2001), and development of recommendations for further work to improve aquatic habitat conditions. The Department of Conservation/ California Geological Survey (CGS) updated existing landslide maps, provided new landslide maps where they did not currently exist, and provided stream channel geomorphic maps for the watershed. That effort was geared toward providing essential baseline geologic data to aid in the development of watershed restoration projects, watershed management strategies, and watershed plans. CGS produced a map of potential restoration sites with the data and recommendations from CDF and DFG.

The Regional Water Board assessment included comparison of recently collected and past available water quality information comprised predominately of a water temperature data set, some limited water chemistry data, and some limited sediment data. Those data were compared to the Water Quality Control Plan water quality objectives, and thresholds from the literature. Stream substrate core sample results were compared to targets from the Gualala River Watershed Technical Support Document for the Board's Total Maximum Daily Load program (TMDL).

Data and metrics from permanent stream monitoring reaches collected over the last five years by Gualala Redwoods, Inc and the GRWC were evaluated. This included results from continuous temperature measurements, thalweg surveys, pebble counts, canopy cover measurements, large woody debris inventories, macroinvertebrate sampling, riparian condition, stream cross sections, snorkel surveys and photo records.

The California Department of Water Resources conducted a hydrologic assessment of the Gualala River Watershed, which included climate and precipitation, stream flow, and stream flow diversion information. In addition, three stream flow gages were installed in the major branches of the river network.

The results of the assessments conducted by the various department personnel on the Gualala Team were brought together in an integrated synthesis process. This process attempts to describe the spatial and temporal relationships between the watershed and stream conditions and the dynamic watershed processes that have been at work to form them. To assist in this process, the team used GIS based watershed data coverages and an Ecological Management Decision Support (EMDS) model to help evaluate watershed conditions and processes.

SCALE OF INFORMATION

NCWAP's Gualala Team sub-divided the Gualala River Watershed into five subbasins for assessment purposes: North Fork, Rockpile, Buckeye, Wheatfield Fork, and the Gualala Mainstem/South Fork (Figure ES-2). Each subbasin has somewhat unique attributes that are generally common to the several CalWater 2.2a Planning Watersheds (PWS) contained within each subbasin. These PWS are approximately 3,000-10,000 acres and are used as planning and evaluation units for projects such as Timber Harvesting Plans submitted to CDF. These common subbasin attributes pertain to its geology, vegetation, climate, land use, streams, fisheries, towns and communities, access corridors, etc. The reader will encounter the term "blue line streams," which refers to those streams identified on standard U.S. Geologic Survey (USGS) topographic maps as solid blue lines.

Figure ES-2
The Gualala River Watershed with NCWAP subbasins and Calwater 2.2a Planning Watersheds.

Subbasins and their planning watersheds are used as the basis of the format of the assessment report. They also are used as the basis for display of the Ecological Management Decision Support system GIS images, geologic and landslide maps, landslide potential maps, potential restoration sites maps, and tabular data.

Assessment Products

The assessment is intended to be useful to landowners, residents, watershed groups, agencies, and individuals to help guide restoration, land use, and management decisions, and to direct further studies. The report includes descriptions of historical and current vegetation cover and change, land use, geology and geomorphology, water quality, water temperature, stream flow, water use, and instream habitat conditions. The compilation of existing data, collection of new data, and synthesis of those data provided the following products:

- New California Geological Survey (CGS) maps of landslides, relative landslide potential, and instream sediment features at a 1:24,000 scale for the entire Gualala River Watershed. Mapping was conducted from 1984 and 1999/200 aerial photo sets.
- New California Department of Fish and Game (CDFG) habitat inventory surveys and fish presence data for large portions of the major tributaries in the watershed (101.1 miles).
- New CDFG electrofishing presence/not detected status of coho salmon and steelhead trout.
- Historical fisheries data for some areas in the Gualala River Watershed.
- New CDFG table of Limiting Factors Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 1999 and 2001, and EMDS Stream Reach Scores in the Gualala River Watershed, California.
- New CDFG table of Potential Salmonid Refugia Based Upon Habitat Inventory Surveys, EMDS Stream Reach, professional judgment, and local expertise in the Gualala River Watershed, California.
- New California Department of Forestry and Fire Protection (CDF) mapping of historical and current land use patterns across the Gualala River Watershed.
- New CDF description of historical land use in the Gualala River Watershed.
- Data excerpted from the North Coast Regional Water Quality Control Board (NCRWQCB) TMDL study and other water quality studies of the Gualala River.
- Various data provided by cooperative landowners and the Gualala River Watershed Council in the Gualala River Watershed.
- A hydrologic report for the Gualala River Watershed prepared by the Department of Water Resources.
- New CGS, CDF, and CDFG map of Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed (Plate 3).
- New CDFG table of Priorities for Restoration for the Gualala River tributaries.
- Recommendations for management and restoration.
- Recommendations for additional monitoring.

- Ecological Management Decision Support system (EMDS) models to help analyze data.
- Databases of information used and collected.
- A data catalogue and bibliography.
- Web based access to the Program's products: http://ncwatershed.ca.gov.
- A CD under development through the Institute for Fisheries Resources (IFR) which uses the Klamath Resource Information System (KRIS) to present and describe selected assessment information.

General Assessment Questions, Conclusions, and Recommendations

The NCWAP Gualala Team utilized the six NCWAP assessment questions presented in the program description at the beginning of this summary to organize conclusions and recommendations. Discussion of this Team's findings and recommendations for improvement activities specific to subbasins, streams, stream reaches, and in some cases potential project sites are included in each subbasin section of this report. The Appendices to this report contain even more specific assessment methods, findings, conclusions, and recommendations for stream and watershed improvements.

Summary information is presented below, first for the Gualala River Watershed as a whole, then by individual subbasin. A summary table of conditions and recommended actions is provided as Table ES-1 at the end of this Executive Summary.

Watershed-Wide Findings, Conclusions, and Recommendations

What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations in the Gualala River Watershed?

Salmonid population data are limited for the Gualala River Watershed. Limited fish surveys combined with anecdotal evidence suggest that coho salmon and steelhead trout populations on the Gualala River were large and experienced a decline prior to the 1960s. Thirty years of extensive planting of coho salmon occurred in an attempt to reestablish a viable population. In 2001, the Coho Salmon Status Report did not find coho salmon in their historical streams, and possibly extirpated from the watershed. In September 2002, a few coho salmon young-of-the–year were observed in tributaries of the Little North Fork and North Fork. Insufficient data exist to assess the current steelhead trout population, although it is likely that it also decreased in the 1960s. The steelhead trout distribution does not appear to have changed over the past 37 years.

What are the current salmonid habitat conditions in the Gualala River Watershed? How do these conditions compare to desired conditions?

[Erosion/Sediment] Instream sediment conditions in regards to salmonid habitat in some stream reaches in the watershed are considered unsuitable for salmonids. For example, in the inventoried section of Rockpile Creek pool depth was unsuitable and embeddedness was somewhat unsuitable, and extensive timber harvest between 1952 and 1960 (42 percent of the subbasin) created many streamside roads and landings that contributed sediment to the streams. Most of the Gualala River Watershed has improved from 1984 to 1999/2000, based on aerial photo interpretation of accumulations of sediment that were interpreted as indicative of channel disturbance.

[Instream Habitat] Pool habitat, escape and ambush shelter/cover, and water depth are unsuitable for salmonids in some mainstem and tributary stream reaches in the Gualala River Watershed. Large woody debris function in the channel is low throughout the watershed. Increasing the instream habitat complexity is the top recommendation category for all of the subbasins. The Gualala Mainstem/South Fork Subbasin has roads as a co-recommendation;

[Riparian/Water Temp] Water temperatures are suitable in the smaller tributaries for which we had data. In contrast, mainstem temperatures were in the unsuitable range in most of the subbasins. Canopy density also is limited in some areas of the watershed. Riparian/Water Temperature is a top recommendation category in the Wheatfield Subbasin;

[Gravel/Substrate] Available data from sampled streams suggests that suitable spawning gravel for salmonids is limited in some streams, and abundant in others;

[Other] Salmonid habitat conditions are the best in the North Fork Subbasin. Macroinvertebrate surveys indicate generally good conditions.

What are the relationships of geologic, vegetative, and fluvial processes to natural events and land use history?

The Coast Ranges in general and the Gualala River Watershed in particular are areas of naturally high background levels of landslide activity due to climate, steep slopes, weak rock, high rainfall, seismic shaking, and uplift. Natural disturbances such as large storms, earthquakes, and fires are triggers for episodes of widespread landsliding. Stream sedimentation trends fluctuate with the episodic recurrence of natural disturbances.

The large portions of the river flow along the San Andreas Fault Zone. Damage from the 1906 San Francisco earthquake was reported to include landslides from heavily timbered slopes that entered the river from both sides of the valley.

Certain land use activities have accelerated erosion into the river. Between 1950 and 1970, many timbered areas of the watershed were clearcut. Tractors were operated on steep, erosion prone slopes. Erosion and landsliding during the winters of those years appeared excessive compared to that of similar winters as seen in earlier photos. Widespread erosion of logging roads and landings was noted in aerial photos taken in 1965. CDF reports from that period described logging related erosion. More recent reports show that some of the roads in the watershed are still eroding periodically.

The intensity and the extent of timber harvest are lower in recent decades as compared to the 1950-1970 period. The degree of related erosion also has decreased. Further analysis is needed to determine to what extent recent land use related erosion is either retarding recovery or is detrimental to salmon habitat conditions. Regrowth of the timber stands and riparian areas indicates some degree of recovery throughout the watershed. Between 1984 and 1999/2000, sediment loads as evident from aerial photos have declined substantially, indicating some level of recovery. Specifically this indicates that since 1984, total erosion from upslope areas has not resulted in a net increase of sedimentation within the majority of the tributaries to a degree discernable in 1999/2000 aerial photos.

Future disturbances can variably aid or impede stream channel recovery. This natural variability and uncertainty makes prediction of the effects of current land use speculative. However modified practices and erosion control (such as those recommended in this report) in those areas identified and mapped as geologically unstable can reduce the degree to which land use related erosion may impact stream sedimentation and recovery.

How has land use affected these natural processes?

The Gualala River Watershed has been subject to three eras of intensive land use: 1) old growth redwood harvesting in the lower watershed reaches between 1868 to 1911, 2) tractor harvesting of remaining old growth areas between 1942 to 1968, and 3) cable/tractor harvesting of second growth in the lower watershed coastal reaches between 1991 and 2001. These activities were separated in time and space and have been affected by variable recovery functions.

Major rainstorm events have interacted with natural geologic instabilities and other natural conditions and processes to establish stream conditions. Anadromous salmonids have developed adaptive strategies to cope with this natural variability to a substantial extent. However, land use activities have accelerated natural erosion to varying degrees. Approximately 95 miles of instream/streamside roads simplified the stream channel complexity and structure throughout the watershed between 1952 and 1968. Timber operations and ranchland conversions removed riparian canopy cover, changing streambank exposure from about five percent in 1942 to a range of 40 to 70 percent bank exposure in the Gualala River Watershed by 1968. Most large woody debris was removed during mid-20th-century streamside road construction and stream clearance projects during the 1970s and 1980s.

Heavy rainfall and high river flows during mid-20th-century storm events activated many road debris slides and washed out large sections of streamside roads. Road failures were more pronounced in steep terrain and along streams and historically active landslides. Sediment generated by the mid-20th-century tractor era disturbances would be routed through the river network over a period of decades to centuries. Lower gradient stream reaches have longer residency time of this material. Higher embeddedness and a shallow pool structure can be long-term impacts in lower gradient reaches.

The early logging activities left a legacy of impacts, some of which persist to the present. The mid-20th-century tractor era caused the heaviest impacts. The use of crawler tractors was characterized by large-scale sideslope excavations and skid trail networks. Streamside road building pushed sidecast over the streambank, frequently burying the stream channel. Heavy winter storms during the mid-20th-century period caused channel aggradation, evidenced by temporary channel adjustments such as flow deflection around multiple road debris slides in logged areas.

The mid-20th-century harvests basically defined canopy conditions today. Current riparian canopy generally consists of mid sized 40-year-old second growth coniferous/mixed conifer hardwood stands in the middle to upper reaches. In the oak savanna that overlies the melange of the Franciscan Complex, riparian vegetation has not re-established since logging, probably due to continued grazing, slope instability, and higher air temperatures than in the coastal areas. Overall, watershed-wide riparian shade canopy has improved since the 1960s, but still falls short of the 1942 levels of canopy density and coverage. Large woody debris has not recovered from mid-20th-century removals. However, riparian zones in the western portion have largely recovered from the first round of logging. There are many large trees adjacent to the streams, in most cases providing recruitable large wood for the smaller tributaries.

Channel braiding and/or aggradation patterns spatially associated with the historical instream road network may persist in some of the middle reaches. The current road network shows less overall coincidence of debris slides and stream crossing failures compared to historical times. However, most of the contemporary road failures are in close proximity to streams and steep slopes. Timber Harvest Plan records generally indicate that road failures triggered by storm events represent a portion of contemporary management related sediment pulses in the watershed. The degree to which recent sediment inputs may delay, or possibly reverse channel recovery is not known.

Interpretation of aerial photos points out that stream channel characteristics associated with disturbance from sediment have improved from 1984 to 1999/2000. This period includes recent timber harvesting in the northern portion of the watershed that included new road building. Harvest of coastal redwood and Douglas fir actively occurs today, but with substantially improved practices. While some areas of the watershed experienced more improvement than others during this period, an overall trend towards improvement in the transport reaches was observed. Response reaches were varied. With continued reductions in the amounts of in-channel sediment accumulations, fish habitat values should also improve.

Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead trout production?

Based on the information available for the Gualala River Watershed, salmonid populations are currently being limited by:

- General watershed-wide lack of instream habitat complexity;
- Instream sediment conditions in some areas;
- High summer water temperatures in the mainstems;
- Reduced watershed-wide coho salmon and steelhead trout populations over those observed in the 1960s.

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

A restoration action plan that targets the general areas identified below, and the specific locations identified in the subbasin sections that follow would help create a systematic viable approach. Watershed groups that work with the landowners, such as the Gualala River Watershed Council, may be well suited for this.

Flow and Water Quality Improvement Activities

- Continue stream flow gage maintenance for long-term flow studies.
- Reductions in sediment delivery and deposition, as well as improved riparian canopy density and diversity as presented in recommendations below, should improve water quality conditions for salmonids.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road assessments, storm proofing, improvements, and decommissioning throughout the watershed to reduce sediment delivery to the Gualala River and its tributaries.
- Evaluate and address sediment sources such as bank erosion, road erosion, gullies, road-stream crossing failures, skid trails, and erosion features associated with timber harvest through efforts such as road assessments, storm proofing, improvement, and road decommissioning, etc. Some historically active sediment sites are identified on Plate 3, Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed.

Riparian and Instream Habitat Improvement Activities

- Maintain and enhance existing riparian density and diversity. Where current canopy is inadequate and site conditions are appropriate, initiate tree planting and other vegetation management to hasten the development of denser, more extensive and diverse riparian canopy. The natural large woody debris recruitment process should be enhanced by

developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Artificial regeneration and vegetation management efforts should be targeted in the eastern reaches of the watershed, since riparian canopy has improved during the last 40 years in the lower and middle watershed reaches;

- Land managers should work to add more large organic debris and shelter structures to streams in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. Pool depth and shelter consistently were limiting;
- Ensure that stream reaches with high quality habitat are protected from degradation. The best stream conditions as evaluated by the stream reach EMDS and identified as potential refugia were found in the North Fork and Little North Fork;
- Reduce livestock and feral pig entry into the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone.

Supplemental Fish Rescue and Rearing Activities

- Evaluate fish rescue activities and continue if deemed appropriate.

Education, Research and Monitoring Activities

- Encourage continuation and expansion of the in-channel monitoring using the protocols developed by GRWC.
- Expand the aerial photo interpretation of channel characteristics to include pre-1984 conditions. This will provide a better idea of the trajectory of improving conditions. Ground-truth the aerial photo interpretation of channel characteristics to compare to actual habitat conditions and fine-tune the analytical techniques for trend comparisons.
- Expand continuous temperature monitoring (water and air) into locations in the eastern portion of the watershed to help explain warmer water temperatures in those areas. Conduct canopy density and diversity sampling to enhance the water temperature data and facilitate modeling.

Subbasin Findings, Conclusions, and Recommendations

NORTH FORK SUBBASIN

The most northerly of the five subbasins, the North Fork Subbasin has the steepest topography and broadest tributary valleys. Although the formation of this region created steep slopes, the area is relatively more stable and coherent compared to the rest of the watershed. About 56 percent of the Subbasin has a high to very high potential for landsliding. Major tributaries include the Little North Fork and Robinson, Dry, Stewart and Billings creeks. The land is primarily used for timber production, grazing, small vineyards and rural 40 acre and larger subdivisions. The Subbasin supports populations of steelhead trout, with coho salmon only occasionally observed.

Key Findings:

- Historically the Subbasin supported populations of coho salmon and steelhead trout. Steelhead trout and coho salmon were observed in the Little North Fork and North Fork in 1964. During the 1990s, 45,280 coho salmon were planted on the Little North Fork. The North Fork Subbasin supports populations of steelhead trout and shows some presence of coho salmon. Though information is limited, coho salmon and steelhead trout studies indicate that numbers are

depressed compared to pre-1960s populations. Potential refugia have been identified in the North Fork and Little North Fork.

- Habitat elements in the North Fork Subbasin downstream of Stewart Creek are suitable and salmonids are present.
- Tributary water temperatures were mostly in the suitable ranges, with many deemed as "fully suitable." Water temperatures over the period of record (1994-2001) were in the unsuitable ranges in the mainstem of the North Fork upstream of the confluence with the Little North Fork. It appears that water temperatures in the mainstem are warmer upstream, due in part to higher air temperatures and low canopy density in the grassland/oak woodland areas. As the mainstem flows toward the ocean, water temperatures decrease in response to cooler air temperatures, better canopy density, and tributary inflows.
- The North Fork Subbasin has the highest road density in the watershed. Mid-20th-century roads and landings built in or near the main channel of the North Fork may still be contributing excess sediment. Streamside roads and landings were densely concentrated along Stewart, Dry, Robinson, and Doty Creeks. According to THP records and CDF aerial photo analysis, historical sediment sources still exist in this Subbasin. For example, in McGann Gulch, a large instream landing complex built in the late 1960s more recently failed in the 1990s. However, recent upgrade measures completed after the 1986 and 1996 storms have reduced overall failures.
- Harvesting prior to 1968 removed riparian canopy throughout the middle and upper mainstem North Fork (upstream from the confluence with Dry Creek) and higher tributaries in the Subbasin. Shade canopy has improved based on 1999/2000 aerial photos, but has not recovered to 1936 levels. Canopy density was fully to moderately suitable on six out of the eight streams that were habitat inventoried. The exceptions were Dry and Robinson, which were both somewhat unsuitable.
- Pool depth and shelter are the most limiting factors (rank 1 and 2) for the Subbasin as a whole. Large woody debris is important in pool formation and shelter. Large wood was removed from the streams during the 1950s, 1960s and 1970s in association with timber harvest activities and stream clearance projects to improve fish migration access. Large wood surveys conducted in 1998-2000 in Robinson Creek, Dry Creek, the Little North Fork, and the lower section of the North Fork mainstem as part of the Watershed Cooperative Monitoring Program demonstrated that large wood is deficient in most areas of the Subbasin.
- Thalweg surveys indicate the channels have been stable over the last several years.
- Macroinvertebrate surveys indicate generally good conditions.
- Instream channel characteristics indicative of disturbance (sediment depositions, eroding banks, etc.) decreased by forty percent between the 1984 and 1999/2000 aerial photos, with 29 of 127 miles of blue line stream impacted in 1999/2000.

Key Recommendations:

- Land managers in this Subbasin should be encouraged to add more large organic debris and shelter structures in order to meter sediment inputs, improve channel structure, channel function, habitat complexity, and habitat diversity for salmonids. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream enhancement is the top tributary recommendation.

- Continue efforts such as road erosion proofing, improvements, and decommissioning throughout the Subbasin to reduce sediment delivery to the North Fork and its tributaries. Road sediment inventory and control is second of the top three tributary recommendations. Activities to reduce road-related sediment inputs are suggested for the Little North Fork and tributaries (Doty Creek, Log Cabin Creek, Tributary #1), Robinson Creek, Stewart Creek, McGann Gulch, and the mainstem North Fork.
- At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Bank stabilization is the third priority of tributary recommendations. Bank stabilization is a restoration priority 2 for McGann Gulch, and priority 3 for Log Cabin Creek.
- Evaluate the fish rescue activities and fish holding facilities on Doty Creek to determine if it is causing a migration barrier and/or habitat degradation due to water diversion.
- Maintain and enhance existing riparian cover. Where current canopy density and diversity are inadequate and site conditions are appropriate, initiate tree planting, thinning, and other vegetation management to hasten the development of a denser, more extensive and diverse riparian canopy. Dry Creek, Robinson Creek, the central and higher reaches of the mainstem, and the lower reaches of Bear and Stewart Creeks are high priority areas for riparian improvements.
- Encourage the use of cable or helicopter yarding on steep and unstable slopes to reduce soil compaction, surface disturbance, surface flow interference, and the resultant sediment yield.
- Evaluate the possibility of spreading timber harvesting operations over time and space to avoid concentrated road use by heavy equipment and resultant mobilization of road surface fines into watercourses.
- Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 56 percent of the Subbasin.
- Encourage continuation and expansion of the in-channel monitoring using the protocols developed by GRWC.
- Encourage more habitat inventory surveys and biological surveys of tributaries, as only 81 percent of the Subbasin has been completed.

ROCKPILE SUBBASIN

The Rockpile Subbasin is bounded to the north by the North Fork Subbasin and to the south by the Buckeye Subbasin. It encompasses 35 square miles of private land primarily used for timber production and grazing. This Subbasin is not as steep as the North Fork Subbasin, but with the same zigzag pattern to the main channel. About 60 percent of the Subbasin is in the high and very high landslide potential categories. There are 88 miles of “blue line” streams, and two major tributaries: Red Rock Creek and Horsethief Canyon.

Key Findings:

- No historical fish data were available. Young-of-the-year, one year, and older steelhead trout were observed during habitat inventory surveys in 2001. Gradient is suitable for coho salmon in the mainstem of lower Rockpile up through the Middle Rockpile PWS, although tributaries to lower Rockpile mainly are too steep for the species. High water temperatures and restricted pool depth are likely limiting steelhead trout production.
- Conditions for salmonids generally were unsuitable in the mainstem of Rockpile Creek. The lower 8.5 miles of the 21.8 miles of the mainstem Rockpile Creek were habitat inventoried. Pool

depth, pool shelter, and canopy density were the three most limiting factors. Embeddedness of spawning gravel was rated somewhat suitable.

- A small tributary near the mouth had suitable water temperatures as measured in 1997-1998. Water temperatures were in the unsuitable ranges for summertime rearing of salmonids for the period of record (1994-2001) in the lower 11 miles of the mainstem and in Horsethief Canyon.
- The Rockpile Subbasin has yet to recover from logging practices from the 1950s and 1960s. Those practices resulted in a legacy of poorly sited roads and landings and sediment influxes to the system still observed today. A high density of road debris slides was observed in 1963 and 1981 aerial photos. Many sources may still be contributing excess sediment, especially where channel braiding and/or aggradation are persistent as noted in the mainstem, Red Rock Creek, and Horsethief Canyon.
- The canopy conditions seen today were essentially defined by mid-20th-century logging, and have not recovered to pre-1942 conditions. Current riparian canopy consists of mid-size 40 year old second growth coniferous and mixed conifer/hardwood stands in the middle to upper reaches.
- Large wood, important in metering sediment as well as creating pools and pool complexity, was deficient in the stream, based on data from the Watershed Cooperative Monitoring program and biologist's observations during the habitat inventory survey in 2001.
- Overall levels of channel disturbance as interpreted from aerial photos were less in the Subbasin in 1999/2000 than in 1984. Instream sediment depositions indicative of disturbance occur along 20 of 88 miles of blue line streams, representing a 38 percent reduction from 1984 observations. Most of the reduction occurred in the tributaries, while the lower reaches showed less improvement.

Key Recommendations:

- Land managers in this Subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. Pool shelter is the most limiting factor in Rockpile Creek, the stream surveyed in the Subbasin. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is the first of the top three recommendations.
- Maintain and enhance existing riparian cover. Where current canopy is inadequate and site conditions are appropriate, initiate tree planting and other vegetation management to hasten the development of denser and more extensive riparian canopy. Riparian canopy development is the second priority recommendation. The mainstem, Red Rock Creek and Horsethief Canyon are the primary areas needing attention.
- At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Grazing is an issue in the upper Subbasin. Bank stabilization is the third of the top three recommendations.
- Continue efforts such as road erosion proofing, improvements, and decommissioning throughout the Subbasin to reduce sediment delivery to central Rockpile Creek and Rockpile Creek tributaries. Focus efforts on areas adjacent to the streams, abandoning and vegetating historical streamside roads were feasible. Channel characteristics improved the least in the Middle and Upper Rockpile Creek PWSs.

- Encourage the use of cable or helicopter yarding on steep and unstable slopes to reduce soil compaction, surface disturbance, and resultant sediment yield.
- Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 60 percent of the Subbasin.
- Encourage more stream inventories and biological surveys of tributaries, as only 39 percent of the Subbasin has been completed.
- Encourage continuation and expansion of the in-channel monitoring using the protocols developed by GRWC.

BUCKEYE SUBBASIN

The Buckeye Subbasin is bounded to the north by the Rockpile Subbasin and to the south by the Wheatfield Subbasin. It encompasses 40.3 square miles of private land used primarily for timber production, grazing, and small vineyards. It contains more moderate terrain compared to the North Fork and Rockpile. About 53 percent of the Subbasin falls into the high and very high categories for landslide potential. There are 90 miles of "blue line" streams, and three major tributaries: Flat Ridge, Grasshopper, and Osser creeks.

Key Findings:

- No current salmonid or other fish population data exist, and historical data are very limited. Though data are limited, historically the Subbasin probably supported populations of coho salmon and steelhead trout.
- Conditions for salmonids generally were unsuitable in the mainstem of Buckeye Creek. The lower 9.6 miles of the mainstem were habitat inventoried, and pool depth, shelter, and canopy density were the three most limiting factors. Embeddedness of spawning gravel was rated somewhat suitable.
- Water temperatures for the period of record (1994-2001) in the lower 13.5 miles of the mainstem and in Flat Ridge, Franchini, Grasshopper, and Soda Springs creeks were in the unsuitable ranges for summertime rearing of salmonids. A small tributary near the mouth had suitable temperatures as measured in 1998.
- Most of the middle reaches of the Buckeye Subbasin were clear-cut between 1952 and 1968 and included roads in or along the major tributaries, streams and the mainstem Buckeye. Timber harvesting activities today are much reduced in comparison. Debris flows and debris slides involved roads, and numerous failures occurred along instream and near-stream roads and landings as observed from historical aerial photos. These probably resulted in increased sedimentation in the streams. The Little Creek, Grasshopper, and Flat Ridge Creek PWSs have a high density of streamside roads and landings, a potential for large sediment inputs during storm events.
- Post World War II construction of roads, landings, and skid trails in riparian zones by crawler tractors eliminated overstory shade canopy cover on long sections of Buckeye Creek and tributaries. There was near entire canopy elimination in the Subbasin, with operations concentrated in the late 1950s to 1964. Some shade canopy in the highest tributary reaches was observed in 1999-2000 aerial photos. Several decades will be needed for shade canopy to recover to the 1942 conditions of mostly old growth coniferous cover.

- Review of 1961 and 1963 aerial photos showed riparian areas entirely cleared of vegetation and remnant downed logs. Construction of roads, landings, and skid trails in or adjacent to streams between 1952 and 1968 buried, removed, or dispersed large woody debris in the Subbasin. Field observations confirm low amounts of large woody debris. Although riparian areas are regrowing under current land management practices, dense buffers of conifers large enough to serve as large wood recruitment have not reestablished, except on the alluvial flats in the lower Subbasin.
- Overall levels of channel disturbance as interpreted from aerial photos were less in the Subbasin in 1999/2000 than in 1984. Instream sediment depositions indicative of disturbance occur along 18 of 90 miles of blue line streams, representing a 57 percent reduction from 1984 observations. Most of the reduction occurred in the tributaries, while the response (lower) reaches showed less change.

Key Recommendations:

- Land managers in this Subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. Pool shelter is the most limiting factor in the Buckeye Creek, the stream surveyed in the Subbasin. Instream structure enhancement is the first of the top three recommendations.
- Enhance large woody debris through short and long-term efforts through 1) ongoing large wood placement efforts, and 2) enhancement of the natural large woody debris recruitment process by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques.
- Landowners should develop erosion control plans for decommissioning old roads, maintaining existing roads, and constructing new roads. Decommission and revegetate streamside roads where feasible, focusing on those associated with unsuitable fish habitat conditions such as Little, Franchini, Grasshopper, and Osser creeks.
- Maintain and enhance existing riparian cover. Ensure that adequate streamside protection zones are used on Buckeye Creek to reduce solar radiation and moderate air temperatures, particularly on mainstem and upper tributaries. Retain, plant, and protect trees to achieve denser riparian canopy where current canopy is inadequate, particularly on the mainstem and Francini, Grasshopper and Soda creeks.
- Evaluate the possibility of spreading timber harvesting operations over time and space to avoid concentrated road use by heavy equipment and resultant mobilization of road surface fines into watercourses.
- Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 53 percent of the Subbasin.
- Conduct both instream and hillslope monitoring to determine whether current timber harvest practices are allowing for recovery and protection of the salmonid habitat in the Subbasin. Use GRWC protocols for instream monitoring. Improve baseline information on habitat conditions by conducting inventory surveys in Buckeye Creek major tributaries.
- Expand continuous temperature monitoring efforts into the upper Subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.
- Encourage more habitat inventory surveys and biological surveys of tributaries as only 37 percent of the Buckeye Subbasin has been completed.

WHEATFIELD FORK SUBBASIN

The Wheatfield Fork Subbasin has 246 miles of "blue line" stream in a watershed area of 111.6 square miles in the middle and eastern portion of the Gualala River Watershed. The mélange of the Franciscan Complex predominates in the eastern portion of the Subbasin. About 60 percent of the Subbasin is categorized as high to very high landslide potential. Most of the Subbasin is privately owned (166 acres of federal land), with land uses in timber production, grazing, vineyards, and some rural subdivisions.

Key Findings

- Historically the Subbasin supported populations of coho salmon and steelhead trout. Currently the Subbasin supports populations of steelhead trout. Though information is limited, coho salmon and steelhead trout studies indicate that populations are depressed compared to pre-1960s populations.
- Conditions for salmonids were generally unsuitable in the Wheatfield Fork Subbasin. The lower 22 miles of the mainstem were habitat inventoried, and pool shelter, depth, embeddedness and canopy density were the limiting factors. Embeddedness of spawning gravel varied, ranging from moderately unsuitable to moderately suitable.
- Water temperatures for the period of record (1995-2001) in the lower mainstem Wheatfield Fork and Fuller Creek were in the unsuitable ranges for summertime rearing of salmonids. Moderately to fully suitable temperatures were observed in the tributaries: Annapolis Falls Creek, Crocker Creek, and a small tributary near the mouth for the period 1995-1999. Some evidence of cooling of the mainstem by tributaries was observed in 2001.
- Most of the lower and middle reaches of the Wheatfield Fork Subbasin were clear-cut between 1952 and 1961, with roads in or along the major tributary streams. This left large areas of disturbed ground prone to erosion. Both mid-20th-century and modern aerial photos show numerous debris flows and debris slides involving roads and numerous failures along instream and near-stream roads and landings. Streamside roads and landings were prominent in Tobacco Creek, lower House Creek, central North Fork Wheatfield, and central to higher Tombs Creek. Still-active sediment sources occur in the lower reaches of Haupt Creek and Tobacco Creek. More landslides were observed in Fuller Creek in the 1965 and 1984 aerial photos compared to the 1942 photos, which represented an undisturbed old growth condition.
- Post World War II construction of roads, landings, and skid trails in riparian zones by crawler tractors eliminated overstory shade canopy cover in long sections of the Wheatfield Fork and tributaries. There was near entire canopy elimination along the lower mainstem and main tributaries, especially pronounced during the mid to late 1950s. There is measured improvement in canopy cover since 1968, but it has not recovered to 1942 levels.
- Large wood is lacking in streams in this Subbasin, as reflected in some of the habitat values. Construction of roads, landings, and skid trails in or adjacent to streams between 1952 and 1968 buried, removed, or dispersed LWD. Aerial photos from 1961 and 1965 show riparian areas entirely cleared of vegetation and remnant downed logs in the Fuller Creek, Tobacco, and Annapolis PWSs. The lower Wheatfield lacks volume and pieces of large woody debris (Watershed Cooperative Monitoring Program).
- Overall levels of channel disturbance as interpreted from aerial photos were less in the Subbasin in 1999/2000 than in 1984. Instream sediment depositions indicative of disturbance occur along 56 of 300 miles of blue line streams, representing a 52 percent reduction from 1984 observations. Most of the reduction occurred in the tributaries.

Key Recommendations:

- Maintain and enhance existing riparian cover. Improvement of riparian canopy is a priority 1 restoration recommendation. Ensure that adequate streamside protection zones are used on the Wheatfield Fork and tributaries to reduce solar radiation and moderate air temperatures, particularly on the mainstem and upper tributaries. Retain, plant, and protect trees to achieve denser riparian canopy where current canopy is inadequate, particularly in the Lower Wheatfield SPWS: Fuller, Tobacco, and Haupt Creeks.
- Land managers in the Subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is a restoration priority 2.
- At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Grazing is an issue in the Subbasin. Bank stabilization is the third of the top three recommendations.
- Reduce livestock and feral pig entry into the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone. Improvement of riparian canopy is a priority 1 restoration recommendation, and bank stabilization is a priority 3.
- Decommission and revegetate streamside roads, focusing on those where channel braiding and/ or aggradation are persistent today, such as:
  - the lower reaches of Haupt and Tobacco Creeks,
  - the Lower to middle reaches of Tombs, Wolf, and Elk Creeks, and unnamed tributaries to the mainstem Wheatfield Fork upstream from Tombs Creek,
  - the larger tributary watercourses in the lower reaches of House Creek, and
  - the middle to higher reaches of House, Pepperwood, Danfield and Cedar Creeks.
- Landowners should develop erosion control plans for decommissioning old roads, maintaining existing roads, and constructing new roads. Target road upgrade and repair in the areas identified above.
- Incorporate mitigation elements into Timber Harvest Plans in the timber dominant Lower Wheatfield SPWS to decommission historical streamside roads and upgrade road drainage facilities.
- Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 60 percent of the Subbasin.
- Pursue cost sharing grants organized by the Sotoyome RCD to upgrade roads in the ranching-dominated Walters Ridge and Hedgepeth Lake SPWSs.
- Conduct both instream and hillslope monitoring to determine whether current land use practices are allowing for recovery and protection of the salmonid habitat in the Subbasin. Use GRWC protocols for instream monitoring. Improve baseline information on habitat conditions by conducting inventory surveys in more Wheatfield Fork tributaries.

- Expand continuous temperature monitoring efforts into the upper Subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.
- Encourage more habitat inventory surveys and biological surveys of tributaries, as only 45 percent of the Subbasin has been completed.

GUALALA MAINSTEM/SOUTH FORK SUBBASIN

The Gualala Mainstem/South Fork Subbasin contains 134 miles of "blue line" stream in its 63.7 square mile watershed. The river system originates in the far southern end of the Gualala River Watershed and flows north as an alluvial stream along the San Andreas Fault to meet the North Fork Gualala. From that point to the ocean, the stream is considered the Gualala River mainstem. The upper reaches flow from steeper terrain outside the San Andreas Fault zone. About 50 percent of the Subbasin is categorized as high to very high landslide potential. Nearly all of the Subbasin is privately owned, with 15 acres of federal land and 38 acres of state land. Predominant land uses are timber production, grazing, and small vineyards.

Key Findings:

- The Subbasin historically supported populations of coho salmon and steelhead trout. During the 1970s, 105,000 coho salmon and 83,320 steelhead trout were planted in the Subbasin. The Subbasin supports populations of steelhead trout, but coho salmon have not been observed recently where very limited electrofishing was conducted. Information is limited, but coho salmon and steelhead trout studies indicate that populations are depressed compared to pre-1960s populations.
- Habitat inventories were difficult to obtain on the South Fork due to access problems. Camper, Carson, McKenzie and Wild Hog creeks were inventoried in 1999, and Palmer Canyon Creek and parts of Marshall Creek and the upper South Fork were inventoried in 2001. Pool shelter and depth were unsuitable in the areas inventoried. Pool shelter, depth, and embeddedness were the three most limiting factors in the Subbasin.
- Moderately to fully suitable water temperatures for the period of record (1994-2001) were observed in McKenzie Creek in the upper Subbasin, and Little and Big Pepperwood Creeks and Groshong Gulch in the lower Subbasin. Water temperatures were in the unsuitable ranges for summertime rearing of salmonids in Palmer Canyon Creek and the South Fork.
- Most of the higher and eastern reaches of the South Fork Subbasin were clear-cut and roaded between 1952 and 1961 in or along the major tributary streams. This left large areas of disturbed ground prone to erosion and mass wasting. Numerous debris flows and debris slides involved roads, and numerous failures occurred along instream and near-stream roads and landings during large storm events as observed in 1961 and 1965 aerial photos. Most of those roads and landings are concentrated in the McKenzie, Palmer Canyon, and Marshall Creek watersheds.
- Timber harvest operations and road building in riparian zones shortly after WW II eliminated overstory shade canopy in large areas of the headwaters: the mainstem South Fork upstream of the Marshall Creek confluence, Wild Hog and Palmer Canyon creeks, and the central and upper reaches of the McKenzie Creek watershed. Prolonged ranchland operations prevented timely reestablishment of vegetative cover over streams. Overstory shade canopy has improved since 1968 on approximately 25 percent of the stream areas, most notably in the upper Subbasin. The mainstem South Fork down stream of the Marshall Creek confluence was clearcut around 1900,

and has had two or three selection harvests in the 1980s and 1990s. The riparian zone is dominated by large second growth, some of suitable size to function as LWD.

- Large wood recruitment was limited by streamside road construction, timber harvesting, and salmonid migration barrier removal programs. The reduction of LWD likely reduces pool formation, pool complexity, and sediment storage in the tributaries. Approximately 15 miles of historical logging roads that were built in or along the streambed simplified pool structure and complexity throughout the Marshall and McKenzie Creeks, and the upper mainstem tributaries. Large wood surveys conducted in 1998-2001 at one site on Pepperwood Creek (a tributary to the lower South Fork) and two sites in the lower South Fork as part of the Watershed Cooperative Monitoring Program identified the lack of large woody debris.
- Overall levels of channel disturbance as interpreted from aerial photos were less in the Subbasin in 1999/2000 than in 1984. Instream sediment depositions indicative of disturbance occur along 33 of 140 miles of blue line streams, representing a 42 percent reduction from 1984 observations. Most of the reduction occurred in the tributaries. Similar degrees of streambed aggradation were observed in aerial photos from1942 and 1999/2000. Gravel mining records indicate that the lower South Fork may have down cut between 1921 to 1993, suggesting sediment transport exceeding supply in the lower reaches.

Key Recommendations:

- Land managers in the Subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is a restoration priority 1.
- Decommission and revegetate streamside roads, focusing on those where channel braiding and/or aggradation are persistent today, such as the central and upper reaches of McKenzie Creek, and the lower reaches of Marshall Creek including Palmer Canyon and Wild Hog Creeks. Road repair and removal is a restoration priority 3.
- Incorporate mitigation elements into Timber Harvest Plans for decommissioning legacy streamside roads and upgrading road drainage facilities in the timber-dominant lower Subbasin, including Little and Big Pepperwood Creeks.
- Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 50 percent of the Subbasin.
- Maintain and enhance existing riparian cover. Improvement of riparian canopy is a priority 3 restoration recommendation. Ensure that adequate streamside protection zones are used to reduce solar radiation and moderate air temperatures. Retain, plant, and protect trees to achieve denser riparian canopy where current canopy is inadequate, particularly in the Upper South Fork and its tributaries, McKenzie, Wild Hog, and Palmer Canyon creeks.
- Reduce livestock and feral pig entry into the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone.
- Consider migration barrier removal in Palmer Canyon and McKenzie Creeks.
- At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Grazing is an issue in the Subbasin. Bank stabilization is the third of the top three recommendations.

- Conduct both instream and hillslope monitoring to determine whether current land use practices are allowing for recovery and protection of the salmonid habitat in the Subbasin. Use GRWC protocols for instream monitoring. Improve baseline information on habitat conditions by conducting inventory surveys in the South Fork and major tributaries upstream of the confluence with the Wheatfield Fork.
- Expand continuous temperature monitoring efforts into the upper Subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.
- Encourage more habitat inventory surveys and biological surveys of tributaries as only 31 percent of the Subbasin has been completed.

Table ES-1

Summary of Gualala River Watershed Conditions and Recommended Actions by Subbasins Based Largely on Habitat Inventory Surveys

Note that the following designations are based largely on habitat inventory data, which does not include entire subbasin stream systems. Consequently, the designations below are applicable only to the sections of stream that were inventoried. Refer to the subbasin information for more detail, pages 12-19.

	North Fork Subbasin	Rockpile Subbasin	Buckeye Subbasin	Wheatfield Fork Subbasin	Main/South Fork Subbasin
Identified Conditions					
Flow	~	~	~	~	~
Fish Passage Barriers	~ (+/-) [a]	+	+	+	–
Water Temperature	~ (+/-)[a]	–	–	–	~ (+/-) [a]
Canopy Cover	r	r	r		
Instream Sediment	~/R	~/R	~/R	~/R	R
Natural Sediment Sources	~	–	–	~	~
Management-Related Sediment Sources	~	–	–	~	~
Pools	–	–	–	–	–
Escape Cover	–	–	–	–	–
Recommendations					
Flow	#	#	#	#	#
Erosion/Sediment	X	X	X	X	X
Riparian/Water Temperature	X	X	X	X	X
Instream Habitat	X	X	X	X	X
Gravel/Substrate					
Other	†			*	*/†

+ condition is favorable for anadromous salmonids
- condition is not favorable for anadromous salmonids
~ condition is mixed or indeterminate for anadromous salmonids
R trend indicates improved conditions 1984-2000
r trend indicates improved condition 1964-2001
X recommendation applies
recommendation may apply, but needs more study
* there is evidence that stock and/or feral pigs are impacting the stream or riparian area, and exclusion should be considered
† there are barriers to fish migration in the stream
a ~ (+/-) both suitable and unsuitable areas were identified.

Chapter 1

Program Introduction and Overview

North Coast Watershed Assessment Program (NCWAP) for Salmon Recovery and Watershed Protection

The North Coast Watershed Assessment Program (NCWAP) is an interagency effort between the California Resources Agency and the California Environmental Protection Agency (CalEPA), established to provide scientifically credible, interdisciplinary assessments that will facilitate watershed management and restoration, recovery of threatened and endangered salmonid species, and protection of water quality. It is designed to provide a consistent body of information for use by landowners, stakeholders, and collaborative watershed groups.

The program was developed by a team of managers and technical staff from the California Resources Agency, California Department of Fish and Game (CDFG), California Department of Forestry and Fire Protection (CDF), California Department of Conservation/California Geological Survey (DOC/CGS), California Department of Water Resources (DWR), and the North Coast Regional Water Quality Control Board (NCRWQCB) of the State Water Resources Control Board (SWRCB). The Institute for Fisheries Resources (IFR) also is a partner and participant in this program.

Its goals are to:

1. Organize and provide existing information and develop limited baseline data to help evaluate the effectiveness of various resource protection programs over time.

2. Provide assessment information to help focus watershed improvement programs, and assist landowners, local watershed groups, and individuals to develop successful projects. This will help guide support programs, like CDFG's Fishery Restoration Grants Program, toward those watersheds and project types that can efficiently and effectively improve freshwater habitat and lead to improved salmonid populations.

3. 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.

4. Provide assessment information to help landowners and agencies better implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

The program's work is intended to provide answers to the following assessment questions at the basin and subbasin scales in California's North Coast watersheds:

- What are the history and trends of the size, distribution, and relative health and diversity of salmonid populations?

- What are the current salmonid habitat conditions? How do these conditions compare to desired conditions?
- What are the past and present relationships of geologic, vegetative, and fluvial processes to stream habitat conditions?
- How has land use affected these natural processes?
- Based upon these conditions, trends, and relationships, are there elements that could be considered to be limiting factors for salmon and steelhead production?
- What watershed and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

Each participating department is responsible for products related to their primary discipline and for conducting an interdisciplinary analysis and synthesis. For the Gualala River Watershed Assessment:

- CDFG compiled, collected, and analyzed data related to anadromous fisheries habitat and populations, developed a stream reach module for the program's Ecosystem Management Decision System (EMDS) model, and identified limiting factors and restoration priorities for coho salmon and steelhead trout.
- CDF compiled, developed, and analyzed data related to historic land use change, including vegetation, timber harvest, and road maps, and developed a preliminary upslope sediment module for the EMDS watershed model.
- CGS compiled, developed, and analyzed data related to the geology and geologic processes, and produced maps of geology, geomorphic features related to landsliding, instream sediment and transport zones, and relative landslide potential.
- NCRWQCB compiled, collected, and analyzed water chemistry and temperature data for the assessment, served as Team Lead, and assisted with public outreach.
- DWR installed and maintained three stream flow monitoring gages for future hydrologic information and analysis, compiled water rights information, and provided a hydrologic analysis for the watershed.

1.1 Salmon / Stream / Watershed / Land Use Relationships

Anadromous Pacific salmonids are dependent upon a high-quality freshwater environment at the beginning and end of their life cycles. As such, they thrive or perish during their freshwater phases depending upon the availability of cool, clean water, free access to migrate up and down their natal streams, clean gravel for successful spawning, adequate food supply, and protective cover for escaping predators and ambushing prey. These life requirements must be provided by diverse and complex instream habitats as the fish move through their life cycles. If any of these elements is missing or in poor condition at the time a fish or stock requires it, its survival can be adversely impacted. These life requirement conditions can be identified and evaluated on a spatial and temporal basis at the stream reach and watershed levels. They comprise the factors that support or limit salmonid stock production.

"Protection and maintenance of high-quality fish habitats should be among the goals of all resource managers. Preservation of good existing habitats should have high priority, but many streams have been

damaged and must be repaired. Catastrophic natural processes that occlude spawning gravels can reduce stream productivity or block access by fish (for example), but many stream problems, especially in western North America, have been caused by poor resource management practices of the past. Enough now is known about the habitat requirements of salmonids and about good management practices that further habitat degradation can be prevented, and habitat rehabilitation and enhancement programs can go forward successfully" (Meehan 1991).

"In streams where fish live and reproduce, all the important factors are in a suitable (but usually not optimum) range throughout the life of the fish. The mix of environmental factors in any stream sets the carrying capacity of that stream for fish, and the capacity can be changed if one or more of the factors are altered. The importance of specific factors in setting carrying capacity may change with life stage of the fish and season of the year" (Bjorrn and Reiser 1991).

Through the course of the years, climate, watershed hydrologic responses, and erosion events interact to shape freshwater salmonid habitats. These include the kind and extent of the watershed's vegetative cover as well, and act to supply nutrients to the stream system. "In the absence of major disturbance, these processes produce small, but virtually continuous changes in variability and diversity against which the manager must judge the modifications produced by nature and human activity. Major disruption of these interactions can drastically alter habitat conditions." (Swanston 1991).

Major watershed disruptions can be caused by catastrophic events, such as the 1964 flood. They can also be created over time by multiple small natural or human disturbances. All these disruptions can drastically alter instream habitat conditions and the aquatic communities that depend upon them. Thus, it is important to understand the critical, dependent relationships of salmon and steelhead trout with their natal streams during their freshwater life phases, their streams' dependencies upon the watersheds within which they are nested, and the energy of the watershed processes that binds them together.

In general, natural disturbance regimes, like landslides and wildfires, do not impact larger watersheds, like the 298-square-mile Gualala, in their entirety at any given time. Rather, such disturbances normally rotate episodically across the entire Gualala River Watershed as a mosaic composed of the smaller subbasin, watershed, or sub-watershed units over long periods of time. This creates a dynamic variety of habitat conditions and quality over the larger watershed (Reice 1994).

The rotating nature of these relatively large, isolated events at the regional or basin scale assures that at least some streams in the area will be in suitable condition for salmonid stocks. A dramatic, large-scale example occurred in May 1980 in the Toutle River, Washington, which was inundated in slurry when Mt. St. Helens erupted. The river rapidly became unsuitable for fish. In response, returning salmon runs avoided the river that year and used other nearby and suitable streams on an opportunistic basis, but returned to the Toutle two years later as conditions improved. This return occurred much sooner than had been expected initially.

Human disturbance sites, although individually small in comparison to natural disturbance events, are usually spatially distributed widely across basin-level watersheds (Reeves, et al. 1995). For example, a rural road or building site is an extremely small land disturbance compared to a 40-acre landslide or wildfire covering several square miles. However, when all the roads in a basin the size of the Gualala River Watershed are looked at collectively, their disturbance effects are much more widely distributed than a single large, isolated landslide that has a high, but relatively localized impact to a single sub-watershed.

Human disturbance regimes collectively extend across basin and even regional scales and have lingering effects. Examples include water diversions, conversion of near stream areas to urban usage, removal of large mature vegetation, widespread soil disturbance leading to increased erosion rates, construction of levees or armored banks that can disconnect the stream from its floodplain, and the installation of dams and reservoirs that disrupt normal flow regimes and prevent free movement of salmonids and other fish. These disruptions often develop in concert with and in an extremely short period of time, on the natural geologic scale.

These human disturbances are often concentrated in time because of newly developed technology or market forces such as the California Gold Rush or the post-World War II logging boom in northern California. This intense human land use of the last century, combined with the transport energy of two mid-century, record floods on the North Coast, created stream habitat impacts at the basin and regional scales. The result of these recent combined disruptions has overlain the pre-European disturbance regime process and conditions.

Consequently, stream habitat quality and quantity are generally depressed across most of the north coast region. It is within this generally impacted environment that both human and natural disturbances continue to occur, but with vastly fewer habitat refugia "lifeboats" than were historically available to salmon and steelhead trout. A general reduction in salmonid stocks can at least partially be attributed to this impacted freshwater environment.

1.1.1 Factors Affecting Anadromous Salmonid Production

Chinook salmon, coho salmon, and steelhead trout all utilize headwater streams, larger rivers, estuaries and the ocean for parts of their life history cycles. There are several factors necessary for the successful completion of an anadromous salmonid life history.

A main component of the NCWAP is the analysis of these factors in order to identify whether any of them are at a level that limits production of anadromous salmonids in north coast watersheds. This "limiting factors analysis" (LFA) provides a means to evaluate the status of a suite of key environmental factors that affect anadromous salmonid life history. The concept that fish production is limited by a single factor or by interactions between discrete factors is fundamental to stream habitat management (Meehan 1991). A limiting factor can be anything that constrains, impedes, or limits the growth and survival of a population. These analyses are based on comparing measures of habitat components such as water temperature and pool complexity to a range of reference conditions determined from empirical studies and/or peer reviewed literature. If the component's condition does not fit within the range of the reference values, it may be viewed as a limiting factor. This information will be useful to identify the underlying causes of stream habitat deficiencies and help reveal if there is a linkage to watershed processes and land use activities.

In the freshwater phase in salmonid life history, stream connectivity, stream condition, and riparian function are essential for survival. Stream connectivity describes the absence of barriers to the free instream movement of adult and juvenile salmonids. Free movement in well-connected streams allows salmonids to find food, escape from high-water temperatures, escape from predation, and migrate to and from their stream of origin as juveniles and adults. Dry or intermittent channels can impede free passage for salmonids; temporary or permanent dams, poorly constructed road crossings, landslides, debris jams, or other natural and/or man-caused channel disturbances can also disrupt stream connectivity.

Stream condition includes several factors: adequate stream flow, suitable water quality, suitable stream temperature, and complex habitat. For successful salmonid production, stream flows should mimic the natural hydrologic regime of the watershed. A natural regime minimizes the frequency and magnitude of storm flows and promotes better flows during dry periods of the water year. Salmonids evolved with the natural hydrograph of coastal watersheds, and changes to the timing, magnitude, and duration of low flows and storm flows can disrupt the ability of fish to follow life history cues. Adequate instream flow during low flow periods is essential for good summer time stream connectivity, and is necessary to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia provided by seeps, springs, and cool tributaries.

Three important aspects of water quality for anadromous salmonids are water temperature, turbidity, and sediment load. In general, suitable water temperatures for salmonids are between 48° and 56° Fahrenheit (F) for successful spawning and incubation, and between 50-52 and 60-64 F for growth and rearing, depending on species. Additionally, cool water holds more oxygen, and salmonids require high levels of dissolved oxygen in all stages of their life cycle.

A second important aspect of water quality is turbidity, which is the relative clarity of water. Water clarity and turbid suspended sediment levels affect nutrient levels in streams that in turn affect primary productivity of aquatic vegetation, and insect life. This eventually reverberates through the food chain and affects salmonid food availability. Additionally, high levels of turbidity interfere with juvenile salmonids' ability to feed and can lead to reduced growth rates and survival (B. Trush, personal communication).

A third important aspect of water quality is stream sediment load. Salmonids cannot successfully reproduce when forced to spawn in streambeds with excessive silt, clays, and other fine sediment. Eggs and embryos suffocate under excessive fine sediment conditions because oxygenated water is prevented from passing through the egg nest, or "redd." Additionally, high sediment loads can "cap" the redd and prevent emergent fry from escaping from the gravel into the stream at the end of incubation. High sediment loads can also cause abrasions on fish gills, which may be susceptible to infection. At extreme levels, sediment can clog the gills causing death. Additionally, materials toxic to salmonids can cling to sediment and be transported through the downstream areas.

Habitat complexity for salmonids is created by a combination of deep pools, riffles, and flatwater habitat types. Pools, and to some degree flatwater habitats, provide escape cover from high velocity flows, areas to hide from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas, particularly for young coho salmon. They are also necessary for adult resting areas. A high level of fine sediment fills pools and flatwater habitats, reducing water depths and potentially burying complex niches created by large substrate and woody debris. Riffles provide clean spawning gravels and oxygenate water as it tumbles across them. Steelhead trout fry use riffles during rearing. Flatwater areas often provide spatially divided "pocket water" units that separate individual juveniles which helps promote reduced competition and successful foraging (Flosi et al. 1998).

A functional riparian zone helps to control the amount of sunlight reaching the stream, and provides vegetative litter and invertebrate fall. These contribute to the production of food for the aquatic community, including salmonids. Tree roots and other vegetative cover provide stream bank cohesion and buffer impacts from adjacent uplands. Near-stream vegetation eventually provides large woody debris and complexity to the stream (Flosi et al. 1998).

Riparian zone functions are important to anadromous salmonids for numerous reasons. Riparian vegetation helps keep stream temperatures in the range that is suitable for salmonids by maintaining cool stream temperatures in the summer and insulating streams from heat loss in the winter. Larval and adult macroinvertebrates are important to the salmonid diet and they are in turn dependant upon nutrient contributions from the riparian zone. Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintains diverse salmonid habitat, and helps reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel morphology, helps a stream retain organic matter and provides essential cover for salmonids (Murphy and Meehan 1991).

Therefore, excessive natural or man-caused disturbances to the riparian zone, as well as the directly to the stream and/or the watershed itself can have serious impacts to the aquatic community, including anadromous salmonids. Generally, this seems to be the case in streams and watersheds in the north coast of California. This is borne out by recent decisions to "list" many north coast chinook and coho salmon, and steelhead trout stocks under the Federal Endangered Species Act and to list coho salmon under the State Endangered Species Act.

1.1.2 Disturbance and Recovery of Stream and Watershed Conditions

Natural and Human Disturbances

The forces shaping streams and watersheds are numerous and complex. Streams and watersheds change through dynamic processes of disturbance and recovery (Madej 1999). In general, disturbance events alter streams away from their equilibrium or average conditions, while recovery occurs as stream conditions return towards equilibrium after disturbance events. Given NCWAP's focus on anadromous salmonids, an important goal is to determine the degree to which current stream and watershed conditions in the region are providing salmonid habitat capable of supporting sustainable populations of anadromous salmonids. To do this, we must consider the habitat requirements for all life stages of salmonids. We must look at the disturbance history and recovery of stream systems, including riparian and upslope areas, which affect the streams through multiple biophysical processes.

Disturbance and recovery processes can be influenced by both natural and human events. A disturbance event such as sediment from a natural landslide can fill instream pools providing salmon habitat just as readily as sediment from a road failure. On the recovery side, natural processes (such as small stream-side landslides) that replace instream large woody debris washed out by a flood flow help to restore salmonid habitat, as does large woody debris placed in a stream by a landowner as a part of a restoration project.

Natural disturbance and recovery processes, at scales from small to very large, have been at work on north coast watersheds since their formation millions of years ago. Recent major natural disturbance events have included large flood events such as occurred in 1955 and 1964 (Lisle 1981a) and ground shaking and related tectonic uplift associated with the 1992 Cape Mendocino earthquake (Carver et al. 1994). Major human disturbances (e.g., post-European development, dam construction, agricultural and residential conversions, and the methods of timber harvesting practices used particularly before the implementation of the 1973 Z'Berg-Nejedly Forest Practice Act) have occurred over the past 150 years (Ice 2000). Salmonid habitat also was degraded during parts of the last century by well-intentioned but misguided restoration actions such as removing large woody debris from streams (Ice 1990). More recently, some efforts at watershed restoration have been made, generally at the local level. For

example, in California and the Pacific Northwest, minor dams from some streams have been removed to clear barriers to spawning and juvenile anadromous fish. For a thorough treatment of stream and watershed recovery processes, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Defining "Recovered"

It is generally agreed that improvements in a condition or set of conditions are a process of recovery. One can determine a simple rate of recovery by degree of improvement over some time period, and from only two points in time. And one can discuss recovery and rates of recovery in a general sense. However, a simple rate of recovery is not very useful until put into the context of its position on a scale to the endpoint of "recovered."

Recovered not only implies, but necessitates, knowledge of an endpoint. In the case of a "recovered watershed," the endpoint is a set of conditions deemed appropriate for a watershed with its processes in balance and able to withstand purturbations without large fluctuations in those processes and conditions. Recovered fish habitat could be habitat in an optimum state or in state that allows for a suitable and stable population or something in between. As discussed below, the endpoint of "recovered" for one condition or function may be on a different time and geographic scale than for another condition or function.

In this report we use the term recovery in two ways. We use it in discussing the concept of recovery as in this section. We also use it when qualified with an endpoint or benchmark for a condition, such as, "recovered to 1942 conditions" in reference to canopy. The Gualala Total Maximum Daily Load (TMDL) contains several targets that were developed as benchmarks for recovery of the system with regard to physical characteristics of the stream channels, both in terms of suitability for salmonids and as indicators of fluvial stability. The targets were developed with information and knowledge available at the time and are expected to change, to be improved upon in the future. In the meantime, they exist as one set of benchmarks to provide a context for recovery and "recovered." The Flosi et al (1998) targets and EMDS relationships also constitute benchmarks for salmonid habitat based on current knowledge.

Factors and Rates of Recovery

Over the past quarter-century, several changes have allowed the streams and aquatic ecosystems to move generally towards recovery. The rate of timber harvest on California's north coast has slowed during this period, with declining submissions of timber harvesting plans (THPs) and smaller average THPs (T. Spittler, pers. comm.). In addition, timber harvesting practices have improved over those of the post-war era, due to increased knowledge of forest ecosystem functions, changing public values, advances in road building and yarding techniques, and regulation changes such as mandated streamside buffers that limit equipment operations and removal of timber. For example, Cafferata and Spittler (1998) found that almost all of the more recent landslides occurring in an area logged in the early 1970s were related to the legacy logging roads. In contrast, in a neighboring watershed logged in the late 1980s to early 1990s, landslides to date have occurred with about equal frequency in the logged areas as in unlogged areas.

Further, most north coast streams have not recently experienced another large event on the scale of the intense storms of 1964. Therefore, we would expect most north coast streams to show signs of recovery

(i.e., "passive restoration" [FISRWG 1998]). However, the rates and degrees of stream and watershed recovery will likely vary across a given watershed and among different north coast drainages.

In addition to the contributions made to recovery through better land management practices and natural recovery processes, increasing levels of stream and watershed restoration efforts also are contributing to recovery. Examples of these efforts include road upgrades and decommissioning, removal of road-related fish passage barriers, installation of instream fish habitat structures, etc. While little formal evaluation or quantification has been made of the contributions of these efforts towards recovery, there is a general consensus that many of these efforts have resulted in important improvements.

Some types and locations of stream recovery for salmonids can occur more readily than others. For example, in headwater areas where steeper source reaches predominate, suspended sediment such as that generated by a streamside landslide or a road fill failure may start clearing immediately, while coarser sediments carried as bedload tend to flush after a few years (Lisle 1981a, Madej and Ozaki 1996). Broadleaf riparian vegetation can return to create shading, stabilize banks and improve fish habitat within a decade or so. In contrast, in areas lower in the watershed where lower-gradient response reaches predominate, it can take several decades for deposited sediment to be transported out (Madej 1982, Koehler et al. 2001), for widened stream channels to narrow, for aggraded streambeds to return to pre-disturbance level, and for streambanks to fully revegetate and stabilize (Lisle 1981b). Lower reach streams will require a similar period for the near-stream trees to attain the girth needed for recruitment into the stream as large woody debris to help create adequate habitat complexity and shelter for fish, or for deep pools to be re-scoured in the larger mainstems (Lisle and Napolitano 1998).

Continuing Challenges to Recovery

Given improvements in timber harvesting practices in the last 30 years, the time elapsed since the last major flood event, and the implementation of stream and watershed restoration projects, it is not surprising that many north coast streams show indications of trends towards recovery (Madej and Ozaki 1996). Ongoing challenges associated with past activities that are slowing this trend include chronic sediment delivery from legacy roads (pre-1975) due to inadequate crossing design, construction and maintenance (California State Board of Forestry, Monitoring Study Group 1999), skid trails and landings (Cafferata and Spittler 1998), the lack of improvements in stream habitat complexity for successful fish rearing (from a dearth of large woody debris), and the continuing aggradation of sediments in low-gradient reaches that were deposited as the result of activities and flooding in past decades (Koehler et al. 2001).

Increasing development on several north coast watersheds raises concerns about new stream and watershed disturbances. Private road systems associated with rural development have historically been built and maintained in a fashion that does little to mitigate risks of chronic and catastrophic sediment inputs to streams. While more north coast counties are beginning to put into place grading ordinances that will help with this problem, there is a substantial legacy of older residential roads that pose an ongoing risk for sediment inputs to streams. Other issues appropriate to north coast streams include potential failures of roads during catastrophic events, erosion from house pads and impermeable surfaces, removal of water from streams for domestic uses, effluent leakages, and the potential for deliberate dumping of toxic chemicals used in illicit drug labs.

Some areas of the North Coast have seen rapidly increasing agricultural activity, particularly conversion of grasslands or woodlands to vineyards. Such agricultural activities have typically been subject to little agency review or regulation and can pose significant risk of chronic sediment inputs to streams.

Associated with development and increased agriculture, some north coast river systems, such as the Navarro, are seeing increasing withdrawal of water, both directly from the stream and from groundwater sources connected to streams, for human uses. Water withdrawals pose a chronic disturbance to streams and aquatic habitat. Such withdrawals can result in lowered summer stream flows that impede the movement of salmonids and reduce important habitat elements such as pools. Further, the withdrawals can contribute to elevated stream water temperatures that are harmful to salmonids.

Key questions for landowners, agencies, and other stakeholders revolve around whether the trends toward stream recovery will continue at their current rates, and whether those rates will be adequate to allow salmonids to recover their populations in an acceptable timeframe. Clearly, the potential exists for new impacts from both human activities and natural disturbance processes to compromise recovery rates to a degree that threatens future salmonid recovery. To predict those cumulative effects will likely require additional site-specific information on sediment generation and delivery rates and additional risk analyses of other major disturbances. Also, our discussion here does not address marine influences on anadromous salmonid populations. While these important influences are outside of the scope of NCWAP, we recognize their importance for sustainable salmonid populations and acknowledge that good quality freshwater habitat alone is not adequate to ensure sustainability.

1.2 Policies, Acts, and Listings

Several federal and state statues have significant implications for watersheds, streams, fisheries, and their management. A very brief listing and description of several laws are included below.

1.2.1 Federal Statutes

One of the most fundamental of federal environmental statutes is the National Environmental Policy Act (NEPA). NEPA is essentially an environmental impact assessment (EIS) and disclosure law. Projects contemplated or plans prepared by federal agencies or funded by them must have an environmental assessment completed and released for public review and comment, including the consideration of more than one alternative. The law does not require that the least impacting alternative be chosen, only that the impacts be disclosed.

The federal Clean Water Act has a number of sections relevant for watersheds and water quality. Sections 208 and 319 deal with non-point source pollution, including development, agricultural, and silvicultural activities, and cumulative impacts. Section 303 deals with waterbodies that are impaired such that their water quality is not suitable for the beneficial uses identified for those waters. For water bodies identified as impaired, the U.S. Environmental Protection Agency (USEPA) or its state counterpart (here, the NCRWQCB and the SWRCB) must set targets for TMDLs of the pollutants that are causing the impairment. Section 404 deals with the alterations of wetlands and streams through filling or other modifications, and requires the issuance of federal permits for most such activities.

The federal Endangered Species Act (ESA) addresses the protection of animal species whose populations are dwindling to critical levels. Two levels of species risk are defined. A “threatened” species is any species that is likely to become an endangered species within the foreseeable future

throughout all or a significant portion of its range. An “endangered” species is any species that is in danger of extinction throughout all or a significant portion of its range. In general, the law forbids the “take” of listed species. Taking is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting a species or attempting to engage in any such conduct. A take of a species listed as threatened may be allowed where specially permitted through the completion and approval of a Habitat Conservation Plan (HCP). A HCP is a document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. A HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the take of species that are covered by the plan. Listings under the federal ESA for areas within the NCWAP region (the North Coast Hydrologic Unit) began with coho salmon in 1996, followed by Chinook salmon in 1999, and steelhead trout in 2000. They all are listed as threatened below impassable barriers

1.2.2 State Statutes

The state analogue of NEPA is the California Environmental Quality Act (CEQA). CEQA goes beyond NEPA in that it requires the project or plan proponent to select for implementation the least environmentally impacting alternative considered. When the least impacting alternative would still cause “significant” adverse environmental impacts, a statement of overriding considerations must be prepared.

The Porter-Cologne Water Quality Control Act establishes state water quality law and defines how the state will implement the federal authorities that have been delegated to it by the USEPA under the federal Clean Water Act. For example, the USEPA has delegated to the state certain authorities and responsibilities to implement TMDLs for impaired water bodies, and the national pollution discharge elimination system (NPDES) permits for point-source discharges to water bodies.

Sections 1600 et seq. of the Fish and Game Code, implemented by CDFG are required for any activities that alter the beds or banks of streams or lakes. This typically would be involved in a road project where a stream crossing was constructed. While treated as ministerial in the past, the courts have more recently indicated that these constitute discretionary permits and, thus, must be accompanied by an environmental impact review per CEQA.

The California Endangered Species Act (CESA) (Fish and Game Code Section 2050, et seq.) generally parallels the main provisions of the federal ESA and is administered by CDFG. In August 2002, the California Fish and Game Commission voted to list the coho salmon, on north coast California rivers from the Gualala to the Oregon border, as “threatened” under CESA.

The Z’Berg-Nejedly Forest Practice Act (FPA) and associated Forest Practice Rules establish extensive permitting, review, and management practice requirements for commercial timber harvesting. Evolving in part in response to water quality protection requirements established by the 1972 amendments to the federal Clean Water Act, the FPA and Rules provide for significant measures to protect watersheds, watershed function, water quality, and fishery habitat.

Chapter 2

Assessment Strategy and General Methods

The North Coast Watershed Assessment Program (NCWAP) developed in 2000, a draft methods manual that identified a general approach to conducting a watershed assessment, described or referenced methods for collecting and developing new watershed data, and provided a preliminary explanation of analytical methods for integrating interdisciplinary data to assess watershed conditions. NCWAP methods continued to evolve over the course of this assessment.

This chapter provides brief descriptions of data collection and analysis methods used by each of NCWAP's participating departments, and an introduction to methods for analyzing data across departments and disciplines. Additional explanation and discussion of interdisciplinary data analysis is provided in Chapter 4. While the information contained in the report is extensive, more detail is included in a set of appendices to this report:

1. Hydrology
2. Geology
3. Land Use
4. Water Quality
5. Fish Habitat Conditions
6. Interdisciplinary Synthesis
7. Public Responsiveness Summary

The reader is referred to those appendices for more detail on methods, data used in the assessment, and assessments of the data.

2.1 Methods by Department

2.1.1 HYDROLOGIC ANALYSES

The Gualala River Watershed assessment team has divided the watershed into five principal watersheds for assessment purposes: Wheatfield Fork (37 percent of drainage), South Fork (21 percent), North Fork (16 percent), Buckeye Creek (14 percent), and Rockpile Creek (12 percent).

Precipitation

The California Department of Water Resources (DWR) analyzed precipitation data for 12 gages with long-term periods of record within or near the Gualala River Watershed, summarizing and graphing gages, location, period of record, and annual, and maximum daily precipitation. Details about this process are available in Appendix 1.

Streamflow

DWR also analyzed streamflow data. Since few streamflow gaging stations have operated historically within the Gualala River Watershed, and streamflow data had not been collected by any agency since

1994, DWR installed three stream gaging stations during the fall of 2000. NCWAP gage installations were prioritized by the need for data at the terminus of the watersheds or major subbasins. Stations were installed near each of the confluences of the North Fork and Wheatfield Fork with the South Fork and another on the South Fork above the Wheatfield Fork. The three new gages were also equipped with water temperature sensors.

The new gages will measure the discharge from about 207 square miles or 69 percent of the entire drainage watershed and provide runoff data from subbasins with varying hydrological, geographical, and land use characteristics. The new Wheatfield and South Fork gages combined will be comparable to the long-term historic gage "South Fork Gualala River near Annapolis." Electronic multiple parameter data loggers may be used at stations to collect detailed time series data, normally every 15 minutes or hourly, for all sensors.

Water stage and water quality time series data will be downloaded from the station data loggers, uploaded into a database, and reviewed and edited for accuracy on a monthly basis. Time series streamflow data will be determined by correlating the direct discharge measurements with the simultaneous water stage data. This stage vs. discharge relationship or rating curve will be applied to the stage recordings from the station's stage sensor and data logger to compute streamflow for the same time series interval as water stage, normally every 15 minutes.

Once the rating curves are developed, real-time flow data will be provided over the Internet via the California Data Exchange Center (CDEC) website (http://cdec.water.ca.gov/) for those stations equipped with telemetry. Real-time telemetry also allows the station's operator to remotely monitor the operation of the station allowing a timely response to station malfunctions. Real-time data are not reviewed and edited for inaccuracies such as telemetry transmission error, sensor drift or malfunction, or discharge rating curve shift and are considered preliminary and subject to revision. The reviewed and finalized data for the October through September water year will usually be available about three to six months after the end of the water year.

DWR provided information about new and discontinued streamflow gaging stations on location, flow data type, and period of record in Appendix 3 (Table III-1, Figure III-1) and graphically illustrates the period of record for each gage (Chart III-1).

Water Rights

California law recognizes surface and groundwater rights, the latter with few exceptions not being subject to California law. The two predominate types of water rights within the Gualala River Watershed are riparian and appropriative. No State permit is required for a riparian water right, however, current water appropriation requires a permit which establishes a record. Appendix 1 provides a more detailed discussion of water rights law, history, and application processes.

DWR searched the California State Water Resources Control Board's (SWRCB) Water Right Information System (WRIMS) to determine the number and types of water rights within the Gualala River Watershed. The WRIMS database is under development and may not contain all post-1914 appropriative water right applications that are on file with the SWRCB at this time. Some pre-1914 and riparian water rights are also contained in the WRIMS database for those water rights whose users have filed a "Statement of Water Diversion and Use." A list of water rights and associated information contained within WRIMS for the Gualala River Watershed is presented in Table IV-1, Appendix 1. A

location map of the point of diversion is shown in Figure IV-1, Appendix 1. CDWR also estimated municipal water use based on 1986 land and water use surveys by its Statewide Planning Program, coupled with delineations of cultivated agricultural lands from 1997 aerial photographs (Table IV-2, Appendix 1).

2.1.2 GEOLOGIC ANALYSIS

Landslide Assessment

CGS developed detailed information on landslide and geomorphic features as a keystone of its NCWAP work. Landslides that appeared to be fresh or to have moved within the last 150 years are classified as historically active; older landslides are classified as dormant. The historically active landslides are presumed to represent a major source area of natural sediment that entered the stream system over the past 150 years. Much of the coarser fraction of that sediment, mixed with older sediment, likely remains in the channels as indicated by the presence of well-rounded gravels and cobbles stored in the active channels. Historically active and dormant landslides and geomorphic features were mapped from primarily two sets of aerial photos (1984 and 1999/2000) and limited fieldwork. The mapped landslides were separated into multiple layers. Historically active landslides and dormant landslides were differentiated (page 2-6, Activity of Landslides), and landslides too small to capture at the map scale (less than the minimum mapping unit for polygons of approximately 100 feet in diameter) were captured as lines or points. If a historically active landslide observed on the 1984 photos appeared to be the same as was mapped from the 2000 photos, it was not redigitized into the 1984 layer. Thus, the 1984 layer does not include all the landslides observed in these photos, but only those that were not observed in the 2000 photos, or appeared to differ substantially between the two sets of photos.

Each landslide is classified according to the materials involved and the movement type, as deduced from the associated landforms. A two-part designation is given to each slide, based on the system of Cruden and Varnes (1996). Materials are called either rock or soil, and soil is subdivided into fine-grained (earth) and coarse-grained (debris). This system was designed to allow a series of names that describes the materials and processes involved in a landslide. California Geologic Survey (CGS) simplified the system to use it in preparing the landslide maps of the watershed. The terms and definitions of Cruden and Varnes (1996) were used, but were simplified to listing only the primary classification of a given landslide. For example, a rotational rock slide-flow in which the upper part of the slide has moved by sliding, but the lower part has disaggregated and is flowing is shown simply as a rockslide in the NCWAP landslide map. In the north coast of California, many geologic formations are not hard or indurated rock and it is possible to find all gradations between weak, soil-like rocks, and hard rocks. Therefore, CGS simplified the classification of rock versus soil and called material “rock” if it had a geologic formation name and the original geologic structure could be discerned.

The following landslide types and geomorphic features were used to develop the Geologic and Geomorphic Features Related to Landsliding maps (Plate 1) developed under NCWAP. The features are described below as well as general management and mitigation guidelines for each feature.

Rock Slide

Rock slides involve bedrock in which much of the original structure is preserved, and the strength of the rock is usually controlled by zones of weakness such as bedding planes or joints. Movement occurs primarily by sliding on a narrow zone of weakness as an intact block. Typically these landslides move downslope on one or several shear surfaces called slide planes. The failure surface(s) may be curved

(rotational slide) or planar (translational slide). In some older classification systems, slides with curved failure surfaces are commonly referred to as slumps, while those with planar failure surfaces are called block glides.

The major management objectives for mitigating potential problems on translational/rotational slides are to: 1) minimize water concentration on the steep scarp and lateral margins of the slides, 2) avoid undercutting of the toe areas, 3) minimize loading the upper bench of the slide, and 4) avoid the activation of debris sliding on steep scarp and toe areas.

Earth Flow

Earth flows are a mixture of fine-grained soil, consisting of surficial deposits and deeply weathered, disrupted bedrock. The material strength is low through much of the slide mass, and movement occurs on many discontinuous shear surfaces throughout the landslide mass. Although the landslide may have a main slide plane at the base, many internal slide planes disrupt the landslide mass leading to movement that resembles the flow of a viscous liquid. Earth flows commonly occur on less steep slopes than rock slides, and in weak, clay-rich soils or disrupted rock units.

Because earthflow materials are so easily erodible, the main objective is to minimize the physical disturbance of the slide by avoiding the concentration of water onto the slide mass, and avoiding deep cut slopes into slide deposits.

Debris Slide

Debris slides are composed of coarse-grained soil, commonly consisting of a loose combination of surficial deposits, rock fragments, and vegetation. The strength of the material is low, and there may be a very low strength zone at the base of the soil or within the weathered bedrock. Debris slides typically move initially as shallow intact slabs of soil and vegetation, but break up after a short distance into rock and soil falls and flows.

Debris slides are characterized by unconsolidated materials above a shallow slide plane, therefore, the main management objectives are to: 1) retain root support, 2) minimize water flow along the soil/rock interface, 3) avoid the undercutting of materials above the slide plane, and 4) minimize the weighting of unconsolidated materials on steep slope

Debris Slide Slopes

Debris slide slopes are geomorphic features characterized by steep, usually well-vegetated slopes that appear to have been sculpted by numerous debris slides and debris flows. Upper reaches (source areas) of these slopes are often tightly concave and very steep. Soil and colluvium atop bedrock may be disrupted by active debris slides and debris flows. Slopes near the angle of repose may be relatively stable except where weak bedding planes, bedrock joints, and fractures parallel the slope.

Road construction and other activities should be avoided on debris slide slopes. If a road must be constructed it should be done using a full bench cut and the spoils should be removed to prevent discharge into any nearby watercourses.

Debris Flow

A debris flow is a mass of coarse-grained soil that flows downslope as a slurry. Material involved is commonly a loose combination of surficial deposits, rock fragments, and vegetation. High pore water

pressures, typically following intense rain, cause the soil and weathered rock to rapidly lose strength and flow downslope. Debris flows commonly begin as a slide of a shallow mass of soil and weathered rock. Their most distinctive landform is the scar left by the original shallow slide. In many cases debris flows leave a linear scar called a torrent track.

The main management objectives in mitigating areas containing debris flow/torrent tracks are to: 1) protect water quality and 2) to avoid or minimize the possibilities of reactivating debris flow and debris torrent failures. Efforts should be made to identify colluvial-filled hollows that may develop into debris flows. Concentrated drainage into colluvial-filled hollows should be avoided.

Rock Fall

A rock fall is where a fragment or fragments break off of an outcrop of rock and falls, tumbles or rolls downslope. Rock falls typically begin on steep slopes composed of hard rocks and result in piles of loose rubble at the base of the slope.

It is recommended that excavation near the base of the rock fall be avoided. A site-specific evaluation is advised before any land use alterations are made on or adjacent to a rock fall.

Disrupted Ground

This category is defined as irregular ground surface caused by complex landsliding processes resulting in features that are indistinguishable or too small to delineate individually at 1:24,000 scale, and also may include areas affected by downslope creep, expansive soils, and/or gully erosion.

Because disrupted ground may include a variety of landslide features, site-specific management recommendations must be developed before any land-use changes are undertaken.

Inner Gorge

An inner gorge is a geomorphic feature consisting of steep slopes adjacent to channels. The gorge typically is created by accelerated down cutting in response to regional uplift. It is defined as an area of streambank between the channel and the first break in slope.

Extreme caution should be exercised before any land use modifications are undertaken on an inner gorge. The Forest Practice Rules require that any construction activities associated with timber management on an inner gorge area be approved by a Certified Engineering Geologist.

Gullies

Gullies are distinct, narrow channels formed by the erosion of soil or soft rock material by running water. Channels are larger and deeper than rills and usually carry water only during and immediately after heavy rain, or following the melting of ice or snow.

A site-specific evaluation must be conducted prior to any land use activity in a gullied area.

Activity of Landslides

Landslides are classified based on the recency of activity as modified from Keaton and DeGraff (1996). Under NCWAP, landslides were categorized as historically active or dormant. In some cases, dormant landslides were further subdivided.

The classification system of Keaton and DeGraff (following Varnes, 1978) uses the term “active” to mean active in the past year and “dormant-historic” to mean active within the last 100 years. These terms were combined as “historically active” for NCWAP and the time period increased 150 years to reflect the time since European settlers arrived in the North Coast. In the North Coast, landslides that have not revegetated with mature forest or grasslands that show immature drainage are considered to be historically active (less than 150 years old). Historically active landslides under NCWAP are landslides that can be actively moving or have moved within the past 150 years, based on freshness of features related to most recent movement.

Landslides with movement more than 150 to over thousands of years ago based on geomorphic features are classified as dormant. Some of the dormant landslides are further classified based on relative age and geomorphic features. These classifications are dormant young, dormant old, and dormant mature. Dormant young landslides are characterized by rounded scarps, the absence of cracks, and partially filled depressions or ponds. Dormant old are characterized by extensive erosion of landforms related to the landslide, including substantial gullies or canyons cut into the landslide mass by streams, and rounding of original headscarp benches and hummocky topography. Dormant mature slides are recognized by the fact that the landforms have been smoothed by erosion, re-vegetated, main scarp rounded, erosion of the toe area, and well established drainage.

In many cases in the Gualala River Watershed landslide mapping, dormant landslides were not differentiated as dormant young, dormant old, or dormant mature due to time constraints. Therefore, many dormant landslides are classified simply as dormant.

CGS considers both dormant and historically active landslides capable of generating natural sediment loads in proportion to their size, rate of movement, geologic materials, steepness of slope, density and type of vegetation, and hydrologic setting. Although the CGS’s distinction between dormant and historically active landslides is characterized by movement within the last 100 to 150 years, this criterion does not place an upper limit on the age of any landslide. Thus, a historically active landslide may be hundreds of years old. In fact, many historically active landslides are found within larger areas of older dormant landslides, suggesting that some recent landslides are the result of reactivation of dormant landslides. The activity rating of a landslide is based on geomorphic characteristics that suggest recent movement as observed either in the field or on aerial photos.

Historically active landslides have an overall higher rate of movement than dormant or stable ground that results in more disruption to the terrain, which produces sharper topography, hummocky undrained depressions, angular blocks and scarps. These in turn provide more opportunity of infiltration of rainfall that maintains the instability and accelerated surface erosion. In comparison, the rate of movement of dormant landslides is sufficiently low to allow surface geomorphic processes to erode and smooth the landscape reducing topographic irregularities and allowing the development of internal drainage networks.

There is a general relationship between the area of earthflows and rockslides and the depth of failure. Typically, the depth of rotational landslides in soils range from 15 to 33 percent, and are less than 10 percent for translational landslides in soils (Cruden and Varnes, 1996). The deep-seated earthflows and rockslides mapped by CGS as polygons are larger than 1/5 of an acre with moderate (11 to 50 feet) to deep (> 50 feet) depths. In the Gulalala River Watershed, the average area of an historically active earthflow and rockslide mapped as a polygon is approximately 40 acres. Thus, the mass of an average

deep-seated landslide is approximately 1,000,000 tons. While recent land uses can increase their sediment yield, it is not likely these historically active landslides are the result solely of recent land uses.

Other Attributes

The landslide data were captured as different attributes in the Geographic Information System (GIS) database. These attributes include landslide type, confidence of interpretation, relative age of the feature, thickness, whether material was delivered directly to a watercourse, and whether features such as roads, timber harvests, or stream undercutting were observed in the immediate vicinity of the landslide (Appendix 2). However, it should be noted that due to resource constraints, not all attributes were captured for all features for the Gualala River Watershed. As such, a blank in a specific attribute field does not necessarily mean that the specific attribute is not present or does not apply, but could be that it was not captured during the mapping efforts.

Additional details are located in Appendix 2 and in the electronic database .

Confidence of Interpretation

Each mapped landslide is also classified as definite, probable, or questionable. Because landslides are mapped based on their landforms, the confidence of identification is dependent on the distinctness of those landforms. Landslide size also limits the confidence. Those that are too small to see clearly or those that have been altered substantially are more difficult to identify. Confidence of interpretation is classified according to the criteria below.

Definite Landslide

Nearly all of the diagnostic landslide features are present, including but not limited to headwall scarps, cracks, pronounced toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The clarity of the landforms and their relative positions clearly indicate downslope movement.

Probable Landslide

Several of the diagnostic landslide features are observable, including but not limited to headwall scarps, rounded toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The shapes of the landforms and their relative positions strongly suggest downslope movement, but other explanations are possible such as faulting.

Questionable Landslide

One or a few, generally very subdued, features commonly associated with landslides can be discerned. The area typically lacks distinct landslide morphology, but may exhibit disrupted terrain or other abnormal features that vaguely to strongly imply the occurrence of mass movement. Includes bulges low on the slope below upper slope concavities.

Relative Landslide Potential

Once relevant relationships between geology and landsliding were recognized, a landslide potential map was created in GIS. The landslide potential map was compared with the slope maps, landslide density thematic map, and other available slope models for important variations. Any important variations were

interpreted and subclassified, which are explained in further detail in Appendix 2. The relative landslide potential was defined and illustrated in five categories from 1 (most stable) to 5 (least stable). Additional modifiers, which supplement the primary definitions, were added as relevant.

The assignment of the categories was an interpretative process and was based on relations drawn from the Landslide and Geomorphic Features Related to Landsliding Map, statistical analysis, and general field observations.

The landslide potential map was constructed as an individual GIS layer and produced at a scale of 1:24,000. Further explanation of the categories and their implications for land use follows:

- ***Category 1, Very Low Landslide Potential:*** Landslides and other features related to slope instability are very rare to non-existent within this area. This area includes relatively flat marine terraces, lower stream valleys, and flat-topped ridges in the Gualala River Watershed. There is the possibility that small areas with much higher landsliding potential (similar to Categories 3, 4, or 5) could be present. A limited site-specific evaluation is recommended to address slope stability issues prior to changes in existing slopes or drainage.

- ***Category 2, Low Landslide Potential:*** Gentle to moderately steep slopes underlain by relatively competent material that is considered unlikely to mobilize as landslides under natural conditions given the current understanding of regional seismicity. Landsliding in these areas is not common. This area generally includes the flat-topped ridges of the Ohlson Ranch Formation and marine terraces west of the San Andreas Fault. There is the possibility that small areas with much higher landsliding potential (similar to Categories 3, 4, or 5) could be present. A site-specific evaluation is recommended to address slope stability issues prior to changes in existing slopes or drainage.

- ***Category 3, Moderate Landslide Potential:*** Moderate to moderately steep, relatively uniform slopes that are generally underlain by competent bedrock, and may also include older dormant landslides. Some slopes within this area may be at or near their stability limits due to weaker materials, steeper slopes, or a combination of these factors. This area dominantly occurs in dormant landslides west of the San Andreas Fault and in the rocks of the Coastal Terrane west of the Tombs Creek Fault zone. Landslides in this category typically occur as small (less than an acre) debris flows, debris slides, and rockslides. In addition, there is the possibility that isolated areas within Category 3 could include features that represent higher likelihood of landsliding more similar to categories 4 and 5. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability.

- ***Category 4, High Landslide Potential:*** Moderately steep to steep slopes that include many dormant landslides in upslope areas and slopes upon which there is substantial evidence of down slope creep of surface materials. This area consists of large dormant earthflows dominantly occurring (earthflows occur in earth not rocks) east of the Tombs Creek Fault zone, areas of disrupted ground on moderately steep (30-64 percent) slopes, and much of the incised and moderately steep area of the Coastal Terrane. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability. Additional caution is advised in these areas.

- ***Category 5, Very High Landslide Potential:*** Areas include historically active landslides (<150 years old) and inner gorges, as well as debris slide/flow source areas on steep to very steep slopes (>65 percent). Landslides typically occur as large earthflows in the Central Terrane east of the Tombs Creek Fault zone and as small (less than one acre) rock slides, debris slides, and debris flows in the Coastal Terrane. A site-specific review is recommended to evaluate effects of proposed changes to existing land use with respect to slope stability. Extreme caution is advised in these areas.

Management practices that are adaptive to various levels of slope stability can reduce or avoid adverse sediment effects within the watershed. Preventing slope failures and/or avoiding naturally unstable areas prior to land use changes or operations are generally more cost effective and achieve better results than mitigating slope failures and stream impacts after the fact. Therefore, consideration of the landslide potential and the relevant recommendations during land use planning is recommended. Areas in landslide potential categories 4 and 5 deserve particular attention and caution based on the known presence of factors affecting unstable slopes, including active and dormant landslides, steep slopes, inner gorges and debris slide slopes. In many cases, several interrelated factors can affect the natural slope stability and anthropogenic activities can worsen the conditions.

Fluvial Geomorphic Analysis

The CGS evaluated, compiled, and mapped channel fluvial characteristics for the Gualala River Watershed. Mapping was done through interpretation of aerial photographs from two time periods, 1984 and 1999/2000, and calibrated with limited field studies. CGS mapped 32 types of fluvial geomorphic attributes (Table 2-1). The purpose of the time-series analysis was to document site conditions using multiple sources of information, and to obtain information that reveals changes in channel characteristics.

The methodology developed by CGS for mapping fluvial geomorphic features was modified after the RAPID technique (Grant 1988) for evaluating downstream effects of forest practices on riparian zones. The basic technique of mapping channel change is the same for both methods. However, the methodology used by RAPID to measure patterns of riparian canopy disturbance was modified to include additional information on channel geomorphic characteristics that are observable on aerial photos. These features were then attributed in the GIS database for map preparation and data analysis.

CGS's fluvial geomorphic mapping identified 32 features indicative of stored channel sediment or sources of sediment that could be resolved on the available aerial photographs. The attributes in Table 2-1 in bold are those that may be indicators of excess sediment in storage or sediment sources that could be considered detrimental to optimum habitats for anadromous salmonids. While most of these features are always associated with increased sediment or impaired conditions, others, such as lateral bars, may or may not represent impairment. To be conservative, if one of the features in Table 2-1 is assigned an attribute that indicates excess sediment storage or sediment sources, it is included with those characteristics considered as a "negative" attribute.

While the significance of each mapped feature relative to channel habitat quality varies, the time-series mapping helps track changes and trends in channel conditions. As an example, the lateral bars were considered a detrimental feature, whereas, the point bars were not. The lateral bars were considered detrimental because they appeared more dynamic than the point bars (i.e., changing their size and position more readily than point bars). Lateral bars were often observed directly adjacent to a source of channel sediment, such as a landslide, and often remain for some time after the landslide has revegetated. The association of lateral bars and sediment sources is not unique to the Gualala River Watershed. By tracking all of the lateral bars, the changes in channel deposits can be better documented. Lateral bars that remain stable become a measure of the baseline condition. This method was applied to all of the north coast watersheds being studied by the NCWAP program.

Table 2-1
Database Dictionary for GIS Mapped Fluvial Geomorphic Attributes

wc - wide channel	**ag – aggrading reach**
br – braided channel	**dg – degrading reach**
rf – riffle	**in – incised reach**
po – pool	ox – oxbow meander
fl – falls	ab – abandoned channel
uf – uniform flow	am – abandoned meander
tf – turbulent flow	**cc – cutoff chute**
bw – backwater reach	**tf – tributary fan**
pb - point bar	lj - log jam
lb - lateral bar	**ig - inner gorge**
mb – mid-channel bar	**el - eroding left bank (facing downstream)**
jb - bar at junction of channels	**er - eroding right bank (facing downstream)**
tb - transverse bar	**la - active landslide deposit**
vb - vegetated bar	**lo - older landslide deposit**
vp - partially vegetated bar	**dr – displaced riparian vegetation**
bc – blocked channel	ms – man-made structure

The CGS developed maps of the fluvial geomorphology for all watercourses in the Gualala River Watershed designated by blue lines on published U.S. Geological Survey (USGS) 1:24,000-scale topographic quadrangle maps. Time-series fluvial geomorphic mapping conducted for the project provided data to allow for evaluation of changes in channel geomorphology between 1984 and 1999/2000. Other fluvial parameters mapped by CGS at this reconnaissance scale include channel slope calculated from a 10-meter Digital Elevation Model (DEM) (provided by Fire and Resource Assessment Program [FRAP]) and channel type, using the Rosgen classification system (Rosgen, 1996).

2.1.3 VEGETATION AND LAND USE

Progression of Timber Harvest Operations and Ranchland Development

Presenting the progression of timber operations and ranchland conversions was limited by air photo availability. This includes 1936 (Mendocino), 1942 (Sonoma), 1952 (Mendocino) 1961 (Entire Watershed) 1963 (Mendocino) 1965 (Sonoma) and 1981 (Entire Watershed). A few gaps in air photo coverage have been age projected back by vegetational typing (i.e., 1952 and some 1965 interpretations). For the 1974 to 1990 era, a combination of LANSAT imagery and 1988/1996 air photo interpretation was used. The CDF GIS overlays of Timber Harvest Plans were used to develop the 1991 to 2001 harvest mapping.

Road Networks

CDF examined both historic and modern road networks to characterize impacts by road debris slides and road crossing failures on stream channel morphology. Maps of road networks were interfaced with CGS Relative Landslide Potential maps and historically active landslides to show slide prone areas with

roads. CGS mapping of landslides and selected fluvial geomorphic features allowed comparison of landslide activity to instream sediment accumulations and comparison of instream sediment levels between 1984 and 1999/2000. This analysis then compared the naturally occurring historically active landslides with the road network. In addition, CDF used 1965 air photos at close scale (1:1200) to compare evolving stream channel morphology with the CGS 1984 and 1999/2000 fluvial geomorphology mapping.

CDF mapped the historic timber and ranchland roads using 1961, 1963, 1965, and 1981 aerial photographs. CDF mapped only those road segments that were in the streambed or following the stream channel at an equal elevation to the outer streambank. Maps of the modern road network used the "ICE", or U.C. Davis roads layer developed for the Gualala Total Maximum Daily Load (TMDL) (NCRWQCB 2001b). We clipped the "ICE" roads within 50 feet of a watercourse to show lengths of current roads within 50 feet of blue line streams within each subbasin.

Riparian Canopy Cover

CDF mapped riparian canopy cover throughout the watershed during three time periods that capture pre and post land use impacts to stream cover. The intent of this analysis was to provide information on trends in stream conditions thru time. The three time periods were:

1. 1942 –a period of general inactivity after the Great Depression. Approximately 80 percent of the watershed consisted of undisturbed old growth timberstands in the central and upper reaches at this time.

2. 1968 – marked the end of the tractor era when most of the old growth timber base had been harvested by timber operations and ranchland conversions.

3. Current canopy cover conditions. Mapping of current conditions incorporated both the CDFG habitat inventory surveys and GRWC/GRI stream measurements where available.

Stream reaches exposed on each side of the channel streambank at a cross section were mapped. This method mapped those reaches of blue line streams exposed bank-to-bank along the immediate stream channel, not the streambank vegetational transition line, or the flood line. Aerial photos dating to the summer low flows were used. These were the same photo sets used with the land use mapping.

2.1.4 WATER QUALITY

The NCRWQCB's Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 1994) designates ten existing and one potential beneficial use of water for the Gualala River Watershed. The NCRWQCB has responsibility for protecting all beneficial uses of water. Accordingly, the water quality parameters assessed in this report are compared to water quality objectives for the protection of all beneficial uses. However, the assessment is focused primarily on the salmonid fishery beneficial uses of COLD (cold freshwater habitat), SPWN (spawning, reproduction, and/or early development), MIGR (migration of aquatic organisms), EST (estuarine habitat), and REC-1 (water contact recreation-fishing). A complete list of beneficial uses is available in Appendix 4.

Collection of water quality data was according to standard techniques at the time of sampling. Water chemistry information collected at four sites in the watershed by the NCRWQCB in 2001 were according to standard protocols. All other data were obtained from various sources. The data from USEPA's StoRet system were collected by USGS, DWR, and NCRWQCB according to standard

protocols at the time of collection. Water temperature, aquatic macroinvertebrates, streambed particle sizes, canopy, streambed coring data, and channel profiles were collected by Gualala Redwoods, Inc. and the Gualala River Watershed Council according to accepted protocols. More detail on methods is available in Appendix 4 and the draft water quality methods manual (NCRWQCB 2001a).

Surface water quality data obtained from the USEPA's StoRet system and from NCRWQCB files were compared to water quality objectives from the Basin Plan, the Total Maximum Daily Load suggested targets, EMDS dependency relationships (thresholds) and other ranges and thresholds derived from the literature as cited in Table 2-2, below. Only the Basin Plan objectives are legal regulatory thresholds. All of the reference criteria were based on available information at the time, and may change as new data and analyses become available.

The stream water temperature range for salmonids was developed by the NCWAP team as an average of the needs of several cold water fish species, including coho salmon and steelhead trout. As such, the range does not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho salmon). The breakdowns follow:

50-60 F (10-15.6 C)	"fully suitable"
61-62 F	"moderately suitable
63 F	"somewhat suitable"
64 F	"undetermined"
65 F	"somewhat unsuitable"
66-67 F	"moderately unsuitable"
68 F	"fully unsuitable"

The literature supports a critical lethal temperature threshold of 75 F, above which death is usually imminent for many Pacific Coast salmonid species (NCRWQCB 2000).

Knopp (1993) measured a variety of instream parameters on 60 north coast streams within the Franciscan Complex. The watersheds were divided into three disturbance categories based on relative upslope disturbance and erosion potential: Index (little or no land use in the prior 40 years), Moderately Disturbed (recent land management, good stream course protection, avoidance of unstable areas), and Highly Disturbed (recent land management, large areas of disturbed soil, poor stream course protection, inconsistent avoidance of unstable areas). Knopp concluded that the median particle size of instream sediment samples was bstantially different at the 95 percent confidence level between the Index reaches and those of Moderate and High disturbance. Knopp's relationships were not used for median particle size data from the Gualala River Watershed as explained below.

Table 2-2
In-Channel Criteria Used in the Assessment of Water Quality Data

Water Quality Parameter	Range or Threshold	Source of Range or Threshold
pH	6.5-8.5	Basin Plan, p 3-3.00
Dissolved Oxygen	7.0 milligrams per liter (mg/L)	Basin Plan, p 3-3.00
Temperature	No alteration that affects BUs 1 No increase above natural > 5 F 50-60 F MWAT 2 – "fully suitable"(see EMDS breakdown above) 75 F daily max (lethal)	Basin Plan, p 3-3.00 Basin Plan, p 3-4.00 EMDS Fully Suitable Range 3 Cold water fish rearing, NCRWQCB (2000), p. 37
Settleable matter	Not to cause nuisance or adversely affect BUs	Basin Plan, p 3-2.00
Suspended load	Not to cause nuisance or adversely affect BUs	Basin Plan, p 3-2.00, 3-3.00
Turbidity	no more than 20 percent increase above natural occurring background levels	Basin Plan, p 3-3.00
Percent fines <0.85 mm	<14 percent in fish-bearing streams 4	Gualala TSD, NCRWQCB (2001b)
Percent fines <6.4 mm	<30 percent in fish-bearing streams	Gualala TSD, NCRWQCB (2001b)
V* in 3rd order streams with slopes 1-4 percent	<0.15 (mean)<0.45 (max)	Gualala TSD, NCRWQCB (2001b)
Median particle size	Please see the discussion below	Knopp (1993)

1 BUs = Basin Plan beneficial uses

2 MWAT = maximum average weekly temperature, to be compared to a 7-day moving average of daily average temperature

3 EMDS = Ecological Management Decision Support model used as a tool in the fisheries limiting factors analysis.

4 Fish-bearing streams = streams with cold water fish species

Median particle size data were available from Gualala Redwoods Inc./Gualala River Watershed Council and Coastal Forest Lands at 38 low-gradient sites (<2 percent slope) in the Gualala watershed from 1995-2001. However, those sites were predominantly less than 1 percent slope, and Knopp used sites of 1-4 percent slope. Additionally, the analysis provided in Knopp (1993) does not account for variation in the Franciscan Complex. For those reasons, the Knopp (1993) relationship of median particle size to watershed disturbance was not used. However, the NCRWQCB intends to create a workgroup to evaluate Knopp's raw data (which includes information on local site geology) to consider moving the current Gualala Redwoods, Inc./Gualala River Watershed Council (GRI/GRWC) monitoring locations to sites more comparable to Knopp, and to work towards building upon and improving the work that Knopp started.

The water quality data used in this assessment and summary plots are included in Appendix 4. The following parameters were compared to the above ranges and thresholds:

- Dissolved oxygen, pH, conductance (dissolved solids), nutrients (nitrogen, phosphorus)
- Continuous water temperature recordings from data loggers

- Turbidity and suspended solids data were not available for this assessment, and represent a limitation in the water quality part of the assessment

2.1.5 FISH HABITAT AND POPULATIONS

Data Compilation and Gap Identification

CDFG compiled existing available data and anecdotal information pertaining to salmonids and the instream habitat on the Gualala River and its tributaries and entered it into a database. Anecdotal and historic information was cross referenced with other existing data whenever possible, and rated for quality. Both were used when the information was of good quality and applicable. Instream habitat gaps were mapped and matched with corresponding land parcels. Where data gaps were identified, access was requested from landowners to conduct habitat inventory and electrofishing surveys.

Data Collection

Habitat inventories and biological data were collected following the protocol presented in the California Salmon Stream Habitat Restoration Manual (Flosi et al. 1998). Two-person crews trained in those methods conducted physical habitat inventories June through November 2001. Stream reaches were stratified based upon Rosgen channel types, and the habitat type and stream length determined for all habitat units within a survey reach.

The parameters measured were streamflow, channel type, temperature, fish habitat type, embeddedness (amount of fine sediment surrounding larger substrate particles) , shelter rating (habitat complexity based on elements such as overhanging banks, boulders, large woody debris, submerged vegetation, etc.), substrate composition (percent of different sizes), riparian canopy cover, bank composition, and bank vegetation. The data reflect instream conditions at the time of the survey.

During basin level habitat typing, full sampling of each habitat unit requires recording all characteristics of each habitat unit as per the “Instructions for completing the Habitat Inventory Data Form” (Part III). It was determined that similar stream descriptive detail could be accomplished with a sampling level of approximately 10 percent (Flosi et al. 1998).

When sampling 10 percent of the units all habitat types are measured when encountered for the first time. Thereafter, approximately 10 percent of the habitat units are randomly selected for measurement of all the physical parameters. The habitat unit type, mean length, mean width, mean depth, and maximum depth are determined for the other 90 percent of the units. Pool habitat types are also measured for instream cover and embeddedness.

Streams were surveyed until the end of anadromy was determined. Crews based this judgment on the presence of physical barriers to fish passage, a steep gradient of 8-10 percent, or a dry section of the stream 1,000 feet or more in length.

Canopy cover, embeddedness, pool depth, pool frequency, and pool shelter/cover were reported in bar charts for each of the streams surveyed. Salmonid distribution in the Gualala River Watershed was obtained using the Modified Ten Pool Protocol (Preston et al. 2001) with Smith Root Model 12 backpack electro-fishing units on eight tributaries. The Ten Pool Protocol was designed to detect the presence of coho salmon and is not a valid method for calculating fish density or age class structure (pers comm. L. Preston).

2.2 Interdisciplinary Synthesis

The interdisciplinary synthesis process involved the development of a number of tools, including models, maps, and matrices for integrating information from multiple disciplines on a watershed and subbasin scale to explore linkages among watershed processes, conditions and use. The process resulted in an expression of relationships of the landscape and its features, both natural and human-induced, to fish habitat. These tools provided a framework for identifying limiting factors and potential refugia, for developing restoration, management and conservation recommendations, and for understanding the potential for cumulative impacts.

2.2.1 Ecological Management Decision Support

To assist in the assessment, NCWAP selected the Ecological Management Decision Support (EMDS) software (Reynolds 1999) to evaluate and synthesize information on watershed and instream conditions important to salmonids during the freshwater phases of their life history. The EMDS is described in more detail in the Interdisciplinary Synthesis section of this report.

The NCWAP scientists constructed "knowledge base" models to help them evaluate how numerous management-related and environmental factors (e.g., watershed geology, stream sediment loading, land use) interact to shape anadromous salmonid habitat. Based upon these models, EMDS evaluates available data to provide insight into the conditions of the streams and watersheds for salmonids.

The NCWAP watershed assessment teams used EMDS model outputs in conjunction with other information as indicators to help them determine the patterns and processes that appear to be most important in shaping a given watershed. A scientific peer review process conducted in April of 2002 indicated that, while NCWAP's initial efforts at EMDS modeling were laudable, substantial changes to NCWAP's EMDS modeling approach were needed. At the time of the production of this report, NCWAP has implemented some, but not all of the review panel's recommendations. Hence, the model outputs are used with caution at this time. However, NCWAP staff are continuing to work to refine and improve the EMDS models, based on the peer review and further internal review.

2.2.2 Integrated Analyses Tables

NCWAP developed a number of large tabular presentations of data intended to help identify and highlight relationships across a number of important watershed factors. Key relationships examined were those among land use, landslides, relative landslide potential, and instream fish habitat. They include comparisons of:

- Landslides (acres and percent of watershed) to land type or use (woodland/grassland, areas with recent timber harvest (1991-2000), and timberland with no harvest since 1990
- Relative landslide potential classes (acres and percent watershed) to land type or use (woodland/grassland, areas with recent timber harvest (1991-2000), and timberland with no harvest since 1990
- Relative landslide potential classes (acres and percent watershed) by silviculture systems (e.g., clearcut, shelterwood, selection, etc.) and harvest practices (tractor, cable and helicopter)
- Historically active landslides and geomorphic features at different distances from streams.

These analyses are presented at the level of the overall watershed, subbasins, and planning watersheds. These are discussed in more detail in Chapter 4.

2.2.3 LIMITING FACTORS ANALYSIS

A main objective of the NCWAP and a task assigned to CDFG was to identify factors that limit production of anadromous salmonid populations in north coast watersheds. A loosely termed approach to identify these factors is often called a "limiting factors analysis" (LFA). The limiting factors concept is based upon the assumption that eventually every population must be limited by the availability of resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an over abundance, deficiency, or absence of a watershed habitat component. Identifying stream habitat factors that limit or constrain anadromous salmonid populations is an important step towards setting priorities for habitat improvement projects and management strategies aimed at the recovery of declining fish stocks and protection of viable fish populations. The NCWAP LFA was centered on evaluating summer aquatic habitat conditions. Only the freshwater habitat requirements of anadromous salmonids were addressed.

Two general categories of factors or mechanisms limit salmonid populations: density independent and density dependent mechanisms. Density independent mechanisms generally operate without regard to population density. These include factors related to habitat quality such as stream flow and water temperature. In general, if water temperatures exceed lethal levels, fish will die regardless of the population density. Density dependant mechanisms generally operate according to population density and habitat carrying capacity. Competition for food, space, and shelter are examples of density dependant factors, which affect growth and survival when populations reach or exceed the habitat carrying capacity. The NCWAP's approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. The LFA was a simplified approach to identify ecosystem components that constrain habitat capacity, fish production, and species life history diversity (Mobrand et al. 1997). The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components and may not satisfy the need for site-specific analysis at an individual landowner scale.

Components essential to the health of anadromous fish populations in freshwater habitat include canopy cover, embeddedness, pool depth, pool frequency, pool quality, and shelter/cover. Unsuitable components were associated with their effects on salmonid health and productivity. Unsuitable canopy cover was associated with increases in water temperature; unsuitable embeddedness was related to poor spawning substrate; unsuitable pool depth and frequency was associated with poor summer conditions; unsuitable shelter was related to decreased escape cover, which relates to increased predation and decreased high-flow refuge.

Both the analysis of data collected during habitat inventory surveys taken in 1999 and 2001, and the EMDS outputs identified unsuitable key components for each stream surveyed. After identifying the potential limiting factors, the factors were ranked according to the most detrimental habitat deficiencies. Higher rankings indicated higher unsuitability. The biologist's professional judgment took precedence when partial surveys were conducted which did not represent the limiting factor or data and observations inconsistencies that existed. Last, recommendations were selected and prioritized for potential habitat improvement activities.

2.2.4 RESTORATION NEEDS

Habitat Restoration Needs

Restoration priorities were developed for surveyed streams to assist landowners and watershed groups in identifying future improvement projects and watershed management strategies. CDFG used habitat survey data coupled with field observations to identify habitat restoration needs. They then considered which activities would need to come first in time in order for restoration objectives to be successful. For example, recommendations for erosion and sediment reduction would likely take priority in time over instream recommendations because instream projects would likely fail without treating upslope sediment sources. These are described in more detail in Chapter 4.

A map of potential restoration areas, Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*, was developed to incorporate multi-disciplinary sets of data to look at limiting factors that are potentially sediment-related in relationship to potential sediment sources. It includes CGS landslide data, CGS fluvial sediment mapping, CDFG instream habitat surveys, CDF mapping of historic roads that were either in streams or near streams, and U.C. Davis's Information Center for the Environment (ICE) map of the current roads in the watershed. All of the GIS data are available to the public.

The map shows:

1. Segments of the modern roads that cross or are within 60 meters of an historically active landslide.
2. Segments of the modern roads that are both within 60 meters of historically active landslides and within 60 meters of eroding stream banks.
3. The segments of the modern roads that are within 60 meters of dormant landslides.
4. The segments of the historic instream or near stream roads that may be active sediment sources.
5. Areas of upslope stream reaches in which embeddedness is a limiting factor.
6. Limiting factor for salmonids for each stream reach that was surveyed.
7. The extent of the CDFG stream surveys in 2001.

This map can be used to quickly locate:

1. Limiting factors for salmonid habitiat in surveyed streams.
2. Streams that were surveyed in 2001.
3. Areas upslope of stream reaches in which embeddedness is a limiting factor.
4. Potential sediment sites in upslope areas that may be contributing to embeddedness or shallow pool depths.

The steps involved in generating this map and the results are described in more detail in Chapter 4 and in the subbasin sections of Chapter 5.

2.2.5 POTENTIAL SALMONID REFUGIA

Establishment and maintenance of refugia or watershed reserves that contain the best existing aquatic habitat is a vital course of action toward conservation of anadromous salmonid resources (Moyle and Yoshiyama 1992, Li et al. 1995, Reeves et al. 1995). The concept of refugia is based on the premise that "patches" of aquatic habitat provide the critical ecologic functions to support wild anadromous salmonids. Anadromous salmonids exhibit typical features of "patchy populations"; they exist in dynamic environments and have developed various dispersal strategies including juvenile movements, adult straying, and relatively high fecundity for an animal that exhibits some degree of parental care through nest building (Reeves et al. 1995). Conservation of patchy populations requires conservation of several suitable habitat patches and maintaining passage corridors between them.

Spatial and Temporal Scales of Refugia

Refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams. If altered streams or watersheds recover their historic natural productivity, the abundant "source" populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat. Protection of refugia areas is noted as an essential component of salmonid conservation to ensure long-term survival of viable stocks, and is a critical element towards recovery of depressed salmonid populations (Sedell et al. 1990, Moyle and Yoshiyama 1992, Frissell 1993, Trombulak and Frissell 2000).

Refugia habitat is defined as: areas that provide shelter or protection during times of danger or distress; locations and areas of high-quality habitat that support populations limited to fragments of their former geographic range, and centers from which dispersion may take place to re-colonize areas after climate readjustment.

This definition soon becomes more complex upon considering the wide range of spatial and temporal habitat required by viable salmonid populations. Refugia habitat varies in scale from a piece of wood that provides instream shelter for a single fish or individual pools that provide cool water for groups of juveniles during hot summer months, to watersheds where conditions support viable populations of salmonid species. Refugia may also be areas where critical life stage functions such as migrations and spawning occur. Refugia of the reach scale or larger are generally more resilient than those of smaller scale to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities (Sidell et al. 1990). Although fragmented areas of suitable habitat may be important, watershed scale refugia may be needed to recover aquatic species (Moyle and Sato 1991).

Li et al. (1995) suggested three steps to use the refugia concept to conserve salmonid resources: first priority is to identify salmonid refugia and insure they are protected; second, to identify potential habitats that can be rehabilitated quickly; and third, determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Metapopulation Concept

The concept of anadromous salmonid metapopulations is important when discussing refugia. The "classic" metapopulation model proposed by Levins (1969) assumes the environment is divided into discrete "patches" of suitable habitat. These patches include streams or stream reaches that are inhabited by different breeding populations, or sub-populations (Barnhart 1994, McElhany et al. 2000).

A metapopulation consists of a group of these sub-populations which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994).

Anadromous salmonids fit nicely into the sub-population and metapopulation concept because they exhibit a strong homing behavior to natal streams forming sub-populations, and also have a tendency to stray into new areas. The straying or movement into nearby areas results in genetic exchange between sub-populations or "seeding" of other areas where populations are at low levels. This seeding comes from abundant or "source" populations supported by high-quality habitat patches which may be considered as refugia.

Habitat patches differ in suitability and population strength. In addition to the classic metapopulation model, other theoretical types of spatially structure populations have been proposed (Li et al. 1995, McElhany et al. 2000). For example, the "core and satellite" (Li et al. 1995) or "island-mainland" population (McElhany et al. 2000) model depicts a core or mainland population from which dispersal to satellites or islands results in smaller surrounding populations. Most straying occurs from the core or mainland to the satellites or islands. Satellite or island populations are more prone to extinction than the core or mainland populations (Li et al. 1995, McElhany et al. 2000). Another model termed "source-sink populations" is similar to the core-satellite or mainland-island models, but straying is (one way) only from the highly productive source towards the sink subpopulations. Sink populations are not self-sustaining and are highly dependant on migrants from the source population to survive (McElhany et al. 2000). Sink populations may inhabit typically marginal or unsuitable habitat, but when environmental conditions strongly favor salmonid production, sink population areas and may serve as important sites to buffer populations from disturbance events (Li et al. 1995) and increase basin population strength. In addition to testing new areas for potential suitable habitat, the source-sink strategy adds to the diversity of behavior patterns salmonids have adapted to maintain or expand viable populations in a dynamic aquatic environment.

The metapopulation and other spatially structured population models are important to consider when identifying refugia because in dynamic habitat, the location of suitable habitat continually changes (McElhany et al. 2000) from natural disturbance regimes and human activities (Reeves et al. 1995). Satellite, island, and sink populations need to be considered in the refugia selection process because they are an integral component of the metapopulation concept and may become the source population or refugia areas of the future.

Refugia Identification and Categorization Methods

Currently there is no established methodology to designate refugia habitat for California's anadromous salmonids. This is mainly due to a lack of sufficient data describing fish populations, meta-populations and habitat productivity across large areas. This lack of information holds true for NCWAP basins especially in terms of metapopulation dynamics. Studies are needed to determine population growth rates and straying rates of salmonid populations and sub-populations to better utilize spatial population structure to identify refugia habitat.

Classification systems, sets of criteria and rating systems, have been proposed to help identify refugia type habitat in north coast streams, particularly in Oregon and Washington (Moyle and Yoshiyama 1992, FEMAT 1993, Li et al. 1995, Trombulak and Frissell 2000, Kisup County 2000). Upon review of these works, several common themes emerge. A main theme is that refugia are not limited to areas of pristine habitat. While ecologically intact areas serve as dispersal centers for stock maintenance and

potential recovery of depressed sub-populations, lower quality habitat areas also play important roles in long term salmonid production. These areas may be considered the "islands, satellites, or sinks" in the metapopulation concept. With implementation of ecosystem management strategies aimed at maintaining or restoring natural processes, some of these areas may improve in habitat quality, show an increase in fish numbers and add to the metapopulation strength. Another common conclusion is that over time as good habitats "wink out" either through human caused, natural disturbances, or succession to new ecological states, other areas "wink on". It is important that a balance is maintained among the "winking out" sites and the "winking on" sites to insure adequate good quality habitat is available to support viable anadromous salmonid populations (Reeves et al. 1995).

NCWAP Approach

The NCWAP interdisciplinary team identified and categorized refugia habitat by using professional judgment and criteria developed for north coast watersheds. The criteria considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. Information from CDFG's habitat inventory surveys, NCWAP's EMDS stream reach, professional judgment, and local Gualala expertise were used to assess streams as potential refugia.

To help identify refugia, evaluation scores from the EMDS stream condition model were summed and ranked by highest total scores at the stream scale. The higher scores indicate higher habitat quality as measured by EMDS evaluations. Stream reach scale parameters used were canopy cover, embeddedness, pool depth, and pool shelter rating. Water temperature data were used when available. The individual parameter scores identified which habitat factors support or limit fish production (see limiting factors section). See attachments to Appendix 6 for examples of how the stream reach conditions parameters are used to rank streams according to EMDS evaluation scores.

Road density, number of stream crossings, roads proximity to streams, riparian cover, and LWD potential comprised the parameters used at the planning watershed scale. See attachments to Appendix 6 for examples of how landscape condition parameters are used to rank planning watersheds according to EMDS evaluation scores.

High Quality Refugia

- Maintains a high level of ecologic integrity (Trombulak and Frissell 2000)
- Contains the range and variability of environmental conditions necessary to maintain community and species diversity and supports natural salmonid production (Moyle and Yoshiyama 1992, Trombulak and Frissell 2000)
- Relatively undisturbed and intact riparian corridor
- All age classes of historically native salmonids present in good numbers, and a viable population of an ESA-listed salmonid species is supported (Li et al. 1995)
- Provides population "seed sources" for dispersion, gene flow and re-colonization of nearby habitats from straying local salmonids
- Contains a high degree of protection from degradation

High Potential Refugia

- Ecological integrity is diminished but remains good (Trombulak and Frissell 2000)
- Instream habitat quality remains suitable for salmonid production and is in the early stages of recovery from past disturbance
- Riparian corridor is disturbed, but remains in fair to good condition
- All age classes of historically native salmonids are present including ESA-listed species, although in diminished numbers
- Salmonid populations are reduced from historic levels, but still are likely to provide straying individuals to neighboring streams
- Currently is managed to protect natural resources and has resilience to degradation, which demonstrates a strong potential to become high-quality refugia (Moyle and Yoshiyama 1992, Trombulak and Frissell 2000)

Potential Refugia

- Ecological integrity is degraded or fragmented (Trombulak and Frissell, 2000)
- Components of instream habitat are degraded, but support some salmonid production
- Riparian corridor components are somewhat disturbed and in degraded condition
- Native anadromous salmonids are present, but in low densities; some life stages or year classes are missing or only occasionally represented
- Relative low numbers of salmonids make bstantial straying unlikely
- Current management or recent natural events have caused impacts, but if positive change in either or both occurs, responsive habitat improvements should occur

Low Quality Habitat

- Ecological integrity is impaired (Trombulak and Frissell 2000)
- Most components of instream habitat are highly impaired
- Riparian corridor components are degraded
- Salmonids are poorly represented at all life stages and year classes, but especially in older year classes
- Low numbers of salmonids make bstantial straying very unlikely
- Current management and/or natural events have substantially altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions

Potential Future Refugia

- Areas where habitat quality remains high but does not currently support anadromous salmonid populations

- An area of high-habitat quality, but anadromous fish passage is blocked by man made obstructions such as dams or poorly designed culverts at stream crossings etc.

Critical Contributing Areas

- Area contributes a critical ecological function needed by salmonids such as providing a migration corridor, conveying spawning gravels, or supplying high-quality water (Li et al. 1995)

- Riparian areas, floodplains, and wetlands that are directly linked to streams (Huntington and Frissell 1997)

Other

- Areas with insufficient data describing fish populations, habitat condition watershed conditions, or management practices

2.2.6 Development and Evaluation of Hypotheses

NCWAP provides a first cut at watershed assessment by evaluating current watershed conditions, exploring linkages among current and historic conditions and processes, and providing concrete direction for future activities. Given the challenge of accomplishing so complex a task at multiple watershed scales, the program has not established controlled experimental studies, but has instead brought together many types of information and examined it from various perspectives.

Using this material, NCWAP has formulated a set of reasonable hypotheses that can be used to take immediate steps to protect and improve watersheds and streams and to implement additional focused monitoring, assessment or research to fill information. This approach provides a framework for adaptive management.

NCWAP uses hypotheses to assess watershed conditions for supporting salmonids, to identify likely "limiting factors" and potential causes for areas with unsuitable conditions, and to consider potential trends.

The NCWAP team used a weight-of-evidence approach to reach conclusions and to develop appropriate restoration, management, conservation, and monitoring recommendations. They articulated both supportive and contrary findings as well as limitations of the information. This process included results from both disciplinary and interdisciplinary data analyses. Hypotheses and recommendations are provided for each subbasin in Chapter 5.

2.3 Watershed Assessment Approach in the Gualala

The NCWAP approach emphasizes close coordination with stakeholders. The Method Manual provides six general steps for working with local groups and other interested and knowledgeable groups or individuals. The following describes how these were implemented in the Gualala River Watershed:

- **Step One:** ***Scoping.*** The watershed assessment team met with stakeholders to identify watershed concerns, local assessment interests, existing data and gaps, and opportunities to work with local interests to answer the critical questions about watershed condition.

- **Step Two:** ***Data compilation.*** The team compiled and screened existing data according to the quality and usefulness for answering critical questions and its application to the program's EMDS

system model. Quality control processes are described in more detail in Chapter 4 of the NCWAP's draft Method Manual. Information was coordinated among the several departments.

- **Step Three:** ***Initial Analyses*****.** Preliminary reviews and assessments of the data compiled from existing sources resulted in recommendations for field work to ground-truth information from the desk top, fill data gaps, and provide perspective on the watershed that was not available from written and spatial information from the initial data compilation. While the team considered data needs in light of the guiding questions and relative importance in addressing those questions, it was not realistic within time and resource constraints to address all data gaps. For example, it was not possible to collect current water diversion information from the streams in the Gualala.

- **Step Four:** ***Fieldwork.*** Some agencies conducted necessary fieldwork, including validation of existing data, verification of imagery or photo-based analyses, and collection of new data to fill critical gaps. CGS field verification of existing data and photo interpretation was limited. This process was coordinated with the Gualala River Watershed Council, other groups, and landowners on access to private property and validation of findings.

- **Step Five:** ***Analyze data.*** This included the generation of maps, databases, and the more integrative analyses such as potential sediment restoration sites, EMDS outputs, Integrated Analysis tables, limiting factors analysis, and restoration and management recommendations.

- **Step Six:** ***Develop Watershed Synthesis Reports for Public Review.*** This included development of draft reports, workshops to review them with the public, and responses to public and peer review comments. Final products include a revised report with synthesis and detailed appendices, a state website with the report, spatial data, and an interactive GIS, and Institute for Fisheries Resources' (IFR) Klamath Resource Information System (KRIS) Gualala.

2.4 Assessment Report Conventions and Use

2.4.1 Report Utility and Usage

This report is intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, and management decisions. As noted above, the assessment operates on multiple scales ranging from the detailed and specific stream reach level to the very general basin level. A user can focus down from the subbasin finding and recommendation concerning sediment levels, for example, to the stream reach level information to determine which streams in the subbasin may be affected by a limiting factor.

2.4.2 NCWAP Products

NCWAP products available through this synthesis report, appendices, and website (www.ncwatershed.ca.gov) include the following :

- Databases of information that the NCWAP has used and collected for its analyses.

- A data catalogue which identifies all the information we considered, as well as a bibliography of other references cited in the assessment report.

- Maps showing geology, geomorphic features related to landsliding, instream sediment, relative landslide potential, and map of potential restoration sites and habitat limiting factors developed by the Department of Conservation/California Geologic Survey (DOC/CGS). Also an electronic database with information not available on the maps.

- An EMDS model that describes how watershed conditions interact at the stream reach and watershed scale to affect suitability for salmonids.
- GIS-based models and analyses such as timber harvest frequency, vegetation history, stream buffers, road locations, road density, road and stream interactions, and roads on unstable slopes.
- An interdisciplinary analysis of the results of fieldwork, historical analyses, EMDS data, and other analytical products about the suitability of stream reaches and the watershed for salmonids.
- An interagency description of historic and current conditions as they relate to suitability for salmonid production: vegetation cover and change, land use, geology and geomorphology, water quality, stream flow, water use, and instream habitat conditions for salmonids.
- Hypotheses and evaluation about watershed conditions that contribute to factors affecting salmonids.
- Recommendations for management and restoration to address limiting factors.
- Recommendations for additional monitoring to improve the assessment process.
- A CD developed through the IFR which uses the KRIS tool to store data, provide a regional bibliography of watershed studies and reports (including some NCWAP products), and store community based data over time (www.krisweb.com).

2.4.3 CALWATER 2.2A PLANNING WATERSHEDS

NCWAP is using the California Watershed Map (Calwater version 2.2a) to delineate watershed units. Calwater is a set of standardized watershed boundaries meeting standardized delineation criteria. The hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region (HR), Hydrologic Unit (HU), Hydrologic Area (HA), Hydrologic Subarea (HSA), Super Planning Watershed (SPWS), and Planning Watershed (PWS). The primary purpose of Calwater is the assignment of a single, unique indentifier code to a specific watershed polygon. The Calwater Planning Watersheds are generally from 3,000 – 10,000 acres in size.

Primary purposes for Calwater 2.2a include, but are not limited to, mapping, reporting, and statistical analysis of water resources, water supply, water quality, wildlands, agriculture, soils, forests, rangelands, fish habitat, wildlife habitat, and cross-referencing state and federal hydrologic unit or watershed codes and names.

Calwater version 2.2a is the third version of Calwater (after versions 1.2 and 2.0), and is a descendent of the 1:500,000-scale SWRCB Basin Plan Maps drawn in the late 1970s.

Line work was captured by overlaying the Basin Plan Maps on 1:24,000-scale USGS quad sheets, redrawing and digitizing lines to match 1:24,000-scale watershed boundaries, and subdividing the 4th level Hydrologic Subareas (HSAs) into 5th level Super Planning Watersheds (SPWS) and 6th level Planning Watersheds (PWS).

2.4.4 HYDROLOGY HIERARCHY

Watershed terminology often becomes confusing when discussing the different scales of watersheds involved in planning and assessment activities. The conventions used in the Gualala assessment follow the guidelines established by the Pacific Rivers Council. The descending order of scale is from basin

level (e.g., Gualala Watershed); subbasin level (this corresponds in many cases to the "super planning watershed" level in Calwater 2.2a, e.g., North Fork Gualala); watershed level (e.g., Little North Fork); and sub-watershed level (e.g., Doty Creek). The Calwater 2.2a designations are identified at the beginning of each subbasin section.

The subbasin is the assessment and planning scale used in this report as a summary framework; subbasin findings and recommendations are based upon the more specific watershed and sub-watershed level findings. Therefore, there are usually exceptions to the subbasin findings and recommendations at the finer scales. As such, the findings and recommendations at the subbasin level are somewhat more generalized than at the finer scales of watershed and sub-watershed levels. In like manner, subbasin findings and recommendations are somewhat more specific than the even more generalized, larger scale basin level findings and recommendations that are based upon a group of subbasins.

The term "watershed" is used in both the generic sense, as to describe "watershed" conditions at any scale, and as a particular term to describe the watershed scale introduced above, which contains, and is made up from multiple, smaller sub-watersheds. The watershed scale is often approximately 20 to 40 square miles in area; its sub-watersheds can be much smaller in area, but for our purposes contain at least one perennial, un-branched stream. Please be aware of this multiple usage of the term watershed, and consider the context of the term's usage to reduce confusion.

For purposes of assessment and its presentation, the Gualala River Watershed (Hydrologic Area 113.8) was subdivided into the five subbasins further defined below:

North Fork Subbasin

Same as the Calwater North Fork HSA (#113.81)

Same as the Calwater North Fork Super Planning Watershed.

Rockpile Creek Subbasin

Same as the Calwater Rockpile Creek HSA (#113.82)

Same as the Calwater Rockpile Creek Super Planning Watershed.

Buckeye Creek Subbasin

Same as the Calwater Buckeye Creek HSA (#113.83)

Same as the Calwater Buckeye Creek Super Planning Watershed.

Wheatfield Fork Subbasin

Same as the Calwater Wheatfield Fork HSA (#113.84)

Includes the following Calwater Super Planning Watersheds:

- Lower Wheatfield Fork
- Hedgepeth Lake
- Walters Ridge

South Fork/Main Gualala Subbasin

Same as the Calwater Gualala HSA (#113.85)

Includes the following Calwater Super Planning Watersheds:

- Lower South Fork Gualala River
- Marshall Creek

2.4.5 ELECTRONIC DATA CONVENTIONS

The NCWAP collected or created thousands of data records for synthesis and analysis purposes and most of these data were either created in a spatial context or converted to a spatial format. Effective use of these data between the five partner departments required establishing standards for data format, storage, management and dissemination. Early in the assessment process, we held a series of meetings designed to gain consensus on a common format for the often widely disparate data systems within each department. Our objective was to establish standards which could be used easily by each department, that were most useful and powerful for selected analysis, and would be most compatible with standards used by potential private and public sector stakeholders.

As a result, we agreed that spatial data used in NCWAP and base information disseminated to the public through the program would be in the following format (see the data catalog, Appendix 6d, for a complete description of data sources and scale):

***Data form*:** standard database format usually associated with a GIS shapefile© (ESRI) or coverage. Data were organized by watershed and distributed among watershed synthesis teams. Electronic images were retained in their current format.

***Spatial Data Projection*:** spatial data were projected from their native format to both Teale albers, North American Datum (NAD) 1927 and Universal Transverse Mercator (UTM), Zone 10, NAD 1983. Both formats were used in data analysis and synthesis.

***Scale*:** most data were created and analyzed at 1:24000 scale to (1) match the minimum analysis scale for planning watersheds, and (2) coincide with base information (e.g., stream networks) on USGS quadrangle maps (used as Digital Raster Graphics [DRG]).

***Data Sources*:** data were obtained from a variety of sources including spatial data libraries with partner departments or were created by manually digitizing from 1:24000 DRG.

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in NCWAP. Spatial data sets that formed the foundation of most analysis included the 1:24000 hydrography and the 10 meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing from a series of 1:24000 DRG then attributing with direction, routing, and distance information using a dynamic segmentation process (for more information, please see http://arconline.esri.com/arconline/whitepapers/ao/ArcGIS8.1.pdf). The resulting routed hydrography allowed for precise alignment and display of stream habitat data and other information along the stream network. The DEM was created from base contour data obtained from the USGS for the entire NCWAP region.

Source spatial data were often clipped to watershed, planning watershed, and subbasin units prior to use in analysis. Analysis often included creation of summary tables, tabulating areas, intersecting data based on selected attributes, or creation of derivative data based on analytical criteria. For more information regarding the approach to analysis and basis for selected analytical methods, see Chapter 2, Assessment Strategy and General Methods, and Chapter 4, Interdisciplinary Synthesis and Findings.

Chapter 3

Gualala Watershed Profile

A summary of the Characteristics of the Gualala River Watershed

The Gualala River watershed drains 298 square miles along the coast of southern Mendocino and northern Sonoma counties. The river enters the Pacific Ocean near the town of Gualala, 114 miles north of San Francisco and 17 miles south of Point Arena. The Gualala River Watershed is elongated, running over 32 miles long north-south, with an average width of 14 miles. Elevations vary from sea level to 2,602 feet at Gube Mountain, and terrain is most mountainous in the northern and eastern parts of the watershed (Figure 3-1). A long history of movement along the San Andreas Fault and the Tombs Creek Fault has been a dominant force in shaping the watershed. The climate is influenced by fog near the coast with seasonal temperatures ranging from 40 to 60 F, with the interior areas of the watershed ranging from below freezing to over 90 F seasonally. Rainfall also varies by location within the watershed with 33 inches falling on average near the town of Gualala and totals reaching over 63 inches in some areas within the interior.

The complexity of large watersheds makes it difficult to speak about them concerning watershed assessment and recommendation issues in other than general terms. In order to be more specific and useful to planners, managers, and landowners, it is useful to subdivide the larger watershed units into smaller subbasin units whose size is determined by the commonality of many of the distinguishing traits. Natural variation in subbasins is at least partially a product of natural and human disturbances. Other variables that can distinguish areas, or subbasins, in larger watersheds include differences in elevation, geology, soil types, aspect orientation, climate, vegetation, fauna, human population, land use and other social-economic considerations.

The Gualala River Watershed was divided into five principal subbasins for this assessment: Wheatfield Fork (37 percent of drainage), Gualala Mainstem/South Fork (21 percent), North Fork (16 percent), Buckeye 14 percent), and Rockpile (12 percent) (Figure 3-1, Table 3-1). The five subbasins conform with Calwater 2.2 Planning Watershed boundaries as explained in the Hydrology Hierarchy section at the end of this chapter. The mainstem Gualala extends only from the convergence of the North Fork and South Fork to the ocean, with much of this reach comprising the estuary. Coastal conifer forests of redwood and Douglas fir occupy the northwestern, southwestern, and central portions of the watershed, while oak-woodland and grassland cover many slopes in the interior. Coho salmon naturally inhabited the streams flowing from coniferous forest, but likely were sub-dominant to steelhead trout in interior areas due to the more open nature of the channels, less suitable habitat, and naturally warmer stream temperatures. The interior is largely grassland with scattered oaks. Surface waters in this area generally lack shade and are warmed with abundant sunshine and warmer air temperatures.

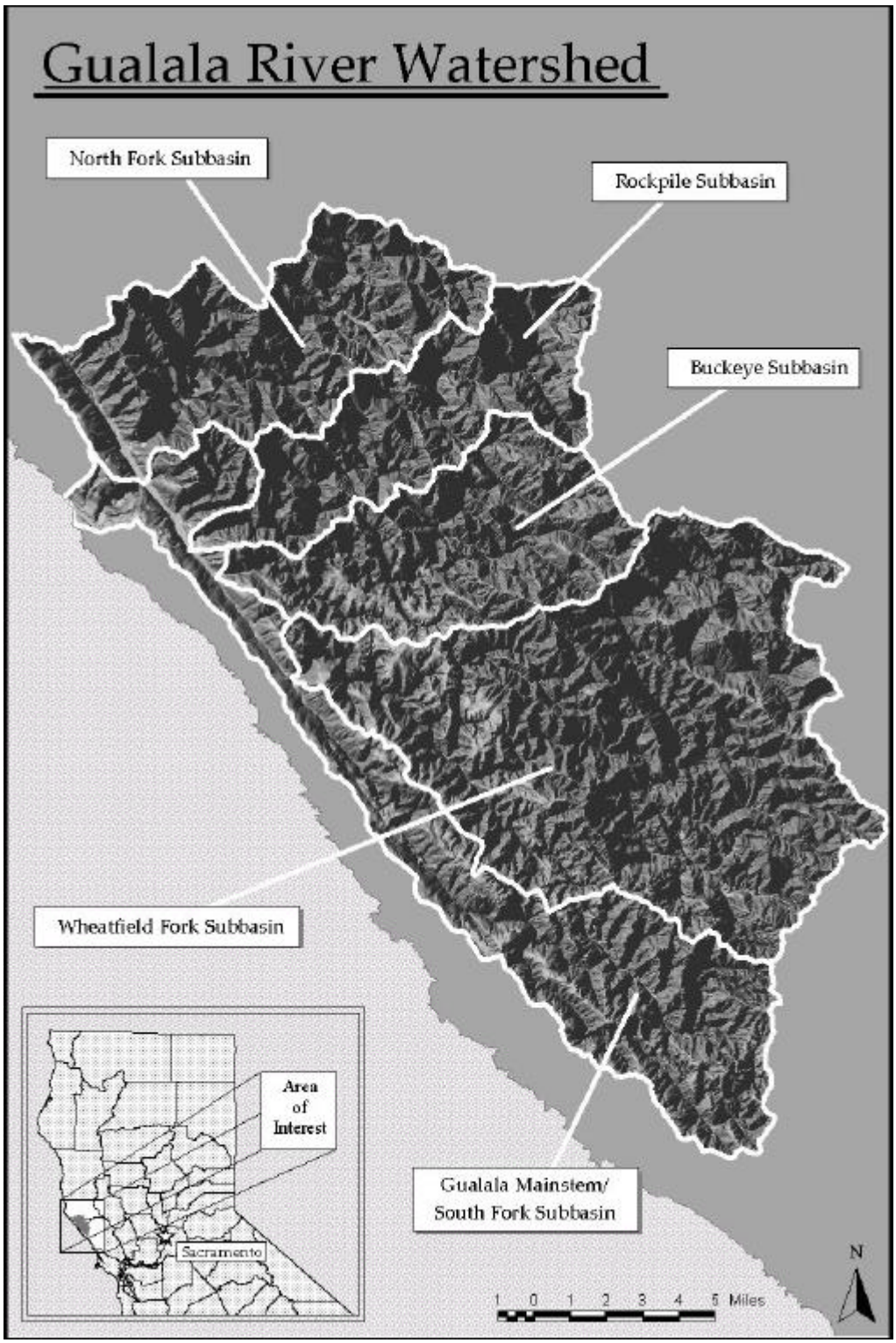


Figure 3-1
NCWAP Subbasins in the Gualala River Watershed, California

Table 3-1
Characteristics and Land Ownership of the Five Gualala River Subbasins for the NCWAP Assessment

Subbasin	North Fork	Rockpile	Buckeye	Wheatfield Fork	Mainstem South Fork	Total
Square Miles	47.9	35.0	39.9	111.6	63.7	298
Acreage, Total	30,635	22,389	25,767	71,445	40,756	190,992
Private Acres	30,635	22,389	25,767	71,279	40,703	190,773
Federal Acres	0	0	0	166	15	181
State Acres	0	0	0	0	38	38
Principal Communities	Gualala	Gualala	Gualala	Annapolis	Cazadero	
Predominant Land Use	Timber Grazing Subdivision	Timber Grazing	Timber Grazing Agriculture	Timber Grazing Agriculture	Timber Grazing Agriculture	
Predominant Vegetation Type	Coniferous Deciduous	Coniferous Deciduous	Coniferous Deciduous	Coniferous Deciduous	Coniferous Deciduous	
Miles of Blue Line Stream	127	88	90	246	134	685

The Wheatfield Fork Hydrologic Subarea is further subdivided by:				
	Super Planning Watershed			
	Hedgepeth Lake	**Lower Wheatfield Fork**	**Walters Ridge**	**Total**
Square Miles	28.5	44.8	38.3	111.6
Acreage, Total	18,230	28,703	24,511	71,445
Private Acres	18,229	28,538	24,511	71,279
Federal Acres	1	165	0	166
Principal Communities	None	Annapolis	None	
Predominant Land Use	Grazing/Vineyards	Grazing Vineyards/limited timber Grazing/vineyards		
Predominant Vegetation Type	Fir/Oak/Grasslands	Mixed young conifer/hardwood	Fir/Oak/Grassland	
State Acres	0	0	0	0
Miles of Blue Line Stream	66.1	90.8	89.0	246

3.1 Hydrology

A rainfall/runoff hydrology predominates in the Gualala River Watershed, with minimal snow accumulation. Detention time and time of concentration of rainfall are reduced by steep slopes and high rainfall amounts, causing stream levels to rise quickly in response to rainfall. Alterations of the landscape can change the hydrologic curves, flood frequencies and peaks within the subbasins of the Gualala watershed.

The mainstem of the Gualala River flows from the confluence of the South Fork and North Fork to the Pacific Ocean. This reach is influenced by seasonal closures of the river mouth, which typically occur in early summer and last until the first heavy rains of October or November, although it may also close briefly during the winter months (California Department of Fish and Game [CDFG] 1968 and EIP 1994).

Precipitation in the Gualala River Watershed is highly seasonal, most precipitation occurring October through April. Average annual precipitation ranges from 33 inches at the lower elevations near the Pacific Ocean to 63 inches at the higher elevations in the southeastern upper watershed. A list of long-term precipitation gages within or near the Gualala River Watershed and a location map are included in Appendix 1.

Two long-term precipitation stations are still operating near the watershed at lower elevations:

- The Fort Ross gage is located in the town of Fort Ross along the coast near the southern portion of the watershed, and has the longest period of record (1876 – present). It lies approximately two miles outside of the watershed boundary.
- The Cloverdale gage is located in the town of Cloverdale northeast of the central eastern portion of the watershed, approximately 11 miles outside of the watershed boundary, and has a period of record from 1894-1896 and 1903–2000.

Similar to other watersheds within the North Coast, only a few streamflow gaging stations have historically operated within the Gualala River Watershed. Streamflow data had not been collected by any agency since 1994. To gain additional streamflow data, three streamflow gaging stations were installed by North Coast Watershed Assessment Program (NCWAP) during the fall of 2000 (one on the North Fork, one on the Wheatfield Fork, and one on the South Fork above the Wheatfield Fork). Zero flow occurred at the new Wheatfield and South Fork gages during the late summer months of 2001, but the North Fork maintained a minimum base flow and was the major if not the only contributor of surface water flow to the estuary during low-flow periods. A list of existing and discontinued streamflow gaging stations, their locations, and period of record along with a location map are provided in Appendix 1.

Only one streamflow gage, South Fork Gualala River near Annapolis, U.S. Geological Survey (USGS) Station #11467500, operated within the watershed for a significant period (October 1950 - September 1971 and June 1991 - June 1994). This station was located below the confluence with the Wheatfield Fork and measured the runoff from a drainage area of 161 of the 298-square-mile Gualala River Watershed (54 percent). During the period of 1991-1994, the gage was operated to record low flows only. A summary and statistical analysis of the flow data for this station is included in Appendix 1.

The two highest flood events during the 21-year operation of the gage occurred in December 1955 at 55,000 cubic feet per second (cfs) and January 1966 at 47,800 cfs. Seven other annual peak events during the operation of the gage exceeded 30,000 cfs. While other north coast rivers experienced near record flood flows in December 1964, the South Fork Gualala gage recorded only 21,000 cfs. An examination of other streamflow gages in the area indicates recent flood events at the South Fork Gualala gage site of 30,000 cfs or greater probably occurred in 1974, 1983, 1986, 1993, 1995, and 1997.

Long-term trends in precipitation or streamflow are difficult to assess due to the general lack of spatial and temporal data. However, based on available long-term records, Maury Roos, the Chief Hydrologist for DWR, does not believe a significant trend in annual precipitation or runoff has occurred statewide or the North Coast during the last century. Affects on unit discharge hydrographs due to changes in land use or geomorphology within the watershed can not be directly assessed with existing data. Changes in rainfall/runoff characteristics can currently only be assessed by the use of computer models. The operation of the new streamflow gaging stations installed within the Gualala River Watershed for NCWAP and other existing streamflow and precipitation gages within the North Coast region should be continued. These data are crucial to modeling as well as watershed restoration activities such as determination of stream sediment and chemical transport total loads; floodplain management; design of bridge and road crossing, water diversion, fish ladder and screen, and streambank stabilization projects; and the California State Water Resources Control Board (SWRCB) water right application and license reviews and judicial water supply allocations.

A search of the SWRCB's Water Right Information System (WRIMS) was performed to determine the number and types of water rights within the Gualala River Watershed. The WRIMS database is under development and may not contain all post-1914 appropriative water right applications that are on file with the SWRCB at this time. Some pre-1914 and riparian water rights are also contained in the WRIMS database for those water rights whose users have filed a "Statement of Water Diversion and Use." SWRCB appropriative water rights and statements of use exist for a total of about 4,500 acre-feet per year (ac-ft/yr) of water from the Gualala River Watershed, at a maximum diversion rate of about 8 cfs for domestic, fire protection, irrigation, municipal, recreation, and stock watering. A list of water rights and associated information contained within WRIMS for the Gualala River Watershed along with a location map are presented in Appendix 1.

Estimated water uses for the Gualala River Watershed are presented in Table 3-2. Detailed explanations of the estimates are provided in Appendix 1.

Table 3-2
Estimated Water Uses in the Gualala River Watershed

Water Use	Estimated Maximum Withdrawal Rate (cfs)
SWRCB appropriative rights	8
Vineyards—dry and frost	27-100
Rural Residential	2.5
North Gualala Water Company	2
Sea Ranch	2.8
Potential total diversion amount	42.3 – 115.3

Any water extraction from surface or groundwater supplies, depending on the amount, location, and season, can affect streamflow, water quality, and consequently, fish habitat. The method of diversion of surface flows, such as dams and pumps without properly designed fish ladders or screens, can also impede and adversely affect all species of fish. Based on existing water rights, land use data, and observations by CDFG staff during their stream field surveys conducted from June – November 2001, current water diversions within the watershed do not appear to significantly affect streamflows, but most actual diversions or resulting streamflow reductions have not been recorded.

Current low-flow constraints in the Gualala River will most likely prohibit future additional SWRCB appropriative water allocations. However, higher use of the rights allocated to the Sea Ranch and North Gualala Water Company is expected in the future. Unregulated water rights or illegal extraction of water may, at times, have an adverse impact on fish habitat and should be monitored.

3.2 Geology

The Gualala River watershed is transected by the San Andreas Fault and the Tombs Creek Fault zones along northwest-oriented lines. The latter separates highly unstable mélange on the east from relatively more stable terrain on the west. The South Fork and the Little North Fork of the Gualala River flow within a linear valley presumably formed by the San Andreas Fault near the coast. (Plate 1, *Geologic and Geomorphic Features Related to Landsliding, Gualala River Watershed, Sonoma and Mendocino Counties, California*).

The Gualala River system and surrounding topography evolved in response to rapid geologic changes along the west coast of North America over the past 30 million years, and especially in the last five million years. The drainage networks evolved along with the changing landscape. The drainage network of the Gualala River is bedrock controlled and records the major geologic changes that took place. The landscape continues to change most notably by mass wasting. Mass wasting and erosion affect fluvial geomorphic conditions, which in turn affect aquatic habitat conditions.

In the Gualala River Watershed, the distribution of landslides, channel types, and sediment yield is controlled by the distribution and physical properties of the various geologic formations that form the foundation of the watershed. Understanding those background relationships can aid in the identification of operative processes, such as changes in the stream channel.

Over the past 5-20 million years ago, much of the region was uplifted. As it was raised and tilted, the rivers incised into bedrock in many places. Large portions of the Gualala River system are incised into heterogeneous bedrock. The bedrock is composed of several rock formations of very different properties that have been juxtaposed in a complicated pattern through multiple generations of folding, faulting, uplift, and subsidence, many of which remain evident in the topography. The resistance of the bedrock to erosion is extremely variable and depends in many ways on the rock composition and the degree of deformation. As the bedrock was uplifted, crushed, and redistributed along active faults, the Gualala River system concurrently evolved. The network of watercourses followed paths of least resistance across the landscape as determined by the distribution of hard, durable rock versus soft, easily erodible rock. Many watercourses lengthened along the weakened rock within fault zones. Many of the streams in the Gualala River Watershed and surrounding area are clearly fault controlled. All of the faults, with the exception of the San Andreas Fault, are now considered inactive. The Tombs Creek Fault System was probably active during the Pleistocene (10,000- 1.1 million years ago).

The present landscape in the Gualala River Watershed continues to change through the processes of erosion and mass wasting in ways that force the streams channels to continually adjust. The timescale over which these changes occur vary from years to millennia. The forces of erosion work against the weaker rock moving them down into the stream channels in the form of landslides. Streams erode into bedrock forming canyons. The local strength of the bedrock determines the steepness of the canyons. Over the long term, the canyon slopes steepen to a threshold at which there is quasi-equilibrium between continued steepening and mass wasting. For example, steep canyons form where bedrock is

harder and resistant. Where uplift and incision outpace mass wasting, the slopes are oversteepened. Sediment yield in the watershed is likely between 1,000 to 4,000 tons per square mile per year. Earthflows contribute about 80 percent of this amount. Shallow landsliding is common in many of the steep canyons in the watershed as equilibrium is gradually established. In many areas, large landslides are obstacles that cause the streams to change course and grade. Even in areas where faulting and landsliding are dormant, the resultant distribution of varying rock types still determines stream channel processes.

Historically active landslides (movement within the last 150 years) comprise approximately 10 percent of the watershed, while dormant landslides constitute approximately 25 percent. Large earthflows (approximately one-third of which are historically active) and gullies occur dominantly east of the Tombs Creek Fault zone and in the southern portion of the watershed. Gullies typically erode the surface of the earthflows. Rock slides, debris slides, and debris flows occur dominantly in the rocks of the Coastal Terrane where slopes are steep, as in the North Fork Subbasin and the Fuller Creek watershed in the Wheatfield Fork Subbasin. Large dormant rock slides (no movement within the last 150 years and in some cases movement thousands of years ago) occur along the San Andreas Fault zone and the Tombs Creek Fault zone (Plate 1, *Geologic and Geomorphic Features Related to Landsliding, Gualala River Watershed, Sonoma and Mendocino Counties, California*).

3.2.1 FLUVIAL GEOMORPHOLOGY

In 1984, roughly 300 of 750 miles of stream channel appeared in a disturbed condition as a result of excess sediment. By 2000, this improved by almost 50 percent with only 156 miles of the channels appearing disturbed. The distribution of the excess sediment within the stream channels is controlled by the location of sediment input and by the effectiveness of the streams to transport the sediment. Higher gradient reaches are more effective in sediment transport. The distribution of channel gradients in the Gualala River Watershed is depicted in Figure 3-2. The distribution of the excess sediment observed in 2000 aerial photos was mainly in low gradient reaches (Figure 3-3).

Low-gradient reaches tended to accumulate excess sediment over long periods. For example, rising sea levels at the end of the Ice Ages (10,000 years ago) drowned the lower reaches of the major tributaries resulting in substantial sediment deposition that formed a near level wedge of sediment. The wedge of sediment comprises the flood plains of the Little North, North, Wheatfield, and South Forks of the Gualala River. Those streams are very low gradient.

Landslides are the main source of sediment delivered to the streams. The distribution of instream sediment reflects the distribution of landslides indicating a strong relationship (Figure 3-4). Sixty-six percent of the excess sediment occurred within 50 meters of landslides. Even landslides classified as dormant seem to play a continuing role on the distribution of instream sediment.

Comparison of the distribution of instream sediment between 1984 and 1999/2000 shows a general watershed-wide reduction in excess instream sediment. This indicates that sediment transport exceeded sediment input over this period and may indicate progressive recovery from past disturbances. The amount of this change is tabulated in Table 3-3.

Table 3-3
Gualala River Watershed - Stream Characteristics Representing Sediment Sources or Storage

Subbasin	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Disturbed Channel Length (miles)	Percent Total Stream for Entire Watershed or Subbasin	Disturbed Channel Length (miles)	Percent Total Stream for Entire Watershed or Subbasin	Percent Length Change	Total Stream Length (miles)
Gualala River Watershed	***156.8***	***21.0***	***297.8***	***39.9***	***-47.3***	***745.8***
North Fork Subbasin	29.2	23.0	48.3	38.1	-39.5	126.7
Rockpile Creek Subbasin	19.8	22.4	32.0	36.3	-38.3	88.2
Buckeye Creek Subbasin	17.9	19.8	41.6	46.0	-56.9	90.4
Wheatfield Fork Subbasin	56.7	18.9	118.9	39.6	-52.3	300.6
Gualala Subbasin	33.2	23.7	57.0	40.8	-41.8	140.0

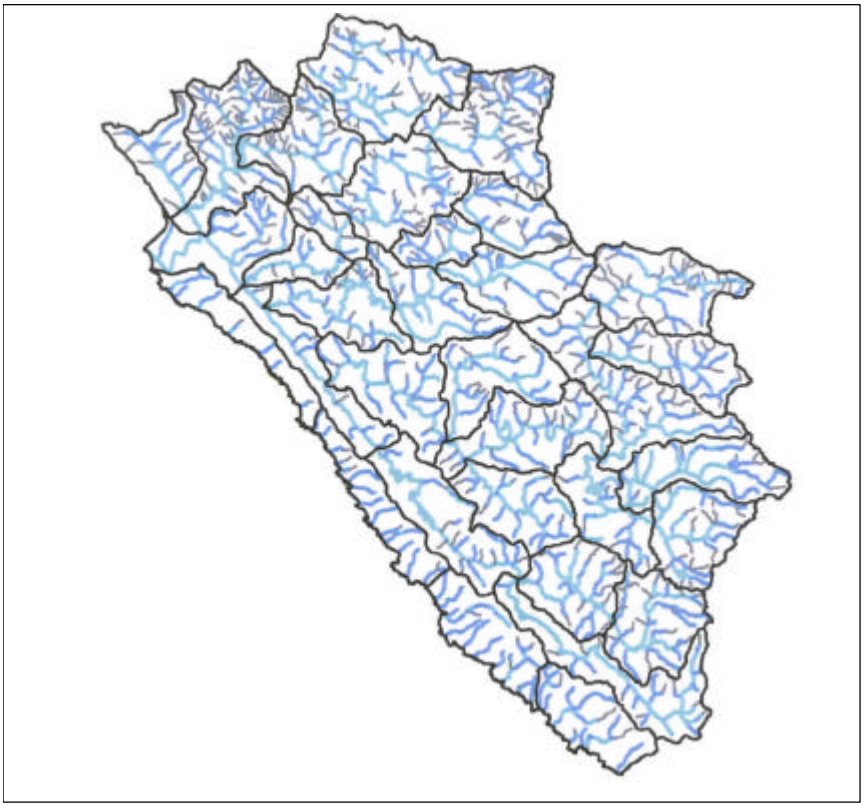


Figure 3-2
Distribution of Channel Gradients in the Gualala River Watershed

Gualala River watershed showing channel type as response (light blue), transport (violet) or source (gray). Response reaches are approximately 459 km (39 percent) of the total 1188 km USGS 1:24,000 blue line streams. Transport reaches are approximately 439 km (37 percent) of the USGS channels. Source reaches are the remaining 290 km (24 percent). Response reaches are those with a blue line channel gradient of less than 4 percent. Transport reaches have gradients of between 4 and 20 percent. Source reaches have gradient above 20 percent. Channel gradients are calculated from USGS 10 meter grid DEMs. Green grid is USGS topographic 7.5-minute boundaries. Black dashed lines are CalWater2.2 planning watershed boundaries.

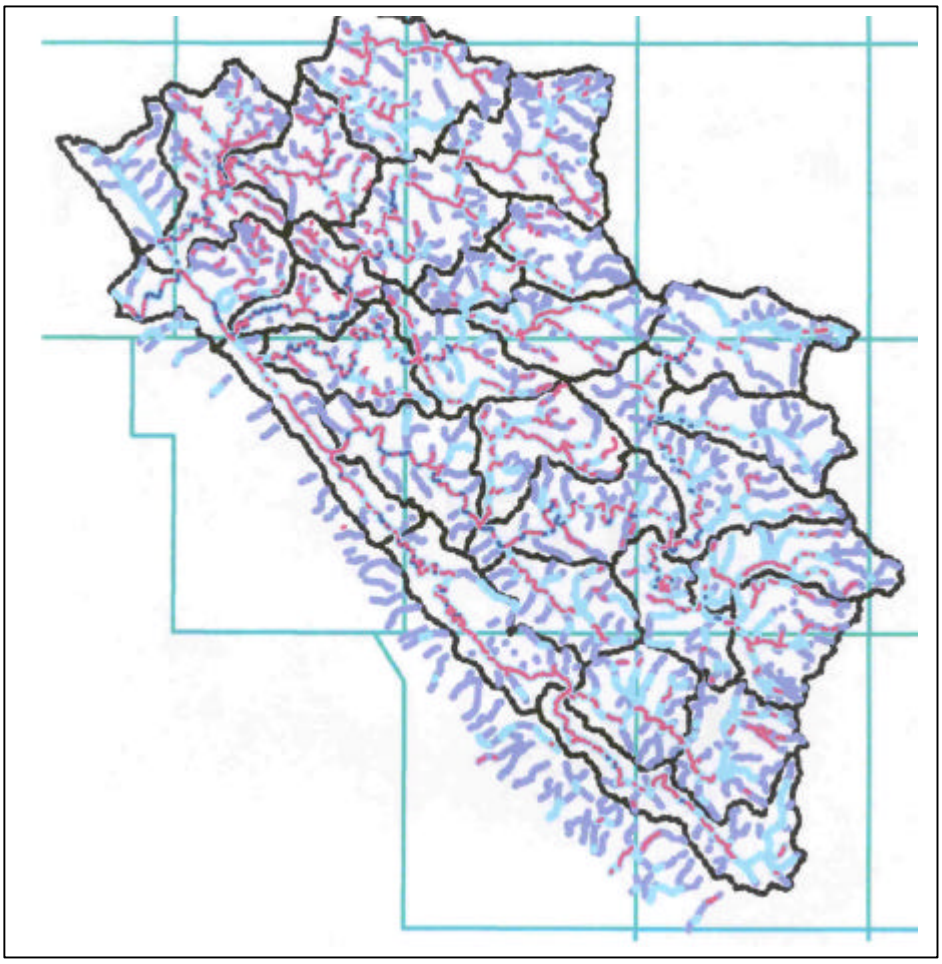


Figure 3-3
Distribution of the Excess Sediment in the Gualala River Watershed in 2000, Mainly in Low-Gradient Reaches

Mapped channel characteristics for 1999 and 2000 that suggest excess deposition or sediment delivery are shown in red, and other mapped channel sediment deposits in blue. Light blue lines are response reaches, slope less than 4 percent, and violet lines are transport reaches, slopes between 4 and 20 percent. Green grid is USGS topographic 7.5-minute boundaries. Black dashed lines are CalWater2.2 planning watershed boundaries.

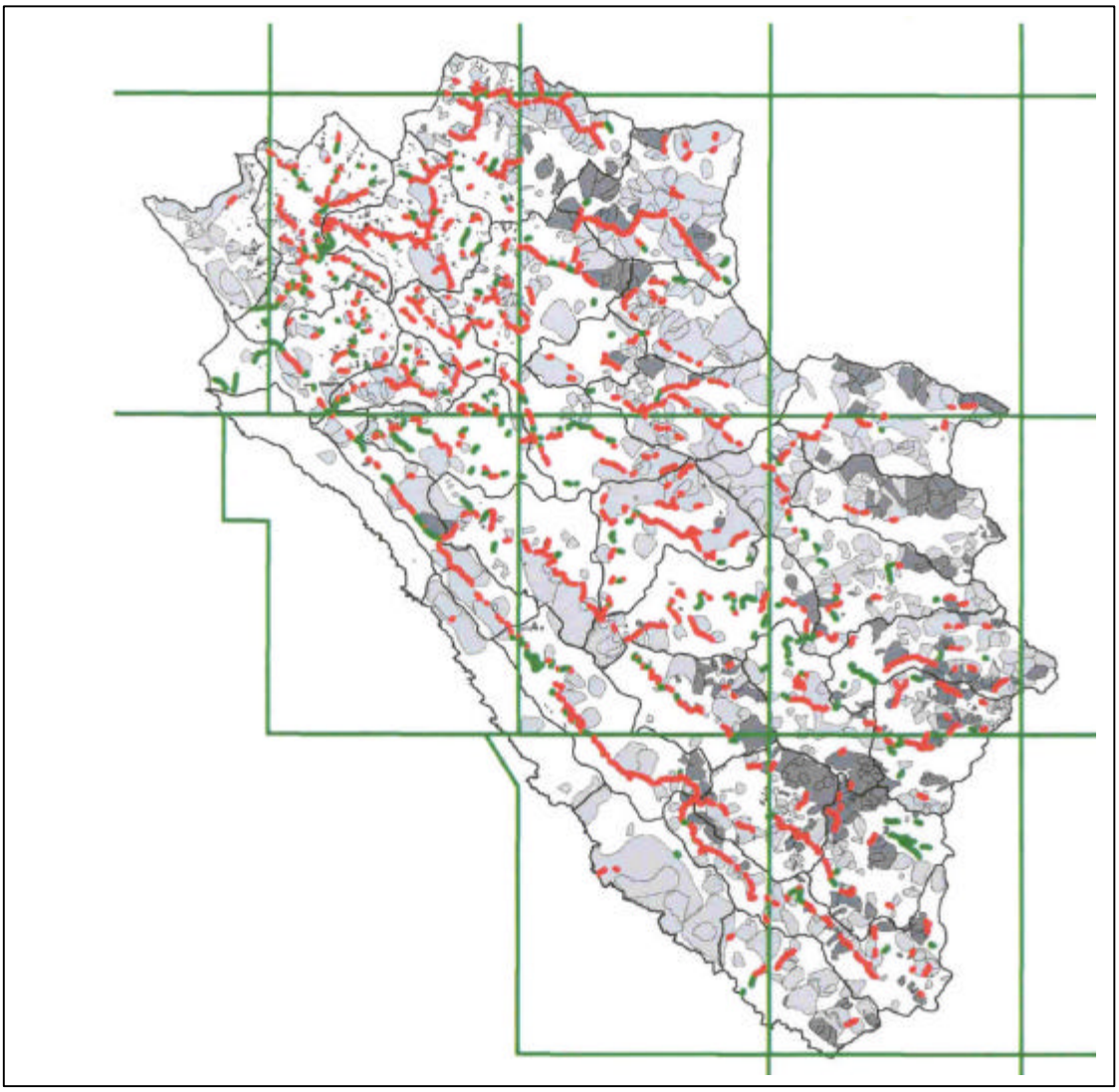


Figure 3-4
Distribution of Landslides in the Gualala River Watershed

Those reached shown in red represent the 70 percent of 1,355 mapped reaches with sediment deposition and erosion stream characteristics within 50 meters of an active or dormant deep seated landslide. Other mapped stream reaches are shown in green. Light gray polygons are dormant and dark gray are historically active deep-seated landslides. Green grid is USGS topographic 7.5-minute boundaries.

3.3 Vegetation

Prior to European settlement, coniferous forest extended throughout approximately two thirds of the Gualala River Watershed. Dense old growth redwood forests occupied the northwestern portion of the Gualala River Watershed, particularly the alluvial North Fork Subbasin. Old growth redwood also lined the long and narrow South Fork valley. Douglas fir predominated in central and mid-slope locations more distant from the coast.

Further inland in the eastern portion of the Gualala River Watershed, the natural distribution of Douglas fir becomes increasingly fragmented. Here, the long summer drought limits Douglas fir to north facing slopes. The oak-woodland predominates as a more continuous distribution on higher, inland terrain the more distant from the coastal marine influence. Large areas of prairie grassland occupy the driest sites along ridge and upslope locations. These occupy larger continuous areas on the highest and easternmost areas of the Gualala River Watershed. Quantitative details are provided in Appendix 3, pages 30–32.

3.4 Land Use

The Gualala River Watershed has one of the longest spans of historical use compared to other north coast watersheds. Logging of the virgin old growth redwood forest began during the mid 1800s. The first documented account dates to 1862 in lower portions of the watershed near coastal ramp and port facilities. This includes the lower reaches of the Little North Fork, North Fork, Pepperwood creeks, and the lowest reaches of Rockpile and Buckeye creeks at the confluence with the South Fork. There was concentrated demand for the resource after the 1906 earthquake and rebuilding of San Francisco. The first logging methods used oxen teams to move large old growth redwood logs to terminal points of lateral connecting rail lines. The original rail line ran along the South Fork. Watercourses were frequently used as skid paths to move logs downslope including the use of splash dams. Main rivers were used to float logs downstream. Fire was used extensively to reduce slash during logging and in attempts to convert redwood forest to grazing land after the logging.

Early logging activities left a legacy of impacts, some of which persist to the present. Splash dams and log drives tended to flatten and simplify stream channels. Rail line construction included massive cut and fill excavation along roadbeds which followed streams. Although wood trestles were built over larger watercourses, smaller watercourses were crossed by wood and earth fill which later failed. The introduction of the steam donkey by the turn of the century reduced ground impacts by cable pulling large logs from fixed locations, but allowed much more widespread forest harvest. These operations did not disturb the ground to the extent of more recent tractor operations characterized by large-scale sideslope excavations and skid trail networks. The gasoline powered crawler tractors made their appearance in the North Coast in the late 1920s, but logging in the Gualala was inactive during the Great Depression.

Increased demand for lumber products during the 1950s coincided with the widespread deployment of heavy tractors that were greatly improved by technology advanced during World War II. Early versions of the D-8 and D-10 tractors, using refined track mounts and suspension systems, and powered by diesel engines, were ideally suited for moving large diameter logs over difficult terrain. This equipment was readily maneuverable, enabling large areas to be worked over in short time periods. Rail line networks were quickly abandoned and diesel powered log trucks transported logs along seasonal roads. Between 1952 and 1960, tractor method harvesting extended in a broad sweep from the upper reaches of the North Fork, east through the central and upper reaches of Rockpile and Buckeye creeks, and throughout lower and middle reaches of Wheatfield Fork. Harvest operations followed straight parcel lines regardless of watercourse condition or difficult terrain. Roads often followed the stream channel to enable downslope skidding. Many roads had steep gradients designed to access all positions of the sideslope. Skid trails frequently followed or crossed ephemeral stream channels. Landings were often located in, or adjacent to, watercourses. These were built by pushing woody debris into the channel,

and overtopping by dirt fill. Across steep terrain, skid trials cut deep into the sideslopes, creating a terraced effect. By 1964, tractor harvesting had continued at an active pace to comprise a majority, and in some areas, most of the timbered areas in the west and central reaches of the watershed Figures 3-5.

Figure 3-5
1961 Aerial photo, Post World War II Pre-Forest Practice Rules Logging in the Buckeye Subbasin
(Franchini Creek and a new Streamside Road are in upper right)

The lack of any erosion control facilities installed throughout large areas of the watershed, coupled with the uncontrolled installation of fills and the failure to remove fills adjacent to watercourses, left the entire watershed particularly vulnerable to large storm events. Intense prolonged runoff during large storm events in 1962, 1964, and 1966 caused large scale erosion from downcutting, slides, and washing of soil and debris into watercourses. The residual effects are still observed in some areas today. The California Department of Transportation (Caltrans) aerial photos taken in June 1965 at 1:1,200 scale show stream channels meandering through wide, flat areas of buried stream pools, indicating channel aggradation. Roads following the stream channel repeatedly failed as fill sidecast washed out during peak flows. Debris slides above and below roads were frequent. Deep blowouts through landings built over the channels are numerous throughout the 1965 photos. In addition, there were numerous watercourse diversions onto roads and skid trails.

After 1964, harvest operations resumed at an active rate in the lower and middle reaches of the North Fork and entire Little North Fork to remove most of the available timber base in these areas by 1973. Other areas of mature Douglas fir in (1) higher elevation areas and (2) eastern reaches of the watershed were harvested during this time. Only pocket stands and scattered larger timbered blocks remained. Roads and landings continued to be located low on the sideslope, frequently following the stream channel. Subsequent landing blowouts and road failures have been documented along the Little North Fork and central North Fork. There were large storm events in 1972 and 1974. With ranching being the dominant use in mixed conifer, oak and woodland areas, logging of Douglas fir was frequently followed by prolonged cattle grazing. This reduced, and in many locations prevented, conifer reestablishment

altogether. Grassland became permanently established throughout the more compacted ground. In addition, removal of Douglas fir in mixed conifer-hardwood forests converted these stands to tan oak and madrone. Prolonged cattle grazing in riparian areas after harvest prevented timely reestablishment of canopy cover over fish bearing watercourses, elevating stream temperatures.

After 1973, logging operations had slowed. Smaller selection method harvests were predominant. By this time, tractor-yarding methods changed to maintain equipment exclusion zones and minimum vegetation retention standards adjacent to watercourses per 1973 Forest Practice Rules. New road locations were moved upslope, but the practice of using existing roads located near streams continued. The new forest practice rules limited the cutblock size, creating smaller logged areas.

In the 1990s, harvest activity increased. Smaller but numerous clearcut blocks appear in the redwood lowland areas of the Gualala Redwoods, Inc. ownership. Throughout the watershed, cable method yarding appears with new road construction now moved to upslope and ridgeline locations. Many sections of the older seasonal roads following the stream channel either are abandoned or removed. Numerous seasonal roads still exist in close proximity to streams, and are used as needed during timber harvest activities. During the mid 1990s, Coastal Forestlands (formerly R&J Timber Co., and purchased by Pioneer Resources in 1998) submitted numerous seed tree overstory removal/dispersed timber harvest plans (THPs), covering large areas but removing scattered single trees and remnant stands left from 1960s era entries. Agency review of these THPs clarified road upgrade work requirements to repair the erosion conditions of pre-1973 operations. There has been little harvesting in these areas since 1998. Residential development near the coast, and vineyard development inland, become more active by the1990s. Ninety-five percent of the Gualala watershed is privately owned.

Table 3-4
Timber Harvest History - Gualala Watershed

Time Period	Acres Under Operation	Type of Operation	Mean Annual Increment (acres/percent by year)
1932– 1942	1,010	Stand Replacement	101 (.05)
1942 – 1952	4,260	Stand Replacement	426 (0.2)
1952 – 1960	54,200	Stand Replacement	6,775 (3.5)
1960 – 1964	20,400	Stand Replacement	5,100 (2.7)
1964 – 1973	10,950	Stand Replacement	1,950 (1.0)
1974 – 1990	9,900	Stand Replacement	619 (.3)
1991 – 2001	45,070	Timber Harvest Plans (THPs)	4,507 (2.4)

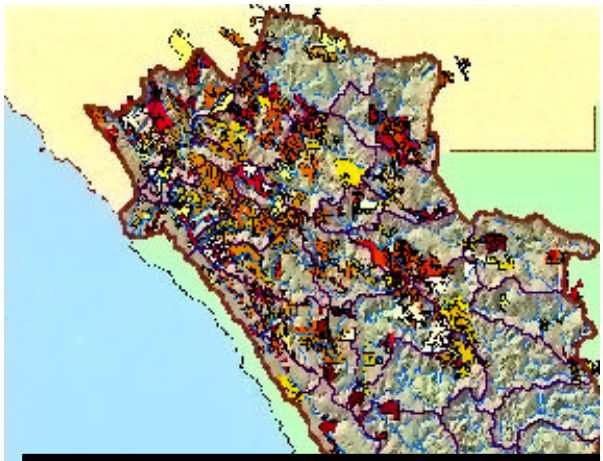
1942 – 1952 Stand Replacement Operations

1942 – 1960 Stand Replacement Operations

1942 – 1964 Stand Replacement Operations

1942 - 1973 Stand Replacement Operations
[1964 – 1973 (red)]

1973 – 1990 Stand Replacement Operations



1991 – 2001 Timber Harvest Plans

Figure 3-6
Cumulative Stand Replacement Operations 1942 – 1973, and Post 1973 Operations and THPs

Changes in canopy conditions in the Gualala River Watershed were observed from summertime aerial photo sets for 1942, 1968, and 1999. Those photos provide a good perspective on conditions through the period to the present. Bank-to-bank canopy coverage was determined from aerial photos and mapped as "canopy" where canopy was fully covering stream banks. Canopy that covered only one bank or fully exposed channel were mapped as "exposed." This method maps those reaches of blue line streams exposed bank to bank along the immediate stream channel, not the streambank vegetational transition line, or flood line.

Canopy cover was complete in most tributaries in 1942 indicating advanced regeneration from the original old growth logging along the South Fork and lower to mid reaches of the North Fork. The remainder of this subbasin in 1942 consisted of undisturbed old growth conifer timberland in the central reaches, and natural grassland oak woodlands in upland areas. Most stream reaches at this time had nearly full canopy cover. The larger order, downstream stream reaches were naturally aggraded and wide and thereby exposed (Figure 3-7).

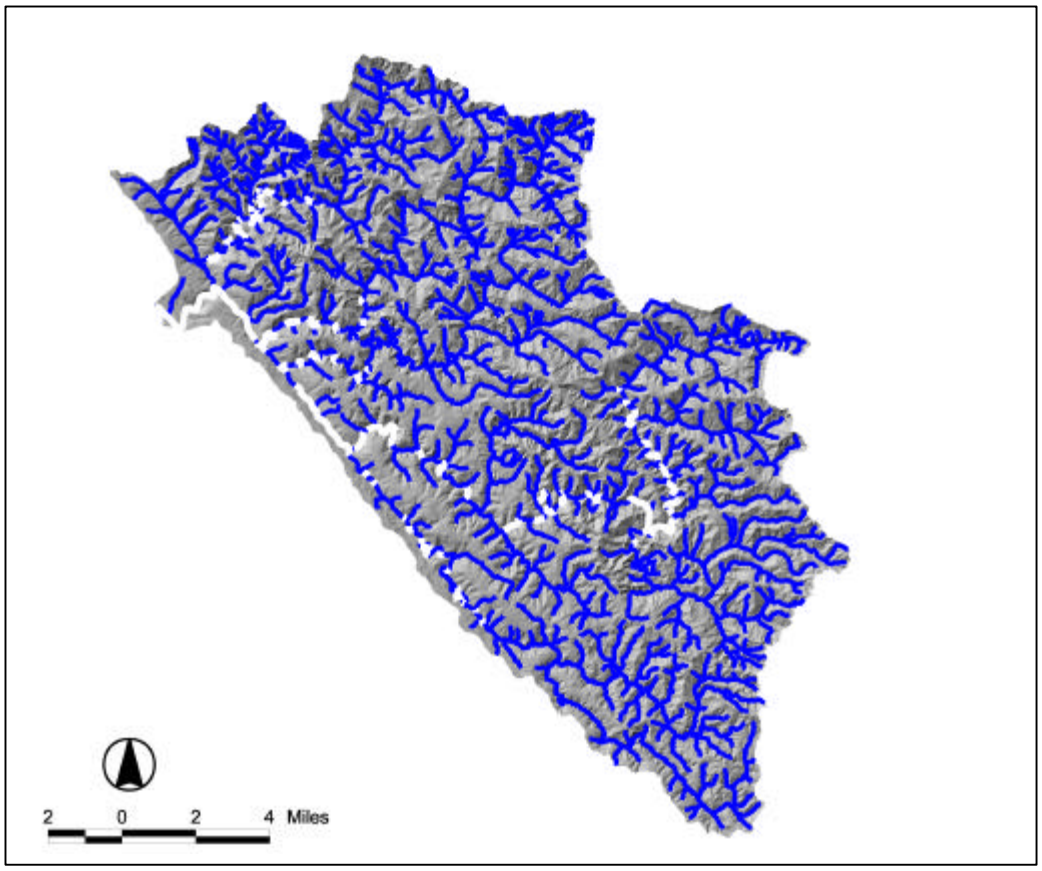


Figure 3-7
1942 Bank-to-Bank Stream Exposure (white) in Generally Undisturbed Old Growth Watershed Conditions
Turn of the century logging was limited to the South Fork valley watershed, and the lower to middle reaches of the North Fork. Dark blue represents partial to entire canopy cover over blue line streams.

Large-scale block clearance timber harvest projects in the mid-20th-century entirely eliminated overstory shade canopy over most salmonid spawning ground by 1968 (Figure 3-8).

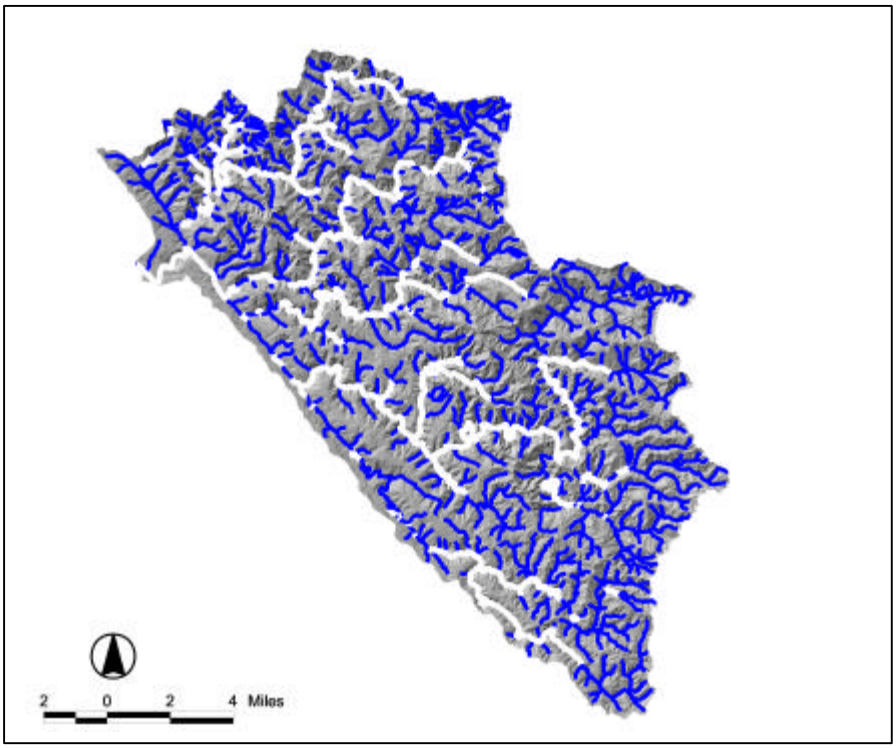


Figure 3-8
1968 Bank-to-Bank Stream Exposure (white)
Pre-1973 tractor harvesting was mostly complete. Partial to entire stream cover is shown in dark blue.

The end of the tractor logging era and infrequent timber harvesting until the late 1980s allowed canopy cover in-growth in most areas. These improvements in canopy coverage are evident in comparing the 1968 map to the 1999 map, with the amount of exposed stream length reduced from a range of 40-70 percent to approximately 25 percent averaged throughout the watershed (Figure 3-9). Streamside canopy now consists primarily of 40-year-old pole- to mid-sized conifers and mixed conifer/hardwood stands in the middle to upper subbasin reaches.

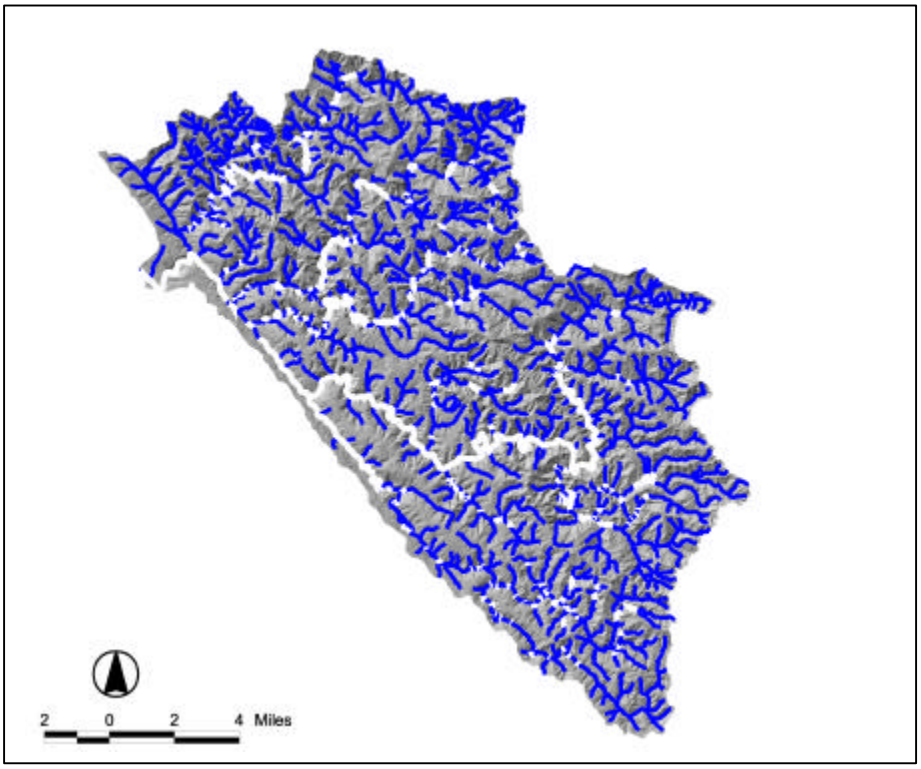


Figure 3-9
1999/2000 Bank-to-Bank Stream Exposure (White), Reflecting Vegetational Ingrowth Since 1968

3.5 Water Quality

The U. S. Environmental Protection Agency (USEPA) data from April of 1974 to June of 1988 at the South Fork near Valley Crossing, the Wheatfield Fork near Valley Crossing, and the mainstem Gualala downstream of the North Fork indicate a moderately hard water stream with pH slightly above neutral, high dissolved oxygen, low dissolved solids, and low nutrients (nitrogen and phosphorus). Sampling by the NCRWQCB during 2001 at those and two additional sites (South Fork at Hauser Bridge, and House Creek near the mouth) were not substantially different from the StoRet data. While these parameters may vary to some degree with season and local conditions, all values were within the NCRWQCB's Basin Plan limits and comparable to data in the NCRWQCB files for other north coast streams. There were no large differences among the stations, though it appears that House Creek may be higher in hardness, alkalinity, and conductance than the mainstem stations. However, the small amount of data available are not sufficient to make a conclusive statement. Appendix 4 contains the raw data and graphs.

Water temperature data were available from the Gualala River Watershed Council and Gualala Redwoods, Inc and NCRWQCB file copies of Coast Forest Lands, Ltd activities. Water temperatures expressed as the highest of the floating weekly average for the summer (maximum weekly average temperature [MWAT]) and seasonal maximum were in the range of suitability for salmonids in the North Fork mainstem and other tributaries where measured. MWAT values exceeded suitable conditions in most of the mainstem areas where measured in the Rockpile, Buckeye, Wheatfield Fork, and South Fork/Main Gualala. Seasonal maxima followed the same pattern, approaching lethal or above lethal in mainstem areas mentioned and not in the North Fork mainstem and other tributaries.

Linear regression of canopy and water temperature metrics (MWAT and seasonal maximum) for 11 sites in the Gualala River Watershed showed a relationship of higher water temperatures with lower canopy values (Appendix 4). Shade is one factor in water temperatures, with flow, air temperature, and humidity being other major controlling factors. As such, the correlation of lower canopy values with higher water temperatures is expected.

Generally, as watershed size increases, so does water temperature. As water moves downstream the length of exposure to air temperature and sunlight increase and an increase in temperature is expected. Additionally, streams tend to widen as they flow downstream, and wider channels are less apt to have full shade cover and will be influenced by cooler riparian air temperatures to a lesser degree due to the volume of water. A linear regression of watershed size to MWAT using data from north coast streams showed a relationship of warming downstream as watershed size increased (Appendix 4). However, the opposite is true when one looks at water temperatures in the North Fork mainstem. Temperatures actually cool as the stream moves downstream (larger watershed) most likely due to cooling from tributary flows, increased canopy, and coastal influences.

While the regressions are easily explained in a general sense, neither of those analyses included the factors of stream flow, stream aspect, thermal reach length, air temperature, relative location in the watershed, contributions from tributaries and groundwater inflow, and differences among years. However, in order to provide a better perspective on the spatial distribution of water temperatures in the watershed, further analysis by the Gualala River Watershed Council (GRWC) using the spot temperatures from the CDFG habitat inventory survey for 2001 is planned, as is a search for data from the upper areas of the watersheds. GRWC also is actively seeking access for temperature monitoring

locations in the upper watershed areas for the coming years to develop more information and explore the temperature relationships on a broader scale in the watershed. Water temperature modeling would also help in explaining these relationships.

On December 20, 2001, the USEPA established a sediment Total Maximum Daily Load (TMDL) for the Gualala River based on the information contained in the Gualala Technical Support Document (TSD) prepared by Regional Board staff and their consultants. The purpose of the TSD was to estimate current discharges of sediments to the surface waters of the Gualala River Watershed, and to identify the reduction in discharges necessary for achieving water quality standards contained in the North Coast Region Water Quality Control Plan. The Gualala TSD (NCRWQCB 2001b) listed eight sediment sources: road mass wasting, bank erosion, natural mass wasting, surficial road erosion, road gullies, road-stream crossing failures, skid trails, and features associated with other timber harvest activities. Rates of sediment delivery were estimated based on feature area, average depth of failure of 56 measured features, proximity to watercourses, and a conversion factor of 1.48 tons/yd^3. Estimates of sediment delivery were presented by geographic association with management activity. For TMDL purposes, the NCRWQCB contractor only mapped a subset of the total small landslide population, with smaller features accounted for through field surveys.

The purpose of the TSD mass wasting inventory was to identify recently active (1978-2000) mass wasting features (defined as those features that exhibit signs of movement discernible from sequential sets of aerial photos at a 1:24,000 scale) for purposes of developing estimates of current sediment delivery associated with both natural and anthropogenic sources.

The TSD mass wasting inventory focused only on recent (1978-2000) features. Relict mass wasting features that were re-vegetated in the 1988 photos were not mapped by the NCRWQCB contractor.

The Regional Board aerial photo analysis mass wasting inventory included only features > 10,000 feet^2 in plan area. NCRWQCB developed estimates of delivery from mass wasting features < 10,000 feet^2 from on-the-ground measurements to account for the contribution of smaller features difficult to identify due to photo scale, aspect, and shading. Features were mapped on 1988 (entire watershed), 1999 (Sonoma County), and 2000 (Mendocino County) aerial photos.

The NCRWQCB classified features by management association based on (1) geographic intersection of mass wasting features with management features and (2) professional judgment. NCRWQCB assumed that features with no apparent association with management activities were natural.

The NCRWQCB contractor identified only the recently active portions of large, deep features, usually the toe or side scarps. Similarly, large, complex earthflows were not identified in their entirety for the TSD mass wasting inventory. Instead, recently actively eroding surfaces larger than 10,000 ft^2 were individually identified within complex earthflow features. NCRWQCB estimated delivery associated with earthflow creep separately.

In the course of geologic mapping completed by CGS, partial estimates of sediment loads were developed (see Section 2.1.2 and Appendix 2 for complete description of mapping). CGS documented all observable landslides regardless of their potential for sediment delivery to streams and included both small landslides as well as other sediment sources including large earthflows, rockslides, debris slide slopes and inner gorges. CGS also categorized landslides as historically active (movement within the last 150 years) and dormant (movement older than 150 years) based on geomorphic characteristics that

suggest recent movement as observed either in the field or on aerial photos. Mapped deep-seated landslides include both earthflows and rockslides that are of sufficient size that their estimated depth of lower failure surface is greater than 10 feet.

CGS found a substantially larger number of small landslides depicted as points on the geologic map than previously mapped by the NCRWQCB (2001b), 618 versus 2128, possibly because NCRWQCB mapped only features greater than 10,000 feet^2 in plan area judged to have occurred within the timeframe of their analysis (1978-2000). NCRWQCB estimated the contribution of features smaller than 10,000 feet^2 from field data. CGS found that approximately 34 percent of the 298 square mile Gualala River Watershed is underlain by deep-seated landslides, e.g., earthflows or rock slides. Approximately 9 percent of the entire watershed contains historically active earthflows (8.3 percent) and rock slides (0.5 percent). The remaining deep-seated landslides are either dormant earthflows (8 percent of watershed area) or dormant rockslides (16.8 percent of watershed area).

CGS did not examine whether human activity contributed to deep-seated landslides, however**,** CGS considers both dormant and historically active landslides capable of generating background sediment loads. Many historically active landslides are found within larger areas of older dormant landslides, suggesting that some recent landslides are the result of reactivation of portions of dormant landslides. In addition, CGS found that most (58 percent) of the CGS smaller landslides mapped as points lie within larger deep-seated landslides or geomorphic terrains created by landsliding. This suggests preferential development of smaller landslides on existing unstable slopes. Additional study is needed in order to assign the actual cause of small landslides to either background or anthropogenic activities or some combination of both. It should be noted that the activity rating of a landslide (historically active or dormant) is based on geomorphic characteristics that suggest recent movement as observed either in the field or on aerial photos.

The overall rate of movement of historically active landslides is higher than for dormant landslides and stable ground. Historically active landslides result in greater disruption to the terrain (disruptions include sharper topography, angular blocks and scraps, and hummocky undrained depressions) and this provides greater opportunity of infiltration of rainfall that maintains the instability and accelerated surface erosion. In comparison, the rate of movement of dormant landslides is sufficiently low to allow surface geomorphic processes to erode and smooth the landscape reducing topographic irregularities and allowing the development of internal drainage networks. In the Gualala River watershed, the average area of historically active deep-seated landslides mapped as a polygon is approximately 40 acres, equating to at least 1,000,000 tons. The Monitoring Study Group Report (1999, and references therein) found that a majority of very small landslides (significantly less than one acre) that occur after timber harvesting activities was directly related to roads; field experience shows that most road-caused failures are significantly less than an acre in size. This size disparity (40 acres for the average historically active deep-seated landslide versus road-related failures after timber harvesting of less than one acre) indicates that deep-seated landslides result dominantly from larger scale conditions different than the likely anthropogenic landslides caused by road construction.

Using this assumption, CGS estimated a background sediment load in the Gualala River Watershed based on the large, deep-seated landslides and from creep of soils on the other more stable terrains. This estimate was made using information on the landslide type, landslide area, stream density, stream length and stream order developed by CGS as part of their geologic and geomorphic mapping (see Appendix 2). The rates for landslide movement used in background sediment load estimates were taken

from literature and varied by landslide type. The range of rates of movement included both high and low rates; high rates included historically active earthflows (300 mm/year), historically active rockslides (50 mm/year), dormant earthflows (20 mm/year), dormant rockslides (10 mm/year), and other areas (1.6 mm/year). Low rates of movement included historically active earthflows (130 mm/year), historically active rockslides (25 mm/year), dormant earthflows (10 mm/year), dormant rockslides (5 mm/year), and other areas (1.6 mm/year). (Harden and others, 1978; Kelsey, 1977, 1978, 1987; Nolan and Janda, 1995; Swanston and others, 1995). The difference in lower and higher estimates of background sediment load reflects the variability of movement rates and soil thickness. All other model parameters were held constant (e.g., number of stream banks delivering sediment and the lengths of stream banks delivering sediment). For the purposes of estimating background sediment, terrains other than the deep-seated landslides were combined with other unmapped more stable areas even though CGS mapped much of the area as geomorphically unstable terrains (i.e., debris slide slopes or disrupted ground). Both a low and high estimate of background sediment load was developed in order to evaluate the importance of the variations in rate of landslide movement.

The results of CGS's estimate found a watershed wide annual average background sediment load of approximately 1,000 to 3,100 tons/mi^2/yr from large, deep-seated landslides, both earthflows and rockslides, combined with slower soil creep on more stable terrain. Sediment delivery from these sources was considered background for the purpose of this investigation. Most of the sediment delivered from large, deep-seated landslides (85 to 90 percent) was derived from deep-seated landslides mapped as historically active, of which 94 percent are earthflows. The remaining mass of background sediment was primarily delivered from the larger area of dormant deep-seated landslides. This range of background sediment load is consistent with those found in other sediment load studies on the north coast of California including a sediment transport study later used for reservoir design (see CGS report in Appendix 2). In addition, a three-fold variability in sediment load rate is consistent with field studies that measured sediment delivery over time (Kelsey, 1977, 1987; Nolan and Janda, 1995).

3.5.1 MACROINVERTEBRATES

Freshwater benthic macroinvertebrates live primarily on instream boulder, cobble or gravel substrate, and include worms, snails, clams, crustaceans, aquatic beetles, the nymph forms of mayflies, stoneflies, dragonflies and damselflies and larval forms of caddisflies and true flies. They are most easily categorized into feeding guilds, species that obtain a common food source in a similar manner: shredders, filter-collectors, collect-gatherers, scrapers-grazers, and predators.

The complex of benthic macro invertebrates is influenced by location in the watershed. The Gualala River mainstem is a fourth order stream, all other tributaries within the watershed are of smaller order. The predominant feeding guilds in fourth order streams are scrapers, which consume the algal growth associated with a more open canopy cover and collectors utilizing the high amount of fine particulate organic matter which has drifted downstream. First and second order streams are usually dominated by shredders, which process leaf litter and other forest debris, and collectors, which further process shredder excrement.

Species richness, species composition, and tolerance/intolerance metrics can be used as indicators of biotic conditions in a stream. Species richness and composition tend to decrease in response to habitat disturbance. Tolerance measures reflect the sensitivity of the community to aquatic sensitivity. Harrington (2000) developed the Russian River Index of Biological Integrity, which includes six metrics: taxa richness, percent dominant taxa, EPT taxa, modified EPT taxa, Shannon diversity and

tolerance value. EPT refers to the taxa of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders. The Shannon diversity index is a quantitative measure of habitat diversity. These six metrics were integrated into a single score for biotic condition categories: excellent (30-24), good (23-18), fair (17-12), and poor (11-6).

Gualala Redwoods, Inc. provided benthic macroinvertebrate data from three replicate samples collected at four sites: two sites in Dry Creek, and one site each in the Little North Fork and mainstem Gualala. The biological metrics from these sites were averaged, then compared to modified biotic condition categories. The Shannon Diversity metric was unavailable and not included in the score, thus biotic condition categories were decreased by five points to arrive at the "Visual Distribution Score": excellent (25-19), good (18-13), fair (12-7), and poor (<7) (pers comm. A. Rehn). The sites sampled on Dry Creek, Little North Fork and the mainstem Gualala indicated a "good biotic condition" (Figure 3-10).

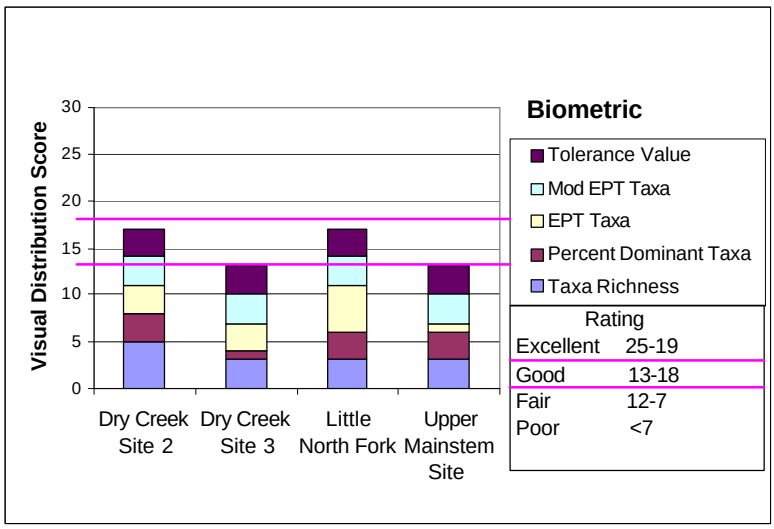


Figure 3-10
North Fork Gualala Macroinvertebrate Data, 2001

3.6 Fish/Habitat Relationships

3.6.1 Historic Fish Habitat Relationship

In 1964, 1970, 1977 and 1981, CDFG conducted stream surveys on various tributaries in the five subbasins of the Gualala River. The stream surveys conducted in 1964 and 1970 coincided with the end of an extensive period of logging in the Gualala River Watershed. The results of the historic stream surveys were not quantitative and cannot be used in comparative analyses with current habitat inventories. The data from these stream surveys provide a snapshot of the conditions at the time of the survey (Table 3-5). Terms such as excellent, good, fair and poor were based on the judgment of the biologist or scientific aid conducting the survey.

Table 3-5

Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala River Watershed, California

Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
North Fork Subbasin North Fork	9/17 and 18/1964	Excellent steelhead trout, coho salmon spawning and nursery stream. Spawning areas poor in the upper ½ of the stream and excellent in the lower ½ of the stream; Pool: Riffle ratio 50:50; Good shelter provided by logs, boulders, algae, and roots.	None	Should be managed as a steelhead trout, coho salmon stream; The future planting of coho salmon is recommended to increase the population; The removal of log jams is not recommended.
Little North Fork	9/10/1964	Fair spawning area with loose gravel available, approximately 60 percent of the stream available for spawning, spawning area suitable for steelhead trout and coho salmon; Pool: Riffle ratio 80:20; Good shelter available as undercut banks, overhanging vegetation, logs, and rocks.	30 partial barriers	Continue to manage as a steelhead trout, coho salmon spawning and nursery stream; Habitat improvement, consisting of removal of slash and debris and log jams to improve fish passage and stream condition is suggested; Possible planting of coho salmon to establish a better run is recommended.
Buckeye Subbasin Buckeye Creek	8/27/1964 8/19/1970	Good spawning and rearing area; 50 percent pools; Steelhead present. Silt and sand dominated substrate indicating poor spawning; 25 percent pools;	Some partial barriers	Replant riparian vegetation; remove log jams
North Fork Buckeye Creek	8/5/1964 8/5/1982	25 percent pools; Sluggish water with algal bloom. 40 percent pools	Slash; Log jams	Plant riparian; Improve poor logging practice. Plant riparian to reduce water temperature.
Wheatfield Subbasin Wheatfield Fork	9/28/1964	Good spawning beds; Pool: Riffle ratio 75:25; Shelter provided by boulders, logs, overhanging water grasses, and undercut banks.	Waterfall ¼ mile below the upper limit of anadromy; No complete fish passage barriers,	Clearing of the log jam and clearing of the falls

Table 3-5

Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala River Watershed, California

Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
Fuller Creek	8/18 - 19, 1964	Spawning area fair, with less than 50 percent of the streambed containing suitable spawning area and gravel; Pool: Riffle ratio 70:30; Logs, rocks, and undercut banks provided good shelter.	9 partial barriers consisting of log jams.	Removal of log jams to improve passage; Possible planting of coho salmon to re-establish a self-supporting run.
Haupt Creek	8/25/1964 6/24/1970	With a general clean-up and proper management, could become a first class steelhead trout, coho-salmon producing stream. A large amount of good spawning area available, consisting of loose gravel deposits, some places 60 feet wide; Pool: Riffle ratio 80:20; Good shelter provided by algae, boulders, undercut banks, and logs. Spawning area from mouth to upper fish limit; About 60 percent pools; About 25 percent of shelter in the first 100 feet of stream.	17 partial barriers, consisting of log jams; 1 fish passage barrier20 log jams; no fish passage barriers,	Removal of barriers; Removal of slash from streambed to improve nursery area; Careful management of a coho salmon program to re-establish a run in a stream which has a tremendous amount of suitable coho salmon spawning areaRemove log jams from mouth to upper fish limit 6 miles upstream.
House Creek	9/17/1965- 9/18/1965	Pools: 60-80 percent in summer; Shelter is inadequate; Conditions favor rough fish over salmonids.	Concrete dam Numerous small log jams in headwaters and tributaries	Manage as steelhead spawning and nursery.
Patchett Creek	8/20/1964	40 percent of the streambed below the upper anadromy limit good; Shelter provided by logs, undercut banks, overhanging grass – scarce in some areas	15 log jams between mouth and upper limit of anadromy; 3 waterfalls.	Removal of 15 log jams from mouth to bedrock falls 150 feet below the first fork

Table 3-5
Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala River Watershed, California

Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
South Fork Main Stem Subbasin South Fork	9/23 and 9/24 1964	Plentiful spawning areas throughout the stream. Pool:Riffle 95:5 Generally poor shelter consisting of overhanging banks, boulders, logs, aquatic plants and overhanging aquatic plants.	Old Log JamsNone Complete.	Continue to manage for production of juvenile steelhead trout and coho salmon.
	5/17 and 18/1977	Summer flows are limited ; Pool: Riffle ratio 7:3; The majority of pools had little to no shelter; Shelter consisted of boulders, aquatic plants, logs, undercut banks, and overhead canopy	No barriers observed; Each summer a dam is constructed approximately ½ mile below the Wheatfield Fork.	
Marshall Creek	9/28/1964	Deposits of good spawning gravel exist throughout the stream from the mouth to the upper fisheries value; Pool: Riffle ratio 50:50; Good shelter provided by logs, boulders, undercut banks, roots, and trees.	No complete barriers	Should be managed as a steelhead trout and coho salmon spawning and nursery stream
Marshall Creek Tributary #3	9/28/1964	Very limited fisheries value; Watershed severely burned 10 years ago Lower half mile has spawning gravel available, but summer flow is very low.	Total barrier to fish a half mile above the mouth.	None
Marshall Creek Tributary #5	9/29/1964	Summer flows are limited. Some suitable spawning gravel directly above large log jams.	Over 40 log jams in a 1 mile stretch of stream; A number form complete fish passage barriers.	Remove log jams
McKenzie Creek	9/23 and 24/1964	Spawning areas fair to good in the lower 1/3 of stream, excellent in the middle section of stream, and fair in the upper 1/3 of stream; Pool: Riffle ratio 60:40; Good shelter provided by rocks and undercut banks.	7 partial barriers; Large 7 feet high 40 feet dam present 1/6 mile upstream from mouth; Large bedrock falls 1-1/4	Continue to manage as a coho salmon, steelhead trout spawning and nursery area; After removal of falls, possible planting of coho salmon to re-establish a self-supporting run.

Table 3-5
Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala River Watershed, California

Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
			miles upstream	
McKenzie Creek Tributary #6	10/1/1964	Streambed unsuitable for spawning except for the lower ½ mile of stream which is dry in the summer.	Impassable 10 feet falls ½ mile upstream from the mouth.	None
Palmer Canyon Creek	7/31/1981	Could become a good spawning area and nursery habitat for rainbow trout/steelhead trout if improved Occasional small isolated spawning areas separated by areas of boulders or heavily silted areas; Adequate vegetative cover, undercut banks and logs are present in the lower and mid sections of stream.	9 partial fish passage barriers; 2 complete fish passage barriers.	Needs removal of log jams, healing of eroded areas and stream bank cover in upper sections.

In response to the 1964 management recommendations, logging debris, log jams, and other woody materials were cleaned (cleared) from the streams by CDFG and the California Conservation Corps throughout the Gualala River Watershed in the 1970s and 1980s.

3.6.2 TARGET VALUES FROM HABITAT INVENTORY SURVEYS

Target Values from the Habitat Inventory Surveys (Flosi et al 1998)

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. Target values are provided in the *California Salmonid Stream Habitat Restoration Manual* for each of the individual habitat elements measured (Flosi et al. 1998) (Table 3-6). When habitat conditions fall below the target values, restoration projects may be required to meet critical habitat needs for salmonids.

Table 3-6
Habitat Inventory Target Values Taken from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998)

Habitat Element	Canopy Density	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or greater of the pool tailed surveyed provides good spawning conditions	Depth - 1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet Frequency->40% of stream	>80

Canopy Density- 80 Percent or More of the Stream is Covered by Canopy

Near-stream forest density and composition contribute to microclimate conditions. These conditions help regulate air temperature and humidity, which are important factors in determining stream water temperature. Along with the insulating capacity of the stream and riparian areas during winter and summer, canopy levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel. Revegetation projects should be considered when canopy density is less than the target value of 80 percent.

Good Spawning Substrate- 50 Percent or More of the Pool Tails Sampled are 50 Percent or Less Embedded

Cobble embeddedness is the percentage of an average sized cobble piece, embedded in fine substrate at the pool tail. The best coho salmon and steelhead trout spawning substrate are 0-50 percent embedded. Category 1 is defined by the substrate being 0-25 percent embedded. Category 2 is defined by the substrate being 26-50 percent embedded. Cobble embedded deeper than 51 percent is not within the range for successful spawning. The target value is 50 percent or greater of the pool tails sampled are 50 percent or less embedded, thus provides good spawning substrate conditions. Streams with less than 50 percent of their length greater than 51 percent embedded do not meet the target value or provide adequate spawning substrate conditions.

Pool Depth/Frequency- 40 Percent or More of the Stream Provides Pool Habitat

During their life history, salmonids require access to pools, flatwater, and riffles. Pool enhancement projects are considered when pools comprise less than 40 percent of the length of total stream habitat.

The target values for pool depth are related to the stream order. First and second order streams are required to have 40 percent or more of the pools over 2 feet to meet the target values. Third and fourth order streams are required to have 40 percent or more of the pools over 3 feet to meet the target values. A frequency of less than 40 percent or inadequate depths indicates that the stream provides insufficient pool habitat.

Shelter/Cover- Scores of 80 or Better Means that the Stream Provides Sufficient Shelter/Cover

Pool shelter/cover provides protection from predation and rest areas from high velocity flows for salmonids. Shelter/cover elements include undercut bank, small woody debris, large woody debris, root mass, terrestrial vegetation, aquatic vegetation, bubble curtain (whitewater), boulders and bedrock ledges. All elements present are measured and scored. Shelter/cover values of 80 or less indicates that shelter/cover enhancement should be considered.

3.6.3 CURRENT FISH HABITAT RELATIONSHIP

Habitat inventory surveys were conducted on a total of 26 streams. In 2001, CDFG conducted over 100 miles of habitat inventory surveys on 18 streams. These surveys were completed under the direction of NCWAP. Prior to NCWAP, approximately 15 miles of current habitat inventory data existed. This included four streams by Sotyome Resource Conservation District in 1995 and four streams inventoried by CDFG in 1999. Canopy density, embeddedness, primary pool depth/frequency and shelter cover are summarized in Table 3-7.

In the North Fork Subbasin, the Flosi, et al (1998) canopy cover target value was reached on Log Cabin Creek. All of the other streams surveyed in the North Fork Subbasin were close to the target value except Dry and Robinson creeks. Embeddedness target values were attained or exceeded on all tributaries except Doty and McGann creeks. The target values for Pool Frequency/Depth and Pool Shelter/Cover were not met on any of the streams surveyed.

In the Rockpile Subbasin, the canopy cover target value was not met on Rockpile Creek, the only stream surveyed in the Rockpile Subbasin. Embeddedness target values were reached on Rockpile Creek in the 8.5 miles surveyed. The target values for Pool Frequency/Depth and Pool Shelter/Cover were not met.

In the Buckeye Subbasin, the canopy cover target value was not met on Buckeye Creek, the only stream surveyed in the Buckeye Subbasin. Embeddedness target values were reached on Buckeye Creek. The target values for Pool Frequency/Depth and Pool Shelter/Cover were not met.

In the Wheatfield Subbasin, the canopy cover target value was met on Sullivan Creek. None of the other nine streams surveyed met the target value. House, Pepperwood, Sullivan, and Tombs creeks, and the Wheatfield Fork met the target values for embeddedness. The target values for Pool Frequency/Depth or Pool Shelter/Cover were not met in any of the streams surveyed.

In the Mainstem/South Fork Subbasin, the canopy cover target value was met on Palmer Canyon, Carson, and Camper creeks, and on surveyed reaches of the upper South Fork. The target values for Pool Frequency/Depth or Pool Shelter/Cover were not met in any of the streams surveyed.

Table 3-7
Summary of Current (1995, 1997, and 2001) Conditions Based Upon Habitat Inventory Surveys from the Gualala River Watershed, California
Condensed Tributary Reports are located in Appendix 6

Habitat Element Stream Name	Surveyed Length (feet).	Canopy Density Cover	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
Target Values (Flosi et al 1998)		***>80%r***	***>50%***	***>40%***	***>80***
North Fork Subbasin	***111,758***				
Doty Creek	6,237	74%	25%	4%	36
Dry Creek	11,161	58%	70%	6%	32
Dry Creek Tributary #1	2,695	59%	51%	22%	30
Little North Fork	20,806	76%	83%	16%	54
Log Cabin Creek	1,698	83%	90%	1%	43
McGann Creek	1,980	76%	0%	3%	5
North Fork *(partial survey)*	59,362	78%	82%	29%	28
Robinson Creek	7,819	66%	65%	3%	70
Rockpile Subbasin	**44,500**				
Rockpile Creek	44,500	55%	52%	22%	41
Buckeye Subbasin	**51,085**				
Buckeye Creek	51,085	61%	68%	11%	44
Wheatfield Fork Subbasin	**289,627**				
Danfield Creek	2,103	49%	28%	5%	26
Fuller Creek (1995)	17,952	66%	3%	5%	25
North Fork Fuller Creek (1995)	14,275	68%	20%	13%	58
South Fork Fuller Creek (1995)	23,198	59%	28%	13%	37
House Creek	54,916	21%	70%	8%	15
Pepperwood Creek	17,931	19%	70%	16%	12
Sullivan Creek (1995)	5,015	89%	63%	7%	36
Tombs Creek	37,359	65%	55%	9%	51
Wheatfield Fork	116,878	45%	50%	25%	17
Mainstem/South Fork Subbasin	**57,218**				
Camper Creek (1999)	3,546	86%	70%	3%	25
Carson Creek (1999)	6,834	83%	50%	14%	19
Marshall Creek *(partial survey)*	21,698	55%	90%	13%	13
McKenzie Creek (1999)	3,801	69%	60%	18%	23
Palmer Canyon Creek	95	82%	65%	3%	12
Upper South Fork *(partial survey)*	8,451	96%	73%	5%	22
Wild Hog Creek	2,493	73%	52%	2%	8

3.6.4 CHANGES IN HABITAT CONDITIONS FROM 1964 TO 2001

Streams surveyed in 1964 and habitat inventory surveyed in 1995, 1999, and 2001 were compared to indicate changes between historic and current conditions. Data from the 1964 stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor were

based on the judgment of the biologist or scientific aid conducting the survey. The results of the historic stream surveys were qualitative and cannot be used in comparative analyses with the more quantitative data provided by the habitat inventory surveys, with any degree of accuracy. However, the two data sets may be compared to show general trends (Table 3-8). Data were not available to indicate habitat conditions prior to 1964, thus it is unknown if the conditions observed in 1964 showed a decline or improvement in habitat conditions.

According to aerial photographs, the canopy density of the 1960s was substantially reduced from the conditions observed in the 1940s. The canopy appeared to be low or absent in the 1960s in many parts of the watershed. Mid-20th-century timber operations and ranchland conversions removed riparian canopy cover, changing streambank exposure from about five percent in 1942 to a range of 40 to 70 percent bank exposure in the Gualala River Watershed by 1968. Bank exposure was lower in 1999, reduced to approximately 25 percent averaged throughout the watershed.

The Little North Fork and the North Fork mainstem (North Fork Subbasin) were both surveyed in 1964 and 2001. The canopy cover increased substantially, indicating improved conditions over those observed in the 1960s aerial photographs. The 2001 spawning substrate conditions may have improved on the Little North Fork and remained or returned to the same conditions observed in 1964. The 2001 spawning substrate improved on the upper reach and remained the same on the lower reach of the North Fork compared to conditions observed in 1964. The 2001 primary pool frequency and shelter/cover appear to have decreased since 1964.

Historic data were unavailable for the Rockpile Subbasin because surveys were not conducted.

Buckeye Creek was surveyed in 1964 and 2001. The canopy cover appeared to have increased somewhat, but remained below target values, indicating some improvement toward a recovered condition since the 1960s aerial photographs. The 2001 spawning substrate conditions continued to provide the same acceptable conditions observed in 1964. The 2001 primary pool frequency and shelter/cover appear to have decreased since 1964.

House Creek and the Wheatfield Fork mainstem (Wheatfield Fork Subbasin) were surveyed in 1964 and 2001. Fuller Creek was surveyed in 1964 and 1995. The canopy cover on House Creek and the Wheatfield Fork appeared to have decreased or remained the same and remains below target values, indicating little or no improvement toward a recovered condition over those observed in the 1960s aerial photographs. Fuller Creek's canopy cover appears to have increased somewhat, but still does not meet target values, indicating some improvement toward a recovered condition. The spawning substrate on House Creek appears to have improved somewhat, while the Wheatfield Fork has remained or returned to the same conditions observed in 1964. Spawning substrate conditions appear to have decreased on Fuller Creek indicating a worsening of embeddedness possibly from upstream or upslope fine sediment. The 2001 primary pool frequency and shelter/cover decreased substantially since 1964 on Fuller Creek and the Wheatfield Fork. On House Creek, the primary pool frequency appear to have decreased while the shelter/cover values have remained inadequate.

Table 3-8

Comparison Between Historic Habitat Conditions Observed in 1964 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 1995, 1999 and 2001 from the Gualala River Watershed, CA

Target Values (Flosi et al 1998): Canopy 80 Percent; Spawning Substrate Embeddedness <50 Percent; Primary Pool/Frequency 40 Percent; Shelter/Cover Value 100

Habitat Element Stream Names	1960s Canopy Cover Photos	2001 Canopy Density	1964 Spawning Substrate	2001 Spawning Substrate Embedded-ness	1964 Pool Depth/ Frequency	2001 Primary Pool/ Frequency	1964 Shelter Cover	2001 Shelter/ Cover Value	Change in Conditions from 1964 to 2001
North Fork Subbasin									
Little North Fork	Low or Absent	76%	Good	83%	50%	16%	Good	54	Increase in spawning substrate conditions. Decrease in pool habitat and shelter/cover.
North Fork	Low or Absent	78%	Excellent	82%	80%	29%	Good	28	No change in spawning substrate conditions. Decrease in pool habitat and shelter/cover.
Buckeye Subbasin									
Buckeye Creek	Low or Absent Replant	61%	Good	68%	50%	11%	N/A	44	Increase in spawning substrate conditions. No change in canopy conditions. Decrease in pool habitat and shelter/cover.
Wheatfield Fork Subbasin									
Fuller Creek (1995)	Low or Absent	66%	Fair	3%	70%	5%	Good	25	Decrease in spawning substrate and pool habitat and shelter/cover.
House Creek	Low or Absent	21%	Good	70%	70%	8%	Inadequate	15	Increase in spawning substrate. Decrease in pool habitat and shelter/cover.

Table 3-8

Comparison Between Historic Habitat Conditions Observed in 1964 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 1995, 1999 and 2001 from the Gualala River Watershed, CA

Target Values (Flosi et al 1998): Canopy 80 Percent; Spawning Substrate Embeddedness <50 Percent; Primary Pool/Frequency 40 Percent; Shelter/Cover Value 100

Habitat Element Stream Names	1960s Canopy Cover Photos	2001 Canopy Density	1964 Spawning Substrate	2001 Spawning Substrate Embedded-ness	1964 Pool Depth/ Frequency	2001 Primary Pool/ Frequency	1964 Shelter Cover	2001 Shelter/ Cover Value	Change in Conditions from 1964 to 2001
Wheatfield Fork	Low or Absent	45%	Good	50%	75%	25%	Good	17	No change in spawning substrate. Decrease in pool habitat and shelter/cover.
Main stem /South Fork Subbasin									
Marshall Creek (*partial survey*)	Low or Absent	55%	Good	90%	50%	13%	Good	13	Increase in spawning substrate. Decrease in pool habitat and shelter/cover.
McKenzie Creek (1999)	Low or Absent	69%	Good	60%	60%	18%	Good	23	Increase in spawning substrate. Decrease in pool habitat and shelter/cover.
Upper South Fork (*partial survey*)	Low or Absent	96%	Good	73%	95%	5%	Poor	22	

Marshall Creek and the South Fork mainstem (Gualala Mainstem/South Fork Subbasin) were surveyed in 1964 and partial surveys were conducted in 2001. McKenzie Creek was surveyed in 1964 and 1995. The canopy cover increased substantially in the headwaters area of the South Fork, indicating improved conditions over those observed in the 1960s aerial photographs. On Marshall and McKenzie creeks, the canopy cover appears to have increased somewhat, but still does not meet target values, indicating some improvement toward a recovered condition. The 2001 primary pool frequency and shelter/cover have decreased substantially since 1964 on Marshall and McKenzie creeks. The headwaters area of the South Fork appears to have decreased in primary pool frequency since 1964, while the poor shelter/cover conditions have remained the same.

3.7 Fish History and Status

Current fish species of the Gualala River Watershed include coho salmon (silver) (H. Alden, pers comm. 2002; CDFG unpub 2002), steelhead trout, pacific lamprey, roach, coastrange sculpin, prickly sculpin, riffle sculpin (R. Kaye, pers comm. 2002) and three-spine stickleback. Above impassable barriers, resident populations of rainbow trout exist (Cox 1989). Species inhabiting the coastal lagoon/estuary include starry flounder, staghorn sculpin (Brown 1986) and Pacific herring (R. Kaye, pers comm. 2002) (Table 3-9).

Historic anecdotal accounts cite eulachon in the estuary and Sacramento sucker in the main stems of both Buckeye Creek and Wheatfield Fork (Higgins 1997). Snyder (1907) did not observe Sacramento suckers on the Wheatfield Fork. Juvenile Chinook (king) salmon specimens were caught prior to 1945 indicating that they were present at that time (D. Fong pers. comm.). It is unknown if eulachon, Sacramento sucker or Chinook salmon inhabit the watershed today.

Table 3-9
Current Fish Species in the Gualala River Watershed, California

Common Name	Scientific Name
Anadromous	
Coho salmon	*Oncorhynchus kisutch*
Steelhead trout	*Oncorhynchus mykiss*
Pacific lamprey	*Lampetra tridentata*
Freshwater	
Gualala Roach	*Lavinia symmetricus parvipinnis*
Coast range sculpin	*Cottus aleuticus*
Prickly sculpin	*Cottus asper*
Riffle sculpin	*Cottus gulosus*
Threespine stickleback	*Gasterosteus aculeatus*
Marine or Estuarine	
Surf smelt	*Hypomesus pretiosus*
Pacific herring	*Clupea pallasii*
Staghorn sculpin	*Leptocottus armatus*
Starry flounder	*Platicthys stellatus*

3.7.1 SALMONID POPULATION

In assessing salmonid populations, data are collected through various methods: mark and recapture, creel census, juvenile trapping and electrofishing. The data are then analyzed to arrive at a population estimate backed by statistical confidence intervals. Accurate population estimates include some enumeration of the whole or selected portion of the population. Population estimates made without data or by relating one watershed's precipitation, latitude and longitude, and comparing it with better-studied streams of similar size are not credible and cannot be used to establish trends. The National Marine Fisheries Service (NMFS 2001) cites using at least two complete life cycles to indicate a trend.

Salmonid population data is limited for the Gualala River Watershed. Anecdotal evidence suggests that coho salmon and steelhead trout populations on the Gualala River were large and experienced a decline prior to the 1960s. After World War II ended in 1945, the Gualala River became a popular place to fish for coho salmon, steelhead trout, and possibly chinook salmon, based on the 200-300 percent increase in fishing pressure (Taft 1946). The increased fishing pressure indicated that the coho salmon and steelhead trout populations were large in the 1940s. In 1952, electrofishing below the confluence of the North Fork showed healthy population conditions based on the length frequencies of the fish captured (Kimsey 1952). Bruer (1953) wrote that there were millions of young steelhead trout and coho salmon in the Gualala River Watershed.

Although accurate coho salmon population estimates were never conducted, stream surveys indicated that the coho salmon population began to decline prior to the 1960s. Stream surveys from 1964 recommended stocking coho salmon to reestablish viable self-supporting runs in streams with pre-existing populations. This stocking indicated a shift from the large, fishable, population of the 1940s toward the need to reestablish a viable population in the 1960s, further establishing that the coho salmon population declined during the 1950s. In 1956, adverse logging conditions and past improper practices had done considerable damage to the headwaters (Fisher 1957). This was primarily in the form of old logjams, debris and siltation. Coho salmon stocking began in 1969. By 1970, 120,000 coho salmon fingerlings had been stocked; 30,000 of these close to the time when stream surveys were conducted throughout the watershed. Coho salmon were observed in most of the tributaries surveyed, however it is not known whether they were native or hatchery stock. Over the next 30 years, another 347,780 hatchery coho salmon were stocked in the Gualala River Watershed. From the 1995-1998 brood years, 45,000 were planted in the Little North Fork (Figure 3-11). Even with the extensive planting coho salmon had not been regularly observed in the Gualala River Watershed, except in the North Fork Subbasin. Coho salmon were not detected in electrofishing in 2001, and possibly are extirpated from the Gualala River Watershed (Coho Salmon Status Review 2001). In September 2002, young-of-the-year coho salmon were observed in the North Fork Subbasin during snorkel surveys on Dry Creek, a tributary to the North Fork, and in two sites on the Little North Fork and Doty Creek during electrofishing surveys (Table 3-10).

Starting in the 1940s and continuing today, steelhead trout have been actively fished on the Gualala River. In 1945, a summer juvenile steelhead trout closure was ordered to protect juvenile salmonids. This closure remained in effect until 1982. Bruer (1953) stated that the Gualala River was a prime steelhead trout and coho salmon stream and should be used to provide recreation for hundreds of anglers. By 1956, the Gualala River continued to sustain a good steelhead trout population despite the damage to the headwaters. Fishing pressure continued to increase through the early 1970s. In spite of the increased pressure, the steelhead trout catch was less than in the 1950s, probably due to smaller

steelhead trout populations. During the 1970s, CDFG efforts focused on a program to enhance sport fishing on the Gualala River. CDFG began planting steelhead trout in 1970, and by 1976, 83,220 were planted. Using mark and recapture techniques on the mainstem of the Gualala River, two credible steelhead trout population estimates were made in 1975-76 and 1976-77. The populations were estimated at 7,608 in 1975-76 and 4,324 in 1976-77 with 95 percent confidence intervals. From 1983 to 1989, 301,770 steelhead trout were planted in the Gualala River. In 1989, a population estimate of 69.5 juvenile steelhead trout per 1000 square feet was calculated for one location on Fuller Creek, a tributary to the Wheatfield Fork. In 1990, 41,300 steelhead trout were planted in the Gualala River. From 1993-1997 and 1999-2000, the Gualala River Steelhead Project rescued 37,030 steelhead trout, of which 20,328 were released. Steelhead trout young-of-the-year and older were observed in all ten of the tributaries electro fished in September 2001. During the 2001 fishing season, local angler and long time Gualala CDFG Warden Ken Hofer reported that the steelhead trout run was the largest seen in over seven years.

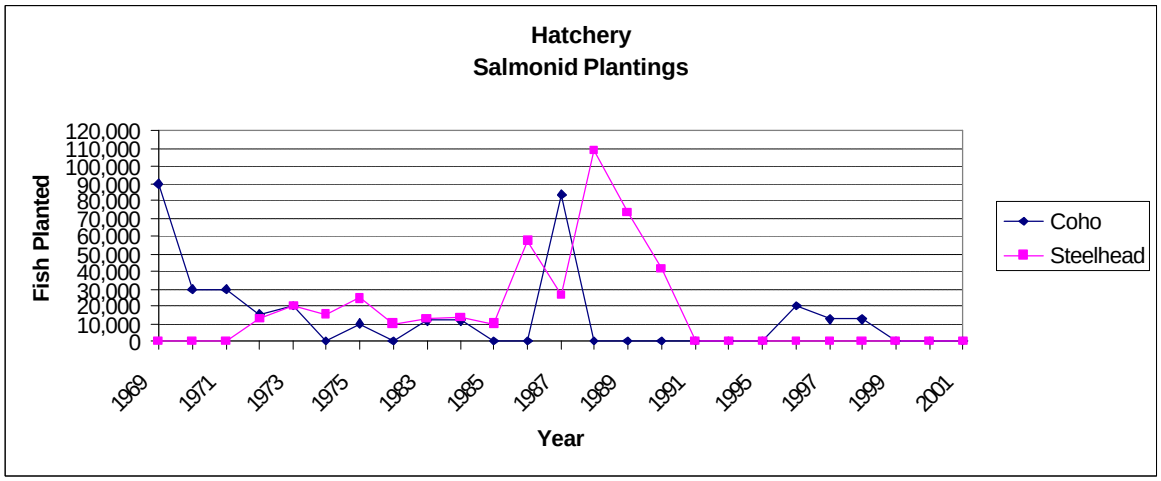


Figure 3-11
Stocking Records from 1969-99 for Coho Salmon and Steelhead Trout in the Gualala River Watershed, California

Table 3-10
Coho Salmon and Steelhead Trout Data Summary by Decade, Gualala River Watershed, California

Decade	Coho Salmon	Steelhead Trout
1940s	A.C. Taft, chief of the Bureau of Fish Conservation, noted that the fishing pressure on the Gualala River increased 200-300% immediately after World War II ended in 1945.	A.C. Taft, chief of the Bureau of Fish Conservation, requested that the entire Gualala River and its tributaries be closed to fishing for small and immature steelhead trout and salmon. Upon his recommendation, the summer closure began in 1945 and remained until 1982.
1950s	In 1952, electrofishing below the confluence of the North Fork revealed that the length frequencies of the fish removed showed a healthy condition (Kimsey 1952). Bruer (1953) wrote that there are millions of young steelhead trout and coho salmon in the Gualala watershed.	During December 1954 through February of 1955, creel surveys were conducted to determine the quality of the steelhead trout fishery on the Gualala River. Five hundred and seven fish were checked. A total catch estimate of 1,352 fish for the season was extrapolated with data from a use count.

Table 3-10
Coho Salmon and Steelhead Trout Data Summary by Decade, Gualala River Watershed, California

Decade	Coho Salmon	Steelhead Trout
	In 1957, Fisher, cited that the adverse logging conditions and past improper practices had done considerable damage to the headwaters. This was primarily in the form of old logjams, debris and siltation. By 1959, the summer opening was not worth while for a person who must travel any distance (Kastner 1959).	In 1956, Fisher, concluded that the Gualala remained one of the better Region III steelhead trout streams. It appeared to sustain a good steelhead trout population despite the poor environmental conditions over a considerable portion of its headwaters. He speculated that unaffected tributary streams must have provided good spawning conditions.
1960s	Stream surveys were conducted in 1964. The species presence and relative abundance of salmonids were estimated from observations recorded while walking upstream along the banks. These surveys had no quantitative basis from which to estimate populations. Where coho salmon were observed during these stream surveys the management recommendations included "possible planting to re-establish a self supporting run" (Table 3-5). Based on CDFG's management prescriptions of the time, this recommendation likely indicated that the native coho salmon populations were not self-sustaining prior to 1964. CDFG reported population estimates of 4000 coho salmon in 1965. This population estimate was made without any supporting data thus is not reliable. The estimate was ranked "C without data" the lowest quality rating designated by the California Fish and Wildlife Plan, Volume III. In 1969, 90,000 coho salmon were planted.	Steelhead trout were present during stream surveys in 1964. Only one creel census survey was conducted on January 24, 1962. The result of the survey showed 11 steelhead trout caught by 18 anglers. Total angler hours were 56.5 resulting in a catch-per-unit-effort of 0.20 fish/hour. CDFG reported steelhead trout population estimates of 16,000 in 1965. This population estimate was made without any supporting data, thus is not reliable. The estimate was ranked "C without data", the lowest quality rating designated by the California Fish and Wildlife Plan, Volume III.
1970s	A 1970s U.S. Bureau of Reclamation study of the Gualala River stated that 75 miles of habitat were available to coho salmon in the Gualala Watershed (U.S. BOR 1974). The "available habitat" estimate was made by relating the Gualala watershed with better-studied streams of similar size and characteristics. This estimate was not substantiated through actual observation. Hatchery plants of coho salmon; 1970, *30,000*; 1971, *30,000*; 1972, *15,000*; 1973, *20,000*; 1975, *10,000*. Total number of coho salmon planted in the 70s, *105,000*. Some streams were surveyed in 1970 with methods similar to those conducted in 1964 (Table 3-5). It is not known how many of the coho salmon observed during these stream surveys were from the 120,000 planted in 1969-1970. No mention of marked or unmarked hatchery coho salmon were found in the planting records or stream reports In the mid-1970s, the CDFG's Coastal Steelhead Project was conducted, in part, on the Gualala River, California. In 1972-73, the creel censuses began in November and resulted in high counts of coho salmon catches with 831 total coho salmon counted. All other years, the creel censuses began in December after the peak of the coho salmon run had passed. In the 1973-74 survey fifty-two coho salmon were counted, in the 1974-75 survey ten coho salmon were counted, in the 1975-76 survey ten coho salmon were counted and in the 1976-77 survey no coho salmon were counted.	A 1970s U.S. Bureau of Reclamation study stated that 178 miles of habitat were available to steelhead trout in the Gualala Watershed (U.S. BOR 1974). Some streams were surveyed in 1970 with methods similar to those conducted in 1964 (Table 3-5). The steelhead trout observed during these stream surveys were assumed native as planting did not occur until 1972. The steelhead trout planted during the 1970s were 12,750 in 1972; 20,300 in 1973; 15,600 in 1974; 24,600 in 1975; and 10,070 in 1976, a total of 83,320. The Mad River Hatchery yearling steelhead trout were marked by a fin-clip. CDFG reports cite origins of brood stocks as Mad River Hatchery, South Fork Eel River and San Lorenzo River. In 1972-73, L.B. Boydstun, CDFG fish biologist, estimated that the fishing effort on the Gualala River had probably increased over 60% since the early 1950s, when the only other creel censuses were conducted. In spite of the increased pressure during the 1972-73 season, the steelhead trout catch was around 25% of what it was during the 1953-54 and 1954-55 seasons. He attributed the poor catch to smaller populations. During the 1972-73 creel census, 288 steelhead trout were caught. No recognizable hatchery fish from the spring planting in 1972 were observed. During 1975-76 and 1976-77, steelhead trout population estimates were made as part of a five-year study. This

Table 3-10
Coho Salmon and Steelhead Trout Data Summary by Decade, Gualala River Watershed, California

Decade	Coho Salmon	Steelhead Trout
	California Drought	study utilized creel census, use counts, adult tagging, and downstream migrant trapping in conjunction with the planting of steelhead trout. The goal of the project was to estimate winter adult steelhead trout populations, estimate angler harvest rates and evaluate the contribution of hatchery steelhead trout to the fishery. This program focused on enhancing the Gualala River as a sport-fishing stream. The steelhead trout population estimate was 7,608 in 1975-76 and 4,324 in 1976-77, 95% confidence intervals. Two years of data is not sufficient to establish a population trend. Adult steelhead trout population data does not exist after 1977. Harvest estimates were made at the end of the fishing seasons for each of the five years studied. In the 1972-73 season, 288 fish were surveyed. In 1973-74, 1682 steelhead trout were marked for possible recapture. In 1974-75, there were 793fish counted and in 1975-76, there were 1418 fish counted. Eleven percent of the fish surveyed in 1975-76 were hatchery fish, and a 20.3 % harvest rate was calculated. In the 1976-77 season, there was a 19.8% harvest rate with no hatchery fish recorded. No creel census results were documented from the 76-77 season. The surveys typically began in December. The 1972-73 survey began in November.
1980s	From 1985-1989, 102,000 coho salmon were planted.	From 1983-89, 301,770 steelhead trout were planted in the Gualala River. The year totals of steelhead trout planted were; 12,500 in 1983; 13,400 in 1984; 9,700 in 1985; 57,450 in 1986; 26,250 in 1987; 108,750 in 1988 and; 73,700 in 1989. Bag seines were employed five times during the years of 1984-1986, to sample the game and non game fishes of the Gualala River estuary. The purpose of this survey was to assess the impact of proposed water diversions on aquatic species, in general, and juvenile salmonids, in particular. On Robinson Creek, one station was three-pass electro fished and showed a steelhead trout density of 0.85 per meter. Since electrofishing data were collected only in 1983 on Robinson Creek, insufficient data exists in which to make comparisons. Three pass electrofishing data were collected on a lower and upper site in the Little North Fork in 1988 and 1989. The surveys resulted in an average steelhead trout density of 0.45 on the Little North Fork. In 1989, juvenile steelhead trout population on Fuller Creek (approx. 6 mile long, 3rd order stream) was estimated at 62 with a standard error of 8.599. Four stations were fished with a two or three pass depletion electro-fish method. These stations were located on South Fork and Mainstem of Fuller Creek. The intent of this survey was to assess the impacts from the upstream logging. Station 4 was upstream of the falls on the South Fork, where resident rainbow trout were observed. Young-of-the-year and one year and older steelhead trout, western roach, and three-spined

Table 3-10
Coho Salmon and Steelhead Trout Data Summary by Decade, Gualala River Watershed, California

Decade	Coho Salmon	Steelhead Trout
		stickleback were found during these surveys.
1990s	Over three years, 45,000 juvenile coho salmon from the 1995-1998 brood years were planted in the Little North Fork. The juveniles were from the Noyo River Egg Collecting Station run by CDFG in Fort Bragg, CA. During snorkel surveys, Gualala Redwoods, Inc. observed coho salmon young-of-the-year on the Little North Fork, Robinson and Dry Creek in 1998 Between July 1, 1999 and June 30, 2000, spawner and electrofishing surveys were conducted on the Little North Fork Gualala River. These surveys were conducted to determine whether the planting of coho salmon during the 1996-98 periods was effective. No coho salmon were found. .	In 1990, a total of 41,300 steelhead trout were planted in the Gualala River. Since1993, the Gualala River Steelhead Project rescued steelhead trout juveniles from streams in danger of drying up during the summer months. Rescued fish are kept in two Doughboy pools at the hatchery on Doty Creek, a tributary to the Little North Fork of the Gualala River. The fish are released in the North Fork Subbasin and main stem Gualala River after the first substantial winter rains increase stream flows. From 1993-1997 and 1999-2000, 37,030 steelhead trout have been rescued and 20,328 have been released. During 1990-93, 95, 98, 99 and 2000 three-pass electrofishing data were collected on a lower and upper site in the Little North Fork. No effort was recorded in 1990-1992. Both sites showed small fluctuations in young-of–the year populations. Both sites showed a slight increase in one year old fish from 1995-2000. Two year and older steelhead trout numbers were identical at the lower site and slightly increased at the upper site from 1998-2000. In 1995, one-pass electrofishing surveys were conducted on Fuller Creek and South Fork Fuller Creek. Young of the year, year plus and two year plus steelhead trout were observed. The results were not comparable to the 1989 survey, due to differences in sampling techniques. Gualala Redwoods, Inc. conducted snorkel surveys in 1997, 1998 and 1999. In 1997-98, one year and older steelhead trout were observed in Buckeye Creek and South Fork. In 1998, one year and older steelhead trout were observed in the Wheatfield Fork. In 1999, one year and older steelhead trout were observed in Little North Fork, Robinson Creek, North Fork and Doty Creek.
2000	Robinson Creek and Dry Creek were surveyed in 1999, 2000, and 2001, no coho salmon were found (CDFG unpubl. data) Historical coho salmon streams listed by Brown and Moyle (1991) were electro-fished in September, 2001. The method used was the modified ten-pool protocol (Attachment D). The streams electro-fished were North Fork, Doty Creek, South Fork, Franchini Creek, Wheatfield Fork, Haupt Creek, Tombs Creek, House Creek, Pepperwood Creek and Marshall Creek. This survey was specifically aimed at establishing coho salmon presence in the streams sampled. Coho salmon were not found in any of the streams surveyed. Coho Salmon Status Review (2001) stated no known	Between July 1, 1999 and June 30, 2000, spawner and electrofishing surveys were conducted on the Little North Fork, a tributary to the North Fork by CDFG. These surveys were conducted to determine whether the planting of coho salmon during the three-year period of 1995/96-1997/98 were effective. In 2000-2001, 7,600 and 5,450 steelhead trout were planted on the North Fork between Elk Prairie and Dry Creek. During snorkel surveys, Gualala Redwoods, Inc. observed one year and older steelhead trout on: Little North Fork, Robinson, North Fork, and Dry Creek in 2000 and 2001; on the mainstem of Buckeye Creek in 2000 and 2001; and on the South Fork in 2000 and 2001.

Table 3-10
Coho Salmon and Steelhead Trout Data Summary by Decade, Gualala River Watershed, California

Decade	Coho Salmon	Steelhead Trout
	remaining viable coho salmon populations in the Gualala River system. In September 2002, coho salmon young-of-the year were present on Dry Creek, a tributary of the North Fork during a snorkel survey and two sites on the Little North Fork and Doty Creek during electrofishing. Coho young-of-the-year were present on McGann Creek, rescued and released (R. Dingman, pers. comm.)	February-April 2001, a volunteer effort steelhead trout spawning surveys observed redds on Wheatfield Fork, Tombs Creek, Britain Creek, House Creek, and South Fork. Redds were observed on Rockpile Creek in 2001 (K. Morgan, pers. comm).

3.7.2 STOCKING OF COHO SALMON AND STEELHEAD TROUT

In the past, stocking of hatchery-raised salmonids was regularly employed to supplement declining stocks and/or to enhance sport-fishing quality. Coho salmon and steelhead trout were stocked on the Gualala River for both of these reasons. Coho salmon stocking began in 1969 and continued until 1999. A total of 342,000 were planted over 30 years. Steelhead trout were stocked as part of sport fishing enhancement projects. Steelhead trout stocking began in 1972 and continued until 1990. Additionally, from 1993 to the present at least 37,030 steelhead trout have been rescued and raised by the Gualala River Steelhead Project, at least 20,328 steelhead trout were released (one year of data is missing). A total of 444,530 steelhead trout were planted over 29 years (Figure 3-13).

3.7.3 SALMONID RANGE OR DISTRIBUTION

Distribution relates to any species' given range at the time the information was collected. Changes in fish distribution result from changes in water and habitat conditions from natural and human-caused impacts, and as a result of over-harvesting, on both a localized and global scale.

The distribution of coho salmon has changed substantially over the past 32 years in the Gualala River Watershed. Coho salmon were known to be distributed in four of the five subbasins, inhabiting 10-15 tributaries (Table 3-11). In 1995, coho salmon were observed in Robinson and Dry creeks (both are tributaries to the North Fork) (Gualala Redwoods, Inc. 2001). Brown and Moyle (1991) did not include Robinson or Dry Creeks as historically containing coho salmon.

Table 3-11
Historic Coho Distribution (Brown and Moyle 1991)

Subbasin	North Fork	Rockpile	Buckeye	Wheatfield Fork	Main Stem South Fork
Tributaries	North Fork Doty Creek Little North Fork	No data available or not surveyed	Franchini Creek	Wheatfield Fork Fuller Creek North Fork Fuller Creek South Fork Fuller Creek Haupt Creek	South Fork Marshall Creek Sproule Creek McKenzie Creek

During 1998 snorkel surveys, coho salmon young-of-the-year were observed on Robinson Creek, a tributary to the North Fork (Gualala Redwoods, Inc.)

For the NCWAP and the CDFG *Coho Salmon Status Review* (CDFG 2001), the known historic coho salmon streams and additional habitat inventoried streams were electro fished to determine presence using the Ten Pool Protocol in 2001 (Preston et al. 2001). The North Fork, Franchini Creek, Wheatfield Fork, Haupt Creek, House Creek, Pepperwood Creek, Danfield Creek, Tombs Creek, Marshall Creek, and the South Fork were electro fished. Coho were not observed on any of these streams.

In 2002, coho salmon were found on Dry Creek, Doty Creek and on the Little North Fork (Gualala Redwoods, Inc. unpub. 2002; CDFG unpub. 2002). The Gualala River Steelhead Project rescued and relocated 163 young-of-the-year coho salmon from McGann Creek during May, June and July 2002 (R. Dingman, pers. comm). The current distribution of coho salmon appears restricted to the North Fork Subbasin in tributaries of both the North Fork and Little North Fork (Table 3-12).

Table 3-12
Current 2001-2002 Coho Salmon Distribution in the Gualala River Watershed, California
(Gualala Redwoods, Inc. and CDFG unpub data 2002)

Subbasin	North Fork	Rockpile	Buckeye	Wheatfield Fork	Main Stem South Fork
Tributaries	Doty Creek Dry Creek Little North Fork McGann Gulch	Not surveyed	Not surveyed	Not surveyed	Not surveyed

Since 1995, coho salmon have been observed in only Robinson and Dry creeks (both are tributaries to the North Fork) (Gualala Redwoods, Inc. 2001). Brown and Moyle (1991) did not include Robinson or Dry creeks as historically containing coho salmon. As a part of the Gualala NCWAP and Coho Salmon Status Review project (CDFG 2001), the listed historical coho salmon streams were surveyed by electrofishing in 2001. Coho salmon were not observed in any of their historic tributaries during electrofishing surveys in September 2001. In 2002, coho salmon were observed on Dry Creek, Doty Creek and on the Little North Fork (Gualala Redwoods, Inc. unpub. 2002).

The historic distribution of coho salmon based upon bank observations during CDFG stream surveys in 1964 and 1970 (Figure 3-12).

From the mid 1950s to the mid 1960s the most substantial tractor logging occurred. During this period extensive damage was inflicted on the watershed, particularly to the streams and the headwaters of the streams. The resulting debris accumulations and log jams created fish passage barriers, reducing the distribution of steelhead trout in the Gualala River Watershed.

Table 3-13
Historic Steelhead Trout (*Oncorhynchus mykiss*) Distribution Based Upon CDFG Stream Surveys from 1960s and 1970s in the Gualala River Watershed, California

Subbasin	North Fork	Rockpile	Buckeye	Wheatfield Fork	South Fork
Tributary Streams	North Fork Dry Creek Robinson Creek Little North Fork Doty Creek	No surveys conducted	Buckeye Creek Franchini Creek	Wheatfield Fork Fuller Creek North Fork Fuller Creek South Fork Fuller Creek House Creek Britain Creek Danfield Creek Jim Creek Sugarloaf Creek Patchett Creek	South Fork Marshall Creek Sproule Creek McKenzie Creek Palmer Canyon Creek Haupt Creek

No data exist to confirm the steelhead trout distribution prior to the mid 1950s-60s logging era. Slash and log jams located in both tributaries and headwater areas were well documented in the 1964 and 1970 stream surveys. This logging debris created barriers to fish passage, thus reducing steelhead trout distribution from its potential pre-logging range.

Steelhead trout distribution in the Gualala River Watershed does not appear to have changed over the past 37 years. This conclusion is based on comparison of stream surveys from 1964 and 1970 and the habitat inventory and electrofishing surveys of 2001 (Table 3-13). Sugarloaf and Patchett Creeks were not surveyed in 2001. Young-of-the-year, one year old and older steelhead trout were observed in all tributaries surveyed. Young-of-the-year steelhead trout were the most numerous age class observed. The 10 Pool Protocol (Preston et al, 2001) was used during the 2001 electrofishing surveys. Population and age class estimates cannot be determined from the resulting data.

3.7.4 Fish Restrictions, Acts, Protections

Due to declining north coast populations, NMFS listed coho salmon under the federal Endangered Species Act (ESA) in 1996. Steelhead trout are currently listed as threatened under the federal ESA. The “threatened” status restricts river sport fishing for steelhead trout on Gualala River. The winter steelhead trout fishery of the Gualala River is currently managed as a catch and release fishery from November 1 to March 31. Only barbless hooks may be used. One hatchery trout or one hatchery steelhead trout may be taken. The summer fishery currently spans from the fourth Saturday of May to October 31. Only artificial lures may be used and no fish may be taken. The legal fishing limits are on the Main Stem (South Fork) of the Gualala River from the mouth, at the Pacific Ocean, to the confluence of the Wheatfield and South forks. Contact CDFG for current regulations.

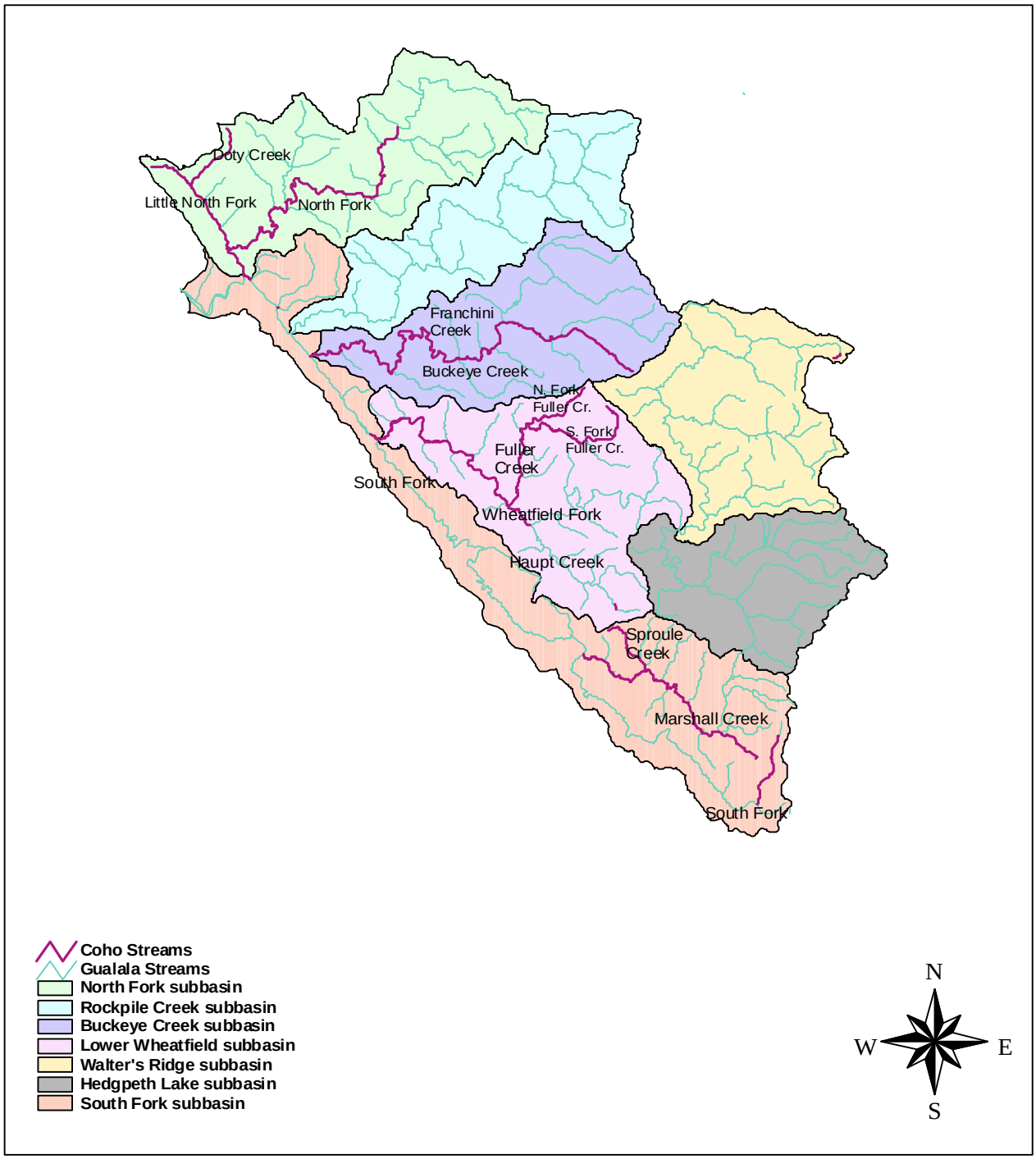


Figure 3-12

Historic coho salmon (*Oncorhynchus kisutch)* distribution based on CDFG stream reports from pre-planting in 1964 and post-planting 1970 in the Gualala River Watershed, California. The coho salmon young-of-the-year observed on Robinson Creek (1998) and Dry Creek (1998 and 2002) were not included on this map.

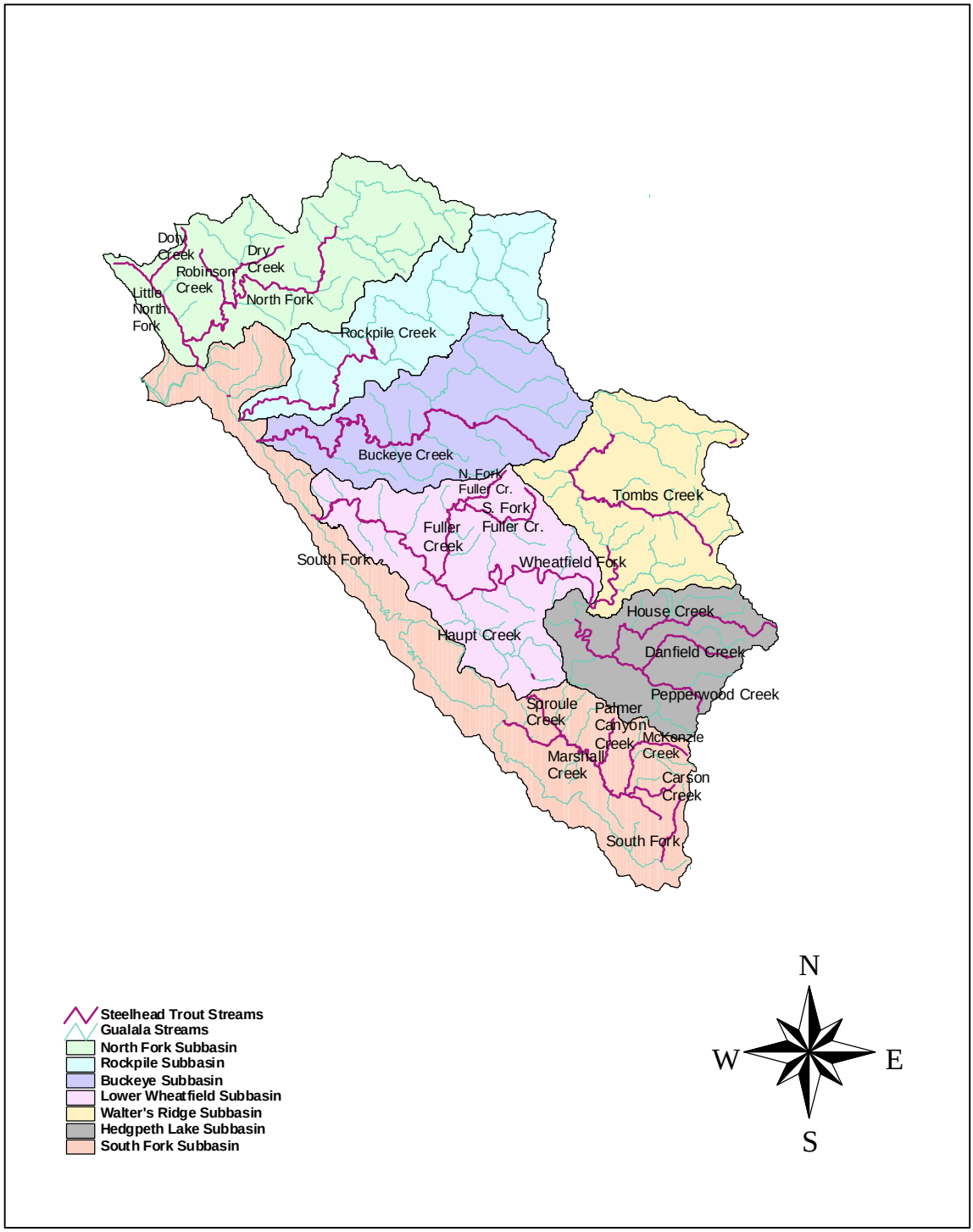


Figure 3-13
Current observed steelhead trout (*Oncorhynchus mykiss*) distribution based on observations (1970-present), and CDFG habitat inventories and electrofishing surveys in 1995, 1999, and 2001 in the Gualala River Watershed, California.

3.7.5 SPECIAL-STATUS SPECIES

The Gualala River is part of the Central California Coast (CCC) coho salmon Evolutionary Significant Unit (ESU). Coho salmon are listed as endangered under both the State and federal Endangered Species Act in the Central California Coast ESU. Most abundance trend indicators for streams in the CCC coho salmon ESU indicate a decline since the late 1980s. However, some streams of the Mendocino County coast show an upward trend in 2000 and 2001. Time-series analysis for these streams showed a declining trend and predicts that this trend will continue, despite the recent increases. However, these populations are more vulnerable to extinction due to their small size, and the spatial isolation of this region due to extirpation of coho salmon populations to the north and south. Coho salmon populations in streams in the northern portion of this ESU seem to be relatively stable or are not declining as rapidly as those to the south. However, the southern portion, where widespread extirpation and near-extinctions have occurred, is a major and significant portion of the range of coho salmon in this ESU. Small population size along with large-scale fragmentation and collapse of range observed in data for this area indicate that metapopulation structure may be severely compromised and remaining populations may face increased threats of extinction because of this. For this reason, the CDFG concludes that CCC coho salmon are in serious danger of extinction throughout all or a significant portion of their range (Coho Salmon Status Review 2001).

3.7.6 OTHER FISH AND AQUATIC ORGANISMS

Historically, the presence of non-game fish species was recorded with varying degrees of accuracy during stream surveys and electrofishing surveys. Observations of these species were made with little attempt to count their numbers or document their presence. Rough-Skinned Newt (*Torch granulose*), Pacific Giant Salamander (*Dicomptodon ensatus*), and Yellow-Legged Frogs (*Rana boyii*) were observed during electrofishing and habitat inventory surveys (Table 3-14).

Table 3-14
Non-salmonid aquatic species documented in the Gualala River Watershed, California.

North Fork Subbasin	Rockpile Creek Subbasin	Buckeye Creek Subbasin	Wheatfield Fork Subbasin	South Fork Subbasin
Gualala Roach		Yellow Legged Frog	Gualala Roach	Gualala Roach
Three-Spine Stickleback		Pacific Giant Salamander	Three-Spine Stickleback	Three-Spine Stickleback
Prickly Sculpin			Prickly Sculpin	Prickly Sculpin
Sculpin			Coast Range Sculpin	Sculpin species
Pacific Lamprey			Pacific Lamprey	Pacific Lamprey
Pacific Giant Salamander			Yellow-Legged Frog	Yellow-Legged Frog
			Rough Skinned Newt	
			Turtles	
			Garter Snakes	

Chapter 4

Interdisciplinary Synthesis and Findings

An integrative analysis of land use, geologic features, and instream fish habitat information.

A major challenge in watershed assessment is integrating a large amount of information from multiple sources and disciplines in a fashion that allows the exploration and understanding of the interrelationships among watershed processes, land use activities, and conditions. Integrated analysis is a critical part in trying to understand linkages and identify watershed cumulative environmental effects.

While Chapter 2 largely focused on single disciplinary areas, this chapter undertakes additional interdisciplinary analyses to explore interrelationships among different disciplines.

Reid (1996) discussed the requirements for integrated watershed assessment approaches:

> Procedures for watershed analysis…are intended to provide integrated, interdisciplinary evaluations of the biological, physical, and socio-economic interactions that influence the [landscape] and to describe environmental changes and their causes. Interdisciplinary implies that expertise from multiple disciplines is providing an integrated attack on a problem area. *Interdisciplinary* is carefully distinguished from *multi-disciplinary*, which implies only that multiple inquiries are being carried out at the same time or in the same place.

An important part of any watershed assessment work is the identification of cumulative environmental effects. Further, assessing cumulative watershed environmental effects is both a practical challenge and a legal requirement for certain kinds of land use activities under the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA) (Henly 1993). A practical working definition of watershed cumulative environmental effects is:

> The interaction of the individual environmental impacts of multiple land management activities on a watershed with each other and with natural processes, resulting in a combined impact on some watershed factor of concern. This interaction occurs across both space and time.

Laws requiring project proponents to assess the potential of their actions for causing or contributing to cumulative effects also require them to assess whether those actions will result in a “significant” level of impact. Determination of the “significance” of either individual or cumulative effects, as is done in the CEQA or NEPA arena, is not appropriate for the context of NCWAP’s work.

NCWAP approaches cumulative effects by looking at the multiple land use and natural process factors that can affect aquatic habitat for salmonids (e.g., landslides, erosion, land use, floods) and examining aquatic habitat conditions themselves. Work under NCWAP assumes that the bulk of the adverse impacts to aquatic habitat observed in the NCWAP process in the Gualala River Watershed are the result of the cumulative effects of landslides, land use, floods, and other factors. However, our level of

watershed assessment does not allow us to tease out of these cumulative effects the causal relationships at a quantitative or even relative level.

The Gualala North Coast Watershed Assessment Program (NCWAP) team used various methods and models to assess relationships between fish habitat and landscape processes and conditions as follows: (1) the Ecological Management Decision Support (EMDS) model was used to process data and create maps of reach conditions based on CDFG raw data and additional maps showing road density and position on hillslope by Planning Watershed; (2) geographic information system (GIS) data from the California Department of Forestry and Fire Protection (CDF), the California Geological Survey (CGS), the California Department of Fish and Game (CDFG) were composited through a series of database queries intended to reveal relationships; (3) the output of the queries was used to build tables (Integrated Data Tables) and maps that help explain the relationships., including Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*; (4) recommendations for restoration priorities were established based on watershed conditions and feasibility of implementation; and (5) potential refugia sites in the watershed were identified.

4.1 Ecological Management Decision Support

4.1.1 INTRODUCTION

NCWAP selected the Ecological Management Decision Support (EMDS) (Reynolds 1999) software to help evaluate and synthesize information on watershed and stream conditions important to salmonids during the freshwater phases of their life history. The general workings of EMDS and the details of the models NCWAP is developing in conjunction with it are described in Appendix 5.

NCWAP staff have constructed “knowledge base” models to identify and evaluate environmental factors (e.g., watershed geology, stream sediment loading, stream temperature, land use activities, etc.) that shape anadromous salmonid habitat. Based upon these models, EMDS evaluates available data to provide insight into the conditions of the streams and watersheds for salmonids. The synthesis EMDS provides can then be compared to more direct measures of salmonid production—i.e., the number of salmonids recently found in streams. EMDS offers a number of benefits for the assessment work that NCWAP is conducting, and also has some known limitations. Both the advantages and drawbacks of EMDS are provided in some detail here and in the appendix.

Our use of the EMDS model outputs in this report is tentative. As discussed below, a scientific peer review process conducted in April of 2002 indicated that substantial changes to NCWAP’s EMDS modeling approach are needed. At the time of the production of this report, we have been able to implement some, but not all of these recommendations. Hence, we use the model outputs with caution at this time. NCWAP will continue to work to refine and improve the EMDS model, based on the peer review.

4.1.2 EMDS DEVELOPMENT AND USE BY NCWAP

EMDS was developed at the USDA-Forest Service, Pacific Northwest Research Station (Reynolds 1999). It employs a linked set of software that includes MS Excel, NetWeaver, the Ecological Management Decision Support (EMDS) ArcView Extension, and ArcView™. Microsoft Excel is a commonly used spreadsheet program for data storage and analysis. NetWeaver (Saunders and Miller [no date]), developed at Pennsylvania State University, helps scientists build graphics of the models

(knowledge base networks) that specify how the various environmental factors will be incorporated into an overall stream or watershed assessment. These networks resemble branching tree-like flow charts, and graphically show the logic and assumptions used in the assessment, and are used in conjunction with environmental data stored in a Geographic Information System (ArcView™) to perform the assessments and facilitate rendering the results into maps. This combination of software is currently being used for watershed and stream reach assessment within the federal lands included in the Northwest Forest Plan (NWFP).

NCWAP staff began development of EMDS knowledge base models with a three-day workshop in June of 2001 organized by the University of California, Berkeley. In addition to the NCWAP staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, NCWAP used an EMDS knowledge base model developed by the NWFP for use in coastal Oregon. Based upon the workshop, subsequent discussions among NCWAP staff and scientists, examination of the literature, and consideration of California conditions, NCWAP scientists then developed preliminary versions of the EMDS models. The first model was for assessing Stream Reach Condition, and the second was designed to assess conditions over the area of the Watershed Condition.

The two initial NCWAP models were reviewed over two days in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to these suggestions, NCWAP scientists revised their EMDS models, as presented below.

4.1.3 THE KNOWLEDGE BASE NETWORKS

For California's north coast watersheds, the NCWAP team has constructed five knowledge base networks reflecting the best available scientific studies and information on how various environmental factors combine to affect anadromous fish on the north coast. All five models are geared to addressing current conditions (instream and watershed) for salmonids, and to reflect a fish's perspective of overall habitat conditions:

1. The Stream Reach model (Figure 4.1-1 and Table 4.1-1), addresses conditions for salmon on individual stream reaches and is largely based on data collected under the Department of Fish and Game's stream habitat inventory survey protocols,

2. The Sediment Production model (Figure 4.1-2 and Table 4.1-2), evaluates the magnitudes of the various sediment sources in the basin according to whether they are natural or management related,

3. The Water Quality model (Figure 4.1-3 and Table 4.1-3) offers a means of assessing the characteristics of the instream water (flow and temperature) in relation to fish,

4. The Fish Habitat Quality model (Figure 4.1-3) incorporates the Stream Reach model results in combination with data on accessibility to spawning fish and a synoptic view of the condition of riparian vegetation for shade and large woody debris,

5. The Fish Food Availability model (Figure 4.1-3) has not yet been constructed, but will evaluate the watershed based upon conditions for producing food sources for anadromous salmonids.

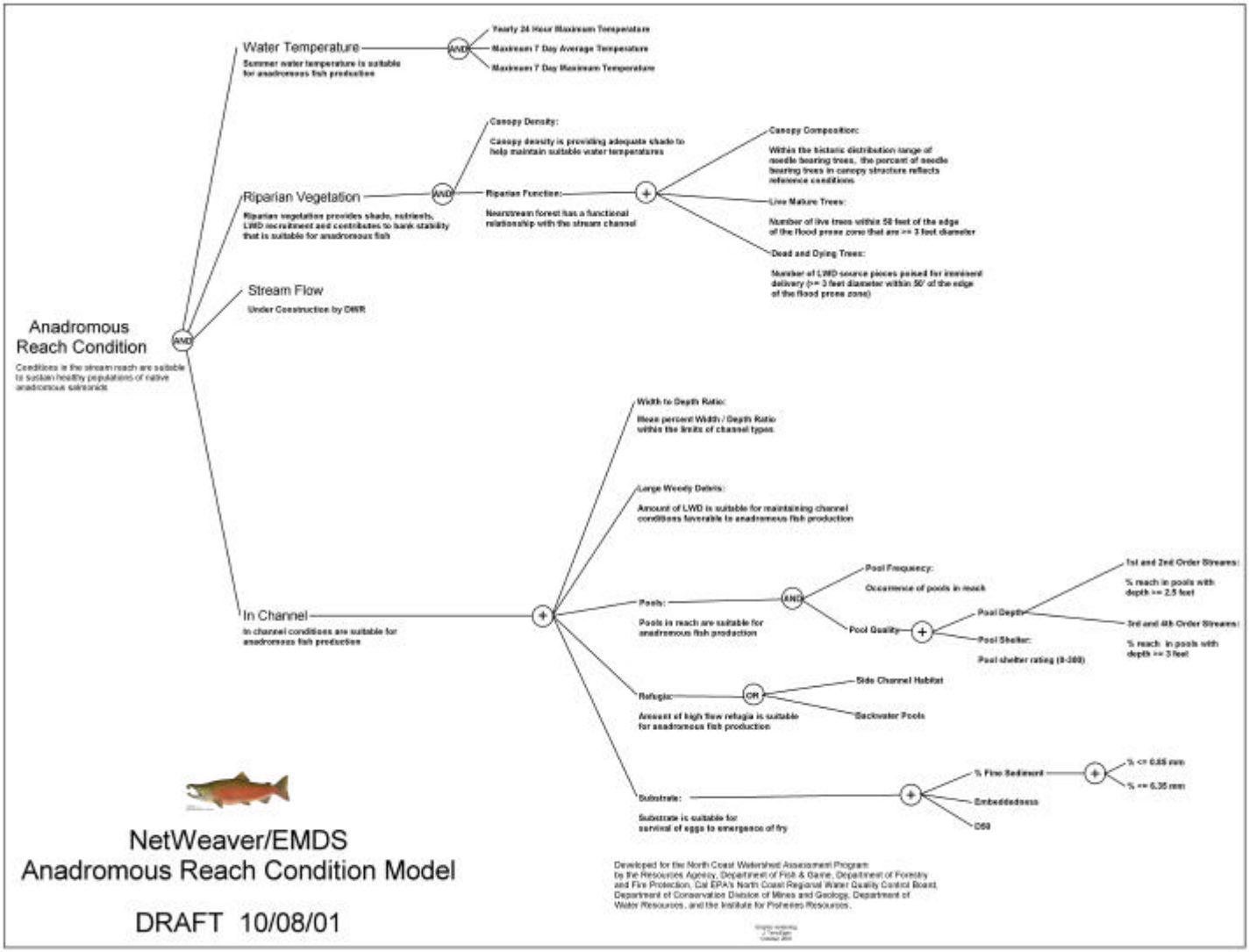


Figure 4.1-1
NCWAP EMDS Anadromous Reach Condition Model

In creating the EMDS models listed above, NCWAP staff have used what is termed a "top-down" approach. This approach is perhaps best explained by way of example. The NCWAP Stream Reach Condition model began with the proposition: The overall condition of the stream reach is suitable for maintaining healthy populations of native coho and chinook salmon, and steelhead trout. A knowledge base (network) model was then designed to evaluate the "truth" of that proposition, based upon data from each stream reach. The model design and contents reflect the specific information NCWAP scientists believe are needed, and the manner in which it should be combined, to test the proposition.

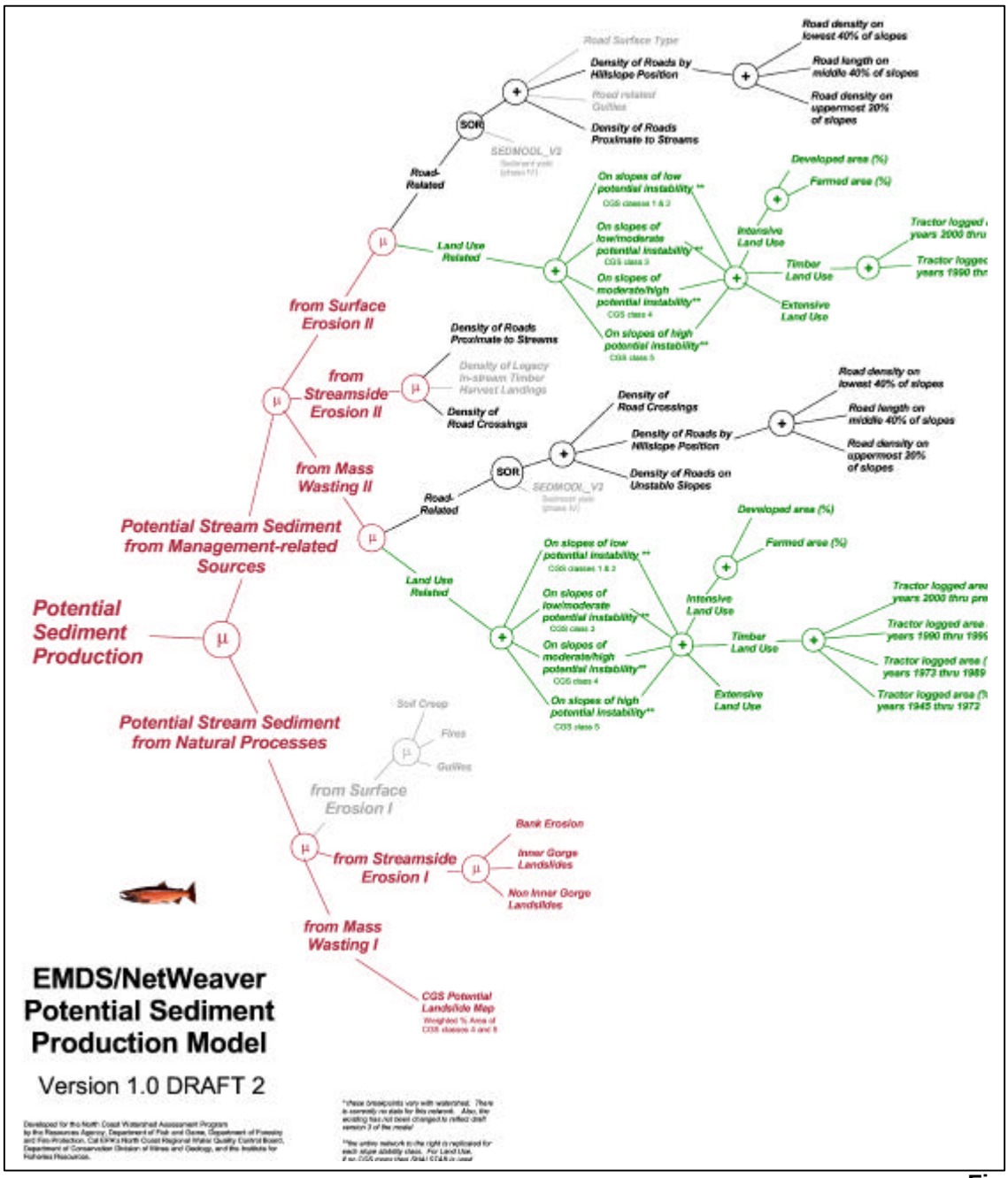


Figure 4.1-2
NCWAP EMDS Potential Sediment Production Model

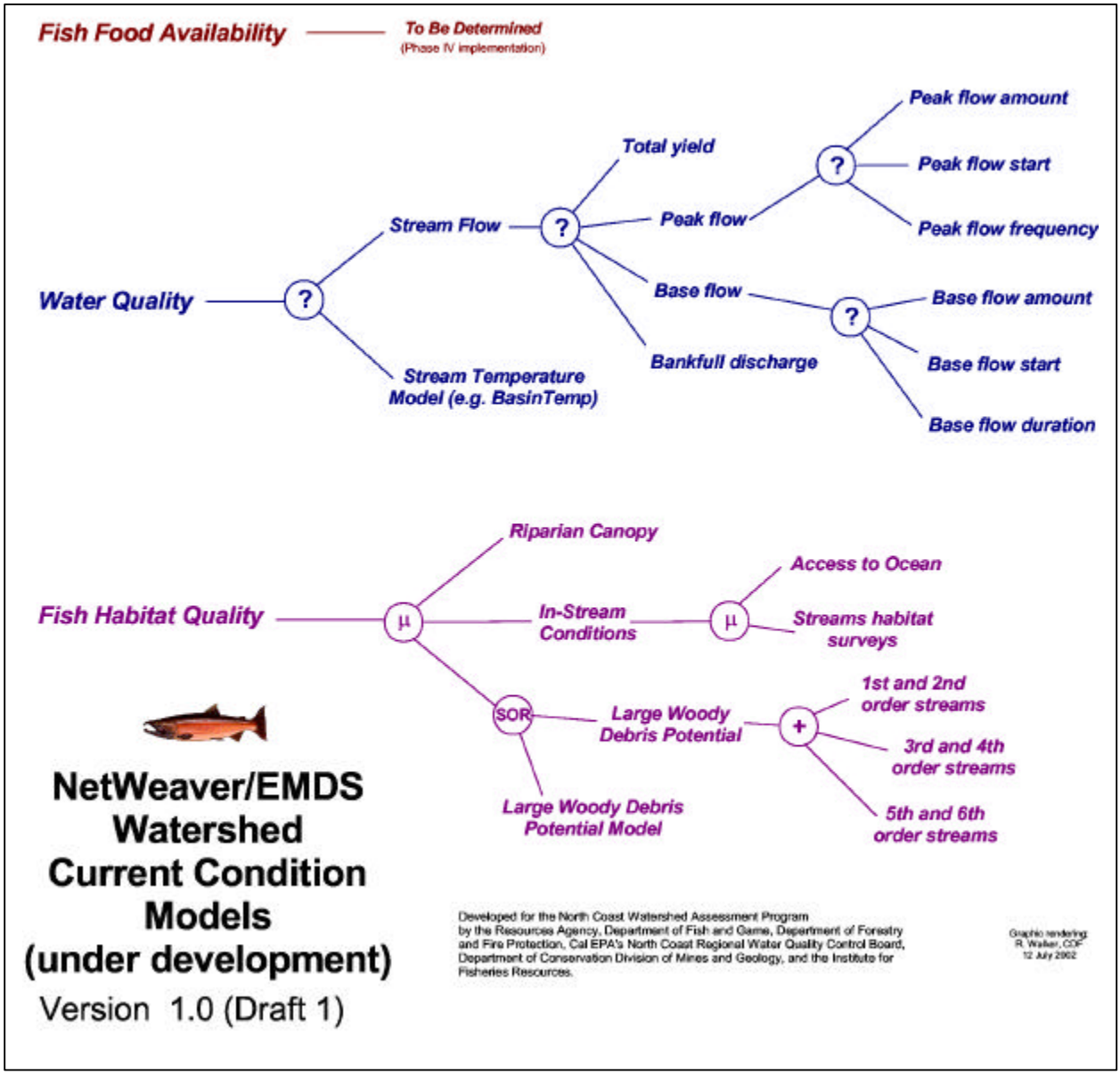


Figure 4.1-3
NCWAP EMDS Fish Food Availability, Water Quality and Fish Habitat Quality Models
Note: None of these models has yet been implemented. This graphic shows their current states of development.

In evaluating stream reach conditions for salmonids, the NCWAP model uses data on several environmental factors. The first branching of the knowledge base network (Figure 4.1-4) shows that information on in-channel condition, stream flow, riparian vegetation and water temperature are all used as inputs in the stream reach condition model. In turn, each of the four branches is progressively broken into more basic data components that contribute to it (not shown). The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation.

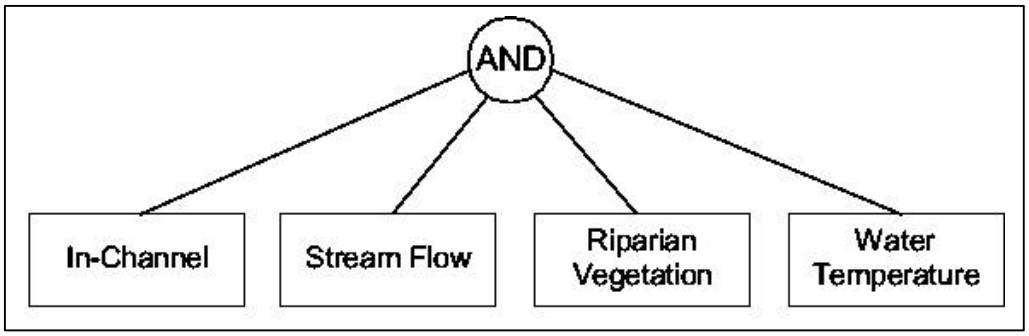


Figure 4.1-4
EMDS Stream Reach Knowledge Base Network
EMDS uses knowledge base networks to assess the condition of watershed factors affecting native salmonids.

Although model construction is typically done top-down, models are run in EMDS from the "bottom up". That is, data on the stream reach is usually entered at the lowest branches of the network tree (the "leaves"), and then is combined progressively with other information as it proceeds up the network. Decision nodes are intersections in the model networks where two or more factors are combined before passing the resultant information on up the network. For example, the "AND" at the decision node in Figure 4.1-4 means that the lowest value of the four general factors coming in to the model at that point is taken to indicate the potential of the stream reach to sustain salmon populations.

EMDS models assess the degree of truth (or falsehood) of each model proposition. Each proposition is evaluated in reference to simple graphs called "reference curves" that determine its degree of truth/falsehood, according to the data's implications for salmon. Figure 4.1-5 is an example reference curve for the proposition: "the stream temperature is suitable for salmon". The horizontal axis shows temperature in degrees Fahrenheit, while the vertical is labeled "Truth Value" and ranges from –1 to +1. The line shows what are fully unsuitable temperatures (-1), fully suitable temperatures (+1) and those that are in-between (> -1 and <+1). In this way, a similar numeric relation is required for all propositions evaluated in the EMDS models.

EMDS uses this type of reference curve in conjunction with data specific to a stream reach. This example curve evaluates the proposition that the stream's water temperature is suitable for salmonids. Break points can be set for specific species, life stage, or season of the year. Curves are dependent upon the availability of data.

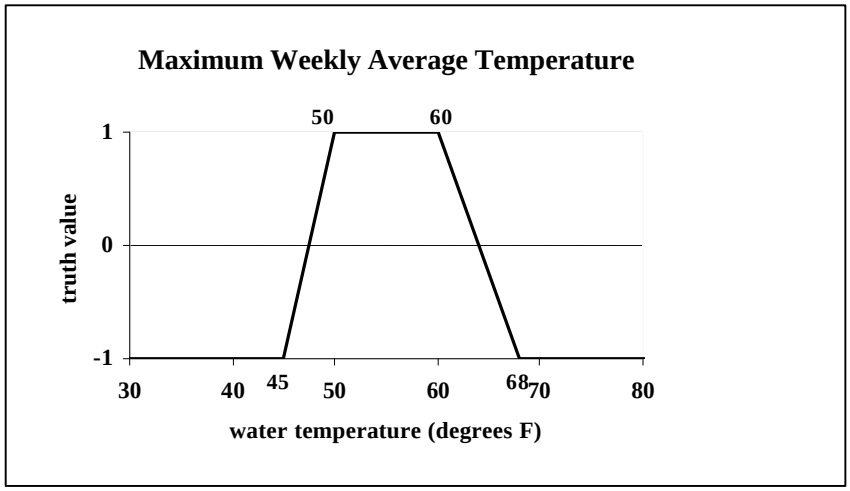


Figure 4.1-5
EMDS Reference Curve

For each evaluated proposition in the EMDS model network, the result is a number between –1 and +1. The number relates to the degree to which the data support or refute the proposition. In all cases a value of +1 means that the proposition is "completely true", and –1 implies that it is "completely false", with in-between values indicate "degrees of truth" (i.e. values approaching +1 being closer to true and those approaching –1 converging on completely untrue). A zero value means that the proposition cannot be evaluated based upon the data available. Breakpoints (where the slope of the reference curve changes) in the Figure 4.1-5 example occur at 45, 50, 60 and 68 degrees Fahrenheit. For the Stream Reach model, NCWAP fisheries biologists determined these temperatures by a review of the scientific literature.

For many NCWAP parameters, particularly those relating to upland geology and management activities, effectively no scientific literature is available to assist in determining breakpoints. Because of this, NCWAP has had little alternative but to use a more empirically based approach for breakpoints. Specifically, for each evaluated parameter, the mean and standard deviation are computed for all planning watersheds in a basin. Breakpoints are then selected to rank each planning watershed for that parameter in relation to all others in the basin. We used a simple linear approximation of the standardized cumulative distribution function, with the 10th and 90th percentiles serving as the low and high breakpoints (Figure 4.1-6). Thus the truth values for all Potential Sediment Production model variables are relative measures directly related to the percentile rank of that planning watershed. While these relative rankings are not comparable outside of the context of the basin, they do provide an indication of relative conditions within the basin.

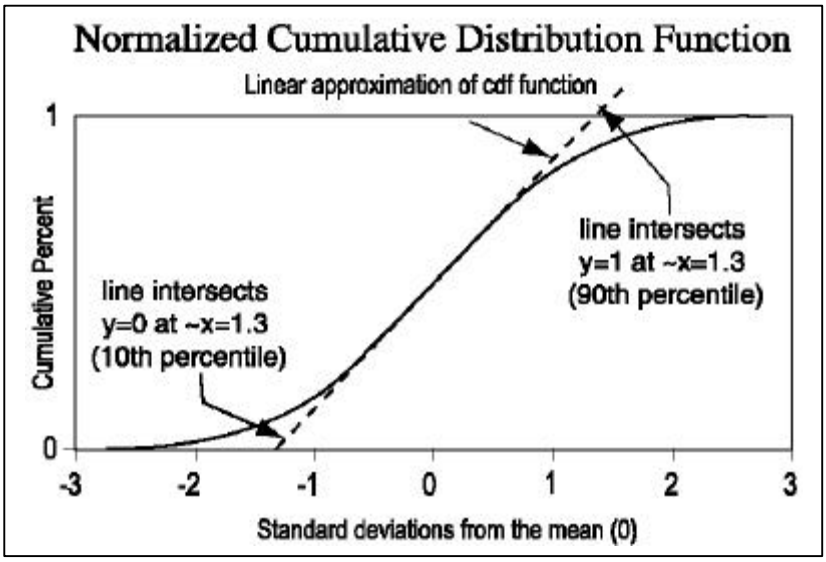


Figure 4.1-6
Using the 10th and 90th percentiles as breakpoints (as with land use) is a linear approximation of the central part of the normalized cumulative distribution function.

The science review panel recommended that this method developed by NCWAP scientists be changed. They advised to use a set of reference watersheds from the region, computing the distributions of land use and other parameters from those watersheds to determine breakpoints. At this point NCWAP staff have not had the resources to select the reference watersheds, nor to process the data for them. This issue will be addressed in future watershed assessment and the breakpoints adjusted as the information from reference watersheds becomes available.

NCWAP map legends use a seven-class system for depicting the EMDS truth-values. Values of +1 are classed as the "highest suitability"; values of –1 are classed as the "lowest suitability"; and values of 0 are undetermined. Between 0 and 1 are two classes which, although unlabeled in the legend, indicate intermediate values of better suitability (0 to 0.5; and 0.5 to 1). Symmetrically, between 0 and –1 are two similar classes which are intermediate values of worse suitability (0 to –0.5; and –0.5 to –1).

In EMDS, the data that are fed into the knowledge base models come from GIS layers stored and displayed in ArcView. Thus EMDS is able to readily incorporate many of the GIS data layers developed for the program into the watershed condition syntheses. Figure 4.1-7 portrays an example map of EMDS results. Reference Curves used in NCWAP's Current EMDS Models

The tables below summarize important EMDS model information. More technical details and justification for each parameter are supplied in the appendix.

1. The Stream Reach Condition model. Parameter definition and breakpoints for this model (shown in Table 4.1-1) are based upon reviews the scientific literature.

2. The Sediment Production Risk model. Parameter definitions and respective weights are shown in Table 4.1-2. Parameters currently not being used in the model for lack of data are noted in the table. All breakpoints for this model are determined empirically (i.e. based upon percentiles of the data distribution, i.e. Figure 4.1-6), due to the use of parameters that have no equivalents nor surrogates in the scientific literature.

3. The Fish Habitat Quality model. This model is still in early stages of development. It will incorporate the results of the Stream Reach model, and breakpoints will be based upon the scientific literature of properly functioning reference watersheds.

4. The Water Quality model. This model is also under development. Water temperature will be modeled with software such as Stillwater Sciences' BasinTemp. Methods for modeling flow parameters have not yet been determined.

5. The Fish Food Availability model. Recommended by the science panel review, this model has yet to be designed and implemented by NCWAP.

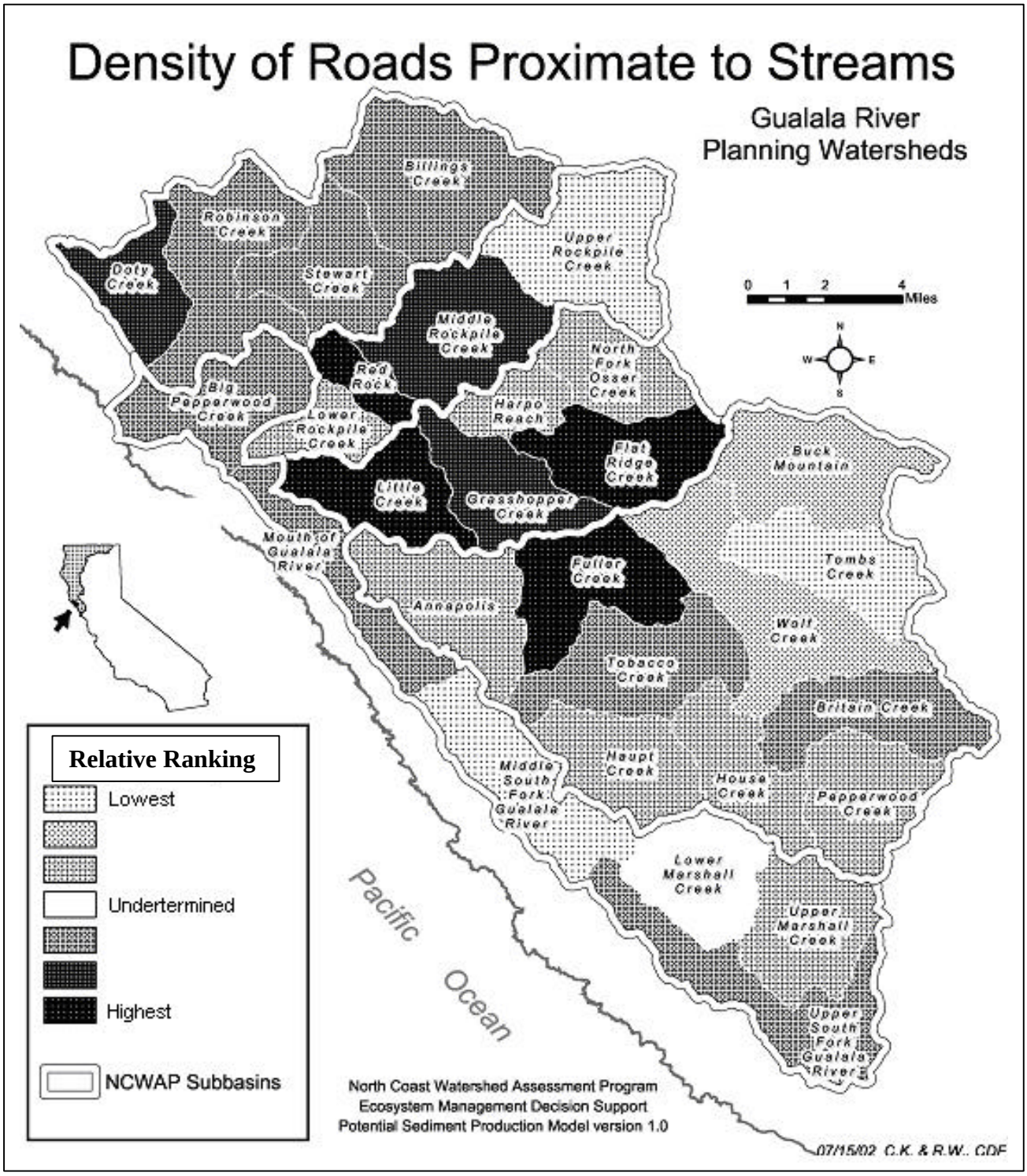


Figure 4.1-7

EMDS Graphical Output, Density of Roads Proximate to Streams

Shows total length of roads near watercourses. Planning watersheds with a high density of roads near streams indicate where additional field scrutiny is advised to determine the necessity of road upgrade and improvement work. Planning watersheds in lighter tones indicate lower priority areas based on this assessment.

Table 4.1-1
Reference Curve Metrics for the EMDS Stream Reach Condition Model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Water Temperature	
Summer MWAT	Maximum 7-day average summer water temperature <45 F fully unsuitable, 50-60 F fully suitable, >68 F fully unsuitable. Water temperature was not included in current EMDS evaluation.
Riparian Function	
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. <50% fully unsuitable, =85% fully suitable.
Seral Stage	Under development
Vegetation Type	Under development
Stream Flow	Under development
In-Channel Conditions	
Pool Depth	Percent of stream reach with pools of a maximum depth of 2.5, 3, and 4 feet deep for first and second, third, and fourth order streams respectively. =20% fully unsuitable, 30 – 55% fully suitable, =90% fully unsuitable
Pool Shelter Complexity	Relative measure of quantity and composition of large woody debris, root wads, boulders, undercut banks, bubble curtain, overhanging and instream vegetation. =30 fully unsuitable, =100 - 300 fully suitable
Pool frequency	Under development
Substrate Embeddedness	Pool tail embeddedness is a measure of the percent of small cobbles (2.5" to 5" in diameter) buried in fine sediments. EMDS calculates categorical embeddedness data to produce evaluation scores between –1 and 1. The proposition is fully true if evaluation sores are 0.8 or more and -0.8 evaluate to fully false.
Percent fines in substrate <0.85 mm (dry weight)	Percent of fine sized particles <0.85 mm collected from McNeil type samples. <10% fully suitable, > 15% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Percent fines in substrate < 6.4 mm	Percent of fine sized particles <6.4 mm collected from McNeil type samples. <15% fully suitable, >30% fully unsuitable. There was not enough of percent fines data to use Percent fines in EMDS evaluations
Large Woody debris	The reference values for frequency and volume are derived from Bilby and Ward (1989) and are dependent on channel size. See appendix for details. Most watersheds do not have sufficient LWD surveys for use in EMDS.
Refugia Habitat	Refugia is composed of backwater pools and side channel habitats and deep pools (>4 feet deep). Not implemented at this time.
Pool to Riffle Ratio	Under development
Width to Depth Ratio	Under development

Table 4.1-2
Reference Curve Metrics for the EMDS Sediment Production Risk Model, Version 1.0

Sediment Production Factor	Definition*	Weights**
Total Sediment Production	**The mean truth value from Natural Processes and Management-related Processes**	
Natural Processes	**The mean truth value from Mass Wasting I, Surface Erosion I and Streamside Erosion I knowledge base networks**	**0.5**
Mass Wasting I	The mean truth value from natural mass wasting: Landslide Potential, Deep-seated Landslides and Earth Flows	0.33
Landslide Potential	A selective OR (SOR) node takes the best available data to determine landslide mass wasting potential.	1.0
CGS Landslide Potential Map	(1st choice of SOR node) Percentage area of planning watershed in the landslide potential categories (4 and 5)	1.0
Landslide Potential Class 5	Percentage area of watershed in class 5 (CGS rating)	0.8
Landslide Potential Class 4	Percentage area of watershed in class 4 (CGS rating)	0.2
Probabilistic Landslide Model	(2nd choice of SOR node) Where option 1 is missing, the Probabilistic Landslide Model is used to calculate area of planning watershed with unstable slopes	1.0
SHALSTAB	(3rd choice of SOR node) Where options 1 and 2 are missing, SHALSTAB model is used to calculate area of planning watershed with unstable slopes	1.0
Surface Erosion I	The mean truth value from natural processes of surface erosion: Gullies, Soil Creep, and Fires	0.33
Gullies	Density of natural gullies in planning watershed (currently no data supplied to model here)	0.33
Soil Creep	Percentage area of planning watershed with soil creep (currently no data supplied to model here)	0.33
Fires	Percentage area of planning watershed with high fire potential (currently no data supplied to model here)	0.33
Streamside Erosion I	The mean truth value from natural processes of streamside erosion: Active Landslides Connected to Streams; Active Landslides Not Connected to Streams; Disrupted Ground Near Streams	0.33
Active Landslides Connected to Streams	Percentage of planning watershed with Active Landslides connected to watercourses	0.60
Active Landslides Not Connected to Streams	Percentage of planning watershed with Active Landslides not connected to watercourses	0.30
Disrupted Ground Near Streams	Percentage of planning watershed with Disrupted Ground near to watercourses	0.10
Management-related Processes	**The mean truth value from Mass Wasting II, Surface Erosion II and Streamside Erosion II knowledge base networks**	**0.5**
Mass Wasting II	The mean truth value from management-related mass wasting: Road-related and Land Use-related	0.33
Road-related	Coarse sediment contribution to streams from roads from either SEDMODL_V2 (first choice) or the mean of Density of Road/Stream Crossing, Density of Roads by Hillslope Position, and Density of Roads on Unstable Slopes	0.5

Table 4.1-2
Reference Curve Metrics for the EMDS Sediment Production Risk Model, Version 1.0

Sediment Production Factor	Definition*	Weights**
SEDMODL-V2	(when model is available – 1st choice of SOR node)	1.0
Density of Road/Stream Crossings	(2nd choice of SOR node, averaged with DRHP directly below) Number of road crossings/km of streams	0.33
Density of Roads / Hillslope Position	Weighted sum of road density by slope position (weights determine relative influence, and sum to 1.0)	0.33
Road Length on Lower Slopes	Density of roads of all types on lower 40% of slopes	0.6
Road Length on Lower Slopes	Density of roads of all types on mid-slope (41-80% of slope distance)	0.3
Road Length on Upper Slopes	Density of roads of all types on upper 20% of slopes	0.1
Density of Roads on Unstable Slopes	Density of roads on geologically unstable slopes	0.33
Land Use related	Coarse sediment contribution to streams from intensive, timber harvest, and ranched areas (*see below in table**) <10th percentile highest suitability; >90th percentile lowest suitability	0.5
On slopes of *low* potential instability	Slope stability defined by CGS map classes 1 and 2 (or SHALSTAB if CGS maps unavailable)	0.04
On slopes of *low/moderate* potential instability	Slope stability defined by CGS map class 3 (or SHALSTAB if CGS maps unavailable)	0.09
On slopes of *moderate/high* potential instability	Slope stability defined by CGS map class 4 (or SHALSTAB if CGS maps unavailable)	0.17
On slopes of *high* potential instability	Slope stability defined by CGS map class 5 (or SHALSTAB if CGS maps unavailable)	0.7
Land Use related mass wasting parameter details (evaluated separately for each category of potential slope instability)	(Weights, showing the relative influence of each parameter, sum to 1.0)	
Intensive Land Use		
- developed areas	Percentage of the planning watershed area in high density buildings and pavement	0.2
- farmed areas	Percentage of planning watershed area in intensive crop cultivation	0.2
- area of timber harvests	Percentage of planning watershed area tractor logged weighted by time period (years)	
- Era 0 (2000 – present)	Tractor logged area 2000-present	0.2
- Era 1 (1990 – 1999)	Tractor logged area 1990-1999	0.12
- Era 2 (1973 – 1989)	Tractor logged area 1973-1989	0.06
- Era 3 (1945 – 1972)	Tractor logged area 1945-1972	0.12
- ranched area	Percentage of watershed area used for grazing livestock; estimated based on vegetation type and parcel type	0.1
Surface Erosion II	The mean truth value from management-related surface erosion: Road-related and Land Use-related	0.33
Road-related	Fine sediment contribution to streams from roads from either SEDMODL_V2 (first choice) or the mean of Density of Roads	0.5

Table 4.1-2
Reference Curve Metrics for the EMDS Sediment Production Risk Model, Version 1.0

Sediment Production Factor	Definition*	Weights**
	Proximate to Streams, Density of Road-related Gullies, Density of Roads by Hillslope Position, and Road Surface Type	
SEDMODL-V2	(when model is available – first choice of SOR node)	1.0
Density of Roads Close to Streams	(2nd choice of SOR node, averaged with 3 subsequent road-related measures directly below)	0.25
Density of Roads by Hillslope Position	Weighted sum of road density by slope position	0.25
Road length on lower slopes	Density of roads of all types on lower 40% of slopes	0.6
Road length on lower slopes	Density of roads of all types on mid-slope (41-80% of slope distance)	0.3
Road length on upper slopes	Density of roads of all types on upper 20% of slopes	0.1
Density of Road-related Gullies	Density of gullies related to roads	0.25
Road Surface Type	Percentage of roads with surfaces that are more likely to deliver fine sediments to streams (no data currently supplied to model here)	0.25
Land Use related	Fine sediment contribution to streams from intensive, timber harvest, and ranched areas (*see below in table***)	0.5
On slopes of *high* potential instability	Slope stability defined by CGS map class 5	0.7
On slopes of *moderate/high* potential instability	Slope stability defined by CGS map class 4	0.17
On slopes of *low/moderate* potential instability	Slope stability defined by CGS map class 3 (or SHALSTAB if unavailable)	0.09
On slopes of *low* potential instability	Slope stability defined by CGS map classes 1 and 2 (or SHALSTAB if unavailable)	0.04
Land Use related surface erosion parameter details	(evaluated separately for each of the four categories of potential slope instability)	
Intensive land use	Land where human activity is intensive	
- developed areas	Percentage of the planning watershed area in high density buildings and pavement	0.2
- farmed areas	Percentage of planning watershed area in intensive crop cultivation	0.2
- area of timber harvests	Percentage of planning watershed area tractor logged, by time period	
- Era 0 (2000 – present)	Tractor logged area 2000-present	0.3
- Era 1 (1990 – 1999)	Tractor logged area 1990-1999	0.2
- ranched area	Percentage of planning watershed area used for grazing livestock; estimated based on vegetation type and parcel type	0.1
Streamside Erosion II	The mean truth value from management-related streamside erosion: Road-related and Land Use-related	0.33

* all breakpoints for the sediment production risk model were created from the tails of the cumulative distribution function curves for each parameter, at the 10th and 90th percentiles. Thus all resultant values are relative to the basin as a whole, but are not rated on an absolute basis

** weights for parameters at each node sum to 1.0; indentation of weight shows the tier where it is summed

4.1.4 ADVANTAGES, APPLICATIONS, AND LIMITATIONS OF EMDS

Advantages

EMDS offers a number of advantages for use by NCWAP. Instead of being a hidden "black box", each EMDS model has an open and intuitively understandable structure. The explicit nature of the model networks facilitates open communication among agency personnel and with the general public through simple graphics and easily understood flow diagrams. The models can be easily modified to incorporate alternative assumptions about the conditions of specific environmental factors (e.g., stream water temperature) required for suitable salmonid habitat.

Using ESRI Geographic Information System (GIS) software, EMDS maps the factors affecting fish habitat and shows how they vary across a basin. At this time no other widely available package allows a knowledge base network to be linked directly with a geographic information system such as ESRI's ArcView. This link is vital to the production of maps and other graphics reporting the watershed assessments. EMDS models also provide a consistent and repeatable approach to evaluating watershed conditions for fish. In addition, the maps from supporting levels of the model show the specific factors that taken together determine the overall watershed condition. This latter feature can help to identify what is most limiting to salmonids, and thus assist to prioritize restoration projects or modify of land use practices.

Another feature of the system is the ease of running alternative scenarios. Scientists and others can test the sensitivity of the assessments to different assumptions about the environmental factors and how they interact, through changing the knowledge-based network and breakpoints. "What-if" scenarios can be run by changing the shapes of reference curves (e.g., Figure 4.1-4), or by changing the way the data are combined and synthesized in the network.

NetWeaver/EMDS/ArcView tools can be applied to any scale of analysis, from reach specific to entire watersheds. The spatial scale can be set according to the spatial domain of the data selected for use and issue(s) of concern. Alternatively, through additional network development, smaller scale analyses (i.e., subwatersheds) can be aggregated into a large hydrologic unit. With sufficient sampling and data, analyses can be done even upon single or multiple stream reaches.

Management Applications

EMDS syntheses can be used at the basin scale, to show current watershed status. Maps depicting those factors that may be the largest impediments, as well as those areas where conditions are very good, can help guide protection and restoration strategies. The EMDS model also can help to assess the cost-effectiveness of different restoration strategies. By running sensitivity analyses on the effects of changing different habitat conditions, it can help decision makers determine how much effort is needed to significantly improve a given factor in a watershed and whether the investment is cost-effective.

EMDS results can be fed into other decision support software, such as Criterium Decision Plus. CDP employs a widely used approach called Analytic Hierarchy Process (AHP) to assist managers in determining their options based upon what they believe are the most important aspects of the problem.

At the project planning level, EMDS model results can help landowners, watershed groups and others select the appropriate types of restoration projects and places (i.e., planning watersheds or larger) that

can best contribute to recovery. Agencies will also use the information when reviewing projects on a watershed basis.

The main strength of using NetWeaver/EMDS/ArcView knowledge base software in performing limiting factors analysis is its flexibility, and that through explicit logic, easily communicated graphics, and repeatable results, it can provide insights as to the relative importance of the constraints limiting salmonids in North Coast watersheds. NCWAP will use these analyses not only to assess conditions for fish in the watersheds and to help prioritize restoration efforts, but also to facilitate an improved understanding of the complex relationships among environmental factors, human activities, and overall habitat quality for native salmon and trout.

Limitations of the EMDS Model and Data Inputs

At the time of the production of this report, we have not been able to implement all of the recommendations made by our peer reviewers. Hence, the current model outputs should be used with caution. NCWAP will continue to work to refine and improve the EMDS model, based on the peer review.

While EMDS-based syntheses are important tools for watershed assessment, they do not by themselves yield a course of action for restoration and land management. EMDS results require interpretation, and how they are employed depends upon other important issues, such as social and economic concerns. In addition to the accuracy of the EMDS model constructed, the currency and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. Where possible, external validation of the EMDS model using fish population data and other information should be done.

One disadvantage of linguistically based models such as EMDS is that they do not provide results with readily quantifiable levels of error. However, we are developing methods of determining levels of confidence in the EMDS results, based upon data quality and overall weight given to each parameter in the model.

NCWAP will use EMDS only as an indicative model, in that indicates the quality of watershed or instream conditions based on available data and the model structure. It is not intended to provide highly definitive answers, such as from a statistically based process model. It does provide a reasonable first approximation of conditions through a robust information synthesis approach; however its outputs need to be considered and interpreted in the light of other information sources and the inherent limitations of the model and its data inputs. It also should be clearly noted that EMDS does not assess the marine phase of the salmonid lifecycle, nor does it consider fishing pressures.

While EMDS provides one part of the watershed picture, integration of physical watershed features and habitat was necessary using GIS and interdisciplinary analysis to gain a better perspective on these relationships.

4.2 Integrated Analysis of Physical Features and Habitat

As introduced in Chapter 2, NCWAP examines relationships among land use, landslides, and relative landslide potential at watershed, subbasin, and planning watershed levels. This section discusses those analyses at the basin (Gualala River Watershed) scale, including comparisons of subbasins. These

tables may be used to assess relative impacts of landslides and potential for delivering sediment to streams to guide future management and mitigation activities.

These tables do not imply nor establish causal mechanisms between land use and landslide features. That would require site-specific investigations, which are beyond the scope of the NCWAP assessment. Additionally, there was limited field reconnaissance and verification. This can result in aerial photo interpretation biases against detecting small landslide features, slides under forest canopy compared to grasslands or recently harvested forestland, and slides occurring after the photo was taken.

These tables also contain only current road network data as developed by the University of California's Information Center for the Environment at Davis for the Gualala total maximum daily load (TMDL). Information about the relationship between historical roads and sediment inputs to streams that NCWAP used in the *Potential Restoration Sites and Habitat Limiting Factors Map* (Plate 3) described later in this chapter.

4.2.1 LANDSLIDES AND LAND USE/LAND TYPE

NCWAP developed a series of tables that compared spatial coincidence of historically active landslide features with land use. Tables 1A-1 to 1A-6 in Appendix 6B examine the occurrence of historically active rockslides, earthflows, debris slides and debris flows with four categories of land use or vegetation in each subbasin for every planning watershed. (Percentages in each table refer to the watershed unit of analysis for that particular subbasin.)

Land use or vegetation types are woodland and grassland acreage, timber harvest plan (THP) acreage from 1991 through 2000, timberland acreage with no recent harvest (since 1991), and road mileage. In the Gualala, woodland or grassland is typically used for grazing, though a small portion (estimated between 700 and 1,000 acres) has been converted to vineyards. Timberland without recent harvest may include less substantial forms of timber management, such as pre-commercial thinning.

The purpose of these comparisons is to understand how landscape stability underlies land use. Utilizing this information will help minimize damage to roads and structures as well as reduce reactivation or triggering of landslides or contributing to slope instability from activities such as timber harvest, roads, or construction.

Table 4.2-1 summarizes land use and historically active landslide features data for the whole Gualala watershed that has the tributary data rolled up to the subbasin scale. Percentages are with respect to the entire Gualala River Watershed.

Table 4.2-1 shows historically active landslide features were observed on approximately 18,000 acres (~9 percent) of the entire Gualala River Watershed area. From Table 1A-1 (appendix), almost 16,000 acres of the 18,000 acres of historically active landslides are earthflows. Approximately 8,900 acres, which is over half of the historically active landslide acreage, are in the Wheatfield Fork Subbasin. Areas of historically active landslides in decreasing order for the other subbasins are: Gualala Subbasin ,~4,500 acres, (~2.5 percent); Rockpile Subbasin, ~2,500 acres (~1 percent); North Fork Subbasin, almost 1,200 acres; and Buckeye Creek, ~ 700 acres. Historically active landslides in both the North Fork and Buckeye subbasins occupy less than 1 percent of the entire watershed.

Table 4.2-1

Acres and Percent Area of Historically Active Landslides Associated with Land Use or Type for the Gualala River Watershed

	Historically Active Landslide Features[a]		Woodland and Grassland[b]		THPs 1991 - 2000		Timberland, No Recent Harvest[c]		Roads[d]	
	Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Length (miles)	% of Total Length
Gualala Watershed (190,992 acres) (1,432 road miles)										
Entire Watershed	**17,785**	**9.3%**	**10,958**	**5.7%**	**1,079**	**0.6%**	**5,520**	**2.9%**	**79**	**5.5%**
Subbasins										
North Fork Subbasin (30,635 acres) - 16% of watershed (291 road miles) - 20% of roads in watershed	1,164	0.6%	361	0.2%	285	0.1%	521	0.3%	8.3	0.6%
Rockpile Subbasin (22,389 acres) - 12% of watershed (167 road miles) - 12% of roads in watershed	2,523	1.3%	1,392	0.7%	435	0.2%	777	0.4%	11.0	0.8%
Buckeye Subbasin (25,767 acres) - 14% of watershed (229 road miles) - 16% of roads in watershed	677	0.4%	452	0.2%	81	0.0%	153	0.1%	1.9	0.1%
Wheatfield Fork Subbasin (71,445 acres) - 37% of watershed (444 road miles) - 31% of roads in watershed	8,899	4.7%	6,281	3.3%	166	0.1%	2,176	1.1%	36.8	2.6%
Gualala Subbasin (40,756 acres) - 21% of watershed (306 road miles) - 21% of roads in watershed	4,522	2.4%	2,472	1.3%	112	0.1%	1,893	1.0%	20.6	1.4%

a Refer to Plate 1 and California Geological Survey appendix. Historically active landslides include earthflows, rock slides, debris slides and debris flows.
b Woodland and grassland includes areas mapped in 1998 as grassland and non-productive hardwood.
c Area of timberlands that were not contained in a THP during the 1991 to 2000 period.
d Roads layer is current roads from University of California at Davis Information Center for the Environment (ICE)
Empty cells denote zero.
Percent of area is based on the area of the entire Gualala River Watershed

Woodland and grassland areas have the largest proportion of historically active landslides in the watershed, approximately 11,000 acres (6 percent) of the entire Gualala watershed, which is consistent with the underlying geology. These areas are in the finer-grained and less competent melange of the Franciscan Complex that typically fail as large earthflows. Conifer forests generally do not grow well on the mélange. Approximately 1,100 acres (less than one percent) of the entire watershed are areas of historically active landslides within THP areas between 1991-2000.

Approximately 5,500 acres (~3 percent) of the watershed area have historically active landslides within timberlands that are not included in THPs since 1991.

With respect to roads, approximately 80 miles or 5 percent of the current roads in the watershed cross areas of mapped historically active landslides. The largest portions of roads that are located in historically active landslides occur in the Wheatfield Subbasin with approximately 37 miles.

4.2.2 RELATIVE LANDSLIDE POTENTIAL AND LAND USE / LAND TYPE

Table 4.2-2 provides information about relative landslide potential in relation to the same land uses or vegetation types used in Table 4.2-1. Relative Landslide Potential categories are based on geology, slope, and presence of historically active and dormant landslides and geomorphic features associated with natural mass wasting processes (Plate 2, *Relative Landslide Potential with Geologic and Geomorphic Features* map shows areas that are prone to different degrees of landsliding potential). These maps can be used to help future land use and management activities avoid or mitigate impacts from landslides. More detailed information on the relative landslide potential map is located in Chapter 2. Appendix 6B contains Tables 2A-1 to 2A-6 which include information down to the planning watershed scale and provide acreage for all five landslide potential categories.

The purpose of these tables is to help landowners, managers, and agencies take measures to protect the naturally unstable slopes. Therefore, Table 4.2-2 focuses on high and very high relative landslide potential areas, based on the assumption that actively sliding material has the lowest relative strength, and thus, the highest relative potential for landsliding of all the geological materials underlying the slopes. The two categories of areas that pose the most concern are the high (Category 4) and very high (Category 5) landslide potential. A brief description of the high and very high relative landslide potential categories and generalized implications and recommendations for each are:

- ***Category 4 – High Landslide Potential:*** Caution should be used before undertaking any land use alteration in these areas. Based on the known occurrence of dormant earth flows, rockslides, disrupted ground and debris slide slopes on moderate to steep slopes (30 – 64 percent), there is the likelihood that land use changes in these areas could activate and or increase existing land sliding activity if appropriate precautions and/or mitigation measures are not considered and implemented. A site-specific evaluation addressing slope stability is recommended prior to changes to existing land use.
- ***Category 5 - Very High Landslide Potential:*** This category includes all historically active landslides. Extreme caution should be used before undertaking any land use alteration in these areas. Based on the known occurrence of historically active earth flows, rockslides, debris flows and debris slides and the presence of debris slide slopes, inner gorges, and slopes over 65 percent, there is a strong likelihood that land use changes in these areas could increase or activate land sliding activity if appropriate precautions and/or mitigation measures are not considered and implemented. A site-specific evaluation with regard to slope stability is highly recommended prior to changes to existing land use.

Table 4.2-2

Acres and Percent of Area by Relative Landslide Potential and Land Use or Type Classes, Gualala River Watershed

Subbasin or Planning Watershed	Relative Landslide Potential[a]	Entire Watershed		Woodland or Grassland[b]		THPs 1991 - 2000[e]		Timberland, No Recent Harvest[c]		Roads[d]	
		Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Length (miles)	% of Total Length
Gualala Watershed (190,992 acres) (1,432 road miles)	Very Low	9,399	5	1,318	1	1,992	1	5,163	3	145.0	10
	Low	17,658	9	3,051	2	4,117	2	9,619	5	246.8	17
	Moderate	54,948	29	9,361	5	14,443	8	30,258	16	450.7	31
	High	75,100	39	23,131	12	16,317	9	34,756	18	432.2	30
	Very High	33,725	18	13,912	7	5,048	3	14,210	7	157.5	11
	High/ Very High Subtotal	108,825	57	37,043	19	21,365	11	48,965	26	589.8	41
	TOTAL	**190,830**	**100**	**50,772**	**27**	**41,918**	**22**	**94,004**	**49**	**1,432.3**	**100**
North Fork Subbasin (30,635 acres) - 16% of watershed (291 road miles) - 20% of roads in watershed	High	12,861	6.7%	2,741	1.4%	4,475	2.3%	5,598	2.9%	101.6	7.1%
	Very High	4,241	2.2%	740	0.4%	1,437	0.8%	2,036	1.1%	29.5	2.1%
	High/ Very High Subtotal	17,101	9.0%	3,481	1.8%	5,911	3.1%	7,633	4.0%	131.1	9.2%
Rockpile Subbasin (22,389 acres) - 12% of watershed (167 road miles) - 12% of roads in watershed	High	9,889	5.2%	1,828	1.0%	3,797	2.0%	4,157	2.2%	63.9	4.5%
	Very High	4,521	2.4%	1,560	0.8%	1,229	0.6%	1,773	0.9%	22.1	1.5%
	High/Very High Subtotal	14,410	7.5%	3,388	1.8%	5,026	2.6%	5,929	3.1%	86.0	6.0%
Buckeye Subbasin (25,767 acres) - 14% of watershed (229 road miles) - 16% of roads in watershed	High	10,607	5.6%	2,906	1.5%	3,019	1.6%	4,847	2.5%	66.1	4.6%
	Very High	2,977	1.6%	700	0.4%	815	0.4%	1,496	0.8%	19.4	1.4%
	High/Very High Subtotal	13,583	7.1%	3,606	1.9%	3,833	2.0%	6,343	3.3%	85.5	6.0%

Table 4.2-2

Acres and Percent of Area by Relative Landslide Potential and Land Use or Type Classes, Gualala River Watershed

Subbasin or Planning Watershed	Relative Landslide Potential[a]	Entire Watershed		Woodland or Grassland[b]		THPs 1991 - 2000[e]		Timberland, No Recent Harvest [c]		Roads [d]	
		Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Area (acres)	% of Area	Length (miles)	% of Total Length
Wheatfield Fork Subbasin (71,445 acres) - 37% of watershed (444 road miles) - 31% of roads in watershed	High	27,577	14.4 %	12,338	6.5%	3,737	2.0%	10,933	5.7%	122.6	8.6%
	Very High	15,545	8.1%	8,224	4.3%	1,236	0.6%	5,595	2.9%	59.2	4.1%
	High/Very High Subtotal	43,122	22.6 %	20,562	10.8%	4,974	2.6%	16,528	8.7%	181.8	12.7%
Gualala Subbasin (40,756 acres) - 21% of watershed (306 road miles) - 21% of roads in watershed	High	14,167	7.4%	3,317	1.7%	1,289	0.7%	9,221	4.8%	78.0	5.4%
	Very High	6,441	3.4%	2,688	1.4%	332	0.2%	3,310	1.7%	27.3	1.9%
	High/Very High Subtotal	20,608	10.8 %	6,006	3.1%	1,621	0.8%	12,531	6.6%	105.3	7.4%

a Refer to Plate 1 and California Geological Survey appendix. Historically active landslides include earthflows, rock slides, debris slides and debris flows.
b Woodland and grassland includes areas mapped in 1998 as grassland and non-productive hardwood.
c Area of timberlands that were not contained in a THP during the 1991 to 2000 period.
d Roads layer is from ICE
Empty cells denote zero.
Percent of area is based on the area of the entire Gualala River Watershed

Table 4.2-2 summarizes the occurrence of woodland/grassland, areas in THPs between 1991 and 2000, and timberlands not included in a THP since 1991-2000 and roads with respect to Relative Landslide Potential Categories 4 (high) and 5 (very high). Results are presented for the entire Gualala River Watershed as well as the five subbasins. All percentages on Table 4.2-2 are with respect to area or miles of the entire watershed.

Approximately 109,000 acres, or 57 percent, of the entire Gualala River Watershed's 191,000 acres are in high (Category 4) or very high (Category 5) landslide potential category. Approximately 39 percent (75,000 acres) are categorized as high relative landslide potential and 18 percent (34,000 acres) are very high relative landslide potential. Areas of moderate landslide potential comprise almost 30 percent (55,000 acres) of the watershed. Provisions to protect the naturally unstable slopes are discussed in the subbasin sections.

Of the five subbasins, the Wheatfield Fork contains the largest area of high and very high landslide potential, over 43,000 acres (more than 22 percent of the entire watershed), approximately half of which are located in woodland or grassland. Areas of high and very high landslide potential in each of the other four subbasins range from approximately 21,000 acres (11 percent of the watershed) in the Gualala Mainstem/South Fork Subbasin to 13,000 acres (7 percent) in the Buckeye Subbasin.

About a third of the high to very high landslide potential areas (37,000 acres) are located in woodlands or grasslands. The Wheatfield has by far the most of these acres (20,562 acres).

Table 4.2-2 shows approximately 21,000 acres (11 percent of the watershed) is categorized as high to very high landslide potential in areas covered by THPs between 1991 and 2000. The North Fork Subbasin had the most acreage of 1991-2000 THPs in the high and very high landslide potential areas in the last decade, approximately 6,000 acres (3 percent of the watershed), commensurate with the steepest slopes in the watershed. Rockpile and Wheatfield Fork subbasins follow closely, each with approximately 5,000 acres or 2.5 percent of the watershed. Buckeye Subbasin contains almost 4,000 acres (2 percent of the watershed).

About 49,000 acres (25 percent of the watershed) is classified as high and very high landslide potential and occurs within timberland that is not included in THPs since 1991. The largest portion of this area is located in the Wheatfield Fork Subbasin (16,500 acres, almost 9 percent of the entire watershed). The Gualala Mainstem/South Fork Subbasin contains 12,500 acres (almost 7 percent of the entire watershed) of high to very high landslide potential in timberlands not harvested between 1991 and 2000. The remaining 20,000 acres of timberland not harvested between 1991 and 2000 that is included in areas of high to very landslide potential are almost equally divided among the North Fork, Rockpile and Buckeye subbasins.

4.2.3 ROADS AND THE LANDSCAPE

CDF's studies of the implementation and effectiveness of the Forest Practice Rules indicate that mass wasting failures associated with current timber operations have been mostly related to roads. Roads produced the highest sediment delivery to watercourse channels when compared to other erosion processes (Monitoring Study Group 1999). The majority of the road related mass failures were associated with fill slope problems, indicating that proper road construction techniques are critical for protecting instream resources.

Timber and ranchland roads crossing steep slopes, historically active landslides, debris slide slopes or inner gorges can be sources of excess sediment to stream channels through erosion, fill failures and landsliding. Roads with undersized culverts and improper drainage design are vulnerable to stream crossing blowouts and debris slide failures during large storm events. Such roads can impact streams and delay or reverse recovery process downstream. In addition, abandoned streamside roads and landings can continue to discharge sediment during these storms. The Gualala River Watershed Council targets much of their restoration funds to abandonment and proper stabilization of the mid-20th-century instream road network (Figure 4.2-1).

Roads as Features

NCWAP examined both historical and modern road networks to characterize impacts by the road debris slides and road crossing failures on stream channel morphology. Maps of road networks were interfaced with (1) CGS Relative Landslide Potential maps, and (2) historically active landslides to show slide prone areas with roads. CGS mapping of landslides and selected fluvial geomorphic features allowed comparison of landslide activity to instream sediment accumulations and comparison of instream sediment levels between 1984 and 1999/2000. The integrated analysis then compared the naturally occurring historically active landslides with the road network. In addition, CDF used 1965 air photos at close scale (1:1200) to compare evolving stream channel morphology with the CGS 1984 and 1999/ 2000 fluvial geomorphology mapping.

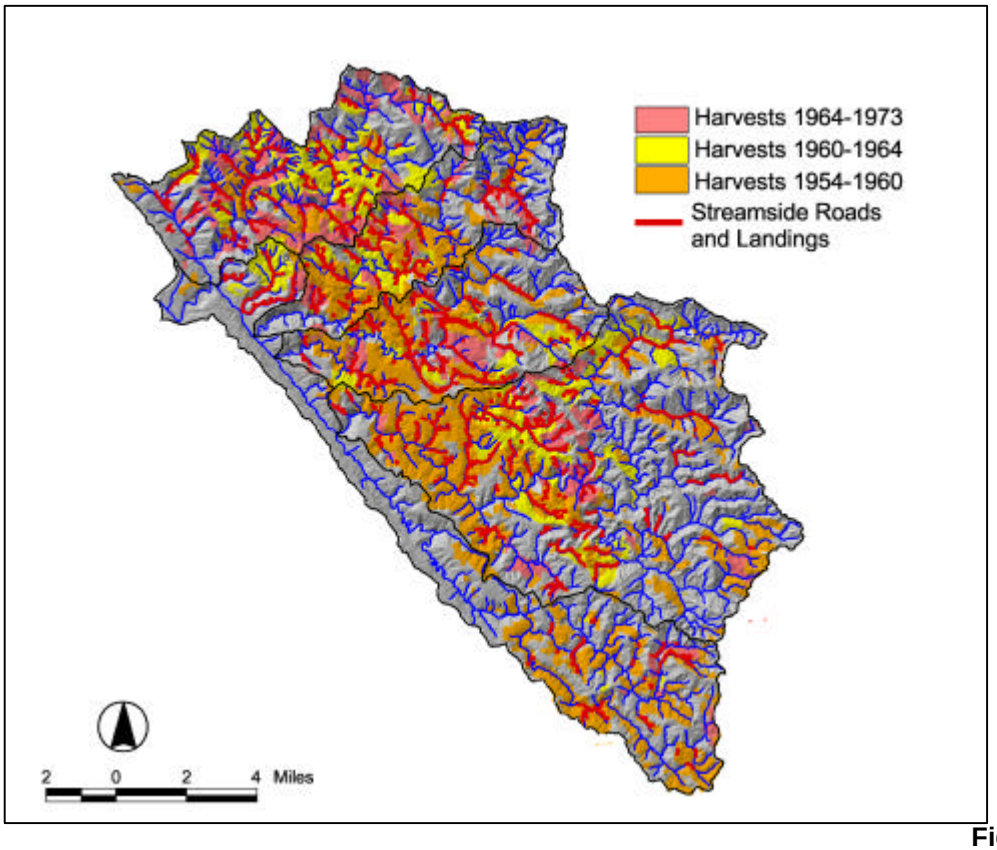


Figure 4.2-1
Mid-20th-Century tractor logging areas shown in three separate time strata, and instream/ streamside roads (lines) and landings (circles)

The following table provides estimates of mileage of historical and modern roads near or within watercourses by subbasin. CDF mapped the historical timber and ranchland roads using 1961, 1963, 1965, and 1981 aerial photographs. CDF mapped only those road segments that were (1) in the streambed or (2) following the stream channel at an equal elevation to the outer streambank. The modern roads were clipped to show those sections within 50 feet of blue line streams (Figure 4.2-2 and Table 4.2-3).

Table 4.2-3
Comparison of Historical Instream Roads with Modern Roads within 50 Feet of Blue Line Streams

Subbasin	In Stream/ Streamside Roads (miles) 1952 – 1968	Modern Roads (miles) Within 50 Feet of Streams/ Total Road Length in Subbasin
North Fork	18	2.5 / 291
Rockpile	16	1.5 / 168
Buckeye	27	1.5 / 229
Wheatfield	19	3.0 / 444
South Fork	15	1.5 / 116

Mid-20th-Century Stream Channel Impacts

1965 photos confined to the east portion of the watershed show stream channel aggradation along (1) Grasshopper Creek in the Buckeye subbasin, and (2) major tributary streams of the Lower Wheatfield Super Planning Watershed. Throughout Grasshopper, Fuller, Sullivan, Tobacco, and Haupt creeks, the sinuous stream channel patterns through the logged areas showed either (1) channel meandering through wide, flat areas of sediment fans in low gradient steps, or (2) stream deflections around fresh debris slides. Multiple road debris slide failures triggered by large storm events represented substantial mid-20th-century sediment sources (Figure 11, Appendix 6a). Meandering channel patterns returned to a more lineal pattern through 1984 and more so by 1999, indicating decreasing bedload sediment (Figure 14, Appendix 6a).

Movement Towards Stream Channel Recovery

Approximately 95 total miles of mid-20th-century in stream/streamside roads followed watercourses in or along the stream banks throughout the watershed. Many more of these roads were located slightly upslope but still within 50 feet of blue line streams. These older road sections were not mapped with this study. However, historical roads were predominately located low on the sideslope, frequently crossing “very high” Relative Landslide Potential Category areas. There were a total of 145 instream landings associated with stream aggradation or braiding.

Thirteen hundred miles of modern timber and ranchland roads (mapped using current photos) mostly follow mid-slope benches and ridgelines. Only approximately 10 miles are located within 50 feet of blue line streams as compared to approximately 95 miles in mid-20th-century.

The database shows that road debris slides can be triggered by proximity to streams and steep sideslopes. A review of fluvial impacts of the mid-20th-century aerial photographs showed a high frequency of road and landing failures along streamside roads throughout steep and deeply incised

terrain. This is especially evident and seen as channel aggradation from pre-1973 unregulated mid-20th-century roads located low on the sideslope following stream channels. These roads frequently crossed inner gorges and slide prone areas. Large storm events activated numerous debris slides that buried stream pools throughout long portions of anadromous fish-bearing streams.

Active timber management during the last decade has required road upgrade specifications with any timber harvesting. New road construction associated with Timber Harvest Plans preferentially follow ridgelines and mid-slope benches to distance excavation disturbances from streams. Timber located near streams on steep slopes can be accessed only by cable yarding systems.

With the shift in road construction practices to mid-slope benches and ridgeline locations most contemporary sediment source sites are associated with road watercourse crossing locations. Modern roads cross streams at a perpendicular angle rather than following the stream on one side. Modern road sediment inputs are more related to the immediate road watercourse crossing sites and road approaches to streams. Historical roads following the creek are prone to failure where stream banks undercut the road causing collapse during storms as a function of stream velocity, slope steepness, and road and geologic instabilities.

The shift in the road network to upslope positions away from blue line streams has allowed improvement towards recovery of channel conditions. Stream channel morphology experienced the following general evolution over the last half century: (1) a high density of debris flow mounds in the active channel triggered by mid-20th-century storm events; (2) progressive abatement of the frequency of these point sources over successive decades; and (3) apparent movement towards recovery of instream channel substrate between 1984 and 1999/ 2000 as evidenced by a reduction in the percentage of channel length affected by excess sediment storage or sediment sources. CGS fluvial geomorphic mapping of stream conditions documents that the channel has improved from 1984 to 1999/2000 throughout the watershed. This period includes recent active timber harvesting in the northern portion of the watershed that included road building.

The current road network shows less overall coincidence of debris slides and stream crossing failures compared to historical times. Proximity to streams and steep slopes, however, continues to be associated with most of the contemporary road failures. Recent Timber Harvest Plans report numerous road failures triggered by the 1986 and 1996 storms. Undersized culverts and substandard road crossings were particularly vulnerable to failure during these storms.

The extent to which additional input of sediment may have slowed channel substrate recovery from mid-20th-century discharges is not known. Sediment generated by mid-20th-century tractor era disturbances would be routed through the river network over a period of decades to centuries. Some of the sediment likely is still stored in the lower stream reaches and flood plains. In addition, as recently as 1996, Timber Harvest Plan records reference mid-20th-century generated debris still present in streams in the middle watershed reaches. This includes Stewart Creek in the North Fork, the central Rockpile Subbasin and the upper reaches of Grasshopper and Osser creeks in the Buckeye Subbasin.

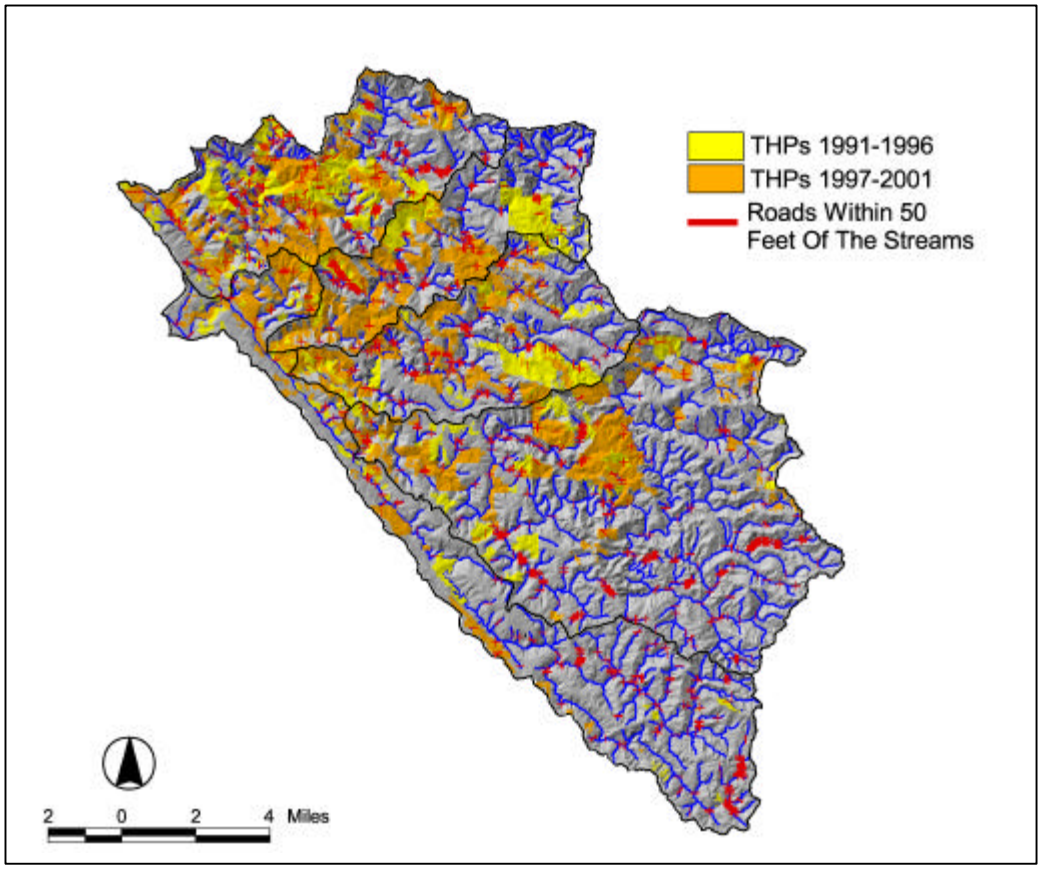


Figure 4.2-2
Segments of Modern Roads Located within 50 Feet of Blue Line Streams (Red), with 1991 to 2001 Timber Harvest Plans indicated.

Relative Landslide Potential and Roads

Prior to 1973, the road network was nearly all located in Relative Landslide Potential Category 5 areas. Road construction following the stream channel was the most efficient and economical log transportation route. Built during the mid-1950s through 1968, streamside and instream road and landing networks spanned most of the natural fluvial drainage system of the north and central watershed areas. These roads dominated stream channel structure throughout the North Fork, Rockpile, Buckeye, and Lower Wheatfield Subbasins.

The steep channels in several Relative Landslide Potential Category 5 areas concentrated flows during storm events. The steep topography and high stream density probably caused intense, flashy runoff that often removed the primitive log and dirt road stream crossings and instream landings. Storm events also undermined the streamside roads collapsing road segments into the streams.

The shift in the road network to upslope positions away from blue line streams resulted in fewer miles of roads located in Relative Landslide Potential Category 5 areas. Approximately 40 percent of the modern roads in the watershed (approximately 600 miles) are located in areas of high to very high relative landslide potential in all of the subbasins. The largest number of miles of modern roads in high to very high relative landslide potential are in the Wheatfield and North Fork subbasins with approximately 180 and 140 miles, respectively. The Gualala Subbasin contains approximately

105 miles and the Rockpile and Buckeye Subbasins each include approximately 85 miles of roads in high to very high relative landslide potential areas.

4.2.4 RELATIVE LANDSLIDE POTENTIAL AND SILVICULTURE AND YARDING METHODS

Tables 2B-1 through 2B-6 (Appendix 6B) compare timber harvesting by silvicultural system and yarding methods. This presentation overlays the amount and types of harvesting activities occurring on various relative landslide potential categories. These are broad comparisons to show general trends throughout variable terrain.

However, this approach has limitations to its usefulness for predicting potential sediment sources. In 1998, the California Board of Forestry's Hillslope Monitoring Study Group found the contribution of rill erosion over clear-cut areas that eventually accessed streams was proportionately small compared to roads, especially road watercourse crossing points (California State Board of Forestry, Monitoring Study Group 1998.

Additionally, while the GIS database includes total acreage within the THP boundary, certain management activities are prohibited as part of a watercourse and lake protection zone (WLPZ) protective buffer corridor ranging from 100 to 150 feet or more from the base of the stream bank, in buffer zones, corridors over streams, and areas of active sediment sources such as inner gorges. Cable yarding is also typically specified for such areas. However, the GIS database includes WLPZ buffer zones as part of overall clearcutting acreage tabulations. Similarly, active landslides and debris slide slopes in the field are excluded from clearcutting. Such field mitigations are verified on the ground during pre-harvest inspections. The NCWAP GIS database does not assimilate these considerations and therefore overestimates the total acreage of harvest in THPs for clearcuts and even more so for selection cuts.

Tables 2B-1 through 2B-6 (Appendix 6B) compare timber harvesting and relative landslide potential. These tables break out timber harvesting by silvicultural system and yarding methods. This presentation compares the amount and types of harvesting activities occurring on areas of various relative landslide potential. In general, cable and helicopter methods are combined to show similar means of mitigation in Relative Landslide Potential category 4 and 5 areas.

The ratio between tractor to cable generally ranges from an even split to a 2 to 1 ratio of tractor to cable for THPs between 1991 and 2001 throughout the subbasins. Table 4.2-4 lists the break down of cable yarding and tractor logging for each subbasin over the period of 1991 to 2001.

Table 4.2-4
THP Yarding Methods By Subbasin, 1991-2001, Gualala River Watershed

Subbasin	Percent Cable Yarding	Percent Tractor Logged
North Fork	43	57
Rockpile	44	56
Buckeye	42	58
Wheatfield	30	70
South Fork	32	68

In the early to mid 1990s, THPs in the central watershed reaches had a higher proportion of tractor yarding and used existing skid trails left from the mid-20th-century logging. The forest practice rules allow tractors to use existing skid trails on sideslopes up to 50 percent. Existing skid trails between 50 percent and 65 percent can be used providing these are explained and justified in the THP and flagged on the ground for review during the pre-harvest inspection. These skid trails must be properly stabilized by completion of operations. Most of the Coastal Forestland THPs in the mid-1990s frequently used older vegetated skid trails as "designated skid trails" to access scattered remnant conifers left on steep terrain that were inaccessible or avoided during the mid-20th-century logging. Other private logging also reused previously excavated skid trails crossing moderate to steep sideslopes. These THPs specified "tractor operations" using "designated skid trails". The operations covered large areas to access scattered leave timber. However, the ground was not fully traversed by tractors to the extent of actual clear cut harvesting when removing an entire mature stand. Such areas were left predominantly vegetated after operations as verified with 1999/2000 photos. However, the GIS database makes no distinction between these degrees of tractor harvesting.

The per cent area of allowable tractor harvesting on Category 4 and 5 clearcut (even-aged silvicultural treatment areas) is under 10 percent and shows proper mitigation applied during multi-agency review on site: North Fork: 109 acres (1.5 percent of watershed), Rockpile: 200 acres (3.4 percent), Buckeye: 261 acres (6.2 percent), Wheatfield: 461 acres (5.8 percent), and South Fork: 364 acres (3.4 percent). These tables show cable/helicopter as predominant methods for steep terrain.

These GIS reference comparisons also show the following trends: (1) the early 1990s had a higher proportion of tractor harvesting than recent years, and (2) the use of cable yarding is expanding. In addition, the shift in the road network to upslope locations is more suited to cable yarding.

In contrast, during the 1950s and 1960s, tractors operated indiscriminately throughout Category 5 (very high landslide potential) areas across steep sideslopes following straight parcel lines regardless of terrain. Across extreme sideslopes in excess of 65 percent, tractors cut into the sidebank to keep from falling over. This created a terraced landscape of step skid trails cut into the sideslope. No erosion control or ditching was installed prior to winter rains. Analysis of 1965 photos found gully erosion and collapsed skid ramp terraces onto one another after the 1964 rains.

Timber Harvest Plan areas (from 1991 to 2001) on high or very high Relative Landslide Potential areas compare similarly with the mid-20th-century areas. For the watershed, overall acreage on Category 4 and 5 areas are about the same (51 and 52 percent, respectively). In the Rockpile Subbasin, a higher percent of 1991 to 2001 THPs occurred in high and very high relative landslide potential classes compared to the percent of previously harvested timberland. In the Buckeye and North Fork Subbasins, the percent of 1991 to 2001 THPs in Category 4 and 5 areas were also slightly higher than that of timberland harvested earlier, while the Wheatfield and South Fork Subbasins' percentages were lower.

Although the overall areas in Relative Landslide Potential categories 4 and 5 areas were similar and operated between the two time periods, the sharp differences in methods of operation showed marked contrasts in stream channel morphology. The 1991 to 2001 THPs combined cable and tractor harvesting, using upslope road locations. The mid-20th-century operations used tractors over all types of terrain and roads following blue line streams. The erosional downcutting, gullying, and multiple debris slide failures caused channel aggradation during storm events. This was not similarly evident in the 1991 to

2001 THP areas. These plans required proper drainage dispersal by completion of operations and restricted tractor access on steep sideslopes.

When comparing acreage harvested from 1932 to 1990 with acreage harvested after 1990, there are approximately twice as many acres harvested in 1932 (100,000 acres to 53,000), but about five times the amount of landslide acreage (2.9 percent of the watershed versus 0.6 percent). This broad comparison suggests that recent regulation under the Forest Practices rules has resulted in more avoidance of landslide features and prevented or mitigated erosion. Historically active landslides on timberland harvested since 1991 occupied approximately 1,000 acres (less than 1 percent) of the entire watershed. Historically active landslides on timberland outside of THP areas since 1991 occupied approximately 5,500 acres (3 percent) of the entire watershed.

4.2.5 Features in and Near Streams with Potential for Sediment Delivery

The association of landslides, gullying, and certain fluvial geomorphic features were analyzed with respect to proximity to the stream channel. Landslides and gullying in close association with stream channels have a higher likelihood of sediment delivery to a stream. Actual fluvial geomorphic features within the stream were analyzed as indicators of stream channel condition, including sediment deposits. This section narrows the perspective from the hillslope associations presented above to the stream channel, a transition in thought to the relevance of hillslope conditions to fish habitat in the streams.

Landslides and Geomorphic Features With High Sediment Delivery Potential

The presence of landslides and geomorphic features proximate to streams is important. Landslides and certain geomorphic features have a high potential to deliver sediment to near-stream or directly into the stream channel, where adverse-impacts to salmonids and their habitat are more likely. The landslide and geomorphic features (as determined from review of aerial photos) are divided into a number of classes (Tables 3A-1 through 3A-6, Appendix 6B):

- Historically active landslide features (movement within the past 150 years) - earthflows, rock slides, debris slides and debris flows
- All dormant landslides as a combined category
- Geomorphic features -- disrupted ground, debris slide slopes and inner gorges.

Most features are reported in terms of area unless they are less than 100 feet wide, in which case the feature was mapped as a linear feature and reported as a length rather than in terms of area. Linear landslide features found on both sides of the stream were counted twice for calculating the percentage of total blue line streams with adjacent linear landslide features. The analysis was based on intersections of listed features with the blue line streams from the United States Geological Survey topographic maps at a scale of 1:24,000.

Areas (acres) or length (miles) of landslide and geomorphic features with respect to three distance ranges from each side of the blue line streams (0 to 180 feet, 180 to 660 feet, and more than 660 feet) were analyzed. Features within 180 feet of the blue line streams were also calculated as: (1) percentage of area of landslides and geomorphic features within 180 feet of blue line streams within the entire Gualala River watershed and (2) percentage of the length of eroding banks, inner gorge and other linear geomorphic features over the total blue line stream length in the entire watershed.

This analysis assumed that landslides (historically active and dormant) and selected geomorphic features including disrupted ground, inner gorges, debris slide slopes, and eroding banks are sources of direct delivery of sediment to streams and that the closer the feature is to a stream, the higher the likelihood of delivering sediment. The rates of delivery of different features vary and are discussed in more detail in Appendix 2. The distance categories used are exclusive, i.e., slide areas or lengths reported in the 0-180 feet column are not repeated in the 180-660 feet or >660 feet columns. Additionally, the >660 feet column includes landslide and geomorphic features that extend to the ridgetop of the unit of analysis (i.e., entire watershed, subbasin, or planning watershed).

Approximately 15,000 acres of landslides (historically active and dormant) and the above listed geomorphic features (covering 7 percent of the watershed area) are located within 180 feet of the blue line streams in the watershed (Table 3A-1, Appendix 6B). This constitutes only 15 percent of all landslides. Approximately 43 miles of the blue line stream in the Gualala River watershed are adjacent to landslides and geomorphic features mapped as linear features as well as inner gorges and eroding banks. These are areas of likely high sediment delivery.

However, using the blue line streams underestimates the total drainage length and in turn underestimates the potential sediment input from historically active and dormant landslides and selected geomorphic features that are sediment sources, many of which are naturally occurring. The drainage network of the Gualala River watershed is much denser than the blue line stream network depicted at a scale of 1:24,000.

Although the actual density of the stream network is much higher than the blue line stream, the relative percentage of landslide area in a subbasin can be used to estimate the relative length of impacted stream after the watershed-wide impact is calculated. (Please refer to the CGS Appendix 2 for further discussion on this issue.) Rather than 15 percent of landslides delivering to blue line streams, analysis using the 10-meter Digital Elevation Models (DEMs) results in 30 percent of landslides contributing to sediment delivery. This is discussed further in Appendix 2 and later in this section.

Gullies and Sediment Delivery

Gullies are another important geomorphic feature for the generation and delivery of sediment to the stream network. Gullies are distinct, narrow channels formed by erosion of soil or soft rock material by running water. As such, they are likely to deliver sediment to streams regardless of their location on the hill slope. Channels are larger and deeper than rills and usually carry water only during and immediately after heavy rain. Gullies often form in response to concentrated surface water flow that can result from high intensity storms, loss of vegetation, and diversion of surface flow at scarps, culverts and road drainage systems. Gullies can deliver sediment from landslides, hillslopes and/or roads directly to drainages and streams as well as widen and downcut hillslopes. Gullies can serve as sediment sources as well as sediment delivery mechanisms.

In the Gualala River Watershed, gullies appear to be stable over the past few decades because gullies visible in aerial photographs are depicted on topographic base maps created at least two decades ago. Although aerial photo analysis identified numerous gullies in the Gualala River Watershed (Table 4.2-5), it is important to note that gullies are often smaller scale geomorphic features, and are difficult to detect under forest canopy or may not be large enough to be visible in aerial photographs. Hence, identifying gullies from aerial photos tends to underestimate the length and number of gullies found in forested areas.

The high occurrence of gullies in the Wheatfield Subbasin is expected because a large portion of the subbasin is underlain with mélange from the Franciscan Complex, and 30 percent of the subbasin is in high or very high landslide potential category. Just as the geologic conditions are responsible for large earthflows in the subbasin, the geology provides the right conditions for gullies. In addition, gullies are more visible in aerial photographs in woodland and grassland areas. Fewer gullies in the other subbasins are likely influenced by several factors and are likely underestimated. These factors can include less visibility in aerial photographs in the forested areas and more competent bedrock (Coastal Belt terrane of the Franciscan Complex) that is less prone to gullying and earthflows. Gullies are shown on Plate 1, *Geologic and Geomorphic Features Related to Landsliding, Gualala River Watershed.*

Table 4.2-5
Length, Number and Percent of Gullies in 1999/2000 Aerial Photographs by Watershed and Subbasin, Gualala River Watershed.

Watershed or Subbasin	Subbasin Area as Percent of Watershed	Length of Gullies (feet)	Percent of Total Gully length	Number of Gullies	Percent of Number Gullies
Entire Gualala		511,413		1,367	
North Fork Subbasin	16	72,561	14%	219	16%
Rockpile Subbasin	12	34,851	7%	86	6%
Buckeye Subbasin	19	58,064	11%	177	13%
Wheatfield Fork Subbasin	37	230,712	45%	601	44%
Gualala Subbasin	21	115,225	23%	284	21%

Fluvial Geomorphic Features and Sediment Delivery

CGS mapped landslides and selected fluvial geomorphic features from aerial photos taken in 1984 and 1999/2000. That mapping allowed comparison of landslide activity to instream sediment accumulations and comparison of instream sediment levels between 1984 and 1999/2000. The methods are described in more detail in Chapter 2 and Appendix 2. More detailed descriptions of the findings are presented in the subbasin sections and Appendix 2.

CGS looked at fluvial geomorphic features indicative of stored channel sediment or sources of sediment that could be identified on the available aerial photographs. Twenty fluvial geomorphic attributes were selected and mapped as indicators of excess sediment in storage or sediment sources that could be considered detrimental to optimum habitats for anadromous salmonids (Table 4.2-6). While most of these features are always associated with increased sediment or impaired conditions, others, such as lateral bars, may or may not represent impairment.

As an example, the lateral bars were considered a detrimental feature whereas the point bars were not. Lateral bars were considered detrimental because they appeared more dynamic than the point bars, changing their size and position more readily than point bars. Lateral bars were often observed directly adjacent to a source of channel sediment, such as a landslide, and often remain for some time after the landslide has healed.

To be conservative, if one of the features on Table 4.2-6 was assigned an attribute that indicates excess sediment storage or sediment sources some of the time, it was included with those characteristics

selected as "negative" attributes. (Refer to CGS Appendix 2 and Chapter 2 for additional information on fluvial geomorphology mapping methods, definitions of mapped features and results.)

Table 4.2-6
GIS Mapped Fluvial Geomorphic Attributes Considered Detrimental to Optimum Habitat for Anadromous Salmonids

Wide channel	Braided channel
Incised	Turbulent flow
Aggrading	Degrading
Cutoff Chute	Backwater
Tributary fan	Eroding left bank (facing downstream)
Transverse bar	Eroding right bank (facing downstream)
Lateral bar	Inner Gorge
Mid-channel bar	Bar at junction of channels
Blocked channel	Displaced riparian vegetation
Active landslide deposit	Older landslide deposit

Time-series mapping helps track changes and trends in channel conditions. The time-series fluvial geomorphic mapping of all watercourses in the Gualala River Watershed provided data to allow for evaluation of changes in channel geomorphology over the 15-year period from 1984 to 1999/2000 (Figure 4.2-3).

The map shows the stream reaches with fluvial geomorphic features detrimental to optimum habitat conditions for anadromous salmonids. The features mapped from 1984 photos are green and 1999/2000 features are blue. The map shows less channel length of fluvial geomorphic features detrimental to optimum habitats for anadromous salmonids mapped in 1999/2000 compared to 1984. Table 4.2-7 shows the length of channel disturbances mapped for the entire watershed and each subbasin and the percent decrease of channel disturbances between 1984 and 2000 based on the aerial photos. Although the NCWAP data do not provide specific information that may be used to clearly identify contributions of individual THPs or other anthropogenic sources of sediment, the fluvial geomorphic mapping documents that throughout the entire watershed approximately 47 percent of the channels with disturbances improved from 1984 to 2000. The largest improvement (57 percent) occurred in the Buckeye Subbasin. Improvements ranged from 38 percent to 47 percent for the other four subbasins. More inclusive tables listing changes in channel disturbances for the Gualala River Watershed and each subbasin are located in the respective subbasin sections of Chapter 5 later in this report and in Appendix 2.

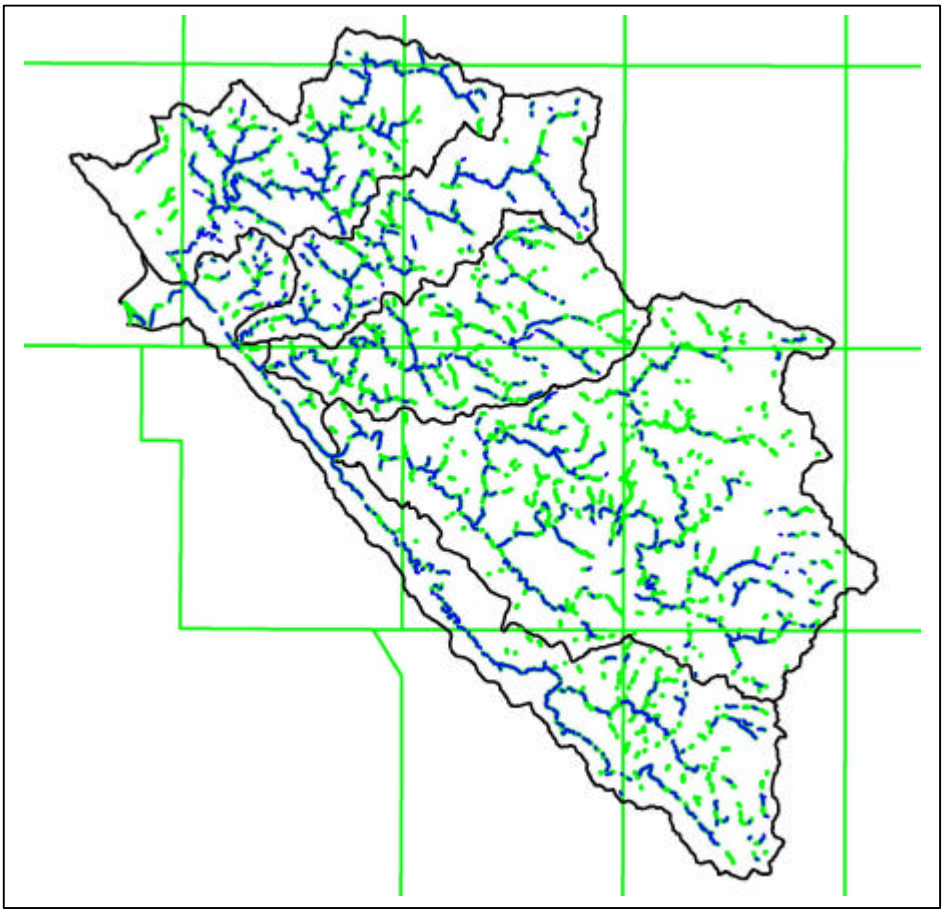


Figure 4.2-3
Fluvial Geomorphic Channel Disturbances Detrimental to Optimum Habitats for Anadromous Salmonids Mapped from Aerial Photographs for the Gualala River Watershed
1984 features are shown in green, 2000 features are shown in blue and the subbasin boundaries are shown in black

Table 4.2-7
Mapped Changes Between 1984 and 1999/ 2000 in Fluvial Geomorphic Channel Disturbances Detrimental to Habitat for Anadromous Salmonids in the Five Subbasins

	Gualala River Watershed	North Fork	Rockpile	Buckeye	Wheatfield Fork	Gualala/ South Fork
Total Stream Length (miles)	746	127	88	90	301	140
Mapped Channel Disturbances from 1984 Photos (miles)	298	48	32	42	119	57
Percent of Total Stream Length with Channel Disturbances in 1984 Photos	40%	38.1%	36.3%	46.0%	39.6%	40.8%
Mapped Channel Disturbances from 1999/2000 Photos (miles)	157	29	20	18	57	33
Percent of Total Stream Length with Channel Disturbances in 1999/2000 Photos	21%	23.0%	22.4%	19.8%	18.9%	23.7%
Percent Change from 1984 to 2000	-47%	-40%	-38%	-57%	-52%	-42%

Historically active landslides are presumed to represent the major source areas of sediment that entered the stream system over the past 150 years (refer to Appendix 2 for more details). Much of the coarser fraction of that sediment, mixed with older sediment, likely remains in the channels as indicated by the widespread correlation of instream sediment with the toes of landslides. Specifically, in the Gualala River Watershed, 70 percent of the "excess" instream sediment occurred within 50 meters of landslides that constitute about 35 percent of the landscape. Dormant landslides are interpreted to be substantial sources for instream sediment loads observed in the aerial photos.

In order to explore the other potential mechanism for major sediment inputs into the streams in the Gualala River Watershed, NCWAP compared instream or near-stream roads, including those constructed during the 1950s and 1960s, with the landslide and fluvial geomorphic mapping.

In addition to landsliding, creep and surface erosion, instream or near stream roads are important sediment source areas. Most of those roads in the Gualala River Watershed were constructed during the 1950s and 1960s. The CDF mapped the instream and near-stream roads across the watershed, and found a strong spatial correlation between those roads and braided and or aggraded stream reaches in 1984. Other relationships including lateral bars and wide channels in 1999/2000 were weak. Despite the strength of the relationship, the total length of channel mapped as aggraded and/or braided is a small fraction of the total length of channel mapped with other "excess" sediment. This suggests that historically active and older landslides are a major source of the sediment load in the Gualala River system.

4.2.6 MANAGEMENT IMPLICATIONS – LAND USE AND ROADS

Indicators of slope instability exist in over half of the watershed and merit caution with respect to land use activities. Given the current extent of land use in the Gualala River watershed and the relatively high potential of landsliding (57 percent of entire watershed is categorized as high or very high landslide potential), land management activities should seek to minimize additional sediment inputs into the streams. New projects should be designed with special care to address unstable slopes and landslide terrain as indicated on the CGS maps, *Geologic and Geomorphic Features Related to Landsliding, Gualala River Watershed* (Plate 1) and *Relative Landslide Potential with Geologic Features, Gualala River Watershed* (Plate 2). Provisions to prevent or minimize activities that could worsen or cause slope failures is highly recommended, especially on areas of high and very relative landslide potential (categories 4 and 5, respectively). Land use management practices should address areas affected by natural mass wasting processes. Preventing slope failures and/or avoiding naturally unstable areas prior to land use changes or operations are generally more cost effective and achieve better results than mitigating a problem.

On the project level, road building across unstable areas can: (1) remove support from the sides or toes of landslides, (2) put weight (such as a landing) on the head of a landslide, or (3) add water to the landslide mass by improper drainage or diverting water onto the landslide. These activities can worsen slope instabilities by initiating slope failures, and/or reactivating landslides. Areas in landslide potential categories 4 and 5 deserve particular attention and caution based on the known presence of factors affecting unstable slopes. Such indicators include, active and dormant landslides, steep slopes, inner gorges and debris slide slopes. These factors are often inter-related and affect the natural slope stability. Anthropogenic activities can worsen the conditions.

Reduction of the fine sediment load across entire planning watersheds is needed to reduce the embeddedness of spawning gravels in those planning watersheds where embeddedness is a limiting factor as shown on Plate 3. Most of the roads in the Gualala River Watershed are unpaved ranch and forest roads. To the degree that roads are a substantial contributor of fine-grained sediment, road improvements can reduce the amount of fine sediment generation. The effectiveness of the improvements in reducing sedimentation should be monitored.

It is important to note that timber harvesting operations that go through the THP preparation and review process are reviewed on a site-specific project level. This review process involves geologic review of unstable areas identified in a THP and on-site inspection of unstable areas by CGS geologists as part of the interdisciplinary THP review process. Representatives from both the Water Quality Control Board and the CDFG also review proposed timber operations proximate to unstable areas. They often develop mitigations to slope instabilities to protect water quality and fisheries resources. As a result, the operating methods and mitigations included in THPs provide a high level of assurance that the operations will adequately address unstable slopes.

Slope is an important consideration for road construction and timber harvesting. Equipment capabilities require that road grades be kept relatively low, predominantly under 10 percent and not exceeding 15 percent. The steeper the slope a road crosses, the higher the road engineering and construction costs. Full bench road construction excavation procedures and end hauling are generally required when building roads across 50 percent sideslopes, and mandatory when crossing sideslopes of 65 percent. Culverts are sized for at least 100-year storm events under current regulations.

For timber harvesting, the Forest Practice Rules require cable yarding on steep sideslopes. Tractors are limited to moderate terrain. Skid roads are more susceptible to erosion and delivery of sediment on steeper slopes.

On woodland and grassland areas, where the predominant land use is presumed to be grazing, the main consideration on sediment control continues to be roads. Gullies are also common in the woodlands and grasslands in the mélange of the Franciscan Complex (east of the Tombs Creek fault zone on Plate 1). Increased sediment delivery to streams and drainages can result from land use activities that do not take into consideration the natural instability present in areas of high and very high relative landslide potential in the Gualala River Watershed.

The CDFG habitat inventory surveys indicate that pool depth and pool shelter in most of the streams are primary limiting factors. Watershed-wide sediment reduction and appropriate flows will improve the streams' ability to flush excess sediment. Where shallow pool depths resulted from increased sediment, reduction of high sediment may improve pool depths. Instream structures should be built to create scour pools, riffles, and shelter that will enhance channel habitat complexity. Natural recruitment of LWD should be encouraged as well.

Canopy cover is a limiting factor in some reaches. Damage to seedlings and saplings by livestock and feral pigs may be inhibiting riparian regeneration. Exclusion of livestock and feral pigs coupled with planting and protecting seedlings should be implemented within the riparian zones of those reaches indicated on the *Map of Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed* (Plate 3) as having inadequate canopy cover.

Some local ordinances are aimed at reducing erosion and mass wasting. Grading ordinances address rural roads, among other disturbances. However, Mendocino County has not adopted a grading ordinance. The Mendocino County Board of Supervisors appointed a committee in 2002, representing both stakeholders and agencies, that drafted a grading ordinance regulating all grading, including agricultural. The draft ordinance is still under consideration by the Planning Commission, who will pass it on to the Board for their decision.

Sonoma County has an active hillside vineyard ordinance and compliance program, aimed at reducing erosion and sediment delivery to streams. The County also has chosen a technical working group to assist in the development of a comprehensive grading ordinance, to be drawn up by County staff.

4.3 Limiting Factors Analysis

A main objective of the NCWAP and a task assigned to CDFG was to identify factors that limit production of anadromous salmonid populations in north coast watersheds. A loosely termed approach to identify these factors is often called a "limiting factors analysis" (LFA). The limiting factors concept is based upon the assumption that eventually every population must be limited by the availability of resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an over-abundance, deficiency, or absence of a watershed habitat component. Identifying stream habitat factors that limit or constrain anadromous salmonid populations is an important step towards setting priorities for habitat improvement projects and management strategies aimed at the recovery of declining fish stocks and protection of viable fish populations. The NCWAP LFA was centered on evaluating summer aquatic habitat conditions. Only the freshwater habitat requirements of anadromous salmonids were addressed.

Two general categories of factors or mechanisms limit salmonid populations: density independent and density dependent mechanisms. *Density independent mechanisms* generally operate without regard to population density. These include factors related to habitat quality such as stream flow and water temperature. In general, if water temperatures exceed lethal levels, fish will die regardless of the population density. *Density dependent mechanisms* generally operate according to population density and habitat carrying capacity. Competition for food, space, and shelter are examples of density dependent factors which affect growth and survival when populations reach or exceed the habitat carrying capacity. The NCWAP's approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. The LFA was a simplified approach to identify ecosystem components that constrain habitat capacity, fish production, and species life history diversity (Mobrand et al 1997). The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components and may not satisfy the need for site-specific analysis at an individual landowner scale.

Components essential to the health of anadromous fish populations in freshwater habitat include canopy cover, embeddedness, pool depth, pool frequency, pool quality, and shelter/cover. Unsuitable components were associated with their effects on salmonid health and productivity. Unsuitable canopy cover was associated with increases in water temperature; unsuitable embeddedness was related to poor spawning substrate; unsuitable pool depth and frequency was associated with poor summer conditions; unsuitable shelter was related to decreased escape cover, which relates to increased predation and decreased high flow refuge.

Both the analysis of data collected during habitat inventory surveys taken in 1999 and 2001 and the EMDS outputs identified unsuitable key components for each stream surveyed. After identifying the potential limiting factors, the factors were ranked according to the most detrimental habitat deficiencies. Higher rankings indicated higher unsuitability. The biologist's professional judgment took precedence when partial surveys were conducted that did not represent the limiting factor, or data and observation inconsistencies existed. Following that, recommendations were selected and prioritized for potential habitat improvement activities.

The overall limiting factors for the Gualala River Watershed are based upon limited data. Only 81 percent of the North Fork Subbasin, 39 percent of the Rockpile Subbasin, 37 percent of the Buckeye Subbasin, 62 percent of the Wheatfield Subbasin, and 31 percent of the South Fork/Mainstem Subbasin were surveyed in 2001. Watershed-wide, pool shelter related to escape cover was the first or most limiting factor, pool depth the second, canopy cover third, and embeddedness was the fourth limiting factor based on the surveys conducted in 2001. Pool depth related to summer conditions and pool shelter related to escape/cover were the most limiting factors on all five subbasins. Canopy cover related to water temperature was the third limiting factor in Rockpile, Buckeye and the North Fork Subbasins. Embeddedness related to spawning substrate conditions was the third limiting factor in the Wheatfield Fork and Mainstem/South Fork Subbasins, and the fourth in both the North Fork, Rockpile and Buckeye Subbasins (Table 4.3-1). Embeddedness related to spawning substrate conditions was the third limiting factor in the Wheatfield Fork and Mainstem/South Fork Subbasins, and the fourth in the North Fork, Rockpile and Buckeye Subbasins (Table 4.3-1).

In 1995, embeddedness related to spawning substrate conditions was the greatest limiting factor in the Fuller Creek areas located in the Wheatfield Fork Subbasin. Pool depth related to summer conditions and pool shelter related to escape/cover were the second and third limiting factor respectively. These data were not included in Table 4.3-1.

Table 4.3-1
Limiting Factors Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 1999 and 2001, and EMDS Scores for the Gualala River Watershed, California
Rank 1 is the most limiting factor

Gualala River Watershed	Canopy Cover Related to Water Temperature	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
Gualala Watershed	3	4	2	1
North Fork Subbasin	3	4	2	1
Rockpile Subbasin	3	4	1	2
Buckeye Subbasin	3	4	1	2
Wheatfield Fork Subbasin	4	3	2	1
Main stem/ South Fork (1999 and 2001)	4	3	2	1

4.4 Potential Restoration Opportunities

Restoration opportunities were explored using GIS queries to create a map based on CDFG, CGS and CDF data for fish habitat, geomorphic and geologic features and historical roads and landings. The following sequence presents the map (Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*), followed by the finer details of restoration priorities arising from the CDFG analyses and a summary of hydrologic characteristics to note when developing restoration projects.

4.4.1 MAP OF POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS

Purpose

Habitat inventory surveys were conducted in 2001 to determine what factors were limiting salmonid populations in the Gualala River Watershed. Generally, the major tributaries showed habitat deficiencies in pool depths, pool shelter, canopy cover, and spawning substrate. The major limitation in regard to spawning substrate was embeddedness. Both embeddedness and pool depths are related to sediment deposition.

Because of this, an effort was made to identify sediment sites (i.e., sources and deposits) that may contribute to the shallow pools and embeddedness. The potential sediment sites, both upslope and instream, are shown on the map along with the limiting factors in order to illustrate spatial relationships and possible linkages between sediment sites and limiting instream sediment conditions (Plate 3, *Map of Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*). Sediment sites were categorized as follows: (1) historically active landslides, (2) historical instream roads possibly related to fluvial sediment, (3) roads possibly related to landslides and/or eroding banks, (4) fluvial sediment conditions possibly related to landslides, and (5) potentially unrelated fluvial sediment conditions.

In order to provide guidance for future analysis, mitigations, and restoration, the sediment sites are considered as potential restoration sites, especially where there are upslope of reaches affected by limiting sediment conditions. General recommendations are made for each category of sediment site and limiting factor.

Intended Use

Use this map to quickly locate:

a. Limiting factors for salmonid habitat in surveyed streams

b. Streams that were surveyed in 2001

c. Areas upslope of stream reaches in which embeddedness is a limiting factor

d. Potential sediment sites in upslope areas that may be contributing to embeddedness or shallow pool depths

Construction

This map was produced using multiple database queries of Geographic Information System (GIS) data developed under the North Coast Watershed Assessment Program (NCWAP). The data are available to the public.

The following data were used:

a. California Geological Survey (CGS) landslide data

b. CGS fluvial sediment mapping

c. California Department of Fish and Game (CDFG) instream habitat inventory surveys

d. California Department of Forestry and Fire Protection (CDF) mapping of historical roads that were either in streams or near streams

e. University of California Information Center for the Environment (ICE) roads map of the current roads in the watershed

The map shows:

a. Segments of the modern roads that cross or are within 60 meters of a historically active landslide

b. Segments of the modern roads that are both within 60 meters of historically active landslides and within 60 meters of eroding stream banks

c. The segments of the modern roads that are within 60 meters of dormant landslides

d. The segments of the historical instream or near stream roads that may be active sediment sources

e. Areas upslope of stream reaches in which embeddedness is a limiting factor

f. The primary limiting factor for salmonids for each stream reach that was surveyed

g. The extent of the CDFG stream habitat inventory surveys in 2001

Recommendations

CDFG stream habitat inventory surveys indicate that pool depth and pool shelter in many of the streams are primary limiting factors. Instream structures can be built to create scour pools, riffles, and shelter that will enhance channel habitat complexity. Instream structures can also meter sediment transport. NCWAP recommends that the construction of instream structures and enhancing the natural recruitment of LWD be considered in the development of a restoration plan.

Embeddedness can result from erosion of fine-grained sediment from instream, stream bank, and upslope sources. Reduction of the fine sediment load across entire upslope areas may be needed to reduce the embeddedness of spawning gravels in those stream reaches where embeddedness is a limiting factor. Most of the roads in the Gualala River Watershed are unpaved ranch and forest roads. To the degree that roads are a substantial contributor of fine-grained sediment, road improvements can reduce generation of fine sediment. The map shows the upslope areas drained by the streams that were surveyed in 2001 by CDFG in which embeddedness was a limiting factor. The survey was limited to

the stream reaches indicated on the map. Additional habitat surveys are needed to determine whether the unsurveyed areas possess any limiting factor.

The map also identifies potential road related sediment sources in each subbasin that may be good remediation targets for the reduction of fine sediment generation. Historically active landslides are shown as additional sediment source areas. Potential road related sediment sites are shown based on the premise that elevated loads of fine sediment from roads can be mitigated. NCWAP recommends field investigation of the potentially road related sediment sites within areas upslope of reaches with embeddedness as a limiting factor. The investigation should verify the actual site conditions and propose road improvements and erosion control as needed.

4.4.2 Priorities For Restoration in the Gualala River Tributaries

The streams listed in Table 4.4-1 and presented in Figure 4.4-1 (Figure 3 of Appendix 5) were habitat inventory surveyed using protocols in the *California Salmonid Stream Habitat Restoration Manual, Third Edition* (Flosi et al, 1998).

Table 4.4-2 (and in Appendix 5) was developed from those in-the-stream habitat inventory surveys conducted by biologists. Within those reaches inventoried, priorities for restoration were assigned based on the biologist's recorded observations from within the stream. This table includes priority ranking of habitat categories that provide improvement opportunities for each stream based upon the habitat survey and observations. The most urgent concern is assigned a '1', the next highest a '2', etc. Conditions not visible from within the stream were neither systematically observed nor considered. Areas identified as potential restoration targets on the map that have not been habitat inventoried should be surveyed to understand their significance to habitat.

Where instream pool shelter/cover was recorded as unsuitable, the placement of instream structures of large wood is recommended to help form scour pools and increase habitat complexity. The design of those structures should consider the hydrologic data table (Table 4.4-2) as well as general temporal trends of aggradation and incision as discussed in Appendix 2.

Table 4.4-1 recommendations are created from the results of standard CDFG habitat inventories. These inventories are a combination of several stream reach surveys: habitat inventories, channel typing, and biological assessments. An experienced biologist and/or habitat specialist conducts quality assurance/quality control (QA/QC) on the field crews and collected data, performs data analysis, and determines general areas of habitat deficiency based upon the analysis and synthesis of information. Finally, recommendation categories for potential habitat improvement activities are selected and ranked.

It is important to understand that these selections are made from stream reach conditions that are observed at the times of the surveys and do not include upslope watershed observations other than those that can be seen from the streambed. They also reflect a single point in time and do not anticipate future conditions. However, these general recommendation categories have proven to be useful as the basis for specific project development, and provide focus for on-the-ground project design and implementation. Stream and watershed conditions change over time and periodic survey updates and field verification are necessary if projects are being considered.

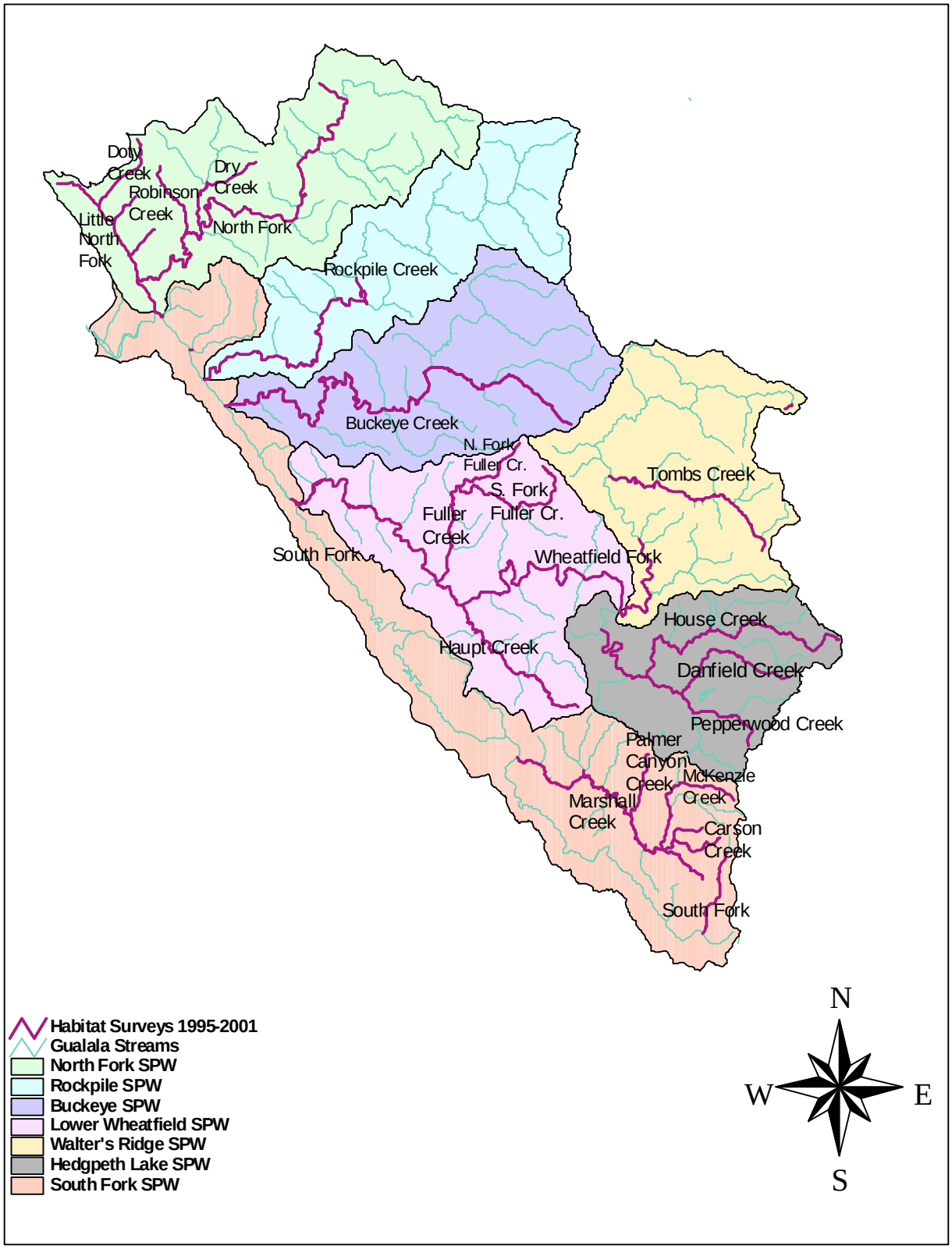


Figure 4.4-1
Areas Habitat Inventoried in the Gualala River Watershed, California (Figure 3 of Appendix 5)

Table 4.4-1

Summary of Habitat Inventory Survey Data From 1995, 1999, and 2001 for the Gualala River Tributaries, Gualala River Watershed, California

Stream	Surveyed Length Feet	Bank	Roads	Canopy	Temp	Pool	Shelter Cover	Spawning Gravel	LDA	Livestock And/or Feral Pigs	Fish Passage
North Fork Subbasin											
Doty Creek	6,237		X			X	X	X	X		X
Dry Creek	11,161			X	X	X	X				
Dry Creek Tributary #1	2,695			X		X	X				
Little North Fork	20,806		X				X				
Little North Fork Tributary #1	5,460						X	X			
Log Cabin Creek	1,698	X	X			X	X		X		
McGann Creek	1,980		X				X				
North Fork	59,362		X		X		X				
Robinson Creek	7,819	X	X	X	X	X	X		X		
Rockpile Subbasin											
Rockpile Creek	44,500	X	X	X	X	X	X				
Buckeye Subbasin											
Buckeye Creek	51,085		X	X	X	X	X				
Wheatfield Fork Subbasin											
Danfield Creek	12,103	X			X	X		X		X	
Fuller Creek	17,952	X	X	X			X	X			
Fuller Creek North Fork	14,275			X	X	X	X	X			
Fuller Creek South Fork	23,198			X	X	X	X	X			
Haupt Creek (*partial survey*)	2,129					X					
House Creek	54,916	X	X	X	X	X				X	?

Table 4.4-1

Summary of Habitat Inventory Survey Data From 1995, 1999, and 2001 for the Gualala River Tributaries, Gualala River Watershed, California

Stream	Surveyed Length Feet	Bank	Roads	Canopy	Temp	Pool	Shelter Cover	Spawning Gravel	LDA	Livestock And/or Feral Pigs	Fish Passage
Pepperwood Creek	17,931	X		X		X	X			X	
Sullivan Creek	5,015					X	X	X			
Tombs Creek	37,359	X		X		X	X			X	
Wheatfield Fork (*partial survey*)	116,878	X	X	X			X			X	
Mainstem /South Fork Subbasin											
Camper Creek	3,546		X				X				
Carson Creek	6,834		X			X	X	X			
Marshall Creek (*partial survey*)	21,698	X	X	X	X	X	X				
McKenzie Creek	13,801		X			X	X				
Palmer Canyon Creek (*partial survey*)	395		X		X						X
South Fork (*partial survey*)	8,451					X	X				
Wild Hog Creek	2,493		X			X	X				

An "X" indicates that the category did not meet the target values in the Salmonid Restoration Manual or were recorded by field crews during the survey period

Key to fields:

Temp = summer water temperatures seem to be above optimum for salmon and steelhead trout
Pool = pools are below target values in quantity and/or quality
Cover = escape cover is below target values
Bank = stream banks 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 = large debris accumulations are retaining large amounts of gravel and could need modification
Livestock/Feral Pig = there is evidence that stock or feral pigs are impacting the stream or riparian area and exclusion should be considered
Fish Passage = there are barriers to fish migration in the stream

Table 4.4-2

Priorities for Restoration for the Gualala River Tributaries, Gualala River Watershed, California
(numbers indicate priority rating with one being the highest priority)

Stream	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
North Fork Subbasin						
Doty Creek		2		1		3
Dry Creek			2	1		
Dry Creek Tributary #1			2	1		
Little North Fork		2		1		
Little North Fork Tributary #1		2		1		
Log Cabin Creek	3	2		1		
McGann Creek	2			1		
North Fork		2		1		
Robinson Creek		2	3	1		
Rockpile Subbasin						
Rockpile Creek	3	4	2	1		
Buckeye Subbasin						
Buckeye Creek		2	3	1		
Wheatfield Fork Subbasin						
Danfield Creek	2		3	4	1	
Fuller Creek	2	3	1	4		
Fuller Creek North Fork			1	2		
Fuller Creek South Fork			1	2		
Haupt Creek (*partial survey*)			1	2		
House Creek	5	4	2	3	1	?
Pepperwood Creek	4		2	3	1	

Table 4.4-2

Priorities for Restoration for the Gualala River Tributaries, Gualala River Watershed, California
(numbers indicate priority rating with one being the highest priority)

Stream	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
Sullivan Creek				1		
Tombs Creek	2		3	4	1	
Wheatfield Fork (*partial survey*)	2	3	4	1		
Main stem /South Fork Subbasin						
Camper Creek		2		1		
Carson Creek		2		1		
Marshall Creek (*partial survey*)	3	4	1	2		
McKenzie Creek		2		1		3
Palmer Canyon Creek (*partial survey*)		3	2			1
Upper South Fork (*partial survey*)		3	2	1		
Wild Hog Creek		3	2	1		

In general, the recommendations that involve erosion and sediment reduction by treating roads and failing stream banks, and riparian and near stream vegetation improvements precede the instream recommendations in reaches that demonstrate disturbance levels associated with watersheds in current stress. Instream improvement recommendations are usually a high priority in streams that reflect watersheds in recovery or good health. Project recommendations can be made in concurrence if conditions warrant.

Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), are usually a treatment priority. In these regards, NCWAP's more general watershed scale upslope assessments can go a long way in helping determine the suitability of conducting instream improvements based upon watershed health. As such, there is an important relationship between the instream and upslope assessments.

Additional considerations enter into the decision process before these general recommendations are further developed into improvement activities. In addition to watershed condition considerations as a context for these recommendations, there are certain logistical 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 propensity for benefit to multiple or single fishery stocks or species. Cost benefit and project feasibility also are factors in project selection for design and development.

4.4.3 GUALALA RIVER WATERSHED GENERAL HYDROLOGIC CHARACTERISTICS

Table 4.4-3 (Table 1 of Appendix 2) presents numerical watershed data at the planning watershed level that can be used as a first approximation of important hydrologic design criteria. The data presented is as follows: subbasin area and subbasin perimeter, upslope area, total stream length, maximum stream length; and bankfull width, bankfull depth, bankfull cross-sectional area, and bankfull discharge.

The units for each are shown on the table. Consideration of these variables is essential for the design of effective instream structures.

The data were developed from a 10-meter digital elevation model using RiverTools hydrologic modeling software, and applying regional hydrologic analysis. The results of this model correlated well with actual conditions during limited field checking. This modeled data can be used as a starting point but should be checked against actual field conditions prior to incorporation in any engineered design. California Department of Water Resources (DWR) installed several new stream gages in the watershed during the last two years. Flow data from those gages should be used to calibrate estimated bankfull discharge and bankfull geometry.

Table 4.4-3

Gualala River Watershed General Geomorphic Characteristics (Table 1 of Appendix 2)

HSA, SPWS, and PWS Name	Subbasin Area-m2	Subbasin Area, km2	Acres	Perimeter, m	Upslope Area km2	Total Stream length, km	Max. Stream Length, km	Width-BF[1] ft	Ave. Depth-BF[2] ft	X-Sec. Area-BF[3], ft^2	Discharge-BF[4] cfs
Buckeye Creek HSA											
Buckeye Creek SPWS											
North Fork Osser Creek	19,812,856	19.813	4,900	20,079	19.859	190	7.8	1012.1	29.83	23,942	219,091
Harpo Reach	11,008,003	11.008	2,722	15,793	30.832	283	13.4	908.2	27.17	19,698	177,142
Flat Ridge Creek	26,403,094	26.403	6,529	24,879	26.356	257	16.6	1114.8	32.41	28,499	264,876
Grasshopper Creek	23,319,840	23.320	5,767	25,432	80.522	748	18.5	1125.9	32.69	29,012	270,076
Little Creek	23,733,334	23.733	5,869	25,951	104.146	957	36.0	1136.2	32.95	29,492	274,947
Gualala River HSA											
Lower S. Fork Gualala R. SPWS											
Mouth of Gualala River	21,453,990	21.454	5,305	33,793	532.212	4,830	67.8	1279.9	36.50	36,552	347,349
Big Pepperwood Creek	26,412,790	26.413	6,532	29,055	772.850	6,901	77.7	1195.6	34.42	32,329	303,867
Marshall Creek SPWS											
Upper Marshall Creek	26,768,052	26.768	6,619	25,035	26.726	262	10.6	1118.0	32.49	28,644	266,341
Lower Marshall Creek	24,329,432	24.329	6,016	20,337	51.101	502	19.8	1017.9	29.97	24,192	221,583
Upper South Fork G.R.	33,980,743	33.981	8,403	44,637	33.950	331	25.0	1451.1	40.66	45,829	444,382
Middle South Fork G.R.	31,987,571	31.988	7,910	31,853	116.339	1,116	44.8	1246.2	35.67	34,837	329,636
North Fork Gualala R HSA											
North Fork SPWS											
Billings Creek	43,071,992	43.072	10,652	31,537	43.022	395	15.5	1240.6	35.53	34,556	326,737
Stewart Creek	26,630,261	26.630	6,586	26,775	69.733	598	28.1	1152.4	33.35	30,252	282,669
Robinson Creek	35,558,066	35.558	8,793	38,874	124.205	1,027	38.3	1363.4	38.54	40,959	393,200
Doty Creek	18,716,086	18.716	4,628	23,571	18.959	152	9.0	1088.0	31.74	27,275	252,510

Table 4.4-3

Gualala River Watershed General Geomorphic Characteristics (Table 1 of Appendix 2)

HSA, SPWS, and PWS Name	Subbasin Area-m2	Subbasin Area, km2	Acres	Perimeter, m	Upslope Area km2	Total Stream length, km	Max. Stream Length, km	Width-BF[1] ft	Ave. Depth-BF[2] ft	X-Sec. Area-BF[3], ft^2	Discharge-BF[4] cfs
Rockpile Creek HSA											
Rockpile Creek SPWS											
Upper Rockpile Creek	36,695,303	36.695	9,075	29,548	36.720	348	11.9	1204.7	34.65	32,774	308,431
Middle Rockpile Creek	33,021,154	33.021	8,166	28,326	69.783	639	26.8	1182.0	34.09	31,669	297,116
Red Rock	8,972,925	8.973	2,219	14,437	78.778	713	29.5	872.2	26.25	18,312	163,614
Lower Rockpile Creek	11,916,460	11.916	2,947	17,392	90.751	813	38.7	948.6	28.21	21,304	192,931
Wheatfield Fork HSA											
Hedgepeth Lake SPWS											
Britain Creek	27,128,844	27.129	6,709	28,610	27.177	237	14.6	1187.3	34.22	31,926	299,748
Pepperwood Creek	25,239,812	25.240	6,242	22,454	25.180	233	8.4	1064.4	31.15	26,220	241,885
House Creek	21,406,679	21.407	5,294	24,328	73.918	677	23.0	1103.6	32.13	27,984	259,671
Lower Wheatfield Fork SPWS											
Haupt Creek	24,439,940	24.440	6,044	23,167	24.869	222	11.2	1079.5	31.53	26,895	248,675
Tobacco Creek	32,599,136	32.599	8,061	31,631	230.421	2,065	46.8	1242.3	35.58	34,639	327,598
Flat Ridge Creek	28,467,315	28.467	7,040	26,959	28.439	247	14.9	1155.9	33.44	30,420	284,383
Annapolis	30,652,247	30.652	7,580	29,222	289.395	2,568	59.8	1198.7	34.50	32,479	305,412
Walters Ridge SPWS											
Buck Mountain	33,117,216	33.117	8,190	29,036	32.936	310	13.0	1195.3	34.41	32,311	303,692
Tombs Creek	25,225,115	25.225	6,238	25,810	25.206	235	12.8	1133.4	32.88	29,363	273,629
Wolf Creek	40,850,686	40.851	10,102	42,693	98.985	896	28.8	31429.0	39.96	44,200	427,202

Bankfull characteristics are based on north coast regional curves developed by Rosgen and Kurz (2000).

1. Bankfull width = $17.827*(Area_{sq.mi.})^{0.4251}$

2. Bankfull mean depth = $0.9253*(Area_{sq.mi.})^{0.3878}$

3. Bankfull cross-sectional area = $16.528*(Area_{sq.mi.})^{0.8127}$

4. Bankfull discharge = $79.013*(Area_{sq.mi.})^{0.8852}$

4.5 Potential Salmonid Refugia

The concept of refugia is based on the premise that patches of aquatic habitat provide the critical ecologic functions to support wild anadromous salmonids. Refugia may exist in areas where the surrounding landscape is marginally suitable for salmonid production or altered to a point that stocks have shown dramatic population declines in traditional salmonid streams. If altered streams or watersheds recover their historical natural productivity, the abundant "source" populations from nearby refugia can potentially re-colonize these areas or help sustain existing salmonid populations in marginal habitat. Protection of refugia areas is noted as an essential component of salmonid conservation to ensure long-term survival of viable stocks and a critical element towards recovery of depressed salmonid populations (Sedell 1990; Moyle and Yoshiyama 1992; Frissell 1993, 2000). Refugia habitat is defined as: areas that provide shelter or protection during times of danger or distress; locations and areas of high-quality habitat that support populations limited to fragments of their former geographic range; refugia remains as a center from which dispersion may take place to re-colonize areas after climate readjustment.

Currently there is no established methodology to designate refugia habitat for California's anadromous salmonids. This is mainly due to a lack of sufficient data describing fish populations, metapopulations and habitat productivity across large areas. This lack of information holds true for NCWAP basins especially in terms of metapopulation dynamics. Studies are needed to determine population growth rates and straying rates of salmonid populations and sub-populations to better utilize spatial population structure to identify refugia habitat.

The NCWAP interdisciplinary team identified and categorized refugia habitat by using professional judgment and criteria developed for north coast watersheds. The criteria considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. Information from CDFG's habitat inventory surveys, NCWAP's EMDS stream reach, professional judgment, and local Gualala expertise were used to assess streams as potential refugia.

NCWAP Refugia Categories and Criteria:

Five categories of refugia were described: (1) High Quality Refugia; (2) High Potential Refugia; (3) Medium Potential Refugia; (4) Low Quality Habitat; and (5) Critical Contributing Areas. Medium Potential Refugia were identified in the Little North Fork and North Fork. The potential refugia identified on the Little North Fork were related to shade canopy and water temperature. The potential refugia identified on the North Fork were related to shade canopy and pool depth. No other refugia were identified in the watershed (Table 4.5-1).

The Gualala North Coast Watershed Assessment Program (NCWAP) team used various methods and models to assess relationships between fish habitat and landscape processes and conditions as follows: (1) geographic information system (GIS) data from the California Department of Forestry and Fire Protection (CDF), the California Geologic Survey (CGS), the California Department of Fish and Game (CDFG) were composited through a series of database queries intended to reveal relationships; (2) the output of the queries was used to build tables (Integrated Data Tables) and maps; and (3) the Ecological Management Decision Support (EMDS) model was used to create maps of reach conditions based on

CDFG raw data and additional maps showing road density and position on hillslope by Planning Watershed.

A map and three tables were developed to help guide future stream restoration activities in the Gualala River Watershed and are illustrated below. The tables shown here are copied from the Appendix 2 and Appendix 5 where in-depth discussion is found. A reduced version of the map is shown for illustration purposes. The full size map is Plate 3. The map and tables represent the results of the NCWAP watershed assessment and provide a starting point for future work. These are not a substitute for on-site analysis and design. The recommendations shown on the map and in the table were developed independently by California Geologic Survey (CGS) and CDFG respectively. Some differences exist for numerous reasons. For example, the map was developed from aerial photo analysis, whereas, CDFG observations were made on the ground. Another example is that the map considers the entire watershed; whereas, habitat inventories were limited to portions of tributaries. Prioritization of restoration efforts involves many factors that beyond the scope of this work; however, the map and tables can be used as building blocks.

Table 4.5-1
Potential Salmonid Refugia Based Upon Habitat Inventory Survey, EMDS Stream Reach, Professional Judgment, and Local Expertise in the Gualala River Watershed, California

Subbasin Stream Name Stream	NCWAP Refugia Categories	Shade Canopy Overstream	Embeddedness Related to Spawning Suitability	Pool Depth Related Summer Conditions	Pool Shelter Related to Escape and Cover	Thermal Refugia Based Upon MWAT Data from 2001
North Fork Subbasin						
Doty Creek	Potential	---				
Dry Creek	Potential					---
Dry Creek Tributary #1	Potential	---	---			
Little North Fork	High Potential	---	---		---	---
Little North Fork Tributary Tributary #1	Potential	---	---			
Log Cabin Creek	Potential	---	---			
McGann Creek	Potential	---				
North Fork	High Potential	---	---	---		**Undetermined**
Robinson Creek	Potential				--	
Rockpile Subbasin						
Rockpile Creek	Low Quality					
Buckeye Subbasin Subbasin Score						
Buckeye Creek	Potential		--			
Wheatfield Fork Subbasin						
Danfield Creek	Low Quality					
House Creek	Potential		---			
Pepperwood Creek	Low Quality		--			
Tombs Creek	Low Quality					

Table 4.5-1
Potential Salmonid Refugia Based Upon Habitat Inventory Survey, EMDS Stream Reach, Professional Judgment, and Local Expertise in the Gualala River Watershed, California

Subbasin Stream Name Stream	NCWAP Refugia Categories	Shade Canopy Overstream	Embeddedness Related to Spawning Suitability	Pool Depth Related Summer Conditions	Pool Shelter Related to Escape and Cover	Thermal Refugia Based Upon MWAT Data from 2001
Wheatfield Fork *(partial survey)*	Potential			---		
Mainstem/South Fork Subbasin						
Camper Creek 1999	Potential	---				
Carson Creek 1999	Potential	---				
Marshall Creek	Potential		---			
McKenzie Creek 1999	Potential	---				
Palmer Canyon Creek	Potential	---	--			
Upper South Fork	Potential	--	--			
Wild Hog Creek 1999	Potential	--				

(---) =great to (-) = good

Chapter 5

Subbasin Profiles and Synthesis

5.1 Gualala River Estuary

5.1.1 INTRODUCTION

The Gualala River Estuary/lagoon is within the Big Pepperwood Creek Planning Watershed (10.2 square miles within the Lower South Fork Gualala River Super Planning Watershed), and is located approximately 0.5 miles south of the town of Gualala. During summer months, a sand bar typically forms across the mouth of the estuary which blocks the flow of tidewater, creating a coastal lagoon. Currently, the Gualala River Watershed Council has a grant for a two-year estuary study that includes the mainstem up to the confluence with the North Fork. The full extent of tidal influence on the mainstem will be further described by that study.

Estuaries and coastal lagoons are critical habitats for all anadromous salmonids by linking freshwater and marine environments. The mixing of sea and fresh waters creates conditions well suited for the anadromous life history strategies of coho salmon and steelhead trout. Coho salmon and steelhead trout pass through the estuary as juveniles during their seaward migrations and again as adults, swimming upstream to their freshwater spawning grounds. The brackish water of the estuary provides an important area where coho salmon and steelhead trout acclimate to changes in salinity as they move between the freshwater and marine environments.

Estuaries also are considered important nursery grounds due to high productivity and isolation from predators. Studies have revealed that juvenile salmonids utilizing estuaries for three months or more return to their natal stream at a higher rate than non-estuarine reared siblings (Riemers 1975). Juvenile salmonids may extend their estuarine residency to utilize the sheltered and food rich environments.

The Sotoyome Resource Conservation District, in partnership with the Gualala River Watershed Council, was awarded a $150,000 grant by the California Coastal Conservancy to perform an assessment and to develop an enhancement plan for the estuary. This project will assess the physical and biological conditions of the estuary and lower river from the confluence with the North Fork, ascertain the estuary's importance to the life history strategies of salmonids, and determine how existing conditions may be impairing aquatic productivity. Enhancement recommendations based on the findings will be a final product.

5.1.2 GEOLOGY

The estuary occupies the mainstem of the Gualala River. At times in during the Holocene, the estuary probably extended at least one mile up the North and South Forks. The mainstem cross cuts a series of Pleistocene marine terraces. The marine terraces record one stage of late-Pliocene to early Quaternary uplift with considerable local deformation and at least three stages of regional uplift during the Quaternary. Localized folding that occurred until the mid-Quaternary is evident in those terraces.

One well log comprises the subsurface sedimentological record adjacent to the estuary. Relatively extensive subsurface exploration was conducted one mile upstream at the confluence with the North Fork.

The marine terraces developed as follows:

- Late Pliocene-Early Quaternary (500,000- 5,000,000 years old)- uplift and topographic inversion of Pliocene basin in which Ohlson Ranch Formation accumulated. This formed flat-topped ridges throughout central basin.
- Older Quaternary (500,000 years old) - regional uplift along San Andreas Fault with local vertical deformation elevated marine terraces to over 600 feet above current sea level.
- Subsequently or concurrently, those strata were folded or faulted such that terraces north of the mainstem are 200 feet higher than presumably equivalent terraces on the south side. Folds may correlate across the San Andreas Fault with uplifted and subsided areas. An anticline, north of the mainstem, predates older Quaternary terrace that cut across both fold core (Anchor Bay Fm) and carapace (German Rancho Fm); however, continued folding may have occurred. The west face of the anticline north of the river is deeply incised with close-spaced gulches, while the east face is steeper and has fewer drainages that are not incised. This anomalous pattern probably indicates additional fold growth since emergence.
- Younger Quaternary (83,000-100,000 years old) – regional uplift elevated the lowest emerged marine terrace 130 feet above current sea level without additional local vertical deformation; fold growth had ceased. At Fort Ross, slip along the San Andreas Fault since the formation of this terrace has been estimated at 0.9 miles (Prentice and others 2000).
- Late Quaternary and early Holocene (about 20,000-10,000 years ago)-sea level dropped during the last global ice age and a marine terrace formed. That terrace lies offshore about 200 feet below current sea level. It is undetermined how much uplift has occurred since the formation of the terrace.
- Holocene- sea level rise and valley filling of the mainstem and estuary.

The valley of the mainstem is the only watergap across the otherwise continuous ridge that separates the watershed from the ocean. Flow through the mainstem was probably established during the Pleistocene marine low-stand when relative sea level was about 200 feet lower than today. One well located about 100 feet south of and 20 feet higher than the mainstem was drilled to 50 feet in depth and revealed brown, black, and blue clay throughout. Bedrock was not encountered. Subsurface information at Elk Prairie (about one mile upstream) at the mouth of the North Fork reveals that the paleo-valley there is nearly 200 feet deep. Thus, the paleo-valley underlying the estuary may also be 200 feet deep. This depth corresponds to the elevation of a submerged marine terrace just off shore, which probably defined base level at the time of paleo-valley development. The well logs at Elk Prairie and adjacent to the estuary both show considerable history of clay deposition indicative of low energy environments, probably estuarine, that extended from the ocean to at least Elk Prairie. Thus, the estuary migrated back and forth from at least Elk Prairie to somewhat off the modern shoreline depending on the interplay of sea level rise and tectonic uplift. Subsurface well logs are not available for the South Fork. However, the estuary may have extended upstream on the South Fork as well as the North Fork.

5.1.3 RIPARIAN VEGETATION

The riparian likely consisted of alders with a redwood over story along the upper estuary above the Highway 1 bridge. Most available photos of the lower estuary were taken after the redwood mill was built, which was located on the flat area on the northwest side of the bridge. It is undetermined if the area was cleared or was scrub naturally.

Wetlands are primarily located on the south side of the estuary towards the ocean, where saltgrass (*Distichlis spicata*) and salt rush (*Juncus lesueurii*) have been observed. Sea rocket (*Cakile spp*) and beach verbena (*Abronia spp*) grow on the dunes between the estuary and beach. Coyote bush (*Baccharis pilularis)* appears to be dominant on the drier, less saline soil located on the southwest landward side (Table 5.1-1).

Table 5.1-1
Riparian Vegetation Inventory of the Gualala River Estuary/Coastal Lagoon, February 2002

Common Name	Scientific Name
North Side of Estuary	
Lupine	*Lupines spp.*
Fennel	*Foeniculum vulgare*
Himalaya Berry	*Rebus thrysauthus*
California Blackberry	*Rubus vitifolius*
Thimble Berry	*Rubus parviflorus*
Coyote brush	*Baccharis pilularus*
Rush	*Juncus spp.*
Pennyroyal	*Mentha spp.*
Teasel	*Dipsacus fullonum*
Horsetail	*Equisetem spp.*
Swordfern	*Polystichum munitum*
Mugwort	*Artemisia douglasiana*
Bull Thistle	*Cirsium vulgare*
Cow Parsnips	*Heracleum lanatum*
Stinging Nettle	*Urtica gracilis*
Dead Nettle	*Lamium spp.*
Small Flowered Nightshade	*Solanum spp.*
Stachys	*Stachys spp.*
Wild Radish	*Raphanus sativus*
Yarrow	*Achillea millefolium*
Horseweed	*Conyza spp.*
Alder	*Alnus rubra*
Poison Hemlock	*Conium maculatum*
English Ivy	*Hedera helix*
Bay Laurel	*Umbellularia californica*
Dock	*Rumex spp.*
Nut Sedge	*Cyperus spp.*

Table 5.1-1
Riparian Vegetation Inventory of the Gualala River Estuary/Coastal Lagoon, February 2002

Common Name	Scientific Name
North Side of Estuary (con't)	
Grass perennial	
Reed (water)	
South Side of Estuary	
Lupine	*Lupines spp.*
Coyote brush	*Baccharis pilularus*
Teasel	*Dipsacus fullonum*
California Iris	*Iris douglasiana*
Pacific Madrone	*Arbutus edulis*
Grand Fir	*Abies grandis*
Swordfern	*Polystichum munitum*
Rush	*Juncus spp.*
Grass perennial	
Nut Sedge	*Cyperus spp.*
Dock	*Rumex spp.*
Stinging Nettle	*Urtica gracilis*
Thimble Berry	*Rubus parviflorus*
Alder	*Alnus rubra*
Poison Hemlock	*Conium maculatum*
Horsestail	*Equisetem spp.*
Dead Nettle	*Lamium spp.*
California Blackberry	*Rubus vitifolius*
Bull Thistle	*Cirsium vulgare*
Island	
Pampas Grass	*Cortaderia jubata*
Dunegrass	*Unsure*
Reed (water)	*Unsure*
Iceplant	*Carpobrotus edulis*
Lupine	*Lupines spp.*
Plantain	*Plantago lanceolata*
Coyote brush	*Baccharis pilularus*
Sand Verbena	*Abronia latifolia*
Yarrow	*Achillea millefolium*

5.1.4 LAND USE

A lumber mill operated at the mouth of the estuary in the 1860s to the early 1900s. Photos from 1936 show the abandoned mill site with minimal development around the estuary. The town of Gualala consisted of several buildings accessed by a dirt road. These photos showed an aggraded stream channel (Figure 5.1-1). Most of the central and upper reaches of the watershed still consisted of virgin

old growth at this time. During the late 1950s, a second mill complex was built near the confluence with the North Fork. Road development along the coastal plateau, a highway bridge and artificial breaching of the bar may have influenced the physical structure of the estuary through actual physical modifications. Commercial, recreational, and residential development characterizes current land use around the estuary (Figure 5.1-2).

1936

1961

Figure 5.1-1
Aerial Photos of the Gualala River Estuary in 1936 and 1961

1981

1999

Figure 5.1-2
Aerial Photos of the Gualala River Estuary in 1981 and 1999

5.1.5 FISH HABITAT RELATIONSHIP

Several fish species occupy the estuary, particularly for reproduction and early stages of their life cycle. Some species deposit eggs or give live birth directly in estuaries, while others have evolved mechanisms

which help the delivery of their young into estuaries by ocean tides or riverine currents which assist in the transition from a freshwater to marine water environment. Fish including salmonids that utilize estuaries for an important part of their life cycle are estuarine-dependant. The estuarine rearing is a strategy that adds diversity to juvenile salmonid life history patterns and likely increases the odds for survival of a species encountering a wide range of environmental conditions in both the freshwater and marine environments. An extended estuarine residency may be especially beneficial for salmonids from rivers where low summer flows or warm water temperatures limit summer rearing habitat.

Fish presence observations in the 1980s were summarized in *An Account of the Fishes Caught in the Lower Gualala River, California, 1984 through 1986* (Brown 1986): "Sampling occurred at seven stations, two upstream of the Highway 1 bridge."…"We caught seven species of fishes in the Gualala Estuary and lower river. Steelhead trout were caught at all stations. Roach, coastrange and prickly sculpin were caught at lower river and upper estuary stations. Starry flounder and Pacific staghorn sculpin were only caught in the lower estuary near the ocean. Threespine stickleback were caught in the lower river and upper to mid-estuary."…"Steelhead trout were larger in the fall than in the spring at mid-estuary stations, but larger in the spring at lower estuary stations."

5.1.6 SUBBASIN ISSUE SYNTHESIS AND RECOMMENDATIONS

The term "issues" is used here in a generic sense to denote any topic of interest, concern, import, or relevance to the watershed assessment. As such, issues can be direct limitations on salmonid suitability, potential factors for consideration, concerns regarding potential practices, suggestions, or observations of the data that are particularly relevant to the development of hypotheses and recommendations.

- Has the estuary filled in since the turn of the century due to sedimentation from logging?
- What is the role of the Gualala River Estuary with respect to salmonid abundance and distribution, especially regarding it use as habitat for steelhead trout and coho salmon?
- What factors may be limiting coho salmon and steelhead trout production in the estuary?

Working Hypotheses

No hypotheses have been developed. This section will be revised upon completion of the estuary study.

5.2 North Fork Subbasin

5.2.1 INTRODUCTION

The North Fork Subbasin (Calwater 2.2a 113.81, North Fork SPWS) encompasses 47.9 square miles of private land in the northern end of the Gualala River Watershed. The main channel has a zig-zag pattern in response to faulting. There are 127 miles of "blue line" streams, and five major tributaries: Little North Fork, Robinson Creek, Dry Creek, Stewart Creek, and Billings Creek (Figure 5.2-1). Predominant land uses include timber production, grazing, small vineyards, and some 40-acre and larger subdivisions.

A stream gage was installed in the fall of 2000 near the confluence of the North Fork with the South Fork (Station NFG, North Fork Gualala River Near Gualala). It is maintained by the California Department of Water Resources (DWR) and has been in operation since installation. Stream flow and water temperature data are available by accessing the California Data Exchange website at http://www.cdec.water.ca.gov.

Historic events and the period of record on the various data sets used in the NCWAP assessment are presented in a graphic format in Figure 5.2-2.

5.2.2 GEOLOGY

Mélange of the Franciscan Complex underlies oak savanna woodland in the eastern headwaters. Large areas of active earthflows and other forms of landsliding are abundant and contribute sediment to the streams (Figure 5.2-3). Figure 5.2-4 presents the relative landslide potential map for the North Fork Subbasin. The complete maps and explanations for both maps are on Plates 1 and 2. The steep tributaries in the upper reaches can be characterized as source (>12 percent slope) and transport (4-12 percent slope) reaches.

5.2.3 VEGETATION

The North Fork Subbasin has the highest timber site quality in the watershed. With over 70 inches of rainfall per year within the coastal fog influence, the lower and middle reaches of the North Fork Subbasin contain prime timber growing ground for Redwood and Douglas fir (Figure 5.2-5). In the upper third of the North Fork Subbasin, there is an abrupt vegetational transition to the mélange clay soil type. At the base of the Billings Creek Planning Watershed (PWS) along the Tombs Creek fault, dense conifer stands give way to prairie grasslands and oak woodland. Mixed conifer hardwood stands dominant north slopes. Conifers dominate stream floors. Approximately 17 percent of the North Fork Subbasin consists of prairie grasslands/oak woodland.

5.2.4 LAND USE

The North Fork Subbasin has the longest span of past land use practices in the watershed. The subbasin has been subject to three eras of intensive land use: (1) old growth redwood harvesting in the lower to central reaches 1868 to 1911, (2) tractor harvesting between 1942 to 1968, and (3) cable/tractor harvesting throughout the lower to central reaches in excess of 50 percent of the Doty, Robinson, and Stewart Creek PWS between 1990 to present.

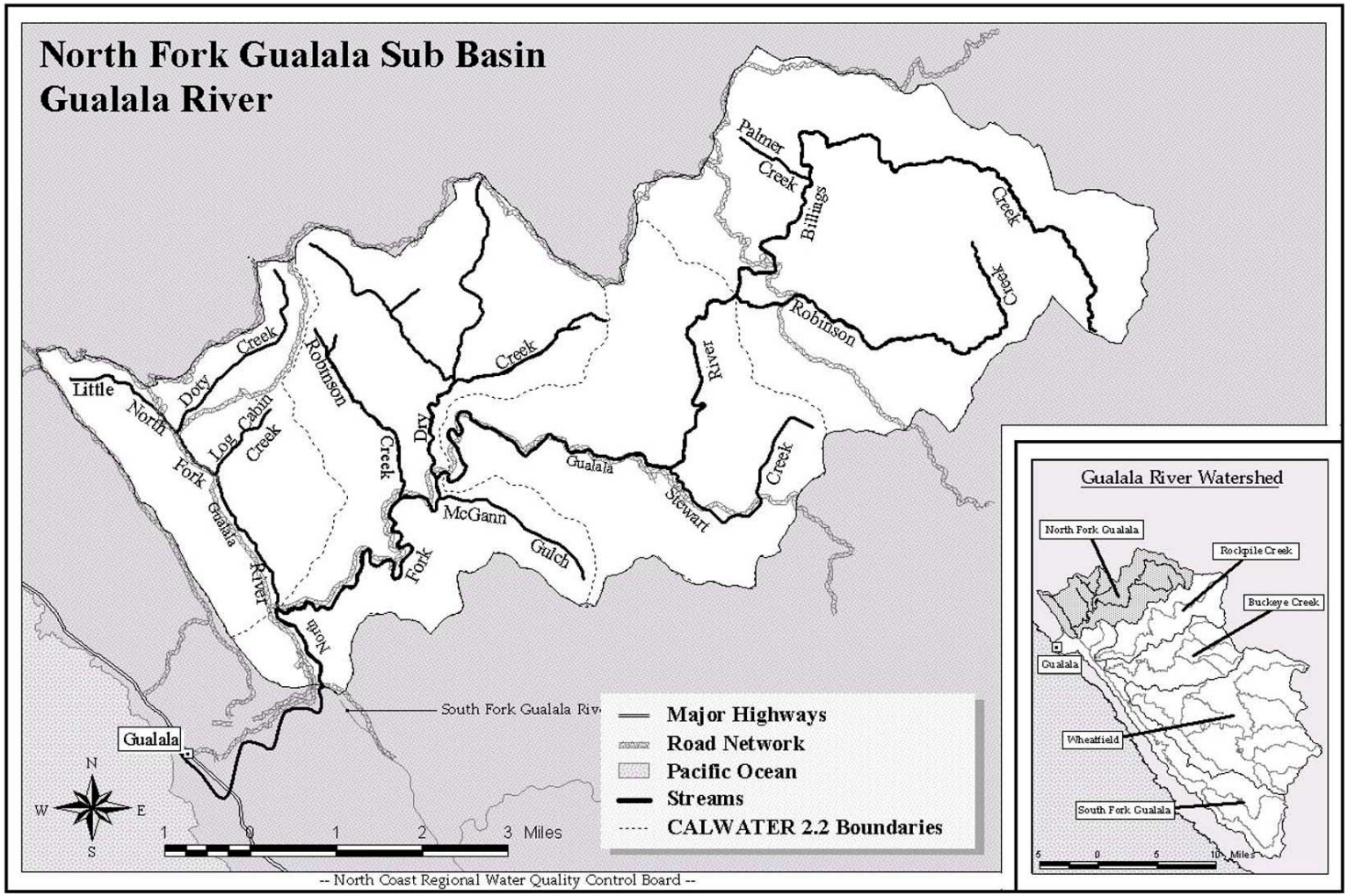


Figure 5.2-1
North Fork Gualala River Subbasin

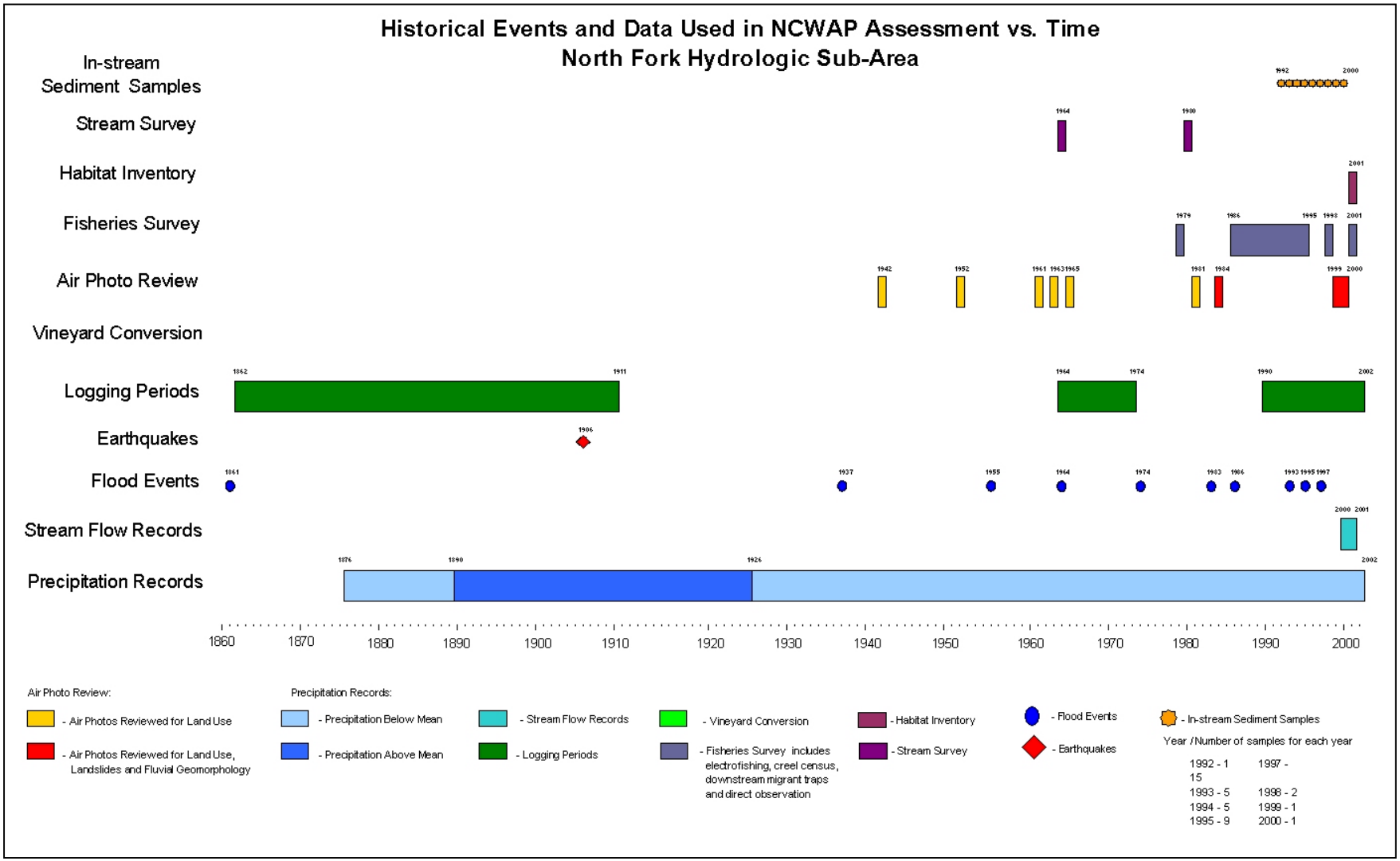


Figure 5.2-2
Historic Events and Data Used in the NCWAP Assessment for the North Fork Gualala River Subbasin

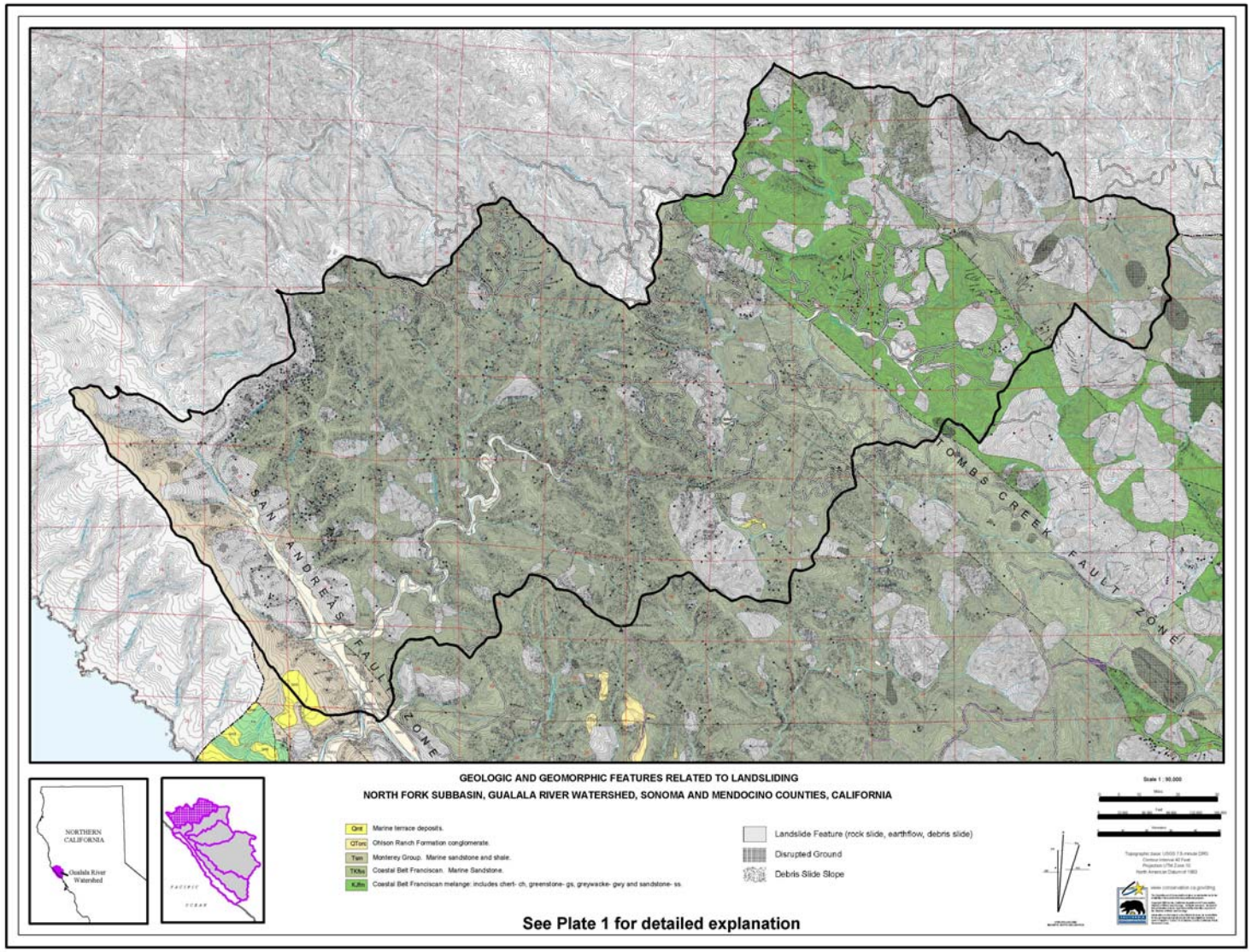


Figure 5.2-3
Geologic and Geomorphic Features Related to Landsliding - North Fork Gualala River Subbasin

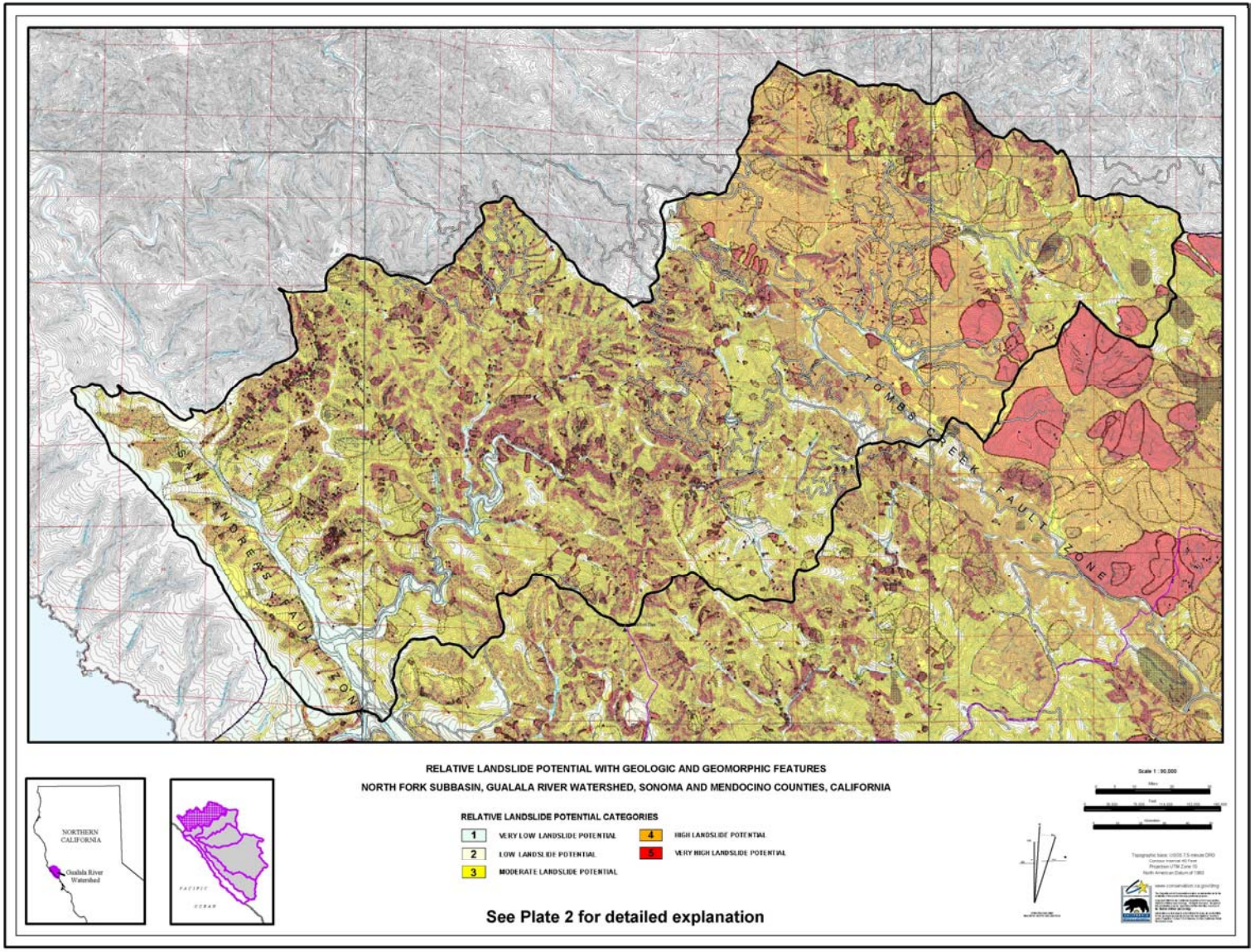


Figure 5.2-4
Relative Landslide Potential with Geologic and Geomorphic Features - North Fork Gualala River Subbasin

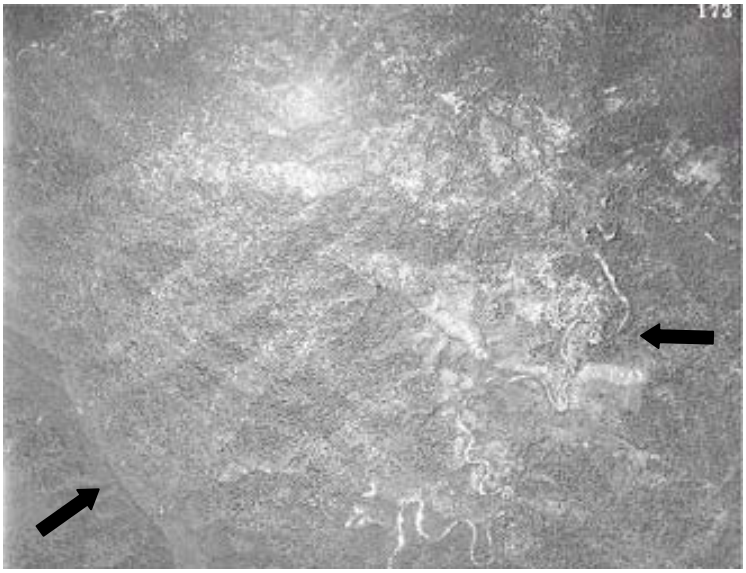


Figure 5.2-5
Lower to Middle Reaches of the North Fork Subbasin in 1936,
Showing Mid-Sized Second Growth Redwood Stands
(Note absence of any road network at this time)

The redwood dominated alluvial flats were clear-cut by the turn of the century. During the logging of the 1950s and 1960s, these areas were considered pre-merchantable young growth. In the purchase discussions for GRI in 1948, the second growth redwood was given zero value. These stands have mostly been selectively cut two times since the original turn-of-the-century clear-cut. Aerial photos from 1936 show predominantly mid-sized second growth redwood with no active road network (Figure 5.2-6).

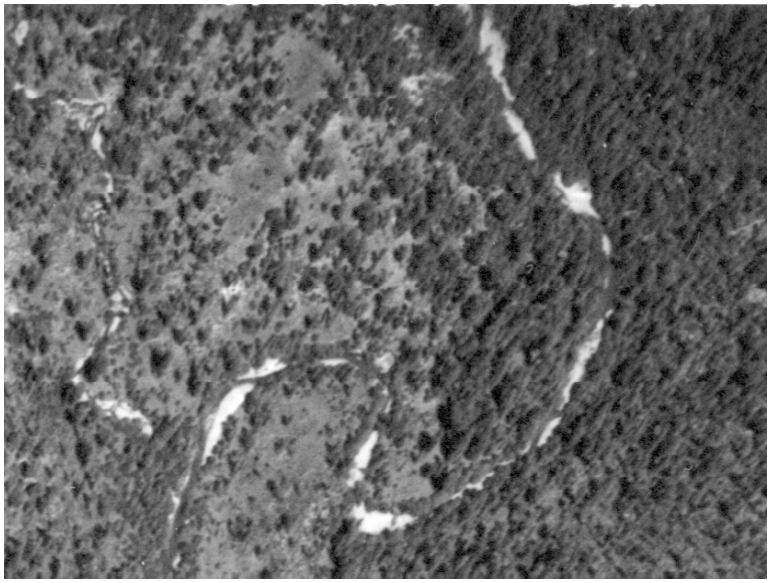


Figure 5.2-6
Confluence with Dry Creek, 1936
(The old growth Redwood had been cleared, and the area burned to create grazing land (left))

The 1936 shade canopy cover map (Figure 5.2-7) shows bank-to-bank exposure limited to the lower subbasins' alluvial floodplains. At this time, the channel was aggraded and wide, preventing dense wooded conifer growth adjacent to the stream channel. Upstream of the confluence with Dry Creek, topography was narrowly incised with conifer canopy entirely covering the mainstem North Fork until one reaches the mélange, which is largely non-coniferous and lacking in canopy. There was entire bank-to-bank cover over all tributary watercourses in the middle and lower North Fork Subbasin, including Stewart, Dry, Robinson, and Doty creeks in 1936.

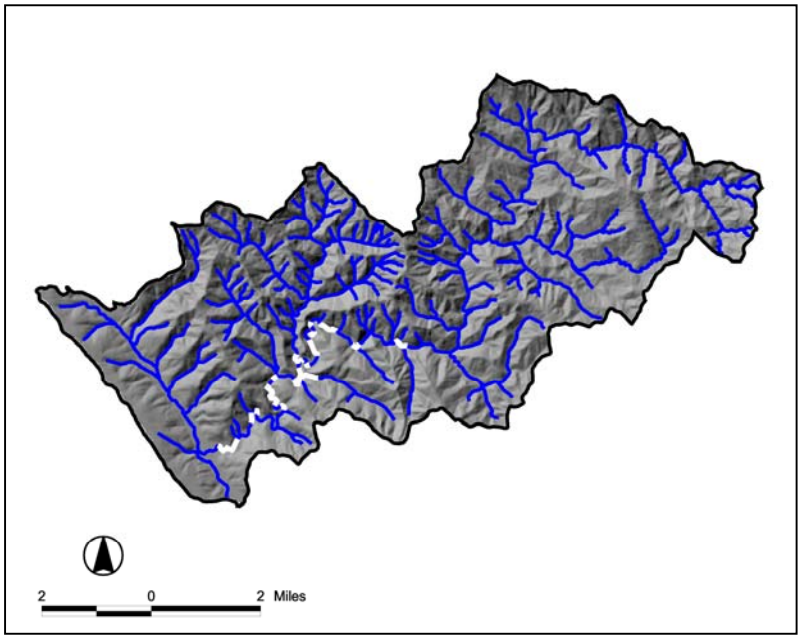


Figure 5.2-7
1936 Bank-to-Bank Stream Exposure (White)
(Dark blue shows partial to entire canopy cover over blue line streams)

Table 5.2-1
North Fork Subbasin Stand Replacement Operations 1932 - 1973 - Total Area = 30,636 acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Operation Since 1932	Mean Annual Increment (acres/percent by year)
1932– 1942	60	Stand Replacement	.2	10 (.02)
1942 – 1952	1,100	Stand Replacement	3.7	110 (0.3)
1952 – 1960	8,800	Stand Replacement	32.5	1,100 (3.6)
1960 – 1964	4,550	Stand Replacement	47.4	1.137 (3.7)
1964 – 1973	3,750	Stand Replacement	59.7	375 (1.2)

Tractor logging operations accelerated during the mid-1950s in the middle reaches flanked by Dry Creek to the south. These operations removed old growth redwood and Douglas fir. Roads were built adjacent to the stream channel of all primary tributary watercourses (Figure 5.2-8). The most active logging period occurred between 1952 and 1960. Thirty-three percent of the entire 30,600-acre North Fork Subbasin was logged. In a four-year period between 1960 and 1964 an additional 16 percent of the

subbasin was tractor logged. By 1968, 12 percent more area was harvested, totaling 56 percent of the subbasin from 1952.

Figure 5.2-8
Old Growth Tractor Logging by 1963 in the Central Reaches of the North Fork Subbasin, at the Confluence with Stewart Creek (bottom center)

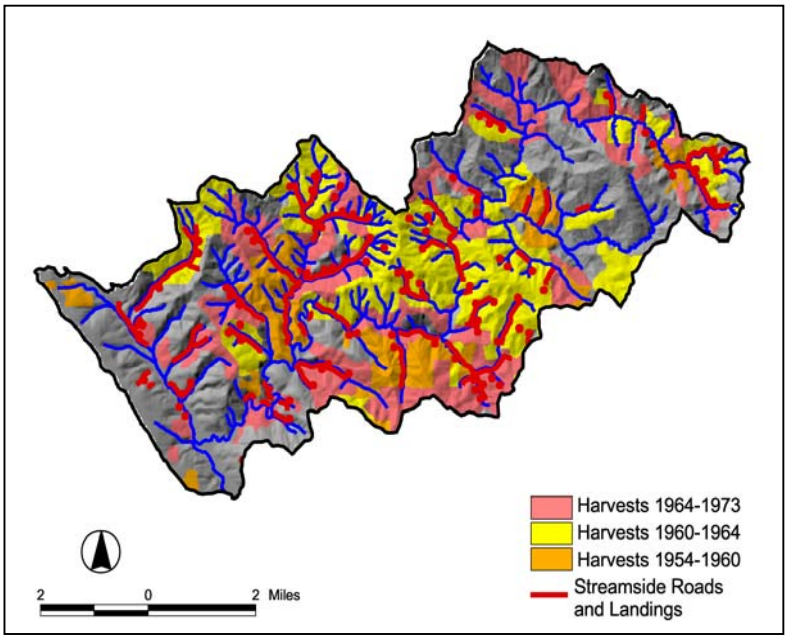


Figure 5.2-9
Mid-20th-Century Tractor Operations and Streamside/Instream Roads and Landings.
Red lines (roads) and circles (landings) show where sidecast fill has been pushed into the creek burying the streambank.

Roadfill sidecast to the stream channel was undermined during peak flows creating numerous debris slides and road fill failures thatdischarged into watercourses. Many of these relict road debris slides have been mapped by the California Geologic Survey (Plate 3 and Figure 5.2-10).

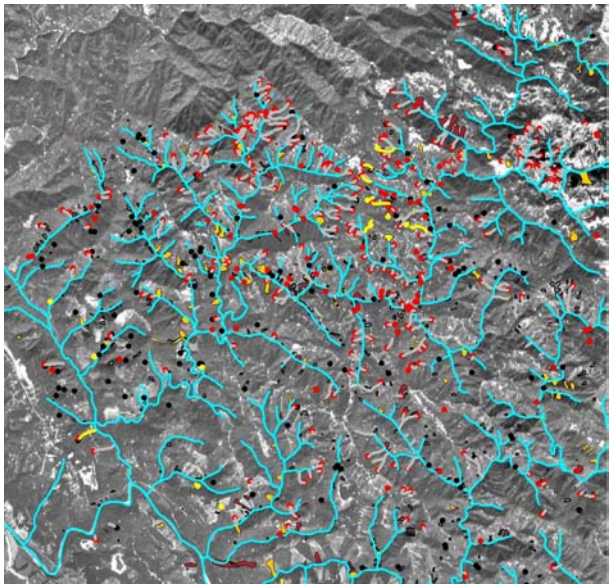


Figure 5.2-10
Smaller Debris Slides and Debris Flows
(red: 2000, black: 1984). Mapped by CGS

Peak storm events occurred in the 1962, 1964, 1966, and 1971 water years. In addition, streamside/ instream road and landing construction and timber clearing left bank-to-bank watercourse exposure throughout the central and upper reaches of the mainstem of the North Fork, and all major tributary watercourses including Stewart Creek, Dry Creek, Robinson Creek, and Doty Creek (Figure 5.2-11).

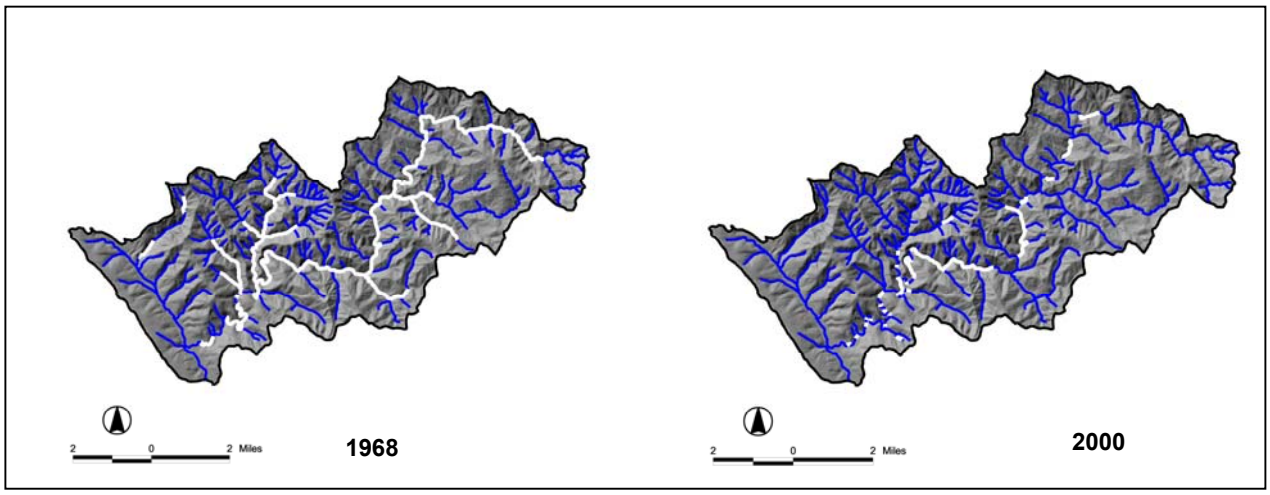


Figure 5.2-11
Bank-to-Bank Shade Canopy Exposure (White) from 1968 (left) and 2000 (right)
Dark blue shows partial to entire shade canopy cover.

Most of the lower reaches and alluvial flats of the North Fork Subbasin, including the Little North Fork, were logged between 1965 and 1968. Because of the younger age of these stands at the time, selective removal of higher quality trees continued to leave a vegetated appearance after logging. This practice tended to leave partial canopy cover over streams. Road construction continued to follow the streambank channel to one side, typically clearing riparian canopy within the right-of-way.

Overstory shade canopy cover for 2001 shows improvement compared to 1968, reflecting vegetational ingrowth over 34 years. In 1936, 5 percent of the blue line streams were exposed bank-to-bank (Figure 5.2-7), limited to alluvial openings in the lower subbasin reaches throughout generally wooded conditions (Figure 5.2-5). In 1968, approximately 65 percent of the blue line streams were entirely exposed bank-to-bank by the end of the tractor harvesting era in the middle and upper subbasin reaches. By 2000, this improved to approximately 25 percent of blue line streams exposed bank-to-bank. Streamside canopy in the middle subbasin reaches now consists primarily of 40-year-old pole to mid-sized conifers. Ground surveys support these findings. The California Department of Fish and Game (CDFG) habitat typing data for 2001 shows average canopy density improving with 77 percent density for the North Fork mainstem and 84 percent for the North Fork Subbasin tributaries. The habitat typing results are consistent with canopy measurements surveyed by the cooperative monitoring program between the Gualala River Watershed Council (GRWC) and GRI. The canopy condition is also consistent with the results of the Hillslope Monitoring Group Study (1998). This study found that the various riparian retention regulatory standards developed in varying and incremental degrees over the last 25 years have allowed recovery of riparian canopy over post WWII logging conditions, when all canopy was removed.

The time period 1968 to 1990 was inactive compared to previous eras, with an additional 4 percent of the subbasin subject to stand replacement harvests. Logging operations were slow during the recessions of 1970 and 1973. During the later 1970s and throughout the 1980s, stand thinnings were the dominant treatment. These operations extended throughout the lower reaches and alluvial basins in second growth redwood dominated areas. Habitat conditions began to recover. Overall streamside canopy cover continued to improve (see 2000 stream cover in Figure 5.2-11). There was improvement in dispersal of sediment discharges by implementation of the Forest Practice regulations, compared to nothing prior to 1973. However, substandard road networks continued to be vulnerable to large storm events, particularly during the 1986 and 1996 water years.

Table 5.2-2
North Fork Subbasin Timber Harvest Operations 1974 – 2001 - Total Area = 30,636 Acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Operation Since 1974 Some Overlap with Mid-20th-Century Areas	Mean Annual Increment (acres/ percent by year)
1974 – 1990	550	Stand Replacement	1.8	34.4 (0.1)
1991 – 2001	11,220	THPs	38.4 (43% cable, 57% tractor)	1,020 (3.5)

Active harvest operations resumed from 1990 to the present (Figure 5.2-12), with the clearcut method predominant. Areas that had once been understocked, and therefore avoided during the 1950s, had become mature and were subject to harvest. Since 1973, a total of 38.4 percent of the subbasin have been subject to Timber Harvest Plans (THPs). This acreage includes minimal entry Watercourse and Lake Protection Zone (WLPZ) riparian buffer corridors, and some selection removal areas. The

Hillslope Monitoring Project (California State Board of Forestry 1998) found roads as the dominant land use sediment source of modern harvest operations. Discharge problems from waterbars expressed as a function of acreage were not found to be as substantial a source.

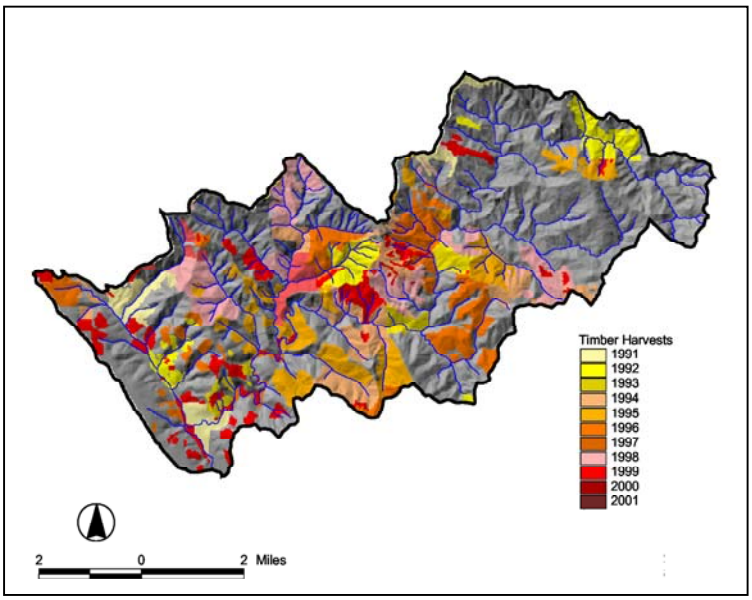


Figure 5.2-12
Timber Harvest Plans from 1991 to 2001

5.2.5 ROADS

Historic Roads (1952 to 1968)

Built during the late 1950s thru 1968, streamside/instream road and landing networks spanned most of the natural fluvial drainage system of the central North Fork Subbasin. These roads dominated stream channel structure throughout Stewart, Dry, Robinson, and Doty creeks. The mid-20th-century road networks followed streams up the narrow valleys and inner gorger canyons of the central North Fork. Heavy tractors cut into the steep sidebanks at the base of the streams, making the near vertical cut banks along the roads prone to failure during winter storms. Tractors graded the streambank flat to one side, simplifying channel complexity and structure. These operations pushed large volumes of dirt debris into the streams as road fill sidecast. In addition, CGS mapping found that the mid-20th-century road networks crossed a high density of debris slides and debris flows.

The deeply incised channel topography tended to concentrate flows during storm events. The steep topography and high stream density probably caused intense, flashy runoff, that (1) challenged and often removed the primitive log/dirt road stream crossings and instream landings, and (2) undermined the streamside roads collapsing road segments into the streams. CGS mapping found a high density of mid-20th-century road debris slide failures in the central subbasin reaches (Figure 5.2-10). 1963 and 1981 aerial photos showed a high frequency of road and landing failures along streamside roads particularly concentrated in the central subbasin reaches throughout the steep terrain.

A total of approximately 18 miles of roads were built at near or equal elevation to the streambank transition line with sidecast covering the streambank leading to the creek. More roads were located

slightly upslope, but still near the creek (not mapped with this study). On a watershed-wide basis, about 80 percent of the aggraded reaches and about 70 percent that were braided occurred in areas of historic instream/streamside roads and landings in 1984. Some 145 instream landings and 174 km of instream/streamside roads were spatially associated with stream braiding and aggradation. The dense network of historic instream/streamside roads and landings that lined Robinson, Dry, and Stewart creeks showed a similar high correlation with stream braiding and aggradation (excess of 75 percent) in 1984.

Modern Roads

Successive aerial photo overlays show a shift in current road locations to ridgelines and mid-slope benches. This coincides with general field observations that the older streamside roads are now mostly vegetated and wooded. The current road network now consists of 291 miles. The U.C. Davis Information Center for the Environment ("ICE") developed a contemporary road map for the total maximum daily load (TMDL), which shows most of the current roads located distant from watercourses. We clipped all "ICE" roads within 50 feet of a watercourse to find about 2.5 miles of current roads within 50 feet of blue line streams in the subbasin. Of these roads, about one mile are located in areas that may be affected by historically active landsliding and stream bank erosion. These are concentrated in the steep central subbasin reaches throughout the Robinson Creek and Stewart Creek PWSs.

Although the current road network has less overall coincidence of debris slides and stream crossing failures compared to historic times, most of the contemporary road failures are in close proximity to streams and steep slopes. There are approximately 3 miles of roads crossing steep slopes (excess of 60 percent), mostly located throughout the deeply incised central subbasin reaches. Combining roads segments with streams and steep slopes shows that active point slides are found within 60 meters of a road and predominantly along blue line streams in steep areas. These areas occur primarily throughout the central subbasin reaches, in the Robinson Creek and Stewart Creek PWSs. The Ecological Management Decision Support (EMDS) model shows the North Fork Subbasin with a high road density for the Gualala River Watershed overall at 6.1 miles per square mile, reflecting active timber harvesting during the 1990s. This can indicate a need to evaluate and potentially upgrade road drainage facilities to current sizing standards, and to actively monitor the road network during the winter period to assure functional dispersal of drainage.

Landowners within the North Fork Subbasin have implemented some road-upgrading programs. Many programs are developed in conjunction with the GRWC, government agencies and/or Resource Conservation Districts. For example, GRI, in partnership with the Watershed Council and the Sotoyome Resource Conservation District (Sonoma County) has assessed and produced an implementation plan for the entire Little North Fork watershed. When the work is completed approximately 45 miles will be upgraded and an estimated 57,993 cubic yards of sediment will be prevented from entering the watercourses. As part of GRI road management program, an additional 32 miles of roads (26 percent) has been upgraded in the North Fork Subbasin in the last three years reducing sediment delivery to streams by an estimated 8,606 cubic yards.

The 1986 and 1996 storms produced the dominant sediment pulses in the subbasin in recent times, causing blowouts of substandard road watercourse crossings (log, etc) and undersized culverts. There are 2.7 road crossings per mile of stream in the North Fork Subbasin. Recent upgrade measures completed after these storms have reduced overall failures. More recent surveys of the GRI road network to detail additional upgrade specifications have occurred, and some of the recommended road

upgrade work has been completed. The NCWAP potential restoration map (Plate 3, Figures 5.2-23a and 5.2-23b) identifies high probability sediment source areas, combining the analysis for both historic and current roads. This map shows the central subbasin reaches of the North Fork Subbasin with the highest priority for future restoration work for sediment abatement.

5.2.6 FLUVIAL GEOMORPHOLOGY

In the lower reaches of the subbasin, streams generally meander through alluviated valleys that range from a couple of hundred feet to almost a thousand feet across within steep valleys. The mainstem North Fork channel is sinuous and low gradient with a well-developed floodplain and stable point bars.

About 56 percent of the Subbasin has a high to very high potential for landsliding and represents a major source area for stream sediment (Figure 5.2-4). Instream sediment levels, indicative of disturbance, occur along 29 of 127 miles of the blue lines streams in the subbasin. This is a 40 percent reduction compared to levels in 1984. Most of the reduction occurred in the tributaries, while the lower reaches showed less change. Table 5.2-3 lists the lengths of sediment storage mapped and relative change between 1984 to 1999/2000 for the North Fork Subbasin.

Table 5.2-3
North Fork Subbasin Stream Characteristics Representing Sediment Sources or Storage

Planning Watershed	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Length Miles	Percent Total Stream for Subbasin	Length Miles	Percent Total Stream for Subbasin	Length Miles	Total Length Miles
Billings Creek	10.4	26.7	15.5	40.0	-33.1	38.8
Stewart Creek	9.4	34.6	15.9	58.5	-40.9	27.1
Robinson Creek	9.2	20.2	14.5	31.6	-36.2	45.9
Doty Creek	0.2	1.4	2.4	16.2	-91.5	14.9
Total	**29.2**	**23.0**	**48.3**	**38.1**	**-39.5**	**126.7**

5.2.7 WATER QUALITY

Instream Sediment

Streambed substrate cores can be quite variable across a riffle area, however, the percent fines <0.85 mm from McNeil cores of riffles at four sites in the mainstem Little North Fork, one site in Doty Creek, and one site in McGann Gulch (sites dot 256, mcg 209, lnf 255, lnf 201, lnf 202, lnf 203), often exceeded the Gualala proposed TMDL target of 14 percent. Dry Creek site 211 was closer to the target, but was exceeded three out of the four years.

According to THP records and California Department of Forestry and Fire Protection (CDF) aerial photo analysis, historic sediment sources still exist in this subbasin. For example, in McGann Gulch, a large instream landing complex built in the late 1960s more recently failed in the 1990s. The upper reaches have scoured out leaving the sediment to settle out in the lower reaches. Due to the loading, McGann Gulch now flows underneath the gravel at the base of the Gulch during low flows, upstream of the North Fork, or dries up, stranding young-of-the-year steelhead trout. Instream landings and streamside roads from the 1960s are densely concentrated in Dry and Robinson creeks, some of which continue to discharge during high stream flows. Pebble count data are available from GRI for a total of

12 sites for the period of 1997-2001. Data from the Coastal Forest Lands (CFL) are available for three sites for the period of 1995-1997 (Figure 5.2-13). Those data are presented in Appendix 4.

Water Temperature

Water temperature data from continuous recorders were available for 29 sites in the North Fork Subbasin (Figure 5.2-14). The period of record from 1994 to 2001 yielded 81 observations for maximum weekly average temperature (MWAT) and seasonal maximum temperature.

MWATs in the tributary sites were moderately to fully suitable. The mainstem sites varied from moderately suitable to moderately unsuitable for summertime rearing (Table 5.2-4, Figure 5.2-15). There was a trend from higher water temperatures upstream in the North Fork to lower temperatures as the stream flowed towards the ocean (Figure 5.2-16). Air temperatures are generally higher and canopy density lower in the upper, northeastern oak woodland and grassland, probably contributing to higher water temperatures. As the North Fork flowed west into the coastal influence and better canopy coverage, it also received flows from cooler tributaries, combining to reduce the mainstem water temperatures.

Seasonal maximum temperatures were below the lethal limit of 75 F except for the three upper-most stations in the northeastern area (sites NF214, NF272, NF216). Seasonal maxima at those stations ranged from 75-80 F for values from 1994-2001 (nine observations at the three sites).

Table 5.2-4
EMDS Ratings for Maximum Weekly Average Temperatures (MWATs) in the North Fork Subbasin

Stream	No. of Sites	No. of Observations	Period of Record	EMDS Suitability Ratings						
				+++	++	+	0	-	--	---
North Fork Mainstem	10	25	1994-2001							
Lost Creek	1	3	1995-1998							
Dry Creek	4	14	1994-2001							
McGann Gulch	2	4	1995-1997							
Robinson Creek	5	16	1994-2001							
Doty Creek	2	2	1994, 1998							
Little North Fork	5	17	1994-2001							

EMDS ratings:
+++ = fully suitable (50-60F)
++ = moderately suitable (61-62 F)
+ = somewhat suitable (63 F)
0 = undetermined (between somewhat suitable and somewhat unsuitable) (64 F)
- = somewhat unsuitable (65-66 F)
-- = moderately unsuitable (67 F)
--- = unsuitable (> 68 F)

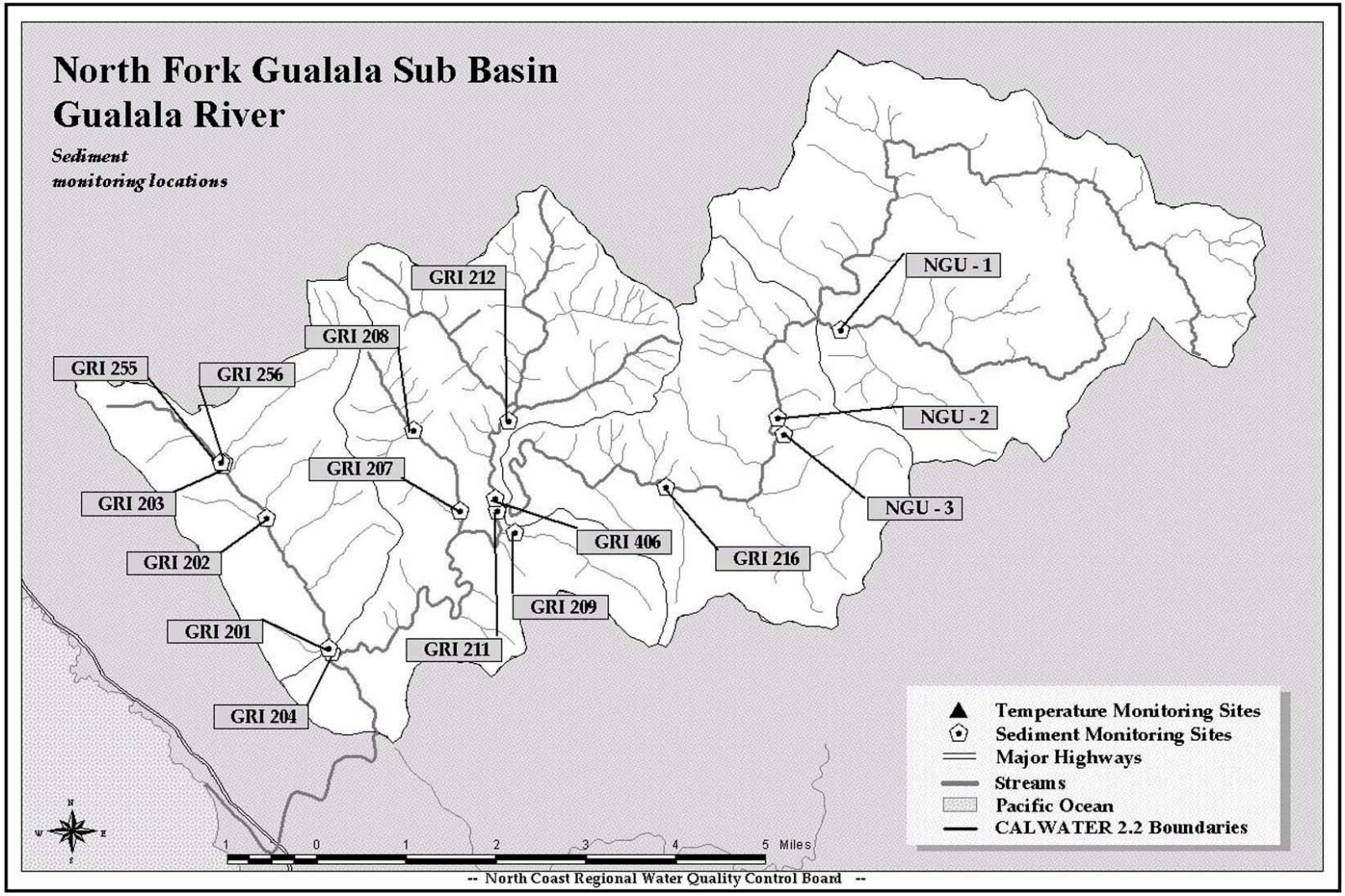


Figure 5.2-13
Instream Sediment Sampling Sites, North Fork Subbasin

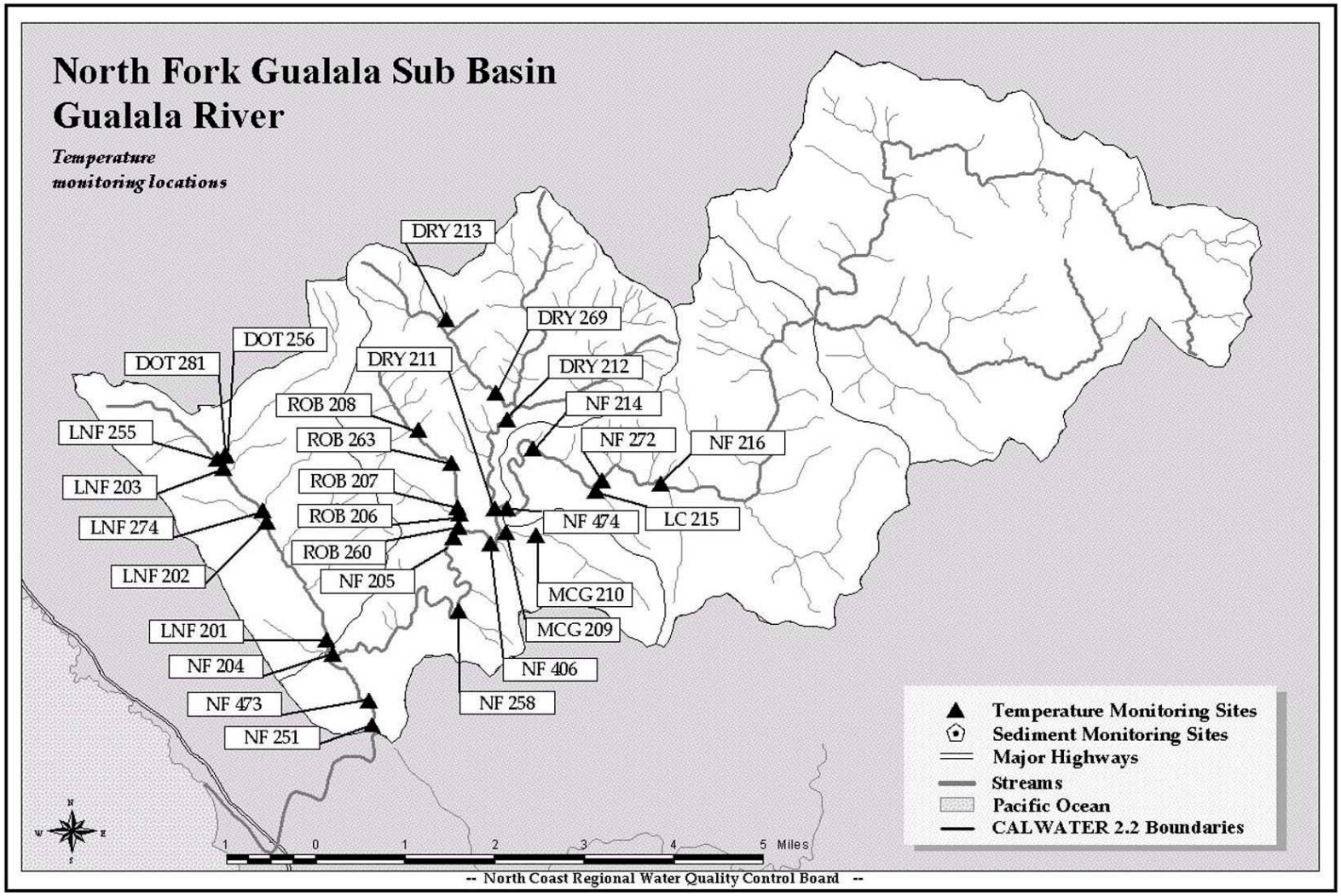


Figure 5.2-14
Instream Temperature Sampling Sites, North Fork Subbasin

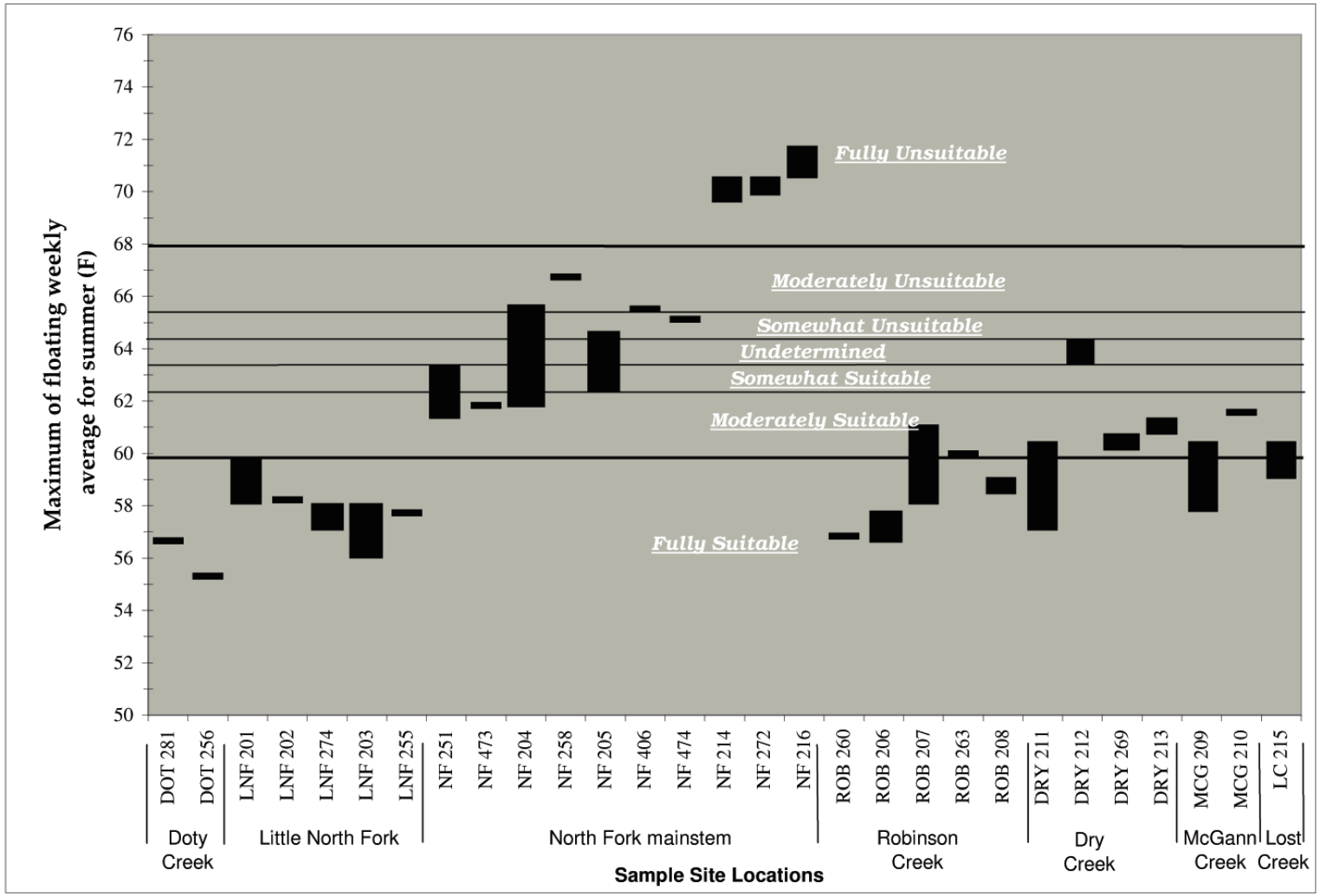


Figure 5.2-15
Maximum Weekly Average Temperature (MWAT) Ranges for the North Fork Subbasin from 1994-2001
(Data from GRI and GRWC continuous monitoring devices. See Figure SF1 for locations)

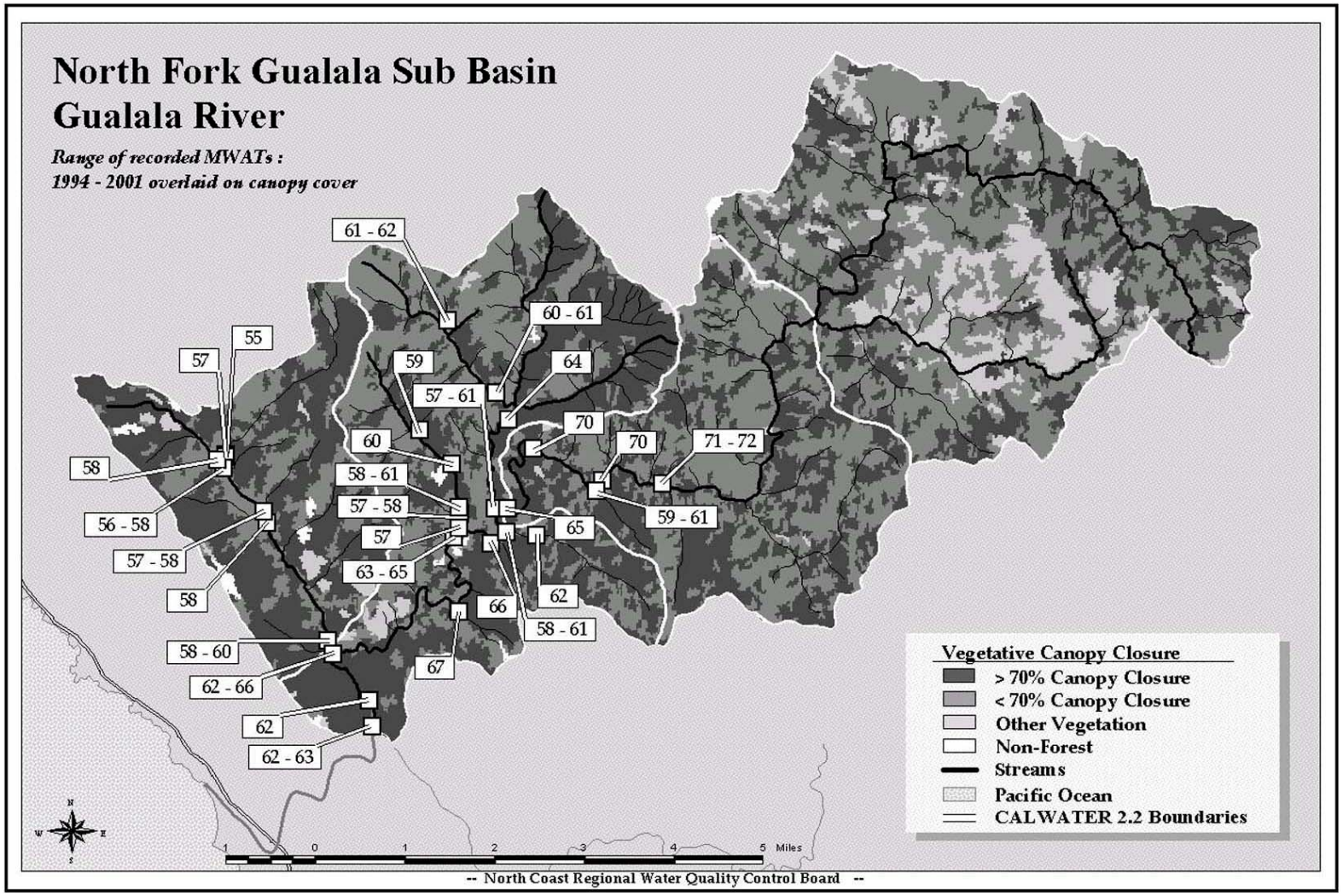


Figure 5.2-16
MWAT Temperature Ranges in the North Fork Subbasin for the Period of Record, 1994-2001
Overlaid on the LanSat Vegetation Layer for 2000

5.2.8 FISH HABITAT RELATIONSHIP

Historic Habitat Conditions

In 1964, CDFG stream surveys were conducted on the mainstem North Fork and the Little North Fork in the North Fork Subbasin. These surveys were made by direct observation and were not accompanied by quantitative data (Table 5.2-5).

Table 5.2-5
Summary of Historic (1964) Stream Surveys Conducted in the North Fork Subbasin, Gualala River Watershed, California

Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
North Fork Subbasin				
North Fork	9/17 and 18/1964	Excellent steelhead trout, coho salmon spawning and nursery stream. Spawning areas poor in the upper ½ of the stream and excellent in the lower ½ of the stream; Pool: Riffle ratio 50:50; Good shelter provided by logs, boulders, algae, and roots.	None	Should be managed as a steelhead trout, coho salmon stream. The future planting of coho salmon is recommended to increase the population. The removal of log jams is not recommended.
Little North Fork	9/10/1964	Fair spawning area with loose gravel available, approximately 60 percent of the stream available for spawning, spawning area suitable for steelhead trout and coho salmon. Pool: Riffle ratio 80:20. Good shelter available as undercut banks, overhanging vegetation, logs, and rocks	30 partial barriers	Continue to manage as a steelhead trout, coho salmon spawning and nursery stream. Habitat improvement, consisting of removal of slash and debris and log jams to improve fish passage and stream condition is suggested. Possible planting of coho salmon to establish a better run is recommended.

Current (2001) Conditions

Target Values from the Habitat Inventory Surveys (Flosi et al 1998)

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. Target values were given for each of the individual habitat elements measured in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) (Table 5.2-6). When habitat conditions fall below the target values, restoration projects may be recommended to meet critical habitat needs for salmonids.

Table 5.2-6
Habitat Inventory Target Values taken from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998)

Habitat Element	Canopy Cover	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or more of the stream length is < 50% embedded	Depth-1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet. Frequency->40% of stream	>80

Habitat inventory surveys were conducted in 2001 on eight streams in the North Fork Subbasin. Most of the tributaries surveyed were close to the target value for canopy cover with the exception of Dry Creek and Robinson Creek. Canopy cover target values were reached on Log Cabin Creek. North Fork, Log Cabin Creek, Robinson Creek and Little North Fork met the target values for pool tail embeddedness. Doty Creek and McGann Gulch did not meet the target value for embeddedness. The target values for pool frequency/depth were not met on any of the streams surveyed. The target values for pool shelter/cover were not met on any of the streams surveyed (Table 5.2-7). Robinson Creek had the highest shelter/cover rating, reflecting the addition of large wood by the Gualala River Watershed Council's Cooperative Monitoring Program.

Table 5.2-7
Summary of Current (1995, 1997, and 2001) Conditions Based Upon Habitat Inventory Surveys from the North Fork Subbasin, Gualala River Watershed, California

Condensed Tributary Reports are located in Appendix 5, Attachment E

Habitat Element Stream Name	Surveyed Length (feet)	Canopy Cover	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
North Fork Subbasin*					
Doty Creek	6,237	74%	25%	4%	36
Dry Creek	11,161	58%	70%	6%	32
Dry Creek Tributary #1	2,695	59%	51%	22%	30
Little North Fork	20,806	76%	83%	16%	54
Log Cabin Creek	1,698	83%	90%	1%	43
McGann Gulch	1,980	76%	0%	3%	5
North Fork	59,362	78%	82%	29%	28
Robinson Creek	7,819	66%	65%	3%	70

Log Cabin Creek had a canopy cover over 80 percent not a habitat deficiency. Canopy cover on the North Fork, Little North Fork, McGann, Robinson, Dry and Doty Creeks showed a habitat deficiency related to canopy cover (Figure 5.2-17).

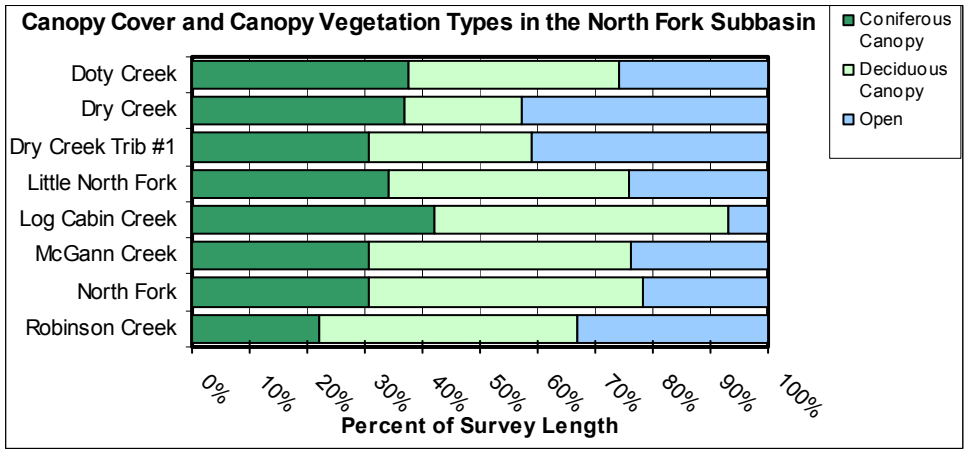


Figure 5.2-17
Canopy Cover and Canopy Vegetation Types in the North Fork Subbasin 2001, Gualala River Watershed, California

The GRWC measured canopy cover independent of CDFG's surveys (Figure 5.2-18). Their method differed in that they measured in the middle of the habitat unit, whereas CDFG measured at the head (upstream end) of the unit. Canopy composition was also measured differently. GRWC calculated composition type by identifying and counting tree species in riparian plots that extended from bank full to 100 feet inland on both sides of the channel. CDFG calculated the percent vegetative composition by estimating the percent of shade each vegetation type represented in the densiometer.

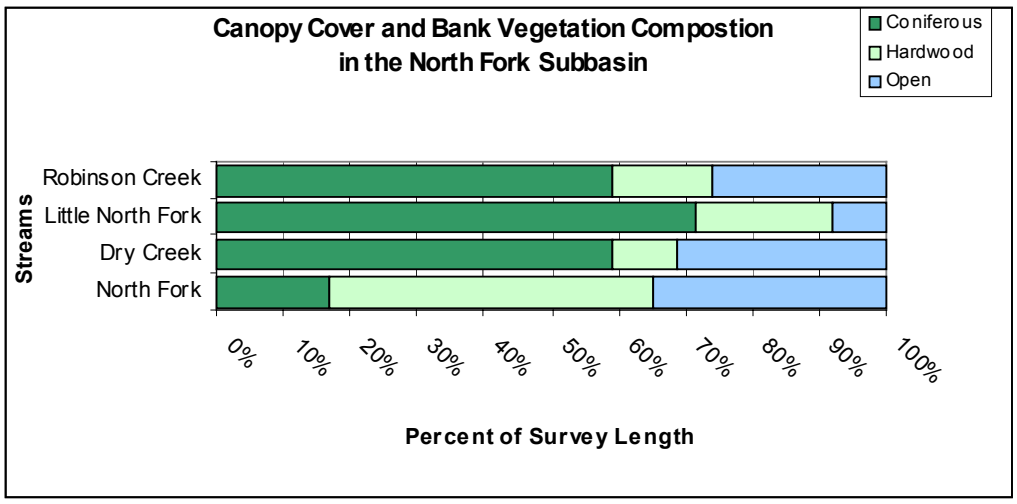


Figure 5.2-18
Canopy Cover and Canopy Vegetation Types in the North Fork Subbasin measured by the Gualala River Watershed Council, Gualala River Watershed, California

Categories 1 and 2 embeddedness (<50 percent embedded) are considered the most suitable for spawning. Category 5 is unsuitable spawning substrate, which includes clay, bedrock, and logs. Embeddedness was not a habitat deficiency on Dry Creek, Dry Creek Tributary #1, Little North Fork, Log Cabin Creek, the North Fork, and Robinson Creek. Embeddedness values on both Doty Creek and McGann Gulch showed habitat deficiency (Figure 5.2-19).

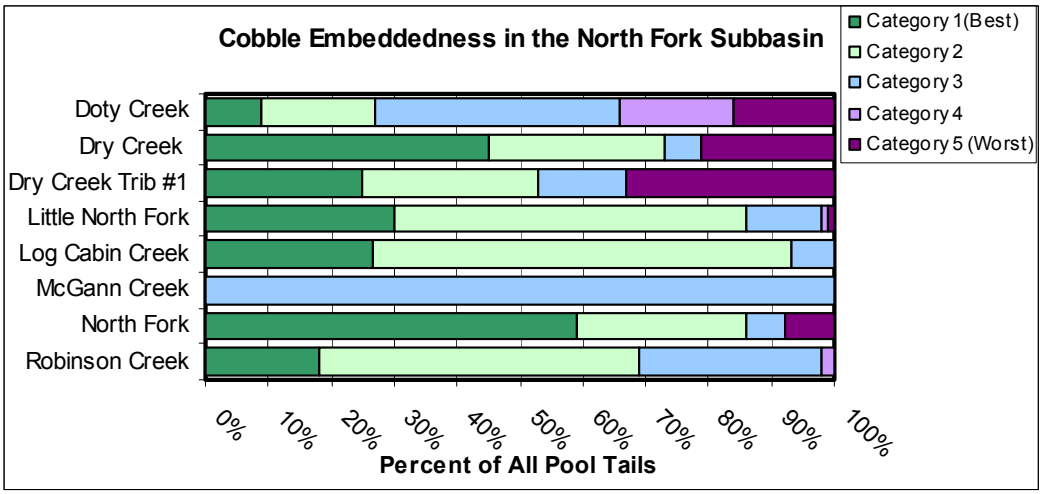


Figure 5.2-19
Cobble Embeddedness in the North Fork Subbasin 2001, Gualala River Watershed, California

All of the streams surveyed in the North Fork Subbasin showed habitat deficiencies in pool depth/frequency (Figure 5.2-20). Both the Little North Fork and North Fork had a pool frequency over 40 percent pools, meeting the frequency target value. However, neither met the depth target value based on the stream order. The Little North Fork is a second order stream with a target of 40 percent of the pools 2 feet or over. The North Fork mainstem is a third order stream with a target of 40 percent of the pools 3 feet or over.

Shelter/cover ratings were below target values for all of the streams surveyed in the North Fork Subbasin (Figure 5.2-21). The top three types of shelter/cover provided were mostly small woody debris, large woody debris and boulders (Figure 5.2-22). Small woody debris, large woody debris, and boulders provided most of the shelter on Doty and. Dry Creeks. Small woody debris, large woody debris, and root masses provided most of the shelter on the Little North Fork. Small woody debris, undercut banks, and root masses provided most of the shelter on Log Cabin Creek. Most of the shelter was provided by undercut banks, root masses and aquatic vegetation on McGann Gulch. Small woody debris, terrestrial vegetation, and boulders provided most of the shelter on the mainstem North Fork. Small woody debris, large woody debris, and undercut banks provided most of the shelter on Robinson Creek.

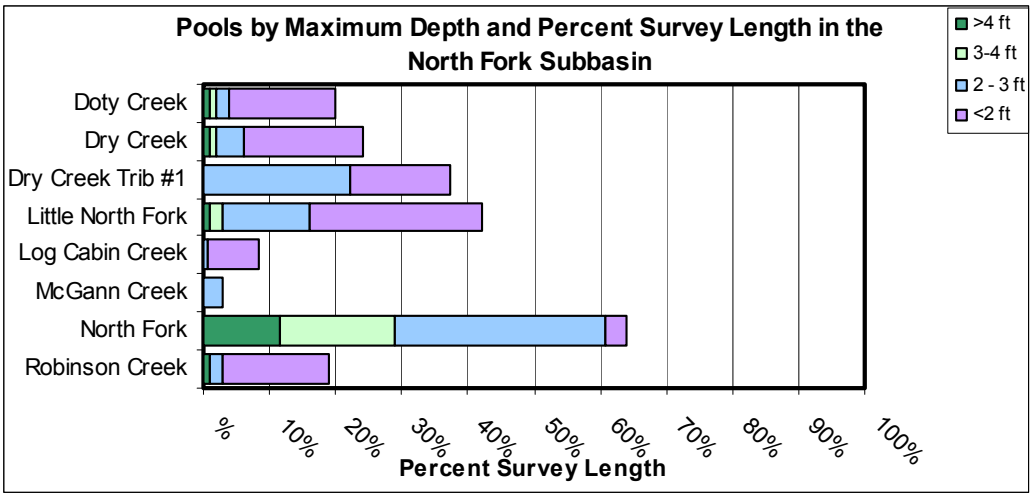


Figure 5.2-20
Pools by Maximum Depth and Percent Survey Length in the North Fork Subbasin 2001, Gualala River Watershed, California

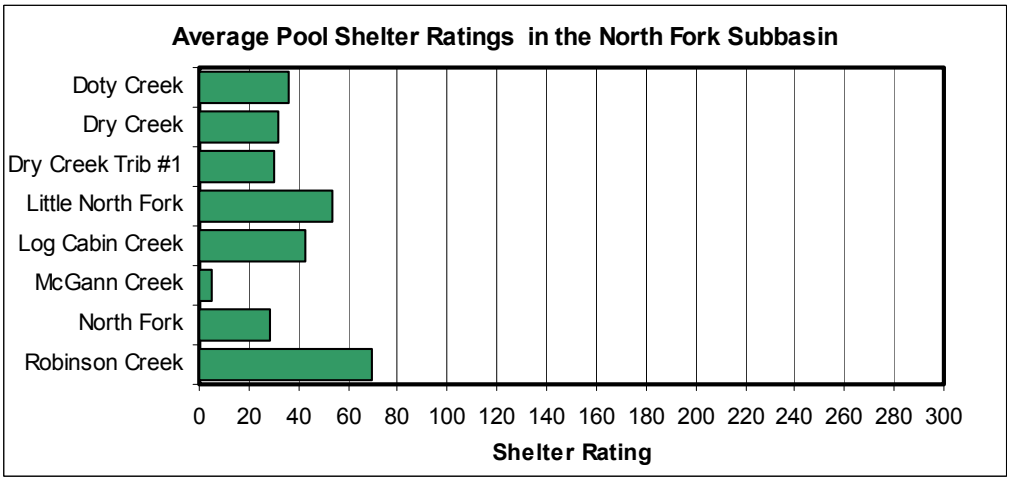


Figure 5.2-21
Average Pool Shelter Ratings in the North Fork Subbasin 2001, Gualala River Watershed, California

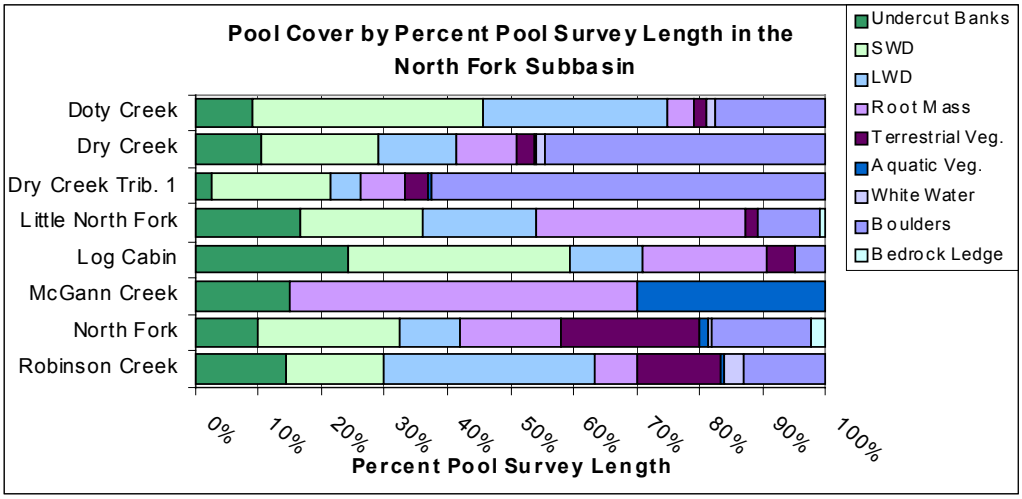


Figure 5.2-22
Type of Pool Shelter/Cover by Percent of Pool Survey Length in the North Fork Subbasin 2001, Gualala River Watershed, California

Large Woody Debris Data

Large woody debris data were provided by the GRWC's Cooperative Monitoring Program. Most large wood was cleared from the streams during the 1950s, 1960s and 1970s. The literature suggests a target value of 130 pieces of large wood >8 inches per 1,000 feet (Beechie and Sibley 1997, Martin 1999).

Large wood surveys were conducted on Robinson Creek, Dry Creek, the Little North Fork, and the lower section of the North Fork mainstem. Both Dry Creek and the Little North Fork have the highest wood volume and most pieces per 1,000 feet of stream reach for the subbasin. The high pool ratios in both tributaries could be a reflection of the higher large wood volumes.

A large wood placement project placed 9,100 cubic feet of large woody debris in the Little North Fork and Robinson Creek tributaries. Approximately 64 pieces of large woody debris with an average diameter of 32 inches were added to the Little North Fork at eight sites along the stream reach. The placement of wood is not included in Table 5.2-8.

Table 5.2-8
Summary of Watershed Cooperative Monitoring Program large woody debris data, North Fork Subbasin (1998 - 2000) Watershed size is calculated as the area above the monitoring site.

Tributary	Site Number	Watershed Size (acres)	Volume Cubic Feet/1,000	Quantity Pieces/1,000
North Fork	473	30,600	1,567	33
North Fork	204	25,433	1,958	35
Little North Fork	404	4,217	5,099	50
Little North Fork	203	1,963	3,843	77
Robinson	207	1,068	1,592	39
Dry Creek	211	4,104	5,168	69
Dry Creek	212	3,756	2,470	27

Changes In Habitat Conditions From 1964 to 2001

Changes between historic and current instream conditions were compared on the streams surveyed in 1964 and subsequently habitat inventoried from 2001. Data from the 1964 stream surveys provide only a qualitative snapshot of the conditions at the time of the survey, and terms such as excellent, good, fair and poor were based on the judgment of the biologist or scientific aid conducting the survey. The results of the historic stream surveys cannot be used in comparative analyses with the quantitative data provided by the habitat inventory surveys with any degree of accuracy. However, the two data sets may be used to show general trends.

According to aerial photographs, the canopy cover of the 1960s was reduced substantially from the conditions observed in the 1940s. The canopy appeared to be low or absent throughout the subbasin.

In the North Fork Subbasin, both the Little North Fork and the North Fork were surveyed in 1964 and 2001. The canopy cover increased indicating improved conditions over those observed in the 1960s aerial photographs. The spawning substrate conditions appear to have improved or remained the same between 1964 and 2001. The 2001 pool frequency/depth and shelter cover appear to have decreased since 1964 (Table 5.2-9).

Table 5.2-9
Comparison Between Historic Habitat Conditions Observed in 1964 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 2001 from the North Fork Subbasin, Gualala River Watershed, California

Habitat Element Stream Name	1964 Canopy Cover Photos	2001 Canopy Cover	1964 Spawning Substrate	2001 Spawning Substrate	1964 Pool Depth/ Frequency	2001 Pool Depth/ Frequency	1964 Shelter Cover	2001 Shelter Cover Value	Change in Conditions from 1964 to 2001
North Fork Subbasin				>50%		>40%		>80	
Little North Fork	Low or Absent	76%	Good	83%	50%	16%	Good	54	Recovered canopy; Improved spawning conditions; Decreased pool habitat and shelter/cover.
North Fork	Low or Absent	78%	Excellent	82%	80%	29%	Good	28	Recovered canopy; No change or return of spawning conditions; Decreased pool habitat and shelter/cover.

Ecological Management Decision Support (EMDS) Reach Model

Although the EMDS Reach Model scores are based upon the habitat inventory survey data, the analysis differed. The habitat inventory data were divided into reaches based upon Rosgen Channel type and

then converted to a weighted average. Each weighted average reach was compared to a set of habitat reference conditions which were determined from empirical studies of naturally functioning channels, expert judgment, and peer reviewed literature. EMDS rated each habitat component with a suitability score between -1 and +1, where suitability is a function of salmonid health and productivity. The reference curve breakpoints for these habitat parameters are presented in Table 4.1-1, Chapter 4.

EMDS scores for the subbasin overall were not calculated because only 81 percent of the blue line streams were habitat inventoried, and water temperature data was recorded in 2001 on only four of the eight streams surveyed. The MWAT on the Little North Fork was fully suitable at both of the sites sampled. The MWAT on Dry Creek was fully suitable at the only site sampled. The five MWATs on the mainstem North Fork in 2001 ranged from moderately suitable to fully unsuitable. The MWAT's increased as the sample sites moved upstream in an easterly direction away from the coast. The average of the five MWAT's was 64 F, an undetermined EMDS score for the mainstem (Table 5.2-10).

Table 5.2-10
Ecological Management Decision Support (EMDS) Reach Model Scores on Salmonid Heath and
Productivity Suitability for the North Fork Subbasin, Gualala River Watershed, California , Based Upon
Habitat Inventory Surveys Conducted in 2001

Subbasin Stream Name	Canopy Cover Score	Embeddedness Score	Pool Depth Score	Pool Shelter Score	Pool Quality Score	2001 MWAT Water Temperature Score
North Fork Subbasin	n/a	n/a	n/a	n/a	n/a	n/a
Doty Creek	+++	-	- - -	- -	-	
Dry Creek	-	++	- - -	- - -	- - -	+++
Dry Creek Tributary #1	-	+	- - -	- -	- -	
Little North Fork	+++	++	- - -	- -	- -	+++
Little North Fork Tributary #1	+++	+	- -	- -	- -	
Log Cabin Creek	+++	+	- - -	- -	- -	
McGann Gulch	++	- - -	- - -	- - -	- - -	
North Fork	++	++	+++	- - -	U	U
Robinson Creek	-	-	- - -	+	-	+++

The 2001 water temperature data was provided by GRI and the GRWC,
+++ = Fully Suitable
++ = Moderately Suitable
+ = Somewhat Suitable
U = Undetermined
- = Somewhat Unsuitable
- - = Moderately Unsuitable
--- = Fully Unsuitable;

Limiting Factors Analysis

The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components. Habitat inventory data, EMDS Reach Model scores, and the biologist's professional judgment were incorporated into both the identification of LFAs and their ranking.

Pool shelter/cover was the predominant limiting factor in the North Fork Subbasin, followed by pool depth, and canopy cover. Pool depth was the predominant limiting factor on most of the streams surveyed with the lack of pool shelter/cover being a close second. Embeddedness was limiting on both Doty Creek and McGann Gulch. Canopy cover was a limiting factor on Robinson and Dry Creeks (Table 5.2-11).

Table 5.2-11
Limiting Factors in the North Fork Subbasin Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 2001 and EMDS Scores in the North Fork Subbasin (*Rank 1 is the most limiting factor*)

Subbasin Stream Name	Canopy Cover Related to Shade over the stream	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
North Fork Subbasin Score				
Doty Creek		3	1	2
Dry Creek	3		1	2
Little North Fork			1	2
Little North Fork Tributary #1			1	2
Log Cabin Creek			1	2
McGann Gulch		3	2	1
North Fork				1
Robinson Creek	2		1	

Restoration Recommendations

The proposed restoration recommendations were based upon the habitat inventory surveys, limiting factors analysis, landowner and local expertise, and the biologist's professional judgment.

Restoration recommendations for the North Fork Subbasin are listed by priority, "1" being the highest priority (Table 5.2-12). The highest priority for restoration is instream structure enhancement. The next four recommendations, in order of decreasing priority, are: road repair or removal, bank stabilization, barrier removal, and riparian/canopy development. Livestock/ feral pig exclusion was not identified as a problem in the sections of the subbasin surveyed.

Table 5.2-12
Priorities for Restoration for the North Fork Subbasin
Rank 1 is the highest priority

Stream Name	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
North Fork Subbasin	3	2	5	1		4
Doty Creek		2	4	1		3
Dry Creek			2	1		
Little North Fork		2		1		
Little North Fork Tributary #1		2		1		
Log Cabin Creek	3	2		1		
McGann Gulch	2			1		
North Fork		2		1		
Robinson Creek		2	3	1		

Figure 5.2-23a illustrates the limiting factors as determined by CDFG and various sediment sites identified by CGS as potential restoration targets. Figure 5.2-23b is the map explanation. General recommendations are made for each limiting factor and type of sediment site. The map is a reduced image of Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed* (See Plate 3 to view details at a higher scale [1:48,000].).

Potential Refugia

The NCWAP interdisciplinary team identified and categorized refugia habitat by using professional judgment and criteria developed for north coast watersheds. The criteria considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, forestry and other land uses, land ownership, potential risk from sediment delivery, water quality, and other factors that may affect refugia productivity. Information from CDFG's habitat inventory surveys, EMDS reach model, professional judgment, and local Gualala River Watershed expertise were used to assess streams as potential refugia. Five NCWAP Refugia Categories and Criteria were described: (1) High Quality Refugia; (2) High Potential Refugia; (3) Medium Potential Refugia; (4) Low Quality Habitat; and (5) Critical Contributing Areas (Section 2.2.5, Chapter 2).

Medium Potential Refugia was identified in the Little North Fork and North Fork. The potential refugia identified on the Little North Fork were related to shade canopy and water temperature. The potential refugia identified on the North Fork were related to shade canopy and pool depth (Table 5.2-13).

Table 5.2-13
Refugia Categories for Surveyed Tributaries in the North Fork Subbasin, Gualala River Watershed, California

Stream	Refugia Categories				Other Categories		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area	Data Limited
North Fork Subbasin							
North Fork Gualala River			X			X	X
Little North Fork			X			X	
Robinson Creek				X		X	
McGann Gulch				X		X	X
Dry Creek				X		X	
Doty Creek				X		X	
Log Cabin Creek				X			X

5.2.9 FISH HISTORY AND STATUS

Salmonid population data is very limited in the North Fork Subbasin.

- **1950s**- No data available.
- **1960s**- In 1964, stream surveys were done on the North Fork and Little North Fork. Both the Little North Fork and North Fork showed steelhead trout and coho salmon present.
- **1970s**- No data available.
- **1980s**- Steelhead trout density in 1983 was 0.85 fish per meter at one station on Robinson Creek (three-pass electrofishing method). Three-pass electrofishing data were collected on a lower and upper site in the Little North Fork in 1988 and 1989, with an average steelhead trout density of 0.45 fish per meter.
- **1990s**- During the 1990s, 45,280 coho salmon were planted on the Little North Fork. GRI observed coho salmon young-of-the-year during snorkel surveys on the Little North Fork, Robinson, and Dry Creeks in 1998. One-year and older steelhead trout were observed on the Little North Fork, Robinson, North Fork, and Dry Creek in 1999 during snorkel surveys. Three pass electrofishing data were collected on a lower and upper site in the Little North Fork in 1990-1993, 1995, 1998, 1999, and 2000. No effort was recorded in 1990-1992. Both sites showed small fluctuations in young-of-the-year populations and a slight increase in one-year-old fish from 1995-2000. Two-year and older steelhead trout numbers were identical at the lower site and slightly increased at the upper site from 1998-2000. Between July 1, 1999 and June 30, 2000, spawner and electrofishing surveys were conducted on the Little North Fork. These surveys were conducted to determine whether the planting of coho salmon during the three-year period of 1995/1996-1997/1998 was effective. These coho salmon were from Noyo River stocks, hatched and reared at the Mad River hatchery. No coho salmon were found on the Little North Fork.
- **2000s**- During the 2000s, 13,050 steelhead trout were planted between Elk Prairie and Dry creeks. Young-of-the-year and one-year-old steelhead trout were observed (no coho salmon) on the North Fork using the Modified Ten Pool Protocol. During snorkel surveys, GRI observed one-year and

older steelhead trout on the Little North Fork, North Fork, Robinson and Dry Creeks in 2000 and 2001. In September 2002, coho salmon young-of-the year were observed in Dry Creek, a tributary of the North Fork during a snorkel survey, and at two sites on the Little North Fork and Doty Creek during electrofishing. Coho young-of-the-year were present on McGann Gulch (pers. comm. R. Dingman).

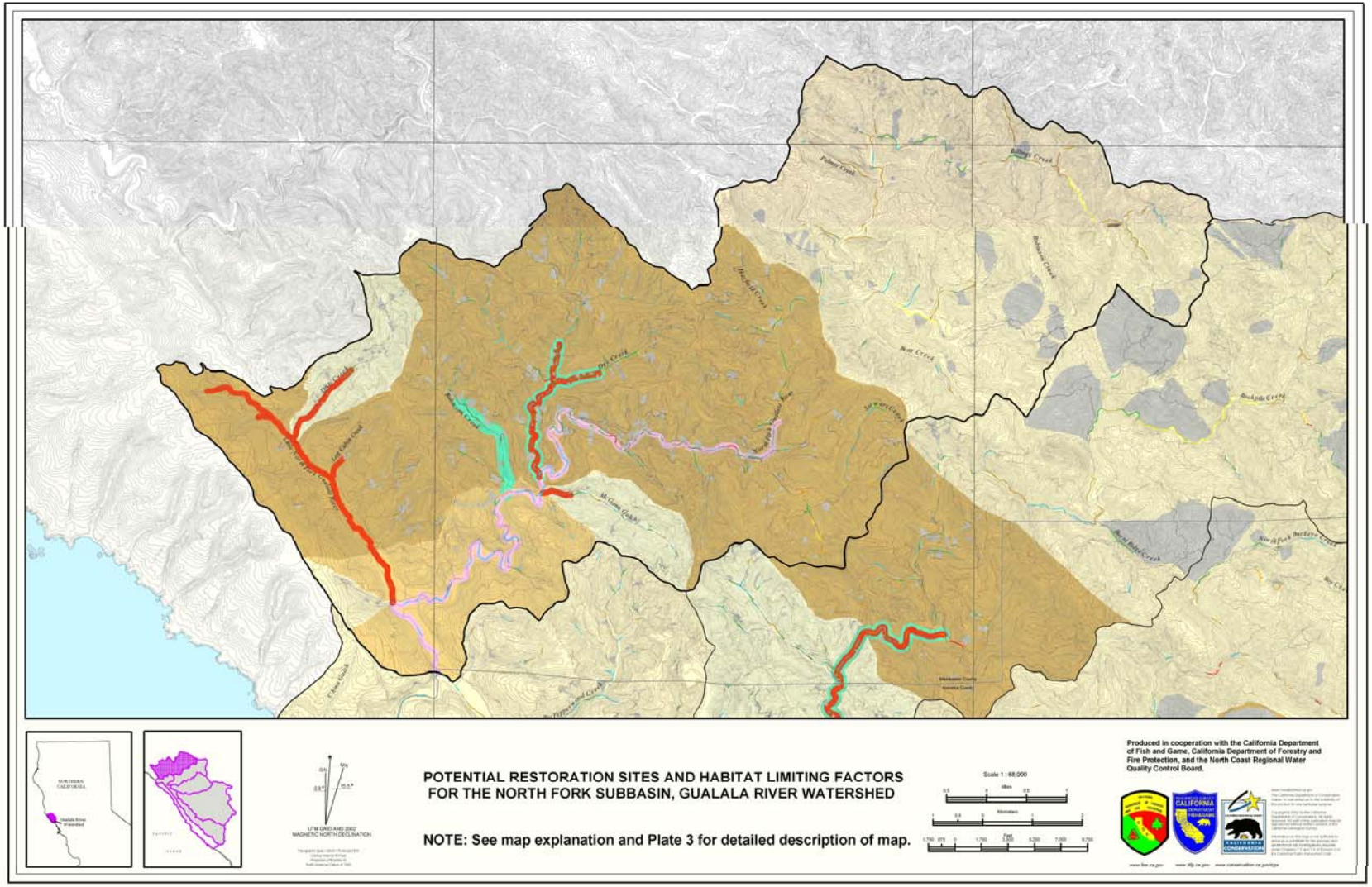


Figure 5.2-23a
Potential Restoration Sites and Habitat Limiting Factors for the North Fork Subbasin, Gualala River Watershed

Roads
Streams
Watershed boundary
Sub-basin boundary
Historically Active Landslides (mapped as a point if too small to delineate at the scale of this map)

I SPATIALLY ASSOCIATED FACTORS DERIVED FROM AERIAL PHOTO INTERPRETATION OF LANDSLIDING AND SEDIMENT CONDITIONS

A *HISTORIC IN-STREAM ROADS POSSIBLY RELATED TO FLUVIAL SEDIMENT*

Stream reaches with persistent aggrading or braiding in both 1984 and 2000 photos that may be associated with historic in-stream roads or landings. See recommendation #5.

B *ROADS POSSIBLY RELATED TO LANDSLIDES AND/OR ERODING BANKS*

Road segments that may be affected by historically active landsliding and bank erosion. See recommendation #6.

Road segments that may be affected by historically active landsliding. See recommendation #7.

C *FLUVIAL SEDIMENT CONDITIONS POSSIBLY RELATED TO LANDSLIDES*

Stream reaches with potentially adverse sediment accumulations that may be affected by historically active landslides and lack any apparent association with the modern road network or the historic in-stream roads or landings. See recommendation #8.

Stream reaches with potentially adverse sediment accumulations that may be affected by erosion from adjacent dormant landslide terrain that lack any apparent association with historically active landsliding, the modern road network, and historic in-stream roads or landings. See recommendation #9.

D *POTENTIALLY UNRELATED FLUVIAL SEDIMENT CONDITIONS*

Stream reaches with potentially adverse sediment accumulations that lack any of the above associations. See recommendation #9.

II LIMITING FACTORS DERIVED FROM GROUND BASED HABITAT SURVEYS (SEE DFG APPENDIX)

A *CANOPY AND POOLS AS LIMITING FACTORS* (All stream reaches surveyed by DFG in 2001 are highlighted as follows. Reaches that were not surveyed in 2001 are not highlighted on the map.)

Stream reaches with inadaquate canopy cover as the limiting factor. See recommendation #2.
Stream reaches with inadequate pool depths as the limiting factor. See recommendation #4.
Stream reaches with inadequate pool shelter as the limiting factor. See recommendation #3.
Stream reaches with both inadaquate pool depths and shelter as limiting factors. See recommendations #3 and #4.

Explanation

B *EMBEDDEDNESS AS A LIMITING FACTOR*

Areas draining into where embededdness conditions are unknown.
Areas draining into reaches where embeddedness is not limiting.
Areas draining into reaches where embeddedness is marginal but not limiting.
Areas draining into reaches where embeddedness is somewhat limiting. See recommendation #1.
Areas draining into reaches where embeddedness is significantly limiting. See recommendation #1.

RECOMMENDATIONS BASED ON LIMITING FACTORS

(1) Reduce production of fine sediment throughout the contributing area. Evaluate contribution from roads and upgrade roads as appropriate. Evaluate contribution from soil disturbance and control erosion as appropriate (see recommendations 5-10). Evaluate contribution from soil disturbance and control erosion as appropriate. Consider the additive effect of the short-term increases in erosion due to mitigation activities. Distribute individual activities both spatially and temporally as appropriate to avoid additive sediment impacts. Institute best management practices in erodible areas; such as, areas shown on the CGS Relative Landslide Potential Map (Plate Two), and National Resources Conservation Service soil maps.

(2) Enhance current riparian vegetation by planting additional trees, and stabilize stream banks as needed. Also, consider both downstream and upstream effects.

(3) Enhance pool shelter by adding submerged or partially submerged structures. Consider both upstream and downstream effects due to operation and possible failure.

(4) Install in-stream structures to produce hydraulic variability and to scour pools. Consider both downstream and upstream effects due to operations and possible failure.

RECOMMENDATIONS BASED ON SPATIAL ASSOCIATIONS

(5) Evaluate relationship on-site. Consider channel restoration and drainage improvements for the road and landing. Consider engineered abandonment.

(6) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible. Consider stream bank stabilization where feasible.

(7) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible.

(8) Evaluate on-site whether these represent natural background conditions. If mitigation is desired, road construction may be needed for equipment access.

(9) No recommendation because potentially associated active sediment sources have not been identified.

EXPLANATION FOR POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS FOR THE GUALALA RIVER WATERSHED MAP

NOTE: See Plate 3 for complete description of map.

Produced in cooperation with the California Department of Fish and Game, California Department of Forestry and Fire Protection, and the North Coast Regional Water Quality Control Board.

www.fire.ca.gov www.dfg.ca.gov www.conservation.ca.gov/cgs

Figure 5.2-23b
Explanation for Potential Restoration Sites and Habitiat Limiting Factors for the Gualala River Watershed Map

5.2.10 NORTH FORK SUBBASIN PUBLIC ISSUES, SYNTHESIS, AND RECOMMENDATIONS

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala River Watershed residents and constituents. The following general concerns were expressed as potential factors affecting the North Fork Subbasin and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.

- Abandoned roads, new road construction, and road maintenance issues related to landsliding and sediment input.
- High-water temperatures and low shade canopy density, as well as the density and diversity of the riparian zone.
- Location and conduct of timber harvest operations.
- Current logging practices on steep unstable slopes and near streams, especially regarding sediment contributions.
- Best management practices required by current forest practice rules are reducing forestry impacts to insignificance.
- Sediment as a limiting factor for salmonids due to pool filling, aggradation, and small-sized spawning substrate.
- Absence of salmonid information, low fish densities, or absences of fish.
- Invasive and exotic plants and wildlife may have affected the subbasin conditions to varying degrees in various locations. Pampas grass was mentioned as one of the prominent problem species.

Working Hypotheses

The primary purpose of these hypotheses is to elucidate in a succinct format the judgment of the Team regarding watershed conditions relative to anadromous salmonids. As such, they are responsive to the assessment questions presented on pages 1-1 and 1-2. The findings supporting the hypothesis are presented, along with recommendations for watershed improvements, and to further investigate the hypotheses. As such, they are not intended to be the final word, but are the best judgment based on the information at hand.

Recommendations for watershed improvements and further study are presented at the end of the section, as single recommendations apply in many cases to more than one hypothesis.

The hypotheses are presented by subbasin because of differences in geology, climate, and land use. However, they follow the same basic format. The three working hypotheses are:

1. Stream conditions in the North Fork Subbasin provide suitable habitat for salmonids.
2. Depleted overstory shade canopy cover along the upper North Fork mainstem and tributaries from legacy harvests and other factors continues to contribute to elevated water temperatures.

3. A lack of in stream large woody debris contributes to a simplified habitat structure (e.g., lack of large, deep pools).

4. Instream conditions are improving in the North Fork Subbasin.

Working Hypothesis 1

Stream conditions in the North Fork Subbasin provide suitable habitat for salmonids.

Supporting Findings

- Young-of-the-year coho salmon were observed in tributaries of both the Little North Fork and North Fork.
- Young-of-the-year, year-old and older steelhead trout were observed in all surveys throughout the subbasin in 2002.
- MWATs from 2001 were fully suitable on Dry Creek, the Little North Fork and Robinson Creek.
- Water temperatures for the period of record (1994-2001) were suitable in the tributaries and the mainstem North Fork downstream of the Little North Fork confluence.
- Canopy cover target values (from Flosi et al 1998) were met on Log Cabin Creek. The North Fork, McGann Gulch, Little North Fork, and Doty Creek nearly met the target values. Canopy cover has improved since the aerial photos of the 1960s. Embeddedness target values were met on Dry Creek, Little North Fork, Log Cabin, North Fork, and Robinson Creek (Section 5.2.8).
- Canopy cover EMDS scores were fully suitable on Doty Creek, the Little North Fork, and Log Cabin Creek. McGann Gulch and the North Fork were moderately suitable. Embeddedness was moderately suitable on Dry Creek, the Little North Fork, and the North Fork. Log Cabin was somewhat suitable. Pool depth was suitable on the North Fork. Shelter was somewhat suitable on Robinson Creek (Table 5.2-10).
- Areas of potential refugia were identified on the Little North Fork and North Fork.

Contrary Findings

- Water temperatures for the period of record (1994-2001) ranged from undetermined to fully unsuitable in the mainstem North Fork upstream of the confluence with the Little North Fork. MWATs and seasonal maxima were higher in the upstream areas, decreasing as the North Fork mainstem flowed off the oak woodland into the coastal areas (Figure 5.2-16).
- Seasonal maximum water temperatures were above the 75 F lethal level at the three upstream-most mainstem sites (nf216, nf272, nf214) for the period of record (Section 5.2.7).
- Canopy cover target values (from Flosi et al 1998) were not met on Dry and Robinson Creek. Embeddedness target values were not met on Doty Creek or McGann Gulch. Primary pool depth and frequency were not met on any of the streams surveyed. Pool shelter target values were not met on any of the streams surveyed (Section 5.2.8).
- Canopy cover EMDS scores were unsuitable on Dry Creek and Robinson Creek. Embeddedness was unsuitable on Dry Creek, McGann Gulch, and Robinson Creek. Pool depth was unsuitable fully unsuitable on Doty Creek, the Little North Fork, Log Cabin, McGann

Gulch, and Robinson Creek. Pool shelter was unsuitable on all inventoried streams except Robinson Creek (Table 5.2-10).

- Canopy cover as interpreted from aerial photos has not recovered to 1942 levels (Section 5.2.4).
- A high proportion of road crossings, and roads are located low on the sideslope (EMDS Watershed model). The EMDS model indicates a higher level of concern for overall subbasin conditions with more than 50 percent of the middle subbasin reaches harvested during the most recent 10 year period as a land use index.

Limitations

- Only 81 percent of the subbasin was habitat inventory surveyed.
- Available temperature data did not span all sites in all years from 1994-2001, however three or more years' data were available for five of the ten mainstem sites. Only one year's data were available for four of the ten mainstem North Fork sites (nf474, nf406, nf258, nf473). No temporal trends were apparent for the mainstem North Fork.
- Temperature data were limited to the lower half of the watershed (9 miles). No stream temperature data were available in the upper reaches of the main stem (Figure 5.2-16).

Conclusions

- The hypothesis is supported.
- Physical habitat conditions are suitable for salmonids in the North Fork Subbasin.
- Water temperatures are suitable for salmonids in the tributaries and in the mainstem North Fork below its confluence with the Little North Fork. Water temperatures were high in the upper mainstem North Fork.

Working Hypothesis 2

Depleted overstory shade canopy cover along the upper North Fork mainstem and tributaries from legacy harvests and other factors continues to contribute to elevated water temperatures.

Supporting Findings

- Canopy cover target values (from Flosi et al 1998) were not met on Dry and Robinson Creek as measured by habitat inventory surveys in 2001 (Section 5.2.8).
- Canopy cover EMDS scores were unsuitable on Dry Creek and Robinson Creek (Table 5.2-10).
- Three points emerged from the comparison of water temperature MWATs for the period of record to the LandSat vegetation layers: (1) water temperatures were higher in the upstream areas draining the northeastern portion of the subbasin, (2) vegetation in the area upstream of those high temperatures (Franciscan Complex mélange) is open oak grasslands with poor canopy, and 3)water temperatures in the mainstem North Fork decreased from upstream of Dry Creek to downstream of Robinson Creek (Figure 5.2-16).
- Timber harvesting prior to 1968 removed riparian canopy throughout the middle and upper mainstem North Fork (upstream from the confluence with Dry Creek) and higher tributaries in the subbasin (Section 5.2.4).

- Current riparian canopy in the middle subbasin reaches consists of mid sized 40 year old second growth coniferous stands. Riparian canopy stocking has not fully recovered to 1936 density and old growth conditions upstream from Dry Creek (Section 5.2.4)

- Linear regression of channel canopy measurements and MWATs for 11 sites in the Gualala River Watershed showed a significant relationship of water temperature to channel canopy (page 3-18).

Contrary Findings

- Canopy coverage as measured by bank-to-bank exposure has improved since 1968 aerial photos.

Limitations

- Only 81 percent of the subbasin was habitat inventory surveyed.

- A hydrothermal area is documented on the North Fork, one mile above the confluence of Stewart Creek approximately in line with two well-documented hydrothermal areas on the Tombs Creek Fault. The extent to which such areas may influence stream temperatures is unknown.

- The linear regression of canopy and MWAT did not account for the factors of stream flow, stream aspect, thermal reach length, air temperature, relative location in the watershed, contributions from tributaries and groundwater inflow, and differences among years.

Conclusion

- The hypothesis is supported.

Working Hypothesis 3

A lack of in stream large woody debris contributes to a simplified habitat structure (e.g., lack of large, deep pools).

Supporting Findings

- Shelter/cover did not meet Flosi, et al (1998) target values on any of the streams surveyed. (Table 5.2-6).

- Pool shelter EMDS scores were somewhat to fully unsuitable for the streams surveyed (Table 5.2-10).

- Pool depth and pool shelter are rank 1 and 2 limiting factors throughout the subbasin (Table 5.2-7).

- LWD is low due to streamside road construction, timber harvesting, and salmonid migration barrier removal. (Sections 5.2.4 and 5.2.8).

- Roads, landings, and skid trails built in or adjacent to streams between 1952 and 1968 buried, removed, and dispersed large woody debris. The reduction of LWD likely reduces pool formation and sediment storage in the tributaries (Section 5.2.4).

- Timber harvest up to the mid-1990s in the lower and middle reaches frequently selectively cut large conifer vegetation down to the stream bank, reducing the available recruitment supply of large woody debris (Section 5.2.4).

- Stream clearance projects in the 1970s and 1980s to clear log jam barriers to salmonid migration removed large amounts of woody debris throughout the North Fork Subbasin, except on the North Fork (Section 5.2.4).
- Stream buffers are regenerating since the mid-1990s under current land management practices and Forest Practice Rules, and large trees are present in the riparian zone in the alluvial flats. However, the dense stands of riparian zone conifers have not reestablished to levels seen before mid-20th-century logging (Section 5.2.4).
- The Watershed Cooperative Monitoring Program identified deficient large woody debris on the North Fork, Little North Fork, Robinson Creek, and Dry Creek (Table 5.2-8).
- Pool depth and pool shelter are rank 1 and 2 limiting factors throughout the subbasin (Table 5.2-7).
- Enhancement of instream structure is a priority 1 restoration priority (Table 5.2-12).

Contrary Findings

- Shelter was somewhat suitable on Robinson Creek.
- In the lower watershed woody debris large enough to function in the channels is abundant adjacent to Little North Fork, lower Doty Creek and lower Robinson Creek.

Limitations

- Only 81 percent of the subbasin was habitat inventory survey.

Conclusion

- The hypothesis is supported.

Working Hypothesis 4

Instream conditions are improving in the North Fork Subbasin.

Supporting Findings

- Overall levels of channel disturbance in the Robinson Creek PWS decreased from 1984 to 1999/2000, based on aerial photo interpretation. Approximately 75 percent of the main channel appeared disturbed with enlarged and numerous bars and lack of riparian vegetation in 1984. By 1999/2000 the main channel appeared to have improved with disturbance between 50 and 75 percent (Section 5.2.6).
- The Dry Creek channel was at least 80 percent disturbed in 1984 images. In the 1999/2000 images, the upper reach of Dry Creek improved to approximately 50 percent of the channel showing disturbance (Section 5.2.6).
- Overall conditions of the channels in the Doty Creek PWS improved from 1984 to 1999/2000, based on aerial photo interpretation (Section 5.2.6).
- At least 80 percent of the North Fork channel within the Stewart Creek PWS appeared disturbed from 1984 aerial photos. By 1999/2000, the channel appears to have improved to 50 to 70 percent disturbance (Section 5.2.6).

- Thalweg profiles from 1998 to 2001 at three sites (nf 204, lnf 203, dry 211) in the subbasin showed no significant changes in bed elevation in these response reaches (Appendix 4).

- Canopy coverage has increased since 1968 aerial photos as measured by bank-to-bank exposure (Section 5.2.4).

Contrary Findings

- Canopy coverage as measured by bank-to-bank exposure has not recovered to the extent observed in 1936 aerial photos (Section 5.2.4).

Limitations

- Canopy coverage (bank-to-bank exposure) and fluvial characteristics came from aerial photo interpretation. The direct linkage to fish habitat conditions has not been made.

Conclusions

- The hypothesis is supported.

- Overall levels of channel disturbance have improved since 1984.

- Canopy coverage as measured by bank-to-bank exposure has improved since 1968, but not to 1936 levels. More information on the improvement with regard to riparian composition over the period of photo records is needed to discuss improvement in the riparian zone beyond canopy coverage.

Subbasin Recommendations

1. Maintain and enhance riparian zones to achieve target canopy density and diversity including large conifers for LWD recruitment.

    a. Ensure that adequate streamside protection zones are used to reduce solar radiation and moderate air temperatures in order to reduce heat inputs to the North Fork and its tributaries.

    b, Maintain or enhance existing riparian cover. Where current canopy density and diversity are inadequate and site conditions are appropriate, initiate tree planting, thinning, and other vegetation management to hasten the development of a denser, more extensive and diverse riparian canopy. Dry Creek, Robinson Creek, the central and higher reaches of the mainstem, and the lower reaches of Bear and Stewart Creeks are high priority areas for riparian improvements. Areas with persistent bank exposure include: (1) the central and higher reaches of the mainstem, (2) the lower reaches of Bear and Stewart Creeks, and (3) the upper reaches of Dry Creek.

    c. Land managers in this subbasin should be encouraged to add more large organic debris and shelter structures in order to meter sediment inputs, improve channel structure, channel function, habitat complexity, and habitat diversity for salmonids. Pool shelter has the lowest suitability for salmonids in the whole subbasin. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream enhancement is the top tributary recommendation.

2. Address existing and potential sediment sources. Refer to Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed* for more specifics.

   a. Continue efforts such as road erosion proofing, improvements, and decommissioning throughout the subbasin to reduce sediment delivery to the North Fork and its tributaries. Road sediment inventory and control is second of the top three tributary recommendations. Activities to reduce road-related sediment inputs are suggested for the Little North Fork and tributaries (Doty Creek, Log Cabin Creek, Tributary #1), Robinson Creek, Stewart Creek, McGann Gulch, and the mainstem North Fork.

   b. At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Bank stabilization is the third priority of tributary recommendations. Bank stabilization is a restoration priority 2 for McGann Gulch, and priority 3 for Log Cabin Creek.

   c. Decommission and revegetate streamside roads:

      i) Focus on the instream and near-stream roads where channel braiding and/or aggradation are still persistent today, as noted in Stewart and Dry Creeks, upper Billings Creek, and upper Robinson Creek tributary to Billings Creek.

      ii) Concentrate on those tributaries in the lower and central subbasin reaches containing the best historical anadromous habitats where mid-20th-century operations caused the worst damage: Doty, Log Cabin, Dry, Robinson, and Stewart Creeks, and McGann Gulch. A waterfall upstream of the confluence of Stewart Creek and the mainstem blocks anadromous fish passage.

   d. Concentrate modern road upgrade/ repairs starting with those associated with historically active landsliding and/ or eroding streambanks on:

      i) The main timber haul route following the North Fork between Dry Creek and Stewart Creek, and 2 upslope roads crossing unnamed tributaries in this area

      ii) Dry and Stewart Creeks, and the upper reaches of Robinson Creek tributary to Billings Creek.

   e. In the timber dominant lower and central subbasin reaches:

      i) Incorporate mitigation elements into Timber Harvest Plans and pursue cost sharing grants to decommission legacy streamside roads and upgrade existing road drainage facilities.

      ii) Encourage the use of cable or helicopter yarding on steep and unstable slopes to reduce soil compaction, surface disturbance, surface flow interference, and the resultant sediment yield.

      iii) Evaluate the possibility of spreading timber harvesting operations over time and space to avoid concentrated road use by heavy equipment and resultant mobilization of road surface fines into watercourses.

   f. Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 56 percent of the subbasin.

   g. Pursue cost sharing grants such as those organized by the Sotoyome RCD to upgrade roads in upland areas underlain by the mélange.

h. Evaluate the fish rescue activities and fish holding facilities on Doty Creek to determine if it is causing a migration barrier and/or habitat degradation due to water diversion.

3. Encourage the continuation and expansion of stream monitoring using the protocols developed by the GRWC.

4. Encourage more habitat inventory surveys and biological surveys of tributaries, as only 81 percent has been completed.

5.3 Rockpile Subbasin

5.3.1 INTRODUCTION

The Rockpile Subbasin (Calwater 2.2a 113.82 Rockpile Creek SPWS) is bounded to the north by the North Fork Subbasin and to the south by the Buckeye Subbasin. It encompasses 35 square miles of private land primarily used for timber production and grazing. This subbasin is steeper than the North Fork Subbasin and with the same zig-zag pattern to the main channel. There are 88 miles of "blue line" streams, and two major tributaries: Red Rock Creek and Horsethief Canyon (Figure 5.3-1).

Historic events and the period of record on the various data sets used in the NCWAP assessment are presented in a graphic format in Figure 5.3-2.

5.3.2 GEOLOGY

Mélange of the Franciscan Complex underlies oak savanna woodland in the eastern headwaters. Large areas of active earthflows and other forms of landsliding are abundant and contribute sediment to the streams (Figure 5.3-3). Figure 5.3-4 is the relative landslide potential map for the Rockpile Subbasin. The complete maps and explanations for both maps are on Plates 1 and 2. The steep tributaries in the upper reaches can be characterized as source (>12 percent slope) and transport (4-12 percent slope) reaches.

Over 60 percent of the subbasin has a high to very high potential for landsliding (Figure 5.3-4).

In the lower reaches of the subbasin, streams meander slightly through narrow alluviated valleys within steep valleys. The main channel is somewhat sinuous and low gradient, with a narrow floodplain and stable point bars.

5.3.3 VEGETATION

The narrow Rockpile Subbasin contains high site timber ground downstream from Rockpile Peak. Upstream areas contain mixed conifer hardwood forests with grassland on ridgelines and south facing slopes. The original old growth logging was limited to the lowest reaches of the subbasin in the alluvial flat. Previous to the mid-20th-century logging boom, old growth coniferous forests occupied the middle reaches. The 1942 photos show dense mature coniferous shade canopy cover over primary streams. Only the lowest reaches near the confluence point with the South Fork is Rockpile Creek wide enough to create bank-to-bank exposure in an alluvial flood plain (Figure 5.3-5).

5.3.4 LAND USE

Two eras of intensive land use characterize the Rockpile Subbasin: (1) tractor harvesting between 1952 to 1968, and (2) cable tractor harvesting throughout the Lower and Middle Rockpile Planning Watersheds (PWSs) from 1990 to the present. The original turn of the century operations were limited to the lowest reaches of the subbasin due to limited rail access from the South Fork.

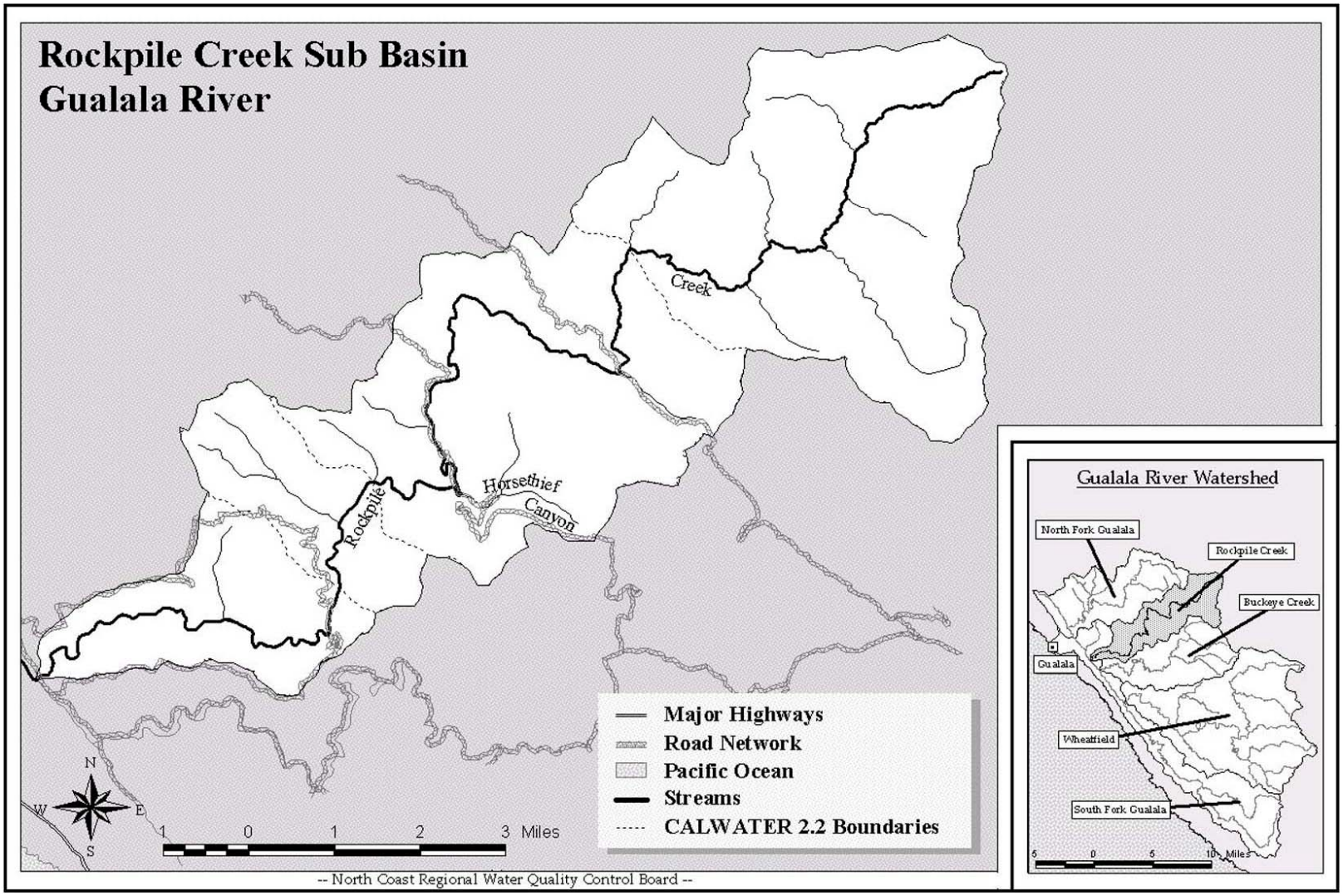


Figure 5.3-1
Rockpile Subbasin

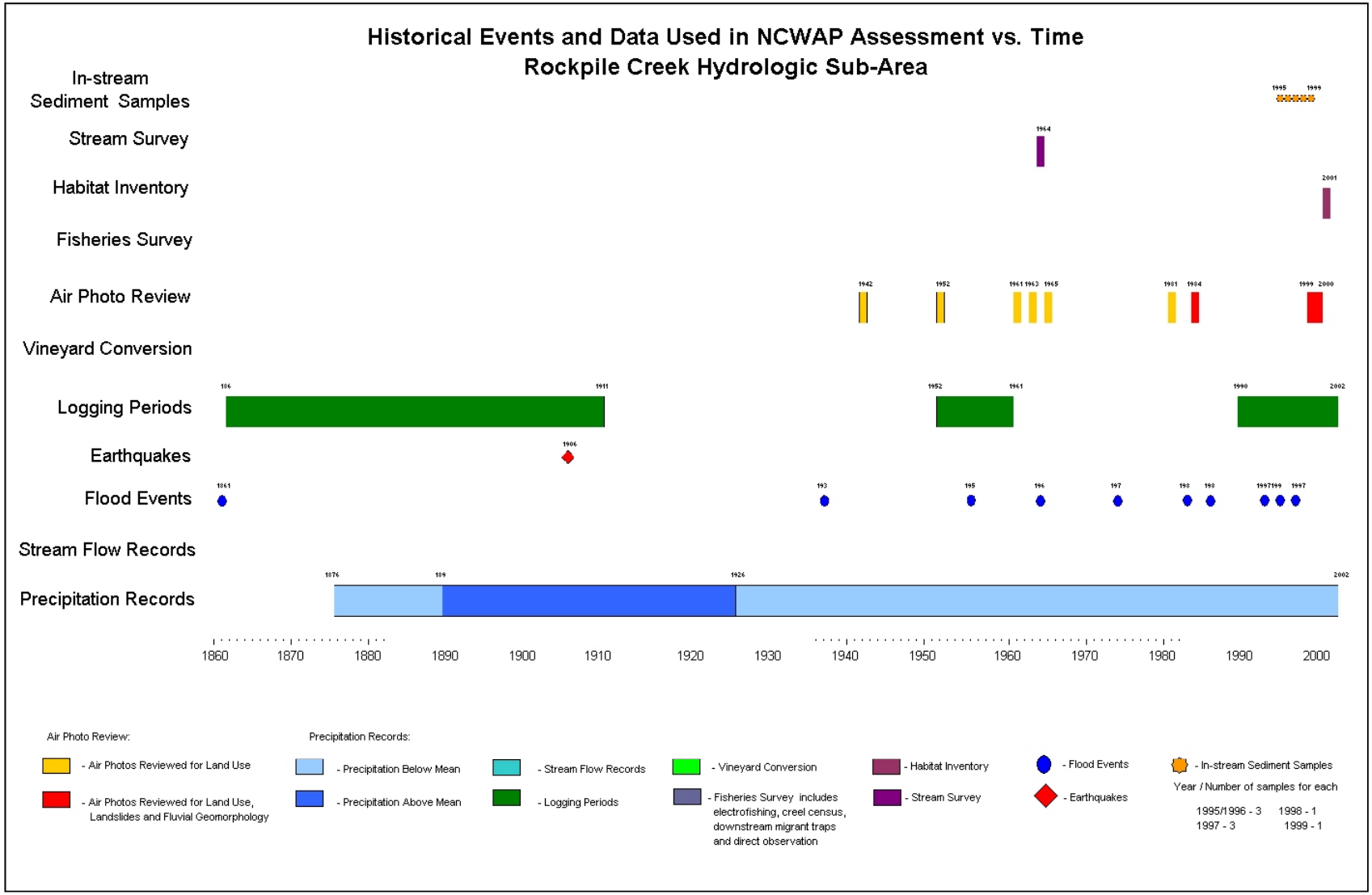


Figure 5.3-2
Historic Events and Data Used in the NCWAP Assessment for the Rockpile Subbasin

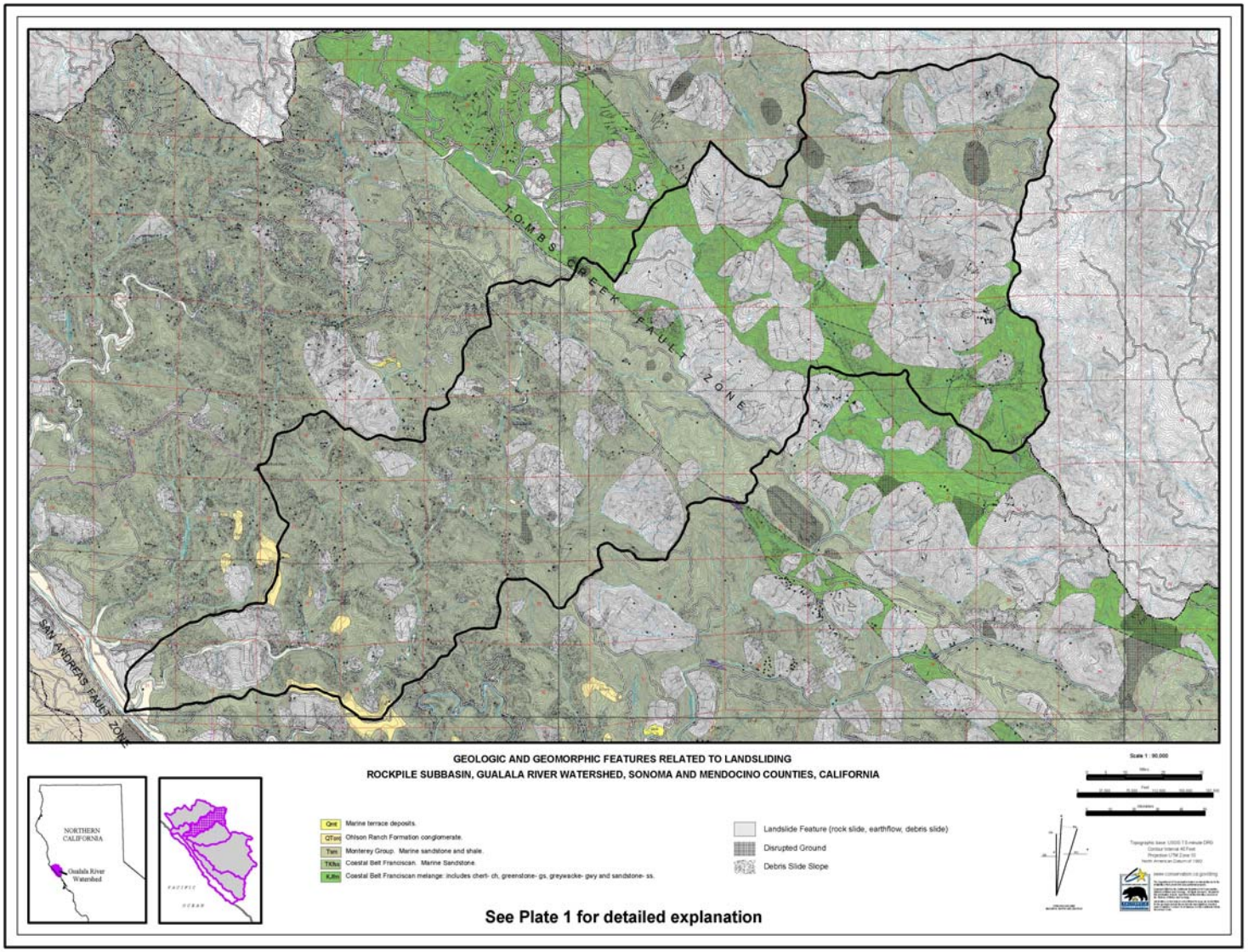


Figure 5.3-3
Geologic and Geomorphic Features Related to Landsliding - Rockpile Subbasin

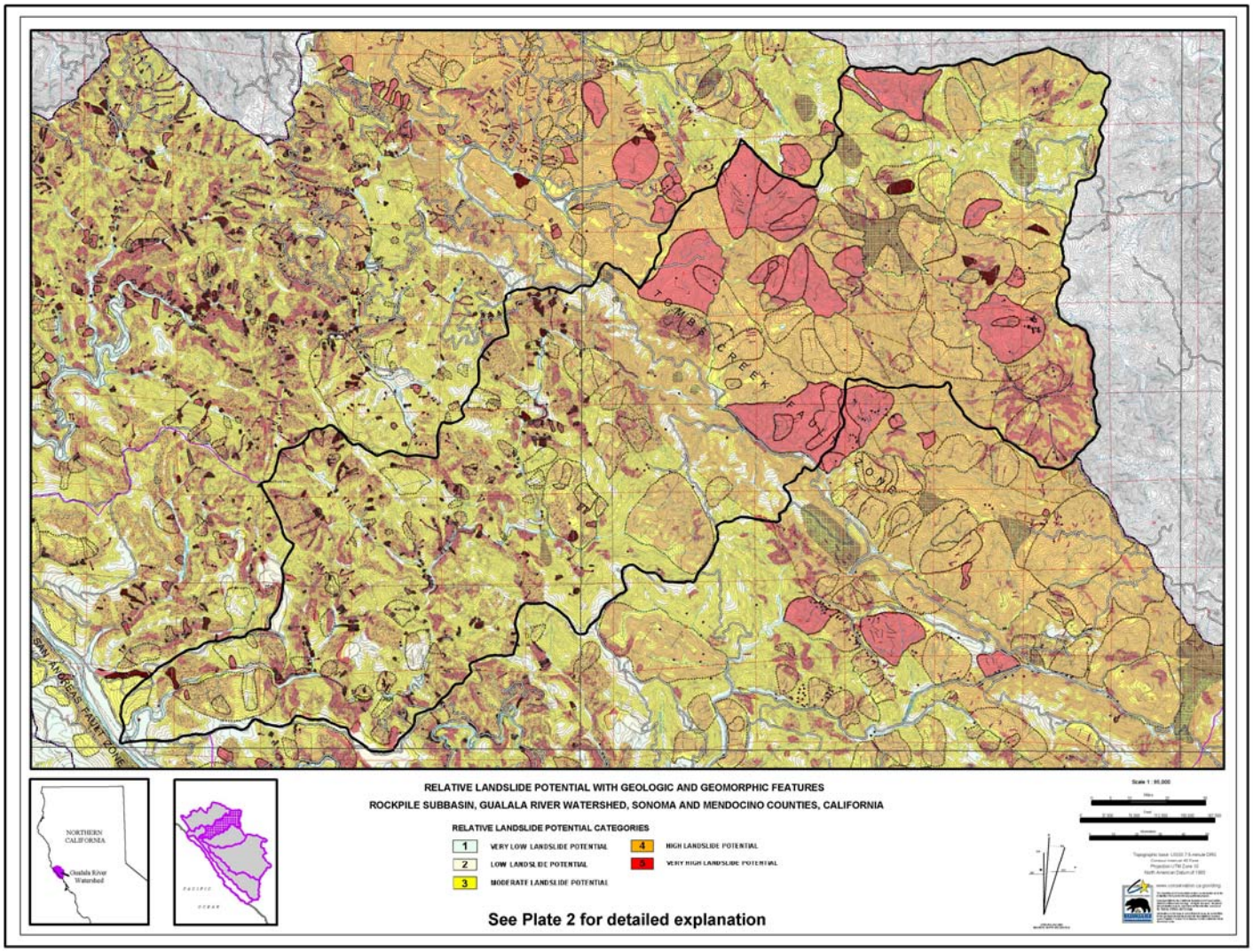


Figure 5.3-4
Relative Landslide Potential with Geologic and Geomorphic Features - Rockpile Subbasin

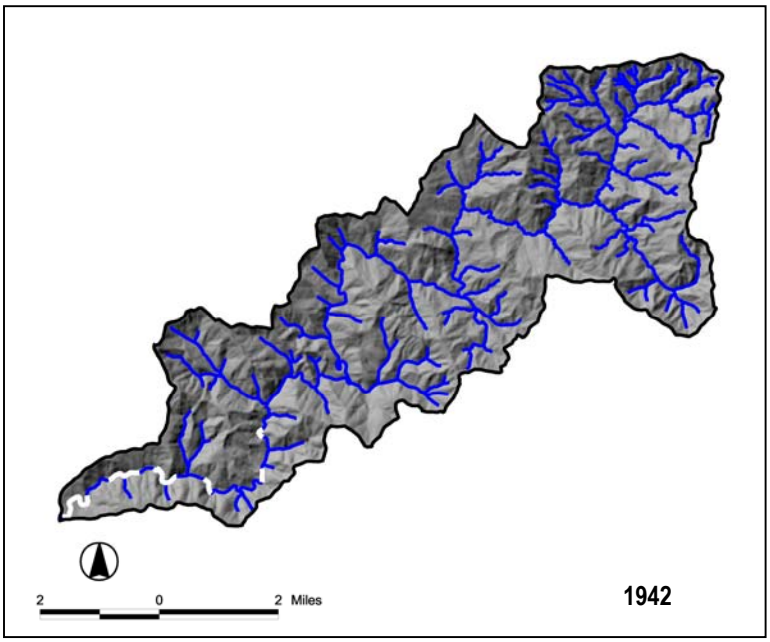
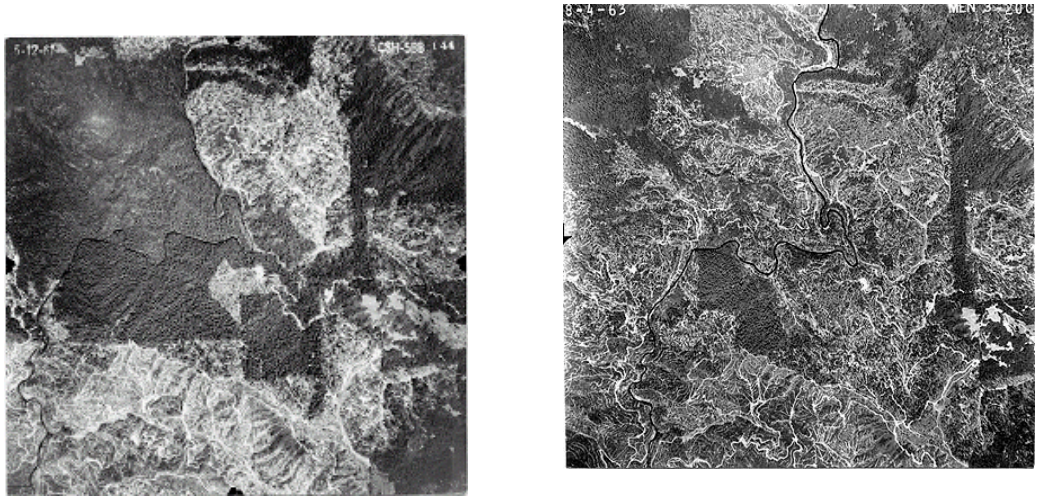


Figure 5.3-5
Bank-to-Bank Exposure (White) on Rockpile Creek in 1942
(Blue lines show partial to entire canopy cover)

Tractor logging operations in the Rockpile Subbasin accelerated in the mid-1950s, after the depression era lull. The middle reaches of Rockpile Creek downstream from Horsethief Canyon formed the central area of a large multi-basin operations unit stretching down from the upper North Fork southeast through Franchini Creek to the mainstem Buckeye Creek. By 1960, rectangular block harvest areas following straight parcel lines appear in the middle to upper reaches, comprising 9,200 acres (42 percent of the subbasin) harvested between 1952 and 1960. By 1964, each of these had enlarged to merge into one continuous harvest area (Figure 5.3-6). Due to the steep, deeply incised terrain, haul roads and landings were densely concentrated along Class I watercourses (Figure 5.3-7). The central reaches of the Rockpile Subbasin had one of the largest continuous areas in the watershed logged between 1960 and 1964, with 5,300 more acres harvested by 1964 (Table 5.3-1). Numerous road washouts, debris slides, and stream aggradations are referenced in the timber harvesting plan (THP) record attributable to this time period (see Land Use Impacts by Major Tributary, page 5.3-11). The 1961, 1963, and 1981 air photos showed road debris slides particularly concentrated in the Red Rock and Middle Rockpile PWSs.

Improvement of stream channel conditions is evident in recent times. Throughout blue line streams of the Rockpile Subbasin, California Geologic Survey (CGS) geofluvial mapping showed an overall reduction in the percentage of channel length affected by excess sediment storage or sediment sources between 1984 and 1999/2000.

Mid-20th-century logging operations removed all riparian canopy cover leaving bank-to-bank watercourse exposure throughout the entire mainstem of Rockpile Creek extending from the South Fork upstream to the Upper Rockpile Planning Watershed (see 1968 Shade Canopy Exposure Map, Figure 5.3-8).



1960 **1963**

Figure 5.3-6
Central Rockpile PWS 1960 (left) and the Same Area in 1963 (right)
Showing a Rapid Rate of Old Growth Harvesting in a Three-Year Period
(Horsethief Canyon is in the central right Note entire bank-to-bank exposure over Rockpile Creek after harvests.)

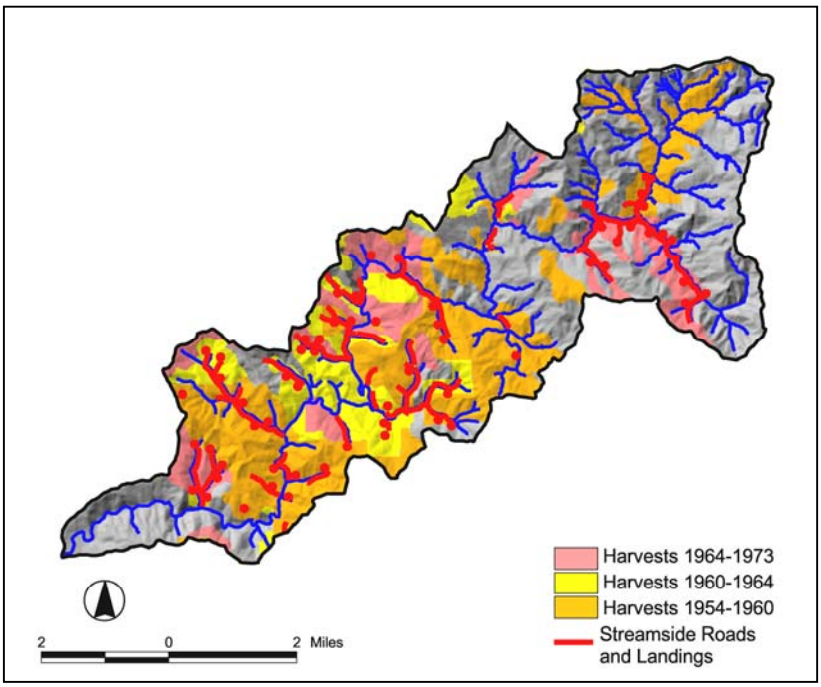
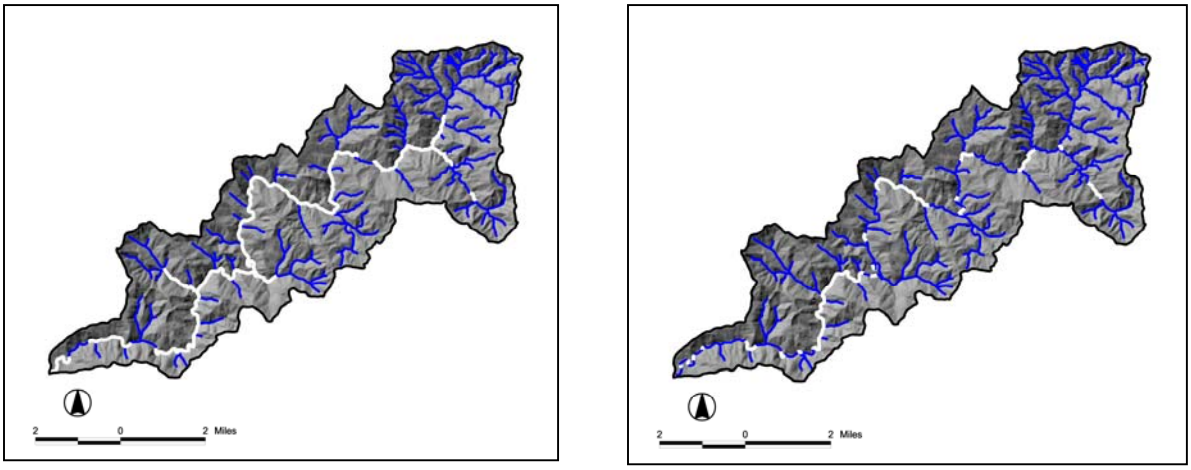


Figure 5.3-7
Mid-20th-Century Tractor Harvest Operations, and Streamside Roads and Landings (red)
(Red lines show where tractors have pushed dirt fill into the watercourse to make the road, covering the streambank.)



1968 **2000**

Figure 5.3-8
1968 Bank-to-Bank Exposure (Left) and 2000 (Right) in Rockpile Subbasin (white lines)
(Blue lines show partial to entire canopy cover.)

Table 5.3-1
Rockpile Subbasin Stand Replacement Operations 1942 – 1973 - Total Area = 22,390 acres

Time Period	Acres Under Operation	Type of operation	Cumulative Percent of Subbasin Under Operation Since 1942	Mean Annual Increment (acres/percent by year)
1932– 1942	0	Stand Replacement	0	0
1942 – 1952	1,200	Stand Replacement	5.3	120 (0.5)
1952 – 1960	9,200	Stand Replacement	47.0	1,150 (5.2)
1960 – 1964	5,300	Stand Replacement	65.0	1,325 (5.6)

In 1942, five percent of the blue line streams were exposed bank to bank (Figure 5.3-5), limited to alluvial openings in the lower subbasin reaches throughout generally wooded conditions. By 1968, approximately 70 percent of the blue line streams were exposed bank-to-bank by the end of the tractor-harvesting era. The bank-to-bank overstory shade canopy cover for 2000 shows improvement compared to 1968, reflecting riparian in-growth since the late 1960s. By 2000, canopy cover improved to approximately 25 percent of blue line streams exposed bank to bank (Figure 5.3-8). Streamside canopy in the middle subbasin reaches now consists primarily of 40-year-old pole to mid sized conifers. Ground surveys support these findings. Coastal Forest Lands (CFL) reported reinstatement of overstory shade canopy in numerous upper reach tributary watercourses (CFL SYP 1997). CFL no harvest Watercourse and Lake Protection Zones (WLPZs) are routinely stipulated for all THPs along Rockpile Creek and Class II tributaries to mitigate temperature impairment throughout the subbasin. Canopy cover is lacking in most areas along the mainstem Rockpile Creek, mid to higher reaches (CFL THP 1-97-475).

The 1970s were a period of relative inactivity compared to previous eras (Table 5.3-2). Partial entries and stand things were common in the alluvial flats downstream from Red Rock Creek. During the late

1980s through mid 1990s, active timber harvesting resumed. In the Middle Rockpile PWS, numerous seed tree overstory removal/dispersed harvest THPs were conducted. These covered large areas but removed scattered single trees and remnant stands left from 1960s era entries. Year 2000 air photos show these areas well vegetated. Agency review of these THPs clarified road upgrade work requirements to repair erosion conditions of pre-1973 operations. Even-aged management has been the predominant silvicultural method in the lower alluvial portion of the subbasin since the mid 1990s. Some 687 acres (3.1 percent) of grazing lands occupy the upper subbasin reaches.

Table 5.3-2
Rockpile Subbasin Timber Harvest Operations – 1974 – 2001 - Total Area = 22,390 acres

Time Period	Acres under operation	Type of operation	Cumulative percent of Subbasin Under Operation Since 1974, Some Overlap with Mid-20th-Century Areas	Mean Annual Increment (acres/ percent by year)
1974 - 1990	3,050	Stand Replacement	13.7%	191 (0.8)
1991 - 2001	11,150	THPs	63.3 (44% cable, 56% tractor)	1,014 (4.5)

5.3.5 ROADS

Historic Roads (1952 – 1968)

Built between the mid 1950s and early 1960s, streamside/instream road and landing networks spanned the natural fluvial drainage system of the Rockpile Subbasin (Figure 5.3-9). These roads dominated stream channel structure throughout the Lower and Middle Rockpile PWSs. Streamside roads and landings were densely concentrated at the base of steep ravines. Throughout Horsethief Canyon, heavy tractors cut into the steep sidebanks at the base of the streams, making the near vertical cut banks along these roads prone to failure during winter storms. The 1963 and 1981 air photos showed a high density of road debris slides accessing streams in the Central Rockpile PWS.

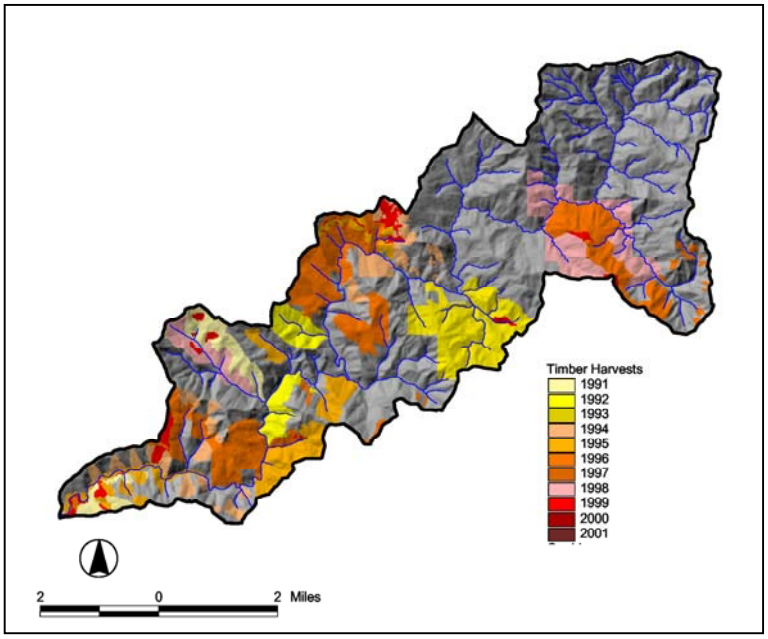


Figure 5.3-9
1991 to 2001 Timber Harvest Plans

A total of approximately 16 miles of road were build at near or equal elevation to the streambank transition line with sidecast covering the streambank leading to the creek. Tractors graded the streambank flat to one side, simplifying channel complexity and structure. More roads were located slightly upslope of streams but still near the creek (not mapped with this study). After 1968, these roads were generally unused and left abandoned. There were no to minimal erosion control facilities left with these roads. The dense network of instream/streamside roads and landings that lined blue line streams in the Central Rockpile PWS showed a high correlation with stream braiding and aggradation (over 75 percent) in 1984.

Modern Roads

Successive air photo overlays show a shift in new road construction to ridgelines and mid slope benches. The total length of the road network now consists of 168 miles of active roads, at a density of 4.8 miles/square mile. The U.C. Davis Information Center for the Environment ("ICE") developed a contemporary road map for the total maximum daily load (TMDL), which shows most of the current roads located distant from watercourses. The "ICE" roads within 50 feet of a watercourse comprise about 1.5 miles of current roads within the subbasin. Of these roads, less than a half mile total length are located in areas that may be affected by historically active landsliding and stream bank erosion.

Although the current road network shows less overall coincidence of debris slides and stream crossing failures compared to historic times, proximity to streams and steep slopes continues to locate most of the contemporary road failures. Approximately one mile of the modern roads cross steep slopes (excess of 60 percent), mostly throughout the deeply incised central subbasin reaches. Most of the historically active point slides found within 60 meters of a road occur dominantly along blue line streams in steep areas.

Substandard road networks continued to be vulnerable to large storm events. Road washouts during the 1986 and 1996 storms generally characterize contemporary land use induced sediment pulses. There are 2.3 road crossings per stream mile. With 63 percent of the Rockpile Subbasin subject to Timber Harvest Plans (THPs) since 1991, considerable road repair and upgrade work has been accomplished. More recent THPs require even higher construction/replacement standards. Remaining areas of the Rockpile Subbasin are recommended as the highest priority for restoration work in this study. The Gualala River Watershed Council (GRWC) has initially directed restoration work in the Lower Rockpile PWS only. The NCWAP restoration map targets the central and upper subbasin reaches with the highest priority for future restoration work in sediment reduction (Plate 3, Figures 5.3-18a and 5.3-18b).

Similar to the North Fork, stream channel morphology in the Rockpile Subbasin shows the following evolution over the last half century: (1) a high density of debris flow mounds in the active channel triggered by mid-20th-century storm events, (2) progressive abatement of the frequency of these point sources over successive decades, and (3) apparent improvement of instream channel conditions between 1984 and 2000 as evidenced by a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. The comprehensive CGS fluvial geomorphic mapping of stream channel conditions documents that the channel has improved from 1984 to 1999/2000 throughout the Rockpile Subbasin. This period includes recent active timber harvesting in the subbasin.

Documentation of Land Use Impacts By Major Tributary

Central Rockpile Creek

- By the early 1960s, the main haul road followed directly along the central reaches of Rockpile Creek. Remnants of road and landings in Rockpile Creek continued to contribute sediment during peak flows. Shade was limited along Rockpile Creek due to large amounts of road segments and landings directly in or adjacent to upper reaches of Rockpile Creek (THP 97-510 CFL) from 30 years ago.

  Skidding and hauling in watercourses during 1950s, 1960s were noted in the central and upper reaches of Rockpile subbasin. High sedimentation and accumulations of debris were found in the stream channels. Downcutting and subsequent downstream aggregations were noted. Conditions were described in 1997 as in a stage of recovery as stream flow continued to flush sediment and organic material downstream (CFL 97 341, 97-345). In very steep areas, Class II and III watercourses were not used as skid trails.

Red Rock Creek

- This watershed was logged in 1959-1960. The main haul road was built along Red Rock Creek for nearly the entire length of the Class I watercourse, and numerous in stream landings lined Red Rock Creek.

- In the mid 1990s, extensive streambank rehabilitation work was carried out by J. Monschke.

Upper Rockpile Creek

- Seven seed tree overstory removal/dispersed harvest THPs dated 1997-98 exceeded 60 percent of the 2,700 acre Brandt tract within the Upper Rockpile Creek area. These plans directed road repair work throughout the area-wide road network. This included (1) repair of two watercourse diversions (CFL 97-371), (2) removal of a long section of seasonal road across Rockpile Creek (legacy road), and (3) repair of two other watercourse diversions, (CFL 98-091). These THPs stipulated temporary watercourse road crossing specifications as dominant among seasonal road laterals. This requires the abandonment of road crossing structures with road approaches bladed back to reestablish the original streambank configuration and treating any exposed soils with grass seed and mulch.

5.3.6 FLUVIAL GEOMORPHOLOGY

Over 60 percent of the subbasin has a high to very high potential for landsliding (Figure 5.3-4) and represents the major source area for stream sediment. Instream sediment levels, indicative of disturbance, occur along 20 of 88 miles of the blue line streams in the subbasin. This is a 38 percent reduction compared to levels in 1984. Most of the reduction occurred in the tributaries, while the lower reaches showed less change. Table 5.3-3 lists the lengths of sediment storage mapped and relative change between 1984 to 1999/2000 for the Rockpile Subbasin.

Table 5.3-3
Rockpile Subbasin Stream Characteristics Representing Sediment Sources or Storage

Planning Watershed	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Length Miles	Percent Total Stream for Subbasin	Length Miles	Percent Total Stream for Subbasin	Length Miles	Total Length Miles
Upper Rockpile Creek	6.7	15.8	8.1	19.1	-17.1	42.7
Middle Rockpile Creek	6.7	23.3	13.4	46.7	-50.0	28.7
Red Rock	2.9	39.1	4.6	62.8	-37.7	7.4
Lower Rockpile Creek	3.4	36.6	5.9	62.4	-41.4	9.4
Total	**3.4**	**22.4**	**32.0**	**36.3**	**-38.3**	**88.2**

5.3.7 WATER QUALITY

Water Temperature

Water temperature data from continuous recorders were available for five sites in the Rockpile Subbasin (Figure 5.3-10). The period of record from 1994 to 2001 yielded 22 observations for maximum weekly average temperature (MWAT) and seasonal maximum temperature (Table 5.3-4).

MWATs in the mainstem ranged from somewhat to fully unsuitable. MWATs in Horsethief Canyon were somewhat unsuitable, while MWATS in the lower tributary were fully suitable for the period of record (Table 5.3-4, Figures 5.3-11 and 5.3-12). There is evidence of slight cooling of water temperatures in the mainstem Rockpile Creek as it flows downstream toward the coast (Figure 5.3-12).

Seasonal maximum temperatures were generally below the lethal limit of 75 F, but above 71 F at the mainstem sites during the period of record. The seasonal maxima in the lower tributary were 59 F in both years.

Table 5.3-4
EMDS Ratings for Maximum Weekly Average Temperatures (MWATs) in the Rockpile Subbasin

Stream	No. of Sites	No. of Observations	Period of Record	EMDS Suitability Ratings						
				+++	++	+	0	-	--	---
Rockpile Mainstem	7	18	1994 - 2001							
Horsethief Canyon	1	2	1997, 1998							
Lower Tributary	1	2	1997, 1998							

EMDS ratings:

+++ = fully suitable (50 - 60 F)
++ = moderately suitable (61 -62 F)
+ = somewhat suitable (63 F)
0 = undetermined (between somewhat suitable and somewhat unsuitable) (64 F)
- = somewhat unsuitable (65-66 F)
-- = moderately unsuitable (67 F)
--- = unsuitable (> 68 F)

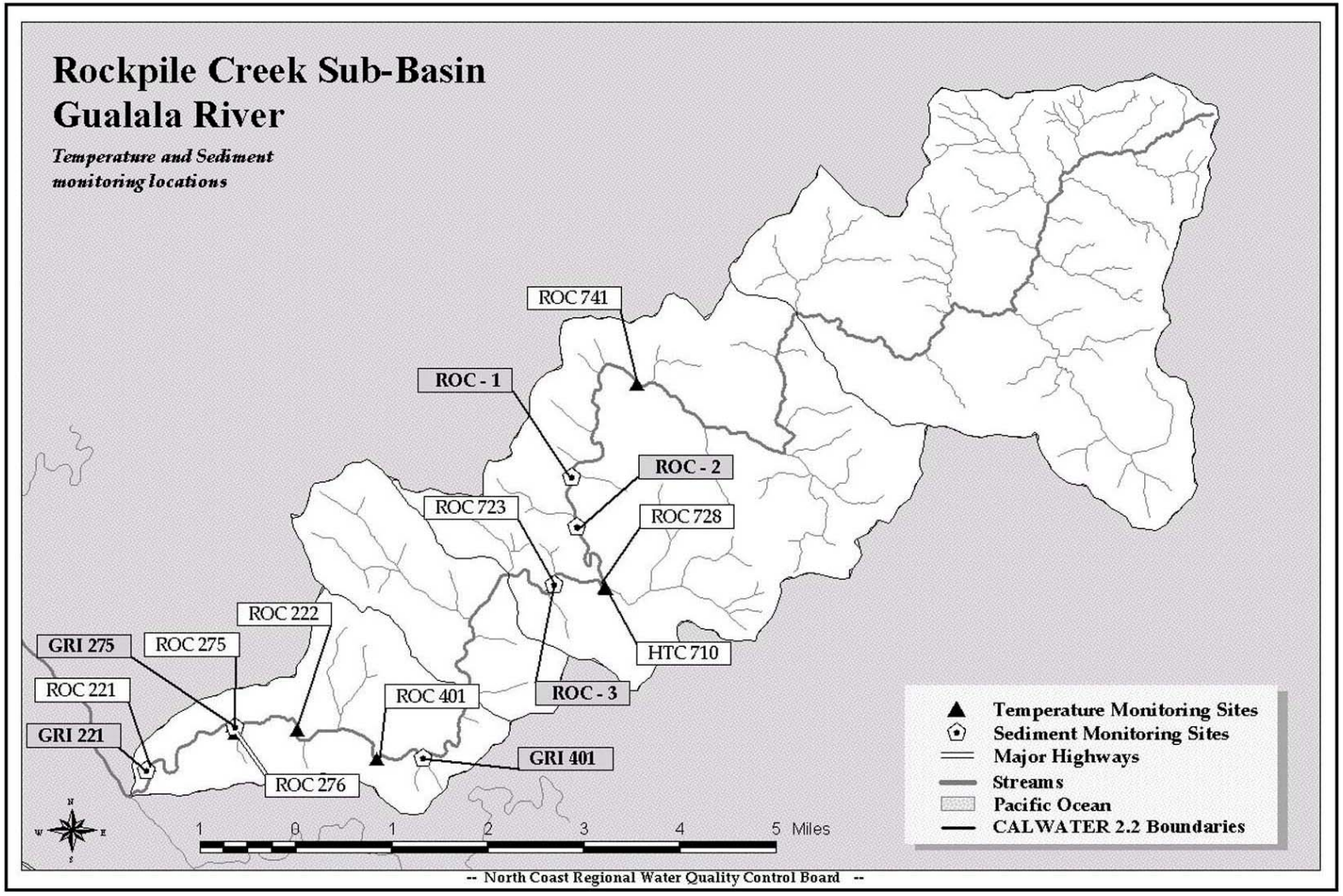


Figure 5.3-10
Instream Sediment and Temperature Sampling Sites, Rockpile Subbasin

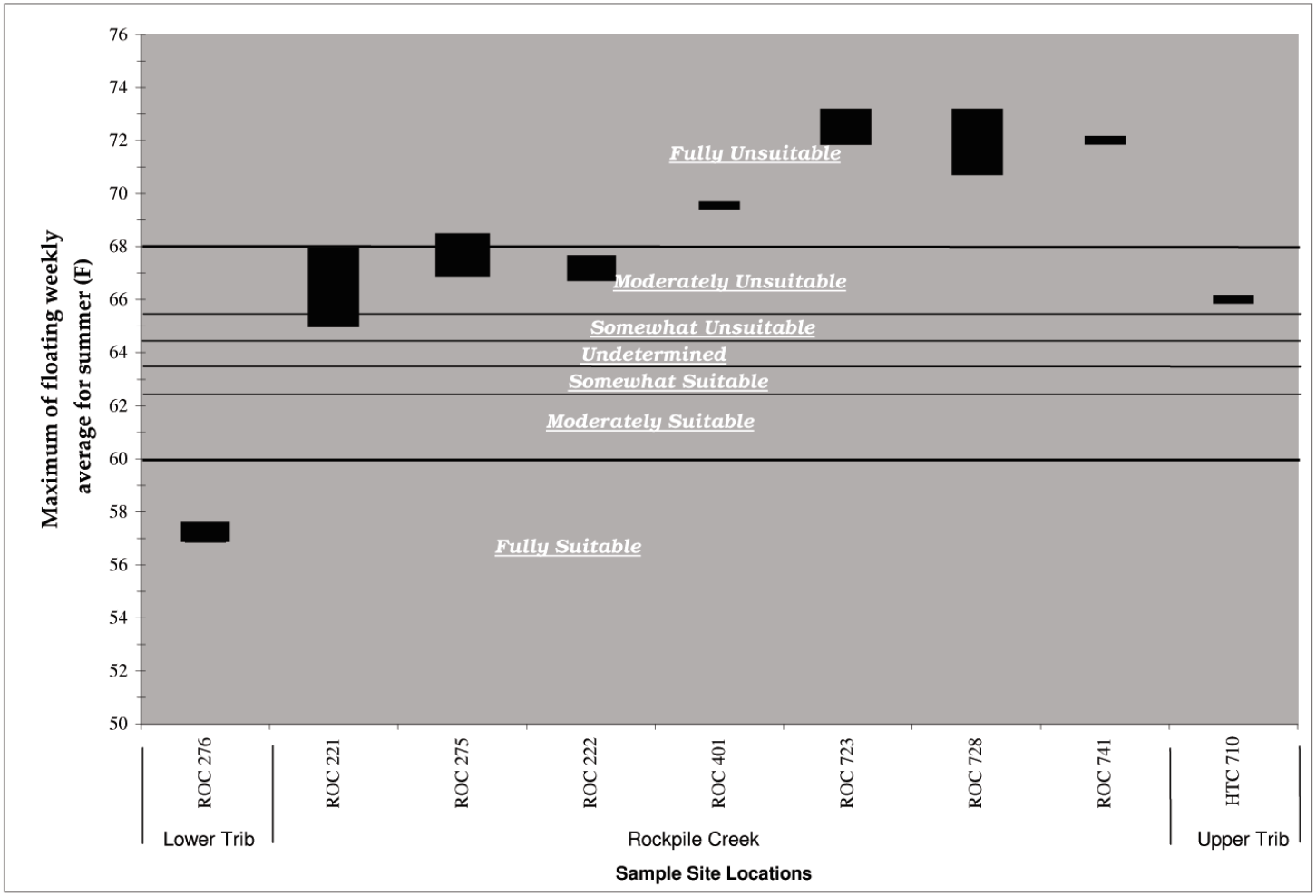


Figure 5.3-11
Maximum Weekly Average Temperature (MWAT) Ranges For The Rockpile Subbasin From 1995-2001
(Data From GRI And GRWC Continuous Monitoring Devices)

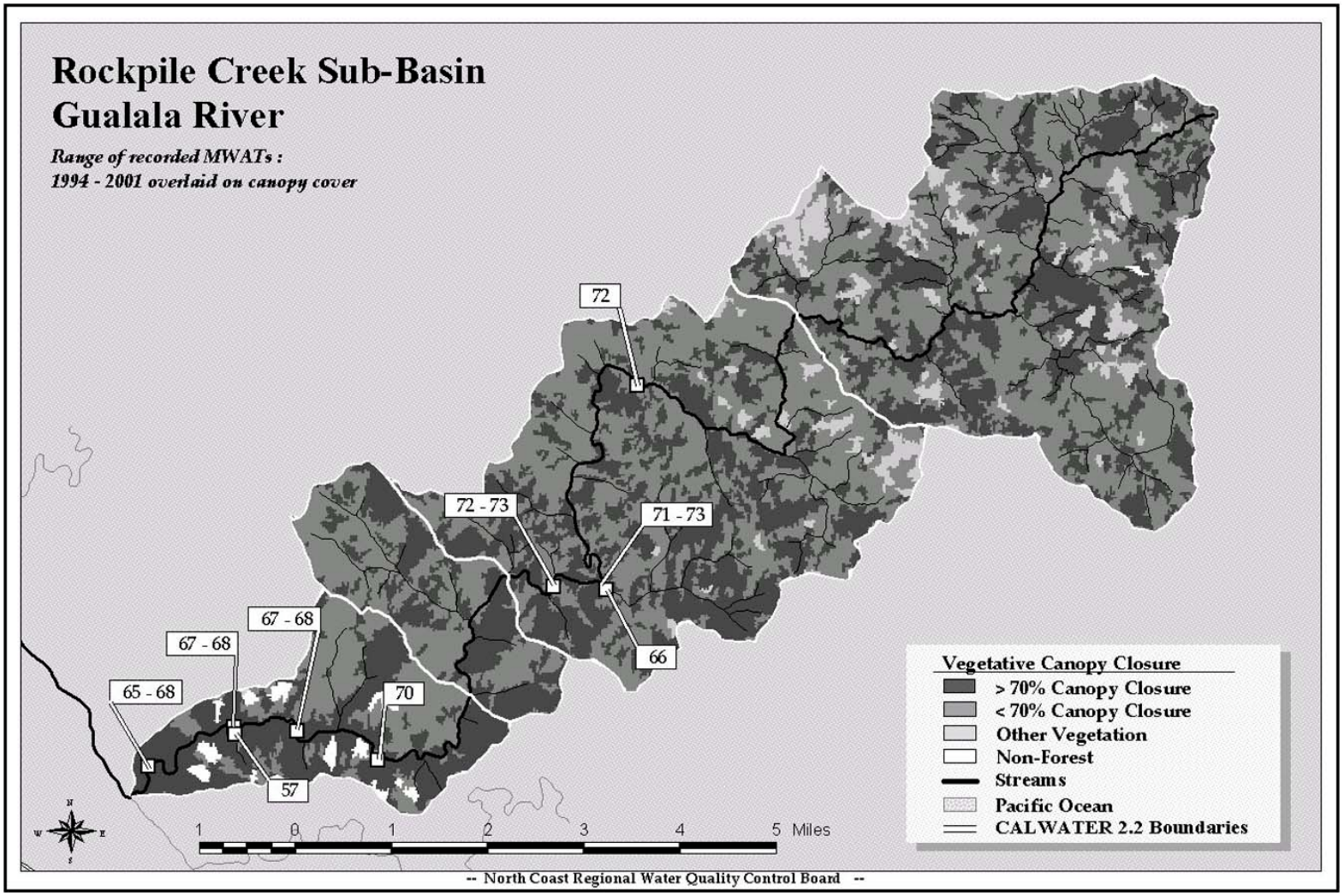


Figure 5.3-12
MWAT Temperature Ranges in the Rockpile Subbasin for the Period of Record, 1995-2001
Overlaid on the LanSat Vegetation Layer for 2000

5.3.8 FISH HABITAT RELATIONSHIPS

Historic Habitat Conditions

No historic stream surveys were conducted.

Current (2001) Conditions

Target Values and Current Conditions from the Habitat Inventory Surveys

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. In the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998), target values were given for each of the individual habitat elements measured (Table 5.3-5). When habitat conditions fall below the target values, restoration projects may be recommended to meet critical habitat needs for salmonids.

Table 5.3-5
Habitat Inventory Target Values Taken From the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998).

Habitat Element	Canopy Cover	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or more of the stream length is <50% embedded	Depth-1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet Frequency->40% of stream	>80

One habitat inventory survey was conducted in 2001on the first 44,500 feet of the mainstem Rockpile Creek with 17,332 feet skipped due to the crew's inability to physically access the stream. Data for 27,168 feet were analyzed. The canopy cover target value was not met on Rockpile Creek. The embeddedness target value was reached, indicating that some good spawning substrate conditions exist. Neither the target values for pool frequency/depth nor the shelter/cover ratings were met (Table 5.3-6).

Table 5.3-6
Summary of Current (2001) Conditions Based Upon Habitat Inventory Surveys from the Rockpile Subbasin, Gualala River Watershed, California
Condensed Tributary Reports are located in CDFG Appendix 5.

Habitat Element Stream Name	Surveyed Length (Feet)	Canopy Cover	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
Rockpile Subbasin					
Rockpile Creek	27,168	55%	52%	22%	41

Rockpile Creek is a second order stream. The habitat inventory survey data showed habitat deficiencies related to canopy cover, pool frequency/depth, and shelter cover. Canopy cover was 55 percent in the lower five miles of Rockpile Creek with conifers contributing 15 percent and deciduous 40 percent (Figure 5.3-13). Fifty-two percent of pool tails surveyed in Rockpile Creek were category 1 or 2 embeddedness (Figure 5.3-14). Twenty-two percent of the survey length consisted of primary pools (Figure 5.3-15). Shelter/cover received a rating of 41 (Figure 5.3-16), and most of the cover was provided by undercut banks, large woody debris, and root masses (Figure 5.3-17).

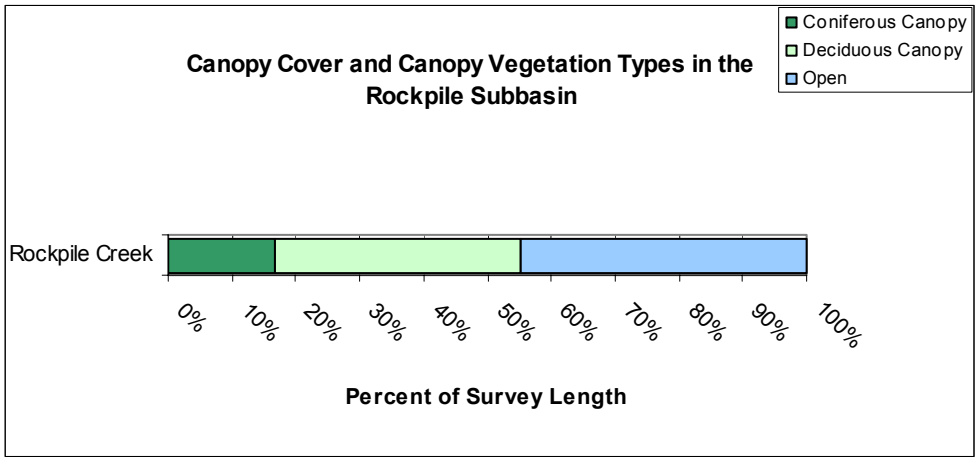


Figure 5.3-13
Canopy Cover and Canopy Vegetation Types by Percent Survey Length in Rockpile Creek, Rockpile Subbasin 2001, Gualala River Watershed, California

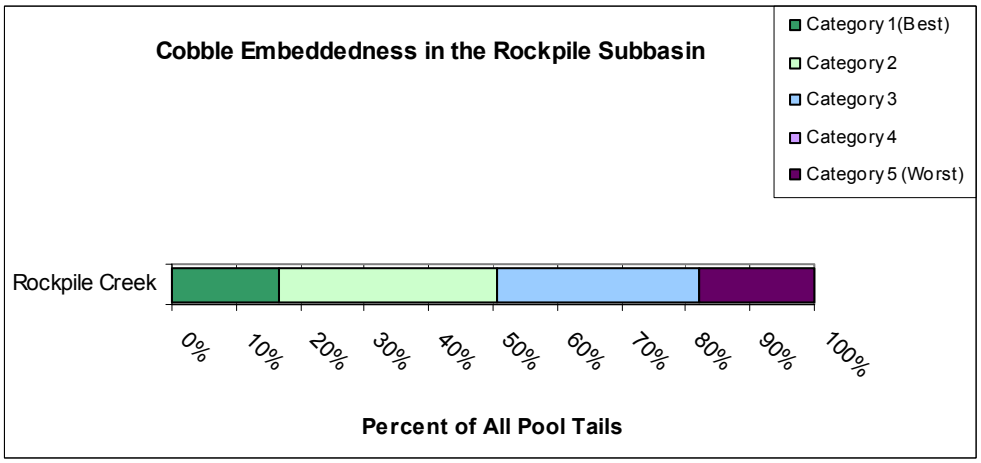


Figure 5.3-14
Cobble Embeddedness in the Rockpile Subbasin 2001, Gualala River Watershed, California

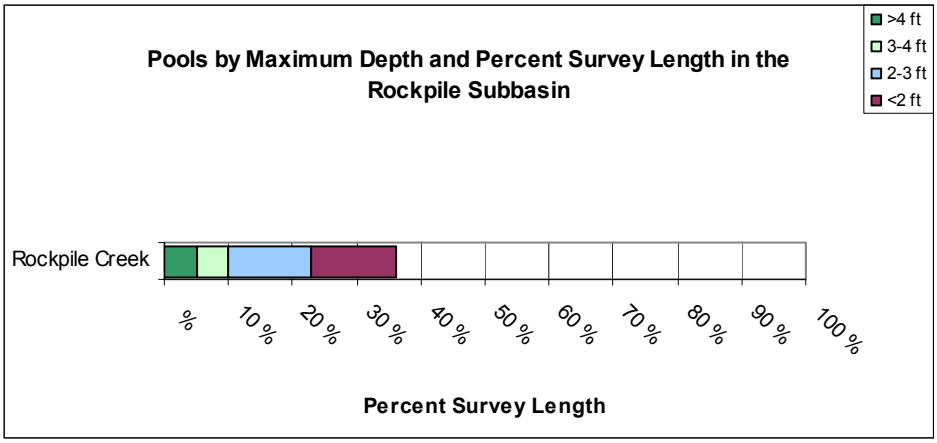


Figure 5.3-15
Pools by Maximum Depth and Percent Survey Length in the Rockpile Subbasin 2001, Gualala River Watershed, California

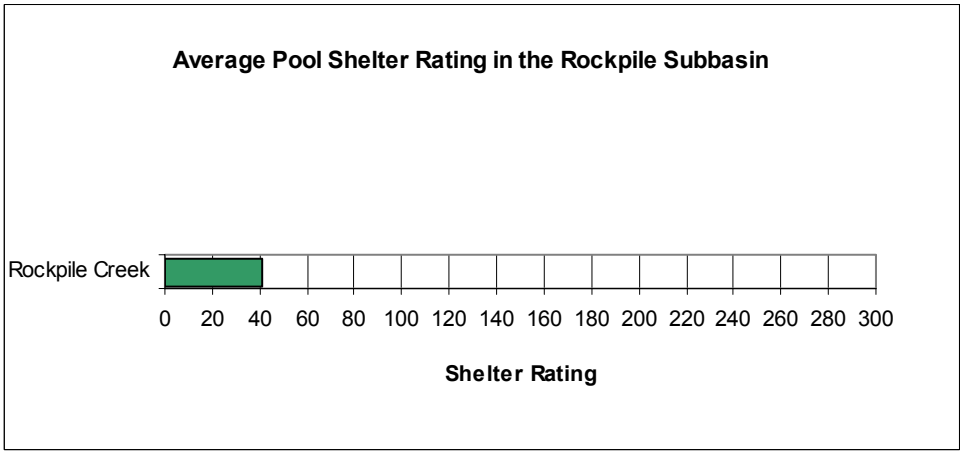


Figure 5.3-16
Average Pool Shelter Ratings in the Rockpile Subbasin 2001, Gualala River Watershed, California

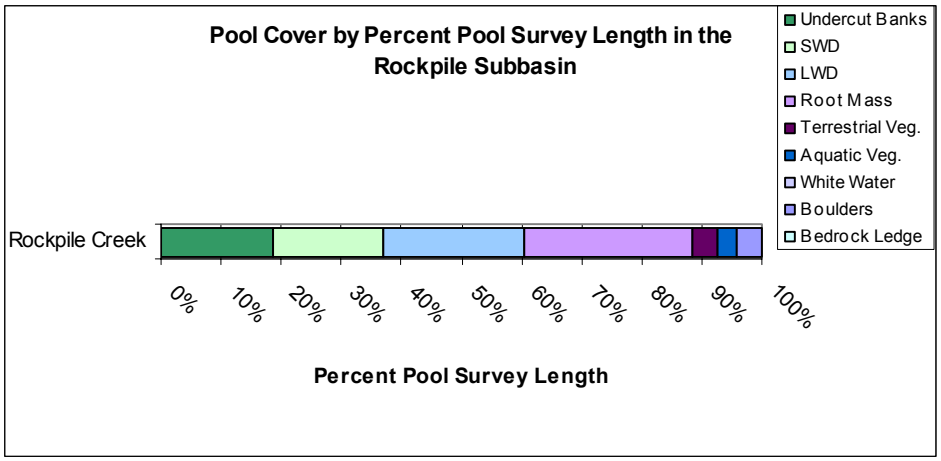


Figure 5.3-17
Pool Cover by Percent of Pool Survey Length in the Rockpile Subbasin 2001, Gualala River Watershed, California

Large Woody Debris Data

Large woody debris data were provided by the Gualala River Watershed Council's Cooperative Monitoring Program. Most large wood was cleared from the streams during the 1950s, 1960s and 1970s. A target value of 130 pieces of large wood > 8 inches per 1,000 feet is recommended in the literature (Beechie and Sibley 1997, Martin 1999). The monitoring surveys demonstrate that large wood is deficient in the section of Rockpile Creek surveyed. This finding is supported by the habitat inventory survey data for 2001 and the EMDS reach model analysis.

Large woody debris surveys conducted by the Watershed Cooperative Monitoring Program in 1998 and 1999 at a site in lower Rockpile Creek (#221) found 18 and 33 pieces per 1,000 feet of stream channel with a volume of 1,291 and 2,520 cubic feet, respectively (Table 5.3-7).

To augment the natural recruitment process of LWD, an ongoing cooperative large wood placement project in the watershed has placed an additional 2,909 cubic feet (18 pieces) of large woody debris into Rockpile Creek, not included in Table 5.3-7.

Table 5.3-7
Watershed Cooperative Monitoring Program Large Woody Debris Survey, Rockpile Subbasin (1998-2001)

Tributary	Site Number	Watershed Size (acres)	Volume in CuFt/1000'	Number of Pieces/1000'
Rockpile Creek	221	22,373	2,412	23

*Watershed size is calculated as the area above the monitoring site.

Changes in Habitat Conditions from 1964 to 2001

No comparison data were available for the Rockpile Subbasin.

Ecological Management Decision Support (EMDS) Reach Model

Although the EMDS Reach Model scores are based upon the habitat inventory survey data, the analysis differed. The habitat inventory data were divided into reaches based upon Rosgen Channel type and then converted to a weighted average. Each weighted average reach was compared to a set of habitat reference conditions which were determined from empirical studies of naturally functioning channels, expert opinion, and peer reviewed literature. EMDS rates each habitat component with a suitability score between -1 and +1, where suitability is a function of salmonid health and productivity. The reference curve breakpoints for these habitat parameters are presented in Table 4-1.

An EMDS score for the subbasin could not be calculated due to limited data. Only one stream equal to 39 percent of all the blue line streams was habitat inventoried. Data from five habitat categories and one temperature site in 2001 were evaluated in EMDS (Table 5.3-8)

Table 5.3-8
Ecological Management Decision Support (EMDS) Reach Model Scores on salmonid heath and productivity suitability for the Rockpile Subbasin, CA., based upon habitat inventory surveys conducted in 1999 and 2001

Subbasin Stream Name	Canopy Cover Score	Embeddedness Score	Pool Depth Score	Pool Shelter Score	Pool Quality Score	2001 MWAT Water Temperature Score
Rockpile Subbasin Score	n/a	n/a	n/a	n/a	n/a	n/a
Rockpile Creek	- -	-	- - -	- -	- -	-

The 2001 water temperature data was provided by GRI and the GRWC.
+++ = Fully Suitable
++ = Moderately Suitable
+ = Somewhat Suitable
- = Somewhat Unsuitable
- - = Moderately Unsuitable
- - - = Fully Unsuitable

Limiting Factors Analysis

The Gualala River Watershed Limiting Factors Analysis (LFA) was developed for assessing coarse scale stream habitat components. Habitat inventory data, EMDS reach model scores, and the biologist's professional judgment were incorporated into both the identification of LFAs and their ranking.

The LFAs for the subbasin could not be calculated due to limited data. Only one stream equal to 39 percent of all the blue line streams was habitat inventoried. Pool depth related to summer conditions was the predominant limiting factor for salmonid health and productivity on Rockpile Creek. Pool shelter/cover was second, canopy cover was third and embeddedness was the fourth limiting factor (Table 5.3-9).

Table 5.3-9
Limiting Factors for the Rockpile Subbasin Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 1999 and 2001 and EMDS scores in the Gualala River Watershed, California (*Rank 1 is the most limiting factor*)

Subbasin Stream Name	Canopy Cover Related to Stream Shading	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
Rockpile Subbasin Score	n/a	n/a	n/a	n/a
Rockpile Creek	3	4	1	2

Figure 5.3-18a illustrates the limiting factors as determined by CDFG and various sediment sites identified by CGS as potential restoration targets. Figure5.3-18b is the map explanation. General recommendations are made for each limiting factor and type of sediment site. The map is a reduced image of Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed* (See Plate 3 to view details at a higher scale [1:48,000]).

Restoration Recommendations

The proposed restoration recommendations were based upon the habitat inventory surveys, limiting factors analysis, landowner and local expertise, and the biologist's professional judgment (Table 5.3-10).

Restoration recommendations for the subbasin overall could not be calculated due to limited data. Only one stream equal to 39 percent of all the blue line streams was habitat inventoried. The addition of instream structures is the highest restoration priority targeted to enhance pool development, increase depth, and provide improved pool shelter cover. The second priority is to increase the riparian canopy to provide more shade over the stream, reduce water temperatures, and provide potential large woody debris. The third priority is to stabilize stream banks. To reduce sediment and improve spawning substrate on the lower reaches, road repair or removal is the fourth restoration priority. Livestock/feral pig exclusion and barrier removal were not identified as restoration needs.

Table 5.3-10
Priorities for Restoration for the Rockpile Subbasin from the 2001 Habitat Inventory Data
Rank 1 indicates highest priority.

Stream Name	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
Rockpile Subbasin	n/a	n/a	n/a	n/a	n/a	n/a
Rockpile Creek	3	4	2	1		

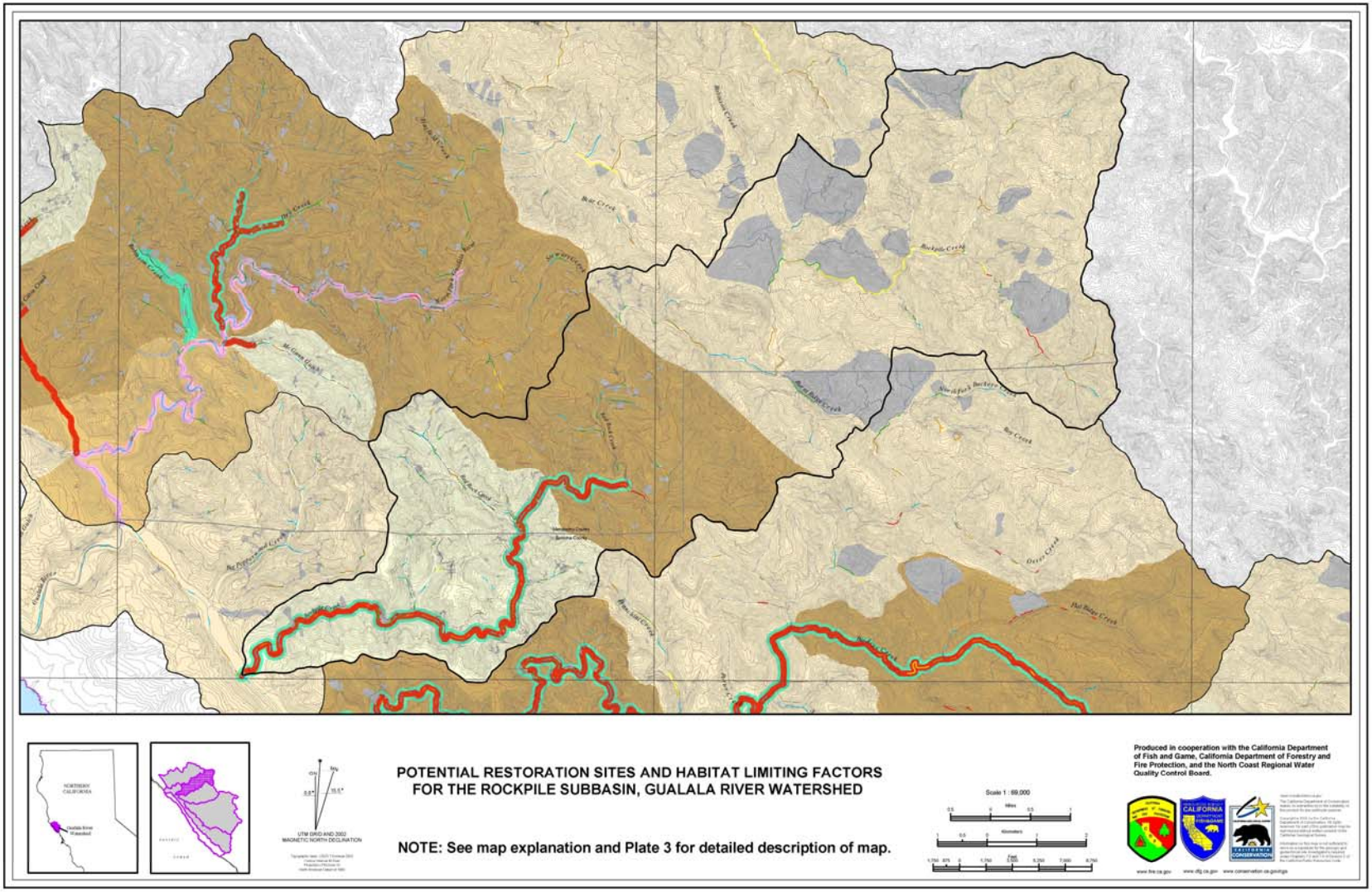


Figure 5.3-18a
Potential Restoration Sites and Habitat Limiting Factors for the Rockpile Subbasin, Gualala River Watershed

Roads
Streams
Watershed boundary
Sub-basin boundary
Historically Active Landslides (mapped as a point if too small to delineate at the scale of this map)

I SPATIALLY ASSOCIATED FACTORS DERIVED FROM AERIAL PHOTO INTERPRETATION OF LANDSLIDING AND SEDIMENT CONDITIONS

A *HISTORIC IN-STREAM ROADS POSSIBLY RELATED TO FLUVIAL SEDIMENT*

Stream reaches with persistent aggrading or braiding in both 1964 and 2000 photos that may be associated with historic in-stream roads or landings. See recommendation #5.

B *ROADS POSSIBLY RELATED TO LANDSLIDES AND/OR ERODING BANKS*

Road segments that may be affected by historically active landsliding and bank erosion. See recommendation #6.

Road segments that may be affected by historically active landsliding. See recommendation #7.

C *FLUVIAL SEDIMENT CONDITIONS POSSIBLY RELATED TO LANDSLIDES*

Stream reaches with potentially adverse sediment accumulations that may be affected by historically active landslides and lack any apparent association with the modern road network or the historic in-stream roads or landings. See recommendation #8.

Stream reaches with potentially adverse sediment accumulations that may be affected by erosion from adjacent dormant landslide terrain that lack any apparent association with historically active landsliding, the modern road network, and historic in-stream roads or landings. See recommendation #9.

D *POTENTIALLY UNRELATED FLUVIAL SEDIMENT CONDITIONS*

Stream reaches with potentially adverse sediment accumulations that lack any of the above associations. See recommendation #9.

II LIMITING FACTORS DERIVED FROM GROUND BASED HABITAT SURVEYS (SEE DFG APPENDIX)

A *CANOPY AND POOLS AS LIMITING FACTORS* (All stream reaches surveyed by DFG in 2001 are highlighted as follows. Reaches that were not surveyed in 2001 are not highlighted on the map.)

Stream reaches with inadaquate canopy cover as the limiting factor. See recommendation #2.
Stream reaches with inadequate pool depths as the limiting factor. See recommendation #4.
Stream reaches with inadequate pool shelter as the limiting factor. See recommendation #3.
Stream reaches with both inadaquate pool depths and shelter as limiting factors. See recommendations #3 and #4.

Explanation

B *EMBEDDEDNESS AS A LIMITING FACTOR*

Areas draining into where embededdness conditions are unknown.
Areas draining into reaches where embeddedness is not limiting.
Areas draining into reaches where embeddedness is marginal but not limiting.
Areas draining into reaches where embeddedness is somewhat limiting. See recommendation #1.
Areas draining into reaches where embeddedness is significantly limiting. See recommendation #1.

RECOMMENDATIONS BASED ON LIMITING FACTORS

(1) Reduce production of fine sediment throughout the contributing area. Evaluate contribution from roads and upgrade roads as appropriate. Evaluate contribution from soil disturbance and control erosion as appropriate (see recommendations 5-10). Evaluate contribution from soil disturbance and control erosion as appropriate. Consider the additive effect of the short-term increases in erosion due to mitigation activities. Distribute individual activities both spatially and temporally as appropriate to avoid additive sediment impacts. Institute best management practices in erodible areas; such as, areas shown on the CGS Relative Landslide Potential Map (Plate Two), and National Resources Conservation Service soil maps.

(2) Enhance current riparian vegetation by planting additional trees, and stabilize stream banks as needed. Also, consider both downstream and upstream effects.

(3) Enhance pool shelter by adding submerged or partially submerged structures. Consider both upstream and downstream effects due to operation and possible failure.

(4) Install in-stream structures to produce hydraulic variability and to scour pools. Consider both downstream and upstream effects due to operations and possible failure.

RECOMMENDATIONS BASED ON SPATIAL ASSOCIATIONS

(5) Evaluate relationship on-site. Consider channel restoration and drainage improvements for the road and landing. Consider engineered abandonment.

(6) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible. Consider stream bank stabilization where feasible.

(7) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible.

(8) Evaluate on-site whether these represent natural background conditions. If mitigation is desired, road construction may be needed for equipment access.

(9) No recommendation because potentially associated active sediment sources have not been identified.

EXPLANATION FOR POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS FOR THE GUALALA RIVER WATERSHED MAP

NOTE: See Plate 3 for complete description of map.

Produced in cooperation with the California Department of Fish and Game, California Department of Forestry and Fire Protection, and the North Coast Regional Water Quality Control Board.

www.fire.ca.gov www.dfg.ca.gov www.conservation.ca.gov/cgs

Figure 5.3-18b
Explanation for Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed Map

Potential Refugia

No potential refugia were identified based upon 2001 data.

5.3.9 FISH HISTORY AND STATUS

Historic fish data don't exist or were unavailable from the 1950s through 2000.

- **2000s** - Young of the year and older steelhead trout were observed during habitat inventory surveys in 2001. Gradient is suitable for coho salmon in the mainstem of lower Rockpile up through the Middle Rockpile Subbasin, although tributaries to lower Rockpile are mainly too steep for the species.

5.3.10 ROCKPILE SUBBASIN PUBLIC ISSUES, SYNTHESIS, AND RECOMMENDATIONS

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala River Watershed residents and constituents. The following general concerns were expressed as potential factors affecting the Rockpile Subbasin and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.

- Abandoned roads, new road construction, and road maintenance related to landsliding and sediment input need to be addressed. Without appropriate maintenance or storm proofing, existing roads, both active and abandoned, may contribute sediment.
- Subdivision development is not an issue at this time. However, Pioneer Ltd owns a larger portion of the upper subbasin and is in escrow.
- Grazing is occurring in the upper portion of this subbasin.
- Water temperatures may exceed suitable conditions for coho salmon and steelhead throughout much of this subbasin.
- Low canopy coverage are effecting water temperatures and large wood recruitment.
- Timber harvest and associated road building have increased erosion, increased landsliding, and negative impacts to the riparian zones.
- Best management practices required by current forest practice rules are reducing forestry impacts to insignificance.
- Sediment as a limiting factor for salmonids due to pool filling, aggradation, and small-sized spawning substrate.
- Water temperature and instream sediment monitoring sites are needed.
- Invasive plant species occur in this subbasin.

Working Hypotheses

The primary purpose of these hypotheses is to elucidate in a succinct format the judgment of the Team regarding watershed conditions relative to anadromous salmonids. As such, they are responsive to the

assessment questions presented on page 1-1 and 1-2. The findings supporting the hypothesis are presented, along with recommendations for watershed improvements along with recommendations, and to further investigate the hypotheses. As such, they are not intended to be the final word, but are the best judgment based on the information at hand.

Recommendations for watershed improvements and further study are presented at the end of the section, as single recommendations apply in many cases to more than one hypothesis.

The working hypotheses are:

1. Stream conditions in the Rockpile Subbasin provide unsuitable habitat for salmonids.
2. Depleted shade canopy cover along the mainstem of Rockpile Creek and tributaries from past timber harvest activities continues to contribute to elevated water temperatures that are unsuitable for salmonids.
3. A lack of instream large woody debris contributes to simplified riparian habitat structure (e.g., lack of large, deep pools).
4. Instream and near stream conditions are improving in the Rockpile Subbasin.
5. Land management activities, especially road building adjacent to stream channels or across debris slide slopes and/or steep terrain have contributed sediment to streams.

Working Hypothesis 1

Stream conditions in the Rockpile Subbasin provide unsuitable habitat for salmonids.

Supporting Findings

- Water temperatures from 1994 to 2001 in the lower 11 miles of the mainstem and in Horsethief Canyon range from somewhat to fully unsuitable for summertime rearing of salmonids (Table 5.3-4, Figure 5.3-11).
- Canopy cover, pool frequency/depth and pool shelter/cover target values were not met on Rockpile Creek, the only tributary habitat inventory surveyed by CDFG in the Rockpile Subbasin.
- Canopy cover, pool shelter and pool quality EMDS scores were moderately unsuitable on Rockpile Creek. Embeddedness was somewhat unsuitable. Rockpile Creek is a second order stream and the pool depth was fully unsuitable. The Maximum Weekly Average Temperature at the only site sampled in 2001 on Rockpile Creek was somewhat unsuitable (Table 5.3.8).
- The Watershed Cooperative Monitoring Program found large woody debris to be deficient at the one monitored site in lower Rockpile (#221) in 1998 and 1999 (Table 5.3-7).
- Approximately 16 miles of historic logging and ranchland roads built in or along the streambed simplified pool structure and complexity throughout the major tributary streams of the Rockpile Subbasin. The residual effects of channel aggradation from streamside road system failures are noted in timber harvest plan records (see Land Use Section), particularly in many of the unnamed tributaries of the central Rockpile PWS. where the channel continues to downcut to pre-logging levels in many areas (Section 5.3.4 and 5.3.5).

- At least 80 per cent of the channel along the mainstem Rockpile Creek in the Middle Rockpile PWS contained sediment accumulations indicative of channel disturbance in 1984 aerial images. In Horsethief Canyon, where streamside roads and landings were densely concentrated, 75 percent of the channels were disturbed in 1984 (Appendix 2).

Contrary Findings

- Embeddedness target values were reached on Rockpile Creek indicating that some good spawning substrate conditions exist in the 8.5 miles surveyed.
- Water temperatures were fully suitable for the two years sampled in a tributary about one and a half miles from the mouth.
- By 1999/2000 the main channel appeared to have shown some improvement with 50 percent of the channel reach appearing disturbed. In-channel disturbance in Horsethief Canyon improved to 25 percent in 1999/2000 (Table 5.3-3).

Limitations

- Water temperature data were limited to the lower 11 miles of the mainstem.
- Habitat inventory surveys were conducted only on 39 percent of stream miles in the Rockpile Subbasin.

Conclusion

- The hypothesis is supported.

Working Hypothesis 2

Depleted shade canopy cover along the mainstem of Rockpile Creek and tributaries from past timber harvest activities continues to contribute to elevated water temperatures that are unsuitable for salmonids.

Supporting Findings

- Temperatures in the lower 11 miles of mainstem Rockpile Creek were unsuitable for summer rearing of salmonids (Table 5.3-4, Figure 5.3-11).
- The CDFG canopy cover target value was not met on Rockpile Creek, the only tributary surveyed in the Rockpile Subbasin. (Table 5.3-6, Figure 5.3-13).
- Canopy cover EMDS scores were moderately unsuitable on Rockpile Creek (Table 5.3-8)
- Post World War II construction of roads, landings, and skid trails in riparian zones by crawler tractors eliminated overstory shade canopy cover over most of the blue line streams in the middle subbasin reaches. Twenty-five percent of the blue line streams still had exposed banks in 2000 photos compared with five percent in the 1942 pre-harvest photos (Figure 5.3-8 and discussion).

Contrary Findings

- Stream bank canopy cover has improved on Red Rock Creek, Horsethief Canyon, and unnamed tributaries downstream of Rockpile Peak, and has increased overall from 70 percent exposure in 1968 photos (Section 5.3.4).

Limitations

- Water temperature data were available for the lower 11 miles of the subbasin.
- Only 39 percent of the subbasin was habitat inventory surveyed.

Conclusion

- The hypothesis is supported.

Working Hypothesis 3

A lack of instream large woody debris contributes to simplified riparian habitat structure (e.g., lack of large, deep pools).

Supporting Findings

- The pool frequency/depth and pool shelter/cover CDFG target values were not met on Rockpile Creek, the only tributary surveyed in the Rockpile Subbasin. Large woody debris is important as a pool-forming component (Table 5.3-6).
- Pool shelter and pool quality EMDS scores were moderately unsuitable on Rockpile Creek. Pool depth was fully unsuitable in this second order stream (Table 5.3-8).
- Construction of roads, landings, and skid trails in or adjacent to streams between 1952 and 1968 buried, removed, or dispersed LWD in the subbasin. Review of 1961 and 1963 aerial photos showed riparian areas entirely cleared of vegetation and remnant downed logs (Section 5.3.4).
- Historic and recent timber harvest in the lower and middle reaches frequently removed large conifer vegetation down to the stream bank, severely reducing the available recruitment supply of large woody debris. Dense buffers of conifers large enough to function, upon recruitment, as LWD in channel formation processes have not reestablished (Section 5.3.4).
- The Watershed Cooperative Monitoring Program found large woody debris to be deficient at the one monitored site in lower Rockpile (#221) in 1998 and 1999 (Table 5.3-7).

Contrary Findings

- In the central subbasin reaches, riparian areas are re-growing under current land management practices.

Limitations

- Habitat inventory surveys were conducted on only 39 percent of the mainstem Rockpile Creek (the lower 8.5 miles).

Conclusion

- The hypothesis is supported.

Working Hypothesis 4

Instream and near stream conditions are improving in the Rockpile Subbasin.

- Overall levels of sediment accumulations indicating channel disturbance were less in the Lower Rockpile PWS 1999/2000 photos compared to 1984. Along the mainstem Rockpile Creek, approximately 80 percent of the main channel appeared disturbed with enlarged and numerous

bars and lack of riparian vegetation in 1984. By 1999/2000 the main channel appeared to have shown some improvement with 50 percent of the channel reach disturbed (Table 5.3-3).

- At least 80 percent of the channel along the mainstem Rockpile Creek in the Middle Rockpile PWS was disturbed in 1984 images. In the 1999/2000 images, there were some improvements to 50 to 75 percent disturbance (Table 5.3-3).

- In Horsethief Canyon, where streamside roads and landings were densely concentrated, 75 percent of the channels were disturbed in 1984 compared with 25 percent in 1999/2000 (Table 5.3-3).

- Visual examination of GIS layers for dominant substrate, embeddedness, adverse fluvial, and landslide potential resulted in three conclusions: (1) 70 percent of adverse fluvial characteristics in the Gualala Basin abutted high and very high landslide potential ratings, (2) adverse fluvial declined from 1984 to1999, and (3) larger streambed particles were observed in upstream compared to downstream areas.

- Stream bank canopy cover has improved on Red Rock Creek, Horsethief Canyon, and unnamed tributaries downstream of Rockpile Peak, and has increased overall from 70 percent exposure in 1968 photos (Section 5.3.4).

Contrary Findings

- No change in channel disturbance at 50 percent was observed in the Upper Rockpile PWS between 1984 and 1999/2000.

Limitations

- None noted.

Conclusion

- The hypothesis is supported.

Working Hypothesis 5

Land management activities, especially past road building adjacent to stream channels or across debris slide slopes and/or steep terrain have contributed sediment to streams.

Supporting Findings

- Approximately 16 miles of historic logging and ranchland roads built in or along the streambed impacted pool structure and complexity throughout the major tributary streams of the Rockpile Subbasin (Section 5.3.4).

- A high density of road debris slides into streams in the Red Rock and Central Rockpile PWSs was visible in the1963 and 1981 air photos (Section 5.3.4).

- Mid-20th-century roads and landings built in or near the main channel may still be contributing excess sediment, especially where channel braiding and/or aggradation are persistent as noted along the mainstem, Red Rock Creek, and Horsethief Canyon (Section 5.3.4).

- The residual effects of heavy channel aggradation from failure of streamside road systems built in the 1950s and 1960s are noted in timber harvest plan records (Section 5.3.4), particularly in many of the unnamed tributaries of the central Rockpile PWS, where the channel continues to downcut.

- Modern road segments within 60 meters of historically active landslides are numerous in the upper stream reaches and may be contributing excess sediment to streams. Debris slides and debris flows are more numerous in the central and upper reaches of the subbasin. Modern road failures were generally more numerous in high or very high potential landslide areas (105 miles, or 62 percent, of current roads in the Rockpile) (Section 5.3.4).

- Many undersized culverts and substandard road drainage facilities failed during the 1986 and 1996 storms, representing a portion of contemporary sediment pulses in the subbasin (Section 5.3.4).

- Large portions of the upper subbasin are underlain with the mélange of the Central Belt of the Franciscan Assemblage and vegetated with prairie and sparse oaks. Landsliding is especially prevalent in the mélange, and active earthflow complexes are very numerous and unavoidably crossed by many roads.

Contrary Findings

- Approximately one and a half miles of modern roads (out of 168 miles total) are located within 50 feet of blue line streams in the subbasin. Of these roads, less than a half mile total length are in areas that may be affected by historically active landsliding and stream bank erosion.

- Distributions of debris slides and debris flows are more numerous in the central and upper reaches of the subbasin. Major earth flows are common in the Central Belt of the Franciscan Complex mélange in the east subbasin (Plate 1 and Appendix 2, and Synthesis Graphics), potentially high in natural background sources.

Limitations

- Although roads are located in erosion-prone areas, the performance of those roads was not evaluated in this assessment.

- Evaluation of the relationship of site specific road failures to regional geologic conditions is beyond the scope of this assessment.

Conclusions

- Sediment contributions from earlier timber harvest and road building activities persist, while sources associated with existing unimproved timber and ranchland roads may still exist.

Rockpile Subbasin Recommendations

Target restoration and land use activities to the three highest priorities for restoration in the Rockpile Subbasin: (1) fish habitat improvement structures including large wood placement, (2) riparian canopy development, and (3) bank stabilization. Cost sharing grants should be pursued to off set the costs of watershed improvements.

1. Install fish habitat improvement structures including large woody debris placement

    a. Promote installation of fish habitat improvement structures as appropriate to the stream channel type and hydrologic conditions.

    b. Land managers in this subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids.

Pool shelter is the most limiting factor in Rockpile Creek, the stream surveyed in the subbasin. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is the first of the top three recommendations.

2. Improve or enhance riparian zones to achieve target canopy density and increase the density and diversity of the riparian zone, including large conifers for LWD recruitment.

    a. Maintain and enhance existing riparian cover. Where current canopy is inadequate and site conditions are appropriate, initiate tree planting and other vegetation management to hasten the development of denser and more extensive riparian canopy. Riparian canopy development is the second priority recommendation. The mainstem, Red Rock Creek and Horsethief Canyon are the primary areas needing attention.

3. Address bank stabilization issues where indicated on the restoration map in Chapter 4.

    a. Encourage cooperative efforts to reduce sediment yield to streams at stream bank erosion sites. Grazing is an issue in the upper subbasin. Bank stabilization is the third of the top three recommendations.

    b. Continue efforts such as road erosion proofing, improvements, and decommissioning throughout the subbasin to reduce sediment delivery to central Rockpile Creek and Rockpile Creek tributaries. Focus efforts on areas adjacent to the streams, abandoning and vegetating historic streamside roads were feasible. Channel characteristics improved the least in the Middle and Upper Rockpile Creek PWSs.

    c. Encourage the use of cable or helicopter yarding on steep and unstable slopes to reduce soil compaction, surface disturbance, and resultant sediment yield.

    d. Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 60 percent of the subbasin.

4. Expand existing monitoring efforts to both better understand relationships in the subbasin and to assist in targeting restoration activities.

    a. Expand continuous temperature monitoring efforts into the upper subbasin and tributaries

    b. Investigate the availability and quality of other temperature and canopy data for the eastern area, and reevaluate the relationship of canopy to actual stream temperatures.

    c. Collect data to evaluate and possibly model the relationship among water temperature, canopy levels, and other factors where canopy is still recovering to establish reasonable recovery targets.

    d. Encourage more stream habitat inventories and biological surveys of tributaries, as only 39 percent has been completed.

e. Survey for salmonids, using consistent methods, to estimate population numbers for comparison with recovery targets to be set by NMFS.

f. Conduct both instream and hillslope monitoring to determine whether land use practices are allowing for recovery and protection of the salmonid habitat in the subbasin. Use GRWC methods for instream monitoring.

5.4 Buckeye Subbasin

5.4.1 INTRODUCTION

The Buckeye Subbasin (Buckeye Creek Super Planning Watershed, Calwater 2.2a 113.83) is bounded to the north by the Rockpile Subbasin and to the south by the Wheatfield Subbasin. It encompasses 40.3 square miles of private land used primarily for timber production, grazing, and small vineyards. It contains more moderate terrain compared to the North Fork and Rockpile. There are 90 miles of "blue line" streams, and three major tributaries: Flat Ridge, Grasshopper, and Osser creeks (Figure 5.4-1).

Historic events and the period of record on the various data sets used in the NCWAP assessment are presented in a graphic format in Figure 5.4-2.

5.4.2 GEOLOGY

Mélange of the Franciscan Complex underlies oak savanna woodland in the eastern headwaters. Large areas of active earthflows and other forms of landsliding are abundant and contribute sediment to the streams (Figure 5.4-3). Figure 5.4-4 is the relative landslide potential map for the Buckeye Subbasin. The complete maps and explanations for both maps are on Plates 1 and 2.

The steep tributaries in the upper reaches can be characterized as source (>12 percent slope) and transport (4-12 percent slope) reaches.

In the lower reaches of the subbasin, streams are mainly bedrock controlled within moderately steep valleys. The narrow floodplain is limited to the lower 1.5 miles.

5.4.3 VEGETATION

The wider Buckeye Subbasin contains high site redwood ground in the lowest reaches. Further inland, Douglas fir and then mixed conifer-hardwood predominates. Oak and prairie grassland is the dominant vegetation type east of Osser and Flat Ridge creeks. As in Rockpile Creek, the 1942 photos show mature coniferous shade canopy cover over all primary streams. Only in the lowest reaches near the confluence with the South Fork is the main channel of Buckeye Creek wide enough to result in bank-to-bank exposure (Figure 5.4-5).

5.4.4 LAND USE

Mid-20th-century pre-1973 tractor method harvesting was the dominant land use period in the Buckeye Subbasin. These operations removed old growth conifer stands to comprise approximately 70 percent of the total subbasin area harvested by 1968. Original turn of the century steam donkey operations were limited to the lowest reaches of the subbasin due to limited rail access from the South Fork.

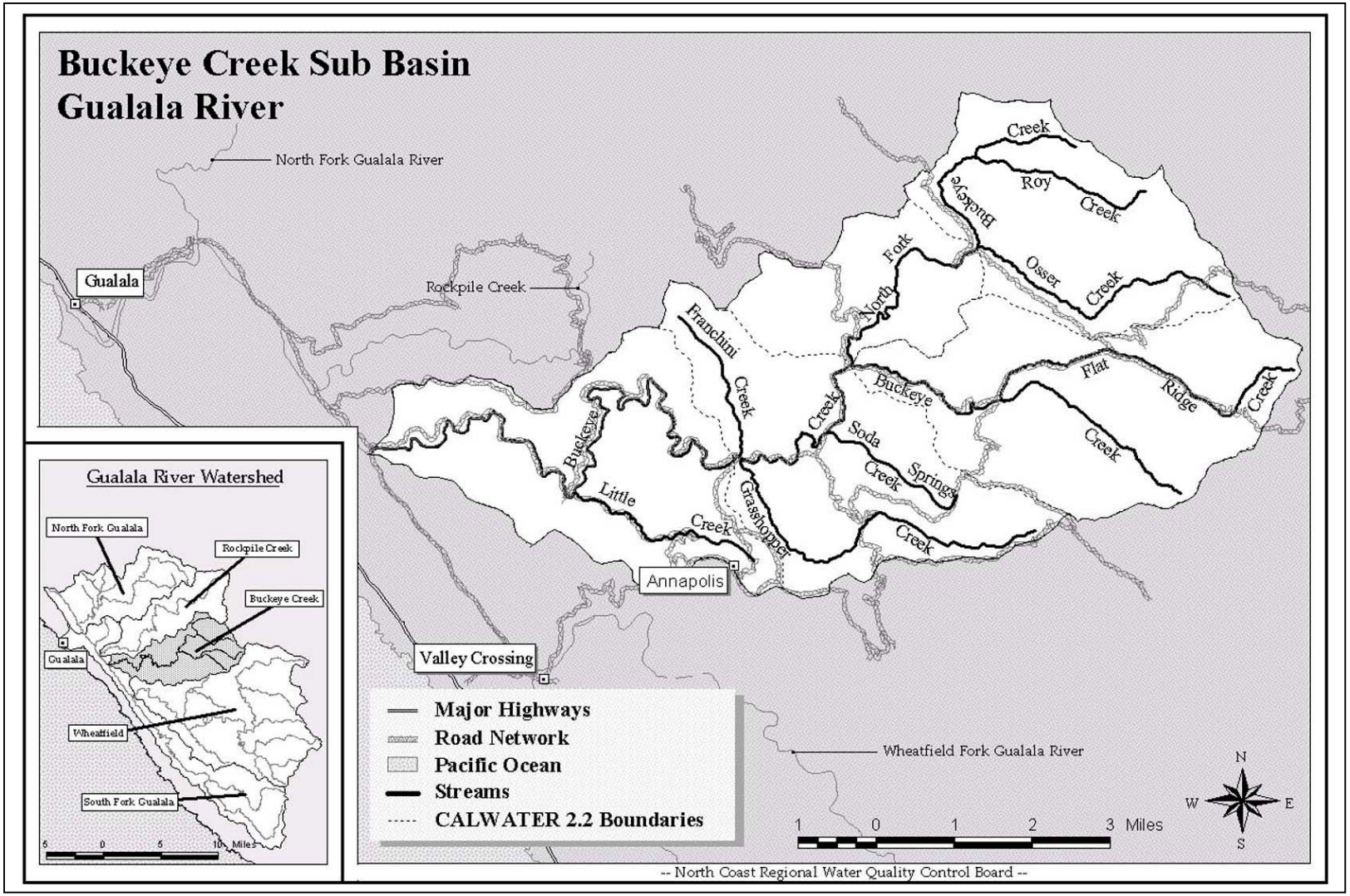


Figure 5.4-1
Buckeye Subbasin

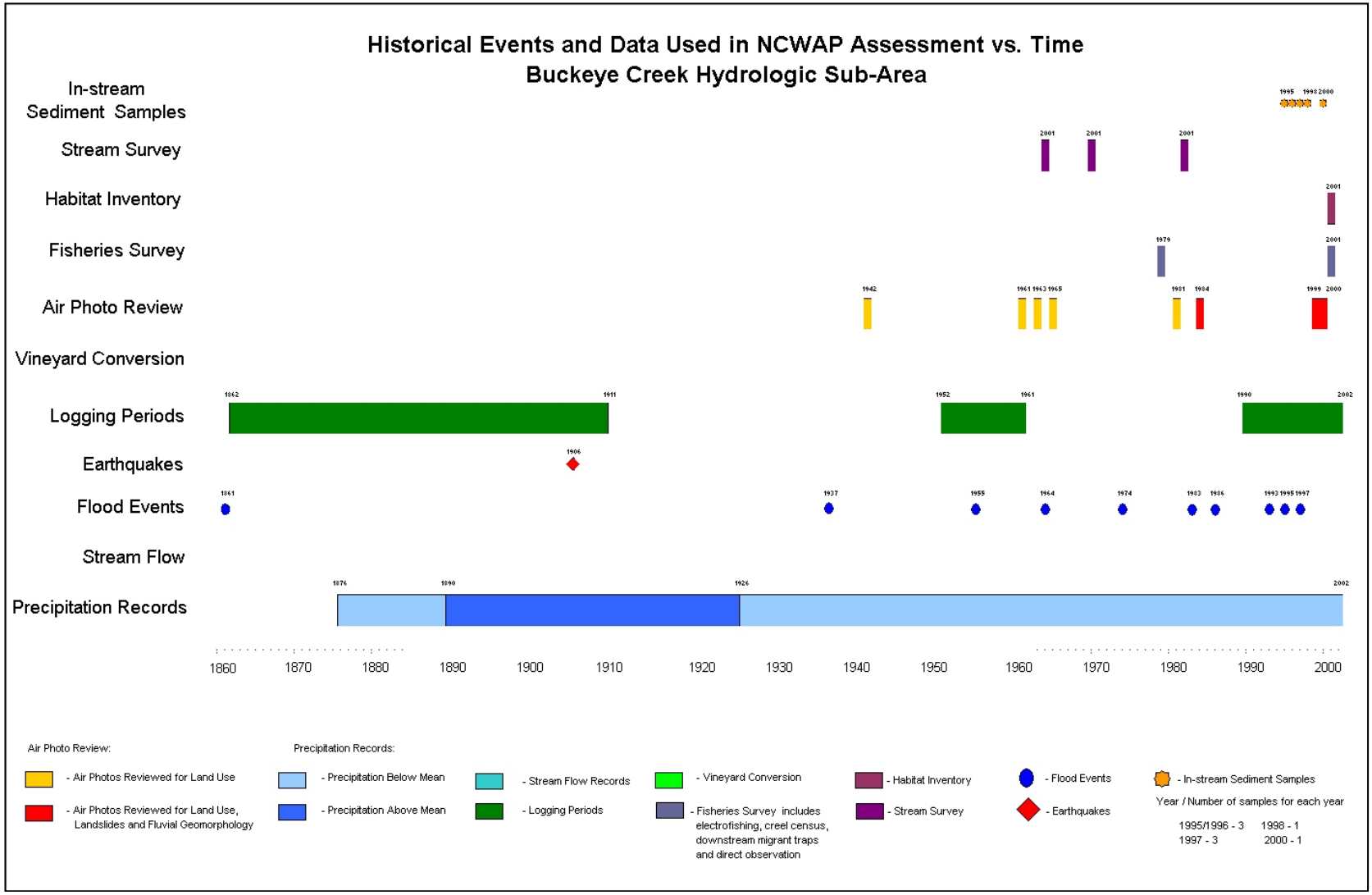


Figure 5.4-2
Historic Events and Data Used in the NCWAP Assessment for the Buckeye Subbasin

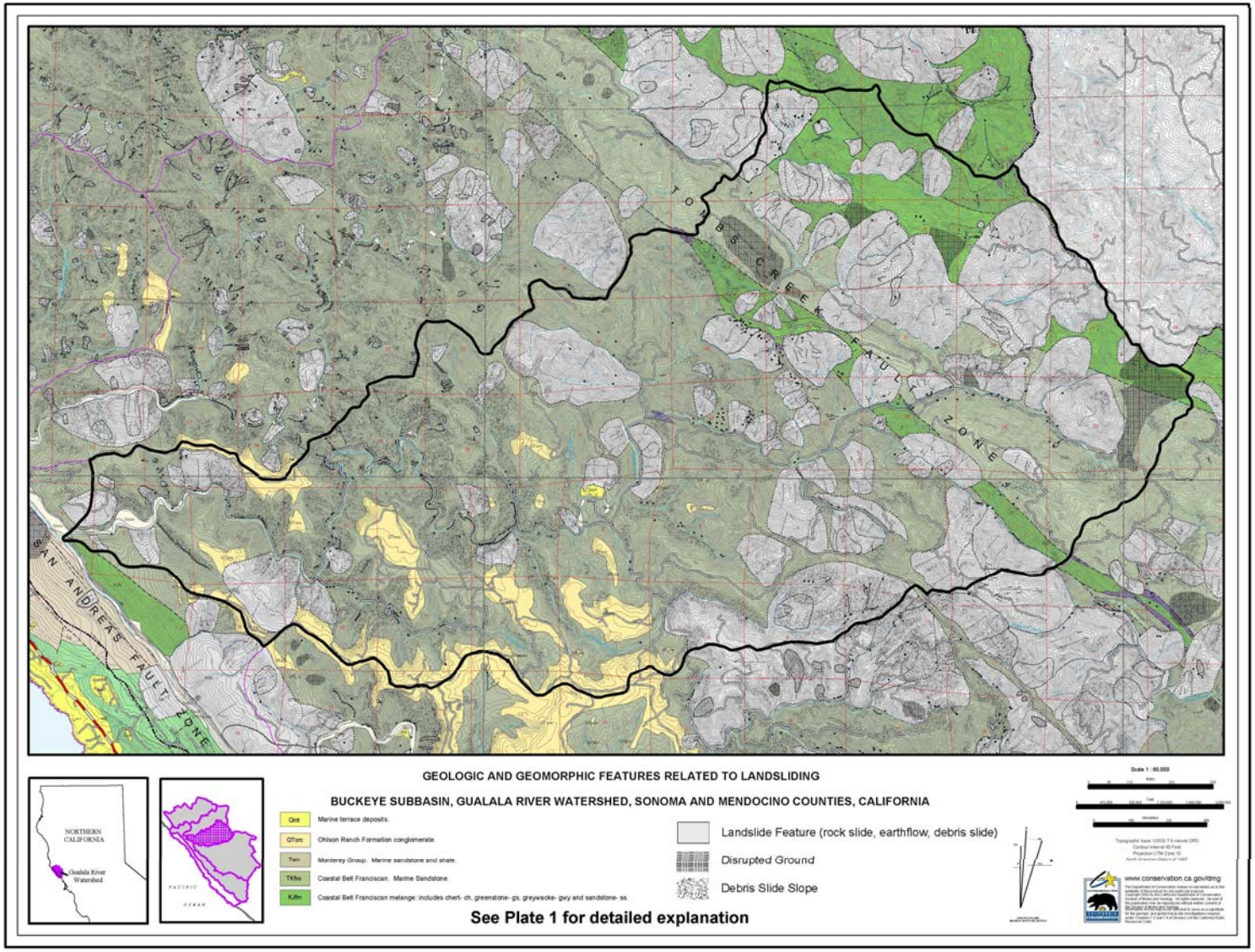


Figure 5.4-3
Geologic and Geomorphic Features Related to Landsliding - Buckeye Subbasin

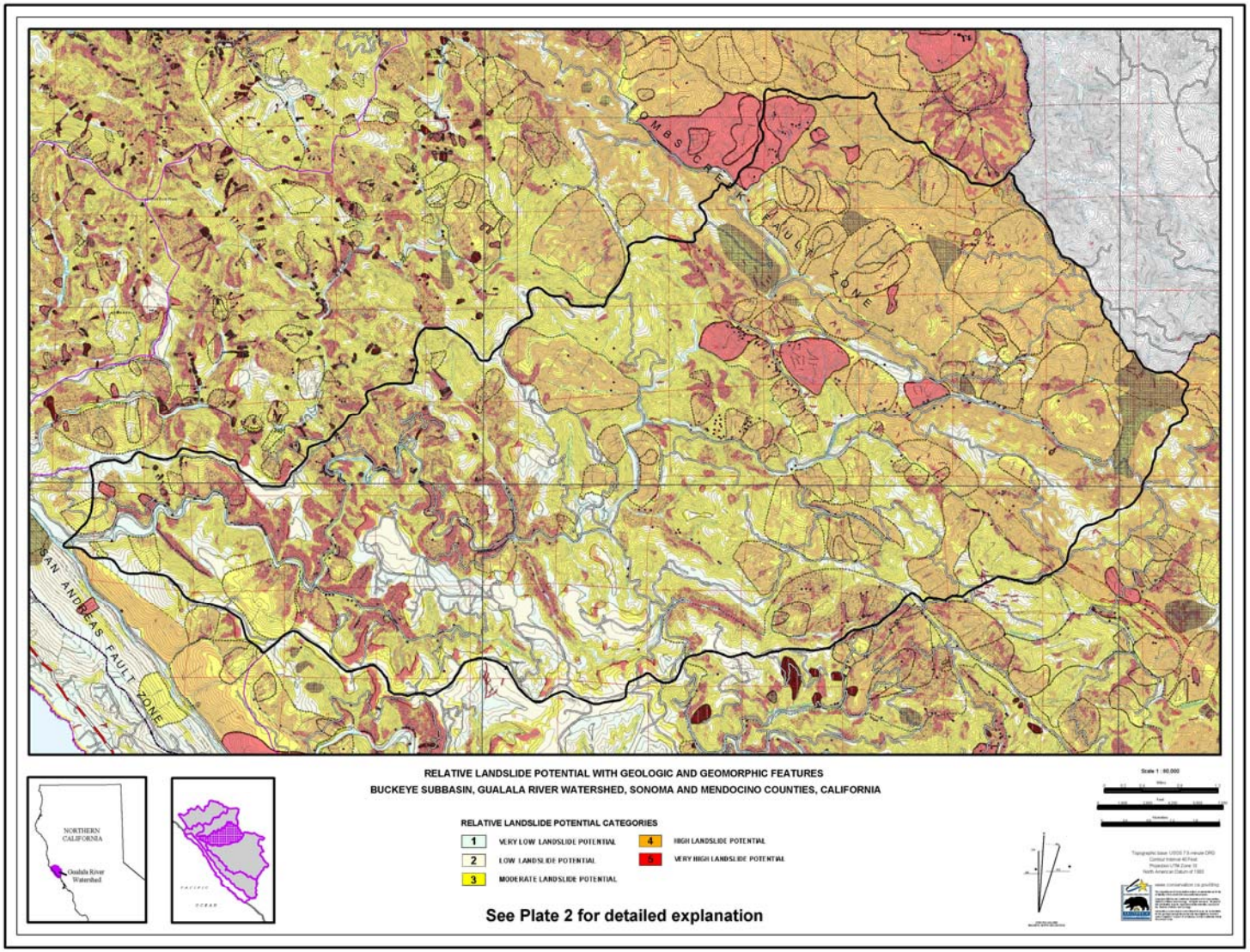


Figure 5.4-4
Relative Landslide Potential with Geologic and Geomorphic Features - Buckeye Subbasin

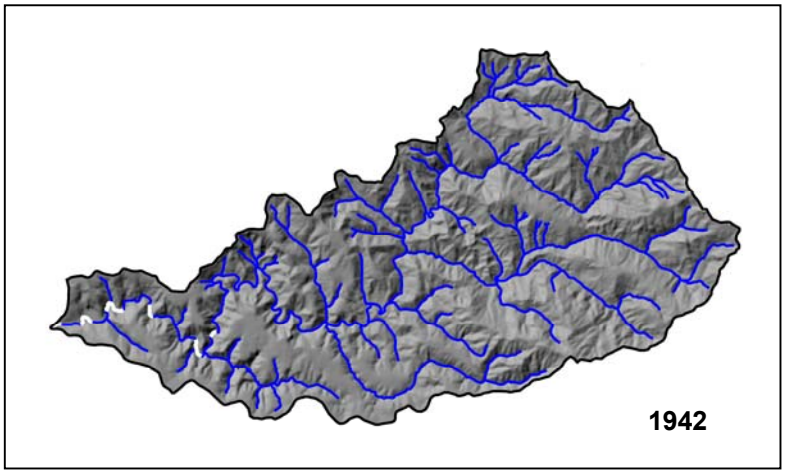


Figure 5.4-5
Bank-to-Bank Stream Exposure (White) and Partial to Entire Cover (Dark Blue) in 1942

In the late 1950s, the Franchini Creek watershed and surrounding area formed the south portion of the large multi-basin harvest complex area bounded by the upper North Fork and the mainstem Buckeye Creek. This unit followed a large mid-1950s operation that extended south from the mainstem Buckeye through the lower Wheatfield Subbasin to lower Fuller Creek. In the middle 1950s, downslope Douglas fir trees lining a narrow riparian corridor were removed from both Roy and Osser creeks. The Grasshopper Creek Planning Watershed (PWS) was logged by 1964 (Figure 5.4-7). Downslope areas of Douglas fir were logged throughout Soda Springs and Flatridge creeks by 1964. Between 1952 and 1964, 61.5 percent of the subbasin had been tractor harvested prior to the 1964 storms (Table 5.4-1). Streamside roads and landings were concentrated throughout: (1) Franchini Creek, (2) Grasshopper Creek, and (3) the North Fork Buckeye including Osser Creek (Figure 5.4-6). By the end of the tractor era in 1968, 69.5 percent of the subbasin had been harvested (Figure 5.4-8 and Table 5.4-1).

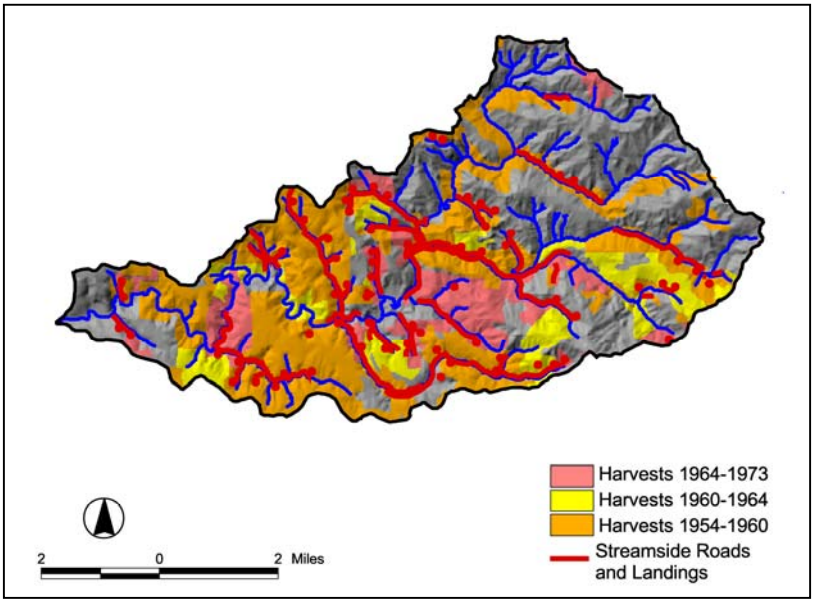


Figure 5.4-6
Mid-20th-Century Tractor Operations in the Buckeye Subbasin and Streamside Roads and Landings
(Red lines show where road fill has been pushed into the creek over the streambank)

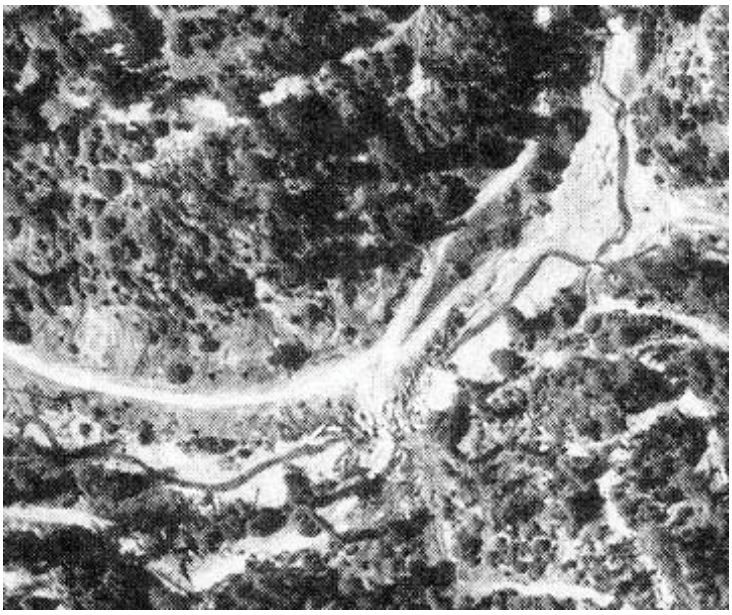
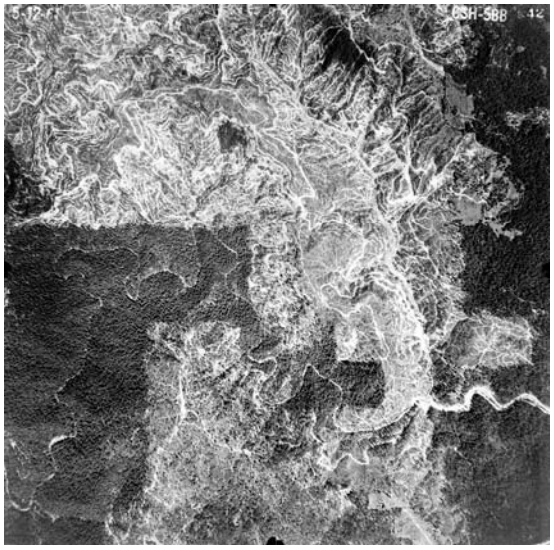
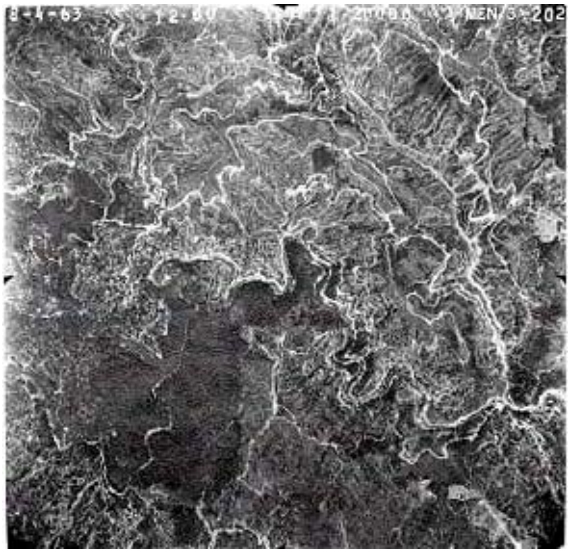


Figure 5.4-7
Tractor yarding was active in the Grasshopper Creek Subbasin in the mid 60s, leaving logs and wood debris piled over the stream channel. During the 1964 flood, this debris floated down to a low road crossing of Grasshopper Creek (left), creating a jam. The resulting dam breached at the south road approach, diverting onto the west road approach, which collapsed into the creek



1960



1963

Figure 5.4-8
Middle reaches of Buckeye Creek 1960, and same area (right) by 1963 showing a high rate of old growth harvesting in a three-year time period. Franchini Creek is in the center right of each photo. Note entire bank-to-bank stream exposure as a result of these operations.

Major sediment inputs from tractor logging areas by mid-20th-century storms are documented (see bullet points in Land Use Documentation, page 5.4-11 through 5.4-14). This coincided with indications of a more shallow pool structure from the early 1970s to present, although actual habitat survey methods and sampling procedures varied between survey years. Historic stream surveys in the Buckeye Subbasin are the most complete in the watershed.

The 1965 photos show extreme stream channel aggradation in Grasshopper Creek (Figure 5.4-7). The sinuous stream channel patterns through the logged areas show either (1) channel meandering through wide, flat areas of sediment fans in low gradient steps, or (2) stream deflections around fresh debris slides.

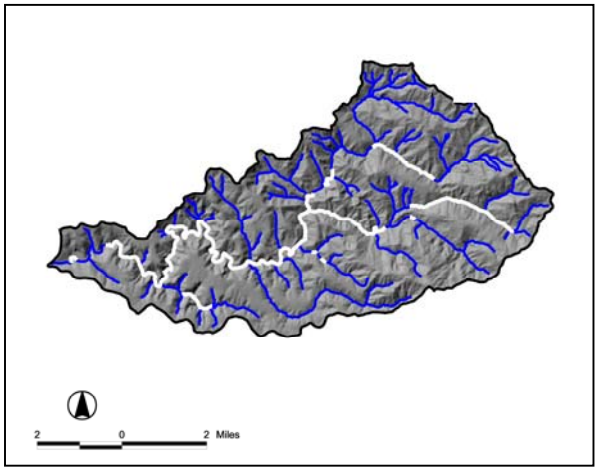
The 1989 Geological Review of Timber Harvesting Plan (THP) 89-091 SON stated "The Buckeye Creek watershed has been severely impacted by tractor logging between World War II and 1973. Skid trails were constructed in streams and draws, watercourses were filled, and surface flows were concentrated and diverted. As a result, Buckeye Creek is severely aggraded, filling most pools" (Geological Review 89-091 SON, T. Spittler).

Pre-2001 damage is still contributing substantial quantities of sediment to streams. Large amounts of stored sediments are still present in these watercourses. During storm events, this material moves downstream filling pools, scouring channels, and silting spawning beds. Old woody debris pushed into the channel now rots out losing support strength among the soil matrix. This causes more stream channel failures and entry of soils and fine sediment into watercourses (THP 1-95-114).

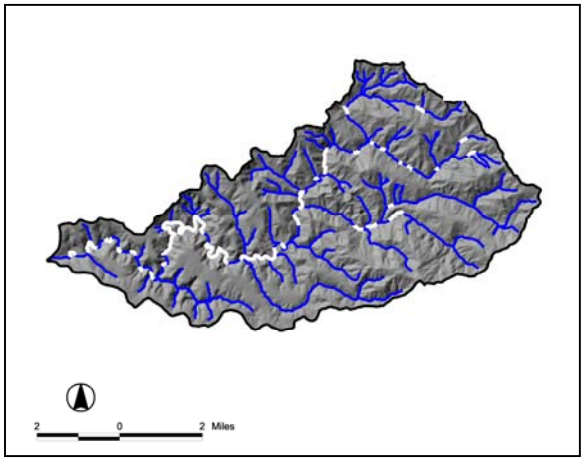
A no-harvest provision within Class I riparian zones (in the middle reaches on Coastal Forest Lands [CFL] lands and vicinity) followed a four year standard of added protection for Buckeye Creek. "The landowners and agencies agree that Buckeye Creek has a temperature problem and needs additional time to develop the shade and pools to improve fish habitat. The pre-1973 practice to build roads and landings in or near streams was widespread and led to massive degradation of the stream system. They were choked with sediment and large woody debris (LWD). Stream side vegetation was eliminated and shade canopy was greatly reduced." (S. Smith, California Department of Forestry and Fire Protection [CDF] Field Inspector)

Table 5.4-1
Buckeye Subbasin Stand Replacement Operations 1942 – 1973 - Total Area = 25,768 acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Operation Since 1942	Mean Annual Increment (acres/percent by year)
1932 – 1942	0	Stand Replacement	0	0
1942 – 1952	100	Stand Replacement	1.3	10 (0.1)
1952 – 1960	10,550	Stand Replacement	41.0	1,382 (5.0)
1960 – 1964	5,300	Stand Replacement	61.5	1,325 (5.0)
1964 – 1973	2,050	Stand Replacement	69.5	205 (0.8)



1968



1999

Figure 5.4-9
Bank-to-Bank Canopy Exposure (White) in the Buckeye Subbasin in 1968 (Left) and 1999 (Right)
(Dark blue lines show partial to entire canopy cover)

Bank-to-bank overstory shade canopy cover for 1999 (Figure 5.4-9) shows improvement compared to 1968, reflecting riparian in-growth since the late 1960s. In 1942, approximately 2 percent of the blue line streams were exposed bank to bank (Figure 5.4-5), limited to alluvial openings in the lower subbasin reaches throughout generally wooded conditions. In 1968, approximately 60 percent of the blue line streams were exposed bank-to-bank by the end of the tractor harvesting era. By 1999, this improved to approximately 25 percent of blue line streams exposed bank-to-bank (Figure 5.4-9). Coastal Forestlands reported reinstatement of overstory shade canopy in numerous upper reach tributary watercourses (Coastal Forest Lands' 1997 Sustained Yield Plan). Coastal Forest Lands, Ltd. (CFL) no harvest Watercourse and Lake Protection Zones (WLPZs) are routinely stipulated for all THPs along Buckeye Creek and Class II tributaries to mitigate temperature impairment throughout the subbasin. Canopy cover is lacking in most areas along the mainstem Buckeye Creek, in the middle to upper reaches.

Table 5.4-2
Buckeye Subbasin timber harvest operations – 1974 – 2001 - Total Area = 25,768 acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin under operation since 1974, some overlap with mid-20th-century areas	Mean annual increment (acres/percent by year)
1974 - 1990	550	Stand Replacement	.2	34 (0.1)
1991 - 2001	8,200	THPs	32.2 (42% cable, 58% tractor)	820 (3.2)

The 1970s were a period of relative inactivity compared to previous eras (Table 5.4-2). Partial entries and stand thinnings were common in the alluvial flats at this time. During the late 1980s through mid 1990s, active timber harvesting resumed. In the middle subbasin reaches, numerous seed tree overstory removal/ dispersed harvest THPs were conducted. These covered large areas but removed scattered single trees and remnant stands left from 1960s era entries. The 1999 air photos show these areas well vegetated. Agency review of these THPs clarified road upgrade work requirements to repair the erosion conditions of pre-1973 operations. Even-aged management has been the predominant silvicultural

method in the lower alluvial subbasin since the mid 1990s (Figure 5.4-10). Some 580 acres (2.2 percent) of grazing lands occupy the upper subbasin reaches.

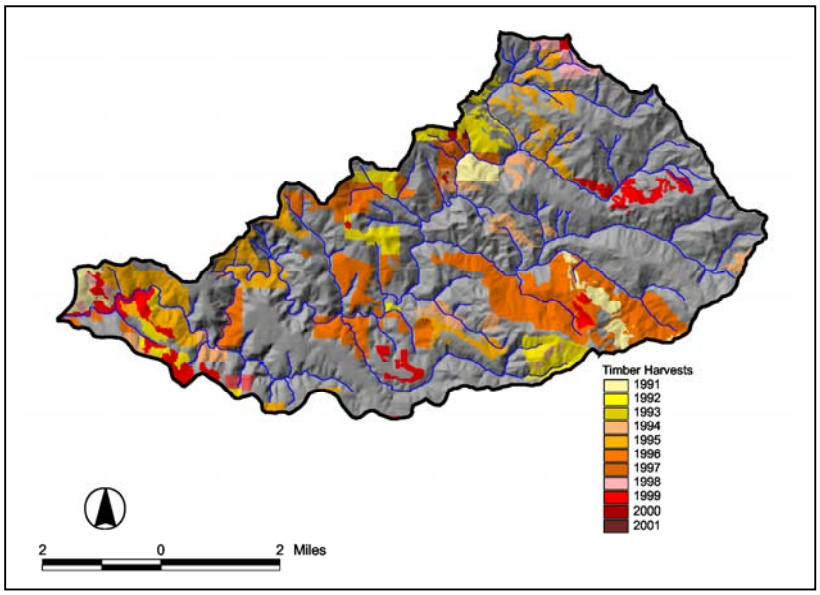


Figure 5.4-10
1991 to 2001 Timber Harvests

5.4.5 ROADS

Historic Roads (1952 – 1968)

Built between the mid 1950s and early 1960s, streamside/instream road and landing networks spanned most of the natural fluvial drainage system of the Buckeye Subbasin (Figure 5.4-6). These roads dominated stream channel structure throughout Franchini, Grasshopper, and the North Fork Buckeye including Osser creeks, simplifying stream channel structure and complexity. A total of approximately 27 miles of road were build at or near equal elevation to the streambank transition line with sidecast covering the streambank leading to the creek. More roads were located slightly upslope but still near the creek. However, these were not mapped with this study. After 1968, these roads were generally unused and left abandoned. There was no to minimal erosion control facilities left with these roads.

Stream channel morphology in the Buckeye Subbasin over the last 50 years experiences the following evolution thru time: (1) a high density of debris mounds in the active channel triggered by mid-20th-century storm events, (2) progressive abatement of the frequency of these point sources over successive decades, and (3) apparent improvements in instream channel conditions between 1984 and 2000 as evidenced by a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. The 1961, 1965 and 1981 photos show that most of the point source sediment discharges consist of road debris slides accessing watercourses activated by large storm events. For example, 1965 photos show multiple road debris slides accessing Grasshopper Creek over relatively short sections of the stream. Fresh debris slides fanned out over the channel, forcing the stream to meander around the slide mass. These meandering stream channel patterns (Figure 5.4-7) returned to a more lineal pattern as observed with the 1984 photos, and again with 1999 photos. Sediment accumulations continue to be noted in low gradient steps. In the Grasshopper Creek tributary, stream

channels in many areas contain large amounts of stored sediment behind jams of LWD. The channel continues to downcut to pre-logging levels.

The California Geologic Survey (CGS) watershed-wide geofluvial mapping compared stored sediment channel characteristics between 1984 and 1999/2000. This comparison basically shows stream channel sediment residency movement thru time. The 1984 mapping spans 16 years after the end of the tractor logging era (by 1968). Most of the stream segments in the Buckeye Subbasin show a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. The dense network of instream/streamside roads and landings that lined blue line streams in the Little Creek, Grasshopper Creek and Flat Ridge Creek PWSs showed a high correlation with stream braiding and aggradation (over 75 percent) in 1984.

Modern Roads

Successive air photo overlays show a shift in new road construction to ridgelines and mid-slope benches. The total length of the road network consists of 229 miles of active roads, at a density of 5.7 miles/square mile. The U.C. Davis Information Center for the Environment ("ICE") developed a contemporary road map for the total maximum daily load (TMDL), which shows most of the current roads located distant from watercourses. Approximately 1.5 miles of current roads are within 50 feet of blue line streams within the subbasin. Of these roads, less than a half mile total length are in areas that may be affected by historically active landsliding and stream bank erosion. Although the current road network shows less overall coincidence of debris slides and stream crossing failures compared to historic times, most of the contemporary road failures are in close proximity to streams and steep slopes. Approximately one mile total of modern road segments cross steep slopes (excess of 60 percent). Most of the historically active point slides found within 60 meters of a road occur predominantly along blue line streams in steep areas.

Substandard road networks continued to be vulnerable to large storm events in the 1980s and 1990s. Road washouts during the 1986 and 1996 storms generally characterize contemporary land use induced sediment pulses. There are 1.8 road crossings per stream mile. With 37.5 of the subbasin subject to Timber Harvest Plans since 1991, some road repair and upgrade work has been accomplished. More recent THPs require even higher construction/ replacement standards. Remaining areas of the subbasin are recommended as the highest priority for restoration work with this study. Gualala Redwoods, Inc. (GRI) has also completed road upgrade work in the lower reaches of the subbasin, with an estimated savings of 3,400 cubic yards. The NCWAP restoration map targets individual stream segments throughout the entire subbasin on a more or less even distribution (Plate 3, Figures 5.4-19a and 5.4-19b).

Documentation Of Land Use Impacts By Major Tributary

Little Creek

- The Little Creek watershed was logged during the late 1950s. The main haul road followed the stream channel throughout the entire Class I portion of Little Creek with numerous instream landings concentrated in this tributary watershed.
- In the lower to middle reaches of Buckeye, Coastal Forest Lands' (CFL's) main seasonal road followed the streambed or adjacent to Buckeye Creek. This road undercut steep ground between Stanly and Brushy Ridges causing debris slides into Buckeye Creek. This road section is currently abandoned due to a rockslide and numerous washouts. A Little Creek tributary also was

similarly tractor logged. Tractor logging occurred on slopes in excess of 65 percent (THP 97-036, CFL).

Franchini Creek

- The entire tributary watershed was logged between 1959-1960. The main seasonal road was located in and adjacent to the stream channel. Numerous debris slide failures were noted along the main instream road in 1961 and 1965 photos as Franchini Creek undermined the road. The Franchini Creek watershed was burned during the 1950s. Subsequent salvage logging used roads adjacent to streams and instream landings (THP 97-034, CFL).

- Stream surveys in Franchini Creek by the North Coast Regional Water Quality Control Board (NCRWQCB) staff during development of the TMDL found fine sediment almost completely burying cobble (NCRWQCB 2001b).

Grasshopper Creek

- The main haul road, now abandoned, followed the stream channel of Grasshopper Creek, leading west to the Buckeye Creek Road. No culverts were used and the road was abandoned with no stabilization measures applied. Logs were skidded downhill, often directly in watercourses. No waterbars were built or stream crossings ditched out. Stream channels in 1993 contained large amounts of stored sediment behind jams of LWD. The channel continued to downcut to pre-logging levels in 1993 (THP 93-328).

- Fine sedimentation in pools relative to the residual pool volume (V*) showed 59 percent pool volume filled with fine sediment, rating comparatively high disturbance (Knopp 1993).

- Grasshopper Creek enters a steep, narrow canyon before its confluence with Buckeye Creek. The canyon walls are mapped as debris slide slopes, although no landslides were found in the photos examined. In fact, landsliding is relatively rare in the Grasshopper Creek watershed.

Middle Reaches Buckeye Creek

- This area was subject to harvest removals and conversion to pastureland, including burning, during the 1950s and 1960s. High sedimentation and accumulation of debris were found in the channels, and downcutting and subsequent downstream aggradations were noted. Uncontrolled installation of fills, failure to remove fills, and lack of erosion control facilities has caused several landslides and locally severe erosion. A Pre-harvest Inspection report described LWD as common in smaller streams. There were major road repairs to correct on-site sediment sources (THPs 97-070 and 442).

- Water temperatures collected during a timber harvest inspection ranged from 61 to 66 F in east and west tributaries to Buckeye Creek, exceeding the optimum for coho salmon south of Bear Ridge, Kelly Road (Flat Ridge Creek PWS). Much of the streams were forested with sapling sized conifers/hardwoods. Extensive grassland areas with more open riparian zones exist from older attempts at rangeland conversion and are now abandoned. Watercourse areas were heavily cut during the late 1950s tractor operations. Stream diversion repairs were noted, as well as new road construction to relocate road segments onto the ridgeline (THP 97-227).

- Stream diversion realignments of Class II watercourses were specified to repair deep gully erosion down roads and skid trails. This was required on an 800-acre plan upslope of Buckeye Creek. A no-harvest provision within the Class I follows a four year standard of added protection for Buckeye Creek. Past cattle grazing in this area after 1960s era harvest entries prevented timely overstory reestablishment of canopy cover over fish bearing watercourses (THP 97-442).

North Fork Buckeye

- Steelhead trout and coho salmon were reported in the North Fork Buckeye in 1964. A 1982 survey found pools at 25-40 percent of the stream. Steelhead trout comprised 40 percent of fish observed, among high water temperatures, algae blooms, and lack of cover. A 1995 survey showed 20 percent pools.

- Specific no-harvest Watercourse and Lake Protection Zone measures were implemented to mitigate streamshade deficiencies from pre-1973 era logging. The area historically was forested with Douglas fir. The area was tractor logged during the 1950s, with some areas entered lightly due to terrain and poor quality of the timber stands. Uncontrolled installation of fills, failure to remove fills, and lack of erosion control facilities has caused several landslides and locally severe erosion. Correction of on-site sediment sources has occurred with THPs (watercourse diversion repairs were noted under THP 1-97-084). Historic attempts at permanent conversion to grazing lands occurred within the Howlett Ranch. A diverted Class II watercourse triggered a large translational/rotational slide and "massive erosion" (California Department of Mines and Geology [DMG] Report, M. Manson THP 97-084). The THP required redirection of the watercourse to the natural channel by excavator work. Class II watercourse tractor crossings left in place from the 1950s have washed through leaving vertical cuts over 6 feet high.

Roy Creek (upper Buckeye Subbasin)

- Most areas were tractor logged during the late 1950s to 1960s. Logging was accompanied by attempted conversion to rangeland. Site reconnaissance during several Pre-harvest Inspections documented tractor skidding down all slopes, regardless of steepness, to roads and landings located in or adjacent to watercourses. The lack of erosion control caused deep gullying down skid trails discharging into watercourses. Large quantities of soil and debris were placed into or washed into watercourses. Debris slides above and below roads are common and frequent. Maintenance of a passable road surface involves clearing of slide debris from the roads and installing infrequent ditch relief culverts. Recent timber harvest activity since 1973 repaired and improved drainage conditions in those areas where operations occurred (M. Jameson, CDF Audit Forester, 1995).

- The lower two miles of Roy Creek above the confluence with Osser Creek was described as in poor condition in 1995. Sediment lined the channel, partially filling pools. LWD was not abundant. An upper tributary of the North Fork Buckeye Creek was reported as wide and shallow with low amounts of LWD. Most of the large hardwood and conifers that once lined the streambanks had been cut and the area was converted to grassland, perhaps creating high stream temperatures (M. Jameson, THP 95-114). One pool was 75 F at 2:00 p.m. on August 19, 1994, a second was 72 F. With the recent elimination of grazing activity, conifers have begun to resestablish in rangeland areas

- The lower half mile of Roy Creek crosses the Tombs Creek Fault Zone and is impacted by a large active earthflow complex that makes up the northwest hillside above the creek. The earthflow formed in the Central Belt Formation which is on the northeast side of the Tombs Creek Fault Zone. The earthflow is a grassy area, and probably never offered LWD.

Osser Creek (upper Buckeye Subbasin)

- Logged by the late 1950s, many areas in the Osser Creek watershed were first harvested by a diameter limit cut. Tractor operations used some creek channels as skid trails, building landings in or near watercourses. Sediment pushed into creeks from historical operations was present in 1999, and was slowly flushing during peak flow events (THP 99-145).

- Field reconnaissance during several Pre-harvest Inspections in 1995 and 1997 described Osser Creek as subject to heavy deposits of soil and debris (THP 97-070 and THP 95-114). The size of pools had been reduced substantially by filling with fine sediments. An active earthflow impinges on the creek in areas, probably contributing fines, but on-site evaluation is needed to verify. Most channel overstory cover was removed by historic logging and conversion to pastureland. Shade on Osser Creek in 2001 was estimated at 80 percent in the upper reaches, and lower in downstream reaches. Conditions were described as in a stage of recovery in 2001, and may require many decades for excess sediment to flush downstream during high flow events. Background levels of sedimentation were generally high but not specifically known and should be considered in evaluating recovery from land use disturbance. Streamside shading will similarly require several decades to recover with conifer ingrowth, after cessation of grazing and conversion to pastureland (M. Jameson, THP 1-95-114).

5.4.6 FLUVIAL GEOMORPHOLOGY

About 53 percent of the subbasin is classified as high to very high potential for landsliding and represents the major source area for stream sediment (Figure 5.4-3). Instream sediment levels, indicative of disturbance, occur along 18 of 90 miles of the blue line streams in the subbasin. This is a 57 percent reduction compared to levels in 1984. Most of the reduction occurred in the tributaries, while the lower reaches showed less change. Table 5.4-3 lists the lengths of sediment storage mapped and relative change between 1984 to 1999/2000 for the Buckeye Subbasin.

Table 5.4-3
Buckeye Subbasin Stream Characteristics Representing Sediment Sources or Storage

Planning Watershed	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Length Miles	Percent Total Stream for Subbasin	Length Miles	Percent Total Stream for Subbasin	Length Miles	Total Length Miles
North Fork Osser Creek	2.2	11.5	4.7	24.5	-53.2	19.0
Flat Ridge Creek	4.1	20.7	8.7	43.8	-52.7	19.8
Grasshopper Creek	4.8	25.1	11.4	59.1	-57.5	19.2
Little Creek	5.6	26.7	12.9	62.0	-57.0	20.8
Total	**17.9**	**19.8**	**41.6**	**46.0**	**-56.9**	**90.4**

5.4.7 WATER QUALITY

Water Temperature

Water temperature data from continuous recorders were available for 15 sites in the Buckeye Subbasin (Figure 5.4-11). The period of record from 1995 to 2001 yielded 39 observations for maximum weekly average temperature (MWAT) and seasonal maximum temperature.

MWATs in the mainstem ranged from undetermined to fully unsuitable (Table 5.4-4). MWATs in Flatridge, Soda Springs, and Grasshopper creeks ranged from moderately to fully unsuitable. MWATs for the lower tributary were fully suitable for the period of record (Table 5.4-4, Figures 5.4-12 and 5.4-13).

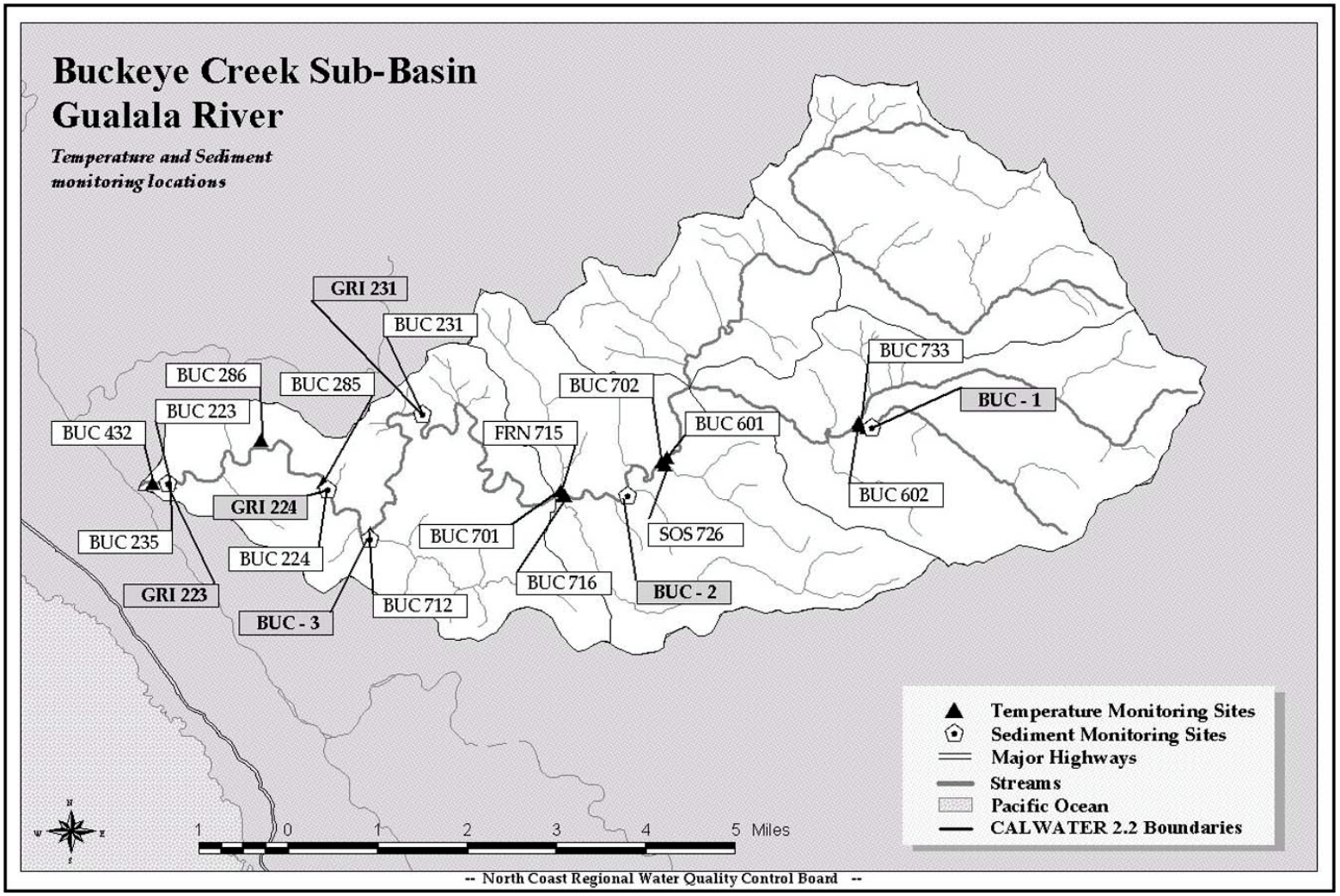


Figure 5.4-11
InStream Sediment and Temperature Sampling Sites, Buckeye Subbasin

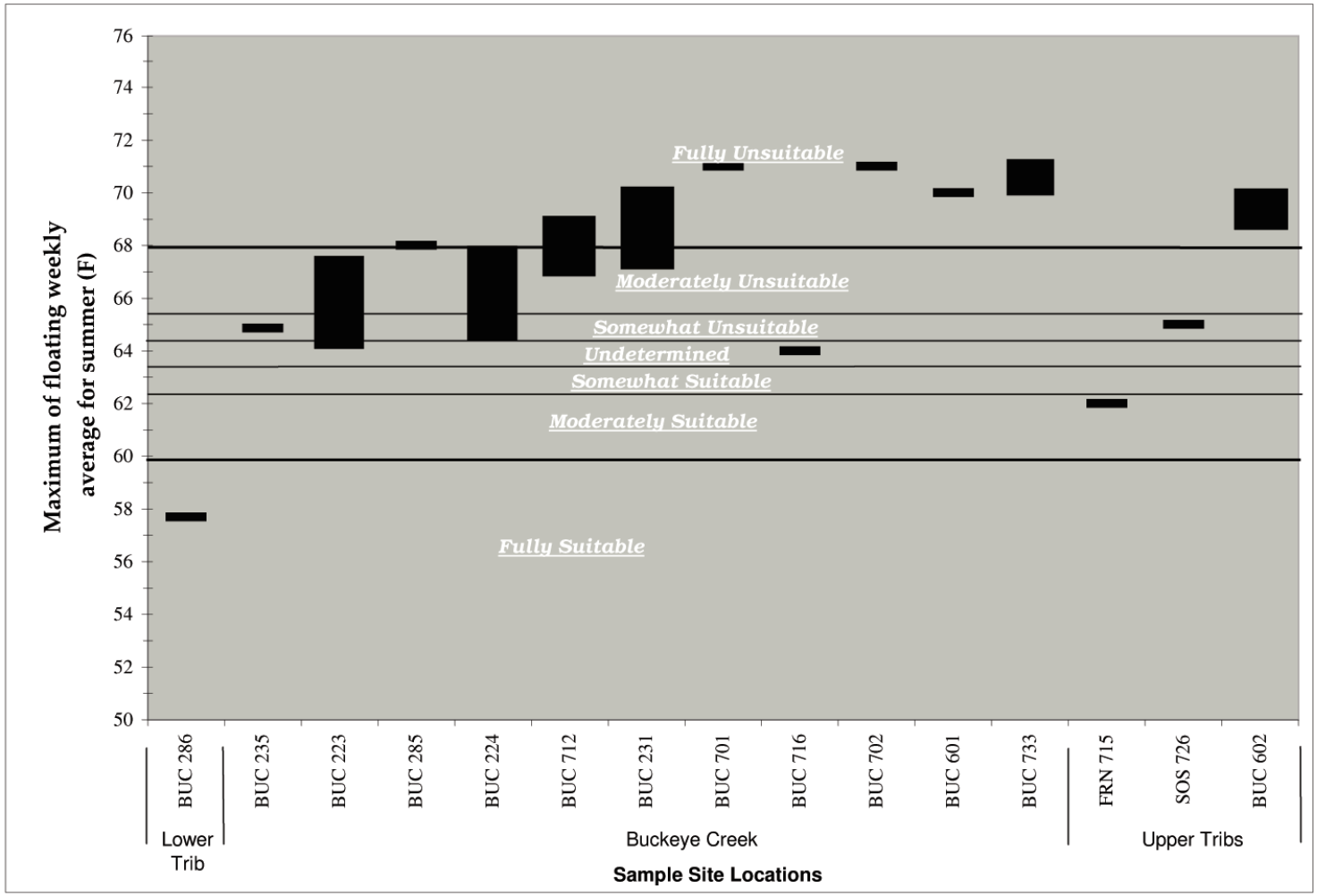


Figure 5.4-12
Maximum Weekly Average Temperature (MWAT) Ranges for the Buckeye Subbasin from 1995-2001
(Data From GRI And GRWC Continuous Monitoring Devices)

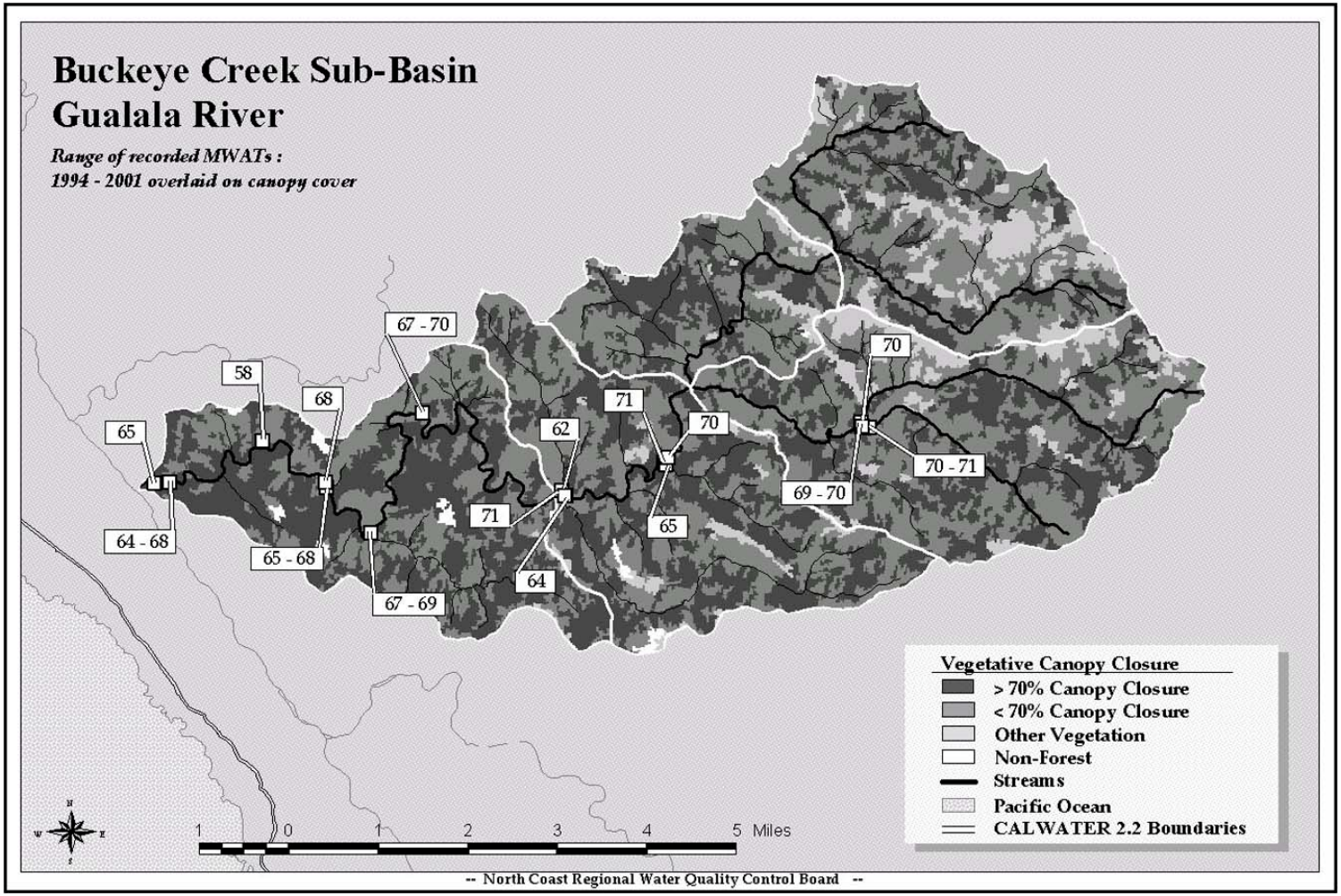


Figure 5.4-13
MWAT Temperature Ranges in the Buckeye Subbasin for the Period of Record, 1995-2001
(Overlaid on the LandSat Canopy Cover for 1999)

Seasonal maximum temperatures were above the lethal limit of 75 F at seven of the ten mainstem sites at one time or another during the period of record (15 of 28 observations). Flatridge, Soda Springs, and Grasshopper creeks seasonal maxima for 2000 and 2001 were 78 F to 77 F. The seasonal maximum in the lower tributary for the one measurement in 1998 was 59 F.

Table 5.4-4
EMDS Ratings for Maximum Weekly Average Temperatures (MWATs) in the Buckeye Subbasin

Stream	No. of Sites	No. of Observations	Period of Record	+++	++	+	0	-	--	---
Buckeye Mainstem	10	28	1994 - 2001							
Flat Ridge Creek	1	4	1997 - 1998 2000 - 2001							
Franchini Creek	1	2	1997 - 1998							
Grasshopper Creek	1	2	1997 - 1998							
Soda Springs Creek	1	2	1997 - 1998							
Lower Tributary	1	1	1998							

EMDS ratings:

+++ = fully suitable (50-60 F)
++ = moderately suitable (61-62 F)
+ = somewhat suitable (63 F)
0 = undetermined (between somewhat suitable and somewhat unsuitable) (64 F)
- = somewhat unsuitable (65-66 F)
-- = moderately unsuitable (67 F)
--- = unsuitable (> 68 F)

5.4.8 FISH HABITAT RELATIONSHIPS

Historic Habitat Conditions

CDFG stream surveys were conducted on Buckeye Creek and North Fork Buckeye Creek in 1964. These surveys were made by direct observation and were not accompanied by quantitative data (Table 5.4-5).

Table 5.4-5
Summary of Historic (1964-1982) Conditions Based Upon Stream Surveys Conducted in the Buckeye Subbasin Gualala River Watershed, California

Buckeye Subbasin Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
Buckeye Creek	8/27/64 8/19/70	Good spawning and rearing area; 50% pools; Steelhead present. Silt and sand dominated substrate indicating poor spawning; 25% pools.	Some partial barriers	Replant riparian vegetation; remove log jams
North Fork Buckeye Creek	8/5/64 8/5/82	Pools 25%; Sluggish water with algal bloom. Pools 40%.	Slash; Log jams	Plant riparian; Improve poor logging practice Plant riparian to reduce water temperature.

Current (2001) Conditions

Target Values and Current Conditions from the Habitat Inventory Surveys

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. Target values for each of the individual habitat elements measured are provided in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) (Table 5.4-6). When habitat conditions fall below the target values, restoration projects may be recommended to meet critical habitat needs for salmonids.

Table 5.4-6
Habitat Inventory Target Values Taken from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998)

Habitat Element	Canopy Cover	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or more of the stream length is <50% embedded	Depth-1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet Frequency->40% of stream	>80

One habitat inventory survey was conducted in 2001on the entire 51,085 feet of the main stem of Buckeye Creek. The embeddedness target value was reached, indicating good spawning substrate conditions. The target values for canopy density, pool frequency/depth, and the shelter/cover ratings were not met (Table 5.4-7).

Table 5.4-7
Summary of Current (2001) Conditions Based Upon Habitat Inventory Surveys from the Buckeye Subbasin, Gualala River Watershed, California
Condensed Tributary Reports are located in CDFG Appendix 5.

Habitat Element Stream Name	Surveyed Length (feet)	Canopy Cover	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
Buckeye Subbasin	51,085				
Buckeye Creek	51,085	61%	68%	11%	44

Buckeye Creek is a third order stream. Habitat deficiencies were documented by the habitat inventory surveys related to canopy cover, pool frequency/depth and shelter cover. Canopy cover averaged 61 percent with conifers contributing 37 percent and deciduous 24 percent (Figure 5.4-14). Sixty-nine percent of pool tails surveyed in Buckeye Creek were category 1 or 2 embeddedness (Figure 5.4-15). Buckeye Creek showed 11 percent of the survey length consisted of primary pools (Figure 5.4-16). Shelter/cover received a rating of 44 (Figure 5.4-17), and the cover was provided by large and small woody debris, boulders and root masses (Figure 5.4-18).

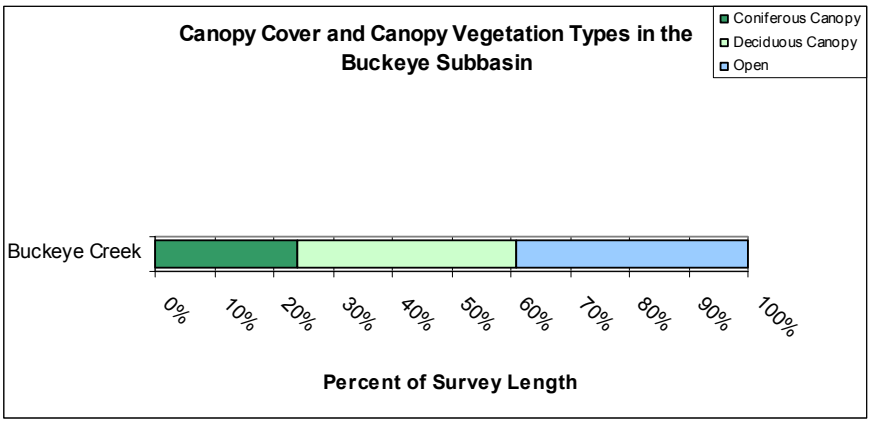


Figure 5.4-14
Canopy Cover and Canopy Vegetation Types by Percent Survey Length in the Buckeye Creek, Buckeye Subbasin 2001, Gualala River Watershed, California

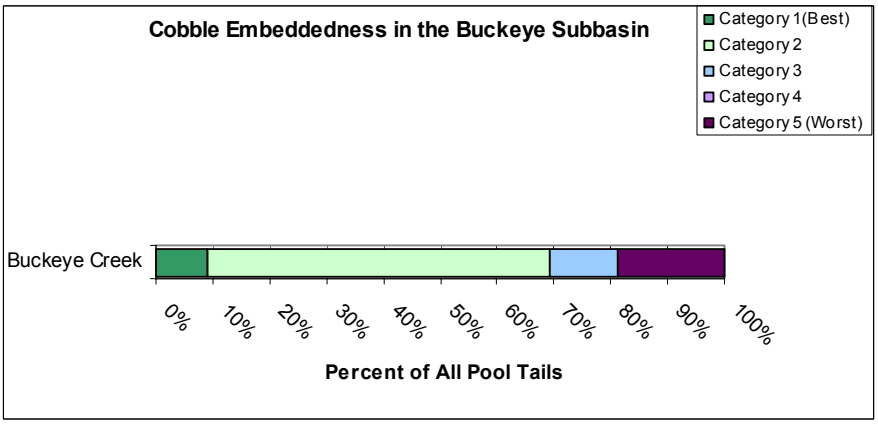


Figure 5.4-15
Percent of Cobble Embeddedness in all Pool Tails in the Buckeye Subbasin 2001, Gualala River Watershed, California

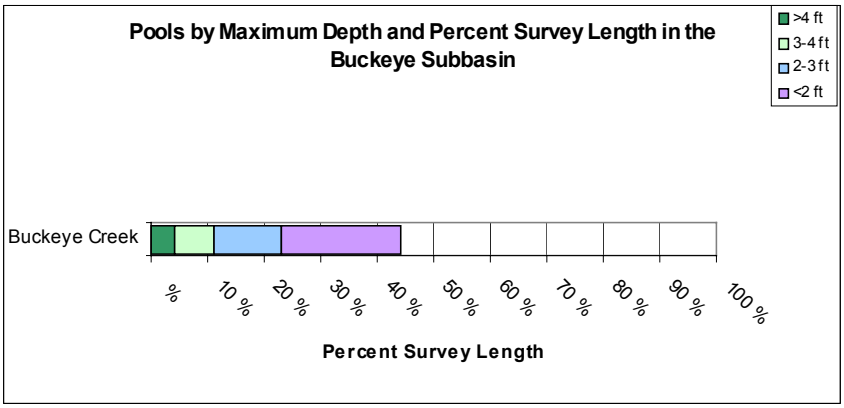


Figure 5.4-16
Pools by Maximum Depth and Percent Survey Length in the Buckeye Subbasin 2001, Gualala River Watershed, California

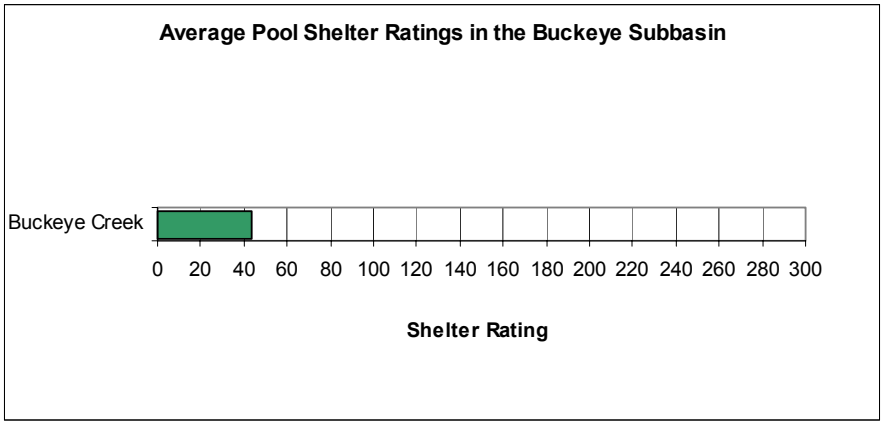


Figure 5.4-17
Average Pool Shelter Ratings in the Buckeye Subbasin 2001, Gualala River, California

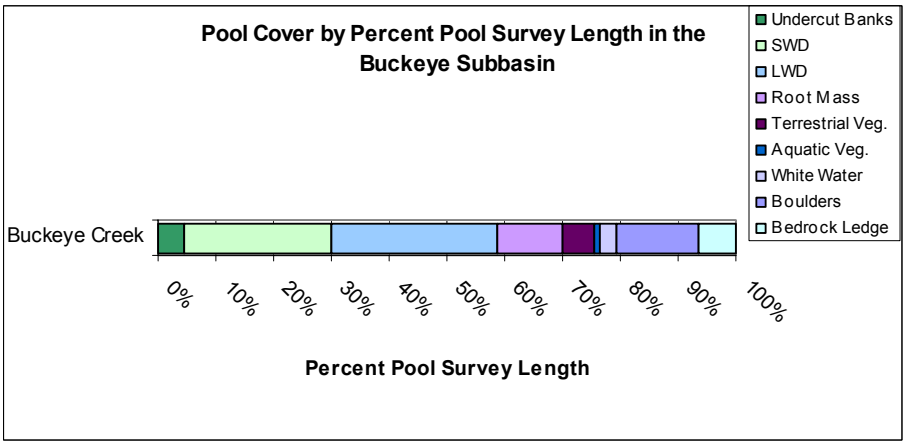


Figure 5.4-18
Pool Cover Types by Percent of Pool Survey Length in the Buckeye Subbasin 2001, Gualala River Watershed, California

Large Woody Debris Data

Large woody debris data were provided by the Gualala River Watershed Council's Cooperative Monitoring Program. Most large wood was cleared from the streams during the 1950s, 1960s and 1970s. A target value of 130 pieces of large wood >8 inches per 1,000 feet of stream is recommended in the literature (Beechie and Sibley 1997, Martin 1999). The monitoring surveys demonstrated that large wood was deficient in the areas of Buckeye Creek surveyed. This finding was supported by the habitat inventory survey data collected in 2001 and the EMDS reach model.

The Cooperative Monitoring Program surveys found both of the Buckeye Creek sites lacking volume and pieces of large woody debris (Table 5.4-8).

Table 5.4-8
Summary of Watershed Cooperative Monitoring Program Large Woody Debris Data, Buckeye Subbasin, (1998 - 2000)

Tributary	Site Number	Watershed* Size (acres	Volume Cubic Feet/1,000'	Quantity Pieces/1,000'
Buckeye Creek	223	25,588	2,946	49
Buckeye Creek	231	21,198	228	7

*Watershed size is calculated as the area above the monitoring site.

Changes in Habitat Conditions From 1964 to 2001

Changes between historic and current instream conditions were compared between the streams surveyed in 1964, 1970, and 1982 and subsequently habitat inventoried in 2001. Data from the 1964, 1970 and 1982 stream surveys provide only a qualitative snapshot of the conditions at the time of the survey and terms such as excellent, good, fair and poor were based on the judgment of the biologist or scientific aid conducting the survey. The results of the historic stream surveys cannot be used in comparative analyses with the quantitative data provided by the habitat inventory surveys with any degree of accuracy. However, the two data sets may be used to show general trends.

According to aerial photographs, the canopy cover of the 1960s was reduced substantially from the conditions observed in the 1940s. The canopy appeared to be low or absent throughout the subbasin.

In the Buckeye Subbasin, Buckeye Creek was surveyed in 1964 and 2001 (Table 5.4-9). The canopy cover appears to have increased somewhat, but still does not meet target values, indicating some improvement over those observed in the 1960s aerial photographs. The 2001 spawning substrate conditions continue to provide the same acceptable conditions observed in 1964. It is unknown whether the substrate has remained acceptable or has returned to the conditions observed in 1964. The 2001 pool frequency/depth and shelter cover appear to have decreased since 1964. The apparent reduction in pool frequency, pool depth and shelter/cover were likely exacerbated by “over” clearing of large woody debris from the stream.

Table 5.4-9
Comparison Between Historic Habitat Conditions Observed in 1964 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 2001 from the Buckeye Subbasin Gualala River Watershed, California

Habitat Element Stream Name	1960s Canopy Cover Photos	2001 Canopy Cover	1964 Spawning Conditions	2001 Spawning Conditions	1964 Pool Depth/ Frequency	2001 Pool Depth/ Frequency	1964 Shelter Cover	2001 Shelter Cover	Change in conditions from 1964 to 2001
Buckeye Subbasin									
Buckeye Creek	Low or Absent Replant	61%	Good	68%	50%	11%	N/A	44	Some canopy recovery: Improved spawning conditions: Decreased pool habitat and shelter/cover.

Ecological Management Decision Support (EMDS) Reach Model

Although the EMDS Reach Model scores are based upon the habitat inventory survey data, the analysis differed. The habitat inventory data were divided into reaches based upon Rosgen Channel type and then converted to a weighted average. Each weighted average reach was compared to a set of habitat reference conditions which were determined from empirical studies of naturally functioning channels, expert opinion, and peer reviewed literature. EMDS rated each habitat component with a suitability score between -1 and +1, where suitability is a function of salmonid health and productivity. The reference curve breakpoints for these habitat parameters are presented in Table 4-1.

An EMDS score for the overall subbasin could not be calculated due to limited data. Only one stream equal to 37 percent of all the blue line streams was habitat inventoried. Data from five habitat categories and four temperature sites in 2001 were evaluated in EMDS (Table 5.4-10).

Table 5.4-10
Ecological Management Decision Support (EMDS) Reach Model Scores on Salmonid Heath and Productivity Suitability for the Buckeye Subbasin Gualala, California, Based Upon Habitat Inventory Surveys Conducted in 2001

Subbasin Stream Name	Canopy Cover Score	Embeddedness Score	Pool Depth Score	Pool Shelter Score	Pool Quality Score	2001 MWAT Water Temperature Score
Buckeye Subbasin Score	n/a	n/a	n/a	n/a	n/a	n/a
Buckeye Creek	-	U	- -	-	-	- -

The 2001 water temperature data was provided by GRI and the GRWC.

+++ = Fully Suitable
++ = Moderately Suitable
+ = Somewhat Suitable
U = Undetermined
- = Somewhat Unsuitable
- - = Moderately Unsuitable
- - - = Fully Unsuitable

Limiting Factors Analysis (LFA)

The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components. Habitat inventory data, EMDS reach model scores, and the biologist's professional judgment were incorporated into both the identification of LFAs and their ranking (Table 5.4-11). The LFAs for the subbasin could not be calculated due to limited data. Only one stream equal to 37 percent of all the blue line streams was habitat inventoried.

Table 5.4-11
Limiting Factors for the Buckeye Subbasin Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 2001 and EMDS Scores in the Gualala River Watershed, California
Rank 1 is the most limiting factor.

Subbasin Stream Name	Canopy Cover Related to Water Temperature	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
Buckeye Subbasin Score	n/a	n/a	n/a	n/a
Buckeye Creek	3	4	1	2

Figure 5.4-19a illustrates the limiting factors as determined by CDFG and various sediment sites identified by CGS as potential restoration targets. Figure 5.4-19b is the map explanation. General recommendations are made for each limiting factor and type of sediment site. The map is a reduced image of Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*. (See Plate 3 to view details at a higher scale [1:48,000].

Restoration Recommendations

The proposed restoration recommendations were based upon the habitat inventory surveys, limiting factors analysis, landowner and local expertise, and the biologist's professional judgment.

Restoration recommendations for the overall subbasin could not be calculated due to limited data. Only one stream equal to 37 percent of all the blue line streams was habitat inventoried. To enhance pool development, increase pool depth, and provide improved pool shelter cover, the addition of instream structures is the highest restoration priority. To reduce sediment and improve spawning substrate on the lower reaches, road repair or removal is the second restoration priority. The third priority is to increase the riparian canopy to provide more shade over the stream, reduce water temperatures, and provided potential large woody debris. Bank stabilization, livestock/feral pig exclusion and barrier removal were not identified as restoration needs (Table 5.4-12).

Table 5.4-12
Priorities for Restoration in the Buckeye Subbasin Based Upon 2001 Surveys
Rank 1 indicates highest priority.

Stream Name	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
Buckeye Subbasin	n/a	n/a	n/a	n/a	n/a	n/a
Buckeye Creek		2	3	1		

Potential Refugia

No potential refugia were identified.

5.4.9 Fish History and Status

Salmonid population data are limited in the Buckeye Subbasin and were not collected or available prior to the 1960s.

- **1960s-**Steelhead trout were observed on the mainstem and North Fork of Buckeye creeks. Coho salmon were observed in Franchini Creek.
- **1970s and 1980s-**Data were not available.
- **1990s-**During snorkel surveys, Gualala Redwoods, Inc. observed one year and older steelhead trout on the mainstem of Buckeye Creek in 1997 and 1998.
- **2000s-**Modified Ten Pool Protocol on Franchini Creek showed young-of-the-year and one-year-old steelhead trout, but coho salmon were not observed on Franchini Creek during electrofishing surveys in 2001. During snorkel surveys, Gualala Redwoods, Inc. (GRI) observed one year and older steelhead trout on the mainstem of Buckeye Creek in 2000 and 2001.

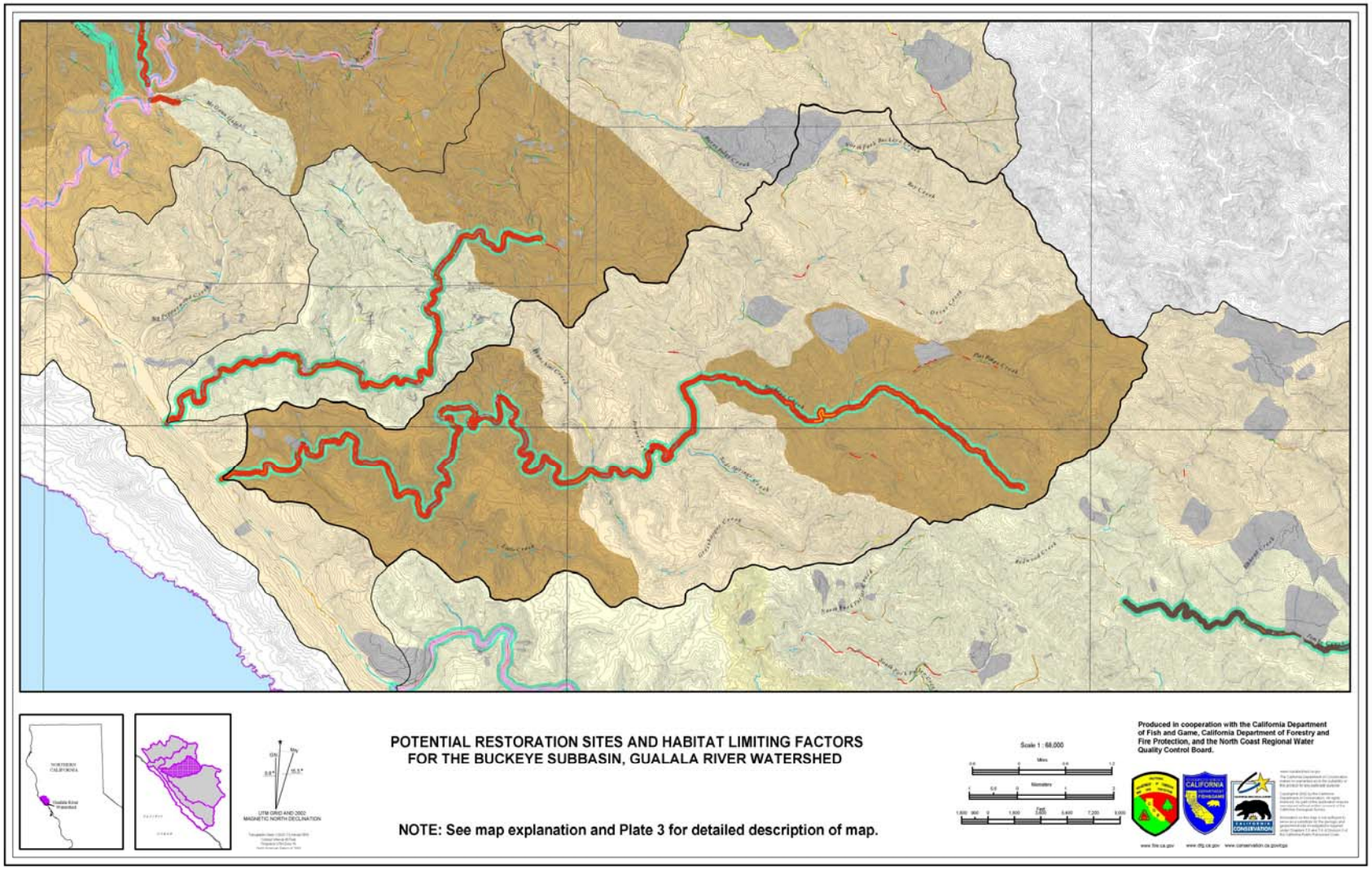


Figure 5.4-19a
Potential Restoration Sites and Habitat Limiting Factors for the Buckeye Subbasin, Gualala River Watershed

Roads
Streams
Watershed boundary
Sub-basin boundary
Historically Active Landslides (mapped as a point if too small to delineate at the scale of this map)

I SPATIALLY ASSOCIATED FACTORS DERIVED FROM AERIAL PHOTO INTERPRETATION OF LANDSLIDING AND SEDIMENT CONDITIONS

A *HISTORIC IN-STREAM ROADS POSSIBLY RELATED TO FLUVIAL SEDIMENT*

Stream reaches with persistent aggrading or braiding in both 1984 and 2000 photos that may be associated with historic in-stream roads or landings. See recommendation #5.

B *ROADS POSSIBLY RELATED TO LANDSLIDES AND/OR ERODING BANKS*

Road segments that may be affected by historically active landsliding and bank erosion. See recommendation #6.

Road segments that may be affected by historically active landsliding. See recommendation #7.

C *FLUVIAL SEDIMENT CONDITIONS POSSIBLY RELATED TO LANDSLIDES*

Stream reaches with potentially adverse sediment accumulations that may be affected by historically active landslides and lack any apparent association with the modern road network or the historic in-stream roads or landings. See recommendation #8.

Stream reaches with potentially adverse sediment accumulations that may be affected by erosion from adjacent dormant landslide terrain that lack any apparent association with historically active landsliding, the modern road network, and historic in-stream roads or landings. See recommendation #9.

D *POTENTIALLY UNRELATED FLUVIAL SEDIMENT CONDITIONS*

Stream reaches with potentially adverse sediment accumulations that lack any of the above associations. See recommendation #9.

II LIMITING FACTORS DERIVED FROM GROUND BASED HABITAT SURVEYS (SEE DFG APPENDIX)

A *CANOPY AND POOLS AS LIMITING FACTORS* (All stream reaches surveyed by DFG in 2001 are highlighted as follows. Reaches that were not surveyed in 2001 are not highlighted on the map.)

Stream reaches with inadaquate canopy cover as the limiting factor. See recommendation #2.
Stream reaches with inadequate pool depths as the limiting factor. See recommendation #4.
Stream reaches with inadequate pool shelter as the limiting factor. See recommendation #3.
Stream reaches with both inadaquate pool depths and shelter as limiting factors. See recommendations #3 and #4.

Explanation

B *EMBEDDEDNESS AS A LIMITING FACTOR*

Areas draining into where embededdness conditions are unknown.
Areas draining into reaches where embeddedness is not limiting.
Areas draining into reaches where embeddedness is marginal but not limiting.
Areas draining into reaches where embeddedness is somewhat limiting. See recommendation #1.
Areas draining into reaches where embeddedness is significantly limiting. See recommendation #1.

RECOMMENDATIONS BASED ON LIMITING FACTORS

(1) Reduce production of fine sediment throughout the contributing area. Evaluate contribution from roads and upgrade roads as appropriate. Evaluate contribution from soil disturbance and control erosion as appropriate (see recommendations 5-10). Evaluate contribution from soil disturbance and control erosion as appropriate. Consider the additive effect of the short-term increases in erosion due to mitigation activities. Distribute individual activities both spatially and temporally as appropriate to avoid additive sediment impacts. Institute best management practices in erodible areas; such as, areas shown on the CGS Relative Landslide Potential Map (Plate Two), and National Resources Conservation Service soil maps.

(2) Enhance current riparian vegetation by planting additional trees, and stabilize stream banks as needed. Also, consider both downstream and upstream effects.

(3) Enhance pool shelter by adding submerged or partially submerged structures. Consider both upstream and downstream effects due to operation and possible failure.

(4) Install in-stream structures to produce hydraulic variability and to scour pools. Consider both downstream and upstream effects due to operations and possible failure.

RECOMMENDATIONS BASED ON SPATIAL ASSOCIATIONS

(5) Evaluate relationship on-site. Consider channel restoration and drainage improvements for the road and landing. Consider engineered abandonment.

(6) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible. Consider stream bank stabilization where feasible.

(7) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible.

(8) Evaluate on-site whether these represent natural background conditions. If mitigation is desired, road construction may be needed for equipment access.

(9) No recommendation because potentially associated active sediment sources have not been identified.

EXPLANATION FOR POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS FOR THE GUALALA RIVER WATERSHED MAP

NOTE: See Plate 3 for complete description of map.

Produced in cooperation with the California Department of Fish and Game, California Department of Forestry and Fire Protection, and the North Coast Regional Water Quality Control Board.

www.fire.ca.gov www.dfg.ca.gov www.conservation.ca.gov/cgs

Figure 5.4-19b
Explanation for Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed Map

5.4.10 BUCKEYE SUBBASIN PUBLIC ISSUES, SYNTHESIS, AND RECOMMENDATIONS

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala River Watershed residents and constituents. The following general concerns were expressed as potential factors affecting the Buckeye Subbasin and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.

- No current salmonid or other fish population data exist. Very limited historical data exist.
- There is concern over abandoned roads, new road construction, and road maintenance issues related to landsliding and sediment input. Without appropriate maintenance or storm proofing, existing roads, both active and abandoned, may continue to supply sediment.
- Best management practices required by current forest practice rules are reducing forestry impacts to insignificance.
- Summertime water temperatures are a concern for salmonid suitability.
- The paucity of large woody debris in streams, especially in the mainstem, is a concern. Low canopy coverage is effecting water temperatures and large wood recruitment.
- Subdivision construction is not an issue at this time. However, Pioneer Ltd owns a larger portion of the upper subbasin and is in escrow.
- Grazing is a possible issue in the upper subbasin.
- Summertime water temperatures are a concern for salmonid suitability.

Working Hypotheses

The primary purpose of these hypotheses is to elucidate in a succinct format the judgments of the Team regarding watershed conditions relative to anadromous salmonids. As such, they are responsive to the assessment questions (pages 1-1 and 1-2). The findings supporting the hypothesis are presented, along with recommendations for watershed improvements as well as recommendations to further investigate the hypotheses. As such, they are not intended to be the final word, but are the best judgment based on the information at hand.

Recommendations for watershed improvements and further study are presented at the end of the section, as single recommendations apply in many cases to more than one hypothesis.

The working hypotheses are:

1. The mainstem of Buckeye Creek provides generally unsuitable habitat for salmonids.
2. Depleted overstory shade canopy cover along the mainstem of Buckeye Creek and tributaries from past harvests continues to contribute to elevated water temperatures that are unsuitable for salmonids.
3. A lack of in stream large woody debris contributes to a simplified habitat structure (e.g., lack of large, deep pools).

4. Instream and near stream conditions are improving.

Working Hypothesis 1

Stream conditions in the Buckeye Subbasin provide unsuitable habitat for salmonids.

Supporting Findings

- Coho salmon were last observed from a bank observation taken during a stream survey on the mainstem of Buckeye in 1964 and in Franchini Creek in 1970.

- Temperatures on the Buckeye Creek mainstem and 3 of the 4 sampled tributaries ranged from fully unsuitable to undetermined (between suitable and unsuitable) (Table 5.4-3), with 7 of 10 seasonal maximum temperatures above the lethal temperature for salmonids.

- CDFG habitat inventory target values for canopy cover, pool frequency/depth and pool shelter/cover were not met on Buckeye Creek, the only stream surveyed in the Buckeye Subbasin (Table 5.4-7).

- Canopy cover, pool shelter and pool quality EMDS scores were somewhat unsuitable on Buckeye Creek. Embeddedness was somewhat unsuitable on the lower reach. Pool depth was fully unsuitable on this second order stream. The Maximum Weekly Average Temperatures at four sites sampled in 2001 on Buckeye Creek were in the somewhat unsuitable range (Table 5.4-10).

- The Gualala River Watershed Council's Cooperative Monitoring Program identified a lack of large woody debris (LWD) at two sample sites on Buckeye Creek (Table 5.4-8).

- Twenty-seven miles of historic logging and ranchland roads built in or along the streambed eliminated pool structure and complexity throughout the major tributary streams of the Buckeye Subbasin (Figure 5.4-6). Early 1960s air photos showed a high density of road debris slides accessing streams in the Little Creek, Grasshopper, and Flat Ridge Creek PWSs (Appendix 2).

- Mid-20th-century roads and landings built in or near the main channel may still be contributing excess sediment (this may be true where channel braiding and/or aggradation are persistent) along the mainstem and Flat Ridge, an unnamed tributary below Flat Ridge, Franchini, North Fork Buckeye, and lower Little creeks. The residual effects of channel aggradation from streamside road failures built in the 1950s and 1960s are noted in timber harvest plan records particularly in the Little Creek, Grasshopper, and Flat Ridge Creek Planning Watersheds (Section 5.4.4).

- The length of channels features indicative of "excess" stream sediment in the mainstem Buckeye Creek in the Grasshopper Creek PWS increased from about 25 to 50 percent of channel length from 1984 to 2000. The length of channels features indicative of "excess" stream sediment in Roy Creek increased from 10 percent to almost 25 percent (Appendix 2).

Contrary Findings

- Steelhead trout one year and older were observed on the mainstem of Buckeye and on Franchini creeks (Section 5.4.9).

- Water temperature MWATs on the lower tributary were fully suitable (Table 5.4-3).

- CDFG habitat inventory embeddedness target values were reached on Buckeye Creek, indicating good spawning substrate conditions.
- The embeddedness EMDS score was somewhat suitable on the upper reach.
- Little Creek PWS improved between 1984 and 1999/2000 from 80 percent of main channel disturbance to 50 to 75 percent disturbance. Little Creek itself improved from 80 percent disturbance and 14 delivering landslides to 25 percent channel disturbance and 6 delivering landslides.
- In the Grasshopper Creek PWS, channel disturbance in Franchini Creek decreased from 90 to approximately 50 percent from 1984 to 1999/ 2000, and in lower reach of Grasshopper Creek disturbance decreased from 50-75 percent to 25 percent. Channel disturbance in the mainstem Buckeye Creek below Flat Ridge Creek decreased from up to 75 percent in 1984 to 20 percent in 1999/2000.
- Bank-to-bank exposure has decreased from 58 percent of the blue line streams in 1968 to approximately 22 percent in 2000.

Limitations

- Habitat inventory surveys were conducted on 39 percent of Buckeye Subbasin.
- Water temperatures were available for the period of record (1994-2001) only in the lower 13.5 miles of the mainstem and in Flat Ridge, Franchini, Grasshopper, and Soda Springs creeks, and a small tributary near the mouth.

Conclusion

- The hypothesis is supported.

Working Hypothesis 2

Depleted overstory shade canopy cover along the mainstem of Buckeye Creek and tributaries from past harvests continues to contribute to elevated water temperatures that are unsuitable for salmonids.

Supporting Findings

- Temperatures on the Buckeye Creek mainstem and 3 of the 4 sampled tributaries ranged from fully unsuitable to undetermined (between suitable and unsuitable), (Table 5.4-3) with 7 of 10 seasonal maximum temperatures above the lethal temperature for salmonids. Temperatures in open areas, such as those in the upper, eastern subbasin, were fully unsuitable (Figures 5.4-12 and 5.4-13).
- The Maximum Weekly Average Temperatures at four sites sampled in 2001 on Buckeye Creek were somewhat unsuitable.
- The CDFG habitat inventory canopy cover target value was not met on Buckeye Creek, the only tributary surveyed in the Buckeye Subbasin (Table 5.4-7).
- The EMDS scores for canopy cover were somewhat unsuitable on Buckeye Creek (Table 5.4-10).
- Post World War II construction of roads, landings, and skid trails in riparian zones by crawler tractors eliminated overstory shade canopy cover throughout long sections of Buckeye Creek

and tributaries. There was near entire canopy elimination in the Buckeye Subbasin, with operations especially pronounced during the late 1950s to 1964 (Figures 5.4-6 and 5.4-9).

- Twenty-five percent of the blue line streams still had bank-to-bank exposure (open canopy) in 1999 photos (Figure 5.4-9) compared with 2 percent in 1942 pre-harvest photos.

- Contrary Findings

- Bank-to-bank canopy cover has improved on upper Buckeye, Osser, Little and Flat Ridge creeks (Figure 5.4-9), and has decreased overall in the subbasin from 60 percent exposure in 1968 photos.

Limitations

- Water temperatures were available for the period of record (1994-2001) only in the lower 13.5 miles of the mainstem and in Flat Ridge, Franchini, Grasshopper, and Soda Springs creeks, and a small tributary near the mouth.

- Habitat inventory surveys were conducted on 39 percent of Buckeye Subbasin.

Conclusion

- The hypothesis is supported.

Working Hypothesis 3

A lack of in stream large woody debris contributes to a simplified habitat structure (e.g., lack of large, deep pools).

Supporting Findings

- CDFG habitat inventory targets for pool frequency/depth and pool shelter/cover target value were not met on Buckeye Creek, the only stream surveyed in the Subbasin (Table 5.4-7).

- The EMDS scores for pool shelter and pool quality were somewhat unsuitable on Buckeye Creek. Pool depth was fully unsuitable on this second order stream.

- The Gualala River Watershed Council's Cooperative Monitoring Program identified a lack of large woody debris (LWD) at two sample sites on Buckeye Creek (Table 5.4-8).

- Historic and recent timber harvest has reduced the available recruitment supply of large woody debris (see findings in Hypothesis 2, above).

- Dense buffers of conifers large enough to function, upon recruitment, as LWD in channel formation processes have not been fully reestablished (Section 5.4.4).

Contrary Findings

- None noted.

Limitations

- Habitat inventory surveys were conducted on 39 percent of Buckeye Subbasin.

Conclusion

- The hypothesis is supported.

Working Hypothesis 4

Instream and near stream conditions are improving.

Supporting Findings

- Little Creek improved between 1984 and 1999/2000 from 80 percent of main channel disturbance and 14 delivering landslides to 25 percent channel disturbance and 6 delivering landslides.
- In the Grasshopper Creek PWS, channel disturbance in Franchini Creek decreased from 90 to approximately 50 percent from 1984 to 1999/ 2000, and lower reach Grasshopper Creek disturbance decreased from 50-75 percent to 25 percent.
- Channel disturbance in the mainstem Buckeye Creek below Flat Ridge Creek decreased from up to 75 percent in 1984 to 20 percent in 1999/2000.
- Bank-to-bank canopy cover has improved on upper Buckeye, Osser, Little and Flat Ridge creeks (Figure 5.4-9), and has decreased overall in the subbasin from 60 percent exposure in 1968 to 25 percent exposure in 1999/2000 photos.

Contrary Findings

- Above the Flat Ridge Creek junction, similar channel disturbance levels were observed in 1999/2000 compared to 1984.
- Twenty-five percent of the blue line streams still had bank-to-bank exposure (open canopy) in 1999 photos (Figure 5.4-9) compared with 2 percent in 1942 pre-harvest photos.

Limitations

- Habitat inventory surveys were conducted on 39 percent of Buckeye Subbasin.

Conclusion

- The hypothesis is supported.
- Overall levels of channel disturbance have improved since 1984.
- Canopy coverage as measured by bank-to-bank exposure has improved since 1968, but not to 1942 levels. More information on the improvement with regard to riparian composition over the period of photo records is needed to discuss improvement in the riparian zone beyond canopy coverage.

Buckeye Subbasin Recommendations

Target restoration and land use activities to the three highest priorities for restoration in the Buckeye Subbasin: large wood placement, road repair or removal, and riparian canopy development.

1. Enhance instream structure, including large woody debris:

    a. Land managers in this subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. Pool shelter is the most limiting factor in the Buckeye Creek, the stream surveyed in

the subbasin. Instream structure enhancement is the first of the top three recommendations.

b. Enhance large woody debris through short and long-term efforts through (1) ongoing large wood placement efforts, and (2) enhancement of the natural large woody debris recruitment process by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques.

c. Support ongoing large wood placement efforts.

2. Address road issues.

a. Landowners should develop erosion control plans for decommissioning old roads, maintaining existing roads, and constructing new roads. Decommission and revegetate streamside roads where feasible, focusing on those associated with unsuitable fish habitat conditions such as Little, Franchini, Grasshopper, and Osser creeks.

b. Size culverts in steep terrain to accommodate flashy, debris-laden flows and maintain trash racks to prevent culvert plugging. Critical dips should be required to minimize the potential for culvert failure.

c. Evaluate the possibility of spreading timber-harvesting operations over time and space to avoid concentrated road use by heavy equipment and resultant mobilization of road surface fines into watercourses.

d. Incorporate mitigation elements into Timber Harvest Plans and pursue cost share grants for decommissioning legacy streamside roads and upgrading road drainage facilities.

e. Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 53 percent of the subbasin.

3. Address riparian canopy issues.

a. Ensure that adequate streamside protection zones are used on Buckeye Creek to reduce solar radiation and moderate air temperatures, particularly on mainstem.

b. Maintain and enhance riparian zones to achieve target canopy density and diversity, including large confiers for LWD recruitment. Ensure that adequate streamside protection zones are used on Buckeye Creek to reduce solar radiation and moderate air temperatures, particularly on mainstem and upper tributaries. Retain, plant, and protect trees to achieve denser riparian canopy where current canopy is inadequate, particularly on the mainstem and Franchini, Grasshopper, and Soda Springs creeks.

c. Collect data to evaluate and possibly model relationship between water temperature and canopy levels where canopy is still recovering to establish reasonable recovery targets.

4. Monitor instream and hillslope conditions.

a. Conduct both instream and hillslope monitoring to determine whether current timber harvest practices are allowing for recovery and protection of the salmonid

habitat in the subbasin. Use GRWC potocols for instream monitoring activities. Improve baseline information on habitat conditions by conducting inventory surveys in Buckeye Creek major tributaries.

b. Expand continuous temperature monitoring efforts into the upper subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.

c. Encourage more habitat inventory surveys and biological surveys of tributaries as only 37 percent of the mainstem Buckeye has been completed.

d. Survey for salmonids, using consistent methods to estimate population numbers, for comparison with recovery targets to be set by NMFS.

5.5 Wheatfield Fork Subbasin

5.5.1 INTRODUCTION

The Wheatfield Fork Subbasin (Wheatfield Fork Hydrologic Subarea, Calwater 113.84 hydrologic subarea) has 246 miles of "blue line" stream in 111.6 square miles in the middle and eastern portion of the Gualala River Watershed. It consists of three Calwater 2.2a SPWSs: Walters Ridge (113.8401, 38.3 square miles), Hedgepeth Lake (113.8402, 28. 5 square miles), and Lower Wheatfield Fork (113.8403, 44.8 square miles). Most of the subbasin is privately owned (166 acres of federal land), with land uses in timber production, grazing, vineyard, and some rural subdivisions.

A stream flow gage was installed in 2001 near the confluence with the South Fork Gualala (Station GWF, Wheatfield Fork near Annapolis). It is maintained by California Department of Water Resources (DWR) and has been in operation since installation. Stream flow and water temperature data are available by accessing the California Data Exchange website at http://www.cdec.water.ca.gov.

Historic events and the period of record on the various data sets used in the NCWAP assessment are presented in a graphic format in Figure 5.5-2.

5.5.2 GEOLOGY

Mélange of the Franciscan Complex underlies oak savanna woodland in the eastern headwaters. Large areas of active earthflows and other forms of landsliding are abundant and contribute sediment to the streams (Figure 5.5-3). Figure 5.5-4 shows the relative landslide potential map for the Wheatfield Fork Subbasin. The complete maps and explanations for both maps are on Plates 1 and 2. The steep tributaries in the upper reaches can be characterized as source (>12 percent slope) and transport (4-12 percent slope) reaches. Table 5.5-3 lists the lengths of sediment storage mapped and relative change between 1984 to 1999/2000 for the Wheatfield Fork Subbasin.

In the lower reaches of the subbasin, streams are mainly bedrock controlled within moderately steep valleys. The narrow floodplain is limited to the lower 2 miles.

5.5.3 VEGETATION

The 1942 photos show dense mature Douglas fir and redwood timber bordering both sides of the lower reaches of the Wheatfield Fork mainstem. However, in 1942, the river frequently shifted back and forth to the opposite stream bank throughout an aggraded channel valley. Despite the large standing timber flanking the streambank, the channel is wide enough to still create longer sections of bank-to-bank canopy exposure from the South Fork upstream to the confluence with Tombs Creek allowing for long term warming (Figure 5.5-5). The main tributary watercourses were largely covered. There was dense coniferous canopy cover over Fuller, Tobacco, and Haupt creeks. There was partial to entire canopy cover over the more inland locations including North Fork Wheatfield, Tombs and House creeks. These were consistent, with partial to entire oak-woodland cover along riparian channels in the dense mélange soil type.

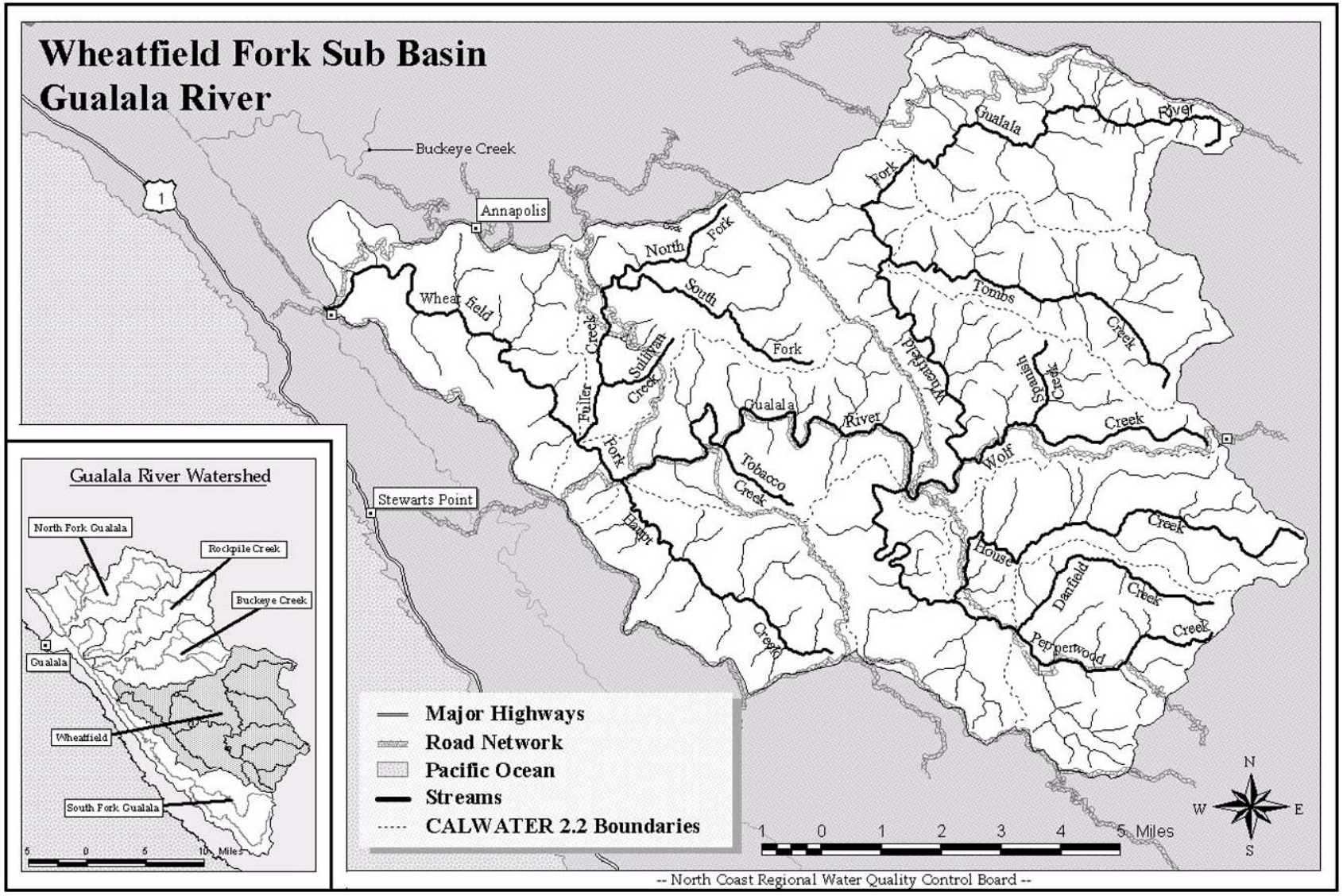


Figure 5.5-1
Wheatfield Fork Subbasin

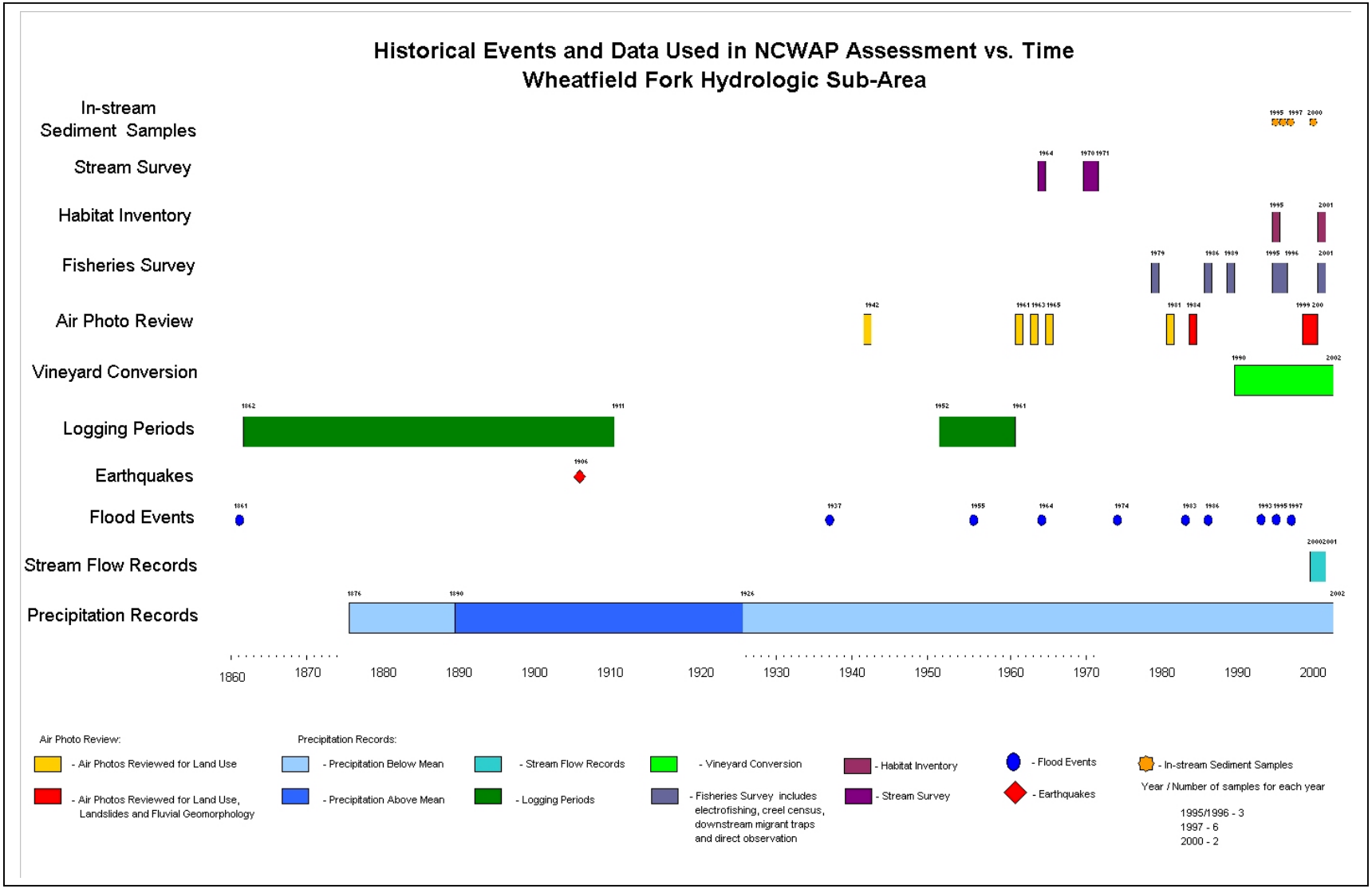


Figure 5.5-2
Historic Events and Data Used in the NCWAP Assessment for the Wheatfield Fork Subbasin

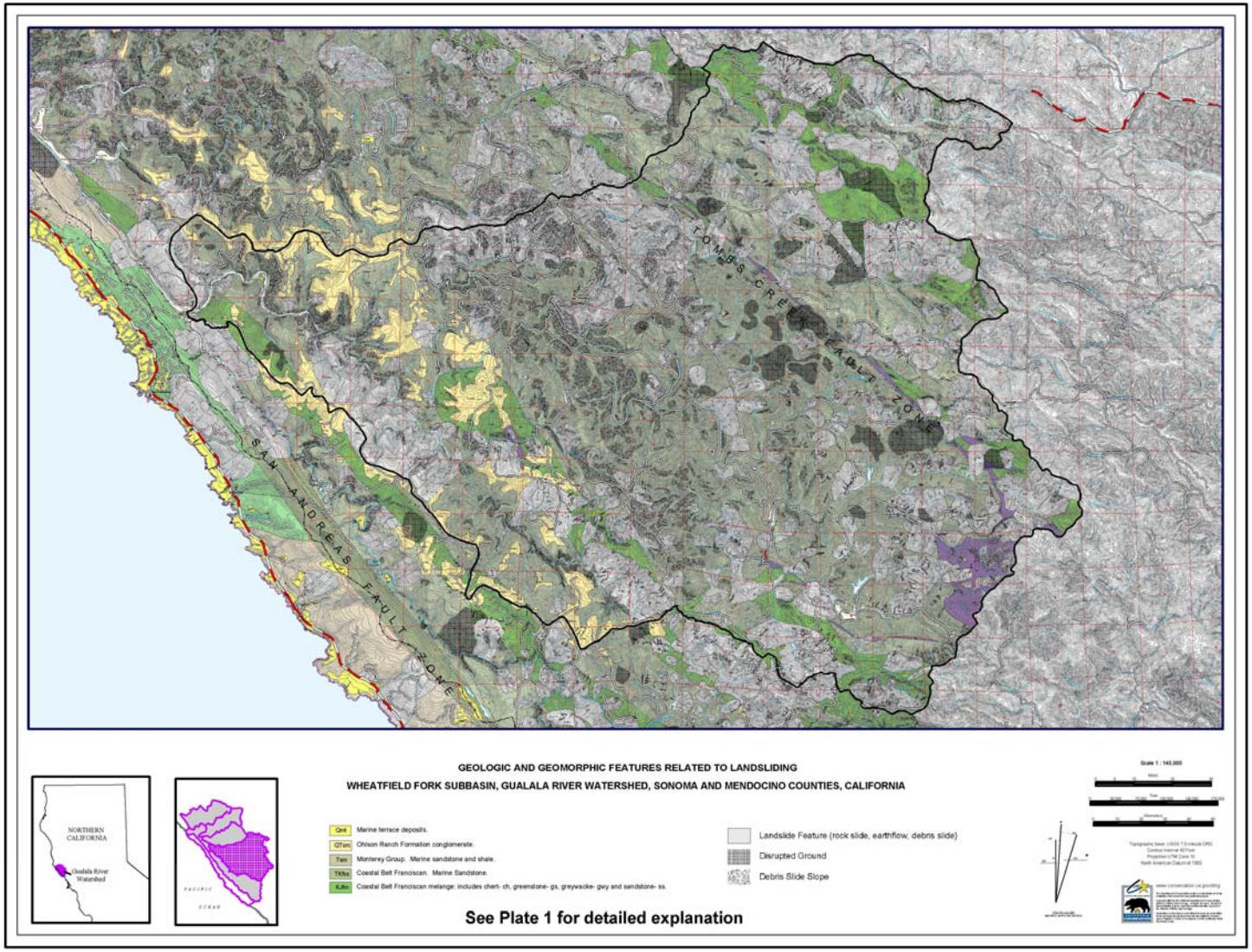


Figure 5.5-3
Geologic and Geomorphic Features Related to Landsliding - Wheatfield Fork Subbasin

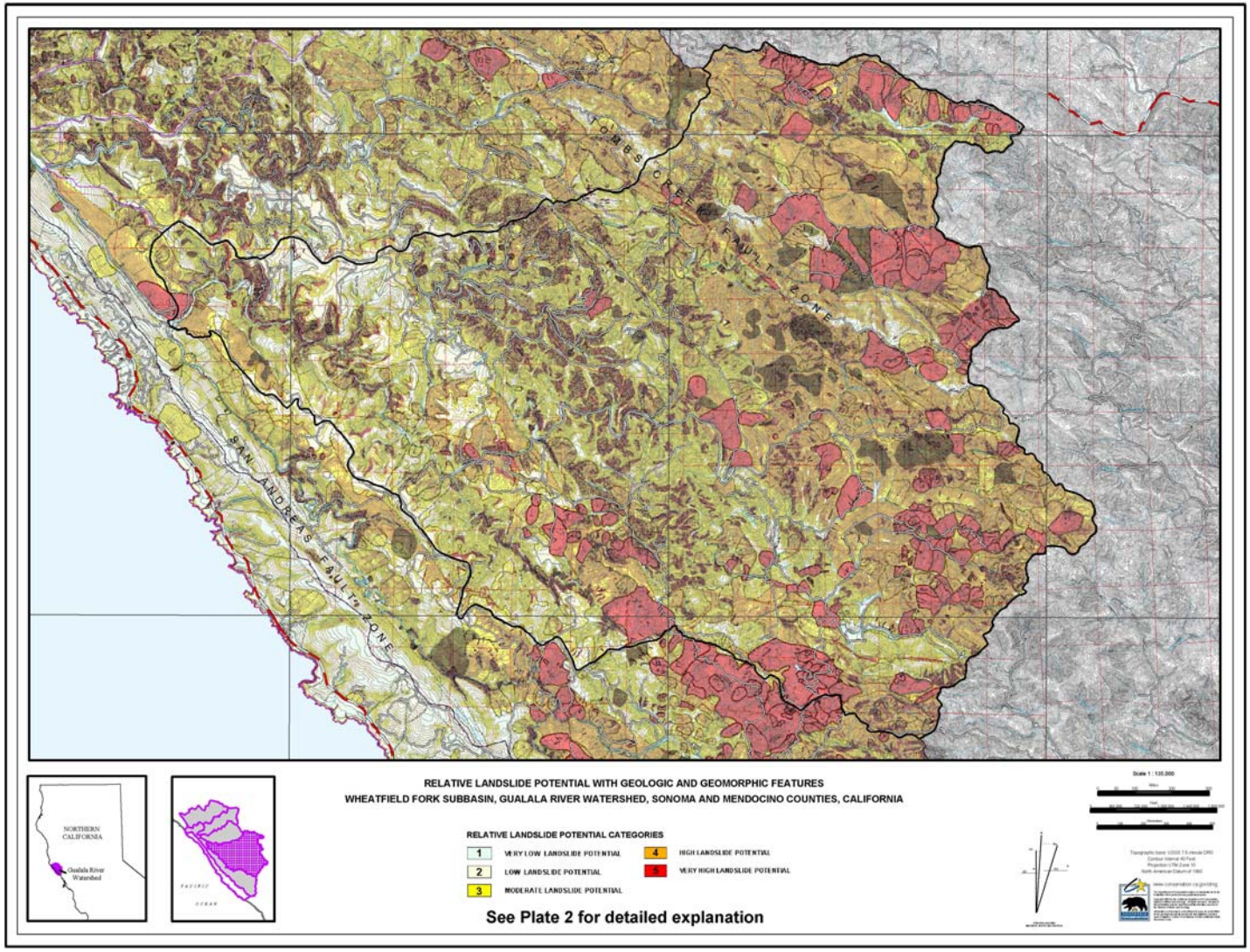


Figure 5.5-4
Relative Landslide Potential with Geologic and Geomorphic Features - Wheatfield Fork Subbasin

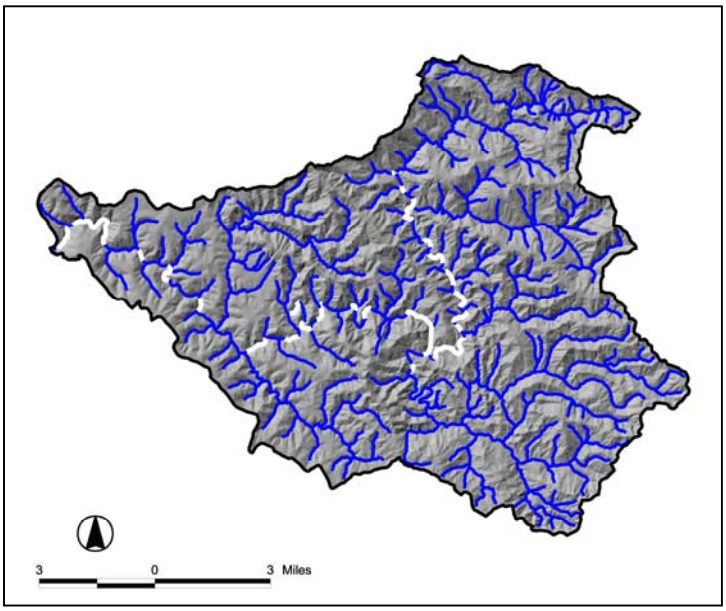


Figure 5.5-5
1942 Bank-to-Bank Exposure (White), Dark Blue Shows Partial to Entire Canopy Cover

5.5.4 LAND USE

Timberland use and ranching have been the dominant land use practices in the Wheatfield Fork Subbasin. Mid-20th-century to pre-1973 tractor method harvesting was the dominant land use era. Original turn-of-the-century steam donkey operations were limited to the lowest reaches of the subbasin at the confluence with the South Fork. Between 1952 and 1960, 15,850 acres were harvested (21 percent of the subbasin). After 1960, harvesting tapered off, with 4,650 acres harvested by 1964, and 2,250 acres by 1973 (Table 5.5-1).

The highest timber site ground occupies the lower reaches within the coastal fog influence. After World War II, these areas were logged first in the early 1950s, south of Knob Hill and flanked by Burnt Knoll Ridge to the east. During the middle to later 1950s, proximity to coastal transportation routes confined logging operations to the lower reaches of Fuller, Tombs, and House creeks. Tractor logging operations then spread east and north when road networks were built inland. The late 1950s, and early 1960s were the most active harvests in the North Fork of the Wheatfield, Tombs, and House creeks (Figure 5.5-7). Timber clearance and road building, followed by prolonged rangeland use, were the dominant practices in this portion of the subbasin, most evident in the Pepperwood Creek tributary to House Creek (Figure 5.5-6).

Figure 5.5-8 shows Tobacco Creek (right) incised through the instream landing (upper left) creating a canyon on the discharge side (red arrow). There were large storm events in 1962 and 1964 prior to this 1965 photo.

Inner riparian areas were the central locations for road building, tractor yarding, and timber removal. In the steep, deeply incised Sullivan and Fuller Creek canyons, the entire road network was built along the creek at the base of steep ravines. Streamside roads and landings are particularly concentrated along Tobacco Creek, lower House Creek, central North Fork Wheatfield, and central to higher Tombs creeks. As a result, 1965 aerial photo analysis found that high runoff from the 1964 storms incised instream landings and undercut streamside roads, collapsing sections into creeks. The

roads concentrated runoff triggering debris slides into watercourses. Storm damage from similar peak flow events in 1962 and 1966 was not evaluated due to a lack of air photo coverage. Mid-20th-century logging operations removed riparian canopy cover leaving bank-to-bank watercourse exposure throughout the larger tributary watercourses by 1968 (Figure 5.5-9). Stream canopy elimination was most pronounced in Fuller, Haupt, Tobacco, Elk, House, and Pepperwood creeks.

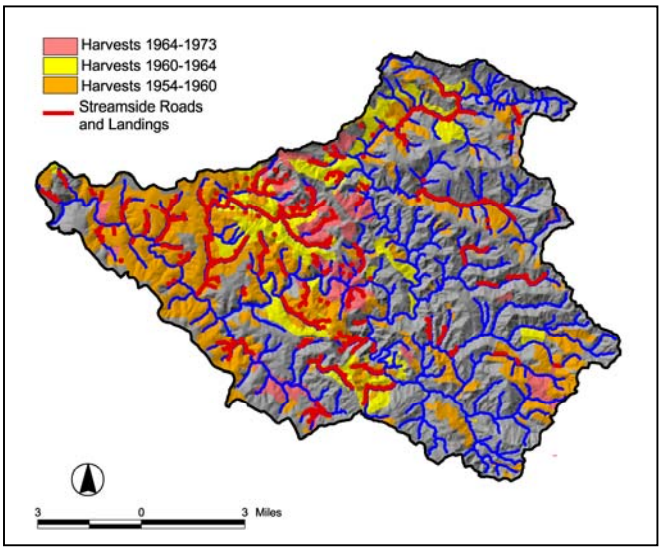
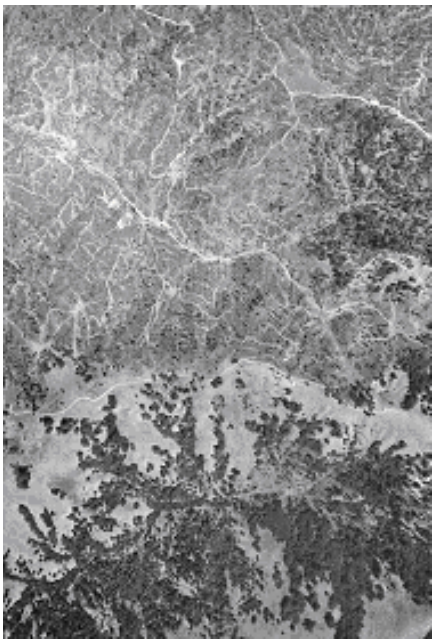


Figure 5.5-6
Mid-20th-Century Timber Harvest Operations and Streamside Roads and Landings (Red)



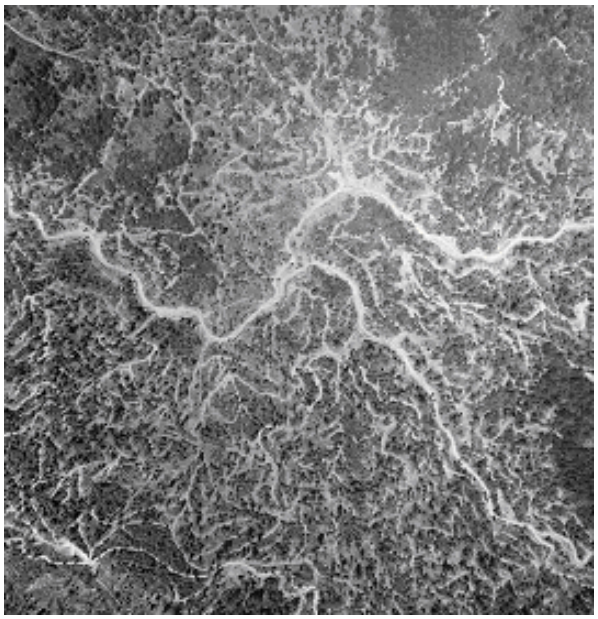


Figure 5.5-7
Conifer Block Removal Exposing Tobacco Creek (Left) and Streamside Roads Along the North Fork Fuller Creek (Right) 1965 Caltrans 1: 1200 Scale

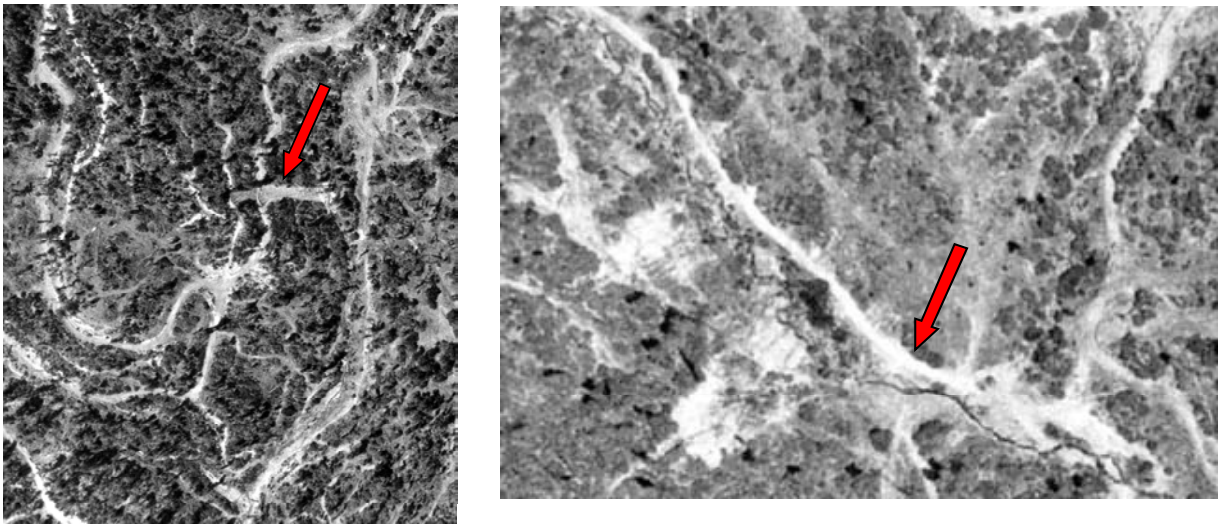


Figure 5.5-8
Debris Slides (Left) Slice Through Several Road Contours, Discharging onto a Tributary Watercourse to Wheatfield Fork, at Annapolis Fire Station, 1965 (Lower Left)
Tobacco Creek (right) incised the instream landings (red arrow) creating a canyon on the discharge side.

Sullivan Creek follows a fault that separates the Coastal and highly erodible Central Belts of the Franciscan Formation and crosses the poorly consolidated Ohlson Ranch Formation. As a deeply incised canyon, the haul road was built along the creek. By 1984, this debris had washed downstream. Sullivan Creek returned to a linear drainage. Much of this debris is probably still deposited and stored in the active channel deposits of gravel bars and/or historic terrace deposits along the aggraded substrate of lower Wheatfield Fork, one quarter mile downstream.

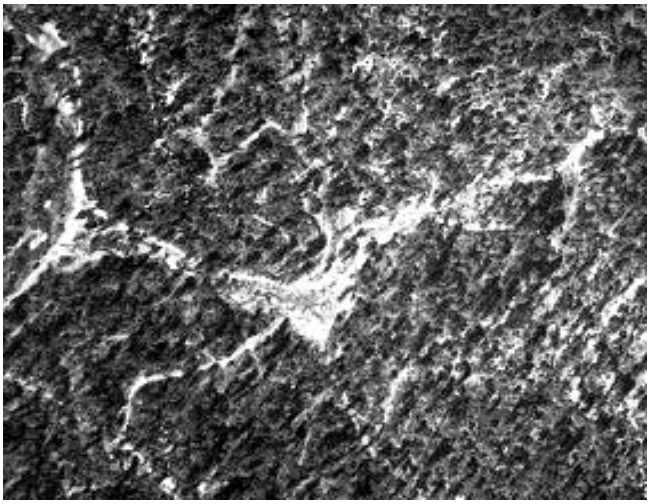
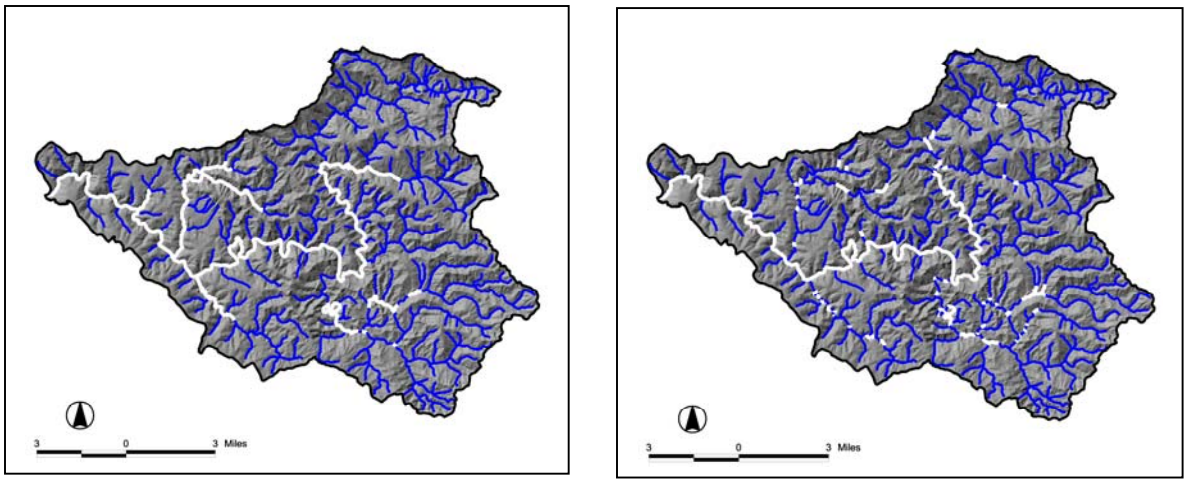


Figure 5.5-9
Sullivan Creek Meanders Around Multiple Debris Slides Over Buried Stream Pools, June 1965

Table 5.5-1
Wheatfield Fork Subbasin Timber Harvest Operations 1932 – 1973 - Total Area = 74,444 acres.

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Tractor Operations Since 1942	Mean Annual Increment (acres/ percent by year)
1932 – 1942	750	Stand Replacement	1.0	75 (.1)
1943 – 1952	1,350	Stand Replacement	2.9	135 (.2)
1953 – 1960	15,850	Stand Replacement	23.0	1,981 (2.5)
1961 – 1964	4,650	Stand Replacement	29.4	1,162 (1.4)
1965 – 1973	2,250	Stand Replacement	32.4	225 (.3)

Approximately 10 percent of the blue line streams in 1942were exposed bank-to-bank (Figure 5.3-5), that was limited to the alluvial openings in the lower subbasin reaches throughout predominantly old growth wooded conditions. By the end of the tractor-harvesting era (1968), approximately 45 percent of the blue line streams were exposed bank-to-bank. Bank-to-bank overstory exposure for 2000 shows improvement compared to 1968, reflecting riparian in-growth since the late 1960s. By 2000, canopy cover improved with approximately 30 percent of blue line streams exposed bank-to-bank (Figure 5.5-10). Streamside canopy in these areas now consists of pole- to mid-sized conifers and mixed conifer/hardwood stands. Regeneration has been delayed by grazing in some of the eastern subbasin reaches.



1968 **1999**

Figure 5.5-10
1968 Bank-to-Bank Stream Exposure. 1999 Bank-to-Bank Shade Canopy Exposure

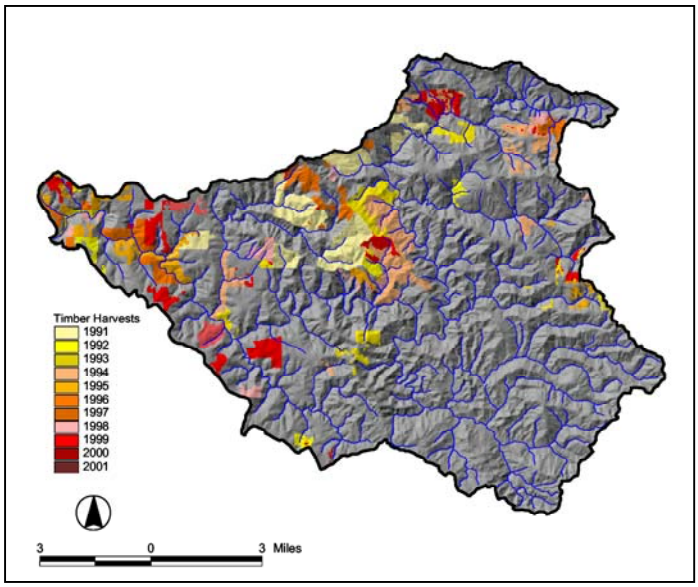
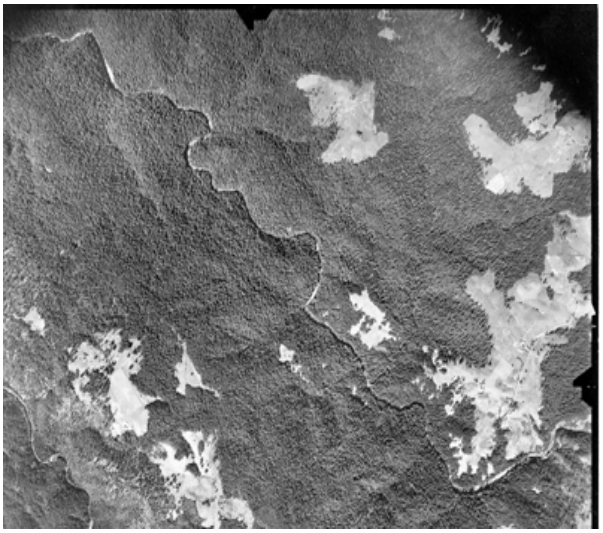
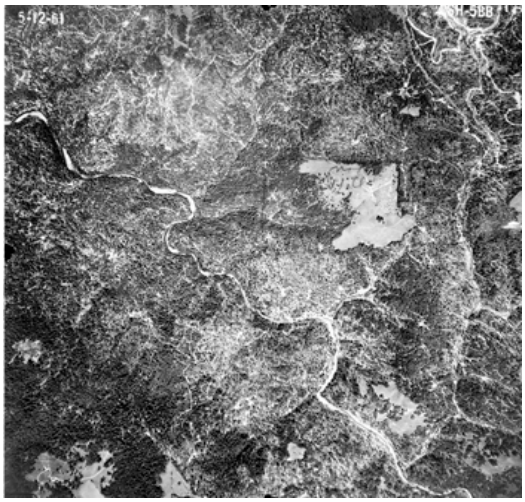


Figure 5.5-11
1991 to 2001 Timber Harvest Plans



1942 lower Wheatfield Fork, Fuller Creek (right). The 1936 and 1942 photos were used to show baseline conditions of riparian cover. Large tracts of old growth redwood and Douglas-fir dominated the middle reaches of Rockpile, Buckeye, and Wheatfield basins by 1942.



1961 Starting during the mid 1950s, early versions of the D-8 and D-10 tractors block-cleared the entire lower Wheatfield Subbasin. Tractors roamed up and down smaller creeks, and built roads and landings in or along larger streams. The lack of any erosion control measures in these areas made large parts of watershed vulnerable to large storm events. Tractors eliminated riparian canopy cover and in stream Large Woody Debris. There were still consistent coho salmon and larger steelhead counts during this time period.

1984 Young conifer in-growth reestablished vegetative cover, although storm run-off continued to concentrate along streamside legacy roads and skid trails. Pool infill, shallow pool structure, stream simplification, and increasing embeddednes impaired anadromous fisheries habitat. CGS mapped stream channel disturbances in addition to landslide densities using the 1984 aerial photos. Stream surveys indicate fewer anadromous fisheries resources.

1999 The area is now more fully vegetated. Streamside legacy roads and landings have increasingly stabilized. Deep road and skid trail gullies may have incised down to rock or hard clay. CGS generally found fewer stream channel disturbances compared to 1984. Road related debris slides generally diminished. The Gualala River Watershed Council has removed many of the old log chunk/ dirt fill road stream crossings in Fuller Creek (right).

The 1970s and 1980s were a period of low timber harvest activity due to depletion of the timber base in previous decades (Table 5.5-2). Ranching became a more dominant land use. Vegetational analysis in 1996 typed 6,004 acres of grazing lands (8.4 percent of the subbasin). Timber harvest operations increased in the 1990s in response to improving markets (Figure 5.5-11). Vineyard development also accelerated. Numerous vineyards are located in the east, upland portions of the subbasin. However, 1996 vegetational analysis found that vineyards consist of small patch clearances diffusely scattered throughout the central and each portions of the watershed. Vineyards typically range from 10 to 40 acres, and rarely exceed 100 acres. Total agricultural development consists of 195 acres (0.3 percent of the subbasin). In addition, California Department of Forestry and Fire Protection (CDF) timberland conversion files show a total of approximately 500 acres of timberland converted to vineyards throughout the entire Gualala River Watershed.

Table 5.5-2
Wheatfield Fork Subbasin Timber Harvest Operations 1974 – 2001 -Total Area = 74,444 acres

Time Period	Acres Under Operation	Type of operation	Cumulative Percent of Subbasin Under Operation Since 1974	Mean Annual Increment (acres/ percent by year)
1974 – 1990	3,350	Stand Replacement	4.5	209 (.3)
1991 – 2001	7,150	THPs	14.170% tractor, 30% c	715 (.9)

5.5.5 ROADS

Historic Roads

Mid-20th-century instream/streamside road and landing networks spanned most tributary streams in the Lower Wheatfield Super Planning Watershed (SPW). This included Fuller, Tobacco, Haupt, and smaller unnamed tributaries leading to the mainstem. Streamside roads lined major portions of Tombs, Elk, and smaller tributaries in the Hedgepeth Lake SPW, and lower House, Pepperwood and Danfield creeks in the Walters Ridge SPW. A total of approximately 19 miles of road were build at near or equal elevation to the streambank transition line with sidecast covering the streambank leading to the creek. The dense network of instream/streamside roads that lined Fuller, Tobacco, Haupt, and Elk creeks showed a high correlation with stream braiding and aggradation (over 75 percent) in 1984. Roads located slightly upslope but near the creek, span longer distances (not measured with this study). After 1968, most of the streamside roads were unused and left abandoned. Some sections have been incorporated with the modern road network.

Stream channel morphology in the Wheatfield Fork Subbasin shows similar evolution through time, but most evident in the Lower Wheatfield SPW: (1) a high density of fresh sediment inputs shortly after mid-20th-century storm events characterized by debris mounds in the active channel, (2) progressive abatement of the frequency of these point sources over successive decades, and (3) apparent recovery of instream channel conditions between 1984 and 2000 as evidenced by a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. The 1965 photos show extreme stream channel aggradation along major tributary streams of the Lower Wheatfield Super Planning Watershed (Figure 5.5-7). Throughout Fuller, Sullivan, Tobacco, and Haupt creeks, the sinuous stream channel patterns through the logged areas show either (1) channel meandering through wide, flat areas of sediment fans in low gradient steps, or (2) stream deflections around fresh debris slides. Multiple road debris slide failures triggered by large storm

events represented the largest mid-20th-century sediment sources (Figure 5.5-8). Meandering channel patterns returned to a more lineal pattern through 1984 and more so by 1999. This indicates decreasing bedload and a move toward recovery of the streambed. CGS fluvial geomorphic mapping of stream conditions documents that the channel conditions have improved from 1984 to 2000 throughout the watershed. Most of the stream segments throughout the Wheatfield Fork Subbasin show a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources.

Modern Roads

Successive air photo overlays show a shift in new road construction to ridgelines and mid-slope benches. The "ICE" contemporary road map shows most of the current roads located distant from watercourses. The entire road network in the Wheatfield Fork Subbasin comprises 444 miles at a density of 4.1 miles/square mile. About 3 miles of modern roads are located within 50 feet of blue line streams. Of these roads, about 1.5 miles total length are in areas that may be affected by historically active landsliding and stream bank erosion. The largest amount of roads in historically active landslide areas unrelated to streams occurs in the Wheatfield Fork Subbasin with approximately 37 miles, in proportion to about 80 miles total in the watershed.

Although the current road network shows less overall coincidence of debris slides and stream crossing failures compared to historic times, most of the contemporary road failures are in close proximity to streams and steep slopes. Approximately two miles of the modern roads cross steep slopes (excess of 60 percent). Substandard road networks were undoubtedly vulnerable to large storm events, particularly during the 1986 and 1996 water years. There are 1.4 road crossings per stream mile. The actual extent of road damage is less documented on non-timber production zone lands. With only 14 percent of the subbasin subject to Timber Plans since 1991, additional road repair and upgrade work is indicated. Haupt, Tobacco, Tombs, and Pepperwood creeks are recommended as the highest priority in restoration work in this assessment. The GRWC has storm proofed most of the Fuller Creek watershed by upgrading or abandoning a total of 39 miles or road, saving an estimated 40,000 cubic yards of annual discharge. Streamside roads and landings have been stabilized/ abandoned throughout major portions of Elk Creek.

Land Use Impacts Documentation

Fuller Creek

- The Fuller Creek Subbasin consists of steep, deeply incised terrain, with upper reaches characterized by inner gorge ravines. In the lower reaches, there has been deep downcutting by Fuller Creek between plateau areas of moderate to near level terrain upslope. The upper subbasin, including North and South forks, were mostly logged by between 1960 and 1964. The lower reaches south of Fuller Mountain were logged during the mid to late 1950s (Figures 5.5-6 and 5.5-11). Main haul roads were all built along the creek channel at the base of steep terrain. Large instream landing complexes were built by filling the channel with wood debris chunks topped with dirt. Skid trails were constructed in streams and draws, and surface flows were concentrated and diverted. High runoff during storm events caused massive erosion by downcutting, slides, and washing of soil and debris into watercourses. More recently, there has been concentrated restoration work to stabilize sediment sources.
- Four large debris flows are apparent in the 1965 photos. These slides originate from areas that were severely disturbed by logging. By 1984 these slides were obscured by revegetation.

Active landsliding is most abundant along the South Fork of Fuller. An unmaintained logging road parallels the creek on the north side. The road is generally 20-30 feet above the creek, with steep slopes. The road has been obliterated by debris slides. The 1961 photos show minimal active slide movement prior to harvesting. The 1942 photos show dense mature wooded cover with few visibly apparent active slides. Similarly, the South Fork contained dense mature conifer cover, which was logged by 1964. To this day, sideslopes along the South Fork continue to discharge sediment into the creek. The roadbed is actually intercepting large volumes of sediment. Field inspection of two of the delivering debris slides revealed that the one consisted mainly of coarse gravel and the other consisted mainly of crumbly shale that would readily decompose into fines. The streambed below these slides consisted of coarse gravel and cobbles and did not seem excessively sediment impacted.

- By 1968, a massive debris slide breached two road spans contouring steep terrain in the South Fork. Starting from the Fuller Mountain Ridge, the slide mass flowed down into the South Fork, creating a lake. This later breached, leaving a waterfall appearance in the channel.

Tobacco Creek

- The main road was built along Tobacco Creek with series of landings in or adjacent to the main creek. High runoff from storm events incised each of these landings cutting deep vertical gorges and creating canyons on the discharge side (Figure 5.5-8).
- By 1964, harvest operations advanced east of the Tobacco Creek area to the higher reaches of an adjacent larger order stream flowing down a ravine to the Wheatfield Fork. High runoff from storm events triggered a long torrent slide all the way down the creek through a mature timbered tract discharging into Wheatfield Fork. By the late 1960s, a haul road was built over the torrent slide and following the creek
- Three large dormant landslides line the creek.

Haupt Creek

- The first logging occurred in the late 1800s to early 1900s with steam donkeys. Ben May Lumber Company was the first major landowner. The lower portion of Haupt Creek was logged during the late 1950s. Most remaining areas upstream were logged by 1970.
- The creek runs through the Coastal Belt Franciscan and forms a steep inner gorge with debris slide slopes. The aggradation point causing subsurface stream flow in lower Haupt had washed downstream by 1970.
- Currently, the Louisiana Pacific Sustained Yield Plan (LP SYP) describes the main channel of Haupt Creek having relatively low structural diversity with long shallow stretches and only occasional pools. Heavy aggregation is not indicated. Historically active landsliding has been limited to small (< 100 foot greatest dimension) events. Haupt Creek is highly responsive to rainfall probably because of its steep narrow inner gorge (98-281 MRC). A major tributary Class II in the lower south bank of Haupt was used as a skid trail prior to 1970, downslope of Tin Barn Road.

North Fork Wheatfield (upstream from Tombs Creek)

- Downslope areas along the Mainstem North Fork Wheatfield, flanked by Bear and Gibson ridges, were tractor logged during the late 1950s. This reach cuts a steep valley across Central Belt terrain and is flanked on both sides by earthflows. Upslope areas were logged by 1964. Tractor skid trails were excavated throughout deeply incised terrain along the North Fork. No active slide areas are apparent in 1942 photos. The 1964 photos show numerous steep inner

channel debris slides along the North Fork among recently logged areas. During the 1964 flood, one watercourse diverted onto the haul road, discharging at the headwall of one the larger slides. Another major watercourse diversion onto roads is noted in this area. An earthflow and rockslides are notable along the stream. Shallow debris sliding is common in the steep canyon, mapped as debris slide slopes.

- The northeast corner of the watershed was logged from 1991 through 1997, and is the most heavily roaded area. The remaining portion of this part of the watershed was helicopter logged due to steep terrain. Ridge tops were converted to orchards or vineyards.

Elk Creek

- Elk Creek, tributary to the higher reaches of North Fork Wheatfield, was used historically for livestock grazing (the Tabor Ranch. Mixed conifer/hardwood stands developed in response to clearing and burning operations with intent to convert to rangeland. Elk Creek was heavily impacted by tractor operations in the 1950s and 1960s. Upper segments of Elk Creek were used as skid trails with instream landings at road crossings, and logging debris and soil was placed in streambeds. Flushing of this material continues with peak flow events. An existing road adjacent to a Class II watercourse was abandoned with the new road relocated to the ridgeline (93-436 CFL). Five stream diversions onto roads were repaired (92-382). The streambank rehabilitation work was directed by J. Monschke.

Tombs Creek

- The subbasin is underlain by the Central Belt of the Franciscan Formation, containing a high concentration of landslides, many of which are active.
- Upper Wheatfield and Tombs Creek were timber harvested to convert to grazing land in larger areas of the subwatershed. Sedimentation and accumulation of organic debris was observed in stream channels during original tractor logging during the late 1950s and 1960s (CFL 97-158). Conversions to pastureland have been the dominant form of historical use. Tractor skidding down watercourses removed overstory canopy cover with intent to maintain permanent conversion for grazing use.

House Creek

- A large portion of the alluvium is out of the active channel. This terrace occurs approximately at the toe of a large active landslide. Some of the coarse material may have derived from the slide. The bedrock terrace may represent a localized uplift or tilting, perhaps due to deep-seated forcing of the landslide against the bank. For example some slides move by rotation about a horizontal axis. Therefore, in rotational slides, the toe area may become somewhat elevated. This has not been confirmed for this site.
- In the lowest reaches of House Creek near Wheatfield Fork, roads were built up several Class I tributary watercourses during the late 1950s throughout a larger timbered tract flanked by Skyline Ridge. Peak flows during storm events removed several sections of the road.
- In the highest reaches of the House Creek watershed, upstream of the confluence with both Brink and Cedar creeks, Douglas-fir tracts on north facing slopes were entirely removed during the mid 1950s. Long sections of riparian areas were entirely cleared of all overstory canopy cover with intent for conversion to rangeland. Lack of erosion control facilities created gully erosion noted in 1965 photos.

Pepperwood Creek (Tributary to House Creek)

- In the headwaters of Pepperwood (Oak Mountain) landsliding is especially abundant, active, and complex. Downstream in map Sections 15 and 16 the stream cuts into a broad alluvial terrace that is almost 900 feet wide at the confluence with Jim Creek. Much of terrace material is outside of the active channel. This terrace and those along House Creek seem to be isolated remnants of former drainage patterns and may even be related to isolated fluvial deposits along the crest of Kings Ridge about a mile to the south and elsewhere in the uplift. It is uncertain whether the coarse and locally abundant alluvial deposits and bedload result solely from sediment transport within the current stream network from the abundant landslides in the headwaters or from a former system that has been deranged by faulting and uplift and no longer operates.
- Other abandoned areas have regenerated with young conifer/hardwood overstory. Numerous active earthflows occur along large portions of channels. Even more abundant are dormant earthflows that potentially could be reactivated. In each of these landslide-impacted reaches, the channels widen.
- Vegetation has been shaped by repeated fires. There was entirely burned over in 1955, with other subsequent fires up to the present. Conversions to pastureland have been the dominant form of historical use. Tractor skidding down watercourses removed overstory canopy cover with intent to maintain permanent conversion for grazing use. In many areas, soil compaction by heavy cattle access has prevented timely reestablishment of overstory canopy cover on watercourses with recent abandonment of rangeland use.

5.5.6 FLUVIAL GEOMORPHOLOGY

About 60 percent of the subbasin has a high to very high potential for landsliding and represents the major source area for stream sediment (Figure 5.5-4). Instream sediment levels, indicative of disturbance, occur along 56 of 300 miles of the blue line streams in the subbasin. This is a 52 percent reduction compared to levels in 1984. Most of the reduction occurred in the tributaries. The lower Wheatfield Fork in the vicinity of Valley Crossing showed channel lowering over the past several decades.

Table 5.5-3
Wheatfield Fork Subbasin Stream Characteristics Representing Sediment Sources or Storage

Planning Watershed	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Length Miles	Percent Total Stream for Subbasin	Length Miles	Percent Total Stream for Subbasin	Length Miles	Total Length Miles
Hedgepeth Lake						
Britain Creek	4.3	17.8	6.1	25.4	-29.8	24.0
Pepperwood Creek	5.0	20.2	7.3	29.5	-31.4	24.7
House Creek	3.2	18.3	5.6	32.3	-43.5	17.5
Total	**21.8**	**33.0**	**32.3**	**48.9**	**-32.5**	**66.1**
Little Wheatfield Fork						
Haupt Creek	2.5	13.0	7.2	37.7	-65.6	19.2
Tobacco Creek	5.7	19.8	16.2	56.0	-64.6	29.0
Flat Ridge Creek	7.4	34.2	14.1	65.6	-47.8	21.5
Annapolis	5.3	25.2	10.0	47.2	-46.7	21.1
Total	**20.9**	**23.0**	**47.6**	**52.3**	**-56.0**	**90.8**
Walters Ridge						
Buck Mountain	1.8	5.9	7.0	22.5	-74.0	30.9
Tombs Creek	0.5	2.0	4.5	20.0	-89.8	22.4
Wolf Creek	4.6	12.9	12.4	34.9	-62.9	35.6
Total	14.0	15.7	39.1	43.9	-64.2	89.0
Watershed Total	**56.7**	**18.9**	**118.9**	**39.6**	**-52.3**	**300.6**

5.5.7 WATER QUALITY

Water Chemistry

Basic water chemistry data were available from USEPA's StoRet system and NCRWQCB sampling for two sites in the Wheatfield Fork Subbasin: the mainstem Wheatfield Fork at the Berkeley YMCA camp (January 6 and June 3, 1988) and House Creek near the confluence with the Wheatfield Fork (February, May, and June, 2001). All parameters were within the water quality objectives in the NCWQCB's *Basin Plan*, and consistent with measurements in other north coastal streams. It appears that hardness, alkalinity, and conductance in House Creek may be higher than in the mainstem stations. However, the small amount of data available are not sufficient to make a conclusive statement. Appendix 4 contains the raw data and graphs for these stations.

Water Temperature

Water temperature data from continuous recorders were available for 17 sites in the Wheatfield Fork Subbasin (Figure 5.5-12). The period of record from 1995 to 2001 yielded 35 observations for maximum weekly average temperature (MWAT) and seasonal maximum temperature (Table 5.5-4).

MWATs in the mainstem were fully unsuitable. MWATs in Fuller Creek ranged from undetermined to fully unsuitable. MWATs for the other three tributaries ranged from moderately to fully suitable for the period of record (Table 5.5-4, Figures 5.5-13 and 5.5-14).

Seasonal maximum temperatures were above the lethal limit of 75 F at all of the six mainstem sites at one time or another during the period of record (12 of 14 observations). Tributary sites were below 75 F except for two measurements in the upper Fuller Creek in 1997 and 1998.

Table 5.5-4
EMDS Ratings for Maximum Weekly Average Temperatures (MWATs) in the Wheatfield Fork Subbasin

Stream	No. of Sites	No. of Observations	Period of Record	EMDS Suitability Ratings						
				+++	++	+	0	-	--	---
Wheatfield Mainstem	6	14	1995-2001							
Fuller Creek	8	14	1997-2001							
Annapolis Falls Creek	1	2	1996, 1999							
Crocker Creek	1	1	1997							
Lower Tributary	1	4	1995-1998							

EMDS ratings:
+++ = fully suitable (50-60°F)
++ = moderately suitable (61-62°F)
+ = somewhat suitable (63°F)
0 = undetermined (between somewhat suitable and somewhat unsuitable) (64°F)
- = somewhat unsuitable (65-66°F)
-- = moderately unsuitable (67°F)
--- = unsuitable (>67°F)

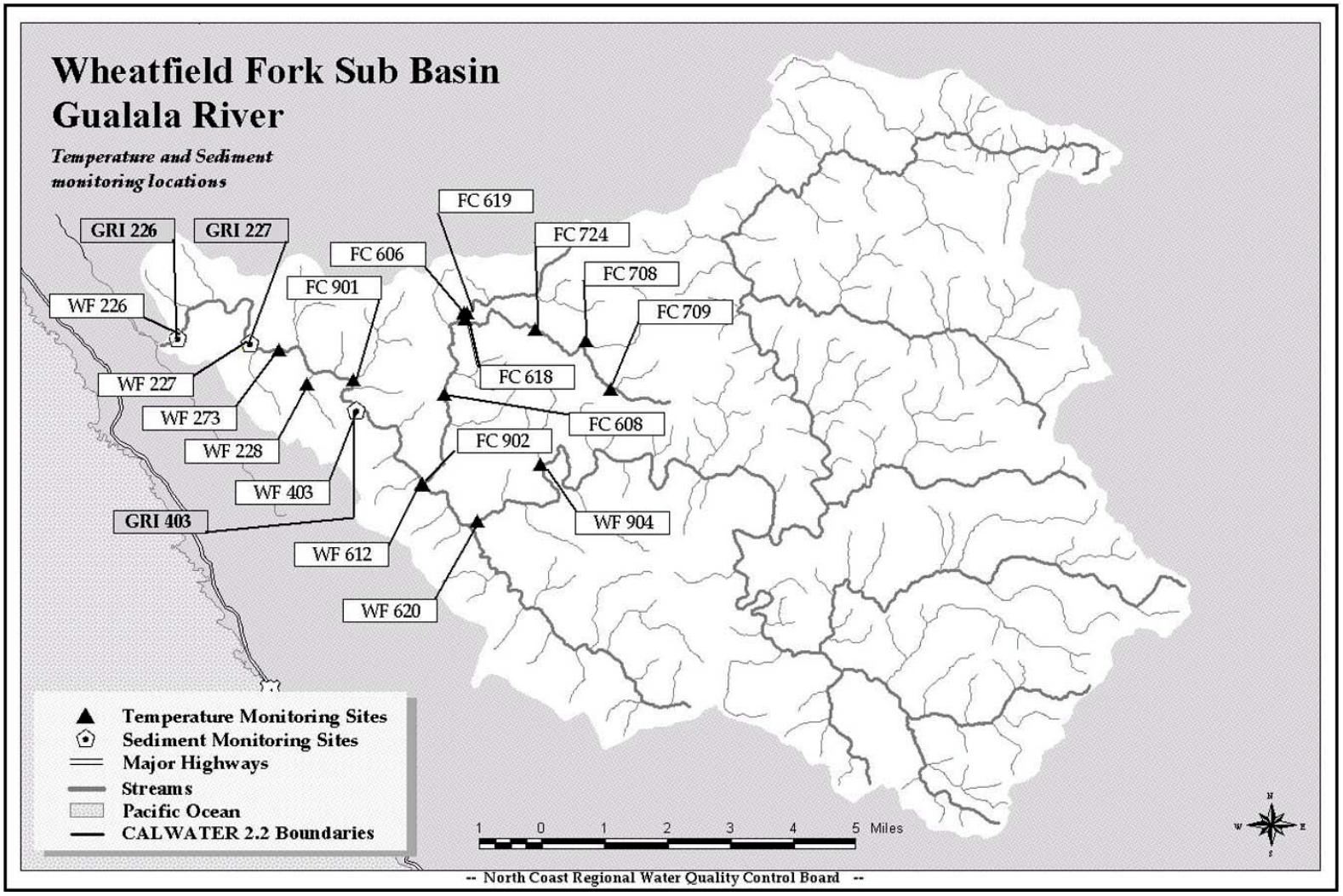


Figure 5.5-12
Instream Sediment and Temperature Sampling Sites, Wheatfield Fork Subbasin

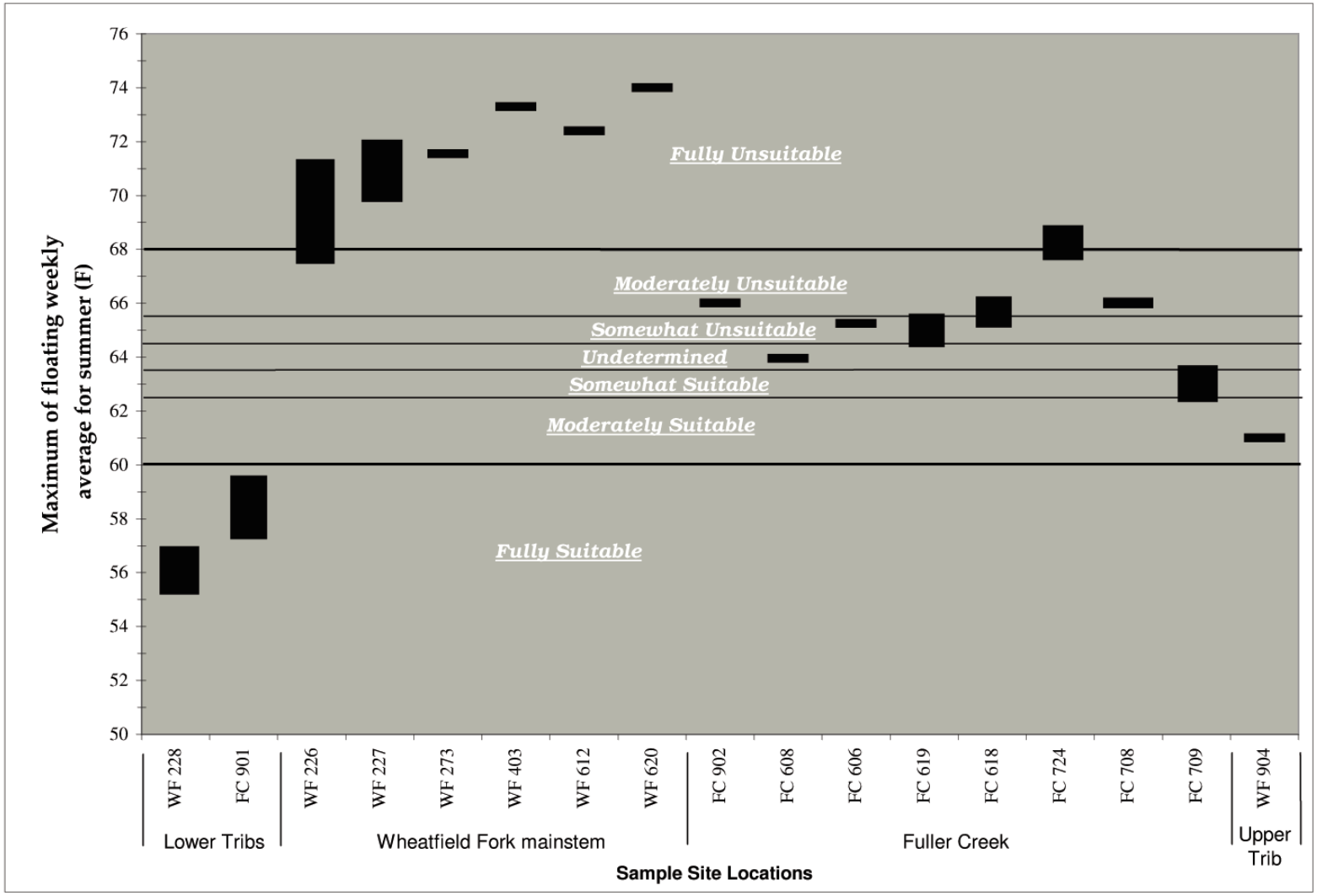


Figure 5.5-13
MWAT Sample Site Locations in the Wheatfield Fork Subbasin

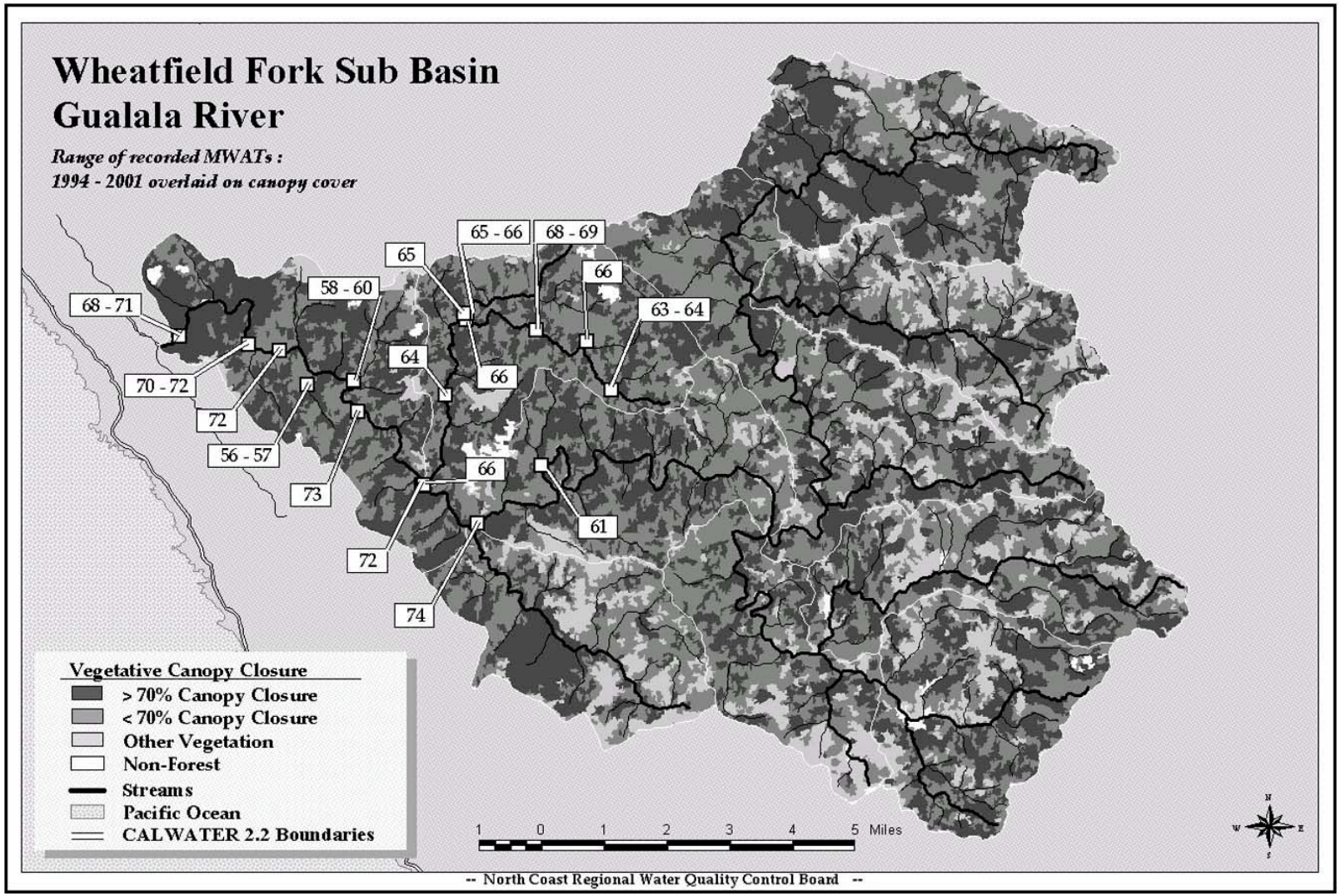


Figure 5.5-14
MWAT Temperature Ranges in the Wheatfield Fork Subbasin for the Period of Record, 1995-2001
(Overlaid on the LanSat vegetation layer for 2000)

5.5.8 FISH HABITAT RELATIONSHIP

Historic Habitat Conditions

In 1964, 1965, and 1970, CDFG stream surveys were conducted on five streams in the Wheatfield Fork Subbasin: Wheatfield Fork, Fuller Creek, Haupt Creek, House Creek, and Patchett Creek. These surveys were made by direct observation and were not accompanied by quantitative data (Table 5.5-5).

Table 5.5-5
Summary of Historic (1964-1970) Stream Surveys Conducted in the Wheatfield Fork Subbasin
Gualala River Watershed, California

Wheatfield Fork Subbasin Tributary	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
Wheatfield Fork	9/28/1964	Good spawning beds; Pool: Riffle ratio 75:25; Shelter provided by boulders, logs, overhanging water grasses, and undercut banks	Waterfall ¼ mile below the upper limit of anadromy; No complete fish passage barriers	Clearing of the log jam and clearing of the falls
Fuller Creek	8/18-19/1964	Spawning area fair, with less than 50% of the streambed containing suitable spawning area and gravel; Pool: Riffle ratio 70:30; Logs, rocks, and undercut banks provided good shelter	9 partial barriers consisting of log jams	Removal of log jams to improve passage; Possible planting of coho salmon to re-establish a self-supporting run
Haupt Creek	8/25/1964 6/24/70	With a general clean-up and proper management, could become a first class steelhead trout, coho-salmon producing stream. A large amount of good spawning area available, consisting of loose gravel deposits, some places 60 feet wide; Pool: Riffle ratio 80:20; Good shelter provided by algae, boulders, undercut banks, and logs. Spawning area from mouth to upper fish limit; About 60% pools; About 25% of shelter in the first 100 feet of stream.	17 partial barriers, consisting of log jams; 1 fish passage barrier 20 log jams; no fish passage barriers	Removal of barriers; Removal of slash from streambed to improve nursery area; Careful management of a coho salmon program to re-establish a run in a stream which has a tremendous amount of suitable coho salmon spawning area. Remove log jams from mouth to upper fish limit 6 miles upstream.
House Creek	9/17/65-9/18/65	Pools: 60-80% in summer; Shelter is inadequate; Conditions favor rough fish over salmonid.	Concrete dam Numerous small log jams in headwaters and tributaries	Manage as steelhead trout spawning and nursery.
Patchett Creek	8/20/1964	40% of the streambed below the upper anadromy limit good; Shelter provided by logs, undercut banks, overhanging grass – scarce in some areas	15 log jams between mouth and upper limit of anadromy; 3 waterfalls	Removal of 15 log jams from mouth to bedrock falls 150 feet below the first fork

Current (1995-2001)

Target Values from the Habitat Inventory Surveys (Flosi et al 1998)

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. Target values for each of the individual habitat elements measured are provided in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) (Table 5.5-6). When habitat conditions fall below the target values, restoration projects may be recommended to meet critical habitat needs for salmonids.

Table 5.5-6
Habitat Inventory Target Values Taken from the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al 1998).

Habitat Element	Canopy Cover	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or more of the stream length is <50% embedded	Depth-1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet. Frequency->40% of stream	>80

Habitat inventory surveys were conducted in 1995 and 2001on nine streams in the Wheatfield Fork Subbasin (Table 5.5-7). Sullivan Creek was the only stream in the subbasin that met the target value for canopy cover. Five streams met the target value for embeddedness: House Creek, Pepperwood Creek, Sullivan Creek, Tombs Creek, and Wheatfield Fork. Danfield Creek, Fuller Creek, North Fork Fuller Creek, and South Fork Fuller Creek did not meet the target value for embeddedness. The target values for primary pool depth/frequency and shelter/cover were not met on any of the streams in the subbasin.

Table 5.5-7
Summary of Current (1995 and 2001) Conditions Based Upon Habitat Inventory Surveys from the Wheatfield Fork Subbasin, Gualala River Watershed, California
Condensed Tributary Reports are located in Appendix 5

Habitat Element Stream Name	Surveyed Length (feet)	Canopy Density	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
Target Values (Flosi et al 1998)		>80%	>50% of the stream <50% embedded	>40% of the length is primary pools	>80
Wheatfield Fork Subbasin	199,627				
Danfield Creek	2,103	49%	28%	5%	26
Fuller Creek (1995)	17,952	66%	3%	5%	25
North Fork Fuller Creek (1995)	14,275	68%	20%	13%	58
South Fork Fuller Creek (1995)	23,198	59%	28%	13%	37
House Creek	54,916	21%	70%	8%	15
Pepperwood Creek	17,931	19%	70%	16%	12
Sullivan Creek (1995)	5,015	89%	63%	7%	36
Tombs Creek	37,359	65%	55%	9%	51
Wheatfield Fork	116,878	45%	50%	25%	17

Canopy coverage was below the target range on all streams surveyed in the Wheatfield Fork Subbasin except Sullivan Creek, which fully met the target value at 89 percent. The ranges were 49 percent on Danfield Creek, 65 percent on Fuller Creek, 21 percent on House Creek, 68 percent on North Fork Fuller Creek, 9 percent on Pepperwood Creek, 59 percent on South Fork Fuller Creek, 65 percent on Tombs Creek, and 45 percent on Wheatfield Fork (Figure 5.5-15).

Categories 1 and 2 embeddedness (<50 percent embedded) are considered the most productive for spawning. Category 5 is unsuitable substrate which includes clay, bedrock, and log. Data collected during 1995 and 2001 habitat inventory surveys showed that House Creek, Pepperwood Creek, Sullivan Creek, Tombs Creek and the Wheatfield Fork had more than 50 percent of all pool tails surveyed that were category 1 and 2. Less than 5 percent of surveyed pool tails were category 1 and 2 on Fuller Creek and less than 30 percent on the North and South Forks of Fuller Creek and Danfield Creek (Figure 5.5-16).

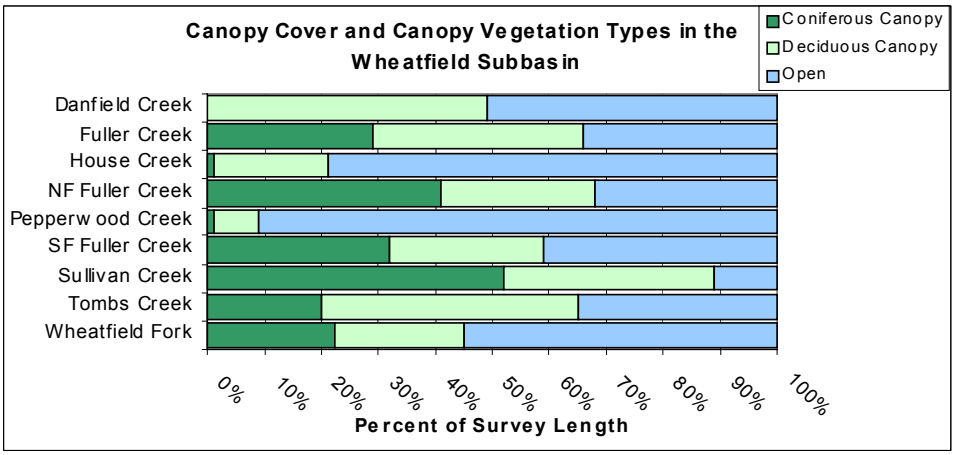


Figure 5.5-15
Canopy Cover and Canopy Vegetation Types by Percent Survey Length in Nine Tributaries, Wheatfield Fork Subbasin 1995 and 2001, Gualala River Watershed, California

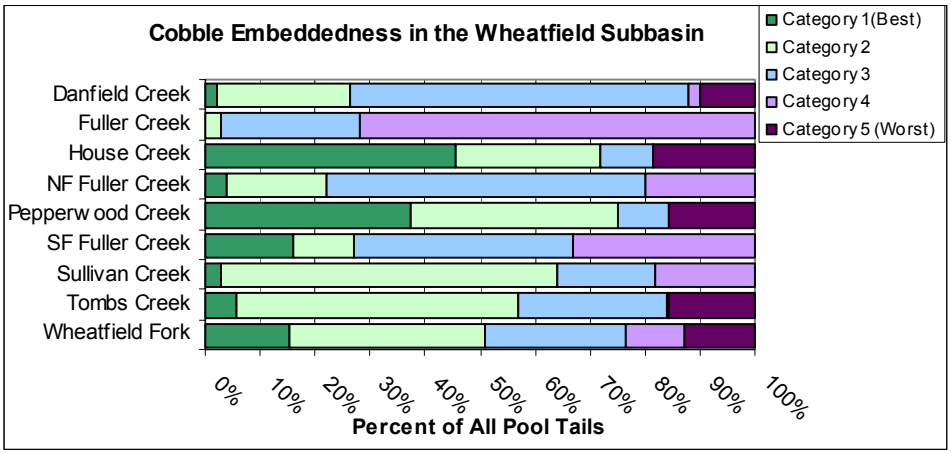


Figure 5.5-16
Percent of Cobble Embeddedness in all Pool Tails in the Wheatfield Fork Subbasin 1995 and 2001, Gualala River Watershed, California

All streams surveyed in the Wheatfield Fork Subbasin had habitat deficiencies in pool depth (Figure 5.5-17). None of the streams surveyed met pool frequency target values, except the Wheatfield Fork. Wheatfield Fork had a pool frequency of over 40 percent pools, meeting the frequency target value but not the depth target value based on stream order. Wheatfield Fork is a third order stream with a target of 40 percent of pools 3 feet or over. The rest of the streams in the subbasin did not meet the criteria for depth or frequency (Figure 5.5-17).

Shelter/Cover ratings were below the target values for all of the streams surveyed in the Wheatfield Fork Subbasin (Figure 5.5-18). The top three types of shelter/cover provided were boulders, large woody debris and terrestrial vegetation (Figure 5.5-19). The primary cover types were root masses, boulders, and bedrock ledge on Danfield Creek. The primary cover types were undercut banks, large woody debris, and terrestrial vegetation on Fuller Creek. The primary cover types were boulders, root masses, and bedrock ledge on House Creek. North Fork Fuller and South Fork Fuller Creeks

showed the primary cover types were undercut banks, large woody debris, and boulders. The primary cover types were boulders, bedrock ledge, and aquatic vegetation on Pepperwood Creek. Undercut banks, small woody debris, and large woody debris provided the most shelter on Sullivan Creek. The primary cover types were small woody debris, white water, and boulders on Tombs Creek. Wheatfield Fork primary cover types consisted of small woody debris, terrestrial vegetation and boulders.

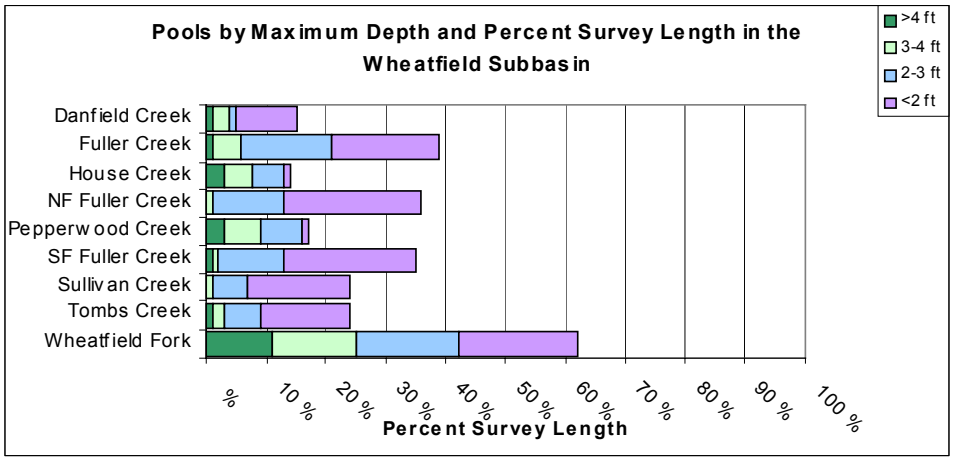


Figure 5.5-17
Pools by Maximum Depth and Percent Survey Length in the Wheatfield Fork Subbasin 1995 and 2001, Gualala River Watershed, California

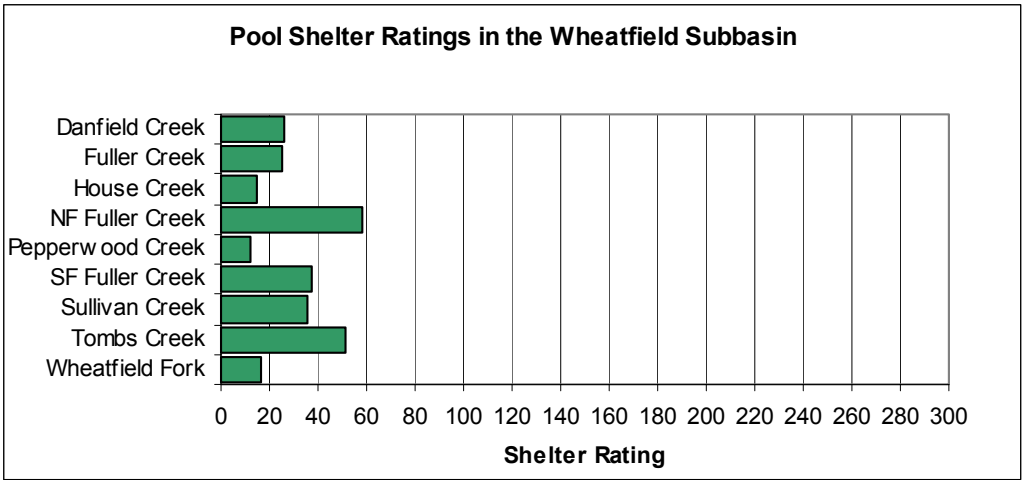


Figure 5.5-18
Average Pool Shelter Ratings in the Wheatfield Fork Subbasin 1995 and 2001, Gualala River Watershed, California

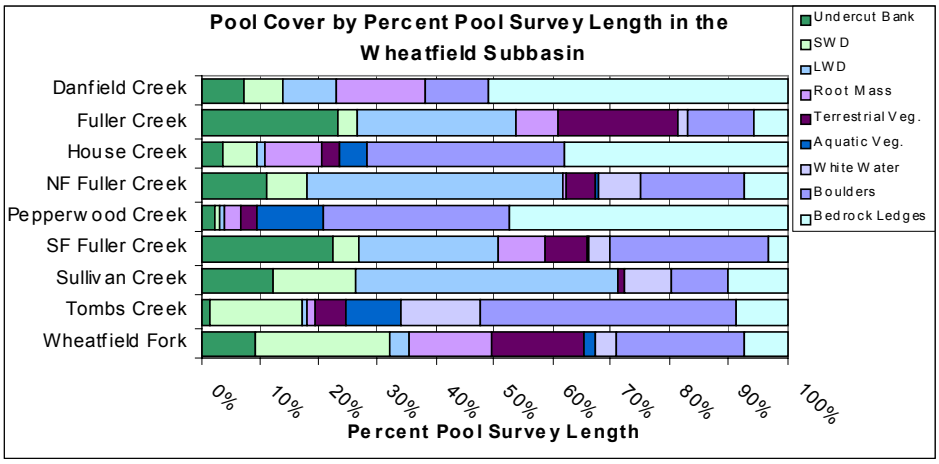


Figure 5.5-19
Type of Pool Cover by Percent of Pool Survey Length in the Wheatfield Fork Subbasin 1995 and 2001, Gualala River Watershed, California

Large Woody Debris Data

Most large wood was cleaned (cleared) from the streams during the 1950s, 1960s and 1970s. A target value of 130 pieces of large woody debris >8 inches per 1,000 feet of stream is recommended in the literature (Beechie and Sibley 1997, Martin 1999).

The Cooperative Monitoring Program surveyed one site for large wood in the lower Wheatfield Fork. This site lacked volume and pieces of large woody debris (Table 5.5-8).

Table 5.5-8
Summary of the Watershed Cooperative Monitoring Program Large Woody Debris Survey, Wheatfield Fork Subbasin (1998 - 2001)

Tributary	Site Number	Watershed* Size (acres	Volume Cubic Feet/1,000'	Quantity Pieces/1,000'
Wheatfield Fork	226	71,409	1,531	15

*Watershed size is calculated as the area above the monitoring site.

Changes in Habitat Conditions From 1964 to 2001

Changes between historic and current instream conditions were compared between the streams surveyed in 1964 and subsequently habitat inventories from 2001 (Table 5.5-9). Data from the 1964 stream surveys provide only a qualitative snapshot of the conditions at the time of the survey and the terms such as excellent, good, fair and poor were based on the judgment of the biologist or scientific aid conducting the survey. The results of the historic stream surveys cannot be used in comparative analyses with the quantitative data provided by the habitat inventory surveys with any degree of accuracy. However, the two data sets may be used to show general trends.

According to aerial photographs, the canopy density of the 1960s was reduced substantially from the conditions observed in the 1940s. The canopy appeared to be below or absent throughout the subbasin.

Table 5.5-9
Comparison Between Historic Habitat Conditions Observed in 1964, 1965, and 1970 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 1995 and 2001 from the Wheatfield Fork Subbasin, Gualala River Watershed, California

Habitat Element Stream Name	1960s Canopy Cover Photos	2001 Canopy Cover	1964 Spawning Conditions	2001 Spawning Conditions	1964 Pool Depth/ Frequency	2001 Pool Depth/ Frequency	1964 Shelter Cover	2001 Shelter Cover	Change in conditions from 1964 to 2001
Wheatfield Fork Subbasin									
Fuller Creek (1995)	Low or Absent	66%	Fair	3%	70%	5%	Good	25	Some canopy recovery: Decreased spawning conditions, pool habitat and shelter/cover.
House Creek	Low or Absent	21%	Good	70%	70%	8%	Inadequate	15	Little or no recovery of canopy: Improved spawning conditions: Decreased pool habitat: No change in shelter/cover.
Wheatfield Fork	Low or Absent	45%	Good	50%	75%	25%	Good	17	Some canopy recovery: No change or return of in spawning conditions: Decreased pool habitat and shelter/cover.

In the Wheatfield Fork Subbasin, House Creek, and the Wheatfield Fork were surveyed in 1964 and 2001. Fuller Creek was surveyed in 1964 and 1995. The canopy cover on House Creek and the Wheatfield Fork appears to have decreased or remained the same and still does not meet target values, indicating no improvement over those observed in the 1960s aerial photographs. Fuller Creek's canopy cover appears to have increased somewhat, but still does not meet target values, indicating some improvement. The spawning substrate on House Creek appears to have improved somewhat, while the Wheatfield Fork has remained or returned to the same acceptable conditions observed in 1964. Spawning substrate conditions appear to have decreased on Fuller Creek indicating a worsening of upstream and/or upslope habitat conditions. The 2001 pool frequency/depth and shelter cover appear to have decreased since 1964 on Fuller Creek and the Wheatfield Fork. On House Creek, the pool frequency/depth appears to have decreased while the shelter/cover values have remained inadequate.

Ecological Management Decision Support

Although the EMDS Reach Model scores are based upon the habitat inventory survey data, the analysis differed. The habitat inventory data were divided into reaches based upon Rosgen Channel type and then converted to a weighted average. Each weighted average reach was compared to a set of habitat reference conditions which were determined from empirical studies of naturally functioning

channels, expert opinion, and peer reviewed literature. EMDS rated each habitat component with a suitability score between -1 and +1, where suitability is a function of salmonid health and productivity. The reference curve breakpoints for these habitat parameters are presented in Table 4-1, Chapter 4.

EMDS scores were not calculated for the Wheatfield Fork Subbasin because only 62 percent of the blue line streams were habitat inventoried and water temperature data were recorded in 2001 on only one stream. MWAT was available for the Wheatfield Fork only and was moderately unsuitable at two sites and fully unsuitable at the third (Table 5.5-10).

Table 5.5-10
Ecological Management Decision Support (EMDS) Reach Model Scores on Salmonid Health and Productivity Suitability for the Wheatfield Fork Subbasin, Based Upon Habitat Inventory Surveys Conducted in 1995 and 2001

Subbasin Stream Name	Canopy Cover Score	Embeddedness Score	Pool Depth Score	Pool Shelter Score	Pool Quality Score	2001 MWAT Water Temperature Score
Wheatfield Fork Subbasin Score	n/a	n/a	n/a	n/a	n/a	n/a
Danfield Creek	- - -	- -	- - -	- - -	- - -	
House Creek	- - -	++	- - -	U	- -	
Pepperwood Creek	- - -	+	- - -	- - -	- - -	
Tombs Creek	-	-	- - -	-	- -	
Wheatfield Fork	- -	-	+	- - -	-	- - -

The 2001 water temperature data were provided by GRI and the GRWC.

+++ = Fully Suitable
++ = Moderately Suitable
+ = Somewhat Suitable
U = Undetermined
- = Somewhat Unsuitable
- - = Moderately Unsuitable
- - - = Fully Unsuitable

Limiting Factors Analysis

The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components. Habitat inventory data, EMDS reach model scores, and the biologist's professional judgment were incorporated into both the identification of LFAs and their ranking (Table 5.5-11). The LFAs for the subbasin could not be identified because only 45 percent of all the blue line streams were habitat inventoried. Canopy Cover was the highest limiting factor on Danfield, House, and Pepperwood creeks. Embeddedness was the predominant limiting factor in the Fuller Creek watershed. Pool depth/summer condition was the highest limiting factor on Tombs and Sullivan Creeks. Pool shelter/cover was the highest limiting factor on the Wheatfield Fork (Table 5.5-12).

Table 5.5-11
Limiting Factors for the Wheatfield Fork Subbasin Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 2001 and EMDS Scores in the Gualala River Watershed, California
Rank 1 is the highest limiting factor

Subbasin Stream Name	Canopy Cover Related to Water Temperature	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
Wheatfield Fork Subbasin Score	n/a	n/a	n/a	n/a
Danfield Creek	1	4	3	2
House Creek	1		3	2
Pepperwood Creek	1		3	2
Tombs Creek	2	4	1	3
Wheatfield Fork	2	3		1

Table 5.5-12
Limiting Factors Affecting Salmonid Health and Production in the Fuller Creek Watershed Located in the Wheatfield Fork Subbasin of the Gualala River Watershed, California Based Upon Habitat Inventory Surveys Conducted in 1995
Rank of 1 is the highest limiting factor.

Watershed Stream Name	Canopy Related to Water Temperature	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
Fuller Creek	4	1	2	3
North Fork Fuller Creek	4	1	2	3
South Fork Fuller Creek	4	1	2	3
Sullivan Creek		3	1	2

Restoration Recommendations

The proposed restoration recommendations were based upon the habitat inventory surveys, limiting factors analysis, landowner and local expertise, and the biologist's professional judgment.

Restoration recommendations for the Wheatfield Fork Subbasin are listed by priority, "1" being the greatest priority. The highest priority for restoration is riparian canopy development. The next four recommendations, in order of decreasing priority, are instream structure enhancements (second), bank stabilization, livestock/feral pig exclusion, and roads repair or removal. Barrier removal is not a restoration priority in the subbasin (Table 5.5-13).

Table 5.5-13
Priorities for Restoration in the Wheatfield Fork Subbasin Based Upon 1995 and 2001 Data
Rank of "1" indicates highest priority

Stream Name	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
Wheatfield Fork Subbasin	3	5	1	2	4	
Danfield Creek	2		3	4	1	
Fuller Creek (1995)	2	3	1	4		
North Fork Fuller Creek (1995)			1	2		
South Fork Fuller Creek (1995)			1	2		
House Creek	3	2	4	5	1	
Pepperwood Creek	4		2	3	1	
Sullivan Creek (1995)				1		
Tombs Creek	2		3	4	1	
Wheatfield Fork	2	3	4	1		

Figure 5.5-20a illustrates the limiting factors as determined by CDFG and various sediment sites identified by CGS as potential restoration targets. Figure 5.5-20b is the map explanation. General recommendations are made for each limiting factor and type of sediment site. The map is a reduced image of Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*. (See Plate 3 to view details at a higher scale [1:48,000]).

Potential Refugia

No potential refugia were identified based upon 2001 data.

5.5.9 Fish History and Status

Salmonid population data were limited in the Wheatfield Fork Subbasin. No data were available for the period, 1950s- 1970

- **1980s**- A population estimate with confidence interval was calculated for one station located on the mainstem of Fuller Creek just upstream of the ford on the entrance road from the Hollowtree store in 1989. The steelhead trout juvenile population, of Fuller Creek (approximately 6-mile-long, 3rd order stream), was estimated at 62 with a standard error of 8.6. Four stations were two or three pass electrofished on the South Fork and Mainstem of Fuller Creek with the intent to collect baseline data to assess the impacts from the upstream logging. Station 4 was upstream of the falls on the South Fork, where rainbow trout were observed. Young-of-the-year and one-year and older steelhead trout, western roach, and three-spined stickleback were found.
- **1990s**-A one-pass electrofishing survey was conducted in 1995 on Fuller Creek and South Fork Fuller Creek. The results were not comparable to the 1989 survey. During snorkel surveys, GRI observed one-year and older steelhead trout on the Wheatfield Fork in 1998.

- **2000s**-As part of NCWAP and the CDFG Coho Status Review, electrofishing surveys were conducted on Wheatfield Fork, Haupt Creek, Tombs Creek, House Creek, and Pepperwood Creek, creeks in 2001. Young-of-the-year and one-year classes of steelhead trout were present on all of the streams surveyed. Two- and three-year old steelhead trout were found on the Wheatfield Fork and Tombs Creek.

  Volunteer spawning surveys were conducted in the Subbasin February through April, 2001. Because of the period in which the surveys took place all of the redds found were considered to be steelhead trout. On the lower 14.1 miles of the Wheatfield Fork, 112 redds were found. During these surveys 26 live fish were observed. Haupt Creek (2.2 miles) was surveyed on 2/16/01, no redds were found.

  Coho salmon were not historically observed in House and Pepperwood Creeks and were not observed during electrofishing surveys in October of 2001.

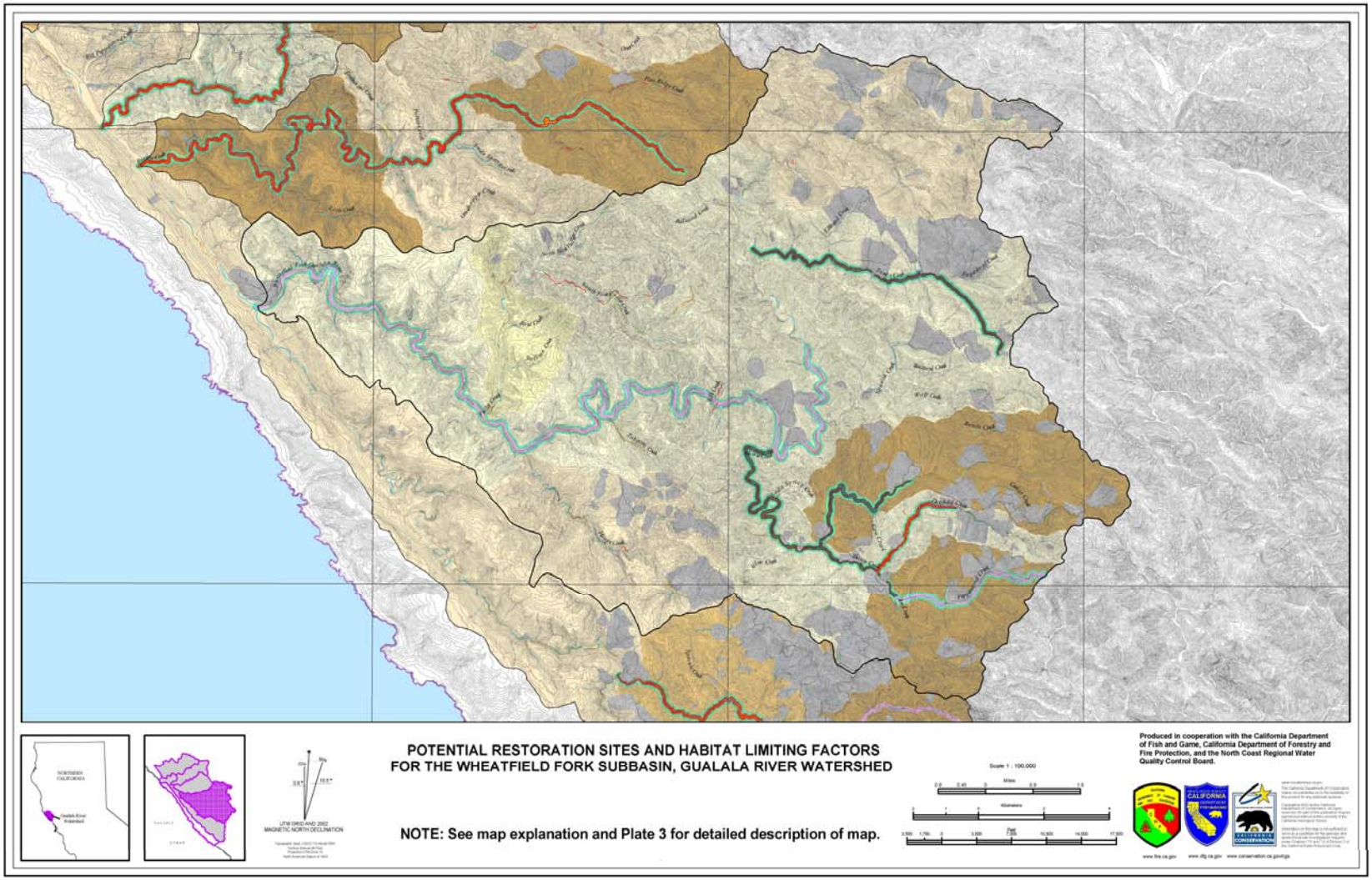


Figure 5.5-20a
Potential Restoration Sites and Habitat Limiting Factors for the Wheatfield Fork Subbasin, Gualala River Watershed

Roads
Streams
Watershed boundary
Sub-basin boundary
Historically Active Landslides (mapped as a point if too small to delineate at the scale of this map)

I SPATIALLY ASSOCIATED FACTORS DERIVED FROM AERIAL PHOTO INTERPRETATION OF LANDSLIDING AND SEDIMENT CONDITIONS

A *HISTORIC IN-STREAM ROADS POSSIBLY RELATED TO FLUVIAL SEDIMENT*

Stream reaches with persistent aggrading or braiding in both 1984 and 2000 photos that may be associated with historic in-stream roads or landings. See recommendation #5.

B *ROADS POSSIBLY RELATED TO LANDSLIDES AND/OR ERODING BANKS*

Road segments that may be affected by historically active landsliding and bank erosion. See recommendation #6.

Road segments that may be affected by historically active landsliding. See recommendation #7.

C *FLUVIAL SEDIMENT CONDITIONS POSSIBLY RELATED TO LANDSLIDES*

Stream reaches with potentially adverse sediment accumulations that may be affected by historically active landslides and lack any apparent association with the modern road network or the historic in-stream roads or landings. See recommendation #8.

Stream reaches with potentially adverse sediment accumulations that may be affected by erosion from adjacent dormant landslide terrain that lack any apparent association with historically active landsliding, the modern road network, and historic in-stream roads or landings. See recommendation #9.

D *POTENTIALLY UNRELATED FLUVIAL SEDIMENT CONDITIONS*

Stream reaches with potentially adverse sediment accumulations that lack any of the above associations. See recommendation #9.

II LIMITING FACTORS DERIVED FROM GROUND BASED HABITAT SURVEYS (SEE DFG APPENDIX)

A *CANOPY AND POOLS AS LIMITING FACTORS* (All stream reaches surveyed by DFG in 2001 are highlighted as follows. Reaches that were not surveyed in 2001 are not highlighted on the map.)

Stream reaches with inadequate canopy cover as the limiting factor. See recommendation #2.
Stream reaches with inadequate pool depths as the limiting factor. See recommendation #4.
Stream reaches with inadequate pool shelter as the limiting factor. See recommendation #3.
Stream reaches with both inadaquate pool depths and shelter as limiting factors. See recommendations #3 and #4.

Explanation

B *EMBEDDEDNESS AS A LIMITING FACTOR*

Areas draining into where embededdness conditions are unknown.
Areas draining into reaches where embeddedness is not limiting.
Areas draining into reaches where embeddedness is marginal but not limiting.
Areas draining into reaches where embeddedness is somewhat limiting. See recommendation #1.
Areas draining into reaches where embeddedness is significantly limiting. See recommendation #1.

RECOMMENDATIONS BASED ON LIMITING FACTORS

(1) Reduce production of fine sediment throughout the contributing area. Evaluate contribution from roads and upgrade roads as appropriate. Evaluate contribution from soil disturbance and control erosion as appropriate (see recommendations 5-10). Evaluate contribution from soil disturbance and control erosion as appropriate. Consider the additive effect of the short-term increases in erosion due to mitigation activities. Distribute individual activities both spatially and temporally as appropriate to avoid additive sediment impacts. Institute best management practices in erodible areas; such as, areas shown on the CGS Relative Landslide Potential Map (Plate Two), and National Resources Conservation Service soil maps.

(2) Enhance current riparian vegetation by planting additional trees, and stabilize stream banks as needed. Also, consider both downstream and upstream effects.

(3) Enhance pool shelter by adding submerged or partially submerged structures. Consider both upstream and downstream effects due to operation and possible failure.

(4) Install in-stream structures to produce hydraulic variability and to scour pools. Consider both downstream and upstream effects due to operations and possible failure.

RECOMMENDATIONS BASED ON SPATIAL ASSOCIATIONS

(5) Evaluate relationship on-site. Consider channel restoration and drainage improvements for the road and landing. Consider engineered abandonment.

(6) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible. Consider stream bank stabilization where feasible.

(7) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible.

(8) Evaluate on-site whether these represent natural background conditions. If mitigation is desired, road construction may be needed for equipment access.

(9) No recommendation because potentially associated active sediment sources have not been identified.

EXPLANATION FOR POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS FOR THE GUALALA RIVER WATERSHED MAP

NOTE: See Plate 3 for complete description of map.

Produced in cooperation with the California Department of Fish and Game, California Department of Forestry and Fire Protection, and the North Coast Regional Water Quality Control Board.

www.fire.ca.gov www.dfg.ca.gov www.conservation.ca.gov/cgs

Figure 5.5-20b
Explanation for Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed Map

5.5.10 WHEATFIELD FORK SUBBASIN PUBLIC ISSUES, SYNTHESIS, AND RECOMMENDATIONS

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala River Watershed residents and constituents. The following general concerns were expressed as potential factors affecting the Wheatfield Fork Subbasin and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.

- Coho have not been observed in the Wheatfield Fork Subbasin since 1970 indicating prolonged habitat impairment.
- Water temperatures may be high for sustainable salmonid health and production.
- Streamside canopy is deficient.
- Excessive sediment influx in parts of the subbasin has impaired salmonid habitat.
- Instream structures are deficient.
- Subdivision development, grazing and new vineyard development are emerging issues.

Working Hypotheses

The primary purpose of these hypotheses is to elucidate in a succinct format the judgment of the Team regarding watershed conditions relative to anadromous salmonids. They are responsive to the assessment questions presented on pages 1-1 and 1-2. The findings supporting the hypothesis are presented, along with recommendations for watershed improvements as well as recommendations to further investigate the hypotheses. As such, they are not intended to be the final word, but are the best judgment based on the information at hand.

Recommendations for watershed improvements and further study are presented at the end of the section, as single recommendations apply in many cases to more than one hypothesis.

The findings are presented for each of three Super Planning Watersheds (SPWS), because of differences in geology, climate, and land use. The hypotheses are:

1. The Wheatfield Fork Subbasin provides unsuitable habitat for salmonids.
2. Depleted overstory shade canopy cover along Wheatfield Fork and tributaries from legacy harvests and other factors continues to contribute to elevated water temperatures (Lower Wheatfield SPWS only).
3. A lack of instream large woody debris contributes to simplified riparian habitat structure (e.g., lack of large, deep pools).
4. Land management activities in the Wheatfield Fork Subbasin, especially road building adjacent to stream channels or across debris slide slopes and/or steep terrain, have contributed sediment to streams.
5. Instream and near stream conditions have improved.

Working Hypothesis 1

Stream conditions in all three of the Super Planning Watersheds in the Wheatfield Fork Subbasin provide unsuitable habitat for salmonids.

Supporting Findings

Lower Wheatfield Super Planning Watershed

- Coho salmon were not observed in the Wheatfield Fork during electrofishing surveys in October of 2001.
- Water temperatures expressed as MWAT ranged from undetermined to fully unsuitable at 13 of 17 sites in the Wheatfield Fork (Table 5.5-4).
- Canopy cover, primary pool depth/frequency, and shelter/cover on the mainstem of Wheatfield Fork did not meet CDFG habitat inventory target values (Table 5.5-7).
- Canopy cover, embeddedness, primary pool depth/frequency and shelter/cover on Fuller Creek and the North and South Forks of Fuller Creek did not meet target values (Table 5.5-7).
- Canopy cover, pool depth and pool Quality EMDS scores were moderately unsuitable for the mainstem of Wheatfield Fork. Embeddedness was somewhat unsuitable. Pool Shelter was fully unsuitable (Table 5.5-10).
- Embeddedness may be naturally high due to the geology coupled with Tombs Fault (page 5.5–1).

Walter's Ridge Super Planning Watershed

- Coho salmon were not observed in Tombs Creek during electrofishing surveys in October of 2001.
- Canopy cover, pool depth and shelter cover did not meet CDFG habitat inventory target values in Tombs Creek (Table 5.5-7).
- The EMDS scores for canopy cover, embeddedness, pool depth and pool shelter were moderately unsuitable for the mainstem of Tombs Creek. Pool depth was fully unsuitable (Table 5.5-10).

Hedgepeth Lake Super Planning Watershed

- Coho salmon were not observed in House and Pepperwood Creeks during electrofishing surveys in October of 2001.
- Canopy cover, primary pool depth/frequency, and shelter/cover did not meet target values on House, Pepperwood and Danfield Creeks.
- The EMDS scores on House, Pepperwood and Danfield Creeks for canopy cover, pool depth were fully unsuitable. Embeddedness was moderately unsuitable on Danfield Creek. Pool Shelter was fully unsuitable on Danfield and Pepperwood Creeks and undetermined on House Creek.

Contrary Findings

Lower Wheatfield Super Planning Watershed

- Steelhead trout (young-of-the-year, one year, two-year and three year olds) were observed in the Wheatfield Fork during electrofishing surveys in October of 2001.

- Steelhead trout (young-of-the-year, one-year, two-year and three-year olds) were observed in Tombs Creek during electrofishing surveys in October of 2001.
- Water temperatures expressed as MWAT ranged from somewhat to fully suitable at 4 of 17 sites in the SPWS (Table 5.5-4).
- The EMDS score for embeddedness was somewhat suitable on the Wheatfield Fork.
- Macroinvertebrate sampling at one site in the lower Wheatfield Fork indicated a good biotic condition.

Walter's Ridge Super Planning Watershed

- Embeddedness may be naturally high due to the geology, coupled with the Tombs Fault.

Hedgepeth Lake Super Planning Watershed

- Steelhead trout (young-of-the-year, one year, two-year and three year olds) were observed in House, and Pepperwood Creeks during electrofishing surveys in October of 2001.
- Embeddedness met the target values on House and Pepperwood Creeks.
- The EMDS scores for House and Pepperwood Creeks for embeddedness were moderately suitable and somewhat suitable, respectively. (Table 5.5-10).

Limitations

- Only 62 percent of the Lower Wheatfield Super Planning Watershed was habitat inventory surveyed.
- Only 32 percent of the Walter's Ridge Super Planning Watershed was habitat inventory surveyed.
- Only 42 percent of the Hedgepeth Lake Super Planning Watershed was habitat inventory surveyed.
- The modified ten pool protocol (electrofishing methodology) used was designed to indicate coho salmon presence/not detected status only, and can not be used to indicate species composition, species density or estimate populations.

Conclusions

- The hypothesis is supported.

Working Hypothesis 2

Depleted overstory shade canopy cover along Wheatfield Fork and tributaries from legacy harvests and other factors continues to contribute to elevated water temperatures.

Supporting Findings

Lower Wheatfield Super Planning Watershed

- Canopy cover did not meet CDFG habitat inventory target values on the mainstem of Wheatfield Fork Fuller Creek and the North and South Forks of Fuller Creek.
- The EMDS score for canopy cover was moderately unsuitable on the Wheatfield Fork.
- Canopy density is known to be naturally low in grasslands and oak woodlands, which appeared to occur naturally in some areas on the 22 of 36 miles of the Wheatfield Fork that were habitat inventoried.

- Timber harvest operations, including road building in riparian zones, shortly after WW II eliminated overstory shade canopy cover throughout long sections of the Wheatfield Fork and tributaries. There was near entire canopy elimination along the lower main stem and main tributaries, especially pronounced during the mid to late 1950s (Figures 5.5-5 and 5.5-10).
- Water temperatures expressed as MWAT ranged from undetermined to fully unsuitable at 13 of 17 sites in the SPWS (Table 5.5-4). Some evidence of mainstem cooling by Fuller Creek was observed (from site WF620 to WF612) (Figures 5.5-13 and 5.5-14).

Walter's Ridge Super Planning Watershed

- Canopy cover did not meet CDFG habitat inventory target values on Tombs Creek. The EMDS score for canopy cover was somewhat unsuitable on Tombs Creek.
- Timber harvest operations, including road building in riparian zones, shortly after WW II eliminated overstory shade canopy cover throughout long sections of the main stem Wheatfield Fork, Tombs and Wolf Creeks, and tributaries (Figures 5.5-5 and 5.5-10).
- Bank-to-bank exposure increased substantially from 1942 to 1999 (Figures 5.5-5 and 5.5-10).
- Prolonged ranchland operations with intent of conversion to pastureland prevented timely reestablishment of vegetative cover over streams.
- Some of the recent vineyard development has encroached into riparian areas that were once covered in 1942 (Section 5.5.4).

Hedgepeth Lake Super Planning Watershed

- Canopy cover did not meet CDFG habitat inventory target values on House, Pepperwood and Danfield Creeks (Table 5.5-7).
- The EMDS scores for canopy cover were fully unsuitable on House, Pepperwood and Danfield Creeks (Table 5.5-10).
- Timber harvest operations, including road building in riparian zones, shortly after WW II eliminated overstory shade canopy cover throughout long sections of House and Pepperwood Creek watersheds (Figure 5.5-6).
- Prolonged ranchland operations with intent of conversion to pastureland prevented timely reestablishment of vegetative cover over streams. This caused longer term warming, and development of algal blooms currently noted in many of these stream reaches.
- Some of the recent vineyard development has encroached into riparian areas that were once covered in 1942.

Contrary Findings

Lower Wheatfield Super Planning Watershed

- Water temperatures expressed as MWAT ranged from somewhat to fully suitable at 4 of 17 sites in the SPWS (Table 5.5-4).
- Photos from 1942 show some bank-to-bank exposure along the lower main stem Wheatfield Fork, where old growth timber occurs along the edge of an alluvial channel (Figures 5.5-5 and 5.5-10).
- Advanced conifer hardwood regeneration since 1968 has reinstated canopy cover throughout many of the highest tributary reaches (Figures 5.5-5 and 5.5-10).

- Bank-to-bank exposure decreased from over 50 percent of the blue line streams in 1968 in the Lower Wheatfield SPW to approximately 20 percent in 1999 (Figure 5.5-10).

Walter's Ridge Super Planning Watershed

- Advanced conifer hardwood regeneration since 1968 has reinstated canopy cover throughout many of the highest tributary reaches.
- Bank-to-bank exposure improved in some areas by 1999 (Figure 5.5-10).

Hedgepeth Lake Super Planning Watershed

- Advanced conifer hardwood regeneration since 1968 has reinstated canopy cover throughout many of the highest tributary reaches.

Limitations

- Only 62 percent of the Lower Wheatfield Super Planning Watershed was habitat inventory surveyed.
- Only 32 percent of the Walter's Ridge Super Planning Watershed was habitat inventory surveyed.
- Only 42 percent of the Hedgepeth Lake Super Planning Watershed was habitat inventory surveyed.

Conclusions

- The hypothesis is supported.

Working Hypothesis 3

- A lack of instream large woody debris contributes to simplified riparian habitat structure (e.g., lack of large, deep pools).

Supporting Findings

Lower Wheatfield Super Planning Watershed

- Shelter/cover did not meet CDFG habitat inventory target values on the mainstem of Wheatfield Fork, Fuller Creek, and the North and South Forks of Fuller Creek (Table 5.5-7).
- The EMDS score for pool shelter was fully unsuitable on the Wheatfield Fork (Table 5.5-10).
- Heavy tractors building roads, landings, and skid trails in or adjacent to streams between 1952 and 1968 buried, removed, or dispersed LWD in the SPWS. Aerial photos from 1961 and 1965 show riparian areas entirely cleared of vegetation and remnant downed logs in the Fuller Creek, Tobacco, and Annapolis Planning watersheds (Section 5.5.4).
- The LP SYP describes LWD as not abundant in any of the survey reaches (Appendix 3).
- While the literature suggests about 130 pieces over 8 inches in diameter per 1,000 feet of stream may be desirable (Beechie and Sibley 1997, Martin 1999) the Watershed Cooperative Monitoring Program (1998-2001) identified 15 pieces per 1000 feet of stream channel (Table 5.5-8).

Walter's Ridge Super Planning Watershed

- Shelter/cover did not meet CDFG habitat inventory target values on Tombs Creek.
- The EMDS score for pool shelter on Tombs Creek was somewhat unsuitable.

Hedgepeth Lake Super Planning Watershed

- Shelter/cover did not meet CDFG habitat inventory target values on House, Pepperwood and Danfield Creeks.
- The EMDS scores for pool shelter on Pepperwood and Danfield Creeks were fully unsuitable. House Creek was moderately unsuitable

Contrary Findings

- None noted.

Limitations

- Only 62 percent of the Lower Wheatfield Super Planning Watershed was habitat inventory surveyed.
- Only 32 percent of the Walter's Ridge Super Planning Watershed was habitat inventory surveyed.
- Only 42 percent of the Hedgepeth Lake Super Planning Watershed was habitat inventory surveyed.

Conclusion

- The hypothesis is supported.

Working Hypothesis 4

Land management activities in the Wheatfield Fork Subbasin, especially past road building adjacent to stream channels or across debris slide slopes and/or steep terrain, have contributed sediment to streams.

Supporting Findings

- Approximately 13 miles of historic logging roads built in or along the streambed in the Lower Wheatfield SPW eliminated pool structure and complexity throughout Fuller, Sullivan, Haupt, and Tobacco Creeks (Section 5.55).
- Most of the lower reaches of the Wheatfield Fork Subbasin were clear-cut and roaded between 1952 and 1961 in or along the major tributaries (Figure 5.5-6). This left large areas of disturbed ground prone to erosion.
- Both historic and modern aerial photos showed that numerous debris flows and debris slides involved roads and that numerous failures occur along instream and near-stream roads and landings. These resulted in increased sedimentation in the streams (Section 5.5.5).
- Modern road segments within 60 meters of historically active landslides are numerous in the upper stream reaches of Haupt Creek and may be contributing excess sediment.
- Analysis of 1942 photos of Fuller Creek in an undisturbed old growth condition found fewer overall landslides compared to 1965 and 1984 photos.
- Embeddedness was somewhat to fully unsuitable on the 22 of the 36 miles of the Wheatfield Fork and on the North and South Forks of Fuller Creeks.
- Four large debris slides are apparent in the 1965 photos. These originate from areas of dense skid trail networks. Active landsliding is most abundant along the South Fork Fuller. By 1968, a massive debris slide starting from Fuller Mountain Ridge breached two road contours and continued down into the South Fork Fuller Creek.

- Photos from 1965 showed an approximate one-quarter mile section of streamside road collapsed into the North Fork Fuller Creek by 1965.
- Photos from 1965 showed sinuous meandering channel patterns in the North and South Forks upper mainstem Fuller Creek from multiple road debris slides entering streams.
- Figure 87 shows two slides that cut through two road contours in the Annapolis PWS.
- Many undersized culverts and substandard road drainage facilities failed during the 1986 and 1996 storms, representing a portion of contemporary sediment pulses in the subbasin. These failures were generally more numerous where the road network crosses high or very high potential landslide areas.

Contrary Findings

- Most of the historic streamside roads are now abandoned and vegetated throughout Fuller, Haupt, Sullivan, and Tobacco Creeks.
- Successional analysis of air photos since 1942 indicates downcutting of the stream channel in the lower Wheatfield suggesting sediment transport was exceeding supply. Bed elevations have lowered since 1942 and perhaps since 1921 (Appendix 2).
- The active program to decommission streamside roads and landings in the Fuller Creek PWS appears to have reduced sediment sources. The graveled stream substrate observed today compares favorably with the aggraded channel infill of silt and sand deposits observed in the 1965 photos in the same stream reaches.
- There is a declining association of the historic instream roads with channel aggradation indicators between 1984 and 1999. This further indicates net outflow of material and gradual recovery of the streambed. The geofluvial analysis indicates that there are fewer areas in the major tributaries of the SPW that may still now be contributing excess sediment from the mid-20th-century instream roads.
- There is no difference in overall landslide mapping over the entire SPWS between 1984 imagery (76 slides accessing watercourses) and 1999/2000 photos (75 slides).

Limitations

- Only 62 percent of the SPWS was habitat inventory surveyed.
- Analysis of sediment sources and changes in fluvial characteristics was from aerial photo interpretation with little ground-truthing.

Conclusions

- The hypothesis is supported.
- Past logging practices, specifically tractor operations on steep slopes and adjacent to streams, accelerated erosion and added excess sediment to stream channels. Modern logging operations are far less intense than those practiced from 1950-1968.
- Indications from the aerial photo analysis of fluvial characteristics, lower river downcutting, and data from the Fuller Creek roads improvement program all point towards reduction of sediment sources and improvement in the stream channel with regard to sediment. Positive responses by the salmonid habitat should be realized in the future.

Working Hypothesis 5

Instream and near stream conditions have improved.

Supporting Findings

- Aerial photo interpretation of the Fuller Creek PWS found overall levels of channel disturbance improved in the 1999/2000 photos compared to 1984. Within the planning watershed, approximately 80 percent of the main channel appeared disturbed with enlarged and numerous bars and lack of riparian vegetation in 1984. By 1999/2000 the main channel appeared to have improved with disturbance at less than 30 percent (Table 5.5-3).
- At least 80 per cent of the South Fork Fuller Creek channel was disturbed in 1984 images, compared to 50 per cent in 1999/2000 images (Table 5.5-3).
- The Wheatfield Fork in the Tobacco Creek PWS showed improvement in channel conditions from at least 75 per cent disturbed in 1984 to less than 50 percent in the 1999/2000 photos. Tobacco Creek had approximately 30 percent channel disturbance in the 1984 imagery compared to less than 20 percent disturbed by 1999/ 2000 (Table 5.5-3).
- Bank-to-bank exposure decreased from over 50 percent of the blue line streams in 1968 in the Lower Wheatfield SPW compared to approximately 20 percent in 1999 (Figure 5.5-10).

Contrary Findings

- There is no substantial difference in overall landslide mapping between 1984 imagery (76 slides accessing watercourses) and 1999/2000 photos (75 slides) at the scale of 1:24000. There is considerable variation between PWSs.

Limitations

- Analysis was limited by a lack of comparable historic stream surveys in this SPW with which to indicate comparative trends.
- Analysis of sediment sources and changes in fluvial characteristics was from aerial photo interpretation with little ground-truthing.
- The extent to which recent and current land use practices may individually or cumulatively affect the rate of improvement in the observed fluvial characteristics, other channel characteristics, and fish habitat is beyond the scope of this assessment and has not been determined.

Conclusions

- The hypothesis is supported.
- Overall levels of channel disturbance have improved since 1984. The streambed in the lower Wheatfield Fork has downcut since 1942 or before.
- Canopy coverage as measured by bank-to-bank exposure has improved since 1968, but not to 1942 levels. More information on the improvement with regard to riparian composition over the period of photo records is needed to discuss improvement in the riparian zone beyond canopy coverage.

Wheatfield Fork Subbasin Recommendations

Restoration and land use activities should be targeted on the three highest priorities for restoration in the Wheatfield Fork Subbasin: (1) riparian canopy development, (2) fish habitat improvement

structures including large wood placement, (3) bank stabilization, (4) feral pig and livestock impacts, and (5) road repair or removal.

1. Address riparian canopy development:
    a. Ensure that adequate streamside protection zones are used to reduce solar radiation and moderate air temperatures in order to reduce heat inputs to Wheatfield Fork and its tributaries
    b. Maintain and enhance existing riparian cover. Improvement of riparian canopy is a priority 1 restoration recommendation. Ensure that adequate streamside protection zones are used on the Wheatfield Fork and tributaries to reduce solar radiation and moderate air temperatures, particularly on the mainstem and upper tributaries. Retain, plant, and protect trees to achieve denser riparian canopy where current canopy is inadequate, particularly in the Lower Wheatfield SPWS: Fuller, Tobacco, and Haupt Creeks.
2. Install fish habitat improvement structures including large woody debris placement:
    a. The suitability of F4 channel types for fish habitat improvement structures include: good for bank placed boulders; fair for plunge weirs, single and opposing wing-deflectors, channel constrictors and log cover; poor for boulder clusters.
    b. Land managers in the subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is a restoration priority 2.
3. Address stream bank stability issues
    a. At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Grazing is an issue in the subbasin. Bank stabilization is the third of the top three recommendations.
    b. Reduce livestock and feral pig access to the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone. Improvement of riparian canopy is a priority 1 restoration recommendation, and bank stabilization is a priority 3.
4. Address road-related sediment sources
    a. Decommission and revegetate streamside roads, focusing on those where channel braiding and/ or aggradation are persistent today (from restoration map)
        i) Lower Wheatfield SPW: The lower reaches of Haupt and Tobacco Creeks
        ii) Walters Ridge SPWS: Lower to middle reaches of Tombs, Wolf, and Elk Creeks, and unnamed tributaries to the main stem Wheatfield Fork upstream from Tombs Creek, to Elk Creek, and flanked by Bear and Gibson ridges.
        iii) Hedgepeth Lake SPW: (a) Larger tributary watercourses to the lower reaches of House Creek, (b) Middle to higher reaches of House, and Pepperwood Creeks, Danfield and Cedar Creeks.
    b. Upgrade and maintain existing road systems to eliminate sediment sources to pools and spawning gravels. Carefully engineer new roads or repairs to reduce adverse sediment impacts. Use the Restoration Map to locate where ranch roads cross

historically active landslides to target further field evaluation. These areas have been mapped in dense concentrations in the east subbasin reaches.

c. Target road upgrade/repair starting with instream sediment indicators where fish habitat is less than suitable, such as (House, Danfield, and Tobacco Creeks.)

d. In the timber dominant Lower Wheatfield SPW: incorporate mitigation elements into Timber Harvest Plans and pursue cost sharing grants for decommissioning legacy streamside roads and upgrading road drainage facilities.

e. In the ranchland dominated Walters Ridge and Hedgepeth Lake SPWs: pursue cost sharing grants organized by the Sotoyome RCD to upgrade ranchland roads.

f. Landowners should develop erosion control plans for decommissioning old roads, maintaining existing roads, and constructing new roads. Target road upgrade and repair in the areas identified above.

g. Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 60 percent of the subbasin.

5. Conduct both instream and hillslope monitoring to determine whether current timber harvesting, ranchland, and vineyard development practices are allowing for recovery and protection of the salmonid habitat in the subbasin.

6. Expand monitoring and analysis efforts:

a. Conduct both instream and hillslope monitoring to determine whether current land use practices are allowing for recovery and protection of the salmonid habitat in the subbasin. Use GRWC protocols for instream and channel measurements. Improve baseline information on habitat conditions by conducting inventory surveys in more Wheatfield Fork tributaries.

b. Expand continuous temperature monitoring efforts into the upper subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.

c. Encourage more habitat inventory surveys and biological surveys of tributaries, as only 45 percent of the subbasin has been completed.

d. Investigate the availability and quality of other temperature and canopy data for the eastern area, and reevaluate the relationship of canopy to actual stream temperatures. Spot temperature and canopy measurements from habitat inventory data may be useful in providing information from areas in the subbasin for which we have no other data.

e. Survey for salmonids using consistent methods to estimate population numbers for comparison.

5.6 Gualala Mainstem/South Fork Subbasin

5.6.1 INTRODUCTION

The Gualala Mainstem/South Fork Subbasin (Gualala Hydrologic Subarea, Calwater 2.2a 113.85) contains 134 miles of "blue line" stream in its 63.7-square-mile watershed. The subbasin is composed of two Calwater 2.2a Super Planning Watersheds (SPWSs): Marshall Creek (113.8501, 45.2 square miles) and Lower South Fork Gualala River (113.8502, 18.5 square miles). The river system originates in the far southern end of the Gualala River Watershed and flows north along the San Andreas Fault to meet the North Fork Gualala. From that point to the ocean, the stream is considered the Gualala River mainstem (Figure 5.6-1). The Gualala River estuary is within that part of the subbasin, however it was parsed out as its own section (Section 5.1).

Nearly the entire subbasin is privately owned, with 15 acres of federal land and 38 acres of state land. Predominant land uses are timber production, grazing, and small vineyards.

A stream flow gage was installed in 2001 near the confluence with the Wheatfield Fork Gualala South Fork Gualala River above Wheatfield Fork near Annapolis. It is maintained by the California Department of Water Resources (DWR) and has been in operation since installation.

Historic events and the period of record on the various data sets used in the NCWAP assessment are presented in a graphic format in Figure 5.6-2.

5.6.2 GEOLOGY

The majority of the length of the South Fork is confined in the narrow linear valley presumably formed by the San Andreas Fault. The stream is low gradient and is slightly sinuous in the narrow valley where it flows across a narrow 12-mile-long floodplain. The upper reaches flow from steeper terrain outside of the San Andreas Fault zone (Figures 5.6-3 and 5.6-5). Figures 5.6-4 and 5.6-6 show the relative landslide potential map for the Gualala Mainstem and South Fork Subbasin. The complete maps and explanations for both maps are on Plates 1 and 2.

About 50 percent of the subbasin has a high to very high potential for landsliding and represents the major source area for stream sediment (Figures 5.6-4 and 5.6-6).

5.6.3 VEGETATION

The 1942 aerial photos show the South Fork upstream of the Wheatfield bordered by a variety of timber types as a result of an area-wide fire in the early 1900s. There was partial to entire canopy cover throughout most reaches along the mainstem Upper South Fork, Marshall Creek, and tributaries in 1942 (Figure 5.6-7). McKenzie Creek had dense mature redwood and Douglas fir cover. There was consistent oak woodland cover along upland riparian channels in the dense mélange soil type. This prairie grassland/oak woodland is the dominant vegetative cover in upslope areas. Dense old growth redwood forests lined the lower South Fork. This area today is occupied by advanced second growth redwood and Douglas fir timberlands. Appendix 3 provides a more detailed description.

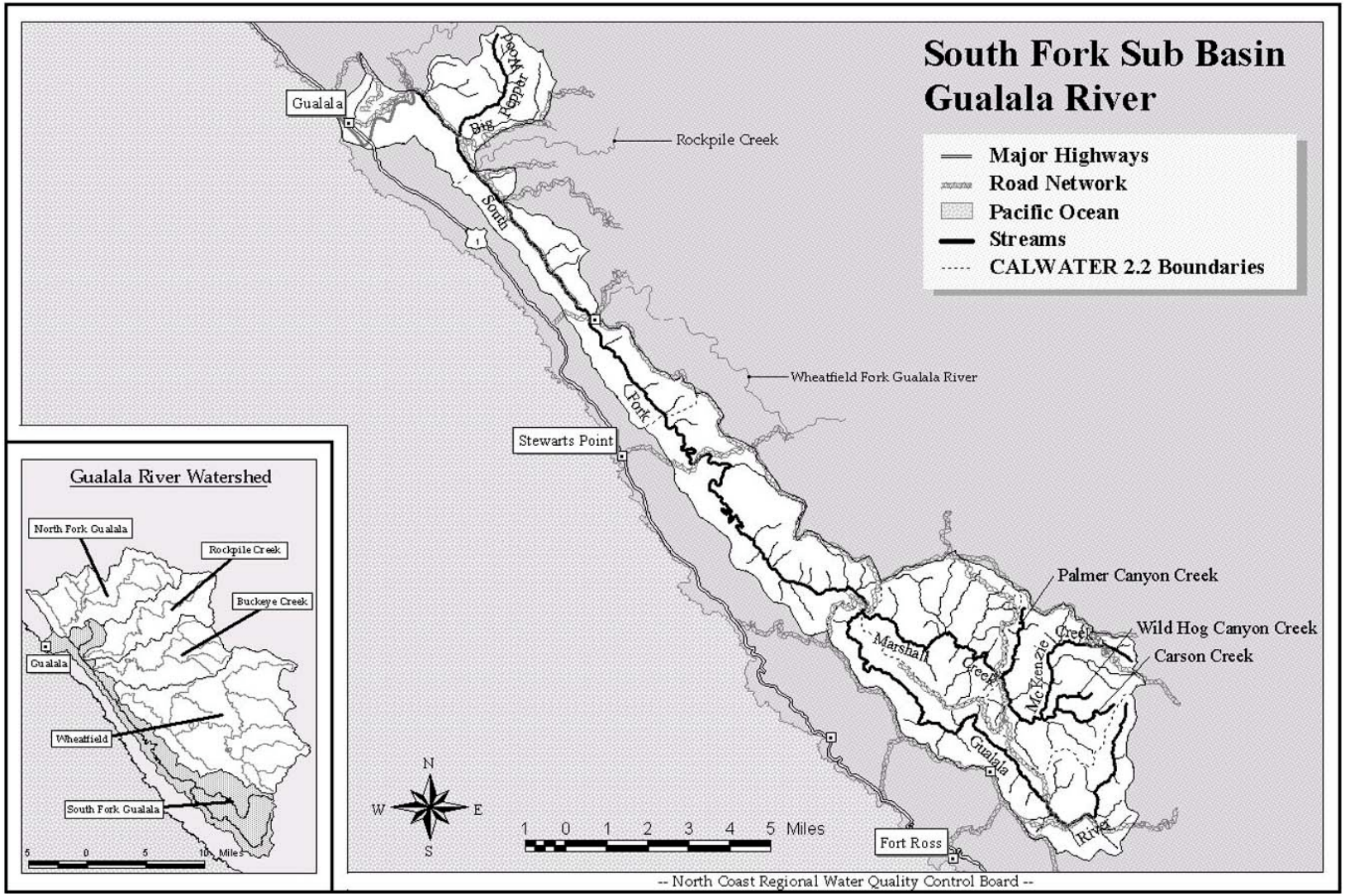


Figure 5.6-1
Gualala Mainstem/South Fork Subbasin

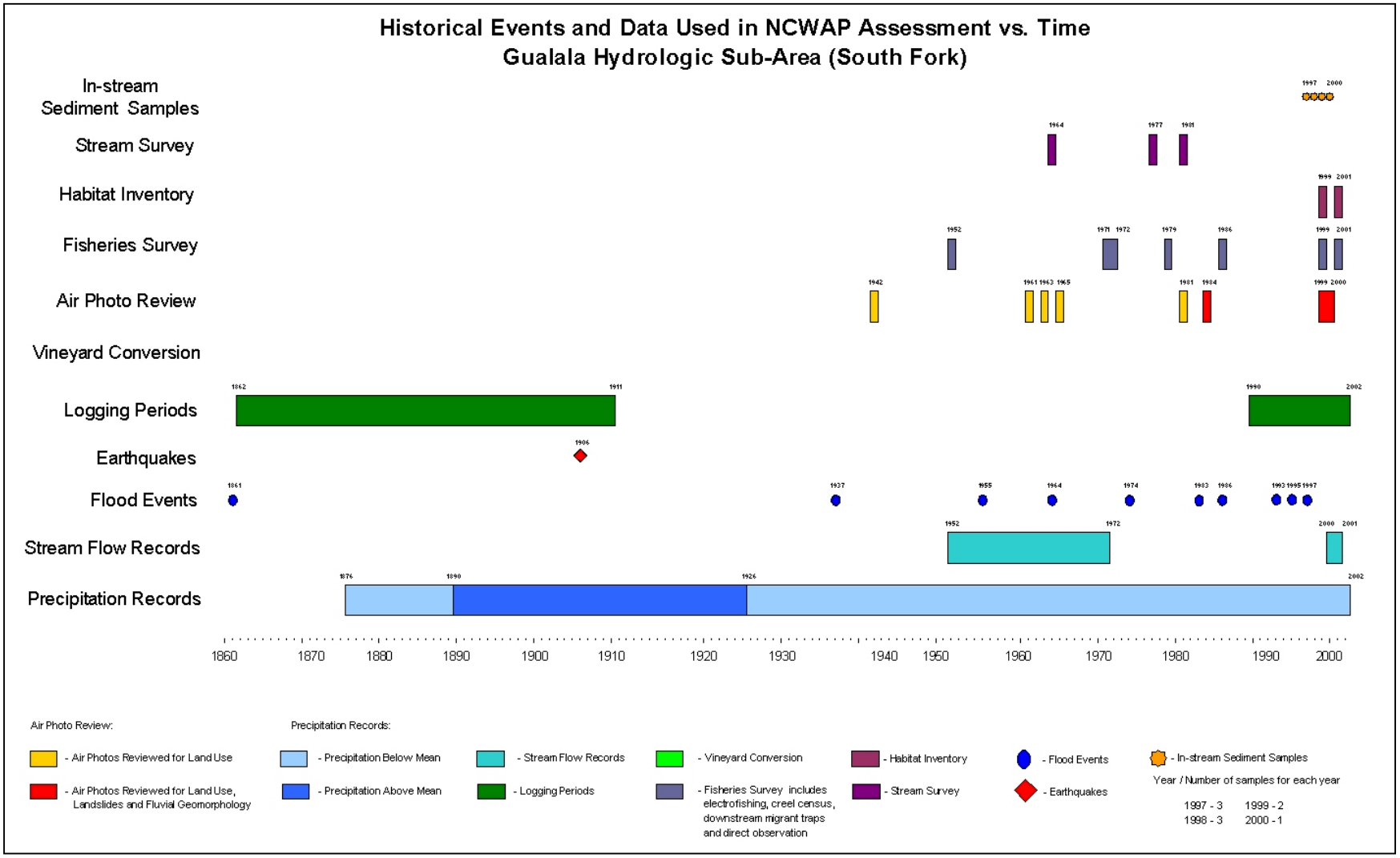


Figure 5.6-2
Historic Events and Data Used in the NCWAP Assessment for the Gualala Mainstem/South Fork Subbasin

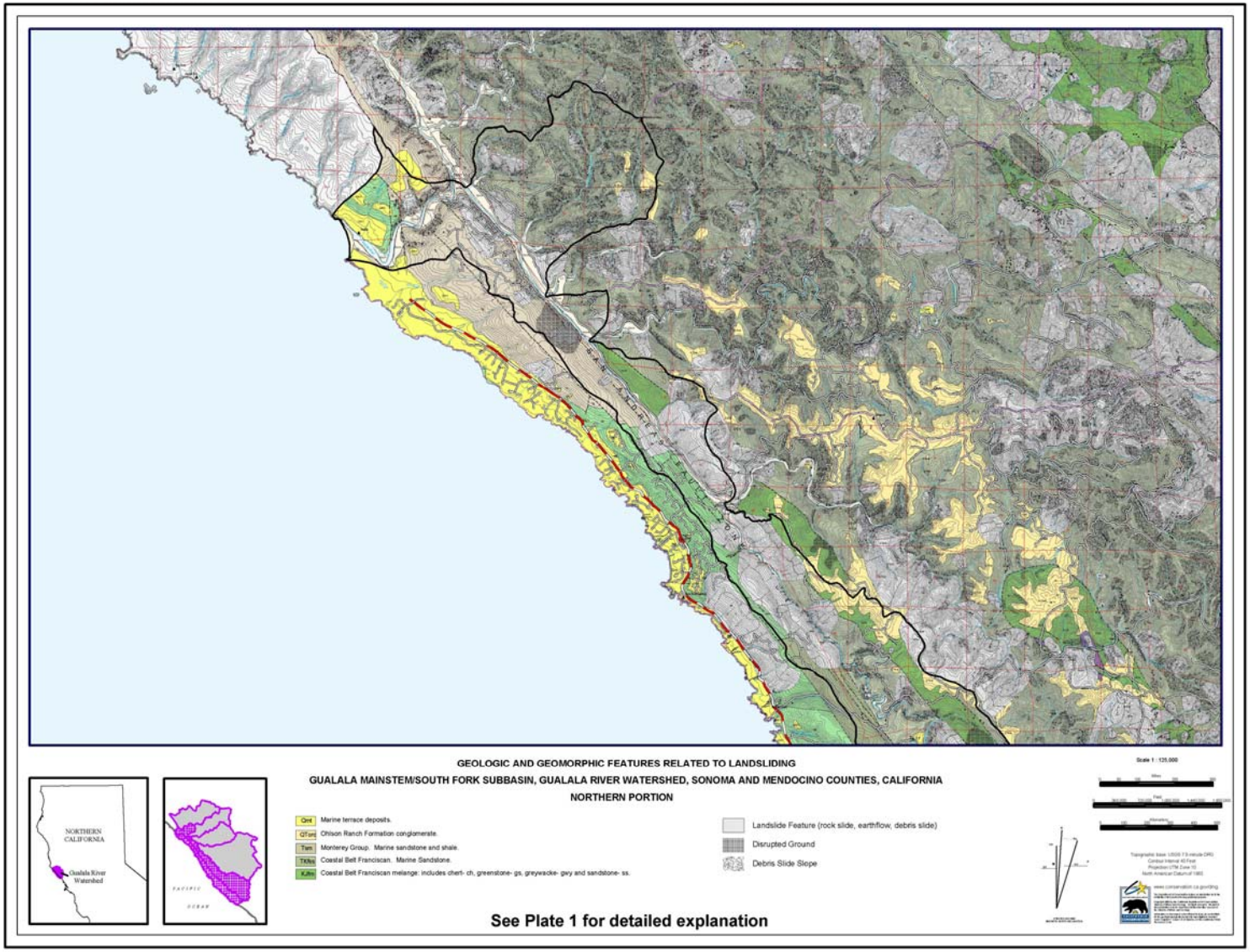


Figure 5.6-3
Geologic and Geomorphic Features Related to Landsliding - Gualala Mainstem/South Fork Subbasin, Northern Portion

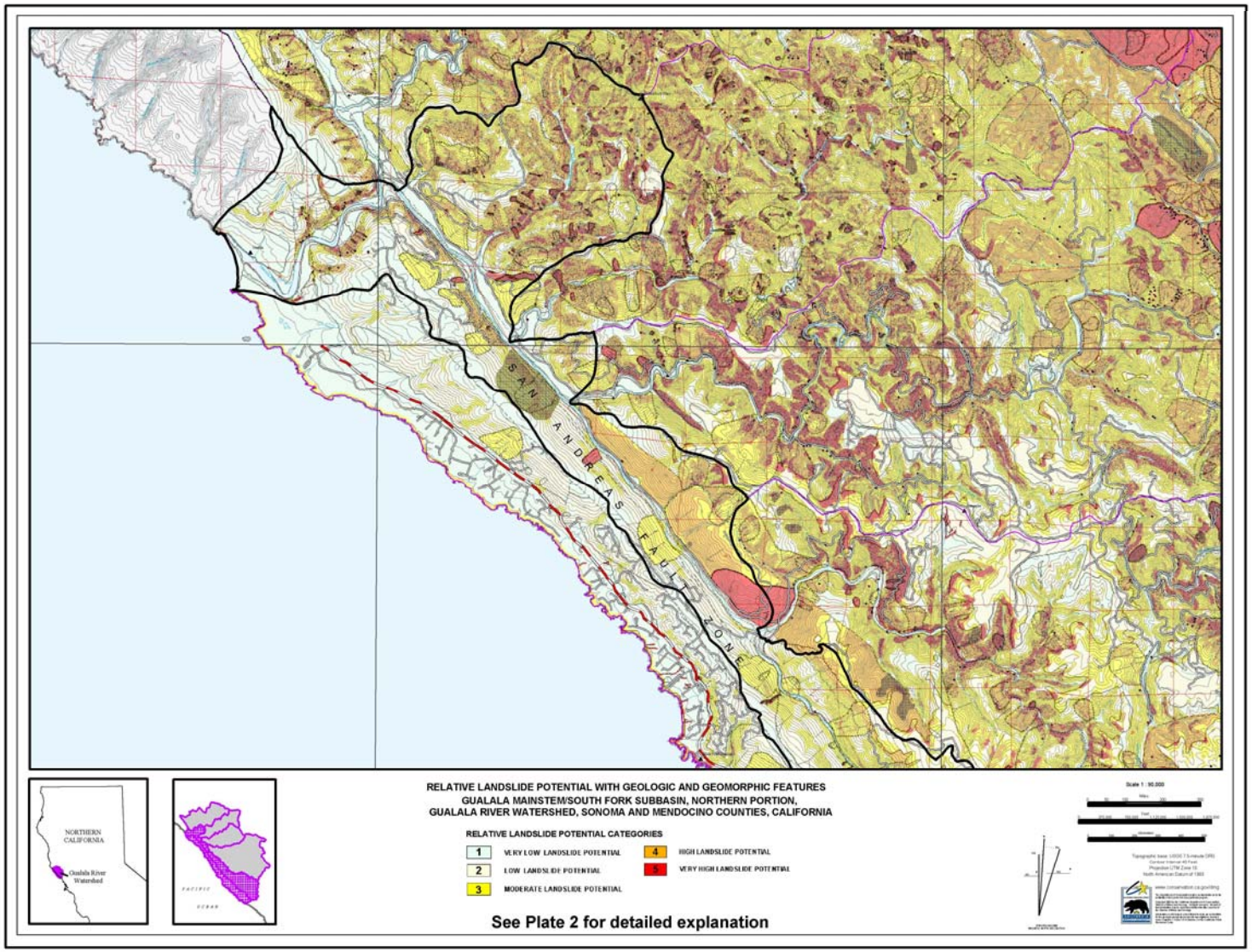


Figure 5.6-4
Relative Landslide Potential with Geologic and Geomorphic Features - Gualala Mainstem/South Fork Subbasin, Northern Portion

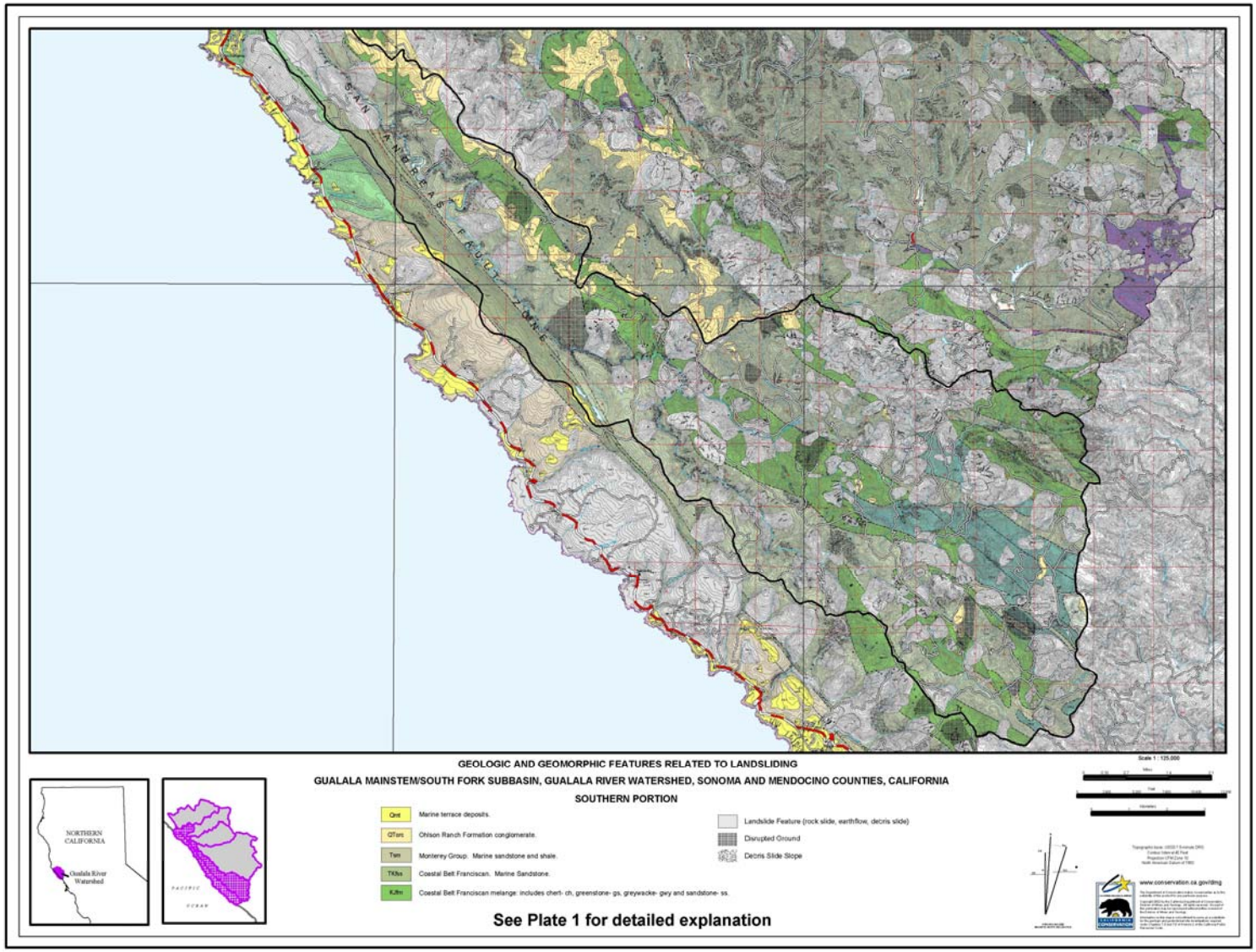


Figure 5.6-5
Geologic and Geomorphic Features Related to Landsliding - Gualala Mainstem/South Fork Subbasin, Southern Portion

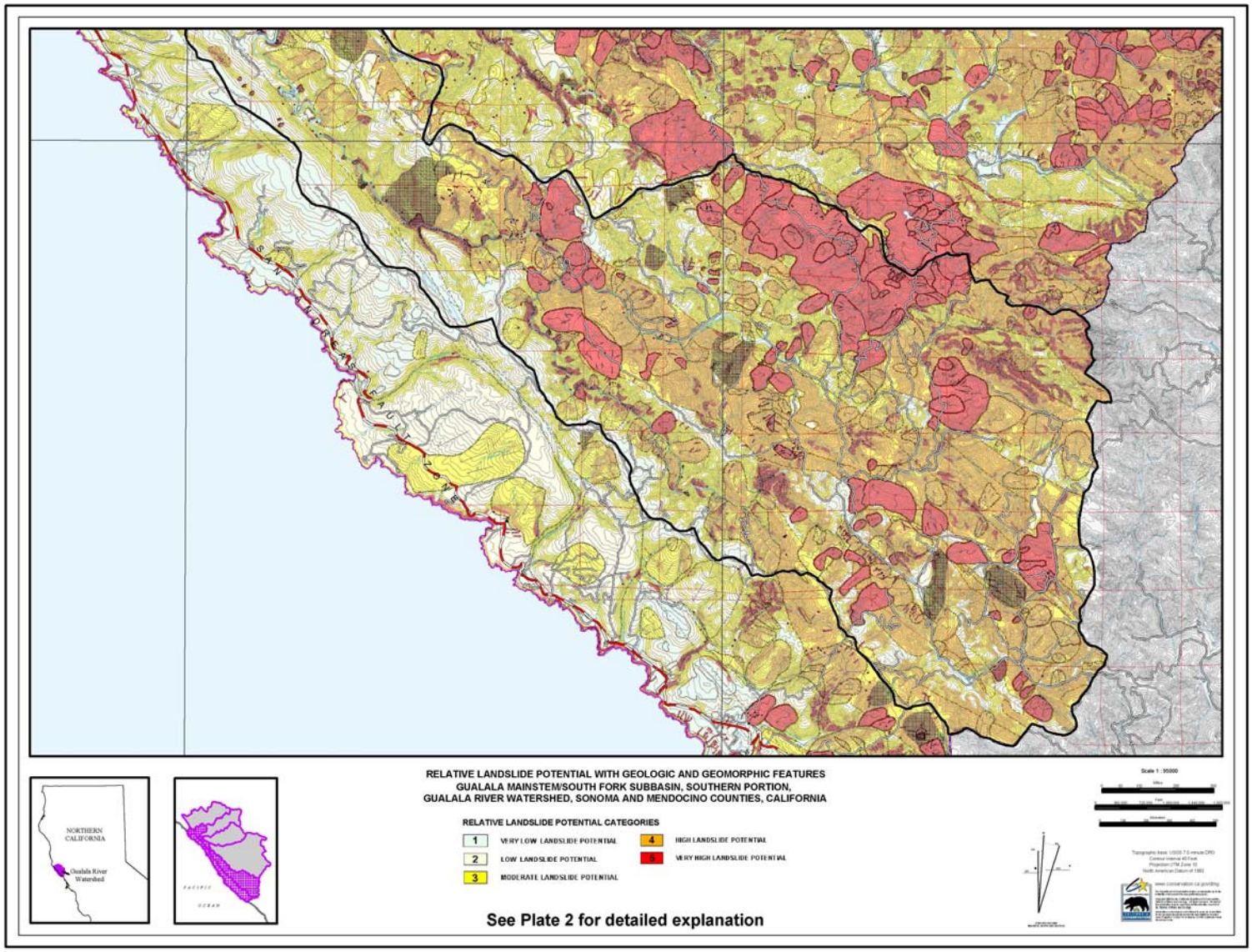


Figure 5.6-6
Relative Landslide Potential with Geologic and Geomorphic Features - Gualala Mainstem/South Fork Subbasin, Southern Portion

Figure 5.6-7
1942 Bank-to-Bank Exposure (White) and Partial to Entire Cover Over Blue Line Streams (Dark Blue)

5.6.4 LAND USE

Timber use and ranching have been the dominant land use activities. At the turn of the century, the railroad was built along the South Fork Gualala to transport old growth logs to the Clipper Mill. The long narrow lower South Fork valley was initially harvested during the turn of the century. Remnants of these logging systems are still evident in portions of the watercourse channel. Old growth redwood cutover areas were then used as grazing land. The current second growth stand in the South Fork is the result of regeneration following a severe fire in the early 1900s. The area was reentered during the 1950s for removal of scattered larger sized timber.

Post World War II tractor logging operations began early in the middle to upper reaches of the subbasin due to the proximity of the coast and available road networks. Timbered areas along the lower to central reaches of the mainstem Marshall Creek were logged during the mid 1950s. This removed overstory shade canopy from north facing slopes where conifered areas were confined (Figure 5.6-8). During the mid to late 1950s, downslope conifered areas throughout Wild Cattle and Palmer canyons were removed during an area-wide conversion (Figure 5.6-9). Logging operations used stream channels for skid trails, truck roads, and landing sites (Figure 5.6-10). Harvest operations removed overstory canopy cover with intent to maintain permanent conversion for grazing use. Two large fires burned through the area: one in 1955, and the Creighton Ridge Fire in the early 1980s.

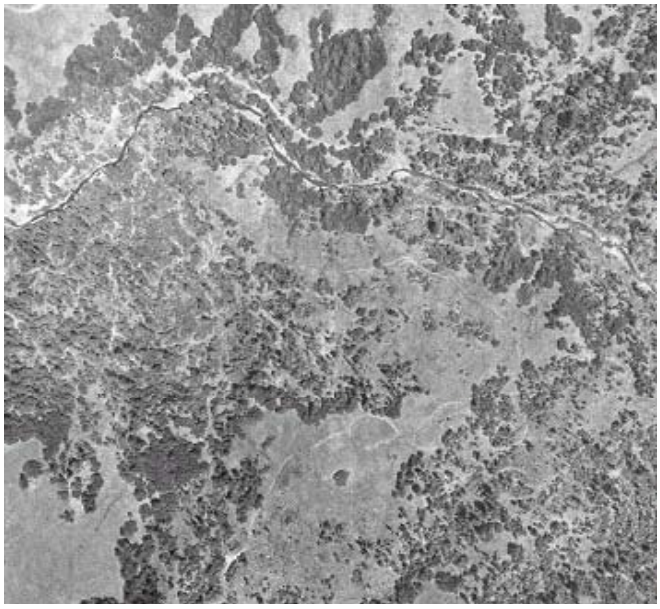


Figure 5.6-8
Overstory Shade Canopy Elimination, Upper South Fork, June 1965

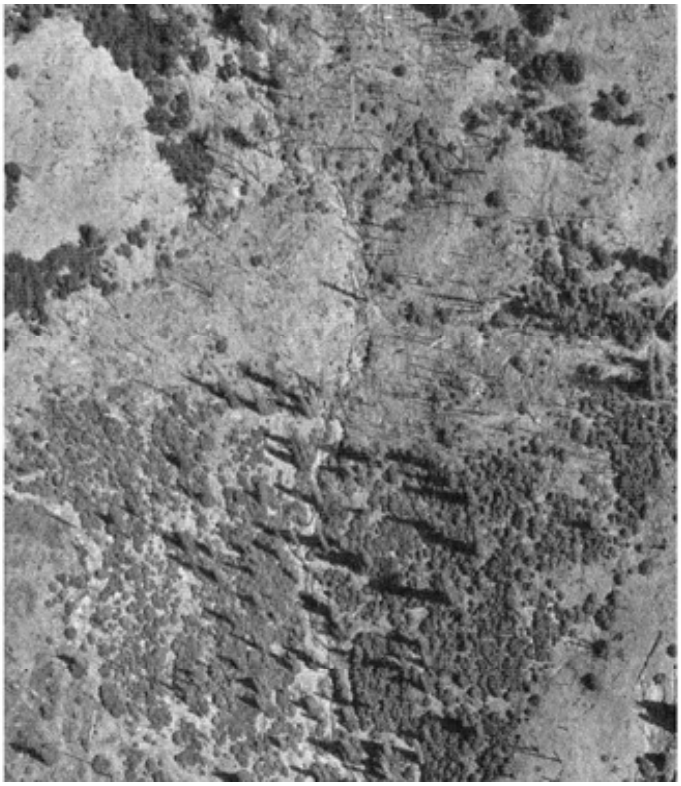


Figure 5.6-9
Conversion Project Removing Conifers Over the Creek in an Upper McKenzie Creek Tributary, Leaving Hardwoods Upslope

Table 5.6-1
Gualala Mainstem/South Fork Subbasin Stand Replacement Operations 1932 – 1973 - Total Area = 40, 756 acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Operation Since 1942	Mean Annual Increment (acres/percent by year)
1932– 1942	200	Stand Replacement	.05	20 (.05)
1942 – 1952	500	Stand Replacement	1.7	50 (.12)
1952 – 1960	9,800	Stand Replacement	25.7	1,187 (3.0)
1960 – 1964	600	Stand Replacement	27.0	150 (0.3)
1964 – 1973	950	Stand Replacement	29.7	95 (0.2)

Turn of the century old growth redwood logging extended along the lower South Fork, clearing the riparian zone along the river (Table 5.6-1). Stand type analysis of 1936 and 1942 photos showed mid-sized second growth redwood stands lining the lower South Fork. This even-aged stand structure indicates that the entire original old growth stand was removed bordering each side of the river, leaving bank-to-bank exposure along the Gualala River at the turn of the century.

The mid-20th-century tractor era largely avoided this area. Mapping of 1968 bank-to-bank exposure conditions showed some reaches with partial to entire canopy cover downstream of the confluence with Wheatfield Fork (Figure 5.6-11), reflecting in-growth of second growth conifer stands lining the aggraded substrate of the Lower South Fork by 1968. The 1964 fisheries surveys report coho salmon presence in conjunction with comparatively favorable habitat conditions along the lower South Fork including mid sized riparian structure lining the river. However, further inland, the 1965 aerial photos show the middle reaches of the North Fork, Rockpile, Buckeye, and Wheatfield subbasins largely removed of the old growth conifer stands by tractors, leaving bank-to-bank exposure over the major tributary streams. Only the Lower South Fork and Mainstem Gualala River maintained a larger sized stand component lining both sides of the streambank in 1965.

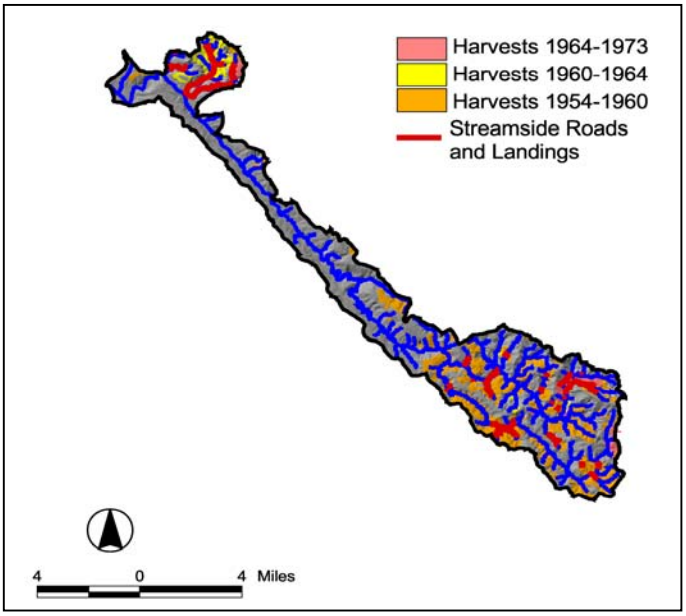
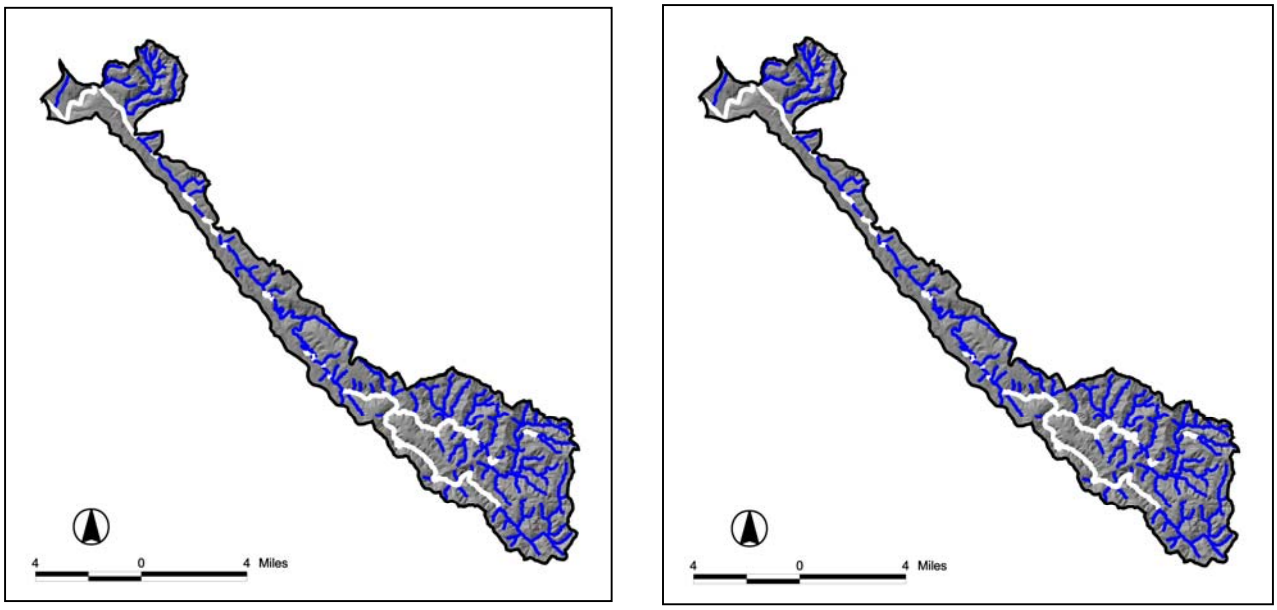


Figure 5.6-10
Mid-20th-Century Stand Replacement Operations, Streamside Roads and Landings (Red)

Mid-20th-century tractor operations were concentrated in the upper reaches of the South Fork Subbasin, eliminating riparian canopy cover along Marshall and McKenzie creeks, and the mainstem South Fork upstream from the confluence with Marshall Creek (Figure 5.6-11). In 1942, approximately 15 percent of the blue line streams were exposed bank-to-bank (Figure 5.6-7). The lower South Fork by 1942 was naturally aggraded and wide, creating bank-to-bank exposure throughout long sections of the river despite the mid-sized timber stand lining the streambank. In 1968, approximately 35 percent of the blue line streams were exposed bank-to-bank by the end of the tractor harvesting era. Bank-to-bank overstory shade canopy cover for 1999 shows improvement compared to 1968 in the upper subbasin reaches, reflecting riparian ingrowth since the late 1960s. By 1999, canopy cover improved to approximately 25 percent of blue line streams exposed bank-to-bank (Figure 5.6-11 above). Streamside canopy in the upper subbasin reaches now consists primarily of mid-sized mixed hardwood/conifer stands. Extended grazing use and conversions to rangeland have delayed vegetational ingrowth in many riparian areas of the upper subbasin.

After the early 1960s, timber harvesting slowed. No more than approximately 1,500 acres was harvested by stand replacement between 1960 and 1973 (Table 5.6-2). Ranching became the more dominant land use activity.



1968 **1999**

Figure 5.6-11
1968 Bank-to-Bank Stream Exposure and 1999 Bank-to-Bank Stream Exposure

After 1990, timber harvesting accelerated in the lowest reaches throughout now-mature second-growth redwood tracts (Figure 5.6-12). Rotating clear cut block units offset uncut areas of equal size by the three-year adjacency requirement. Recently, vineyard development has appeared along the uppermost ridgelines with a decline in rangeland uses. However, 1999 air photos show that vineyards consist of small patch clearances diffusely scattered throughout the east portions of the subbasin separated by wider areas of existing vegetation (Appendix 3). Grazing lands have been vegetationally typed at 2,450 acres (6.1 percent).

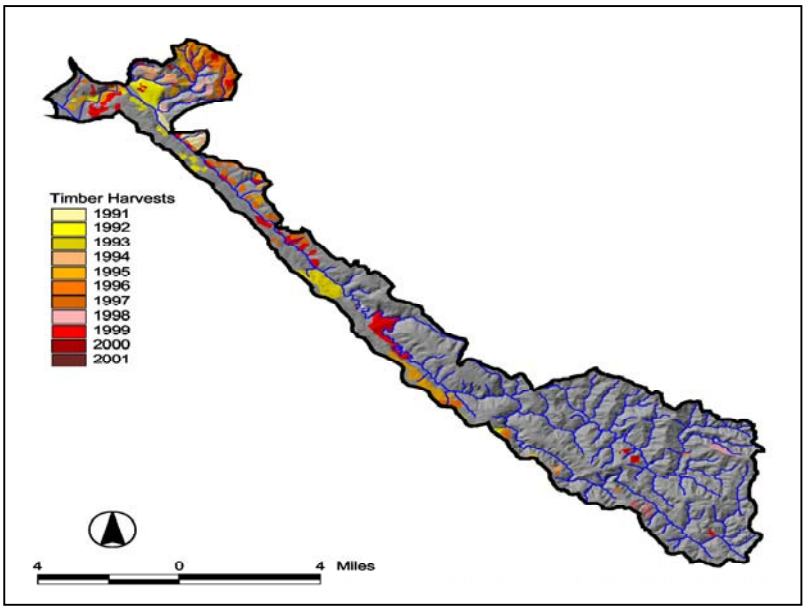


Figure 5.6-12
1991 to 2001 Timber Harvest Plans

Table 5.6-2
Gualala Mainstem/South Fork Subbasin Timber Harvest Operations – 1974 – 2001 - Total Area = 40, 756 acres

Time Period	Acres Under Operation	Type of Operation	Cumulative Percent of Subbasin Under Operation Since 1974	Mean Annual Increment (acres/percent by year)
1974 - 1990	2,400	Stand Replacement	5.8%	150 (0.4)
1991 - 2001	7,350	THPs	21.5 (tractor 58% cable 32%)	735 (1.6)

5.6.5 ROADS

Mid-20th-century streamside roads and landings lined McKenzie and Palmer Canyon creeks, and tributaries to Marshall Creek. Approximately 15 miles of streamside roads were bulldozed along watercourses in the subbasin. Most of these were in the upper subbasin reaches. Multiple debris slide failures have been documented with these roads with the 1965 photos. Instream/streamside roads and landings in 1984 showed a high correlation with stream braiding and aggradation in these areas.

There have been few areas in the upper subbasin that have been under THPs with which to upgrade existing roads and decommission abandoned roads. Mid-20th-century streamside roads in the upper subbasin reaches are recommended as the highest priority for proper abandonment or upgrade procedures.

The current road network in the subbasin consists of approximately 116 miles, at a density of 6.8 miles/square mile. There are approximately 1.5 miles of modern roads located within 50 feet of blue line streams. Of these, less than one-half mile are located in areas that may be affected by historically active landsliding and stream bank erosion.

Documentation of Land Use Impacts

Marshall Creek

- Conversions to rangeland have been the dominant form of historical use with major portions of riparian areas converted to rangeland. A loop conversion project removed all downslope conifered areas eliminating the riparian zone throughout Wild Cattle Canyon, extending east in an arc connecting Palmer Canyon, during the later 1950s. Sheep were noted grazing in the riparian zone in Palmer Canyon Creek during a 1981 survey.

McKenzie Creek

- A continuous wide belt of mature Douglas-fir occupied the lower and central reaches of McKenzie Creek extending from the confluence with Marshall Creek to Devils Rib Ridge. The Upper McKenzie was then logged after the 1964 fisheries survey. The main haul road followed the stream channel. Numerous instream landings are located throughout the subbasin. The riparian zone was cleared of all overstory vegetation.
- Substantial historic logging damage noted. The McKenzie Creek Subbasin is a Gualala River Watershed Council high priority area, with numerous restoration projects already completed.

Wild Hog Canyon Creek and Carson Creek

Both creeks were logged during the late 1950s. The haul road and landing sites lined the main channel. Overstory riparian canopy was largely removed.

5.6.6 FLUVIAL GEOMORPHOLOGY

About 50 percent of the subbasin has a high to very high potential for landsliding and represents the major source area for stream sediment (Figures 5.6-4 and 5.6-6). Instream sediment accumulations, indicative of disturbance, occur along 33 of 140 miles of the blue lines streams in the subbasin. This is a 42 percent reduction compared to levels in 1984, mostly in the tributaries. The lower South Fork in the vicinity of Valley Crossing showed channel lowering over the past several decades. Table 5.6-3 lists the lengths of sediment storage mapped and relative change between 1984 to 1999/2000 for the Gualala Mainstem/South Fork Subbasin.

Table 5.6-3
Gualala Mainstem/South Fork Subbasin Stream Characteristics Representing Sediment Sources or Storage

Planning Watershed	Year 2000		Year 1984		1984 to 2000	1:24K Streams
	Length Miles	Percent Total Stream for Subbasin	Length Miles	Percent Total Stream for Subbasin	Length Miles	Total Length Miles
Marshall Creek						
Upper Marshall Creek	3.6	13.6	6.9	26.1	-47.8	26.3
Lower Marshall Creek	4.1	18.5	9.9	44.0	-58.1	22.4
Upper South Fork Gualala River	6.3	23.9	10.4	39.2	-39.0	26.5
Middle South Fork Gualala River	6.6	27.2	7.6	31.5	-13.6	24.2
Total	**20.6**	**20.8**	**34.7**	**34.9**	**-40.6**	**99.5**
Lower South Fork Gualala River						
Mouth of Gualala River	4.6	34.5	8.2	61.9	-44.2	13.2
Big Pepperwood Creek	5.4	25.0	10.0	46.1	-45.8	21.6
Total	**12.6**	**31.0**	**22.3**	**55.0**	**-43.6**	**40.5**
Total Watershed	**33.2**	**23.7**	**57.0**	**40.8**	**-41.8**	**140.0**

5.6.7 WATER QUALITY

Water Chemistry

Basic water chemistry data were available from USEPA's StoRet system and NCRWQCB sampling for three sites in the Gualala Mainstem/South Fork Subbasin:

- the mainstem near Gualala (15 times between September 14, 1975 and October 14, 1977, February 13, 1975, April 4, 1985 and February, May, and June, 2001),
- the South Fork near Valley Crossing (April and September from 1974 to 1988 and February, May, and June, 2001), and
- the South Fork at Hauser Bridge (February, May, and June, 2001).

All parameters met water quality objectives in the NCWQCB's *Basin Plan*. The data indicated a moderately hard water oligotrophic stream with pH slightly above neutral, high dissolved oxygen, low dissolved solids, and low nutrients (nitrogen and phosphorus), consistent with measurements in other north coastal streams. Appendix 4 contains the raw data and graphs for these stations.

Water Temperature

Water temperature data from continuous recorders were available for 17 sites in the Gualala Main/South Fork Subbasin (Figure 5.6-13). The period of record from 1994 to 2001 yielded 46 observations for maximum weekly average temperature (MWAT) and seasonal maximum temperature.

MWATs in the upper tributary sites (McKenzie and Palmer Canyon creeks) ranged from moderately unsuitable to fully suitable. MWATs in the lower tributaries (Pepperwood creeks, Groshong Gulch) ranged from moderately to fully suitable. (Table 5.6-4, Figures 5.6-14 and 5.6-15)

The mainstem sites varied from somewhat to fully unsuitable (Table 5.6-4, Figures 5.6-14 and 5.6-15).

Table 5.6-4
Ecological Management Decision Support (EMDS) Ratings for Maximum Weekly Average Temperatures (MWATS) in the Gualala Mainstem/South Fork Subbasin

Stream	No. of Sites	No. of Observations	Period of Record	EMDS Suitability Ratings						
				+++	++	+	0	-	--	---
South Fork Mainstem	7	20	1994-2001							
Palmer Canyon Creek	1	1	2000							
McKenzie Creek	2	4	2000, 2001							
Little Pepperwood Creek	2	6	1994-1998							
Big Pepperwood Creek	3	12	1994-2000							
Groshong Gulch	2	3	1996-2000							

EMDS ratings:

+++ = fully suitable (50-60 F)
++ = moderately suitable (61-62 F)
+ = somewhat suitable (63 F)
0 = undetermined (between somewhat suitable and somewhat unsuitable) (64 F)
- = somewhat unsuitable (65-66 F)
-- = moderately unsuitable (67 F)
--- = unsuitable (> 68 F)

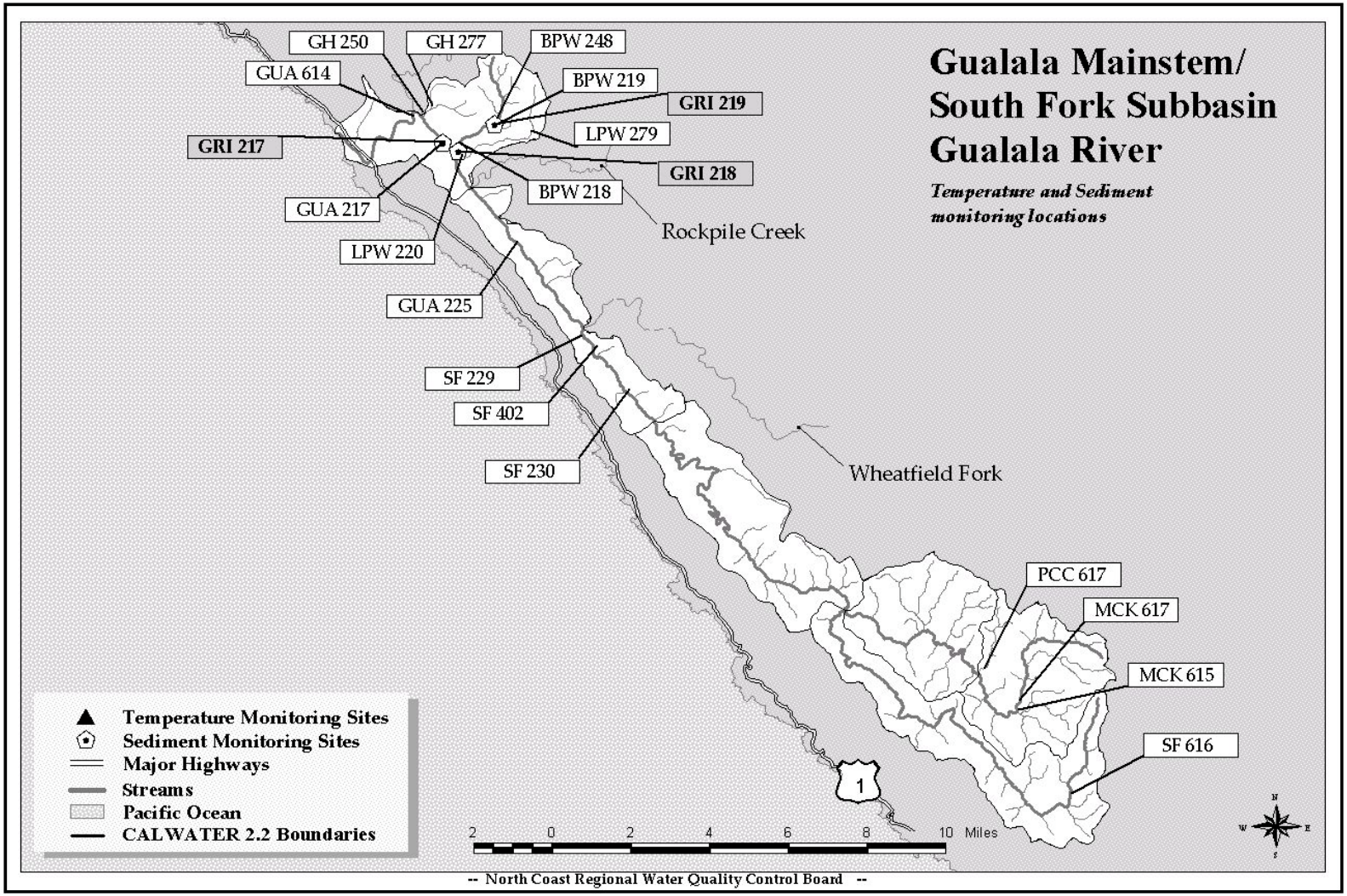


Figure 5.6-13
In-Stream Sediment and Temperature Sampling Sites, Gualala Mainstem/South Fork Subbasin

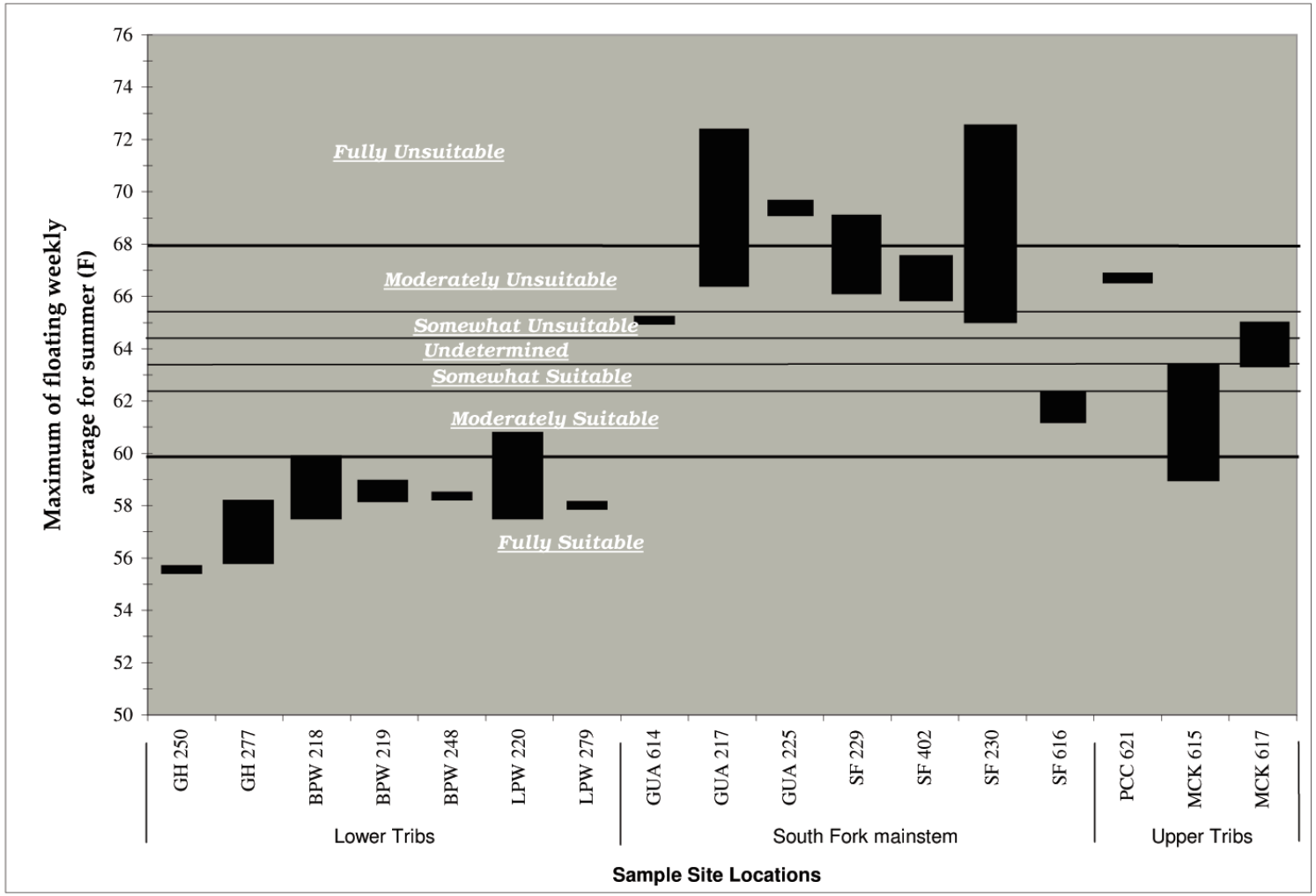


Figure 5.6-14
Maximum Weekly Average Temperatures for the Gualala Mainstem/South Fork Subbasin, 1994-2001, From Continuous Temperature Monitors Maintained by GRI and GRWC

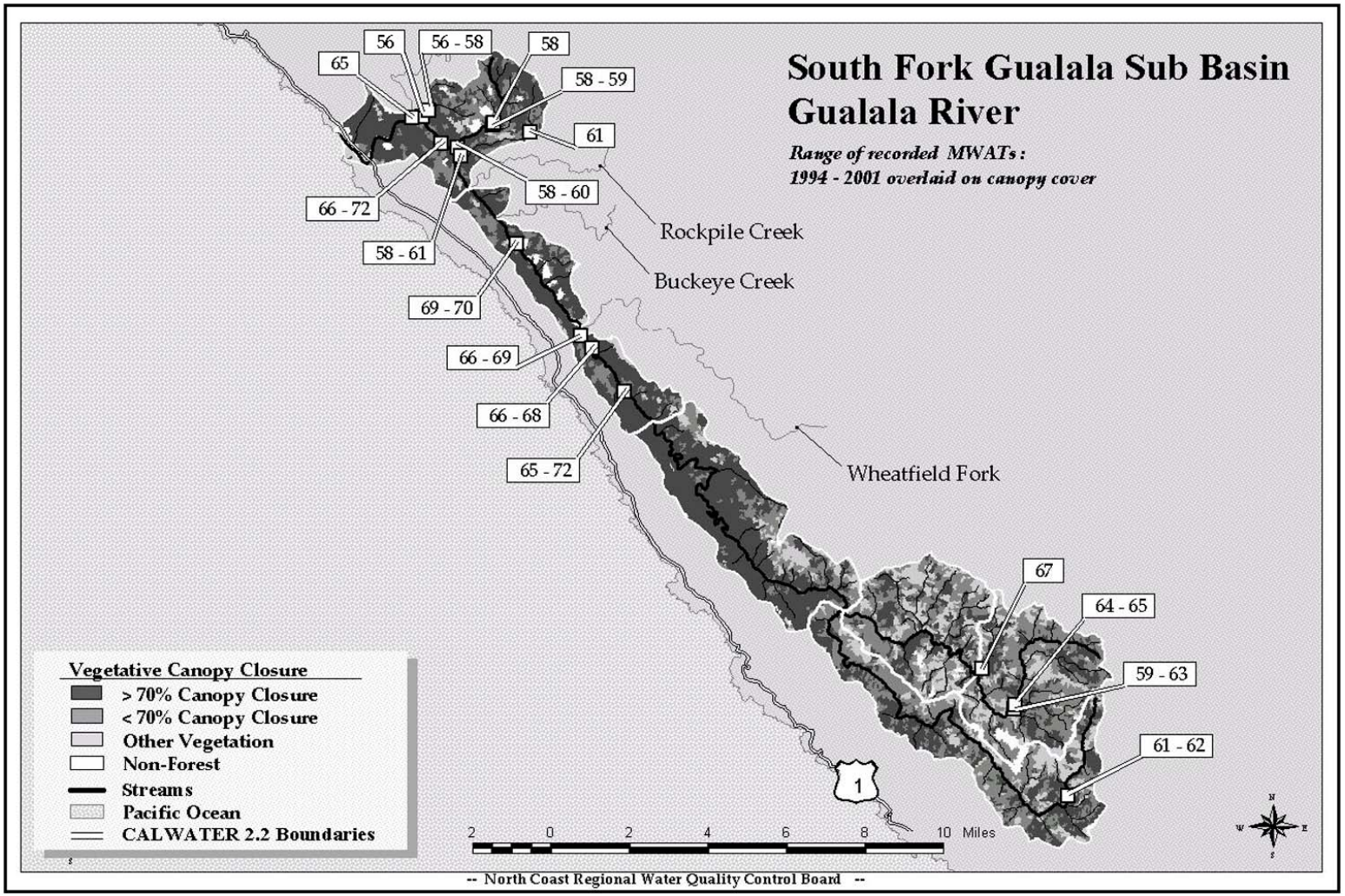


Figure 5.6-15
MWAT Temperature Ranges in the Gualala Mainstem/South Fork Subbasin for the Period of Record, 1994-2001 Overlaid on the LanSat Vegetation Layer for 2000

Seasonal maximum temperatures were above the lethal limit of 75 F at three of the seven mainstem sites (six of 20 observations). Tributary sites were below the limit, with the single observation in Palmer Canyon Creek at 74 F.

5.6.8 FISH HABITAT RELATIONSHIP

Historic Habitat Conditions

CDFG stream surveys were conducted in 1964, 1977, and 1981 on seven tributaries in the South Fork Subbasin, South Fork, Marshall Creek, Marshall Creek Tributary #3, Marshall Creek Tributary #5, McKenzie Creek, McKenzie Creek Tributary #6, and Palmer Canyon Creek. These surveys were made by direct observation and were not backed by quantitative data (Table 5.6-5).

Table 5.6-5
Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala Mainstem/South Fork Subbasin

South Fork Mainstem Subbasin	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
South Fork	9/23 and 9/24 1964 5/17 and 18/1977	Plentiful spawning areas throughout the stream. Pool: Riffle 95:5. Generally poor shelter consisting of overhanging banks, boulders, logs, aquatic plants and overhanging aquatic plants. Summer flows are limited. Pool: Riffle ratio 7:3. The majority of pools had little to no shelter. Shelter consisted of boulders, aquatic plants, logs, undercut banks, and overhead canopy	Old Log Jams. None Complete. No barriers observed. Each summer a dam is constructed approximately ½ mile below the Wheatfield Fork.	Continue to manage for production of juvenile steelhead trout and coho salmon.
Marshall Creek	9/28/1964	Deposits of good spawning gravel exist throughout the stream from the mouth to the upper fisheries value. Pool: Riffle ratio 50:50. Good shelter provided by logs, boulders, undercut banks, roots, and trees.	No complete barriers.	Should be managed as a steelhead trout and coho salmon spawning and nursery stream.
Marshall Creek Tributary #3	9/28/1964	Very limited fisheries value. Watershed severely burned 10 years ago. Lower half mile has spawning gravel available, but summer flow is very low.	Total barrier to fish a half mile above the mouth.	None
Marshall Creek Tributary #5	9/29/1964	Summer flows are limited. Some suitable spawning gravel directly above large log jams.	Over 40 log jams in a 1 mile stretch of stream. A number form complete fish passage barriers.	Remove log jams.
McKenzie Creek	9/23 and 24/1964	Spawning areas fair to good in the lower 1/3 of stream, excellent in the middle section of stream, and fair in the upper 1/3 of stream; Pool: Riffle ratio 60:40; Good shelter provided by rocks and undercut banks.	7 partial barriers; Large 7 feet high 40 feet dam present 1/6 mile upstream from mouth; Large bedrock falls 1-1/4 miles upstream	Continue to manage as a coho salmon, steelhead trout spawning and nursery area. After removal of falls, possible planting of coho salmon to re-establish a self-

Table 5.6-5
Summary of Historic (1964-1981) Stream Surveys Conducted in the Gualala Mainstem/South Fork Subbasin

South Fork Mainstem Subbasin	Date Surveyed	Habitat Comments	Barrier Comments	Management Recommendations
				supporting run.
McKenzie Creek Tributary #6	10/1/1964	Streambed unsuitable for spawning except for the lower ½ mile of stream which is dry in the summer.	Impassable 10 ft falls ½ mile upstream from the mouth.	None
Palmer Canyon Creek	7/31/1981	Could become a good spawning area and nursery habitat for rainbow trout/steelhead trout if improved. Occasional small isolated spawning areas separated by areas of boulders or heavily silted areas. Adequate vegetative cover, undercut banks and logs are present in the lower and mid sections of stream.	9 partial fish passage barriers; 2 complete fish passage barriers.	Needs removal of log jams, healing of eroded areas and stream bank cover in upper sections.

Current 1999 and 2001 Conditions

Target Values from the Habitat Inventory Surveys (Flosi et al 1998)

Beginning in 1991, habitat inventory surveys were used as a standard method to determine the quality of the stream environment in relation to conditions necessary for salmonid health and production. Target values for each of the individual habitat elements measured are provided in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998) (Table 5.6-6). When habitat conditions fall below the target values, restoration projects may be recommended to meet critical habitat needs for salmonids.

Table 5.6-6
Habitat Inventory Target Values from the
California Salmonid Stream Habitat Restoration Manual (Flosi et al 1998).

Habitat Element	Canopy Cover	Embeddedness	Primary Pool Depth/Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-40%	Ratings range from 0-300
Target Values	>80%	>50% or greater of the stream length is <50% embedded	Depth-1st and 2nd order streams >2 feet 3rd and 4th order streams >3 feet. Frequency->40% of stream	>80

Habitat inventory surveys were conducted in 1999 and 2001 on seven streams in the Gualala Mainstem/South Fork Subbasin. The target values for canopy cover were met on Camper Creek, Carson Creek, Palmer Canyon Creek, and upper South Fork. Cobble embeddedness target values were met on Camper Creek, Marshall Creek, McKenzie Creek, Palmer Canyon Creek, upper South Fork, and

Wild Hog Creek. None of the streams in the subbasin met the target values for primary pool depth/frequency or shelter/cover (Table 5.6-7).

Table 5.6-7
Summary of Current (1999 and 2001) Conditions Based Upon Habitat Inventory Surveys From the Gualala Mainstem/South Fork Subbasin, Gualala River Watershed, California
Condensed Tributary Reports are located in Appendix 5

Habitat Element Stream Name	Surveyed Length (feet)	Canopy Density	Embeddedness	Primary Pool Depth/ Frequency	Shelter Cover Ratings
Main stem /South Fork Subbasin	57,218				
Camper Creek (1999)	3,546	86%	70%	3%	25
Carson Creek (1999)	6,834	83%	50%	14%	19
Marshall Creek (*partial survey)*	21,698	55%	90%	13%	13
McKenzie Creek (1999)	3,801	69%	60%	18%	23
Palmer Canyon Creek	95	82%	65%	3%	12
Upper South Fork (*partial survey)*	8,451	96%	73%	5%	22

Canopy coverage was a habitat deficiency on Marshall, McKenzie, and Wild Hog Creeks. The canopy was dominated by deciduous tree species (Figure 5.6-16).

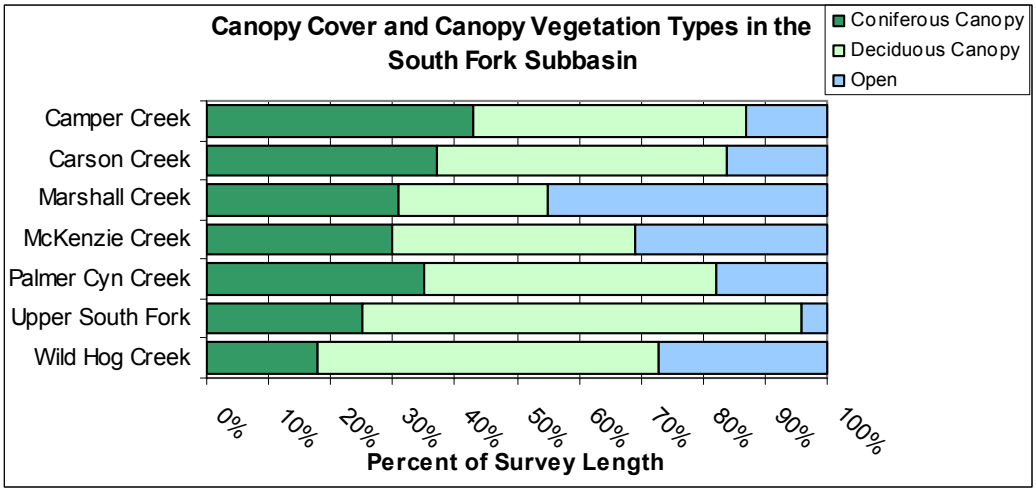


Figure 5.6-16
Canopy Cover and Canopy Vegetation Types in the Seven Tributaries Surveyed, Gualala Mainstem/South Fork Subbasin 1999 and 2001, Gualala River Watershed, California

Categories 1 and 2 embeddedness (<50 percent embedded) are considered the most productive for spawning. Category 5 is unsuitable substrate, which includes clay, bedrock, and logs. Data collected during 1999 and 2001 habitat inventory surveys showed that all streams, except Carson Creek, had greater than 50 percent of the pool tails surveyed were categories 1 and 2. Slightly less than 50 percent of the pool tails surveyed on Carson Creek were categories 1 and 2 (Figure 5.6-17).

All streams surveyed in the South Fork Subbasin had habitat deficiencies in pool depth. Camper, McKenzie, Palmer Canyon, Wild Hog creeks and the Upper South Fork did not meet pool frequency

target values (Figure 5.6-18). Carson and Marshall creeks met the pool frequency target values, however, neither met the depth target value.

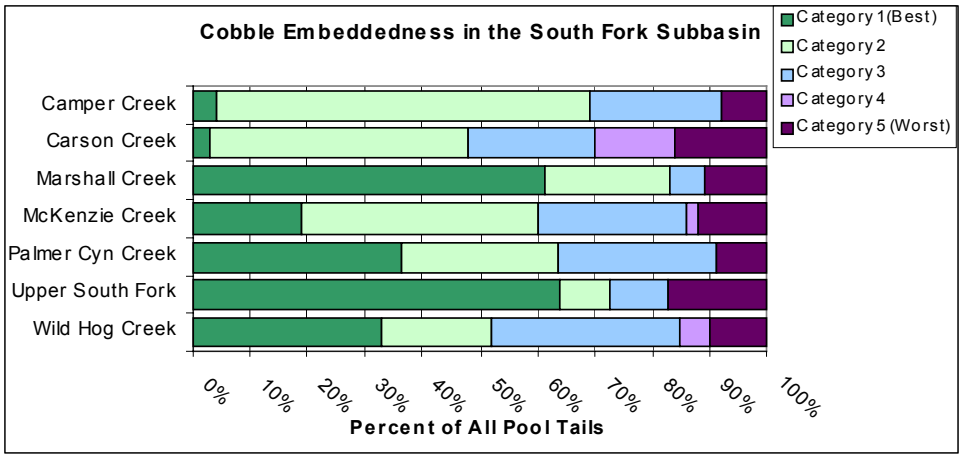


Figure 5.6-17
Cobble Embeddedness in the Gualala Mainstem/South Fork Subbasin 1999 2001, Gualala River Watershed, California

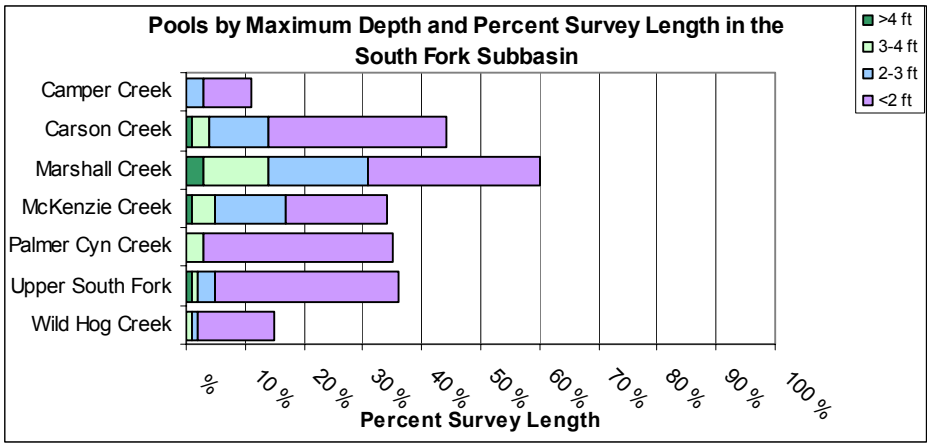


Figure 5.6-18
Pools by Maximum Depth and Percent Survey Length in the Gualala Mainstem/South Fork Subbasin 1999 and 2001, Gualala River Watershed, California

Shelter/cover ratings were below target values for all of the streams surveyed in the South Fork Subbasin (Figure 5.6-19). The top three types of shelter/cover were mostly bedrock ledges, small woody debris, and large woody debris. Small woody debris, boulders, and bedrock ledges provided the most shelter on Camper Creek. The primary cover types were undercut banks, root masses, and white water on Carson Creek. The primary cover types were small woody debris, root masses, and bedrock ledges on Marshall Creek. The primary cover types were boulders, large woody debris, and root masses on McKenzie Creek. On Palmer Canyon Creek, boulders, small woody debris, and aquatic vegetation provided the most shelter. The primary cover types were small woody debris, boulders, and bedrock

ledges on Upper South Fork. Large woody debris and bedrock ledges provided the most shelter on Wild Hog Creek (Figure 5.6-20).

Large Woody Debris Data

Most large wood was cleared from the streams during the 1950s, 1960s and 1970s. A target value of 130 pieces of large wood >8 inches per 1,000 feet of stream is recommended in the literature (Beechie and Sibley 1997, Martin 1999).

Large wood surveys wereconducted in 1998-2001at one site on Pepperwood Creek (a tributary to the lower South Fork) and two sites in the lower South Fork as part of the Watershed Cooperative Monitoring Program. The surveys showed the lower South Fork and Pepperwood Creek lack volume and pieces of large woody debris (Table 5.6-8).

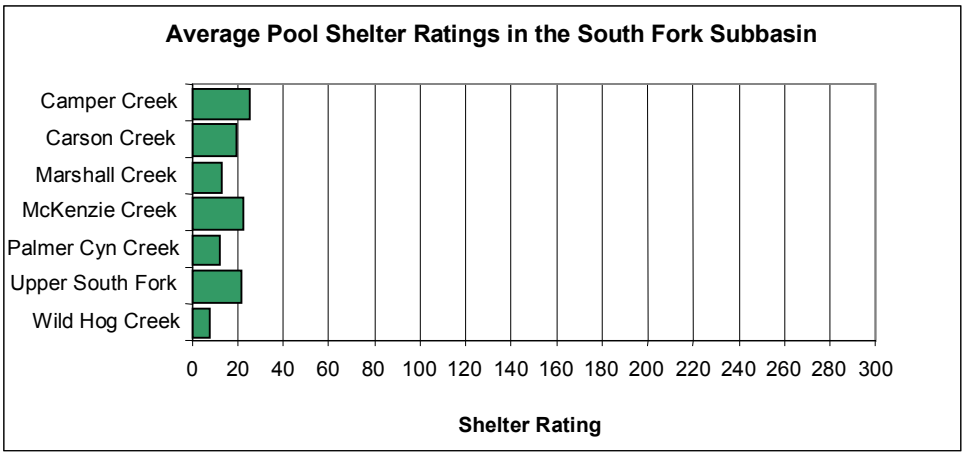


Figure 5.6-19
Average Pool Shelter Ratings in the Gualala Mainstem/South Fork Subbasin 1999 and 2001

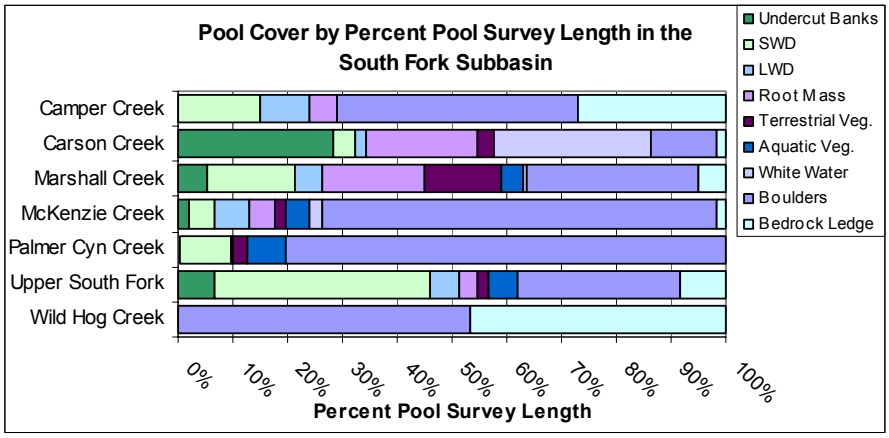


Figure 5.6-20
Types of Pool Cover by Percent of Pool Survey Length in the Gualala Mainstem/South Fork Subbasin, 1999 and 2001

Table 5.6-8
Summary of Watershed Cooperative Monitoring Program Large Woody Debris Surveys, Gualala Mainstem and Lower South Fork Subbasin (1998 - 2001)

Tributary	Site Number	Watershed* Size (acres)	Volume Cubic Feet/1,000'	Quantity Pieces/1,000'
Pepperwood Creek	218	1,825	2,275	61
Gualala South Fork	217	157,415	1,207	23
Gualala South Fork	402	31,081	1,390	23

*Watershed size is calculated as the area above the monitoring site.

Changes in Habitat Conditions From 1964 to 2001

Changes between historic and current instream conditions were compared between the streams surveyed in 1964, 1977, and 1981 and subsequently habitat inventoried in 1999 or 2001. Data from the earlier stream surveys only provide a qualitative snapshot of the conditions at the time of the survey and the terms such as excellent, good, fair and poor were based on the judgment of the biologist or scientific aid conducting the survey. The results of the historic stream surveys cannot be used in comparative analyses with the quantitative data provided by the habitat inventory surveys with any degree of accuracy. However, the two data sets may be used to show general trends (Table 5.6-9).

Table 5.6-9
Comparison Between Historic Habitat Conditions Observed in 1964 with Current Habitat Inventory Surveys Based Upon Quantitative Measurements in 2001 from the Gualala Mainstem/South Fork Subbasin, Gualala River Watershed, California

Habitat Element Stream Name	1960s Canopy Cover Photos	2001 Canopy Cover	1964 Spawning Conditions	2001 Spawning Conditions	1964 Pool Depth/ Frequency	2001 Pool Depth/ Frequency	1964 Shelter Cover	2001 Shelter Cover Values	Change in conditions from 1964 to 2001
Mainstem/South Fork Subbasin									
Marshall Creek *(partial survey)*	Low or Absent	55%	Good	90%	50%	13%	Good	13	Some canopy recovery: Improved spawning conditions. Decreased pool habitat and shelter/cover.
McKenzie Creek (1999)	Low or Absent	69%	Good	60%	60%	18%	Good	23	Some canopy recovery: Improved spawning conditions: Decreased pool habitat and shelter/cover.
Upper South Fork	Low or Absent	96%	Good	73%	95%	5%	Poor	22	Recovered canopy: Improved spawning conditions. Decreased pool habitat and shelter/cover.

According to aerial photographs, the canopy density of the 1960s was reduced substantially from the conditions observed in the 1940s, when canopy appeared to be low or absent throughout the subbasin.

In the South Fork/Mainstem Subbasin, South Fork, Marshall Creek, McKenzie Creek and Palmer Canyon Creek were surveyed in 1964, 1977, and 1981 and partial surveys were conducted in 1999 and 2001. The canopy cover increased in the headwaters area of the South Fork, indicating improved conditions over those observed in the 1960s aerial photographs. On Marshall and McKenzie Creeks, the canopy cover appears to have increased somewhat, indicating some improvement, but still does not meet target values. The 2001 pool frequency/depth and shelter cover appear to have decreased since 1964 on Marshall and McKenzie Creeks. The headwaters area of the South Fork appears to have had a decrease in pool frequency/depth since 1964, while the pool shelter/cover conditions have remained the same.

Ecological Management Decision Support

Although the EMDS Reach Model scores are based upon the habitat inventory survey data, the analysis differed. The habitat inventory data were divided into reaches based upon Rosgen Channel type and then converted to a weighted average. Each weighted average reach was compared to a set of habitat reference conditions which were determined from empirical studies of naturally functioning channels, expert opinion, and peer reviewed literature. EMDS rated each habitat component with a suitability score between -1 and +1, where suitability is a function of salmonid health and productivity. EMDS scores were not calculated for the South Fork Subbasin because only 31 percent of the streams were habitat inventoried (Table 5.6-10).

Table 5.6-10
Ecological Management Decision Support (EMDS) Reach Model Scores on Salmonid Heath and Productivity Suitability for the Gualala Mainstem/South Fork Subbasin, California, Based Upon Habitat Inventory Surveys Conducted in 1999 and 2001

Subbasin Stream Name	Canopy Cover Score	Embeddedness Score	Pool Depth Score	Pool Shelter Score	Pool Quality Score	2001 MWAT Water Temperature Score
South Fork Subbasin Score	+	+	-	- - -	- -	
Camper Creek (1999)	++	- -	- - -	- -	-	
Carson Creek (1999)	+++	- -	-	- - -	- -	
Marshall Creek *(partial survey)*	- -	+	-	- - -	- -	
McKenzie Creek (1999)	+	-	-	- -	-	+
Palmer Canyon Creek	++	+	- - -	- - -	- - -	
Upper South Fork Headwaters	+++	++	- - -	- - -	- - -	+++
Wild Hog Creek (1999)	+	-	- - -	- - -	- - -	

The 2001 water temperature data was provided by GRI and the GRWC.

+++ = Fully Suitable
++ = Moderately Suitable
+ = Somewhat Suitable
U = Undetermined
- = Somewhat Unsuitable
- - = Moderately Unsuitable
- - - = Fully Unsuitable

Limiting Factors Analysis

The Gualala River Watershed LFA was developed for assessing coarse scale stream habitat components. Habitat inventory data, EMDS reach model scores, and the biologist's professional judgment was incorporated into both the identification of LFAs and their ranking. Pool depth was the predominant limiting factor on Camper Creek. Pool shelter/cover was the most limiting factor on Carson, Marshall, McKenzie, Palmer Canyon Creeks and the Upper South Fork (Table 5.6-11).

Table 5.6-11
Limiting Factors for the Gualala Mainstem/South Fork Subbasin Affecting Salmonid Health and Production Based Upon Habitat Inventory Surveys Conducted in 1999 and 2001 and EMDS Scores in the Gualala River Watershed (*Rank 1 is the most limiting factor*)

Subbasin Stream Name	Canopy Cover Related to Water Temperature	Embeddedness Related to Spawning Suitability	Pool Depth Related to Summer Conditions	Pool Shelter Related to Escape and Cover
South Fork Subbasin	4	3	2	1
Camper Creek (1999)			1	2
Carson Creek (1999)		3	2	1
Marshall Creek *(partial survey)*	2	4	3	1
McKenzie Creek (1999)	3	4	2	1
Palmer Canyon Creek		3	2	1
Upper South Fork *(partial survey)*		3	2	1
Wild Hog Creek (1999)	3	4	2	1

Figure 5.6-21a illustrates the limiting factors as determined by CDFG and various sediment sites identified by CGS as potential restoration targets. Figure 5.6-21b is the map explanation. General recommendations are made for each limiting factor and type of sediment site. The map is a reduced image of Plate 3, *Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed*. (See Plate 3 to view details at a higher scale [1:48,000])

Restoration Recommendations

Table 5.6-12
Priorities for Restoration for the Gualala Mainstem/South Fork Subbasin Based Upon 1999 and 2001 Data (*Rank of 1 indicates highest priority*)

Stream Name	Bank Stabilization	Roads Repair or Removal	Riparian Canopy Development	Instream Structure Enhancement	Livestock or Feral Pig Exclusion	Barrier Removal
South Fork Subbasin	5	2	3	1	6	4
Camper Creek (1999)		2		1		
Carson Creek (1999)		2		1		
Marshall Creek *(partial survey)*	3	4	1	2	5	
McKenzie Creek (1999)		2		1		3
Palmer Canyon Creek		3	2			1
Upper South Fork *(partial survey)*		3	2	1		
Wild Hog Creek (1999)			2	1		

Potential Refugia

No potential refugia were identified based upon 2001 data.

5.6.9 FISH HISTORY AND STATUS

Salmonid population data is limited for the Gualala Mainstem/South Fork Subbasin.

- **1950s**- On August 15, 1952, one station was electrofished on the mainstem of the Gualala River 20 yards below the confluence with the North Fork. The purpose of the survey was to determine whether a resident trout population existed, that would warrant the opening of a summer fishery. The criteria used to determine a harvestable resident population was sufficient numbers of fish over the 8.0-8.5 inch size. The report concluded that the opening of a summer trout fishery was not warranted. There were no coho salmon captured during this survey. During December 1954 and January and February of 1955, creel surveys were conducted to determine the quality of the fishery. Some 507 fish were checked. A total catch estimate of 1,352 fish for the season was extrapolated with data from a use count. No distinction was made as to whether the fish were steelhead trout or coho salmon.

- **1960s**- Steelhead trout were present during stream surveys conducted on the lower and upper South Fork, Marshall, McKenzie, and Sproule creeks in 1964.

- **1970s**- During the 1970s, 105,000 coho salmon were planted. Creel censuses conducted in November (1972-73) recorded coho salmon.

  During the 1970s, 105,000 coho salmon, 83,320 steelhead trout were planted at the confluence of Valley Crossing, Pepperwood, North Fork and Clark's Crossing. In the mid 1970s, a five-year study using creel censuses, use counts, adult tagging, and downstream migrant trapping was conducted in conjunction with the planting of steelhead trout (from Mad River and San Lorenzo River stocks). The goal of the program was to estimate winter adult steelhead trout population, estimate angler harvest rate, and to evaluate the contribution of hatchery steelhead trout to the sport fishery. This program was essentially focused on enhancing the Gualala River as a sport fishing stream. Though there was a considerable body of data collected in these years, an effort to standardize results was lacking. In some year's population estimates were backed by data with 95 percent confidence intervals, 7,608 in 1975-1976 and 4,323 in 1976-1977 and the 1974 population estimates are not accompanied by supporting data.

  Harvest estimates were made at the end of the fishing seasons for each of the five years studied. Most of these surveys began in December and recorded steelhead trout.

- **1980s**-No data available.

- **1990s**-GRI observed one-year and older steelhead trout on the South Fork in 1997 and 1998.

- **2000s**-During snorkel surveys, GRI observed one-year and older steelhead trout on the South Fork in 2000 and 2001. The Modified Ten Pool Protocol on Marshall Creek and the Upper South Fork headwaters showed young-of-the-year and one year old steelhead trout, but no coho salmon were observed.

  Volunteer spawning surveys were conducted in the Subbasin February through April, 2001. Because of the period, all of the redds found were considered to be steelhead trout. The South Fork (14.5 miles) survey recorded 12 redds and five live fish.

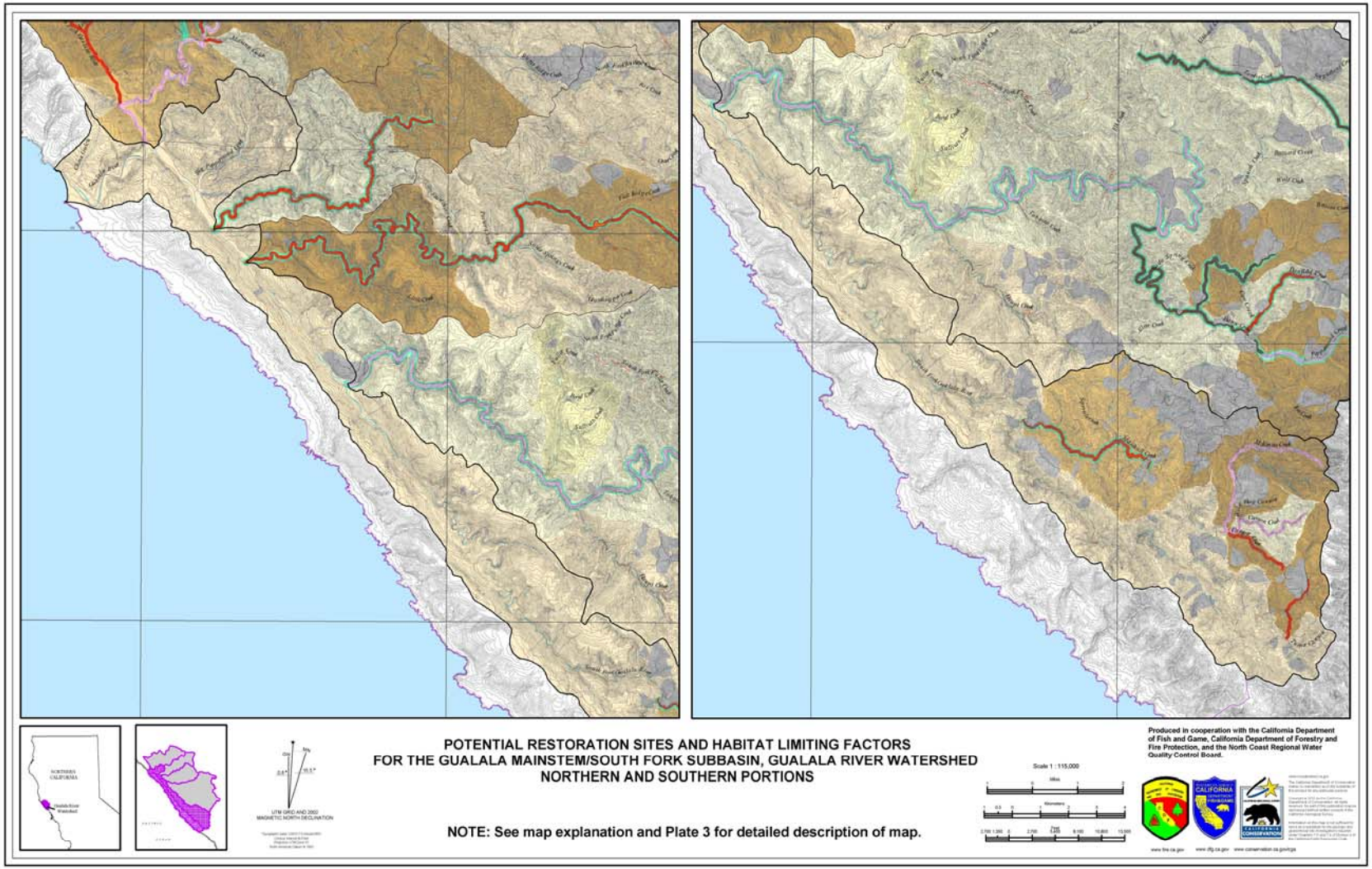


Figure 5.6-21a

Potential Restoration Sites and Habitat Limiting Factors for the Gualala Mainstem/South Fork Subbasin, Gualala River Watershed

Roads
Streams
Watershed boundary
Sub-basin boundary
Historically Active Landslides (mapped as a point if too small to delineate at the scale of this map)

I SPATIALLY ASSOCIATED FACTORS DERIVED FROM AERIAL PHOTO INTERPRETATION OF LANDSLIDING AND SEDIMENT CONDITIONS

A *HISTORIC IN-STREAM ROADS POSSIBLY RELATED TO FLUVIAL SEDIMENT*

Stream reaches with persistent aggrading or braiding in both 1984 and 2000 photos that may be associated with historic in-stream roads or landings. See recommendation #5.

B *ROADS POSSIBLY RELATED TO LANDSLIDES AND/OR ERODING BANKS*

Road segments that may be affected by historically active landsliding and bank erosion. See recommendation #6.

Road segments that may be affected by historically active landsliding. See recommendation #7.

C *FLUVIAL SEDIMENT CONDITIONS POSSIBLY RELATED TO LANDSLIDES*

Stream reaches with potentially adverse sediment accumulations that may be affected by historically active landslides and lack any apparent association with the modern road network or the historic in-stream roads or landings. See recommendation #8.

Stream reaches with potentially adverse sediment accumulations that may be affected by erosion from adjacent dormant landslide terrain that lack any apparent association with historically active landsliding, the modern road network, and historic in-stream roads or landings. See recommendation #9.

D *POTENTIALLY UNRELATED FLUVIAL SEDIMENT CONDITIONS*

Stream reaches with potentially adverse sediment accumulations that lack any of the above associations. See recommendation #9.

II LIMITING FACTORS DERIVED FROM GROUND BASED HABITAT SURVEYS (SEE DFG APPENDIX)

A *CANOPY AND POOLS AS LIMITING FACTORS* (All stream reaches surveyed by DFG in 2001 are highlighted as follows. Reaches that were not surveyed in 2001 are not highlighted on the map.)

Stream reaches with inadaquate canopy cover as the limiting factor. See recommendation #2.
Stream reaches with inadequate pool depths as the limiting factor. See recommendation #4.
Stream reaches with inadequate pool shelter as the limiting factor. See recommendation #3.
Stream reaches with both inadaquate pool depths and shelter as limiting factors. See recommendations #3 and #4.

Explanation

B *EMBEDDEDNESS AS A LIMITING FACTOR*

Areas draining into where embededdness conditions are unknown.
Areas draining into reaches where embeddedness is not limiting.
Areas draining into reaches where embeddedness is marginal but not limiting.
Areas draining into reaches where embeddedness is somewhat limiting. See recommendation #1.
Areas draining into reaches where embeddedness is significantly limiting. See recommendation #1.

RECOMMENDATIONS BASED ON LIMITING FACTORS

(1) Reduce production of fine sediment throughout the contributing area. Evaluate contribution from roads and upgrade roads as appropriate. Evaluate contribution from soil disturbance and control erosion as appropriate (see recommendations 5-10). Evaluate contribution from soil disturbance and control erosion as appropriate. Consider the additive effect of the short-term increases in erosion due to mitigation activities. Distribute individual activities both spatially and temporally as appropriate to avoid additive sediment impacts. Institute best management practices in erodible areas; such as, areas shown on the CGS Relative Landslide Potential Map (Plate Two), and National Resources Conservation Service soil maps.

(2) Enhance current riparian vegetation by planting additional trees, and stabilize stream banks as needed. Also, consider both downstream and upstream effects.

(3) Enhance pool shelter by adding submerged or partially submerged structures. Consider both upstream and downstream effects due to operation and possible failure.

(4) Install in-stream structures to produce hydraulic variability and to scour pools. Consider both downstream and upstream effects due to operations and possible failure.

RECOMMENDATIONS BASED ON SPATIAL ASSOCIATIONS

(5) Evaluate relationship on-site. Consider channel restoration and drainage improvements for the road and landing. Consider engineered abandonment.

(6) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible. Consider stream bank stabilization where feasible.

(7) Evaluate relationship on-site. Consider road drainage improvements to prevent saturation of slide area. Consider abandonment or realignment where feasible.

(8) Evaluate on-site whether these represent natural background conditions. If mitigation is desired, road construction may be needed for equipment access.

(9) No recommendation because potentially associated active sediment sources have not been identified.

EXPLANATION FOR POTENTIAL RESTORATION SITES AND HABITAT LIMITING FACTORS FOR THE GUALALA RIVER WATERSHED MAP

NOTE: See Plate 3 for complete description of map.

Produced in cooperation with the California Department of Fish and Game, California Department of Forestry and Fire Protection, and the North Coast Regional Water Quality Control Board.

www.fire.ca.gov www.dfg.ca.gov www.consrvation.ca.gov/cgs

Figure 5.6-21a
Explanation for Potential Restoration Sites and Habitat Limiting Factors for the Gualala River Watershed Map

5.4.10 GUALALA MAINSTEM/SOUTH FORK SUBBASIN PUBLIC ISSUES, SYNTHESIS, AND RECOMMENDATIONS

After conducting public scoping meetings and workshops, the NCWAP team compiled a preliminary list of general issues based upon public input and initial analyses of the available data. Some issues were suggested by watershed analysis experts, and some by Gualala River Watershed residents and constituents. The following general concerns were expressed as potential factors affecting the Gualala River Watershed and its fisheries, but do not necessarily reflect the findings of the assessment. Some have been disproved by the assessment findings.

- Large Woody Debris (LWD) recruitment potential is a concern.
- There is concern over abandoned roads, new road construction, and road maintenance issues related to landsliding and sediment input. Subdivision construction is not an issue at this time.
- Best management practices required by current forest practice rules are reducing forestry impacts to insignificance.
- Timber harvest, grazing and vineyards are land use concerns from the standpoint of sediment generation and potential for pesticide/herbicide use.
- Summertime water temperatures are a concern in the lower sections of the mainstem.
- There is concern and desire expressed to assess status and trends of exotic flora and fauna, including invasive species. Pampas grass is of particular concern.

Working Hypotheses

The primary purpose of these hypotheses is to elucidate in a succinct format the judgment of the Team regarding watershed conditions relative to anadromous salmonids. As such, they are responsive to the assessment questions presented on pages 1-1 and 1-2. The findings supporting the hypothesis are presented, along with recommendations for watershed improvements, and to further investigate the hypotheses. As such, they are not intended to be the final word, but are the best judgment based on the information at hand.

Recommendations for watershed improvements and further study are presented at the end of the section, as single recommendations apply in many cases to more than one hypothesis.

Hypotheses are presented for the South Fork and tributaries upstream of the confluence with the Wheatfield Fork (Marshall Creek SPWS and the portion of the Lower South Fork SPWS upstream of Wheatfield). No hypotheses are presented for the lower section of the subbasin where data are sparse and inconclusive (see Section 5.1, Estuary).

The hypotheses pertaining to the upper South Fork and tributaries upstream of the confluence with the Wheatfield Fork are:

1. Instream conditions are suitable for salmonids in the South Fork and tributaries upstream of the confluence with the Wheatfield Fork.
2. Historically logged areas have contributed sediment to the streams.
3. Instream and near stream conditions are improving.

Working Hypothesis 1

Instream conditions are suitable for salmonids in the South Fork and tributaries upstream of the confluence with the Wheatfield Fork.

Supporting Findings

- Steelhead trout (young-of-the-year, one year and older) were detected on South Fork during electrofishing surveys in October of 2001.
- Water temperatures were fully suitable for salmonids the headwaters of the South Fork in 2001 and somewhat suitable in McKenzie Creek (Table 5.6-4)
- CDFG habitat inventory survey results met target values for canopy cover in Camper Creek, Carson Creek, Palmer Canyon Creek, and in the headwaters of the South Fork. Embeddedness target values were met on all seven of the streams surveyed (Table 5.6-7).
- The EMDS scores from Carson Creek and in the headwaters of the South Fork were fully suitable for canopy cover. Camper and Palmer Canyon Creeks were moderately suitable for canopy cover. McKenzie and Wild Hog Creeks were somewhat suitable for canopy cover (Table 5.6-10).
- Embeddedness was moderately suitable in the headwaters of the South Fork, and somewhat suitable on Marshall and Palmer Canyon Creeks (Figure 5.6-17).

Contrary Findings

- Coho salmon were not detected on the South Fork during electrofishing surveys in October of 2001.
- Water temperatures (MWAT) in 2001 were unsuitable for salmonids at one of two sites in the lower mainstem South Fork and undetermined at one of two sites in McKenzie Creek (Table 5.6-4).
- Water temperatures (MWAT) in 1995-98 and 2000-2001 were unsuitable for salmonids at five of seven sites in the mainstem, both sites in McKenzie Creek in 2000-2001, and the site in Palmer Canyon Creek in 2000 (Table 5.6-4).
- CDFG habitat inventory target values for canopy cover were not met on Marshall and McKenzie Creeks. The Marshall Creek EMDS score for canopy cover was moderately unsuitable (Table 5.6-7).
- Target values were not met on any of the seven streams surveyed for primary pool depth/frequency or shelter/cover. The EMDS scores ranged from somewhat to fully unsuitable on all of the seven streams surveyed for pool depth, pool shelter and pool quality (Table 5.6-10).

Limitations

- Only 31 percent (1.6 miles) of the SPWS was habitat inventory surveyed.
- The modified ten pool protocol electrofishing methodology was used as designed to indicate coho salmon presence/not detected only. It cannot be used to for species composition, species density or population estimates.
- Water temperature data for the SPWS were restricted to eight sites for the period of 1995-1998 and 2000-2001. Water temperature data were available for only four sites in 2001.

Conclusions

- The Hypothesis is supported within the limitations of the length of streams habitat inventory surveyed.

Working Hypothesis 2

Historically logged areas have contributed sediment to the streams.

Supporting Findings

- Most of the higher and east reaches of the South Fork were clear-cut between 1952 and 1961 building roads in or along the major tributaries streams (Figure 5.6-10). This left large areas of disturbed ground.
- Approximately 15 miles of historic logging roads built in or along the streambed simplified pool structure and complexity throughout the Marshall and McKenzie Creeks, and the upper mainstem tributaries (Section 5.6.4).
- Numerous debris flows and debris slides involved roads, and numerous failures occurred along instream and near-stream roads and landings during large storm events as observed in 1961 and 1965 aerial photos. This increased sedimentation in the streams (Section 5.6.4).
- Many undersized culverts and substandard road drainage facilities failed during the 1986 and 1996 storms, representing a portion of contemporary sediment pulses in the subbasin. These failures were generally more numerous where roads (mostly ranchland roads) cross high or very high potential landslide areas (105 miles) (Section 5.6.4).
- LWD recruitment has been limited due to streamside road construction, timber harvesting, and salmonid migration barrier removal. The reduction of LWD likely reduces pool formation and sediment storage in the tributaries

Marshall Creek

- Streamside roads lined Wild Hog and Palmer Canyon creeks by 1959. Lack of erosion control facilities along streamside roads and landings created gully erosion observed in 1965 photos (Figure 5.6-10).
- Modern road segments within 60 meters of historically active landslides are numerous in the upper tributary stream reaches of Marshall Creek and may be contributing excess sediment to streams.

McKenzie Creek

- Streamside/instream roads and landings were densely concentrated in the central and higher reaches of McKenzie Creek (1961, 1965, and 1981 photos) (Figure 5.6-10).

Contrary Findings

- Embeddedness target values were met on all seven of the streams surveyed.
- Approximately 1.5 miles of modern roads (out of 116 miles total) are located within 50 feet of blue line streams in the subbasin.
- The northeast portion of the Upper South Fork watershed is underlain primarily by Central Belt Franciscan mélange. This may contribute relatively large amounts of fine grained sediment to streams.

Limitations

- Only 31 percent (1.6 miles) of the SPWS was habitat inventory surveyed.
- Observations of landuse and associated impacts are from aerial photo interpretations.

Conclusions

- The hypothesis is supported by the limited data available.

Working Hypothesis 3

Instream and near stream conditions are improving.

Supporting Findings

- Overstory shade canopy as observed from aerial photos has recovered in the middle to upper reaches as indicated by (1) comparison of 1981 bank-to-bank exposure with 2001 habitat inventory survey, and (2) canopy density ranged between approximately 50 to 75 percent between the years 1999, 2000, and 2001 in McKenzie, Carson, Camper, and Wild Hog creeks (Section 5.6.4).
- The McKenzie Creek channel in the Upper Marshall Creek PWS was more than 50 percent disturbed based on 1984 aerial photo interpretation, and improved to less than 25 percent disturbed per 1999/2000 photos (Table 5.6-3).
- Channel disturbance observed from aerial photos for the Upper South Fork PWS decreased from 39.2 percent disturbance in 1984 to 23.9 percent in 1999/2000 photos (Table 5.6-3).

Contrary Findings

- The levels of channel disturbance observed from aerial photos in the South Fork Gualala in the Middle South Fork PWS are similar between 1984 and 1999/2000 (31.5 percent and 27.2 percent, respectively) (Table 5.6-3).
- Channel disturbance was 50 to 75 percent in the lower reach of Marshall Creek downstream of McKenzie Creek (Lower Marshall Creek PWS) in 1984 and nearly the same in 1999/2000 observations with approximately 50 percent of the channel disturbed (Table 5.6-3).
- Riparian canopy has not recovered to 1942 levels observed from aerial photos (Figures 5.6-7 and 5.6-10).

Limitations

- Only 31 percent (1.6 miles) of the SPWS was habitat inventory surveyed. Analysis is limited by a comparable lack of historical stream surveys in this SPW with which to indicate comparative trends.

Conclusions

- The hypothesis is supported by the limited data available.
- Current riparian shade canopy cover has improved from 1968 when long portions of riparian zones had been cleared of all vegetation, but not to the 1942 levels.
- Improvements in the levels of channel disturbances from 1984 to 1999/2000 are generally positive, but mixed, with some areas improving and others staying the same.

Subbasin Recommendations

Target restoration and land use activities to the four highest priorities for restoration in the Gualala Mainstem/South Fork Subbasin: (1) large wood placement, (2) road repair or removal, (3) riparian canopy development, (4) barrier removal, (5) bank stabilization, and (6) livestock or feral pig exclusion.

1. Install fish habitat improvement structures including large woody debris placement.

    a. Land managers in the subbasin should be encouraged to add more large organic debris and shelter structures in order to improve sediment metering, channel structure, channel function, habitat complexity, and habitat diversity for salmonids. The natural large woody debris recruitment process should be enhanced by developing large riparian conifers with tree protection, planting, thinning from below, and other vegetation management techniques. Instream structure enhancement is a restoration priority 1 in McKenzie and Wild Hog creeks, and the South Fork, priority 2 in Marshall Creek.

    b. At stream bank erosion sites, encourage cooperative efforts to reduce sediment yield to streams. Grazing is an issue in the subbasin. Bank stabilization is the third of the top three recommendations.

    c. Reduce livestock and feral pig access to the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone.

2. Address road issues.

    a. Decommission and revegetate streamside roads, focusing on those where channel braiding and/or aggradation are persistent today, such as the central and upper reaches of McKenzie Creek, and the lower reaches of Marshall Creek including Palmer Canyon and Wild Hog Creeks. Road repair and removal is a restoration priority 2. (from CGS restoration map)

    b. Upgrade and maintain existing road systems to eliminate sediment sources to pools and spawning gravels. Carefully engineer new roads or repairs to reduce adverse sediment impacts. Use the CGS Restoration map to locate where ranch roads cross historically active landslides to target further field evaluation. These areas have been mapped in dense concentrations in the east subbasin reaches.

    c. Target road upgrade/repair starting with instream sediment indicators where fish habitat is less than suitable, priority 1 in McKenzie, Wild Hog, and the South Fork, and priority 2 in Marshall Creek.

    d. Incorporate mitigation elements into Timber Harvest Plans and pursue cost sharing grants for decommissioning legacy streamside roads and upgrading road drainage facilities in the timber-dominant lower subbasin, including Little and Big Pepperwood Creeks.

    e. Pursue cost sharing grants organized by the Sotoyome RCD to upgrade ranchland roads in the ranchland upland areas.

    f. Develop erosion control plans for decommissioning old roads, maintaining existing roads, and constructing new roads. Consider careful planning of land uses that could exacerbate mass wasting, since the relative potential of landsliding is high to very high in 50 percent of the subbasin.

3. Address riparian zone issues.

    a. Ensure that adequate streamside protection zones are used to reduce solar radiation and moderate air temperatures in order to reduce heat inputs to the Upper South Fork and its tributaries.

    b. In the east subbasin reaches, retain, plant, and protect trees to achieve denser riparian canopy to enhance current canopy recovery from mid-20th-century block clearance logging and ranchland conversions. The following areas continue to show gaps on riparian shade cover compared to 1942:

        i. The central to upper reaches of the Upper South Fork, McKenzie Creek, and Wild Hog and Palmer Canyon creeks .

        ii. Riparian canopy development is a restoration priority 1 for Marshall Creek and a priority 2 for the South Fork and Palmer Canyon and Wild Hog creeks.

    c. Reduce livestock and feral pig access to the riparian zone to encourage stabilization of stream banks and revegetation of the riparian zone.

4. Expand monitoring efforts in the subbasin.

    a. Conduct both instream and hillslope monitoring to determine whether current land use practices are allowing for recovery and protection of the salmonid habitat in the subbasin. Use GRWC protocols for instream measurements. Improve baseline information on habitat conditions by conducting inventory surveys in the South Fork and major tributaries upstream of the confluence with the Wheatfield Fork.

    b. Expand continuous temperature monitoring efforts into the upper subbasin and tributaries. Consider looking at canopy composition and monitoring air temperatures to examine canopy, temperature, and other microclimate effects on water temperatures.

    c. Investigate the availability and quality of other temperature and canopy data for the eastern area, and reevaluate the relationship of canopy to actual stream temperatures. Spot temperature and canopy measurements from habitat inventory data may be useful in providing information from areas in the subbasin for which we have no other data.

    d. Conduct habitat inventory surveys in the remainder of the SPWS to provide information for restoration priorities and as a baseline for future comparisons.

5. Remove fish migration barriers in Palmer Canyon Creek and McKenzie Creek.

Chapter 6

Limitations of the Assessment

Opportunities for Improvement of Future Assessment Efforts

This assessment was limited in duration, scope, detail, and analysis level due to constraints in budget, time, access, and overall resources. Where data are limited, working hypotheses are offered along with recommendations to test or improve the knowledge base. Specific limitations are presented below to put the assessment into context and to provide guidance to improve future data collections and analysis.

The California Department of Fish and Game's habitat inventory surveys provided the data for instream conditions, the Ecological Management Decision Support Reach Model, the Limiting Factors Analysis, and the Restoration Recommendations and Priorities. None of the subbasins were surveyed 100 percent. The following lists the amount of the Subbasin surveyed: North Fork, 81 percent; Rockpile, 39 percent; Buckeye, 37 percent; Wheatfield 45 percent; and the Mainstem/South Fork, 31 percent. Future use of these data should reflect the amount un-surveyed as well as surveyed.

The California Geological Survey's landslide and geomorphic analyses were limited to aerial photo interpretation primarily from two sets of photos: 1984 and 1999/2000, and limited field verification. A limited number of 1965 aerial photographs were reviewed briefly for only a few selected portions of the watershed. Limited aerial photo coverage does not bracket temporal distribution of important watershed events, which may not be evident in photos taken years after the fact. Field checking of interpretations was limited.

At the analysis scale of 1:24,000, the detection of geologic features smaller than 100 feet in the largest dimension is poor.

Detailed site level mapping of landslides and sediment delivery were conducted by outside parties in various portions of the watershed. However, time and staffing constraints prevented full evaluations of those data.

Existing geologic mapping of the Rockpile Subbasin is limited to the Geologic Map of the Santa Rosa Quadrangle (Wagner and Bortugno 1999), which was mapped at a scale of 1:250,000 (2-degree sheet). The presence and locations of geologic features in this area were inferred from surrounding areas where more detailed mapping was available.

California Department of Forestry and Fire Protection's land use analysis used aerial photos exclusively. Sediment sources found in earlier photo sets were not field reviewed to ascribe current comparative condition.

Localized point source channel aggradations and meandering flows observed shortly after the winter rains during the late 1950s and early 1960s were not systematically compared sequentially through time to detail evolving stream channel morphology. Only spot point comparisons with 1984, 1988, and 1999

photos were done depending on where damage was observed from winter rains during the late 1950s and early 1960s.

There was only time to compare the broadest contrasts between 1950s/1960 era impacts with declining habitat conditions. More subtle habitat changes to properly characterize recent land use activities requires a far larger and detailed data base to make significant conclusions.

North Coast Regional Water Quality Control Board's water chemistry analysis was limited to available U.S. Environmental Protection Agency StoRet data for the period April of 1974 to June of 1988 at three locations, and three samples obtained by NCRWQCB at five locations in 2001. The sampling frequency and small number of locations did not allow for any detailed temporal analysis.

NCRWQCB did not have turbidity nor suspended solids data, though considers them critical to watershed analysis. The absence of those data and any analysis of suspended loads and turbidity are limitations in this assessment.

Pesticide data were not available from StoRet, nor collected in the NCRWQCB sampling of 2001.

NCRWQCB analyzed water temperature and in-channel data supplied by the Gualala River Watershed Council (GRWC), Gualala Redwoods, Inc. (GRI), and from NCRWQCB files containing Coastal Forest Lands, Ltd data for the period from 1992 to 2001. Not all locations received sampling throughout that period, limiting the ability to compare across years and among sites.

In-channel data and some temperature data were provided as summary statistics (medians, means, and maximums), limiting the ability to factor variability into the analysis, and not allowing for independent checks on the data quality.

The temperature range used for "fully suitable" of 50-60 F was developed as an average of the needs of several cold water fish species, including coho salmon and steelhead trout. As such, the range does not represent fully suitable conditions for the most sensitive cold water species (usually considered to be coho salmon).

Water temperature data analysis did not include probability of exceedence from cumulative distribution plots, or hours of exceedance of a threshold. This analysis was limited by not having raw data for all sites, obtaining raw data late in the analysis, and data interface problems. Analysis of temperature information is without knowledge of the extent of a thermal reach upstream of the continuous data logger.

Chapter 7

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Chapter 8

Glossary

AGGRADATION: The geologic process by which stream beds, floodplains, and the bottoms of other water bodies are raised in elevation by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

ALEVIN: The life stage of salmonids that occurs after eggs have hatched but before young emerge from the gravel nests where they have incubated. Alevin still have yolk sacs attached to provide them with nutrition within the nest.

ALLUVIUM: A general term for all deposits resulting directly or indirectly from the sediment transport of streams, thus including the sediments laid down in riverbeds, floodplains, lakes, fans and estuaries. ALLUVIAL, adj.

ANADROMOUS: Fish that leave freshwater and migrate to the ocean to mature then return to freshwater to spawn. Salmon, steelhead and shad are examples.

ANTHROPOGENIC: Caused by humans.

ARCINFO: ESRI (Environmental Systems Research Institute) proprietary software, which provides a complete GIS data creation, update, query, mapping, and analysis system.

AERIAL: Having to do with or done by aircraft. Aerial photographs are taken from aircraft equipped with cameras.

BANKFULL DISCHARGE: The discharge corresponding to the stage at which the floodplain of a particular stream reach begins to be flooded. The point at which bank overflow begins.

BANKFULL WIDTH: The width of the channel at the point at which overbank flooding begins.

BASIN: As used in NCWAP, the largest watershed unit for assessment, e.g., the Gualala Basin. Also see watershed.

BED SUBSTRATE: The materials composing the bottom of a stream.

BENTHIC: Living on or in sea, river or lake bottoms.

BOULDER: Stream substrate particle larger than 10 inches (256 millimeters) in diameter.

CALWATER: A set of standardized watershed boundaries for California nested into larger previously standardized watersheds and meeting standardized delineation criteria.

CANOPY: The overhead branches and leaves of vegetation.

CANOPY COVER: The vegetation that projects over the stream.

CANOPY DENSITY: The percentage of the stream covered by the canopy of plants, sometimes expressed by species.

CENTROID: The center of water mass of a flowing stream at any location. This location usually correlates well with the thalweg, or deepest portion of the stream. Sampling in the centroid is intended to provide a reasonably representative sample of the main stream.

CHANNEL: A natural or artificial waterway of perceptible extent that periodically or continuously contains moving water. It has a definite bed and banks, which serve to confine the water.

COAST RANGE: A string of mountain ranges along the Pacific Coast of North America from Southeastern Alaska to lower California.

COBBLE: Stream substrate particles between 2.5 and 10 inches (64 and 256 millimeters) in diameter. Rubble.

COLLUVIUM: A general term for loose deposits of soil and rock moved by gravity; e.g. talus.

CONIFEROUS: Any of various mostly needle-leaved or scale-leaved, chiefly evergreen, cone-bearing gymnospermous trees or shrubs such as pines, spruces, and firs.

CONSUMPTIVE USE OF WATER: Occurs when water is taken from a stream and not returned.

COVER: As regards fish habitat, anything that provides protection from predators or ameliorates adverse conditions of streamflow and/or seasonal changes in metabolic costs. May be Instream cover, turbulence, and/or overhead cover, and may be for the purpose of escape, feeding, hiding, or resting.

DEBRIS: Material scattered about or accumulated by either natural processes or human influences.

DEBRIS JAM: Log jam. Accumulation of logs and other debris.

DEBRIS LOADING: The quantity of debris located within a specific reach of stream channel due to natural processes or human activities.

DECIDUOUS: A plant (usually a tree or shrub) that sheds its leaves at the end of the growing season.

DEGRADATION: The geologic process by which stream beds and floodplains are lowered in elevation by the removal of material. It is the opposite of aggradation.

DEPOSITION: The settlement or accumulation of material out of the water column and onto the streambed. Occurs when the energy of flowing water is unable to support the load of suspended sediment.

DEPTH: The vertical distance from the water surface to the streambed.

DISCHARGE: Volume of water flowing in a given stream at a given place and within a given period of time, usually expressed as cubic meters per second (m3/sec), or cubic feet per second (cfs).

DISSOLVED OXGYGEN (DO): The concentration of oxygen dissolved in water, expressed in mg/l or as percent saturation, where saturation is the maximum amount of oxygen that can theoretically be dissolved in water at a given altitude, temperature, and salinity.

DIVERSION: A temporal removal of surface flow from the channel.

ECOTONE: A transition area between two distinct habitats that contains species from each area, as well as organisms unique to it.

EMBEDDEDNESS: The degree that larger particles (boulders, rubble, or gravel) are surrounded or covered by fine sediment. Usually measured in classes according to percentage of coverage of larger particles covered by fine sediments.

ECOLOGICAL MANAGEMENT DECISION SUPPORT (EMDS): An application framework for knowledge-based decision support of ecological landscape analysis at any geographic scale.

EMBRYO: An organism in its early stages of development, especially before it has reached a distinctively recognizable form.

ENDANGERED SPECIES: In the context of the federal Endangered Species Act of 1973, any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary of the Interior to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man.

EROSION: The group of natural processes, including weathering, dissolution, abrasion, corrosion, and transportation, by which material is worn away from the earth's surface. EROSIONAL, adj.

ESTUARY: A body of water where fresh water from a river or stream mixes with sea water.

EXTIRPATION: To destroy totally; exterminate.

EXTINCTION: The death of an entire species.

FILL: a) The localized deposition of material eroded and transported from other areas, resulting in a change in the bed elevation. This is the opposite of scour; b) The deliberate placement of (generally) inorganic materials in a stream, usually along the bank.

FINE SEDIMENT: The fine-grained particles in stream banks and substrate. Those are defined by diameter, varying downward from 0.24 inch (6 millimeters).

FISH HABITAT: The aquatic environment and the immediately surrounding terrestrial environment that, combined, afford the necessary biological and physical support systems required by fish species during various life history stages.

FLATWATERS: In relation to a stream, low velocity pool habitat.

FLOOD: Any flow that exceeds the bankfull capacity of a stream or channel and flows out onto the floodplain; greater than bankfull discharge.

FLOODPLAIN: The area bordering a stream over which water spreads when the stream overflows its banks at flood stages.

FLOW: a) The movement of a stream of water and/or other mobile fluid substance from place to place; b) The movement of water, and the moving water itself; c) The volume of water passing a given point per unit of time. Discharge.

FLUVIAL: Relating to or produced by a river or the action of a river. Situated in or near a river or stream.

FRESHETS: A sudden rise or overflowing of a small stream as a result of heavy rains or rapidly melting snow.

FRY: Small fish, especially young, recently hatched fish.

GEOGRAPHIC INFORMATION SYSTEM (GIS): A computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. Typically, a GIS is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature (e.g. roads). Each feature is linked to a position on the graphical image of a map.

GEOMORPHOLOGY: The study of surface forms on the earth and the processes by which these develop.

GRADIENT: The slope of a streambed or hillside. For streams, gradient is quantified as the vertical distance of descent over the horizontal distance the stream travels.

GRAVEL: Substrate particle size between 0.08 and 2.5 inches (2 and 64 millimeters) in diameter.

GRILSE: see jack.

GULLY: A deep ditch or channel cut in the earth by running water after a prolonged downpour.

HABITAT: The place where a population lives and its surroundings, both living and nonliving; includes the provision of life requirements such as food and shelter.

HABITAT CONSERVATION PLAN: In the context of the federal Endangered Species Act of 1973, a document that describes how an agency or landowner will manage their activities to reduce effects on vulnerable species. An HCP discusses the applicant's proposed activities and describes the steps that will be taken to avoid, minimize, or mitigate the "take" of species that are covered by the plan.

HABITAT TYPE: A land or aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance.

HIERARCHY: A series of ordered groupings of people or things within a system.

HYDROGRAPH: A graph showing, for a given point on a stream, the discharge, stage, velocity, or other property of water with respect to time.

HYDROLOGY: The science of water, its properties, phenomena, and distribution over the earth's surface.

HYDROGRAPHIC UNIT: A watershed designation at the level below Hydrologic Region and above Hydrologic Sub-Area.

HYPOTHESIS: A tentative explanation for an observation, phenomenon, or scientific problem that can be tested by further investigation.

INCUBATION: Maintaining something at the most favorable temperature for its development.

INSTREAM COVER: Areas of shelter in a stream channel that provide aquatic organisms protection from predators or competitors and/or a place in which to rest and conserve energy due to a reduction in the force of the current.

INTERMITTENT STREAM: A stream in contact with the ground water table that flows only at certain times of the year when the ground water table is high and/or when it receives water from springs or from some surface source such as melting snow in mountainous areas. It ceases to flow above the streambed when losses from evaporation or seepage exceed the available stream flow. Seasonal.

JACK: An immature male salmonid (usually a two-year old) that returns to freshwater to spawn. Also known as grilse.

KNOWLEDGE BASE: An organized body of knowledge that provides a formal logical specification for the interpretation of information.

LAGOON: A shallow body of water, especially one separated from a sea by sandbars or coral reefs.

LIMITING FACTOR: Environmental factor that limits the growth or activities of an organism or that restricts the size of a population or its geographical range.

LARGE WOODY DEBRIS (LWD): A large piece of relatively stable woody material having a diameter greater than 12 inches (30 centimeters) and a length greater than 6 feet (2 meters) that intrudes into the stream channel. Large organic debris.

MACROINVERTEBRATE: An invertebrate animal (animal without a backbone) large enough to be seen without magnification.

MAINSTEM: The principal, largest, or dominating stream or channel of any given area or drainage system.

MELANGE: A mappable body of rock that includes fragments and blocks of all sizes, both exotic and native, embedded in a fragmented and generally sheared matrix.

MIGRATION: The periodic passage from one region to another for feeding or breeding.

NETWEAVER: A knowledge-based development system. A meta database that provides a specification for interpreting information.

NUTRIENT: A nourishing substance; food. The term nutrient is loosely used to describe a compound that is necessary for metabolism.

ONCORHYNCHUS: The salmon and trouts genus of the family Salmonidae. They are named for their hooked (onco) nose (rhynchus).

ORGANIC DEBRIS: Debris consisting of plant or animal material.

ORTHOPHOTOQUADS: A combined aerial photo and planimetric quad map (with no indication of contour) without image displacements and distortions.

PERMANENT STREAM: A stream that flows continuously throughout the year. Perennial.

pH: A measure of the hydrogen ion activity in a solution, expressed as the negative log 10 of hydrogen ion concentration on a scale of 0 (highly acidic) to 14 (highly basic) with a pH of 7 being neutral.

PLATE TECTONICS: A theory in which the earth's crust is divided into mobile plates which are in constant motion causing earthquake faults, volcanic eruptions, and uplift of mountain ranges.

PHOTOGRAMMETRY: The process of making maps or scale drawings from photographs, especially aerial photographs.

PRODUCTIVITY: a) Rate of new tissue formation or energy utilization by one or more organisms; b) Capacity or ability of an environmental unit to produce organic material; c) The ability of a population to recruit new members by reproduction.

REDD: A spawning nest made by a fish, especially a salmon or trout.

REFERENCE CONDITIONS: Minimally impaired conditions that provide an estimate of natural variability in biological condition and habitat quality.

RIFFLE: A shallow area extending across a streambed, over which water rushes quickly and is broken into waves by obstructions under the water.

RILL: An erosion channel that typically forms where rainfall and surface runoff is concentrated on slopes. If the channel is larger than one square foot in cross-section, it is called a gully.

RIPARIAN: Pertaining to anything connected with or immediately adjacent to the banks of a stream or other body of water.

RIPARIAN AREA: The area between a stream or other body of water and the adjacent upland identified by soil characteristics and distinctive vegetation. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.

RIPARIAN VEGETATION: Vegetation growing on or near the banks of a stream or other body of water on soils that exhibit some wetness characteristics during some portion of the growing season.

Rock Slide. Referred to in previous CGS publications as translational/rotational, this slide type is characterized by a somewhat cohesive slide mass and a failure plane that is relatively deep-seated when compared to that of a debris slide of similar areal extent. The sense of the motion is linear in the case of a translational slide, and is arcuate or "rotational" in the case of the rotational slide. Complex versions involving rotational heads with translation or earthflow downslope are quite common.

Rock slides generally involve relatively cohesive bedrock. The bedrock is typically weaker near the surface due to weathering; however, sliding is not restricted to the zone of weathering. Failure commonly occurs along bedding planes, fractures, or other discontinuities in the bedrock. The concentric, downward movement of slide materials generally exposes a near vertical scarp in the head region and, occasionally, along the lateral margins of the slide. Slide materials are characterized by hummocky topography consisting of rolling, bumpy ground, frequent benches, and depressions. The toe of the slide may be steep where slide material has accumulated. Although the removal of root support is not likely to affect the overall stability of the slide mass, large clear-cuts (relative to slide size) could raise the groundwater table and induce instability. The removal of toe materials on smaller slides may reactivate the entire slide area.

RUBBLE: Stream substrate particles between 2.5 and 10 inches (64 and 256 millimeters) in diameter. Cobble.

SALMONID: Fish of the family Salmonidae, including salmon, trout, chars, whitefish, ciscoes, and graylings.

SCOUR: The localized removal of material from the stream bed by flowing water. This is the opposite of fill.

SEDIMENT: Fragmented material that originates from weathering of rocks and decomposition of organic material that is transported by, suspended in, and eventually deposited by water or air, or is accumulated in beds by other natural phenomena.

SERAL STAGES: The series of relatively transitory plant communities that develop during ecological succession from bare ground to the climax stage.

SHEAR: A deformation resulting from stresses that cause contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact.

SHEAR STRAIN: A measure of the amount by which parallel lines have been sheared past one another by deformation.

SHEAR ZONE: A tabular zone of rock that has been crushed and breciated by many parallel fractures due to shear strain.

SILVICULTURE: The care and cultivation of forest trees; forestry.

SMOLT: Juvenile salmonid one or more years old that has undergone physiological changes to cope with a marine environment; the seaward migration stage of an anadromous salmonid.

SMOLTIFICATION: The physiological change adapting young anadromous salmonids for survival in saltwater.

SPAWNING: To produce or deposit eggs.

STADIA RODS: Graduated rods observed through a telescopic instrument while surveying to determine distances and elevation.

STAGE: The elevation of a water surface above or below an established datum or reference.

STRATH: a) An extensive terrace like remnant of a broad valley floor that has undergone dissection; b) A broad valley floor representing a local base level, usually covered by a veneer of alluvium.

STREAM (includes creeks and rivers): A stream is a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation.

STREAM BANK: The portion of the channel cross section that restricts lateral movement of water at normal water levels. The bank often has a gradient steeper than 45 degrees and exhibits a distinct break in slope from the stream bottom. An obvious change in substrate may be a reliable delineation of the bank.

STREAM CLASSIFICATION: Various systems of grouping or identifying streams possessing similar features according to geomorphic structure (e.g. gradient), water source (e.g. spring creek), associated biota (e.g. trout zone) or other characteristics.

STREAM CORRIDOR: A stream corridor is usually defined by geomorphic formation, with the corridor occupying the continuous low profile of the valley. The corridor contains a perennial, intermittent, or ephemeral stream and adjacent vegetative fringe.

STREAM REACH: A section of a stream between two points.

SUBSTRATE: The material (silt, sand, gravel, cobble, etc.) that forms a stream or lakebed.

SUBWATERSHED: One of the smaller watersheds that combine to form a larger watershed.

TAKE: In the context of the federal Endangered Species Act of 1973, to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.

TERRACE: A former floodplain underlain by sediment deposited by a stream when the stream was flowing at a higher level; typically forming a relatively level bench along a valley side adjacent to a recent floodplain.

TERRAIN: A tract or region of the earth's surface considered as a physical feature, an ecological environment, or a site of some planned activity of man.

TERRANE: A term applied to a rock or group of rocks and to the area in which they crop out. The term is used in a general sense and does not imply a specific rock unit.

THALWEG: The line connecting the lowest or deepest points along a stream bed.

THREATENED SPECIES: In the context of the federal Endangered Species Act of 1973, any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

TOPOGRAPHY: The general configuration of a land surface, including its relief and the position of its natural and man-made features.

TOPOLOGY: The analytical, detailed study of minor landforms, requiring fairly large scales of mapping.

TRIBUTARY: A stream feeding, joining, or flowing into a larger stream. Feeder stream, side stream.

UNDERCUT BANK: A bank that has had its base cut away by the water action along man-made and natural overhangs in the stream.

VELOCITY: The time rate of motion; the distance traveled divided by the time required to travel that distance.

WATER RIGHT: The right to draw water from a particular source, such as a lake, irrigation canal, or stream. Often used in the plural.

WATERSHED ASSESSMENT: An interdisciplinary process of information collection and analysis that characterizes current watershed conditions at a course scale.

WATERSHED: Total land area draining to any point in a stream, as measured on a map, aerial photograph or other horizontal plane. Also called catchment area, watershed, and basin.

WATERSHED MANAGEMENT AREA (WMA): In the context of the North Coast Regional Water Quality Control Board's Watershed Management Initiative, this represents a grouping of smaller watersheds into a larger area for identifying and addressing water quality problems, e.g., the Humboldt WMA includes all watersheds draining to the ocean or bays north of the Eel River to and including Redwood Creek.

WEIR: A barrier constructed across a stream to divert fish into a trap.

WETLAND: An area subjected to periodic inundation, usually with soil and vegetative characteristics that separate it from adjoining non-inundated areas.

WILDLIFE CORRIDOR: Linear spaces that connect the various areas of an animal's habitat; links between feeding, watering, resting, and breeding places.

Chapter 9

List of Abbreviations

The following abbreviations and acronyms were used in the assessment report.

ac-ft/yr	acre-feet per year
C	Celsius
CalEPA	California Environmental Protection Agency
Caltrans	California Department of Transportation
CCC	Central California Coast
CCD	Census County Division
CDEC	California Data Exchange Center
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFL	Coastal Forest Lands
cfs	Cubic Feet per Second
CGS	California Geological Survey (formerly the California Division of Mines and Geology, DMG)
COLD	Cold freshwater habitat
DAU	Detailed Analysis Unit
DEM	Digital Elevation Model
DOC	California Department of Conservation
DOC/CGS	California Department of Conservation – California Geologic Survey
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EMDS	Ecological Management Decision Support
EPA	U.S. Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, Trichoptera (orders of macroinvertebrates)
ESA	Federal Endangered Species Act
EST	Estuarine habitat
ESU	Evolutionarily Significant Unit
F	Fahrenheit
FPA	Z'Berg-Nejedly Forest Practices Act
FPR	California Forest Practice Rules
FRAP	Fire and Resource Assessment Program

GIS	Geographic Information System
GRI	Gualala Redwoods, Inc.
GRWC	Gualala River Watershed Council
HA	Hydrologic Area
HCP	Habitat Conservation Plan
HR	North Coast Hydrologic Region
HSA	Hydrologic Sub-area
HU	Hydrologic Unit
ICE	U.C. Davis's Information Center for the Environment
IFR	Institute for Fisheries Resources
KRIS	Klamath Resource Information System
LFA	Limiting Factor Analysis
LPSYP	Louisianna Pacific Sustained Yield Plan
LWD	Large Woody Debris
MIGR	Migration of aquatic organisms
MOU	Memorandum of Understanding
MWAT	Maximum Weekly Average Temperature. The highest for the season of a weekly floating average temperature
NCRWQCB	North Coast Regional Water Quality Control Board
NCWAP	North Coast Watershed Assessment Program
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
PSA	Planning Sub Area
PWS	Planning Watershed
QA/QC	Quality Assurance/Quality Control
REC-1	Water contract recreation fishing
RM	River Mile
RWQCB	California Regional Water Quality Control Board
SPW	Super Planning Watershed
SPWN	Spawning, reproduction, and/or early development
SPWS	Super Planning Watershed
SRP	Scientific Review Panel
SWRCB	California State Water Resources Control Board
SYP	Sustained Yield Plan
THP	Timber Harvesting Plan
TMDL	Total Maximum Daily Load
TPZ	Timber Production Zone
TSD	Technical Support Document

USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Department of Agriculture, Forest Service
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
WLPZ	Watercourse and Lake Protection Zone
WMA	Watershed Management Area
WQO	Water Quality Objectives
WRIMS	Water Right Information System