Coastal Watershed Planning Assessment Program

Big River Basin Assessment

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State of California

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California Environmental Protection Agency

Secretary, Alan Lloyd

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NCWAP Basin Assessment Products

Reports

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 and partners, constituent groups, and agencies. 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 in PDF format or via the website www.coastalwatersheds.ca.gov. Basin assessment reports are currently available for the Gualala, Mattole, Albion, and Big River basins. CDs containing the reports, appendices, and maps may be requested from:

California Department of Fish and Game
Coastal Watershed Planning and Assessment Program
1487 Sandy Prairie Court, Ste. A
Fortuna, CA 95540
707.725.1070

Klamath Resource Information System CDs and Website

The Institute for Fisheries Resources (IFR) has produced Klamath Resource Information System (KRIS) projects for several North Coast watersheds. KRIS is a custom software program capable of managing watershed data sets, tables, charts, photos, and maps. The current KRIS products are available via the IFR website (www.krisweb.com), or on CD from:

Department of Forestry and Fire Protection
Fire and Resource Assessment Program
PO Box 944246
Sacramento, CA 94244-2460
(916) 327-3939
frap@fire.ca.gov

Maps of Landslides and Relative Landslide Potential

To date, the California Geological Survey has produced maps and GIS coverage of landslides and relative landslide potential on the Mattole, Gualala, and Big rivers, and Redwood Creek basins. To order map sets contact one of the California Geological Survey offices:

Publications Sales-Sacramento (916) 445-6199 fax: (916)324-5644	Publications and Information Office-Sacramento (916) 445-5716
Southern California Regional Office-Los Angeles (213) 239-0878	Bay Area Regional Office-San Francisco (415) 904-7707

You may also download the order form from the web site:
www.consrv.ca.gov/cgs/information/publications/ordering.htm

Data sets and GIS Products

A number of data sets and GIS products have been produced as a part of this work. Some of these products are available at www.coastalwatersheds.ca.gov

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Big River Basin Executive Summary

California Coastal Watershed Planning and Assessment Program

The Big River Basin Assessment began in 2003 as a project of the North Coast Watershed Assessment Program (NCWAP). That program was established by the California Legislature in July 2000 and was managed by the California Resources Agency and the California Environmental Protection Agency. Participating Resource Agency departments included Fish and Game (CDFG), Forestry and Fire Protection (CDF), Conservation/California Geologic Survey (DOC/CGS), and Water Resources (DWR), in conjunction with the North Coast Regional Water Quality Control Board (NCRWQCB) and State Water Resources Control Board.

In July 2003, after conducting large scale assessments on the Mattole and Gualala rivers, and Redwood Creek, the program was eliminated because of reductions in the state budget. However, large-scale watershed assessment efforts are ongoing by the CDFGs Coastal Watershed Planning and Assessment Program (CWPAP), with input from other Resources Agency departments as budgets allow.

The program's work is intended to provide answers to the following assessment questions at the basin, subbasin, and tributary scales in California's coastal 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 impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?
- How has land use affected these natural processes and conditions?
- 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 management and habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

The assessment program's products are designed to meet these strategic 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 to assist landowners, local watershed groups, and individuals in developing successful projects. This will help guide support programs, such as the CDFG 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 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.

General Assessment Approach

Each of the program's participating departments developed data collection and analysis methods used in their basin assessments. The departments also jointly developed a number of tools for interdisciplinary synthesis of information. These tools included models, maps, and matrices for integrating information on basin, subbasin, and stream reach scales to explore linkages among watershed processes, current conditions, and land use. In basins where information was available, these tools provided a framework for identifying refugia areas and factors limiting salmonid productivity, as well as providing a basis for understanding the potential for cumulative impacts from natural and man caused impacts. This information is useful for developing restoration, management, and conservation recommendations.

The general steps in our large-scale assessments include:

- Form multi-disciplinary team;
- Conduct scoping and outreach workshops;
- Determine logical assessment scales;
- Discover and organize existing data and information according to discipline;
- Identify data gaps needed to develop the assessment;
- Collect field data;
- Amass and analyze information;
- Conduct Integrated Analysis (IA);
- Conduct Limiting Factors Analysis (LFA);
- Conduct refugia rating analysis;
- Develop conclusions and recommendations;
- Facilitate implementation of improvements and monitoring of conditions.

The roles of the five original participating NCWAP agencies in these efforts included these activities:

- DOC/CGS compiled, developed, and analyzed data related to the production and transport of sediment;
- CDF compiled, developed, and analyzed data related to historical land use changes in the watersheds;
- NCRWQCB compiled, developed, and analyzed water quality data for the assessment;
- DWR installed and maintained stream monitoring gages where needed to develop and analyze stream flow information;
- CDFG compiled, collected, and analyzed data related to anadromous fisheries habitat and populations.

Results of assessments conducted by various agency personnel on the Big River team were brought together in an integrated synthesis process. This process describes spatial and temporal relationships between watershed and stream conditions and dynamic watershed processes that have been at work to form them. To assist in this process, the team used Geographic Information System (GIS) based watershed data coverage and an Ecological Management Decision Support (EMDS) model to help evaluate watershed conditions and processes.

Scale of Assessment and Results

The Big River assessment team used the California Watershed Map (CalWater version 2.2.1) to delineate the Big River Basin into three subbasins for assessment and analyses purposes (Figure 1). These study areas were the Coastal, Middle, and Inland subbasins. In general, the CalWater 2.2a Planning Watersheds (PWs) contained within each of these assessment subbasins have common physical, biological, and/or cultural attributes. However, there is enough variance between the three areas' attributes that they were delineated as separate subbasins. Demarcation in this logical manner provides a large, yet common scale for conducting assessments. It also allows for reporting of findings and making recommendations for watershed improvement activities that are generally applicable across a large, relatively homogeneous area. The large Inland Subbasin was also sub-divided into the North Fork, South Fork, and headwaters drainages for some analysis purposes.

Assessment Products

This report and its appendices are intended to be useful to landowners, watershed groups, agencies, and individuals to help guide restoration, land use, and management decisions.

Assessment products include:

- A basin level Synthesis Report that includes:
  - Collection of Big River Basin historical and sociological information;
  - Description of historic and current vegetation cover and change, land use, geology and fluvial geomorphology, water quality, and instream habitat conditions;
  - Evaluation of watershed conditions affecting salmonids;
  - An interdisciplinary analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
  - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid productivity;
  - Monitoring recommendations to improve the adaptive management efforts.
- 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: www.coastalwatersheds.ca.gov/, and http://imaps.dfg.ca.gov/, and ArcIMS site.

Salmonids, Habitat, & Land Use Relationships

There are several factors necessary for the successful completion of an anadromous salmonid's life history. In their freshwater phases, important factors include:

- Adequate instream flow during low flow periods to provide juvenile salmonids free forage range, cover from predation, and utilization of localized temperature refugia from seeps, springs, and cool tributaries;
- Good water quality, including appropriate water temperature, water chemistry, turbidity, and sediment load;
- Diverse habitat provided by a combination of deep pools, riffles, and flatwater habitat types;
- Free passage through stream channels;
- A functional riparian zone to control the amount of sunlight reaching the stream, provide vegetative litter and invertebrate fall, contribute to stream bank cohesion, buffer impacts from adjacent uplands, and provide large woody debris and complexity to the stream.

Geology, climate, watershed hydrologic responses, and erosion events interact to shape freshwater salmonid habitats. "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 floods or major earthquakes. They can also be created over time by multiple small natural and/or human disturbances.

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 locally, 1974 (U.S. EPA 2001). Major human disturbances associated with post-European expansion like dam construction, agricultural and residential land development and 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).

Figure 1. Big River Subbasins and CalWater2.2a Planning Watersheds.

Salmonid habitat was also degraded during parts of the last century by well-intentioned but misguided restoration actions such as the removal of large woody debris from streams (Ice 1990). More recently, efforts at watershed restoration have been initiated at the local and state levels by such major programs as CDFGs Fishery Restoration Grants Program (FRGP). For example, several California counties, with FRGP funding, have addressed fish passage problems associated with their roads' stream crossings, opening many miles of historic habitat to salmonids. For additional information on stream and watershed recovery opportunities and project types, see the publication by the Federal Interagency Stream Restoration Working Group (FISRWG 1998).

Thus, a main component of large scale assessment is to identify curable problems that limit production of anadromous salmonids in North Coast streams and watersheds, and prioritize them for treatment. That process begins with the identification of the limiting factors, which can be anything that constrains, impedes, or limits the growth and survival of a population. Limiting factors analysis (LFA) provides a means to evaluate the status of key factors that affect anadromous salmonid life history. This information is useful to understand the underlying causes of stream habitat deficiencies and help determine if watershed processes are being overly influenced by landuse activities, and if so, what can be done to reduce their impacts.

Big River Basin

Named for the giant redwood trees that used to line its banks, the Big River drains a 181.1 square mile watershed located in the northern California Coast Range in western Mendocino County, entering the Pacific Ocean at the town of Mendocino, about 10 miles south of Fort Bragg. The Big River Basin extends 24 miles to the east, to within three miles of Willits and Highway 101. It drains primarily from east to west, sharing ridges with the Noyo River and Caspar Creek basins to the north and the Albion and Navarro river basins to the south. Elevations within the Big River Basin range from sea level at the basin outlet to Irene Peak at 2,836 feet, 5 miles south-southwest of Willits in the east end of the Martin Creek Planning Watershed, Inland Subbasin.

The basin's topography is diverse along its length, varying from flat estuarine environments and uplifted marine terraces to rugged mountains with high relief in the eastern portion. It is characterized by narrow ridgelines separated by deeply incised inner gorges of the major river channels and streams draining the watershed.

The western end of the drainage is distinguished by a long estuary laden with mudflats that become narrow floodplains further upriver and occupy a relatively narrow inner gorge. A sand bar at the mouth partially restricts the connection to the sea during low flow periods in the late summer. Tidal influence extends upward from the mouth three miles in the winter and as far as eight miles during the highest spring tides making the Big River Estuary one of the longest estuaries in northern California (Warrick and Wilcox 1981).

Inland areas of the basin are characterized by second growth forest, with some grasslands in the southeast margins. Logging of the basin started in the 1860s near the mouth and gradually moved eastward. Early logging included heavy use of splash dams, effects of which can still be seen today. Most of the basin is currently owned by large timber companies and managed for timber harvest, though the state owns some sections, and there are smaller ownerships as well.

The Big River is listed on the National Rivers Inventory, a list of potential wild, scenic, and recreational river areas within the United States. The river is listed for five outstandingly remarkable values: scenery, recreation, fish, wildlife, and history (NPS 2004).

The basin supports runs of coho salmon (*Oncorhynchus kisutch)* and steelhead trout (*O. mykiss*). Chinook salmon (*O. tshawytscha*) have been reported occasionally, but there is no significant run. Historical accounts indicate that salmon were plentiful and that salmon fishing was a common activity. However, agency reports starting in the 1950s indicate that salmonid populations were depleted and in decline. In recent years, efforts have been underway to recover salmonid stocks of the Big River Basin. For example, local residents and conservation groups recently organized and purchased a 7,342-acre parcel at the mouth of Big River from a timber company and gave it to California Department of Parks and Recreation to be managed for conservation and recreation.

General Issues, Assessment Sample Base, Assessment Questions, Findings and Conclusions, and Improvement Recommendations

Big River Basin General Issues

Public scoping meetings with Big River Basin residents and constituents and initial analyses of available data by watershed experts developed this working list of general issues and/or concerns:

- Water diversions have the potential to significantly reduce surface water flows of Big River and its tributaries. The potential for land development and increase in demand for water from the basin remains an issue of concern;
- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River and larger tributaries;
- There is concern that chemical and diesel spills in the basin are impairing stream conditions;
- There is concern that large amounts of sediment generated from road related failures have been and may be delivered to stream channels during major storms;
- Chronic fine sediment levels in many tributaries and the mainstem Big River are thought to be high;
- Estuary conditions are thought to be impaired by sediment;
- Fish habitat, including pool frequency, pool depth, shelter, large woody debris presence, cobble embeddedness, and fish passage are though to be unsuitable for salmonids throughout the basin;
- Timber harvest has been and continues to be the dominant land use in the Big River Basin;
- Landsliding related to roads, timber harvesting, and grassland is a concern;
- Long term effects to stream channels from splash dam logging throughout the basin are of concern;
- It is believed that there have been reductions in salmonid populations from historic levels;
- Sport and commercial fish harvests may have played a role in the reduction of numbers of Big River's salmonid populations;
- There is concern that the decline in the abundance of spawning salmon has likely caused a corresponding decrease in nutrients and organic matter available to streams;
- Graham Mathews and Associates (GMA) (2001) may have over-estimated the bankfull width used in the Sediment Source Analysis (CGS 2004).

Assessment Sample Base

This assessment was based on the following information:

- Geologic maps compiled by CGS, United States Geological Survey, California Department of Forestry, aerial photographic mapping, and field reconnaissance geologic mapping. Geologic features were compiled through the previous work of Durham, 1979, Kilbourne, et al, 1982, 1983, and 1984, Short and Spittler, 2002, stereoscopic evaluation of aerial photos, and limited geologic and geomorphic reconnaissance mapping. Aerial photographs and compilation of existing data represent the primary information sources for this product;
- Additional geologic information was used from the CGS geologic reports about the new Big River State Park Unit for DPR (CGS 2004);
- CDF compiled a history of the basin and analyzed historic land uses and vegetation;
- NCRWQCB utilized information provided by private and agency cooperators on water and substrate quality in various years from 1973 to 2002, with the majority of data from 1995 to 2002;
- Stream flow and precipitation information compiled from the Big River Sediment Source Analysis (GMA 2001a) and DWR;
- CDFG surveyed 55 streams and three sections of the mainstem Big River between 1995 and 2002. Private and agency cooperators also contributed various biological and physical data from 1958 to 2002, including a Watershed Analysis of lands in the basin owned by the Mendocino Redwood Company.

Assessment Questions

This assessment uses six guiding assessment questions (page 1) to organize its issues, findings, conclusions, and recommendations. The following discussion of the assessment questions 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 CDFG and NCRWQCB Appendices contain more specific assessment methods, findings, conclusions, and recommendations for stream and watershed improvements.

Big River Basin

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

Findings and Conclusions:

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries Endangered Species Act listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast. Coho salmon in Mendocino County are currently listed as endangered under the California and federal Endangered Species Acts and steelhead trout are listed as threatened under the federal Endangered Species Act;
- Based on limited CDFG, USFWS, Hawthorne Timber Company (HTC), MRC, and the School of Natural Resources at Mendocino High School (SONAR) presence surveys and surveys documented by NMFS, the distributions of coho salmon and steelhead trout do not appear to have changed since the 1960s;
- Steelhead trout were documented in more reaches surveyed by CDFG and MRC since 1990 than coho salmon;
- Thirty tributaries, the mainstem Big River, and the estuary had records of coho salmon and steelhead trout since 1990. Twenty additional tributaries recorded only steelhead trout.

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

Findings and Conclusions:

Flow/Water Quality

- Water temperatures at all seven monitoring sites along the mainstem of the Big River were unsuitable for salmonids;
- Water temperatures in tributaries across the basin showed that temperatures were generally suitable for salmonids in the Coastal and Middle subbasins and mixed in the Inland Subbasin. Temperatures in the larger tributaries in the Inland Subbasin such as the North and South forks Big River were generally unsuitable for salmonids while temperatures in the smaller tributaries were suitable;
- There have been very few water quality samples taken across the basin. Some sites show indications of exceeding NCRWQCB criteria for sodium, copper, specific conductance, total dissolved solids, aluminum, zinc, or boron. However, these findings are based on few sample sites and in some cases may be artifacts of the type of sampling procedure used.

Fish Passage

- Fish passage barriers have been identified in seven surveyed tributaries across the basin and several small tributaries along the estuary are blocked to fish passage by perched culverts;
- Areas of dry channel found during CDFG stream surveys may indicate fish passage problems in some tributaries during periods of low flow.

Erosion/Sediment

- Data collected in four tributaries in the basin indicated excessive amounts of fine sediment in the sub-0.85 mm and/or sub-6.5mm size classes, which would create unsuitable conditions for salmonids. However, much of the basin has not been evaluated for sediment delivery and deposition.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed reaches within the basin except for James Creek and the mainstem Big River. The mainstem Big River has a larger, broader channel and floodplain and is expected to have reduced canopy levels.

Instream Habitat

- A high incidence of shallow pools, and a lack of cover and large woody debris indicate simplification of instream salmonid habitat in surveyed tributary reaches and the estuary.

Gravel/Substrate

- Cobble embeddedness values in many CDFG surveyed reaches were unsuitable for salmonid spawning success. Of surveyed pool tails, only 17.2% had cobble embeddedness less than 26%. In addition, the MRC characterized spawning gravels as fair quality on segments they surveyed;
- Permeability sampling in four locations throughout the basin indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonid in these sample sites.

Refugia Areas

- Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin tributaries where they have generally been rated as high potential refugia. Conditions in the Middle and Inland subbasins are mixed and generally rated as medium potential refugia.

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?

<u>Findings and Conclusions:</u>

- The geology of the Big River Basin is primarily comprised of Coastal Belt Franciscan Complex. This portion of the Franciscan complex is relatively stable compared to the mélange terrane of the Central Belt, which is found only in the upper parts of the watershed. A small portion of Tertiary age sandstone is found in the Greenough Ridge - Montgomery Woods State Reserve area (EPA, 2001);
- The Coastal and Middle subbasins have much lower relief and longer slopes than the Inland Subbasin, which has a high percentage of area in higher slope classes;
- Redwood and Douglas fir forests have historically and continue to dominate the basin. Additional vegetation includes tan oak, madrone, alder, bishop pine, pygmy cypress, willow, grass, oak, bay laurel, alder oak, and blueblossom. Pre-European forests consisted of mostly large old-growth trees;
- A long history of wildfire has influenced the current vegetation of the Big River Basin, although the specifics of fire practices and history are unknown. However, fire was a natural and frequent occurrence. Prior to European settlement, the Mendocino Coast experienced a fire every 6-20 years during the last 200-400 hundred years (Brown 1999). In 1931, the Comptche fire swept across the eastern part of the basin, burning 10,733 acres, 9% of the basin;
- The basin has experienced a variety of natural disturbances such as earthquakes, flooding, droughts, and decadal climate shifts. Examples include a moderate earthquake that originated about two miles south of the Albion Basin during the mid to late 1800s, another strong earthquake that originated near Fort Bragg in 1898, and the distant San Francisco earthquake in 1906. Earthquakes often trigger landsliding;
- Landsliding has occurred across the entire basin. More landslides and more volume from landslides by area are found in the Inland Subbasin than the other two subbasins;
- Many of the tributaries in the basin are intermittent in their upper reaches and usually have summer and fall flows of less than 1 cfs.

How has land use affected these natural processes?

<u>Findings and Conclusions:</u>

- Historic timber harvest activities reduced riparian canopy, 86% of the basin has experienced one or more timber harvests. However, riparian canopy is currently suitable along most surveyed tributary reaches across the basin;

- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times [61% of trees in 75-100 feet wide watercourse buffer zones have diameter at breast height (dbh) less than 24 inches]. The small diameter of near stream trees across the basin limits the recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;
- Splash dam logging involving 27 splash dams across the basin before 1920 likely greatly accelerated erosion and widened stream channels across the basin. However, significant bed lowering along the lowermost reaches of Big River associated with splash dams is unlikely;
- Post splash damming channels are deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD and gravel;
- Early splash dam and barrier removal projects, starting in the 1950s, cleared many streams across the basin of timber-related woody debris. The lack of instream complexity seen today likely results from these past practices;
- A lack of LWD throughout the Big River Basin also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance;
- CGS found that channel narrowing, floodplain growth, and encroachment of forest vegetation on marshes seen since 1900 along the estuary is likely the result of a river channel reclaiming itself after the multiple decades of channel clearing, splash dam flooding, and battering by logs in transport;
- Historic sawmill complexes on the Big River flats reduced wetland habitat;
- Construction of near stream railroads in the Coastal and Middle subbasins and North Fork Big River and roads throughout the basin used fill that constricted stream channels and destabilized streambanks;
- From 1937 to 2000 the rate of landsliding across the basin was 664.3 tons/square mile/year (approximately 332 cubic yards or 33 truck loads). Rates were highest in the Inland Subbasin, followed by the Middle and Coastal subbasins, respectively;
- CGS photo mapping of stream channels in 1984 and 2000 found that negative channel features increased in the Mouth of Big River Planning Watershed (PW) and decreased in the North and South forks Big River and Daugherty Creek, as expected between source and depositional reaches. The greatest reductions in negative channel features were seen in Daugherty Creek;
- There has been a significant increase in road building since 1989 across the basin, especially in the Coastal and Middle subbasins. However, new roads have been built to higher standards, on ridge-tops, and are paved; thus creating less of a sediment source;
- Roads and timber harvesting are listed in the NCRWQCB TMDL report as major sources of human-related sediment into the stream system. The effects from these activities are often spatially and temporally removed from their upland sources;
- County culverts located on three tributaries in the Inland Subbasin have been identified as total salmonid passage barriers by a Mendocino County roads study. Additionally, perched culverts have blocked fish passage to small tributaries along the estuary;
- The recent purchase of a large portion of the estuary and transfer to DPR for management as a park also will likely improve temperature and sediment conditions in the Coastal Subbasin as planned management improves roads and riparian zones.

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

Findings and Conclusions:

Based on the information available for this assessment, it appears that salmonid populations are currently being limited by:

- Low summer stream flows in tributaries in the Inland Subbasin;
- High water temperatures in the mainstem Big River;
- Fish passage barriers;

- Embedded spawning gravels;
- Reduced habitat complexity.

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

Flow and Water Quality Improvement Activities

- To minimize and reduce the effects of water diversions, take action to ensure compliance with state water laws to address seasonal diversion, off-stream reservoirs, bypass flows protective of coho salmon and other anadromous salmonids and the normal hydrograph, and avoidance of adverse impacts caused by water diversion;
- Discourage instream flow diversions in tributaries with cooler water temperatures for thermal refugia delivered to the warmer North and South Forks and mainstem Big River in the summer;
- Land managers should work to reduce the temperature of water flowing into the Middle and Coastal subbasins. In order to do this, they should maintain and/or establish adequate streamside protection zones to increase shade and reduce heat inputs to Big River and its tributaries throughout the basin;
- Follow the procedures and guidelines outlined by NCRWQCB to protect water quality from ground applications of pesticides.

Fish Passage

- Consider modifying debris accumulations to facilitate fish passage where necessary;
- Adequately fund prioritization and upgrading of culverts to provide fish passage within the range of coho salmon and to pass 100-year flows and the expected debris loads.

Erosion and Sediment Delivery Reduction Activities

- To reduce sediment delivery to Big River, land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with landuse activities throughout the basin. Thirty-six CDFG stream surveys had road sediment inventory and control as a top tier tributary recommendation;
- Support and encourage existing and active road management programs undertaken by landowners throughout the basin;
- Map unstable soils and use soil mapping to guide land-use decisions, road design, THPs, and other activities that can promote erosion;
- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks;
- Limit unauthorized and impacting winter use of unsurfaced roads and recreational trails to decrease fine sediment loads;
- Develop erosion control projects similar to the North Fork Ten Mile River erosion control plan (Mendocino Department of Transportation 2001).

Riparian and Instream Habitat Improvement Activities

- Improve instream structure for juvenile ambush escape and cover. Thirty-one CDFG stream surveys and the mainstem Big River have increase escape cover as a top tier tributary recommendation;
- Add LWD to stream channels where appropriate/feasible to develop habitat diversity and to increase shelter complexity. In addition, there is a need to leave large wood on stream banks and in estuarine channels for potential recruitment into stream channels and the estuary;
- Maintain and improve existing riparian cover where needed;
- Encourage growth and retention of near-stream conifers;
- Ensure that any land management activities include protection and preservation of stream and riparian habitats and maintain or improve ecological integrity within the basin;

- Ensure that high quality habitat is protected from degradation. Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins;
- Consider the use of management strategies such as conservation easements to maximize potential benefits to aquatic habitats from near-stream forest protection.

Education, Research, and Monitoring Activities

- State Parks, DFG, MRC, and HTC should continue and expand existing monitoring of anadromous salmonid populations to include some winter and spring fish sampling;
- Support stream gage installations and maintenance to establish a long term record of Big River hydrologic conditions;
- Additional investigations of the physical characteristics of Big River are needed to re-evaluate the Sediment Source Analysis. A regional curve of bankfull dimensions vs. drainage area should be developed for Mendocino County and used to validate CGS (2004) bankfull discharge estimates for Big River;
- Hillslope and in-stream monitoring proposed by the MRC in their Watershed Analysis (2003) should be carried out and additional monitoring programs throughout the basin should be planned with respect to MRC techniques;
- A study examining how sediment plugs moved downstream from historic splash dam locations over time on air photos is recommended;
- Continue water temperature monitoring at current locations and expand these efforts where appropriate;
- Further study of timberland herbicide use is recommended.

Coastal Subbasin

The Coastal Subbasin includes all of the watershed area of the mainstem Big River below its confluence with Peterson Gulch. This encompasses all of the Big River Estuary. Stream elevations across the subbasin range from sea level to 40 feet at the boundary with the Middle Subbasin. The highest point is above Kidwell Gulch on the border with the Middle Subbasin, at 1,235 feet. The subbasin encompasses 32.5 square miles and occupies 17.9% of the total basin area. The Big River estuary is large relative to the size of the Big River drainage, with tidal influence extending approximately 8.3 miles upstream from the ocean. The estuary is the longest undeveloped estuary in California (Warrick and Wilcox 1981). The river joins the Pacific at an opening at the north side of Mendocino Bay. The bay is protected by rocky headlands. This headland minimizes wave-induced longshore sediment transport and allows the mouth to remain open to the sea year round. The town of Mendocino lies just outside of the Big River Basin, north of the river mouth.

Key Findings

Flow/Water Quality

- There are no water temperature data for the Big River Estuary; however, it is expected that the water temperatures in the mainstem Big River quickly cool once they reach the estuary due to the marine influence;
- Water temperatures at monitoring sites on the mainstem of the Big River in this subbasin were fully unsuitable in all years monitored with high diurnal fluctuations (7.9-9.9°F) and high maximum temperatures (75-76°F). This could indicate unsuitable conditions for salmonids in the mainstem upstream of the estuary;
- Most of the Little North Fork Big River and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence. This indicates suitable conditions for salmonids;
- It is probable that the Little North Fork has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- There are no water chemistry data for the estuary and little data for this subbasin as a whole;
- Water chemistry data available from a small stream near the estuary (R.M. 0.4), but not related to the water chemistry in the estuary itself, indicated that alkalinity and sodium appeared to be below the minimum water quality criteria;

- Basic water chemistry on the mainstem Big River both upstream and downstream of the Little North Fork appear to be within applicable numeric Basin Plan water quality objectives. However, sodium at the mainstem sites upstream and downstream of the Little North Fork confluence exceeds its criteria. Additionally, copper, which is used in many herbicides, exceeds its criteria at sites upstream of the Little North Fork. However, these finding may be artifacts of the type of sampling procedure used;
- Total and fecal coliform was detected on the mainstem at the sites upstream of the Little North Fork confluence. It appears as though the levels detected are not hazardous.

Fish Passage

- Winter access problems for adult fish at a non-existent channel near the mouth of Manly Gulch may be stopping it from being utilized for habitat by salmonids;
- Small tributaries along the estuary are blocked to fish passage by perched culverts;
- Areas of dry channel found during CDFG stream surveys on eight streams may indicate fish passage problems in some tributaries.

Erosion/Sediment

- Pebble counts and V* measurements in one sampled tributary (Berry Gulch) and McNeil core sediment samples in the Little North Fork indicated excessive amounts of fine material in these streams. This could indicate unsuitable conditions for salmonids.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream with wide channels.

Instream Habitat

- In the estuary, escape and ambush cover are unsuitable for salmonids;
- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in all nine surveyed tributary reaches.

Gravel Substrate

- Cobble embeddedness values in most surveyed reaches were unsuitable for salmonid spawning success.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as high potential refugia;
- The Big River Estuary and the Little North Fork Big River provide the best salmonid refugia in this subbasin;
- The estuary, mainstem Big River, and Little North Fork Big River serve as critical contributing areas, which provide critical ecological functions needed by salmonids such as providing a migration corridor or supplying high quality water.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in Little North Fork Big River, Railroad Gulch, and Laguna Creek to help moderate or cool the warmer mainstem Big River in the summer.

Fish Passage

- Consider modifying fish passage barriers on Manly Gulch and small tributaries along the estuary.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated that nine out of eleven surveyed tributaries in this subbasin had road sediment inventory and control as a top tier tributary recommendation;

- Continue to support and encourage current and future road management programs undertaken by California State Parks;
- California State Parks should follow the recommendations of CGS (2004) in treating identified sediment sources on roads and road crossings within Big River State Park;
- All roads within Big River State Park and their associated watercourse crossings required for public safety, existing easements, future restoration effort success, and public access must be maintained to high standards (CGS 2004);
- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams. For example, low impact yarding systems should be used in any timber harvest operations on steep and unstable slopes to reduce soil compaction, surface disturbance, and resultant sediment yield;
- California Department of Parks should consult with appropriate resource professionals to assist in transitioning industrial timberlands on the Big River State Park to self-sustaining forest (CGS 2004).

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the main channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated that all nine surveyed tributaries and the mainstem Big River have increase shelter as a top tier tributary recommendation;
- Leave large wood in estuarine channels, on the beach, and on stream banks for potential recruitment into the estuary;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the Big River Estuary, mainstem Big River, Little North Fork Big River, Railroad Gulch, East Branch Little North Fork Big River, Berry Gulch Tributary, and Rocky, Thompson, and Berry gulches;
- Create a channel under the main road to connect Manly Gulch to Little North Fork Big River to address winter access problems for adult fish at the non-existent channel at Camp Three.

Education, Research, and Monitoring Activities

- Conduct surveys of ten small tributaries entering the estuary through blocked culverts in the Big River State Park to determine if they provide salmonid habitat;
- Establish monitoring stations to track instream sediment along the estuary;
- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- Assess water temperature and dissolved oxygen in the estuary as there is currently no data on these indicators;
- Establish long-term water chemistry monitoring stations in the lower mainstem Big River. If there are indications of problems, monitoring should be implemented in tributaries as necessary to determine the source of the problem;
- Encourage the involvement of SONAR in fish and habitat monitoring activities.

Middle Subbasin

The Middle Subbasin includes the watershed area of the mainstem Big River just above its confluence with Peterson Gulch to its confluence with the South Fork Big River, not including the North Fork Big River. Stream elevations range from 40 feet at boundary with the Coastal Subbasin to 210 feet at the confluence with the North Fork Big River. The highest point in the subbasin is above Dietz Gulch at approximately 1,560 feet. The Middle Subbasin is the smallest of the three Big River subbasins at 17.9 square miles and occupies 9.9% of the total basin area. Most of the subbasin is owned by Hawthorne Timber Company or Mendocino Redwood Company and is managed for timber production.

Key Findings

Flow/Water Quality

- All of the water temperature monitoring sites on the mainstem Big River had (MWATs) that varied from moderately to fully unsuitable (67-70°F) with maximum daily temperatures (73-77°F) in excess of the lethal limit for salmonids. High diurnal fluctuations were also recorded (7.5-12.8°F), suggesting poor canopy and/or low flows;
- Data from lower Two Log Creek indicated water temperatures were between fully suitable, with a minimum observed MWAT of 58°F, and undetermined with a maximum observed MWAT of 64°F. However, large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites, which may indicate poor canopy and/or low flows;
- The only monitored tributary to Two Log Creek, Beaver Pond Gulch, had fully suitable water temperatures, but based on the thermograph, the monitoring device may have been placed in a thermally stratified pool or a site with a significant groundwater component;
- Hatch Gulch had fully suitable water temperatures with minimal diurnal fluctuations. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River;
- It is also probable that Two Log Creek has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- There is no water chemistry data for this subbasin.

Fish Passage

- Areas of dry channel in Kidwell and Hatch gulches found during CDFG stream surveys may indicate fish passage problems.

Erosion/Sediment

- McNeil core sediment samples in Two Log Creek indicated excessive amounts of fine material in this stream. This could indicate unsuitable conditions for salmonids.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream.

Instream Habitat

- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in surveyed reaches of Kidwell Gulch, Two Log Creek, and the mainstem Big River between Tramway Gulch and the North Fork Big River.

Gravel Substrate

- Cobble embeddedness values in Hatch Gulch, Saurkraut, and Ayn creeks were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on all seven segments they surveyed;
- Permeability sampling in the Big River below the North Fork Big River indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonids.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- Two Log Creek provides the best salmonid refugia in this subbasin;
- The mainstem Big River serves as critical contributing area.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in Two Log Creek and Hatch Gulch to help moderate or cool the warmer mainstem Big River in the summer.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Saurkraut Creek have road sediment inventory and control as a top tier tributary improvement recommendation.

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the mainstem channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Big River from Tramway Gulch to North Fork Big River have to increase escape cover as a top tier tributary recommendation;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the mainstem Big River, Two Log Creek, Ayn Creek, Tramway and Hatch gulches.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- In lower Two Log Creek, both MRC and HTC have temperature monitoring sites in nearly the same location. It may be more effective if one company monitored the site and shared the information with the other while the second monitoring device is deployed at another location.

Inland Subbasin

The Inland Subbasin includes the entire watershed area of the North Fork Big River, South Fork Big River, and the entire watershed area of the mainstem Big River above the confluence with the South Fork Big River. Stream elevations range from 200 feet at the confluence of the mainstem Big River with North Fork Big River to approximately 1,300 feet in the headwaters of the tributaries. The highest point in the subbasin is Irene Peak at 2,836 feet. The subbasin encompasses 130.8 square miles, occupying 72.2% of the total basin area. Most of the subbasin is owned by MRC, Strategic Timber Trust, and Jackson State Demonstration Forest and is managed for timber production. There are also a large number of smaller privately owned parcels near the western border and the small hamlet of Orr Springs lies near the headwaters of the South Fork Big River.

Key Findings

Flow/Water Quality

- Water temperatures at sites on Donkey House, Frykman, Steam Donkey, Goddard, No Name, Water, Johnston, Wildhorse, and Arvola gulches; Chamberlain, James, West Chamberlain, North Fork Ramon, Montgomery, and Martin creeks; Russell Brook; and East Branch North Fork and North Fork Big River are suitable for salmonids;
- Water temperatures at sites on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks are unsuitable for salmonids;
- Sites that appear to have strong groundwater influences based on their thermographs include Goddard, Donkey House, No Name, Water, Frykman, Steam Donkey, Goddard Wildhorse, and Johnston gulches;
- Relatively large diurnal fluctuations in virtually all of the monitored sites throughout the South Fork drainage indicate that there is poor canopy and/or low flows. The only exceptions to this are the monitoring sites at Montgomery Woods Reserve, and the sites located in gulches that are apparently dominated by groundwater;

- Montgomery Creek was within the fully suitable range at approximately 60°F during all three years monitored. The maximum diurnal fluctuations varied between 4-5°F. This site is in an undisturbed location in the Montgomery Woods Reserve and is probably a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River Basin. It should be noted that much of the interior watershed is naturally grasslands, and could not reasonably be expected to achieve these water temperatures;
- It appears as though James Creek has a cooling effect on the North Fork Big River, Gates Creek provides some cooling effect to Daugherty Creek, Russell Brook contributes cooler water to the mainstem Big River, and Water Gulch and West Chamberlain Creek contribute some amount of cooling to Chamberlain Creek;
- On February 27, 2001 a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on Highway 20 and discharged numerous petroleum compounds into James Creek. Because of active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on fish and wildlife;
- A water quality sampling site on the South Fork Big River below the confluence with Daugherty Creek had specific conductance and total dissolved solids measurements that were relatively high compared to Basin Plan water quality objectives;
- Limited water quality data from Chamberlain Creek indicated that specific conductance was at or slightly below Basin Plan standards. Several other water quality parameters, including aluminum, copper, sodium, and zinc exceeded their respective criteria. Given the limited nature of this sampling effort and uncertainties about the method and exact location of sampling, it is suspected that this does not represent actual in-stream water quality but possibly water quality at some point in the drinking water system;
- Sodium was detected at concentrations above the water quality criteria at the North Fork Big River;
- Ammonia samples collected in the North Fork and South Fork Big River indicated that ammonia did not exceed the numeric criteria in either site;
- The two samples of boron and sodium in the South Fork Big River exceeded their numeric criteria. In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l).

Fish Passage

- Fish passage barriers exist on Dark Gulch, Johnson Creek, an Unnamed tributary to the South Fork of the Big River, Gulch Sixteen Tributary, and Soda Gulch;
- Areas of dry channel found in 31 surveyed tributaries during CDFG surveys may indicate fish passage problems.

Erosion/Sediment

- McNeil core sediment samples indicated that a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek. This could indicate unsuitable conditions for salmonids;
- Turbidity and suspended sediment samples in ten locations across the subbasin showed values ranging from 1.6 NTU in James Creek to 811 NTU in South Fork Big River below the confluence with Daugherty Creek.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin except for James Creek.

Instream Habitat

- A high incidence of shallow pools and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in 21 out of 41 surveyed tributaries.

Gravel Substrate

- Cobble embeddedness values in 36 out of 41 CDFG surveyed tributaries were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on 32 segments surveyed and good quality on four;

- Permeability sampling indicated low to moderate amounts of fine material at East Branch North Fork Big River, and significant fine material at Daugherty and Ramon creeks. This could indicate unsuitable conditions for salmonids in Daugherty and Ramon creeks.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek provide the best salmonid refugia in this subbasin;
- The North Fork and South forks Big River and Daugherty Creek serve as critical contributing areas.

Key Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in James Creek, Chamberlain Creek, East Branch North Fork Big River, Montgomery Creek, and Russell Brook to help moderate or cool the warmer North and South Forks and mainstem Big River in the summer;
- Ensure that adequate streamside protection measures are used to provide shade canopy and reduce heat inputs to the North and South Forks Big River, mainstem Big River, and Daugherty Creek.

Fish Passage

- Consider modifying fish passage barriers on Dark Gulch, Johnson Creek, an unnamed tributary to the South Fork of the Big River, Gulch Sixteen Tributary, and Soda Gulch.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated that road sediment inventory and control were top tier tributary recommendations in:

  Anderson Gulch
  Arvola Gulch
  Boardman Gulch
  Dark Gulch
  Gates Creek
  Gulch Sixteen
  Gulch Sixteen Tributary
  James Creek
  Martin Creek
  Martin Creek Left Bank Tributary
  Mettick Creek
  Montgomery Creek
  North Fork James Creek
  North Fork Ramon Creek
  Park Gulch
  Rice Creek
  Russell Brook
  Soda Gulch
  South Fork Big River
  South Fork Big River Tributary #2
  Valentine Creek
  Water Gulch
  Water Gulch Tributary

- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks in the Chamberlain Creek PW, South Fork drainage, and the headwaters drainage.

Riparian and Instream Habitat Improvement Activities

- Consider adding pool enhancement elements (e.g. LWD) to increase the number of pools or deepen existing pools and add shelter complexity to all surveyed tributaries in the North Fork drainage, Daugherty, Soda, Johnson (tributary to Gates Creek), and Snuffins creeks, and the right bank tributaries of Martin Creek;
- Consider modifying debris accumulations in Horsethief Creek, Dark Gulch, Russell Brook, and Martin Creek to facilitate fish passage;

- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks;
- Conduct a stream habitat survey of the mainstem Big River upstream from the confluence with North Fork Big River.

Propensity for Improvement in the Big River Basin

Advantages

The Big River Basin has several advantages for planning and implementing successful salmonid habitat improvement activities that include:

- An expanding group of cooperative landowners that includes both public and private landowners from all three subbasins in the Big River that are interested in improving watershed and fishery conditions. Additionally, a technical advisory committee has been formed to aid State Park management decisions. The effect of this is the ability to choose locations for projects where the best result can be achieved in the shortest time period;
- The recent purchase of a large portion of the estuary and transfer to the State of California for management as a park also will likely help improve localized temperature and sediment conditions in that area of the Big River Basin;
- Much of the basin is in the ownership of a few large landowners, making the creation and implementation of a coordinated basin-wide watershed program simpler;
- This assessment provides focus on watershed conditions and processes from the basin scale, through the subbasin scale, and down to the level of specific tributaries. This helps focus project design efforts so that local landowners can pursue the development of site specific improvement projects on an adaptive basis;
- Like most river systems, Big River coho salmon and steelhead trout meta-populations have evolved and adapted to the basin's unique conditions. Although these meta-populations are likely below historic levels, there remain local stocks that can take advantage of improved conditions.

Challenges

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

- Not all landowners are interested in salmonid habitat improvement efforts. Without a watershed wide cooperative land-base, treatment options are limited. In some cases this can remove some key areas from consideration of project development;
- Current levels of coho salmon and steelhead meta-populations could limit the amount of needed straying to rapidly colonize fish into improved or expanded habitat conditions.

Table 1. Summary of Big River subbasins stream and basin conditions and recommended actions.

Identified Conditions	Coastal Subbasin	Middle Subbasin	Inland Subbasin
Instream sediment	~	~	~
Water temperature	~	~	~
Water chemistry	~	~	~
Pools	-	-	-
Flow	+	+	~
Escape cover	-	-	-
Fish passage barriers	~	+	~
Natural sediment sources	~	~	~
Management related sediment sources	-	-	-
Recommended Improvement Activity Focus Areas			
Flow			X
Erosion/Sediment	X	X	X
Riparian/Water temperature	X	X	X
Instream habitat	X	X	X
Gravel/Substrate	X	X	X
Fish passage barriers	X		X

\+ Condition is favorable for anadromous salmonids - Condition is not favorable for anadromous salmonids
~ Condition is mixed or indeterminate for anadromous salmonids X Recommended improvement activity focus areas

The likelihood that any North Coast basin will react in a responsive manner to management improvements and restoration efforts is a function of existing watershed conditions. In addition, the status of watershed delivery processes influencing watershed condition will affect the success of watershed improvement activities. A good knowledge base of these current watershed conditions and processes is essential for successful watershed improvement.

Acquiring this knowledge requires property access to design, implement, monitor, and evaluate suitable improvement projects. Thus, systematic improvement project development is dependent upon the cooperative attitude of resource agencies, watershed groups and individuals, and landowners and managers.

The Big River assessment has considered a great deal of available information regarding watershed conditions and processes in the basin. This long assessment process has identified problems and made recommendations to address them while considering the advantages and challenges of conducting watershed improvement programs in the Big River Basin.

After considering these problems, recommendations, advantages and challenges, the Big River Basin appears to be an excellent candidate for a successful long-term, programmatic watershed improvement effort. According to the current refugia analysis, the Big River has medium potential to become a basin with high quality fishery refugia. Reaching that goal is dependent upon the formation of a well organized and thoughtful improvement program founded on broad based community support for the effort. Guidelines and resources made available through the California Coho Recovery effort will also provide key aid for reaching the goal of high quality fishery refugia.

Program Introduction and Overview

Assessment Needs for Salmon Recovery & Watershed Protection

The Big River Basin Assessment began as a project of the North Coast Watershed Assessment Program (NCWAP). That program was established by the state Legislature in July 2000 and was managed by the California Resources Agency and the California Environmental Protection Agency. Participating Resource Agency departments included Fish and Game (CDFG), Forestry and Fire Protection (CDF), Conservation/California Geologic Survey (DOC/CGS), and Water Resources (DWR), in conjunction with the North Coast Regional Water Quality Control Board (NCRWQCB) and State Water Resources Control Board.

In July 2003, after conducting large scale assessments on the Mattole and Gualala rivers, and Redwood Creek, the program was eliminated because of reductions in the state budget. However, large-scale watershed assessment efforts are ongoing by the CDFGs Coastal Watershed Planning and Assessment Program (CWPAP), with input from other Resources Agency departments as budgets allow.

Program Assessment Region

The original NCWAP was to provide baseline environmental and biological information for approximately 6.5 million acres of public and private lands over a several-year period. This area was to include all coastal drainages from Sonoma County north to Oregon, corresponding with the North Coast Region Water Quality Control board's region (Figure 1). The Big River Basin assessment is one of five watershed assessments initiated by NCWAP. Three of them, the Albion River, Redwood Creek, and Big River, were completed by CWPAP. The two NCWAP reports were for the Mattole and Gualala rivers.

Figure 1. Original NCWAP basin assessment area.

Program Guiding Questions

The program's work intends 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 impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream 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?

Program Goals

The program was developed to improve decision-making by landowners, watershed groups, agencies, and other stakeholders with respect to restoration projects and management practices to protect and improve salmonid habitat. It was therefore essential that the program took steps to ensure its assessment methods and products would be understandable, relevant, and scientifically credible. As a result, the interagency team developed the following 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 programs, like the CDFG Fishery Restoration Grants Program, toward those watersheds and project types that can efficiently and effectively improve freshwater habitat and support recovery of 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; and
- 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.

North Coast Salmon, Stream, and Watershed Issues

Pacific coast anadromous salmonids hatch in freshwater, migrate to the ocean as juveniles where they grow and mature, and then return as adults to freshwater streams to spawn. This general anadromous salmonid life history pattern is dependent upon a high quality freshwater environment at the beginning and end of the cycle. Different salmonid species and stocks utilize diverse inter-specific and intra-specific life history strategies to reduce competition between species and increase the odds for survival of species encountering a wide range of environmental conditions in both the freshwater and marine environments. These strategies include the timing and locations for spawning, length of freshwater rearing, juvenile habitat partitioning, a variable estuarine rearing period, and different physiologic tolerances for water temperature and other water quality parameters.

Salmonids 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 suitable for successful spawning, adequate food supply, and protective cover to escape predators and ambush prey. These life requirements must be provided by diverse and complex instream habitats as the fish move through their life cycles. If any life requirements are missing or in poor condition at the time a fish or stock requires it, fish survival can be 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.

The specific combination of these factors in each stream sets the carrying capacity for salmonids of that stream. The carrying capacity can thus be changed if one or more of the factors are altered. The importance of individual factors in setting the carrying capacity differs with the life stage of the fish and time of year. All of the important factors for salmonid health must be present in a suitable, though not always optimal, range in streams where fish live and reproduce (Bjorn and Reiser 1991).

Within the range of anadromous salmonid distribution, historic stream conditions varied at the regional, basin and watershed scales. Wild anadromous salmonids evolved with their streams shaped in accordance with the inherent, biophysical characteristics of their parental watersheds, and stochastic pulses of fires, landslides, and climatic events. In forested streams, large trees grew along the stream banks contributing shade, adding to bank stability, and moderating air and stream temperatures during hot summers and cold winter seasons. The streams contained fallen trees and boulders, which created instream habitat diversity and complexity. The large mass of wood in streams provided important nutrients to fuel the aquatic food web. During winter flows, sediments were scoured, routed, sorted, and stored around solitary pieces and accumulations of large wood, bedrock, and boulders forming pools riffles and flatwater habitats.

Two important watershed goals are the protection and maintenance of high quality fish habitats. In addition to preservation of high quality habitat, reparation of streams damaged by poor resource management practices of the past is important for anadromous salmonids. Science-based management has progressed significantly and "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).

Through the course of natural climatic events, hydrologic responses and erosion processes interact to shape freshwater salmonid habitats. These processes influence the kind and extent of a watershed's vegetative cover as well, and act to supply nutrients to the stream system. When there are no large disturbances, these natural processes continuously make small changes in a watershed. Managers must constantly judge these small natural changes as well as changes made by human activity. Habitat conditions can be drastically altered when major disruptions of these small interactions occur (Swanston 1991).

Major watershed disruptions can be caused by catastrophic events, such as the 1955 and 1964 north coast floods, which were system reset events. They can also be created over time by multiple small natural or human disturbances. These disruptions can drastically alter instream habitat conditions and the aquatic communities that depend upon them. Thus, it is important to understand the critical, interdependent relationships of salmon and steelhead with their natal streams during their freshwater life phases, and their streams' dependency 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 basins like the 181 square mile Big River in their entirety at any given time. Rather, they normally rotate episodically across the entire basin as a mosaic composed of the smaller subbasin, watershed, or sub-watershed units over long periods. This creates a dynamic variety of habitat conditions and quality over the larger basin (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 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 initially expected (Quinn et al. 1991; Leider 1989).

Human disturbance sites, although individually small in comparison to natural disturbance events, usually are 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 forty-acre landslide or wildfire covering several square miles. However, when all the roads in a basin the size of the Big River 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 basins 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 and in an extremely short period of time on the natural, geologic scale.

Human disturbances are often concentrated in time because of newly developed technology or market forces such as the California Gold Rush or the post-WWII logging boom in Northern California. The 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 widely 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. Thus, a general reduction in salmonid stocks can at least partially be attributed to this impacted freshwater environment.

Although no long-term fish counts exist for the Big River Basin, Department of Fish and Game fish ladder counts at Benbow Dam and Cape Horn Dam, in the Eel River system, reflect an over 80% decline in coho salmon, Chinook salmon, and steelhead trout populations over the span of the last century (Figure 2, Figure 3). The Eel River, especially the South Fork Eel River, which is the location of Benbow Dam, although much larger, has similar watershed conditions and land use history to the Big River Basin. Anecdotal evidence from anglers and longtime local residents supports the likelihood of a similar decline in Big River fisheries (see Big River Basin Profile).

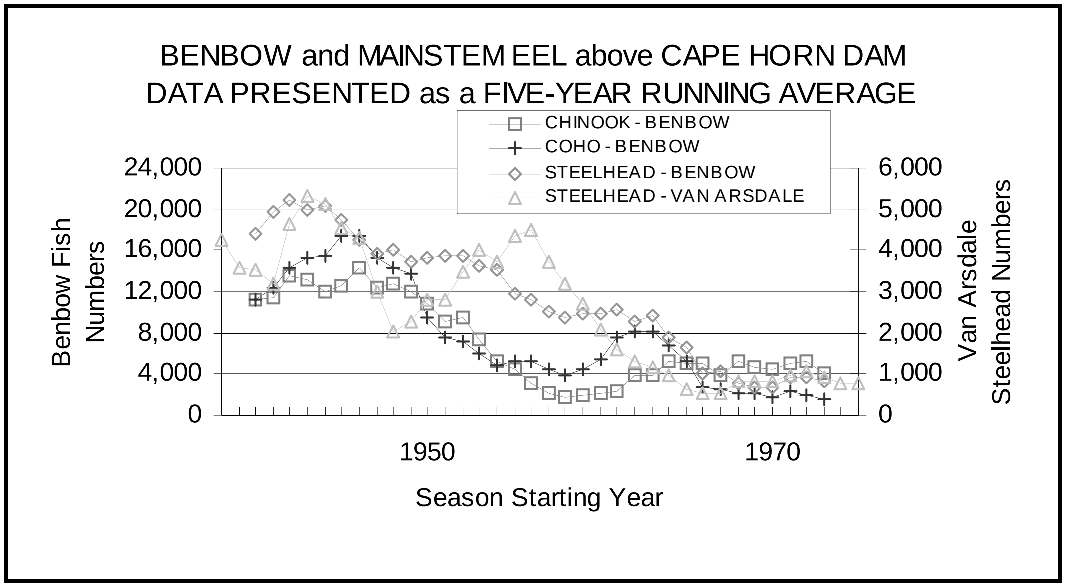


Figure 2. Five-year running average of salmonids at Benbow Dam, South Fork Eel River, and mainstem Eel River above Cape Horn Dam.

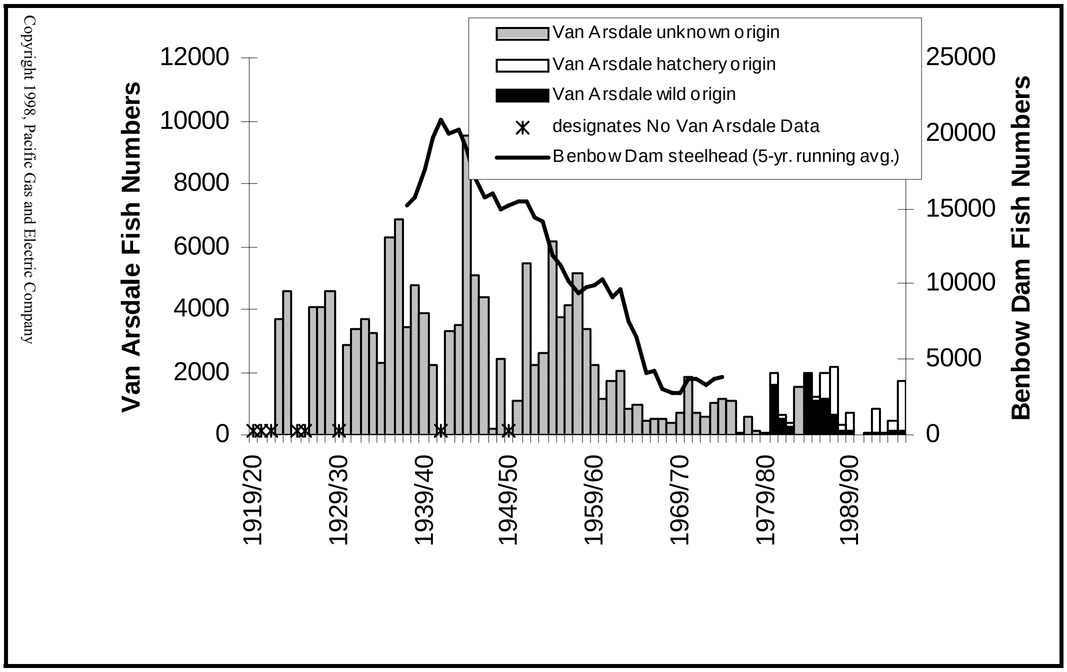


Figure 3. Historical steelhead trout ladder counts at Van Arsdale Fisheries Station, mainstem Eel River, and Benbow Dam, South Fork Eel River.

Factors Affecting Anadromous Salmonid Production

A main component of the program is the analyses of the freshwater factors in order to identify whether any of these factors are at a level that limits production of anadromous salmonids in North Coast basins. 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.[1] 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 a component's condition does not fit within the range of reference values, it may be viewed as a limiting factor. This information will be useful to identify underlying causes of stream habitat deficiencies and help reveal if there is a linkage to watershed processes and land use activities.

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.

In the freshwater phase in salmonid life history, adequate flow, free passage, good stream conditions, and functioning riparian areas are essential for survival. Adequate instream flow during low flow periods is essential for fish passage in the summer time, 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.

Free passage describes the absence of barriers to the free instream movement of adult and juvenile salmonids. Free movement in 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. Temporary or permanent dams, poorly constructed road crossings, landslides, debris jams, or other natural and/or man-caused channel disturbances can disrupt.

Stream condition includes several factors: adequate stream flow, suitable water quality, suitable stream temperature, and complex habitat. For successful salmonid production, stream flows should follow the natural hydrologic regime of the basin. 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

[1] 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.

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.

Habitat diversity 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, hiding areas 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. This reduces depths and can bury complex niches created by large substrate and woody debris. Riffles provide clean spawning gravels and oxygenate water as it tumbles across them. Steelhead fry use riffles during rearing. Flatwater areas often provide spatially divided pocket water units (Flosi et al. 1998) that separate individual juveniles, which helps promote reduced competition and successful foraging.

Important aspects of water quality for anadromous salmonids are water temperature, turbidity, water chemistry, and sediment load. In general, suitable water temperatures for salmonids are between 48-56°F for successful spawning and incubation, and between 50-52°F and 60-64°F, depending on species, for growth and rearing. 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. Fine suspended sediments (turbidity) 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 a juvenile salmonids' ability to feed and can lead to reduced growth rates and survival (Bill Trush, Trush & Associates; 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 the gravel into the stream at the end of incubation. High sediment loads can also cause abrasions on fish gills, which may increase susceptibility 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 downstream areas.

A functional riparian zone helps to control the amount of sunlight reaching the stream, provides vegetative litter, and contributes invertebrates to the local salmonid diet. 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 macro-invertebrates are important to the salmonid diet and are dependent upon nutrient contributions from the riparian zone. Additionally, stream bank cohesion and maintenance of undercut banks provided by riparian zones in good condition maintain diverse salmonid habitat, and help reduce bank failure and fine sediment yield to the stream. Lastly, the large woody debris provided by riparian zones shapes channel morphology, helps 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 directly to the stream and/or the basin 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 the recent decision to list many North Coast Chinook and coho salmon, and steelhead trout stocks under the Endangered Species Act.

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 the program'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 1974 (GMA 2001a) 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, 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

There is general agreement that improvements in a condition or set of conditions constitute recovery. In that context, recovery is a process. One can determine a simple rate of recovery by the degree of improvement over some time period, and from only two points in time. One can also 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.

In general, recovered fish habitat supports a suitable and stable fish population. 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 perturbations without large fluctuations in those processes and conditions. However, the endpoint of recovered for one condition or function may be on a different time and geographic scale than for another condition or function.

Some types and locations of stream recovery for salmonids can occur more readily than others can. 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).

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 Downie 2003). However, in the Big River Basin, the amount of acreage harvested has increased sharply since 1990 as timber stands mature into merchantable second-growth timber and as selection and other partial harvest silvicultural prescriptions are widely implemented.

Timber-harvesting practices have greatly 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. Cafferata and Spittler (1998) found that almost all recent landslides occurring in an area logged in the early 1970s were related to 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 1964 flood. 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 are also 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 of the contributions of these efforts to recovery has been made, there is a general consensus that many of these efforts have made important contributions.

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 (pre-1975) roads due to inadequate crossing design, construction and maintenance (BOF 1999);
- Skid trails and landings (Cafferata and Spittler 1998);
- A lack of improvements in stream habitat complexity, largely from a dearth of large woody debris for successful fish rearing;
- 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 subdivision 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 adopting grading ordinances that will help with this problem, there is a significant 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 grapes. Such agricultural activities have typically been subject to little agency review or regulation and can pose significant risk of chronic sediment, chemical, and nutrient inputs to streams.

Associated with development and increased agriculture, some north coast river systems are seeing increasing withdrawal of water, both directly from streams and 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 time frame. 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 this program, we recognize their importance for sustainable salmonid populations and acknowledge that good quality freshwater habitat alone is not adequate to ensure sustainability.

Policies, Acts, and Listings

Several federal and state statutes have significant implications for watersheds, streams, fisheries, and their management. Here, we present only a brief listing and description of some of the laws.

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 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. Section 208 deals with non-point source pollutants arising from silvicultural activities, including cumulative impacts. Section 303 deals with water bodies that are impaired to the extent that their water quality is not suitable for the beneficial uses identified for those waters. For water bodies identified as impaired, the US Environmental Protection Agency (US EPA) or its state counterpart (locally, the North Coast Regional Water Quality Control Board and the State Water Resources Control Board) must set targets for Total Maximum Daily Loads (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). An HCP is 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. Many of California’s salmon runs are listed under the ESA, including the Chinook and coho salmon found in the Big River Basin (NMFS 2001). Steelhead trout, which are also found in the Big River Basin, have been proposed for listing.

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 US EPA under the federal Clean Water Act. For example, the US EPA has delegated to the state certain authorities and responsibilities to implement TMDLs for impaired water bodies and NPDES (national pollution discharge elimination system) permits to point-source dischargers to water bodies.

Sections 1600 et seq. of the Fish and Game Code are implemented by the Department of Fish and Game. These agreements are required for any activities that alter the beds or banks of streams or lakes. A 1600 agreement 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 agreements constitute discretionary permits and thus must be accompanied by an environmental impact review per CEQA.

The **California Endangered Species Act (CESA)** (Fish & Game Code §§ 2050, *et seq.*) generally parallels the main provisions of the Federal Endangered Species Act and is administered by the California Department of Fish and Game (CDFG). Coho salmon in the Big River Basin are listed as endangered 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.

Assessment Strategy and General Methods

The NCWAP developed a Methods Manual (Bleier et al. 2003) 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.

This chapter provides brief descriptions of data collection and analysis methods used by each of the program's participating departments, and an introduction to methods for analyzing data across departments and disciplines. While the information contained in the report is extensive, more detail is included the appendices to this report:

- California Department of Forestry
- Ecological Management Decision Support
- Department of Water Resources
- North Coast Regional Water Quality Control Board
- California Department of Fish & Game

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

Basin Assessment Approach

The steps in the large-scale assessment include:

Form multi-disciplinary team. In order to assess watershed conditions and processes, several specialists were needed: geologists, fluvial geo-morphologists, foresters, water quality analysts, fisheries biologists, habitat specialists, and planners;

Conduct scoping and outreach workshops. In the Big River Basin assessment, a series of meetings with landowners and interested parties provided the team with local, historic knowledge and valuable critical discussion with which to establish the value of the information in hand;

Determine logical assessment scales. The Big River assessment team used the California Watershed Map (CalWater version 2.2.1) to delineate the Big River Basin into three subbasins (Coastal, Middle, and Inland) for assessment and analyses purposes (Figure 4);

Discover and organize existing data and information according to discipline. This information was used to form the basis of the disciplinary appendices to the assessment report;

Identify data gaps needed to develop the assessment. Working with limited time and resources constrained the amount of fieldwork that was performed. Fortunately, some data existed prior to this effort in the Big River Basin;

Collect field data. Over 79 miles of new stream data and 58 fishery surveys were performed for this assessment. Water Quality data were collected for this assessment at several locations in the basin, and additional data were provided by private and agency cooperators;

Amass and analyze information. Each agency (except California Geological Survey, which contributed limited information and maps) assembled, interpreted, and summarized data to create various specific reports for inclusion into the Assessment Report;

Construct Integrated Analysis Tables (IA). Through the use of IA Tables the information from various disciplines were compared to one another. These comparisons were used to respond to the Assessment Questions. The IA process also helped to identify watershed conditions;

Conduct limiting factors analysis (LFA). The Ecological Management Decision Support system (EMDS) was used, along with expert analysis and local input, to evaluate factors at the tributary scale. These factors were rated to be either beneficial or restrictive to the well being of fisheries. The CDFG Restoration Manual (Flosi et al. 1998), and other literature, provided habitat condition values to help set EMDS reference curves;

Conduct refugia rating analysis. The assessment team created worksheets for rating refugia at the tributary scale (page 43). The worksheets have multiple condition factors rated on a sliding scale from high to low quality. Tributary ratings are determined by combining the results of air photo analyses, EMDS, Water Quality data, data in the CDFG tributary reports, and by a multi-disciplinary team of expert analysts. Ratings of various factors are combined to determine an overall refugia rating on a scale from high to low quality. The tributary ratings are subsequently aggregated at the subbasin scale and expressed as a general estimate of subbasin refugia conditions. Factors with limited or missing data are noted and discussed in the comments section as needed. In most cases, there are data limitations on one to three factors. A discussion of the rating system is located at the end of this summary;

Develop conclusions and recommendations. Recommendation tables for watershed and stream improvement activities were developed at the tributary scale based upon stream inventory information, air photo analysis, field verification samples, workshop inputs, and other information. The recommendations are presented at the end of each Profile chapter as answers to the sixth assessment question;

Facilitate monitoring of conditions. CDFG is developing a monitoring program and will facilitate it in the Big River and other assessed watersheds.

Guiding Assessment Questions and Responses

The NCWAP assessment team developed lists of questions that they considered important to understanding and implementing watershed assessments. From those lists, a short list of guiding assessment questions evolved and was adopted to provide focus for the assessments and subsequent analyses, conclusions, and recommendations.

- What are the history and trends of the sizes, distribution, and relative health and diversity of salmonid populations within this?
- What are the current salmonid habitat conditions in this subbasin? How do these conditions compare to desired conditions?
- What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream 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 habitat improvement activities would most likely lead toward more desirable conditions in a timely, cost effective manner?

These six questions focus the assessment procedures and data gathering within the individual disciplines and also provide direction for those areas of analyses that require more interagency, interdisciplinary syntheses, including the analysis of factors limiting anadromous salmonid production. The questions systematically progress from the relative status of the salmon and steelhead resource, to the focus of the assessment effort, and lastly to the watershed components encountered directly by the fish – flow, water quality, nutrients, and instream habitat elements, including free passage at all life stages. The products delivered to streams by watershed processes and the influence of human activities on those processes shape these habitat elements. The watershed processes and human influences determine what factors might be limiting fishery production and what can be done to make improvements for the streams and fish.

The first two assessment questions point out the importance of salmonid population information for validating the assessment and predicting habitat conditions. In many watersheds, robust population data may not be available, implying a need for future monitoring efforts. In some watersheds, a need for additional physical habitat sampling may be indicated.

The third and fourth assessment questions consider the past and present conditions of the watersheds and their natural and man-caused watershed processes. The answers to these questions provide us with insights into the future of assessed watersheds and streams, and the feasibility of different management techniques for salmon and steelhead in each watershed.

The last two assessment questions consider factors directly encountered by fish that could be limiting salmonid production. These questions seek to identify opportunities and locations for prudent management practices and pro-active salmonid habitat improvement activities.

These six guiding assessment questions are presented and answered in the overall basin section and in each of the subbasin sections of the assessment report. They are also considered in the DFG Refugia Rating process at the subbasin and tributary scales. The responses become more specific as the assessment focuses from the course to the finer scales.

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. Therefore, findings and recommendations also vary in specificity from being particular at the finer scales, and general at the basin scale.

A goal of this program is to help guide, and therefore accelerate the recovery process, by focusing stewardship and improvement activities where they will be most effective. Scaling down through finer levels guided by the recommendations should help accomplish this focus.

To do so, the report is constructed to help provide guidance for that focus of effort. A user can scale down from the general basin finding and recommendation concerning high sediment levels, for example, to the subbasin sections, to the stream reach level information to determine which streams in the subbasin may be most affected by sediment.

There is a list of surveyed streams in each subbasin section. In the general recommendation section, a tributary finding and recommendation summary table indicates the findings and recommendations for the surveyed streams within the subbasin. If indicated, field investigations at the stream reach or project site level can be conducted to make an informed decision on a land use project, or to design improvement activities.

Program Products

The program will produce and make available to the public a set of products for each basin assessed.

These products include:

- A basin level Synthesis Report that includes:
    - Collection of Big River Basin historical and sociological information;
    - Description of historic and current vegetation cover and change, land use, geology, and water quality, stream flow, water use, and instream habitat conditions;
    - List of issues developed by agency team members and constituents;
    - An interdisciplinary analysis of the suitability of stream reaches and the watershed for salmonid production and refugia areas;
    - Tributary and watershed recommendations for management, refugia protection, and restoration activities to address limiting factors and improve conditions for salmonid productivity;
    - Monitoring recommendations to improve the adaptive management efforts.
- 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://coastalwatersheds.ca.gov/, and http://imaps.dfg.ca.gov/, and ArcIMS site.

Assessment Report Conventions

Subbasins

In order to be more specific and useful to planners, managers, and landowners, it is useful to subdivide the larger Big River Basin into smaller subbasin units whose size is determined by the commonality of many distinguishing traits. Variation among subbasins is at least partially a product of natural and human disturbances. Other variables that can distinguish areas, or subbasins, in larger basins include differences in elevation, geology, soil types, aspect, climate, vegetation, fauna, human population, land use and other social-economic considerations.

The Big River assessment team subdivided the Big River Basin into three subbasins for assessment and analyses purposes (Figure 4). These are the Coastal, Middle, and Inland subbasins. In general, these subbasins have distinguishing attributes common to the CalWater 2.2.1 Planning Watersheds (PWs) contained within them.

CalWater 2.2.1 Planning Watersheds

The California Watershed Map (CalWater Version 2.2.1) is used to delineate planning watershed units (Figure 4). This hierarchy of watershed designations consists of six levels of increasing specificity: Hydrologic Region, Hydrologic Unit, Hydrologic Area, Hydrologic Sub-Area, Super Planning Watershed, and Planning Watershed (PW). 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 State Water Resources Control Board Basin Plan Maps drawn in the late 1970s.

The PW level of specificity is used in many analyses. PWs generally range from 3,000-10,000 acres in size and each PW consists of a specific watershed polygon, which is assigned a single unique code. The program used PWs for mapping, reporting, EMDS, and statistical analysis of geology, vegetation, land use, and fluvial geomorphology.

An important aspect of CalWater 2.2a PWs is that individual PWs often do not represent true watersheds. In other words, PWs often cut across streams and ridgelines and do not cover the true catchment of a stream or stream system. Streams, such as the mainstem Big River, can flow through multiple PWs. In addition, a stream may serve as a border between two CalWater 2.2a PWs. This disconnect with hydrologic stream drainage systems is an artifact of the creation of CalWater 2.2.1 as a tool for managing forest lands in fairly consistent sized units.

Figure 4. Big River subbasins and CalWater 2.2.1 planning watersheds.

Hydrology Hierarchy

Watershed terminology often becomes confusing when discussing different scales of watersheds involved in planning and assessment activities. The conventions used in the Big River Basin assessment follow guidelines established by the Pacific Rivers Council. The descending order of scale is from *basin* level (e.g., Big River Basin) – *subbasin* level (e.g., Coastal Subbasin) – *watershed* level (e.g., Little North Fork Big River) – *sub-watershed* level (e.g., Berry Gulch) (Figure 5).

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 at the finer scales to subbasin findings and recommendations. Thus, findings and recommendations at the subbasin level are somewhat more generalized than at the watershed and sub-watershed scales. 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 - 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.

Another important watershed term is river mile (RM). River mile refers to a point that is a specific number of miles upstream from the mouth of a river. In this report, RM is used to locate points along the Big River Basin.

Electronic Data Conventions

The program collected or created hundreds 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 four remaining 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 the program and base information disseminated to the public through the program would be in the following format (see the data catalog at the end of this report for a complete description of data sources and scale):

Data form: standard database format usually associated with a Geographic Information System (GIS) shapefile or coverage (Environmental System Research Institute, Inc. © [ESRI]). 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 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 1:24,000 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]).

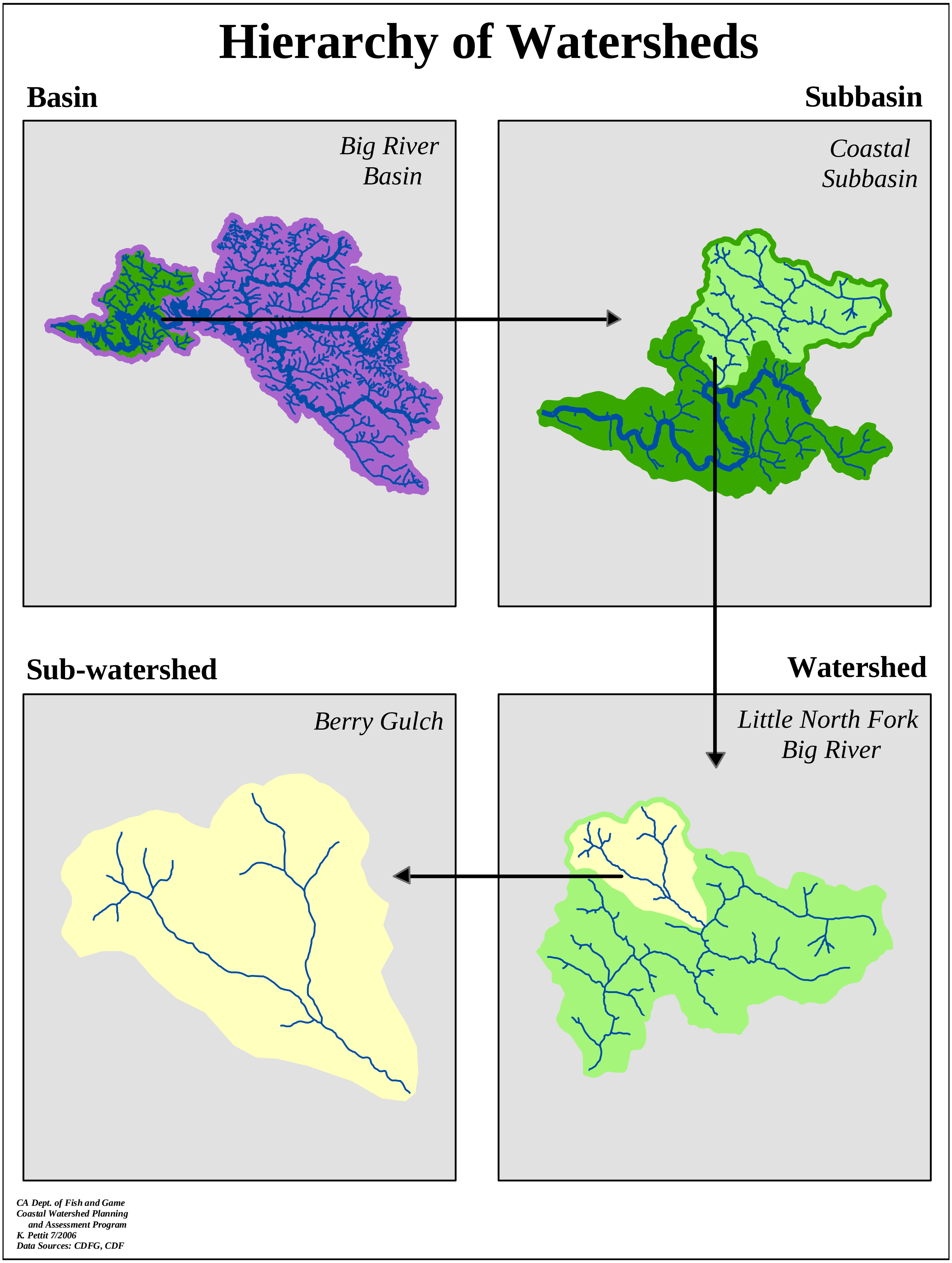


Figure 5. Hydrography hierarchy.

Data Sources: data were obtained from a variety of sources including spatial data libraries with partner departments or were created by manually digitizing from 1:24,000 DRG.

The metadata available for each spatial data set contain a complete description of how data were collected and attributed for use in the program. Spatial data sets that formed the foundation of most analysis included the 1:24,000 hydrography and the 10-meter scale Digital Elevation Models (DEM). Hydrography data were created by manually digitizing from a series of 1:24,000 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 study 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.

Methods by Department

Geology and Fluvial Geomorphology

A geologic map was compiled from numerous sources including published maps and reports, unpublished mapping by CGS, United States Geological Survey, California Department of Forestry, aerial photographic mapping, and field reconnaissance geologic mapping. Geologic features were compiled through the previous work of Durham, 1979, Kilbourne, et al, 1982, 1983, and 1984, and Short and Spittler, 2002, stereoscopic evaluation of aerial photos, and limited geologic and geomorphic reconnaissance mapping. Aerial photographs and compilation of existing data represent the primary information sources for this product.

Three sets of aerial photographs (1947, 1984, and 2000) were stereoscopically evaluated for geomorphic features related to landsliding in the watershed. All photos were black and white, with scales ranging from 1:12,000 to 1:36,000. Fluvial geomorphic features were evaluated using two sets of aerial photos (1984, 2000). Geomorphic features were digitized using ArcView GIS. Limited field assessment was completed of the landslide features mapped. The information was then incorporated into a GIS, with associated data attributes compiled into a spatial database with metadata.

The scale of the geologic map for this watershed limits the delineation of some features, and the map should not be substituted for site-specific studies. Information on the geologic map is not sufficient to serve as a substitute for the geologic and geotechnical site investigations required under Chapters 7.5 and 7.8 of Division 2 of the California Public Resources Code.

Landslides and geomorphic features were mapped from historical aerial photographs (see map references) as follows: 1947 (CDF), 1984 (WAC), 2000 (WAC). Field verification of landslide and geomorphic features was very limited and mapping relied primarily on interpretation of aerial photographs.

Fluvial geomorphic features were mapped from aerial photographs flown in April of 1984 and April of 2000 (WAC Corporation, see map references). Features were not verified in the field.

The bedrock geology depicted on the geologic map was modified from 1:24,000 and 1:62,500-scale non-digital source data (see “Index to Geologic and Geomorphic Mapping References” and References). Although the geologic information has been represented on this map at a scale of 1:24,000, the detail and accuracy of the bedrock and structural data are limited by the spatial resolution of the original source maps.

Landslides shown on the geologic map have been divided into groups based on the clarity of their morphology and inferred type of movement. The landslides are also classified according to the certainty of their existence as determined by analysis of aerial photographs. The various landslide designations are not intended to imply, nor should they be interpreted to imply, the relative stability of slopes involved.

Previous mapping by CGS was reviewed and incorporated using current interpretive protocols for identifying and classifying geomorphic features and/or landslides. Previous map data that were added directly to the Big River Watershed database are referred to in that electronic database with an appropriate citation.

Landslide features locally overlap stream-channel deposits, labeled Qsc2 thru 4. However, landslides do not generally overlie stream-channel deposits. This is a misleading relationship caused by GIS compilation and it has minimal geological significance at the coarse scale of this assessment.

Digital landslide and fluvial geomorphology data are available from the following sources: on the CGS website at www.conservation.ca.gov/cgs, on compact disc from CGS, or on the North Coast Watershed Assessment Program website at http://coastalwatersheds.ca.gov/.

In addition to the study conducted by CGS, geological information for the Big River Basin was obtained from Graham Matthews and Associates' (GMA) Sediment Source Analysis (2001), the Big River Total Maximum Daily Load (EPA 2001), CGSs Engineering Geologic Resource Assessment for the Big River State Park (2004), and the Mendocino Redwood Company's (MRC) Watershed Analysis for their ownership in the Big River Basin.

Hydrology

Data Collection

Only two stream flow gaging stations have operated within the Big River Basin. One gage, South Fork Big River near Comptche (USGS station #11468070), has continuous historical flow records. This gage is located on the South Fork Big River at Orr Springs Road, downstream of the confluence of the South Fork Big River and Daugherty Creek. The gage measures streamflow from 36.14 square miles. It is expected that unit peak discharges (cubic feet per second/square mile) for the entire watershed would be lower than from those recorded at the gaging site because of generally lower rainfall in the lower basin (GMA 2001a). The South Fork gage has continuous records from October 1, 1960 through September 30, 1971, and was reinstalled February 2001 at the same site.

A second gage was installed in May 2001 on the Big River below the confluence with Two Log Creek, near Comptche. Data from these two gages were obtained from the USGS website.

GMA (2001) extended this short streamflow record using a correlation process with the longer record of data available from the adjacent Noyo River Basin. GMA also operated several monitoring stations from November 2000 through April 2001 to gather additional stream flow information.

Mean Discharge

USGS discharge records were used to construct tables and graphs of mean monthly flows; mean, maximum, and minimum daily flows; annual yield or runoff volume in acre-feet; and daily flow duration.

The USGS publishes mean daily discharge records for each of its gages on an annual basis. These values are typically used to construct annual streamflow hydrographs and perform flow duration analyses. Due to the extremely short period of record for the South Fork Big River (eleven years), GMA (2001) used modeling to extend or create a mean daily discharge record for each Big River subbasin and the entire Big River Basin. GMA scaled mean daily discharge measurements from the Noyo Watershed using watershed area and mean annual precipitation as the scaling factors.

Flow Duration and Annual Runoff

GMA (2001) performed a flow duration analysis using a combination of historic data from the USGS gage on the South Fork Big River and synthetic mean daily discharge data calculated as described above. They also calculated annual runoff for the South Fork Subbasin using the USGS streamflow gage records for the period of record and computed from the synthetic data generated for the rest of the basin.

Peak Discharge

USGS peak discharge records are available for eleven years, 1961-1971, and 1974. In addition, synthetic peak discharges for the South Fork Big River were developed by GMA (2001) using peak correlation analysis between the Noyo River and the Big River basins in order to extend the record. GMA estimated peak discharges back to 1952 and forward to 1999, based on the record available from the Noyo River. In addition, GMA measured peak discharge for Water Year 2001 at the South Fork Big River USGS gage during streamflow data collection. GMA also estimated peak discharges for the Big River Basin based on a correlation with the Noyo record adjusted by drainage area and mean annual precipitation ratios.

Flood Frequency

Flood frequency analysis is a method used to predict the magnitude of a flood that would be expected to occur, on average, in a given number of years (recurrence interval) or have a specific probability of occurrence in any one year (a 100-year flood has a 1% chance of occurring in any given year, for example).

A frequency analysis for annual peak and low-flow was completed using the techniques from the USGS Bulletin number 17B, Techniques of Water-Resources Investigation of the USGS (HSIACWD 1981) and Ven Te Chow's Handbook of Hydrology (1964). The data used for the peak flow frequency were the annual instantaneous values. For this analysis the Gringorten plotting position equation was used, as it tended to give better results when using the normal distribution.

The low flow frequency analysis is similar to the peak-flow analysis except that the discharge values were found by calculating the minimum seven-day running average of the mean daily flows for each water year. These values were then used to complete the frequency analysis described above.

Water Rights

A search of the State Water Resources Control Board Water Right Information System (WRIMS) was performed to determine the number and types of water rights within the Big 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."

Vegetation and Land Use

Vegetation

Analysis of the tree size and density was accomplished utilizing CDFs CALVEG 2000 data. Because crown diameter and tree diameter are highly correlated, measuring the tree crowns can make estimates of tree size. Tree size values within the Big River represent the average visible crown diameter bases on the following information outlined in Table 1. The tree size classification is rated on a scale of one to five based on the crown diameter and cross-walked to a tree diameter size. Canopy density is a percent scale reflecting the percent of canopy closure detected within a stand.

Table 1. Comparison chart of the tree size classes.

Size Class	Class Name	Breast Height Tree Diameter (inches)	Conifer Crown Diameter Class	Hardwood Crown Diameter Class
N	Non-stocked	---	---	---
0	Seedlings	---	Derived From Plantation Age	---
1	Saplings	< 6 inches	Derived From Plantation Age	< 15 feet
2	Poles	6 to 11 inches	< 12 feet	15 to 30 feet
3	Small	12 to 24 inches	12 to 24 feet	30 to 45 feet
4	Medium	24 to 40 inches	24 to 40 feet	> 45 feet
5	Large	> 40 inches	> 40 feet	---

Note: Breast height tree diameter classes derived from crosswalk to WHR vegetation size classes.

Fire and Fuels

CDFG personnel analyzed CDF fire data available from the CDF Fire and Resource Assessment Program (FRAP). A statewide GIS layer of large fire history, 300-acre minimum for CDF fires since 1950 and 10-acre minimum for USFS fires since 1910, and a statewide GIS layer of fire threat, combining expected fire frequency with potential fire behavior to create four threat classes were used.

Population

CDFG analyzed year 2000 census data to provide population estimates for each Big River subbasin. The 2000 data were available from FRAP. The Census Bureau statistics are organized at several levels including: State, County, Census County Division (CCD), Census Tract, Block Group, and Block. The Big River Basin straddles the Mendocino-Anderson, Willits, Redwood-Potter, and Fort Bragg CCDs. Additionally, the basin contains sections of six census tracts (010300, 010600, 010900, 011000, 011200, and 011300). Census Tracts are made up of blocks. Block population totals were compiled to determine the estimated population of each Big River subbasin. Blocks that crossed the Big River Basin boundary or subbasin boundaries were examined more closely and population values were allocated by estimated fraction of area.

Land Use

Land use was delineated by placing transparent plastic sleeves directly over the photos and classifying land use change while viewing through a stereoscope. Categories that were delineated were fire, timber harvest, pasture, irrigated crops, orchard, buildings, and urban. Since this is a land use change classification, not all grassland or timberland was delineated or typed. While the full extent of many areas burned by fire could not be estimated, if the fire created a change in vegetation, it was recorded. For example, in 1937 aerial photographs the area of the 1931 Comptche wildfire was evident by the amount of grassy understory, open canopies, and areas of brush. The area of the wildfire itself was derived from an existing electronic database but portions of the burned area were recorded as a permanent conversion, usually subjectively determined by evidence of continued burning, proximity to existing grasslands, barns or other buildings, and roads.

Timber harvest activity was broken into silviculture and logging system categories using the closest approximation to the standard definitions. There is no way of knowing from air photos whether the trees removed were old- growth stands that were present prior to European-American settlement or if these were trees that had grown in due to changes in land-use practices between 1860 and 1937. In some instances, trees had been removed or killed and the closest silvicultural category was used. In many of the earliest photographs, there were no roads or skid trails visible and no logging system was recorded.

Minimum acreage mapped varied by land use classification. Crops and orchards were mapped when seen. It was assumed that fenced grassland was grazed. Silvicultural treatments were difficult to categorize. The large proportion of hardwood and brush was very apparent because there was often a lot of vegetative cover remaining after a harvest that removed most of the conifer. The resultant silviculture was highly variable in many instances. Seed tree removal step was delineated as the silvicultural system used when it appeared that the dominant conifer cover was removed, but considerable hardwood and/or brush remained. When the excluded areas were large relative to the adjacent harvested areas, they were also excluded from the harvest land use polygon.

Disturbance categories were broadly grouped into low, medium and high. Disturbance was based on potential sediment delivery to watercourses. High intensity fire areas, cultivated land and grazed areas immediately adjacent to streams or on steep slopes, and virtually all tractor logging during this time period were classified as high disturbance potential areas. Slides were not mapped although sometimes included as a comment.

The information from the Mylar sleeves was input as polygon features into the ArcView GIS system by onscreen or "heads-up" digitizing using 1993 black and white orthographic quadrangles as the background. Distortion was corrected by using watercourses, ridges, and roads as reference indicators. The scale distortion apparent in the aerial photographs compared to the orthoquads during the heads-up digitizing was manually corrected by changing the scale of the orthoquad to match the area near the polygon to provide the best fit.

These data are similar to other aerial photograph interpretations of various types of land use. The aerial photos used appeared to be of the same age as the flight date. Many were faded and had hand-drawn line work on them from past projects. When using the data, it is important to note that timber harvesting is often used as a surrogate for a change in vegetation type, size, or density. In a general sense, this is true, but early harvesting did not follow the classic silvicultural methodology and even-aged harvests in particular varied widely in the application on the ground. Disturbance was based on potential sediment delivery to watercourses and was evaluated on the project level.

CDF Northern Region Forest Practice GIS Timber Harvesting Plan Data

Spatial timber harvesting plan data are digitized into the GIS at a scale of 1:12,000 or better using the onscreen or "heads-up" digitizing method. Digital USGS 1:24,000 topographic quadrangles and USGS 1:24,000 DLGs (Digital Line Graphs) serve as base data layer. Timber harvesting plan data (THP) are derived from THP maps, amendments, and completion reports contained in the THP of record on file with the California of Forestry and Fire Protection in Santa Rosa, California. The USGS 1:24,000 DLG data are augmented with features derived from the THP of record.

The State of California and the Department of Forestry and Fire Protection make no representations or warranties regarding the accuracy of data or maps. Neither the State nor the Department shall be liable under any circumstances for any direct, special, incidental, or consequential damages with respect to any claim by any user or third party on account of or arising from the use of data or maps.

These records are not fitted to aerial photographs or digital ortho-photo quads and may not be precise in location, but timber harvesting plan boundaries appeared to fit pretty well when qualitatively viewed with 1993 digital ortho photo quads and 2000 aerial photographs. As mentioned previously, one should be cautious about using silviculture as a surrogate for vegetative cover descriptions; some of the rehabilitation and seed tree removal step prescriptions were almost indistinguishable from the pre-harvest condition when viewing aerial photographs. The files are organized by the date of THP submittal. The time between plan submittal and actual harvest varies, often by several years. This time delay occurs for a variety of reasons including long THP review periods for controversial plans, litigation, and landowner attempts to harvest when the market is most favorable. In addition, Non-industrial Timber Management Plans (NTMPs) are only included in the database when a Notice of Operations is filed. The current policy is to digitize all newly submitted NTMPs as they arrive and to retroactively digitize older NTMPs as resources allow.

Roads

Roads data for the Big River Basin are from a compendium of sources compiled by Graham Matthews and Associates (GMA) for the Total Maximum Daily Load (TMDL) report for Environmental Protection Agency (EPA). It includes digitized data based on United States Geologic Survey (USGS) 7.5 minute quadrangle maps, upgraded and added to by CDF Santa Rosa GIS using Timber Harvest Plan (THP) documents, integrated with Mendocino Redwood Company data and finally roads were added based on aerial photos by GMA.

Stream Buffer Vegetation

Stream buffers were established on Class I / Perennial streams at 150 feet from the bank of the watercourse on both sides and 75 feet for Class II / Intermittent streams. Data used for analysis are the USGS 1:24,000 hydrography GIS data layer, upgraded with in field watercourse designation from THPs digitized by CDF Santa Rosa GIS.

Disturbance

Activities and methods are presented here in the form of a relative combined factor as a form of analysis called the Disturbance Level. For the Big River, this includes wildland fires, timber harvesting, and permanent conversions of forest land to other uses such as development and agriculture. Disturbance level is a relative ranking of the inferred overall effect on the landscape due to activities and the method of activity since 1852 when timber harvesting in the Big River began, with a primary focus on the potential for sediment production and transport. It is based on disturbed ground as interpreted from aerial photos and qualitative field checking with consideration for:

- Density of skid roads or overall amount of exposed soil area;
- Skid road proximity to watercourses;
- Direction of yarding-cable: downhill vs. uphill and skidding down to and into watercourses;
- Era/method—stream yarder worst, then tractor pre 1973, tractor post 1973, skyline yarder, and helicopter least impactive;
- Size of equipment and logs yarded which have a direct impact on the amount of soil displaced; these have become progressively smaller and lighter;

- Crown canopy reduction;
- Forest Practice Rules as they apply to logging practices, i.e. skid road, waterbar and crossing construction, standard improvement over time.

Each area of activity was rated low, moderate, or high. Low is minimal ground disturbance such as a commercial thinning logged by yarder, uphill, with full suspension, in later years. A high rating is the most impactive and is typified by an area that was clearcut prior to 1972 by tractor or groundlead cable, no waterbars installed, large logs harvested often downhill with no regard for watercourse protections. Moderate is in between.

Water Quality

Water Quality Criteria

The criteria used for the assessment of the Big River Basin are a compilation of criteria from the Basin Plan, the Big River TMDL, EMDS, and other literature sources discussed in more detail in the Water Quality Appendix (Table 2). Therefore, the water quality assessment discusses the state of the watershed according to comparisons of the appropriate water quality objective or target as noted in the following table. With the exception of the Basin Plan objectives, these ranges and thresholds are not enforceable. Rather, they are criteria based on information available at the time of this assessment and may change as new data, analyses, and research becomes available.

It is worth noting that the criteria for fine sediment are based on wet sieve (percent by volume) determinations. In some cases, stream substrate cores are dry sieved, resulting in a percent by weight determination. The percent of fine sediment arrived at by wet sieving and dry sieving are sufficiently different so that the dry sieve results are not directly comparable to the target values. In those instances where the percent fine sediment was arrived at through dry sieving, it is explicitly noted.

Table 2. Criteria used in the assessment of water quality data

<table>
<tr><th>Water Quality Parameter</th><th colspan="2">Range or Threshold</th><th>Reference</th></tr>
<tr><th colspan="4">Water Column Chemistry</th></tr>
<tr><td>pH</td><td colspan="2">6.5 - 8.5</td><td>Basin Plan, Table 3-1, p 3-7.00</td></tr>
<tr><td>Dissolved Oxygen</td><td colspan="2">7.0 mg/L</td><td>Basin Plan, Table 3-1, p 3-7.00</td></tr>
<tr><td rowspan="2">Specific Conductance</td><td colspan="2">< 90% of upper limit at 300 micromhos</td><td>Basin Plan, Table 3-1, p 3-7.00</td></tr>
<tr><td colspan="2">< 50% of upper limit at 195 micromhos</td><td>Basin Plan, Table 3-1, p 3-7.00</td></tr>
<tr><td>Nutrients
(Biostimulatory Substances)</td><td colspan="2">No increase in concentrations that promote growths and cause nuisance or adversely affect beneficial uses</td><td>Basin Plan, p 3-3.00</td></tr>
<tr><td>General Inorganic & Organic Compounds</td><td colspan="2">Various numeric and narrative Basin Plan objectives.</td><td>Basin Plan, Table 3-2
Various numeric criteria to implement Basin Plan narrative objectives as found in Marshack (2000). The numeric criteria used are also described in the Water Column Chemistry section beginning on page 28.</td></tr>
<tr><th colspan="4">Temperature</th></tr>
<tr><td rowspan="13">Water Temperature</td><td colspan="2">No alteration that affects BUs1</td><td>Basin Plan, p 3-3.00</td></tr>
<tr><td colspan="2">No increase above natural > 5°F</td><td>Basin Plan, p 3-4.00</td></tr>
<tr><th>MWAT[2] Range</th><th>Description</th><td rowspan="8">EMDS[3]</td></tr>
<tr><td>50-60°F</td><td>Fully Suitable</td></tr>
<tr><td>61-62°F</td><td>Moderately Suitable</td></tr>
<tr><td>63°F</td><td>Somewhat Suitable</td></tr>
<tr><td>64°F</td><td>Undetermined</td></tr>
<tr><td>65°F</td><td>Somewhat Unsuitable</td></tr>
<tr><td>66-67°F</td><td>Moderately Unsuitable</td></tr>
<tr><td>≥ 68°F</td><td>Fully Unsuitable</td></tr>
<tr><th>Daily Maximum</th><th>Description</th><td rowspan="2">Cold water fish rearing, RWQCB (2000), p. 37</td></tr>
<tr><td>75°F</td><td>Lethal</td></tr>
<tr><th colspan="4">SEDIMENT</th></tr>
<tr><td>Settleable Material</td><td colspan="2">Cannot cause nuisance or adversely affect BUs[1]</td><td>Basin Plan, p 3-2.00</td></tr>
<tr><td>Suspended Material/Load</td><td colspan="2">Cannot cause nuisance or adversely affect BUs[1]</td><td>Basin Plan, p 3-2.00, 3-3.00</td></tr>
<tr><td>Turbidity</td><td colspan="2">No more than 20 percent increase above natural occurring background levels</td><td>Basin Plan, p 3-3.00</td></tr>
<tr><td>V* in 3rd order streams with</td><td colspan="2">≤0.21 (mean)</td><td>Big River TMDL, US EPA (2001)</td></tr>
</table>

Water Quality Parameter	Range or Threshold	Reference
slopes 1-4 %	<0.45 (max)	Knopp (1993)
Median particle size (D50) in 3rd order streams of slopes 1-4 %	69 mm mean (for index yes/no streams) 38 mm mean (for highly disturbed streams)	Knopp (1993)
Percent fines <0.85 mm	<14% in fish-bearing streams[4] ≤10% - fully suitable	Big River TMDL, US EPA (2001)
Percent fines <6.4 mm	<30% in fish-bearing streams[4] ≤15% - fully suitable	Big River TMDL, US EPA (2001)

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. These ranges and thresholds were derived from the literature and agreed upon by a panel of NCWAP experts.
4 Fish-bearing streams are streams with cold water fish species

Data Analysis Methods

All of the available data were compiled into electronic formats appropriate for the information, such as spreadsheets, databases, etc. The exact method of data analysis is specific to the data type and its quality. However, in general, during the analysis of the water quality data, data were evaluated for exceedences of the criteria established in Table 2 and other patterns or abnormalities in the data. Based on this analysis and the quality of the data, broader hypotheses about potential causes for the exceedences, patterns, or abnormalities were developed. Often, these hypotheses concerned factors that the other NCWAP partners were assessing. Therefore, as the synthesis of the data from each of the NCWAP agencies proceeded, the water quality data were evaluated in the context of influencing factors such as canopy for temperature and land use and/or erosional features/fluvial geomorphology for sediment. These larger scope multi-media evaluations are presented in the synthesis report. Thus, the synthesis report is an interdisciplinary effort to recognize and hypothesize about the linkages, and understanding the data in a broader context.

To the extent possible, all monitoring sites are referenced using the contributors identification number prefaced by the contributors acronym. For example, MRC provided a water temperature data for a site that MRC refers to as “74-1.” In this assessment, that site is referenced as “MRC 74-1.” If no site identifier is provided by the data contributor, a unique identifier was created and assigned to the monitoring location. In those instances where a numbering sequence already exists, that numbering sequence was continued.

Channel Measurements & Sediment Sources

For sediment parameters, we used data available for pebble counts, bulk sediment sampling, suspended sediment sampling, and turbidity sampling. We also utilized values in the preliminary sediment budget for the Big River (GMA 2001a) to estimate the upslope contribution of sediment. This enabled us to draw some correlation with in-channel sediment conditions and upslope activities.

The primary metrics used to analyze percent of fine material in core samples was percent less than 0.85 mm and percent less than 6.5 mm as shown in Table 2. The thresholds are maximas of 14% and 30% by volume, respectively (US EPA 2001). We applied the TMDL targets where data were available in the appropriate size classes or where other size classes could be reasonably evaluated. For example, the target for fines less than 6.5 mm states that the fraction of this size class in the total sample of streambed material is less than 30% by volume. If the percentage of fines less than 4 mm was measured as 50%, then the target for the 6.5-mm size class was exceeded.

The data used for this analysis came primarily from bulk sediment sampling done by MRC, HTC, and GMA. Typically, after collecting a substrate core, it is “wet sieved” in the field to separate the material into its various size fractions. While the dry sieve technique can be more accurate, wet sieving avoids the need to carry out what is sometimes hundreds of pounds of wet gravel for the dry sieve technique. Therefore, wet sieving has become common practice when analyzing core samples in the field.

When using the wet sieve technique, the material retained on each of the sieves is measured volumetrically. This allows for the “percent less than values” to be calculated on a volumetric basis by using the volume retained on the sieve divided by the total volume of material sieved. With smaller size fractions, there can be significant error using the wet sieve method due to the amount of water retained by the particles (Shirazi, Seim, and Lewis, 1979). Therefore, for size fractions less than 4 mm, it is preferable to drain the material in the field or to collect a sample to determine density at a later date.

In the Big River Basin, streambed bulk sediment sampling occurred at 15 sites. In some cases, the same site was sampled by both MRC and GMA. However, the MRC and GMA sediment cores from 13 sites were dry sieved and the HTC sediment cores from two sites were wet sieved. Because the TMDL target values were developed based on research using the wet sieved technique, we were not able to compare the MRC and GMA data to the TMDL target values. Even the MRC and GMA values could not be directly compared to each other because the GMA values did not include the surface material. As a result, GMA bulk sediment data are not directly comparable to the MRC data, neither of which are comparable to the TMDL targets. In an attempt to describe the difference that removing the surface particles had on the size distribution, complete bulk sediment data sets for the Albion River were reviewed (GMA 2001b). One would expect that removing the surface armoring layer would remove the larger rocks from the size distribution, substantially reducing the total sample volume and thus increasing the relative percentages in each of the smaller size classes. However, there was no apparent pattern to indicate how the removal of the surface material shifted the percentages in the size distribution.

The HTC percent fine sediment values, because they were calculated using the wet sieve technique, were directly comparable to the TMDL targets for fine sediment in the sub 6.5 mm and 0.85 mm size classes. All of the data provided for this assessment were already reduced into the percent finer classes.

With streambed substrate samples, it is important to keep in mind that conditions in a riffle may vary considerably and large sample sizes are needed to describe the conditions for salmonids. Nevertheless, streambed substrate samples can provide a perspective on the composition and dynamics of the streambed and add validity to other observations such as the embeddedness and dominant particle size data from habitat surveys done by CDFG.

As discussed in the Water Quality Criteria section, other common techniques for measuring substrate particle size in streambeds include pebble counts and D50's. Unfortunately, there was no raw pebble count data and only one D50 data point calculated by Knopp (1993) in Berry Gulch and one D50 data point calculated by MRC at each of the stream cross-sections measured in 2000. In any case, because there is no D50 target or objective for the Big River and the D50 values for each site were only collected during one year, these values are only reported and not evaluated for salmonid suitability.

To be able to directly compare sediment input conditions from upslope activities, subbasins were compared against one another using the calculated relative disturbance index and sediment input values by activity. Generally, the estimated sediment input values were converted to tons/mi^2/yr to eliminate the factors of watershed size and the number of years in the discrete time period analyzed. This enabled direct comparisons across time periods and between different planning and superplanning watersheds, regardless of size.

For the analysis, the 1989-2000 time period was evaluated to determine the current source(s) of sediment. The sediment input values for this time period were further broken down into specific activities that contributed to the discharge to develop focused restoration and/or activity modification recommendations. If the subbasin being analyzed also had in-channel sediment data (e.g. bulk sediment data, pebble counts, etc.), the estimated sediment inputs were evaluated next to the in-channel sediment conditions in an attempt to draw associations.

It should be noted that in the preliminary sediment budget for the Big River (GMA 2001a), estimated background levels of sediment input were not reported by planning watershed. However, it was estimated over the entire watershed using several short discrete time periods within the overall study period (1921-2000). The long term background sediment input rate was estimated to be 315 tons/mi^2/yr, which consists of background landslides, surface erosion, and fluvial and bank erosion. It was further estimated that 175 tons/mi^2/yr of the total represents background landslides, 75 tons/mi^2/yr represents background surface erosion (soil creep), and 65 tons/mi^2/yr represents background fluvial and bank erosion. However, to discuss background sediment inputs over shorter time periods, these estimated values were adjusted with a factor that represented the hydrologic conditions of the shorter discrete time period. For example, during the 1989-2000 time period, the hydrologic conditions were such that a factor of 0.91 was applied to the input rates, yielding an adjusted background rate of 286 tons/mi^2/yr, an adjusted landslide rate of 159 tons/mi^2/yr, an adjusted soil creep rate of 68 tons/mi^2/yr, and an adjusted fluvial rate of 59 tons/mi^2/yr.

Finally, landslides picked up in the aerial photo analysis were assigned a mean thickness of 5.5 feet if road-related, and a mean thickness of 4.0 feet if non-road related. These values were based on field verified slides from an Albion River watershed analysis conducted by MRC (GMA 2001a). Earthflows were assigned a thickness of 10 feet, while rotation/translation slides were assigned a thickness of 25 feet. The resulting volumes were then converted to tons using a factor of 1.48 tons/yd^3 (GMA 2001a). In addition, the 1936 aerial photographs were not available for the eastern portion of the watershed (Upper Big River, North Fork Big River, and South Fork Big River). Therefore, the 1921-1936 time period was not available for analysis in these subbasins.

Water Temperature

Water temperature data were typically collected through one of two techniques: grab measurements with a thermometer or continuous measurement with a data logger. Most of the grab measurements taken in the Big River Basin were done by CDFG at every tenth habitat unit during stream surveys. However, for the purpose of evaluating the water temperature for suitability for anadromous fish, these data were not used. This is primarily because these measurements only represent a single point in time and are not useful for drawing any larger conclusions about the stream condition with respect to water temperature.

Continuous water temperature measurements were conducted by large landowners or government agencies. For this assessment, continuous water temperature measurements were available for various years and locations from 1990 to 2001. Because high water temperature can be a limiting factor with respect to cold water fisheries, summer data were evaluated to capture the highest temperatures during the year. No temperature data were available for other times of the year, as it was assumed that water temperatures during non-summer months are not limiting for salmonids.

Prior to using the data, raw temperature charts were created for each data set and checked for abnormalities as shown in Table 3, and to trim out any erroneous data at the beginning or end of the data sets where the data loggers were exposed to air. In no cases were the data trimmed or modified other than at either end of the data set.

Table 3. Continuous water temperature data review steps.

Review steps	Purpose
Plot raw data	Check data set for obvious abnormalities such as exposure to air. Check data irregularities against the same time period at other monitoring sites to determine if caused by climatological conditions.
Check data set for interruptions in the recording period.	Check if logger was removed from the water or stopped data collection, and if it would affect the quality of the summary data.
Record number of times that temperature exceeds 4°F (2.2°C) between measurements. Record the maximum of these fluctuations.	Check data for abnormalities such as exposure to air, stream withdrawals/discharges, and data logger errors. The value 4°F was arbitrarily chosen as a screening number because it is an unusually large change in water temperature between measurements, which are typically 96 to 144 minutes apart.
Record the number of measurements that did not change between consecutive readings.	Check for data logger errors, dead or dying batteries, thermally stratified or groundwater dominate pools.
Record the seasonal maximum temperature for each data set. Any data sets that recorded temperatures in excess of 70°F were reviewed in closer detail.	Check data for exposure to air, or other abnormal conditions. Any exceedences of the lethal limit (75°F) were also recorded.
Check period of record and raw data plot for time of peak temperature.	If the raw data plot indicated that the peak temperature may have been missed, the data are generally not used as it would not be representative or comparable to other years or sites.
Record maximum diurnal fluctuation.	Assist in understanding of flow/shading conditions and check for exposure to air.

Analysis of data quality involved plotting all of the raw temperature files and verifying that the warmest part of the year was captured with reasonable certainty. The raw data plots are also useful in that they clearly show how the temperature changes at a specific site, which can lead one to hypothesize about flow and shading conditions. In some cases, particularly where a temperature monitor was placed in a short stream or gulch, the raw temperature plots can clearly show an atypical flat data record. Assuming that the data logger is operating properly, a flat data record suggests that the data logger may be recording a predominately groundwater flow regime with little or no surface flow, or a thermally stratified pool. This situation can occur when the data logger is placed in what becomes a partially or entirely isolated pool, or placed in a deep pool that is thermally stratified. The fact that this behavior was seen primarily in short streams or gulches, it is speculated that the former is true. In any case, if the data logger still appeared to respond to area wide temperature changes (as seen in other nearby sites), or if there were multiple years of data at a flat site to confirm the characteristics of the site, it was assumed that the data logger was recording representative stream conditions and was therefore used in this assessment.

Across all of the available water temperature monitoring sites in the Big River Basin between 1990 and 2001, the maximum water temperatures occurred between May 31 and September 10. However, on average, the maximum water temperatures occurred between the last week of June and the second week of August. Therefore, all of the data sets were checked to ensure that data collection began by June 21 and continued until at least August 15. The data sets were also checked visually to ensure that the highest temperatures appeared to have been captured. If either one of these conditions were not met, the data were qualified or not used at all in those cases where the peak water temperatures were clearly missed. Potential data quality issues, including the resolution to the potential problem, are given in the Water Quality Appendix.

If the data did not exhibit any significant abnormalities, the summary values were then calculated. These summary values included: the maximum weekly average temperature (MWAT), the maximum weekly maximum temperature (MWMT), the seasonal maximum temperature, and the daily minimum, average, and maximum temperatures. The MWAT is the maximum value of a seven day moving average of the daily average temperatures. The MWMT is the maximum value of a seven day moving average of the daily maximum temperatures. Where we did not have the raw data set, we evaluated only the summary statistics provided to us by the contributor. Due to the large amount of data generated during the calculation of the daily minimum, maximum and average, these data are not presented in tabular form in this assessment. For the same reason, raw data are generally not included in either tabular or graphical form in this assessment. However, this raw data are made available to the public in the KRIS Big River database.

Other summary statistics were calculated for each data set, as described in Table 3, including the number of times the water temperature varied by more than 4°F between consecutive measurements and the maximum diurnal temperature fluctuations. If the water temperature did fluctuate more than 4°F between consecutive measurements, then the maximum fluctuation was recorded. These statistics were used to help identify potential problems with the data and to better understand the dynamics of a stream at a particular monitoring location. For example, large fluctuations between measurements could indicate that the data logger either came out of the water, was affected by discharges/withdrawals from the stream, or was exposed to short-term direct sunlight. In most cases where several large fluctuations were observed, they tended to be cyclical increases in temperature that occurred at the same time each day, primarily in the late morning or early afternoon. This type of repetitive, consistent temperature jump would suggest that the cause is not anthropogenic because the jumps happen at the same time for days or weeks in a row. This type of repetitive temperature effect is more likely climatological. It is speculated that it is due to rapid heating of the data logger by direct sunlight exposure or direct sunlight exposure to shallow water in the thermal reach, which then is recorded by the data logger. In the Big River Basin, no data loggers were placed in the estuary, where tidal fluctuations could be another influencing factor.

The maximum diurnal temperature fluctuation recorded at each site is related to climatological, flow (which is related to climatological conditions), and shading conditions. In many cases, the maximum diurnal fluctuations in water temperature tend to be similar between multiple years and can point to shading and/or flow conditions in that thermal reach. This parameter is useful in that it can assist in developing hypotheses about shading conditions at the various monitoring sites. In general, any diurnal fluctuations in the range of 0-6°F was considered good, >6-10 was considered moderate, and >10 was considered poor. These guidelines do not mean anything with respect to salmonids, but are used as a loose guide for interpreting flow and/or shading conditions in a thermal reach. In addition, large changes in diurnal fluctuations between years may indicate some change in shading conditions.

Once the summary statistics were obtained, these values were compared against the water quality criteria shown in Table 2. As indicated in this table, the calculated MWATs were compared against the EMDS targets. The seasonal maxima are also important to consider as they may reflect short-term thermal extremes that, unless salmonids are able to escape to cool water refugia, may be lethal to fish. The literature supports a critical peak lethal temperature threshold of 75°F (24°C), above which death is usually imminent for most Pacific Coast salmonid species (Brett 1952; Brungs and Jones 1977; RWQCB 2000; Sullivan, et al. 2000). As a rule, if the instantaneous maxima at any site exceeded 70°F, the data record was scrutinized in detail as an additional data quality check to ensure that the data logger remained submerged.

To quantify the trend in the MWATs for each site, an MWAT Trend was calculated. This simple calculation consisted of subtracting the MWAT value for the current year from the value from the previous year. These values are then added together to arrive at the MWAT Trend. For example, if there are MWAT values for 1993 (58.60°F), 1995 (57.30°F), and 1998 (60.40°F), the MWAT value for 1993 is subtracted from the 1995 value (-1.3°F). Then the MWAT value for 1995 is subtracted from the 1998 value (+3.1°F). These two numbers are then added together to get the MWAT Trend (+1.8°F). For this assessment, any MWAT trend greater than 2°F was considered a significant trend and discussed in the subbasin analysis sections.

To provide a visual aid in analysis, a chart was made for each subbasin that summarizes the range of MWATs at a given site. For each stream, the monitoring sites are plotted in order from upstream to downstream. In addition, all of the EMDS thresholds are plotted on the same charts as a point of reference.

USFWS Temperature Study

In 1973, the USFWS recorded water temperatures at six sites in the Big River Basin as part of a Fisheries Improvement Study (Perry 1973). Data were reported in the form of daily minimum, maximum, and mean temperatures. CDFG used this data to calculate MWATs, MWMTs, and maximum temperatures. These summary statistics were compared to recent water temperature data at the similar locations. Due to the nature of USFWS data, this data were not subjected to the same level of quality control as data examined by NCWQCB.

Suspended Sediment & Turbidity

Another common metric to measure in-stream sediment are turbidity and suspended sediment. While both of these parameters were sporadically monitored in the Big River Basin, the samples were typically only grab samples and were relatively infrequent. The data that are available are charted for the respective sub-basin sections. While the amount of data available is insufficient to assess the impacts to the cold-water fisheries and other beneficial uses in the Big River, the data did provide at least a preliminary look at the relationship between turbidity and suspended sediment in the Big River Basin. The existing turbidity data are also useful in that it provides the beginning of the data that will be needed to eventually establish a baseline for this parameter.

Water Column Chemistry

Water column chemistry samples were collected in the Big River Basin by the USGS, the Regional Water Board, and community drinking water system operators. In general, these samples were tested for basic water quality chemistry. Additional on-going sampling began after a tanker truck turned over on Highway 20 on February 27, 2001 and spilled approximately 7,000 gallons of recycled motor oil and diesel, some of which discharged to James Creek. The subsequent sampling consisted of testing for a variety of organic and inorganic compounds.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria. The applicable numeric water quality objectives found in the Basin Plan are contained in Table 2. When quantifying narrative water quality objectives, any number of criteria can apply, depending on the designated beneficial uses for the water body. Therefore, these are only incorporated by reference and discussed in detail when used in this assessment. However, to help clarify the process of selecting numeric criteria, Figure 6 from Marshack (2000) is included.

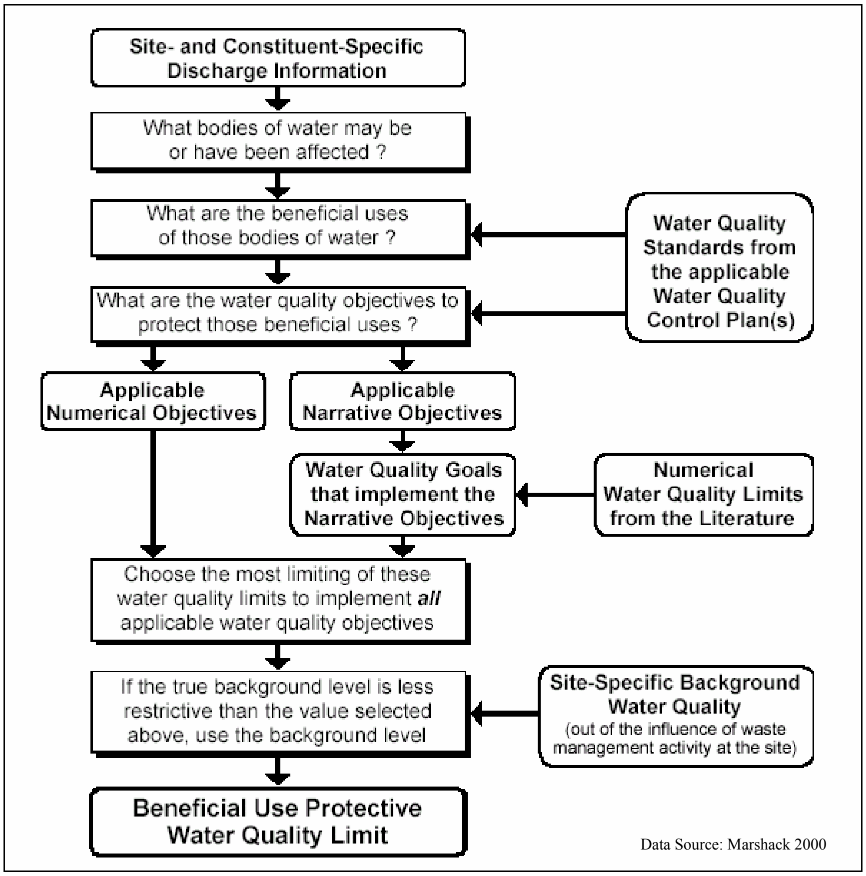


Figure 6. Selecting beneficial use protective numerical limits in water.

Normally, if selecting an enforceable numeric criteria, the lowest applicable value may not apply. For example, if a Maximum Contaminant Level and a Public Health Goal both apply to a selected beneficial use, the Maximum Contaminant Level will usually be the value used to enforce provisions of the Basin plan, even though the Public Health Goal value is typically lower. However, for the purposes of this water quality assessment, the most conservative scientifically based criteria is used so that interested parties are fully informed. To assist resource managers in decision making, all applicable criteria is given in those instances where the most conservative scientifically based criteria is exceeded.

The various categories of criteria used in this assessment have been defined below for ease of reference. More detail on these criteria, which were used to quantify the narrative water quality objectives, is available in Marshack (2000).

Fish Habitat and Populations

Data Compilation and Gap Identification

CDFG collected new data and compiled existing available data and gathered anecdotal information pertaining to salmonids and the instream habitat on the Big River Basin 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 sought from landowners to conduct habitat inventory and fisheries surveys.

Data Collection

Habitat inventories and biological data were collected following the protocol presented in the *California Salmonid Stream Habitat Restoration Manual* (Flosi et al. 1998). Two-person crews trained in those methods conducted physical habitat inventories June through October 2002. Stream reaches were stratified based upon Rosgen (1996) channel types, and the habitat type and stream length determined for all habitat units within a survey reach.

The parameters measured were stream flow, channel type, temperature, fish habitat type, embeddedness (level of fine sediment surrounding cobble sized 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% (Flosi et al. 1998).

When sampling 10% of the units all habitat types are measured when encountered for the first time. Thereafter, approximately 10% 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% of the units. Pool habitat types are also measured for instream cover and embeddedness.

Streams were surveyed until surveyors encountered physical barriers to fish passage, a steep channel gradient of 8-10% for at least 1,000 feet with no anadromous fish above it, 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.

Fish Passage Barriers

Free passage is essential for juvenile and adult anadromous fish. Free movement in 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 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. Of these, poorly installed or worn road culverts commonly disrupt fish passage and disconnect fish passage.

Culverts constructed of steel, aluminum or plastic are the most common stream crossing devices found in rural road systems. Culverts often create temporary, partial, or complete barriers for adult and/or juvenile salmonids during their freshwater migration activities (Table 4). Passage barriers that can be created by culverts include an excessive drop at the culvert outlet (too high of an entry jump is required), an excessive velocity within the culvert; a lack of depth within the culvert, an excessive velocity and/or turbulence at the culvert inlet, and a debris accumulation at and/or within the culvert. The cumulative effect of numerous culvert-related passage barriers in a river system can be significant to anadromous salmonid populations. Inventories and fish passage evaluations of culverts within the coastal Mendocino County road system were conducted between August 1998 and December 2000 by Ross Taylor and Associates, under contract with the Department of Fish and Game’s Fishery Restoration Grants Program. These inventories included 26 stream crossings in Mendocino County, of which three were in the Big River Basin (Taylor 2001).

Table 4. Definitions of barrier types and their potential impacts to salmonids.

Barrier Category	Definition	Potential Impact
Temporary	Impassable to all fish some of the time.	Delay in movement beyond the barrier for some period of time.
Partial	Impassable to some fish at all times.	Exclusion of certain species and life stages from portions of a watershed.
Total	Impassable to all fish at all times.	Exclusion of all species from portions of a watershed.

From Taylor 2001

These culvert inventories and fish passage evaluations followed a standardized assessment procedure. First, all culverts in stream crossings that may inhibit fish passage were located and counted. Second, each culvert location was visited during both late-summer/early fall low flow conditions and after early storm events. Third, information was collected regarding culvert specifications. Fourth, fish passage at each culvert was assessed using culvert specifications and passage criteria for juvenile and adult salmonids (from scientific literature and Fish Xing computer software) and on-site observations of fish movement. Last, the quality and quantity of stream habitat above and below each culvert was assessed. Habitat information was obtained from habitat typing surveys conducted by CDFG, the Coastal Land Trust, and the Mendocino Redwood Company.

Following the culvert inventory and fish passage assessment, a prioritized list of culverts that impede fish spawning and rearing activities was compiled for Humboldt and Mendocino counties. Criteria for priority ranking included salmonid species diversity, extent of barrier problem present, culvert risk of failure, current culvert condition, salmonid habitat quantity, salmonid habitat quality, and a total salmonid habitat score. The reports of the culvert inventories and fish passage surveys were provided to the Humboldt and Mendocino counties' Public Works, Natural Resources and Engineering Divisions, the CDFG Native Anadromous Fish and Watershed Branch, and the CDFG North Coast, Northern California, Region Headquarters.

Large Woody Debris

LWD was inventoried by MRC in 2000 using surveys of their design. The surveys covered 44 segments from 28 streams across MRC lands in the basin. The segments measured 20-30 bankfull channel widths in length, and thus ranged from 60-300 meters.

All wood within the bankfull channel was counted and measured if deemed to provide some habitat or morphologic function in the stream channel (i.e. pool formation, scour, debris dam, bank stabilization, or gravel storage). Wood pieces greater than 12 inches in diameter and 20 feet long were recorded as key pieces if bankfull channel width was less than 20 feet. In wider stream segments, a larger minimum size was used to classify key pieces. Debris accumulations (3-10 pieces) and debris jams (>10 pieces) were counted and measured separately. LWD was classified by tree species class, either redwood, fir (Douglas-fir, hemlock, grand fir), hardwood (alder, tan oak, etc.), or unknown (if tree species is indeterminable). Length and diameter were recorded for each piece so that volume could be calculated.

The quantity of LWD observed was normalized by distance, for comparison through time or to other similar areas, and is presented as a number of LWD pieces per 100 meters. This normalized quantity, by distance, is performed for functional and key LWD pieces within the active and bankfull channel. The key piece quantity in the bankfull channel (per 100 meters of channel) is compared to the target for what would be an appropriate key piece loading. The target for appropriate key piece loading is derived from Bilby and Ward (1989) and Gregory and Davis (1992) and presented in Table 5.

Table 5. Target for number of key large woody debris pieces in watercourses of the MRC ownership in the Big River Basin.

Bankfull Width (feet)	Number of Key Pieces		
	Per 100 meters	Per 1000 feet	Per mile
<15	6.6	20	106
15-35	4.9	15	79
35-45	3.9	12	63
>45	3.3	10	53

Target Values from 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 6). When habitat conditions fall below the target values, restoration projects may be proposed in an attempt to meet critical habitat needs for salmonids.

Table 6. Habitat inventory target values.

Habitat Element	Canopy Density	Embeddedness	Primary Pool Frequency	Shelter/Cover
Range of Values	0-100%	0-100%	0-100%	0-300 Rating
Target Values	>80%	>50% of the pool tails surveyed with category 1 embeddedness values	>40% of stream length Primary pools are pools >2 feet deep in 1st and 2nd order streams, >3 feet deep in 3rd order streams, or >4 feet deep in 4th order streams	>100

From the California Salmonid Stream Habitat Restoration Manual (Flosi et al 1998).

Canopy Density—Eighty Percent or Greater 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. Re-vegetation projects should be considered when canopy density is less than the target value of 80%.

Good Spawning Substrate- Fifty Percent or Greater of the Pool Tails Sampled are Fifty 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 is classified as Category 1 cobble embeddedness or 0-25% embedded. Category 2 is defined by the substrate being 26-50% embedded. Cobble embedded deeper that 51% is not within the range for successful spawning. The target value is for 50% or greater of the pool tails sampled to be 50% or less embedded. Streams with less than 50% of their length greater than 51% embedded do not meet the target value nor provide adequate spawning substrate conditions.

Pool Depth/Frequency- Forty 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% 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% or more of the pools 2 feet or deeper to meet the target values. Third and fourth order streams are required to have 40% or more of the pools 3 feet or deeper or 4 feet or deeper, respectively, to meet the target values. A frequency of less than 40% or inadequate depth related to stream order indicates that the stream provides insufficient pool habitat.

Shelter/Cover- Scores of One Hundred 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 100 or less indicate that shelter/cover enhancement should be considered.

MRC Watershed Analysis

As part of the Watershed Analysis conducted by MRC of their lands in the Big River Basin, MRC evaluated habitat conditions for salmonids in 43 stream segments in 24 tributaries and the mainstem Big River. They used a habitat inventory method during low flow conditions using methods modified from the *California Salmonid Stream Restoration Manual* (Flosi et al., 1998) and described 100% of the wetted width. MRC defined stream segments based mainly on stream gradient and channel confinement. They also took into account the presence of fish, accessibility, stream channel type (response, transport or source reach), and representative segments that were likely to respond similar to other stream channel types within the watershed. Survey efforts focused on low gradient reaches.

Survey lengths were determined to be a distance of 20-30 bankfull widths, representing approximately two meander bends of the stream channel. Data were collected on pool, riffle and flatwater frequency; pool spacing; spawning gravel quantity and quality; over-wintering substrate; shelter complexity and large woody debris (LWD) frequency, condition and future recruitment.

MRC evaluated fish habitat parameters using target values based on scientific literature (Table 7) (Bilby and Ward 1989; Bisson et al. 1987; Bjornn and Reiser, 1991; Flosi et al. 1998; Montgomery et al. 1995; Washington Forest Practices Board 1995) and professional judgment. Spawning habitat conditions were evaluated on the basis of gravel availability and quality (gravel sizes, subsurface fines, embeddedness), and were evaluated for preferred salmonid spawning areas located at the tail-outs of pools. Summer rearing habitat conditions for salmonids were evaluated on the size, depth and availability of pools and the complexity and quantity of cover (particularly large woody debris). Over-wintering habitat was evaluated on the size, depth, and availability of pools, the proportion of habitat units with cobble or boulder-dominated substrate and the quantity of cover.

Table 7. Fish habitat condition indices for measured parameters used by MRC.

Fish Habitat Parameter	Feature	Fish Habitat Quality		
		Poor	Fair	Good
Percent pool/riffle/flatwater (by length)	Anadromous salmonid streams	<25% pools	25-50% pools	>50%pools
Pool spacing (reach length/bankfull/#pools)	Anadromous salmonid streams	> 6.0	3.0 - 5.9	< 2.9
Shelter rating(shelter value x % of habitat covered)	Pools	<60	60-120	>120
% of pools that are >3 feet residual depth	Pools	<25%	25-50%	>50%
Spawning gravel	Pool tail-outs quantity	<1.5%	1.5-3%	>3%
Percent embeddedness	Pool tail-outs	>50%	25-50%	<25%
Subsurface fines (L-P watershed analysis manual)	Pool tail-outs	2.31-3.0	1.61-2.3	1.0-1.6
Gravel quality rating (L-P watershed analysis manual)	Pool tail-outs	2.31-3.0	1.61-2.3	1.0-1.6
Key LWD + root wads / 328 ft of stream	Streams≥40 ft. BFW	<4.0	4.0-6.5	>6.6
	Streams<40 ft. BFW	<3.0	3.0-3.8	>3.9
Substrate for over-wintering	All habitat types	<20% of units cobble or boulder dominated	20-40% of units cobble or boulder dominated	>40% of units cobble or boulder dominated

Analytic Tools and Interdisciplinary Synthesis

Integrated Analysis Tables

The multi-discipline Big River team constructed a series of subject specific data tables, referred to as Integrated Analysis (IA) tables, to track the history and status of watershed processes. Through the use of IA tables the information from CDFG and NCRWQCB were compared to one another, and along with information from CDF and CGS, were used to respond to the six guiding assessment questions. The IA process also helped to identify and explain current watershed conditions. These integrated analyses are presented at both basin and subbasin levels. Land use and vegetation analyses have been further divided at the CalWater 2.2a Planning Watershed level.

The IA approach follows the down-slope movement of the five watershed products commonly delivered to streams by natural or human caused energy: water, sediment, organic woody debris, nutrients, and heat. Fundamental to these watershed processes and products are the underlying geology and geomorphology of the watershed. Geologic conditions determine, in large part, the landslide and sediment production potential of the terrain. Geologic processes are influenced in varying degrees by the vegetative community, which is often linked to human activities across the landscape. Current watershed conditions combine with natural events like fire, flood, and earthquakes to affect the fluvial geomorphology and water quality in the stream reaches of a watershed. Finally, the effects of these combined processes are expressed in stream habitats encountered by the organisms of the aquatic riparian community, including salmon and steelhead.

Ecological Management Decision Support System

The assessment program selected the Ecological Management Decision Support system software to help synthesize information on stream conditions. The EMDS system 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™. The NetWeaver software, developed at Pennsylvania State University, helps scientists model linked frameworks of various environmental factors called knowledge base networks (Reynolds et al. 1996).

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

NWFP scientists constructed knowledge base models to identify and evaluate environmental factors (e.g. watershed geology, land use impacts, water quality, stream sediment loading, stream temperature, etc.) that shape anadromous salmonid habitat. Using this adaptive model structure, EMDS evaluated available NWFP watershed data to provide insight into stream and watershed conditions in relationship to target conditions known to be favorable to salmonids.

Development of the North Coast California EMDS Model

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 assessment program staff, model developer Dr. Keith Reynolds and several outside scientists also participated. As a starting point, analysts used an EMDS knowledge base model developed by the Northwest Forest Plan for use in coastal Oregon. Based upon the workshop, subsequent discussions among staff and other scientists, examination of the literature, and consideration of localized California conditions, the assessment team scientists then developed preliminary versions of the EMDS models.

The Knowledge Base Network

For California's north coast watersheds, the assessment team originally constructed two knowledge base networks: 1) The Stream Reach Condition Model, and 2) The Watershed Condition Model. These models were reviewed in April 2002 by an independent nine-member science panel, which provided a number of suggestions for model improvements. According to their suggestions, the team revised the two original models and added three others focused on the analysis of specific components of instream and watershed conditions that affect salmonids:

- **The Stream Reach Condition model** (Figure 8) addresses conditions for salmon on individual stream reaches and is largely based on data collected using CDFG stream survey protocols found in the California Salmonid Stream Habitat Restoration Manual, (Flosi et al. 1998). This model was used in the Big River Basin assessment;
- **The Sediment Production Risk model** evaluates the magnitudes of the various sediment sources in the basin according to whether they are natural or management related. This model was not used in the Big River Basin assessment;
- **The Water Quality model** has not yet been developed, but will offer a means of assessing characteristics of instream water (flow and temperature) in relation to fish;
- **The Fish Habitat Quality model** has not yet been developed, but will incorporate 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;
- **The Fish Food Availability model** has not yet been developed, but will evaluate the watershed based upon conditions for producing food sources for anadromous salmonids.

Only the Stream Reach Condition model was used in the Big River assessment. For more details of the other models see the EMDS Appendix.

In creating these EMDS models, the team used what is termed a tiered, top-down approach. For example, the Stream Reach Condition model tested the truth of the proposition: *The overall condition of the stream reach is suitable for maintaining healthy populations of native Chinook, coho, and steelhead trout*. A knowledge base network was then designed to evaluate the truth of that proposition, based upon existing data from each stream reach. The model design and contents reflected the specific data and information analysts believed were needed, and the manner in which they should be combined, to test the proposition.

In evaluating stream reach conditions for salmonids, the model uses data from several environmental factors. The first branching tier of the knowledge base network shows the data based summary nodes on: 1) in-channel condition; 2) stream flow; 3) riparian vegetation and: 4) water temperature (Figure 7). These nodes are combined into a single value to test the validity of the stream reach condition suitability proposition. In turn, each of the four summary branch node's values is formed from the combination of its more basic data components. The process is repeated until the knowledge base network incorporates all information believed to be important to the evaluation (Figure 8).

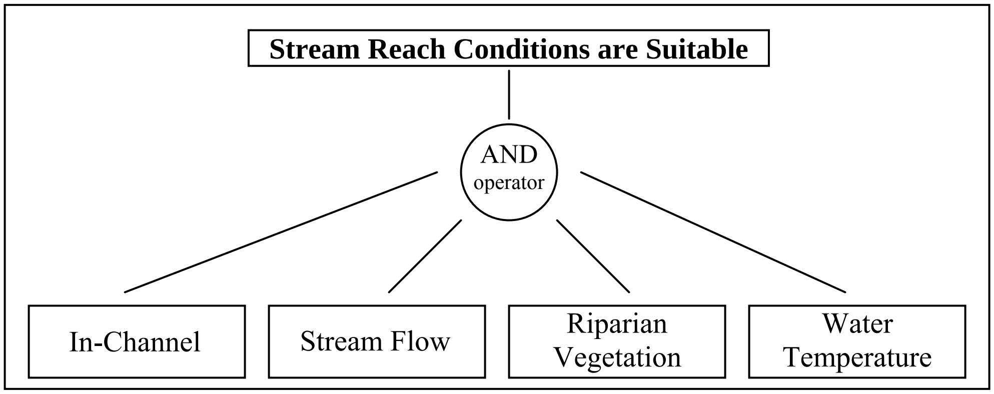


Figure 7. Tier one of the EMDS stream reach knowledge base network.

In Figure 7, the AND operator indicates a decision node that means that the lowest, most limiting value of the four general factors determined by the model will be passed on to indicate the potential of the stream reach to sustain salmonid populations. In that sense, the model mimics nature. For example, if summertime low flow is reduced to a level deleterious to fish survival or well being, regardless of a favorable temperature regime, instream habitat, and/or riparian conditions, the overall stream condition is not suitable to support salmonids.

Although model construction is typically done top-down, models are run in EMDS from the bottom up. That is, stream reach data are usually entered at the lowest and most detailed level of the several branches of the network tree (the leaves). The data from the leaves are combined progressively with other related attribute information as the analysis 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 (Figure 8).

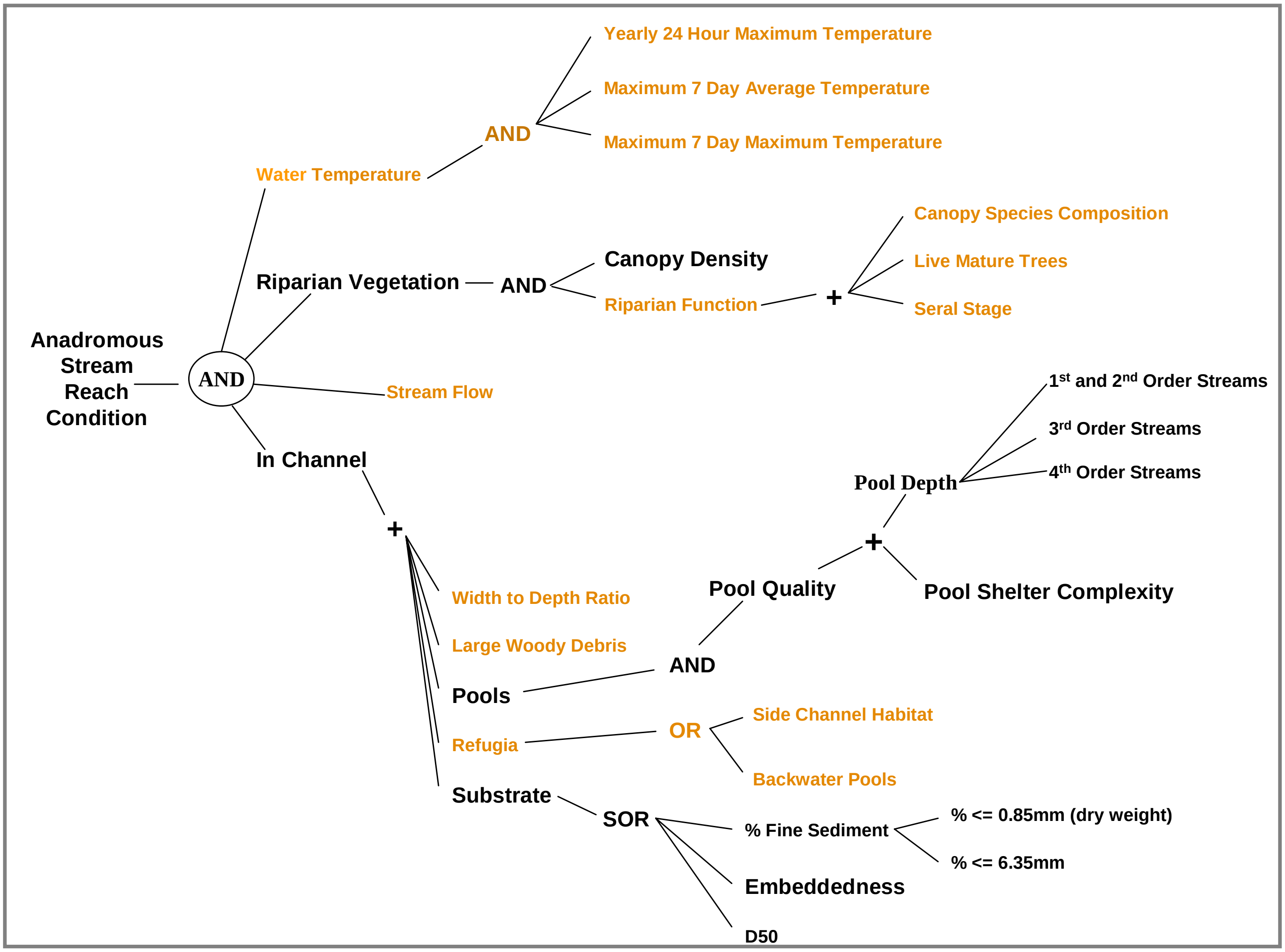


Figure 8. Graphic representation of the Stream Reach Condition model.

Habitat factors populated with data in the Big River assessment model are shown in black. Other habitat factors considered important for stream habitat condition evaluation, but data limited in the Big River assessment, are included in orange.

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 9 shows an example reference curve for the proposition *stream temperature is suitable for salmon*. The horizontal axis shows temperature in degrees Fahrenheit ranging from 30-80° F, while the vertical axis is labeled Truth Value and ranges from values of +1 to -1. The upper horizontal line arrays the fully suitable temperatures from 50-60°F (+1). The fully unsuitable temperatures are arrayed at the bottom (-1). Those in between are ramped between the fully suitable and fully unsuitable ranges and are rated accordingly. A similar numeric relation is determined for all attributes evaluated with reference curves in the EMDS models.

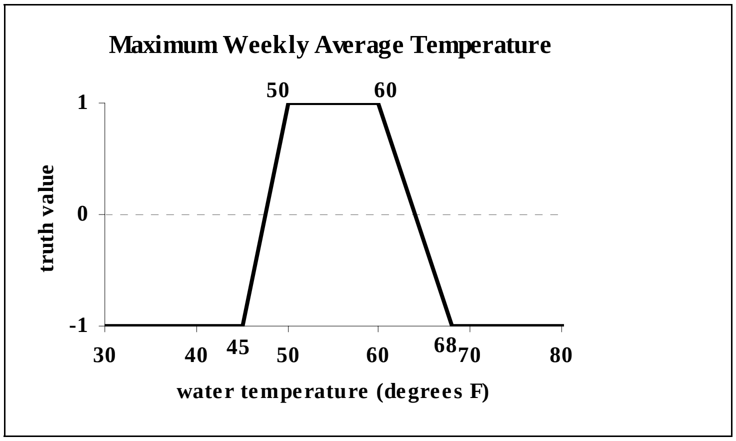


Figure 9. EMDS reference curve for stream temperature.

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

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, while 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 occur where the slope of the reference curve changes. For example, in Figure 9 breakpoints occur at 45, 50, 60, and 68°F.

EMDS map legends use a seven-class system for depicting the 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). These ranking values are assigned based upon condition findings in relationship to the criteria in the reference curves. The following table summarizes important EMDS Stream Reach Condition model information.

Table 8. Reference curve metrics for EMDS stream reach condition model.

Stream Reach Condition Factor	Definition and Reference Curve Metrics
Aquatic / Riparian Conditions	
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	Under development
Canopy Density	Average percent of the thalweg within a stream reach influenced by tree canopy. < 50% fully unsuitable, ≥ 85% fully suitable.
Seral Stage	Seral stage composition of near stream forest. Under development
Vegetation Type	Forest composition 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	Percent of pools by length in a stream reach. 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 scores are 0.8 or greater and -0.8 evaluate to fully false
Percent Fines in Substrate <0.85mm (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

Stream Reach Condition Factor	Definition and Reference Curve Metrics
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 (LWD)	The reference values for frequency and volume are derived from Bilby and Ward (1989) and are dependent on channel size. See EMDS Appendix for details. Most watersheds do not have sufficient LWD survey data for use in EMDS.
Winter Refugia Habitat	Winter refugia is composed of backwater pools and side channel habitats and deep pools (> 4 feet deep). Under development.
Pool to Riffle Ratio	Ratio of pools to riffle habitat units. Under development.
Width to Depth Ratio	Ratio of bankfull width to maximum depth at velocity crossovers. Under development.

Advantages Offered by EMDS

EMDS offers a number of advantages for use in watershed assessments. 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 overall watershed conditions. This latter feature can help to identify what is most limiting to salmonids, and thus assist to prioritize restoration projects or modify 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 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, 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., sub-watersheds) can be aggregated into a large hydrologic unit. With sufficient sampling and data, analyses can be done even upon single or multiple stream reaches.

Limitations of the EMDS Model and Data Inputs

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 dates and completeness of the data available for a stream or watershed will strongly influence the degree of confidence in the results. 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. Therefore, EMDS should only be used as an indicative model, one 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 life cycle, nor does it consider fishing pressures.

Program staff have identified some model or data elements needing attention and improvement in future iterations of EMDS. These currently include:

- Completion of quality control evaluation procedures;
- Adjust the model to better reflect differences between stream mainstems and tributaries, for example, the modification of canopy density standards for wide streams;
- Develop a suite of Stream Reach Model reference curves to better reflect the differences in expected conditions based upon various geographic watershed locations considering geology, vegetation, precipitation, and runoff patterns.

At this time, all of the recommendations made by our peer reviewers have not been implemented into the models. Additionally, EMDS results should be used as valuable but not necessarily definitive products, and their validation with other observations is necessary. The EMDS Appendix provides added detail concerning the system's structure and operations.

Management Applications of Watershed Synthesis Results

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 can also 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.

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 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. Thus, the results have utility to assess fish habitat conditions in watersheds and to help prioritize restoration efforts. They also facilitate an improved understanding of the complex relationships among environmental factors, human activities, and overall habitat quality for native salmon and trout.

Adaptive Application for EMDS and CDFG Stream Habitat Evaluations

CDFG has developed habitat evaluation standards, or target values, to help assess the condition of anadromous salmonid habitat in California streams (Flosi et al. 1998). These standards are based upon data analyses of over 1,500 tributary surveys, and considerable review of pertinent literature. The EMDS reference curves have similar standards. These have been adapted from CDFG, but following peer review and professional discussion, they have been modified slightly due to more detailed application in EMDS. As such, slight differences occur between values found in Flosi et al. (1998) and those used by EMDS. The reference curves developed for the EMDS are provided in the EMDS Appendix of this report.

Both habitat evaluation systems have similar but slightly different functions. Stream habitat standards developed by CDFG are used to identify habitat conditions and establish priorities among streams considered for improvement projects based upon standard CDFG tributary reports. The EMDS compares select components of the stream habitat survey data to reference curve values and expresses degrees of habitat suitability for fish on a sliding scale. In addition, the EMDS produces a combined estimate of overall stream condition by combining the results from several stream habitat components. In the fish habitat relationship section of this report, we utilize target values found in Flosi et al. (1998), field observations, and results from EMDS reference curve evaluations to help describe and evaluate stream habitat conditions.

Due to the wide range of geology, topography and diverse stream channel characteristics which occur within the North Coast region, there are streams that require more detailed interpretation and explanation of results than can be simply generated by EMDS suitability criteria or tributary survey target values.

For example, pools are an important habitat component and a useful stream attribute to measure. However, some small fish-bearing stream channels may not have the stream power to scour pools of the depth and frequency considered to be high value "primary" pools by CDFG target values, or to be fully suitable according to EMDS. Often, these shallow pool conditions are found in low gradient stream reaches in small watersheds that lack sufficient discharge to deeply scour the channel. They also can exist in moderate to steep gradient reaches with bedrock/boulder dominated substrate highly resistant to scour, which also can result in few deep pools.

Therefore, some streams may not have the inherent ability to attain conditions that meet the suitability criteria or target values for pool depth. These scenarios result in pool habitat conditions that are not considered highly suitable by either assessment standard. However, these streams may still be very important because of other desirable features that support valuable fishery resources. As such, they receive additional evaluation with our refugia rating system and expert professional judgment. Field validation of any modeling system's results is a necessary component of watershed assessment and reporting.

Limiting Factors Analysis

A main objective of CDFG watershed assessment is to identify factors that limit production of anadromous salmonid populations in North Coast watersheds. This process is known as 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 necessary support resources (Hilborn and Walters 1992) or that a population's potential may be constrained by an over abundance, deficiency, or absence of a watershed ecosystem component. Identifying stream habitat factors that limit or constrain anadromous salmonids 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.

Although several factors have contributed to the decline of anadromous salmonid populations, habitat loss and modification are major determinants of their current status (FEMAT 1993). Our approach to a LFA integrates two habitat based methods to evaluate the status of key aspects of stream habitat that affect anadromous salmonid production- species life history diversity and the stream's ability to support viable populations.

The first method uses priority ranking of habitat categories based on a CDFG team assessment of data collected during stream habitat inventories. The second method uses the EMDS to evaluate the suitability of key stream habitat components to support anadromous fish populations. These habitat-based methods assume that stream habitat quality and quantity play important roles in a watershed's ability to produce viable salmonid populations.

The LFA assumes that poor habitat quality and reduced quantities of favorable habitat impairs fish production. Limiting factors analysis is focused mainly on those physical habitat factors within freshwater and estuarine ecosystems that affect spawning and subsequent juvenile life history requirements during low flow seasons. 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 or chemistry. In general, fish will die regardless of the population density if flow is inadequate, or water temperatures or chemistry reach lethal levels. 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 that affect growth and survival when populations reach or exceed the habitat carrying capacity.

The program's approach considers these two types of habitat factors before prioritizing recommendations for habitat management strategies. Priority steps are given to preserving and increasing the amount of high quality (density independent) habitat in a cost effective manner. More details of the LFA are presented in the CDFG Appendix.

Restoration Needs/Tributary Recommendations Analysis

CDFG inventoried 57 tributaries to the Big River and three sections of mainstem Big River using protocols in the *California Salmonid Stream Habitat Restoration Manual*. The tributaries of the Big River surveyed were composed of 106 stream reaches, defined as Rosgen channel types. The stream inventories are a combination of several stream reach surveys: habitat typing, channel typing, biological assessments, and in some reaches LWD and riparian zone recruitment assessments. An experienced Biologist and/or Habitat Specialist conducted quality assurance/quality control (QA/QC) on field crews and collected data, performed data analysis, and determined general areas of habitat deficiency based upon the analysis and synthesis of information.

CDFG biologists selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFG habitat inventories, and updated the recommendations with the results of the stream reach condition EMDS and the refugia analysis (Table 9). It is important to understand that these selections are made from stream reach conditions that were observed at the times of the surveys and do not include upslope watershed observations other than those that could be made from the streambed. They 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. Bear in mind that stream and watershed conditions change over time and periodic survey updates and field verification are necessary if watershed improvement projects are being considered.

Table 9. List of tributary recommendations in stream tributary reports.

Recommendation	Explanation
Temp	Summer water temperatures were measured to be above optimum for salmon and steelhead
Pool	Pools are below CDFG target values in quantity and/or quality
Cover	Escape cover is below CDFG 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 CDFG 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	There is evidence that stock is impacting the stream or riparian area and exclusion should be considered
Fish Passage	There are barriers to fish migration in the stream

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. Various project treatment recommendations can be made concurrently if watershed and stream conditions warrant.

Fish passage problems, especially in situations where favorable stream habitat reaches are being separated by a man-caused feature (e.g., culvert), are usually a treatment priority. Good examples of these are the recent and dramatically successful Humboldt County/CDFG culvert replacement projects in tributaries to Humboldt Bay. In these regards, the program'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 must 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 logistic considerations that enter into a recommendation's subsequent ranking for project development. These can include work party access limitations based upon lack of private party trespass permission and/or physically difficult or impossible locations of the candidate work sites. Biological considerations are made based upon the propensity for benefit to multiple or single fishery stocks or species. Cost benefit and project feasibility are also factors in project selection for design and development.

Potential Salmonid Refugia

Establishment and maintenance of salmonid refugia areas containing high quality habitat and sustaining fish populations are activities vital to the conservation of our anadromous salmonid resources (Moyle and Yoshiyama 1992; Li et al. 1995; Reeves et al. 1995). Protecting these areas will prevent the loss of the remaining high quality salmon habitat and salmonid populations. Therefore, a refugia investigation project should focus on identifying areas found to have high salmonid productivity and diversity. Identified areas should then be carefully managed for the following benefits:

- Protection of refugia areas to avoid loss of the last best salmon habitat and populations. The focus should be on protection for areas with high productivity and diversity;
- Refugia area populations which may provide a source for re-colonization of salmonids in nearby watersheds that have experienced local extinctions, or are at risk of local extinction due to small populations;
- Refugia areas provide a hedge against the difficulty in restoring extensive, degraded habitat and recovering imperiled populations in a timely manner (Kaufmann et al. 1997).

The concept of refugia is based on the premise that patches of aquatic habitat provide habitat that retains the natural capacity and ecologic functions to support wild anadromous salmonids in such vital activities as spawning and rearing. 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 relative 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.

Potential 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, through either restoration efforts or natural processes, 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 conservation efforts to ensure long-term survival of viable stocks, and a critical element towards recovery of depressed populations (Sedell 1990; Moyle and Yoshiyama 1992; Frissell 1993, 2000).

Refugia habitat elements include the following:

- 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
- A center from which dispersion may take place to re-colonize areas after a watershed and/or sub-watershed level disturbance event and readjustment.

Spatial and Temporal Scales of Refugia

These refugia concepts become more complex in the context of the wide range of spatial and temporal habitat required for viable salmonid populations. Habitat can provide refuge at many scales from a single fish to groups of them, and finally to breeding populations. For example, refugia habitat may range from a piece of wood that provides instream shelter for a single fish, or individual pools that provide cool water for several rearing juveniles during hot summer months, to watersheds where conditions support sustaining populations of salmonid species. Refugia also include areas where critical life stage functions such as migrations and spawning occur. Although fragmented areas of suitable habitat are important, their connectivity is necessary to sustain the fisheries. Today, watershed scale refugia are needed to recover and sustain aquatic species (Moyle and Sato 1991). For the purpose of this discussion, refugia are considered at the fish bearing tributary and subbasin scales. These scales of refugia are generally more resilient to the deleterious effects of landscape and riverine disturbances such as large floods, persistent droughts, and human activities than the smaller, habitat unit level scale (Sedell et al. 1990).

Standards for refugia conditions are based on reference curves from the literature and CDFG data collection at the regional scale. The program uses these values in its EMDS models and stream inventory, improvement recommendation process. Li et al. (1995) suggested three prioritized steps to use the refugia concept to conserve salmonid resources.

- Identify salmonid refugia and ensure they are protected;
- Identify potential habitats that can be rehabilitated quickly;
- Determine how to connect dispersal corridors to patches of adequate habitat.

Refugia and Meta-population Concept

The concept of anadromous salmonid meta-populations 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 sub-populations which are geographically located such that over time, there is likely genetic exchange between the sub-populations (Barnhart 1994). Metapopulations are characterized by 1) relatively isolated, segregated breeding populations in a patchy environment that are connected to some degree by migration between them, and 2) a dynamic relationship between extinction and re-colonization of habitat patches.

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 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 structured 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 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 into a dynamic aquatic environment.

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

Methods to Identify Refugia

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 conditions and productivity across large areas. This lack of information holds true for all study basins especially in terms of meta-population 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; Frissell et al. 2000; Kitsap 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 metapopulation maintenance. 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.

A second common theme is that over time within the landscape mosaic of habitat patches, good habitat areas will suffer impacts and become less productive, and wink out and other areas will recover and wink in. These processes can occur through either human caused or natural disturbances or succession to new ecological states. Regardless, it is important that a balance be maintained in this alternating, patchwork dynamic to ensure that adequate good quality habitat is available for viable anadromous salmonid populations (Reeves et al. 1995).

Approach to Identifying Refugia

The program's interdisciplinary refugia identification team identified and characterized refugia habitat by using expert professional judgment and criteria developed for North Coast watersheds. The criteria used considered different values of watershed and stream ecosystem processes, the presence and status of fishery resources, water quality, and other factors that may affect refugia productivity. The expert refugia team encouraged other specialists with local knowledge to participate in the refugia identification and categorization process.

The team also used results from information processed by the programs EMDS at the stream reach and planning watershed/subbasin scales. Stream reach and watershed parameter evaluation scores were used to rank stream and watershed conditions based on collected field data. Stream reach scale parameters included pool shelter rating, pool depth, embeddedness, and canopy cover. Water temperature data were also used when available. The individual parameter scores identified which habitat factors currently support or limit fish production (see EMDS and limiting factors sections).

Professional judgment, analyzing field notes, local expert opinion, habitat inventory survey results, water quality data results, and EMDS scores determined potential locations of refugia. If a habitat component received a suitable ranking from the EMDS model, it was cross-referenced to the survey results from that particular stream and to field notes taken during that survey. The components identified as potential refugia were then ranked according to their suitability to encourage and support salmonid health.

When identifying anadromous salmonid refugia, the program team took into account that anadromous salmon have several non-substitutable habitat needs for their life cycle. A minimal list (NMFS 2001) includes:

- Adult migration pathways;
- Spawning and incubation habitat;
- Stream rearing habitat;
- Forage and migration pathways;
- Estuarine habitat.

The best refugia areas are large, meet all of these life history needs, and therefore provide complete functionality to salmonid populations. These large, intact systems are scarce today and smaller refugia areas that provide for only some of the requirements have become very important areas, but cannot sustain large numbers of fish. These must operate in concert with other fragmented habitat areas for life history support and refugia connectivity becomes very important for success. Therefore, the refugia team considered relatively small, tributary areas in terms of their ability to provide at least partial refuge values, yet contribute to the aggregated refugia of larger scale areas. Therefore, the team's analyses used the tributary scale as the fundamental refugia unit.

CDFG created a tributary scale refugia-rating worksheet, (Table 10, page 47). The worksheet has 21 condition factors that were rated on a sliding scale from high quality to low quality. Twenty-one factors were grouped into five categories:

- Stream condition;
- Riparian condition;
- Native salmonid status;
- Present salmonid abundance;
- Management impacts (disturbance impacts to terrain, vegetation, and the biologic community).

Additionally, NCRWQCB created a worksheet specifically for rating water quality refugia, Table 11. The worksheet has 13 condition factors that were rated on a sliding scale from high quality to low quality. Thirteen factors were grouped into three categories:

- In-stream sediment related;
- Stream temperature;
- Water chemistry.

Tributary ratings were determined by combining the results of NCRQCB water quality results, EMDS results, and data in CDFG tributary reports by a multi-disciplinary, expert team of analysts. The various factors' ratings were combined to determine an overall tributary rating on a scale from high to low quality refugia. Tributary ratings were subsequently aggregated at the subbasin scale and expressed a general estimate of subbasin refugia conditions. Factors with limited or missing data were noted. In most cases there were data limitations on 1–3 factors. These were identified for further investigation and inclusion in future analysis.

The program has created a hierarchy of refugia categories that contain several general habitat conditions. This descriptive system is used to rank areas by applying results of the analyses of stream and watershed conditions described above and are used to determine the ecological integrity of the study area. A basic definition of biotic integrity is "the ability [of an ecosystem] to support and maintain a balanced, integrated, and functional organization comparable to that of the natural habitat of the region" (Karr and Dudley 1981).

The Report of the Panel on the Ecological Integrity of Canada's National Parks submitted this definition:

A Definition of Ecological Integrity

The Panel proposes the following definition of ecological integrity: "An ecosystem has integrity when it is deemed characteristic for its natural region, including the composition and abundance of native species and biological communities, rates of change and supporting processes." "In plain language, ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact."

Salmonid Refugia Categories and Criteria:

High Quality Habitat, High Quality Refugia

- Maintains a high level of watershed ecological integrity (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; Frissell 2000);
- Contains 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 of its native components.

High Potential Refugia

- Watershed ecological integrity is diminished but remains good (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; Frissell 2000).

Medium Potential Refugia

- Watershed ecological integrity is degraded or fragmented (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 significant 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, Low Potential Refugia

- Watershed ecological integrity is impaired (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 significant straying very unlikely;
- Current management and/or natural events have significantly altered the naturally functioning ecosystem and major changes in either of both are needed to improve conditions.

Other Related Refugia Component Categories:

Potential Future Refugia (Non-Anadromous)

- 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).

Data Limited

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

Table 10. Refugia rating worksheet.

Stream Name:			**Date:**
Raters:			
Ecological Integrity - Overall Refugia Summary Ratings:	**High Quality; High Potential; Medium Potential; Low Quality (Other: Non-Anadromous; Contributing Functions; Data Limited)**		
Stream Condition:	**High Quality**	**Medium Quality**	**Low Quality**
Stream Flow			
Water Temperature			
Free Passage			
Gravel			
Pools			
Shelter			
In-Channel Large Wood			
Canopy			
Nutrients			
Stream Summary Rating:			
Riparian Condition:	**High Quality**	**Medium Quality**	**Low Quality**
Forest Corridor Seral Stage			
Fluvial Dis-equilibrium			
Aquatic/Riparian Community			
Riparian Summary Rating:			
Native Salmonids Status: (Native Species and Age Classes)	**Present**	**Diminished**	**Absent**
Chinook			
Coho			
Steelhead			
Species Summary Rating:			
Salmonid Abundance:	**High**	**Medium**	**Low**
Chinook			
Coho			
Steelhead			
Abundance Summary Rating:			
Management Impacts:	**Low Impacts**	**Medium Impacts**	**High Impacts**
Disturbed Terrain			
Displaced Vegetation			
Native Biologic Integrity			
Impacts Summary Rating:			
Comments:			

Table 11. Water quality refugia rating sheet.

Stream Name:			**Date:**
Rater(s):			
In-stream Sediment Related:	**Suitable**	**Somewhat Suitable**	**Unsuitable**
Pebble Counts (D50)			
Mc Neil			
Spawning Substrate			
% Fines <0.85 mm			
% Fines <6.4 mm			
V*			
Permeability			
Turbidity/Suspended Sediment			
Thalweg			
Stream Summary Rating:			
Stream Temperature:	**Suitable**	**Undetermined**	**Unsuitable**
MWAT			
Seasonal Maximum			
Riparian Summary Rating:			
Water Chemistry:	**Suitable**	**Somewhat Suitable**	**Unsuitable**
Dissolved Oxygen			
pH			
Specific Conductance			
Species Summary Rating:			
Ecologic Integrity - Overall Refugia Summary Rating:	**Category: High Quality; High Potential; Potential; Low Quality; (Non-Anadromous; Contributing Functions; Data Limited)**		
Comments:			

NI= No Information NR= Not Rated

Big River Basin Profile and Synthesis

The Big River Mill from Freundt residence, 1863.
Courtesy of the Bancroft Library, University of California, Berkeley, photographed by Carleton E. Watkins

Named for the giant redwood trees that used to line its banks, the Big River drains a 181.1 square mile watershed located in the northern California Coast Range in western Mendocino County, entering the Pacific Ocean at the town of Mendocino, about 10 miles south of Fort Bragg. The Big River Basin extends 24 miles to the east, to within three miles of Willits and Highway 101. It drains primarily from east to west, sharing ridges with the Noyo River and Caspar Creek basins to the north and the Albion and Navarro river basins to the south. Elevations within the Big River Basin range from sea level at the basin outlet to Irene Peak at 2,836 feet, five miles south-southwest of Willits in the east end of the Martin Creek Planning Watershed, Inland Subbasin.

The basin's topography is diverse along its length, varying from flat estuarine environments and uplifted marine terraces to rugged mountains with high relief in the eastern portion. It is characterized by narrow ridgelines separated by deeply incised inner gorges of the major river channels and streams draining the watershed.

The western end of the drainage is distinguished by an eight mile long estuary laden with mudflats that become narrow floodplains further upriver and occupy a relatively narrow inner gorge. In contrast to most estuaries in the Pacific Northwest region, which are generally lagoonal or semi-enclosed and isolated by sand spits or bars; the Big River Estuary is long and narrow. A sand bar at the mouth partially restricts the connection to the sea at low flow periods. Tidal influence extends upward from the mouth three miles in the winter and as far as eight miles during the highest spring tides making the Big River Estuary one of the longest estuaries in northern California (Warrick and Wilcox 1981). Several freshwater marshes are found upriver, hidden from the estuary by the surrounding forest.

Inland areas of the basin are characterized by second growth forest, with some grasslands in the southeast margins. Logging of the basin started in the 1860s near the mouth and gradually moved eastward. Early logging included heavy use of splash dams, effects of which can still be seen today. Most of the basin is currently owned by large timber companies and managed for timber harvest, though the state owns some sections, and there are smaller ownerships as well.

The Big River is listed on the National Rivers Inventory, a list of potential wild, scenic, and recreational river areas within the United States maintained by the National Park Service. A section of river may be listed on the inventory if it is free-flowing and has one or more *outstandingly remarkable values*. The Big River was listed in 1982 with five outstandingly remarkable values: scenery, recreation, fish, wildlife, and history. Of the 209 rivers and river segments listed for California in 2004, only 15 had five or more outstandingly remarkable values (NPS 2004).

The basin supports runs of coho salmon and steelhead trout. Chinook salmon (*O. tshawytscha*) have been reported occasionally, but there is no significant run. Historical accounts indicate that salmon were plentiful and that salmon fishing was a common activity. However, agency reports starting in the 1950s indicate that salmonid populations were depleted and in decline. In recent years, efforts have been underway to recover salmonid stocks of the Big River Basin. For example, local residents and conservation groups recently organized and purchased a 7,342-acre parcel at the mouth of Big River from the Hawthorne Timber Company and gave it to DPR to be managed for conservation and recreation.

Subbasin Scale

For analysis and organization, the NCWAP divided the Big River Basin into three subbasins (Coastal, Middle, and Inland) comprised of a total of 16 CalWater 2.2.1 planning watersheds (Figure 10, Figure 11, Table 12). The subbasins were designated based on several attributes, including geography, geology, climate patterns, and land use. The Middle Subbasin is the smallest subbasin, at 11,424 acres and one planning watershed; the Inland Subbasin is the largest, with 83,682 acres and ten planning watersheds.

- The Coastal Subbasin is 32 square miles in area and contains the entire basin downstream of the confluence of Peterson Gulch. This subbasin contains the estuary, which is the longest undeveloped estuary in Northern California (Warrick and Wilcox 1981). Much of the land in this subbasin was recently acquired by DPR. The town of Mendocino lies just north of the river mouth, outside of the basin.
- The Middle Subbasin includes the area of the mainstem Big River just above its confluence with Peterson Gulch up until its confluence with the South Fork Big River, not including the North Fork Big River. The Middle Subbasin is the smallest of the three Big River Subbasins at 17.9 square miles. Most of the subbasin is owned by Hawthorne Timber Company and MRC.
- The Inland Subbasin includes the watershed area of the North Fork Big River, South Fork Big River, and the mainstem Big River above the confluence with the South Fork Big River. These drainages are referred to as the North Fork, South Fork, and headwaters drainages. This subbasin encompasses 130.8 square miles. Most of the subbasin is owned by the MRC, Strategic Timber Trust, and the Jackson State Demonstration Forest (JDSF) and is managed for timber production and recreation. There are also a large number of smaller privately owned parcels near the western border and the small hamlet of Orr Springs lies near the headwaters of the South Fork Big River.

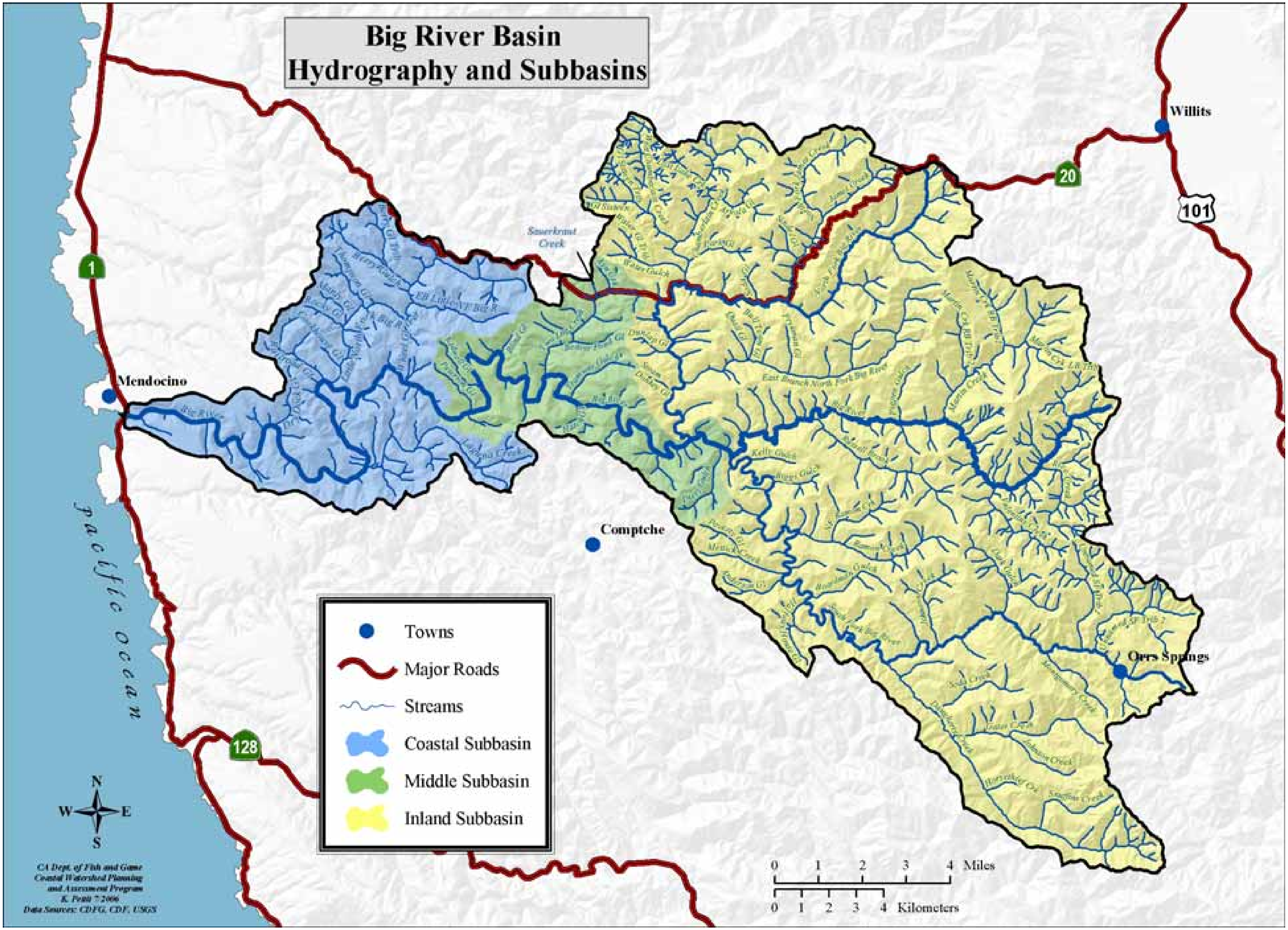


Figure 10. Big River Basin, subbasins, and streams.

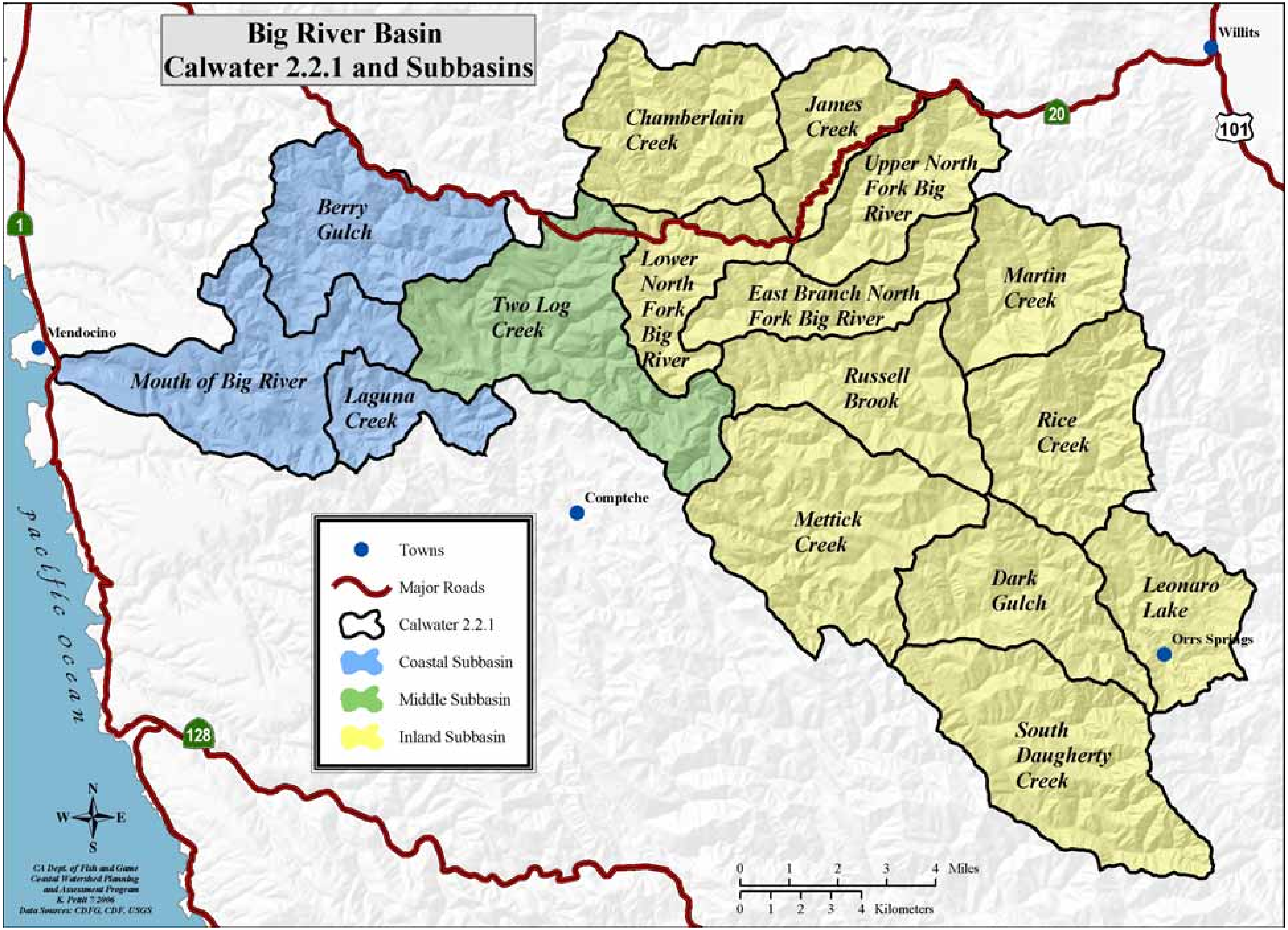


Figure 11. CalWater 2.2.1 planning watersheds, Big River Basin subbasins.

Table 12. Big River Basin and subbasin characteristics.

Attribute	Coastal	Middle	Inland	Total/Average
Square Miles	32.49	17.86	130.853	181.2
Acreage, Total	20,793	11,432	83,746	115,972
Private Land (Acres)	6,803	10,905	66,837	84,545
Public Land (Acres)	13,990	528	16,909	31,427
Low Elevation (Feet)	0	~40	~200	0
High Elevation (Feet)	1235	~1560	2836	2836
Predominant Geology	Coastal Belt Franciscan Complex	Coastal Belt Franciscan Complex	Coastal Belt Franciscan Complex, small area of Tertiary Sandstone in southeast, and Central Belt rocks in central area of eastern margin	Coastal Belt Franciscan Complex
Rainfall (Inches)	~40-55	~55-65	~45-65	~40-65
Miles of Blue Line Stream	42.4	26.0	160.6	228.5
Predominant Vegetation	Redwood-Douglas-fir	Redwood-Douglas-fir	Redwood-Douglas-fir Douglas-fir White, Black, or Live Oak Bay Laurel	Redwood-Douglas-fir Douglas-fir
Principle Communities	Near Mendocino		Orr Springs	
Predominant Land Use	Public Land Recreation Timber Harvest	Timber Harvest	Timber Harvest Grazing Recreation	Timber Harvest Public Land
Fish Habitat Available	Spawning Rearing Migration Corridor	Spawning Rearing Migration Corridor	Spawning Rearing Migration Corridor	Spawning Rearing Migration Corridor
Salmonid Species	Coho salmon Steelhead trout	Coho salmon Steelhead trout	Coho salmon Steelhead trout	Coho salmon Steelhead trout

Climate

The Mediterranean climate of the Big River Basin is characterized by a pattern of low intensity rainfall in the winter and cool, dry summers with coastal fog. Temperatures range from 20 to 100°F. Mean annual precipitation for the basin is about 50 inches and varies from about 38 inches at Fort Bragg near the western margin of the basin, to over 80 inches at the northeastern edges (Figure 13). Rainfall maps for the basin indicate that although annual precipitation generally increases as one moves towards higher elevations along the north and east parts of the basin, there are areas in the Inland Subbasin that are considerably drier (GMA 2001a). The North Fork drainage is noticeably wetter than either the South Fork or headwaters drainages. Precipitation is highly seasonal, with more than 97% falling between October and May. Snowfall occurs occasionally in the higher elevations of the basin but rarely accumulates. Snow does not have any appreciable effect on the basin's hydrology.

There are no long-term precipitation stations located in the Big River Basin and relatively few nearby. There are or were six precipitation gages located near the basin (Table 13). Only two of these gages were in operation longer then twenty years: the Fort Bragg gage, located at an elevation of 80 feet and the Willits NE gage, at an elevation of 1,925 feet. An additional gage was installed at McGuire's Pond on Highway 20 in 1995 (Station MCGC1), but these data were not available for this assessment.

Table 13. Long-term precipitation gages near the Big River Basin.

Station Name	Station Number	Period of Record	Annual Precipitation					Annual 24-Hour Maximum Precipitation				
			Average (Inches)	Maximum (Inches)	Year	Minimum (Inches)	Year	Average (Inches)	Maximum (Inches)	Year	Minimum (Inches)	Year
Willits 1 NE	F60 9685 00	1942-present*	48.13	78.71	1995	20.21	1976	4.11	7.92	1955	2.10	1999
Albion 1 NE	F 80 0077 50	1981-1993	39.04	67.60	1983	23.17	1991	NA**	NA	NA	NA	NA
Fort Bragg 5 N	F 80 3161 00	1989 - present	45.10	77.31	1998	24.47	1991	2.89	3.84	1995	1.48	1992
Fort Bragg ***	F80 3161 00	1896-1988	37.98	62.11	1983	16.56	1924	2.45	4.15	1953	1.03	1977
Russian Gulch State Park	F 80 7608 18	1988-present	41.91	71.45	1998	25.00	1991	2.87	4.43	1998	1.40	1988
Willits Munson	F 60 9685 00	1974-present ****	50.58	85.89	1983	18.84	1977	3.41	6.50	1974	1.21	1977

*Gage inactive 1982-1985, 1988, and 1989 ** NA - Not available *** No record for 24-hour precipitation 1901-1909, 1914, 1917, 1936, and 1940-1947
****Gage inactive in 1995

The mean annual precipitation at the Fort Bragg gage for the 92-year record was 37.98 inches (Figure 12). The wettest year was 1983 with 62.11 inches of rainfall, though a newer gage in Fort Bragg at a different location recorded 77.31 inches of rainfall in 1998. The driest years were 1924 and 1977 with 16.56 inches of rainfall. The mean annual precipitation at the Willits 1 NE gage for the 59-year record is 48.31 inches (Figure 14). The wettest year was 1995 with 78.71 inches of rainfall and the driest year was 1976 with 20.21 inches of rainfall.

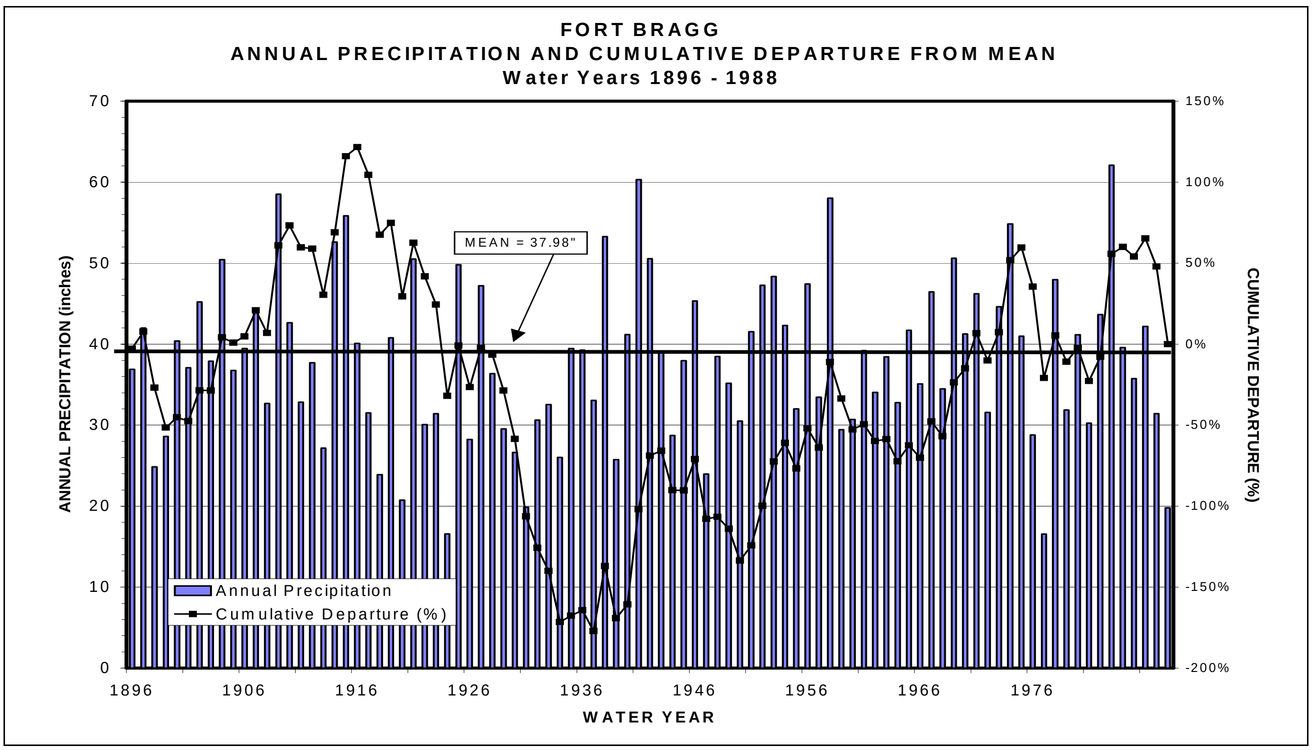


Figure 12. Annual precipitation and cumulative departure from the mean for the Fort Bragg precipitation gage, DWR Station # F80 3161 00, for the period 1886-1988.

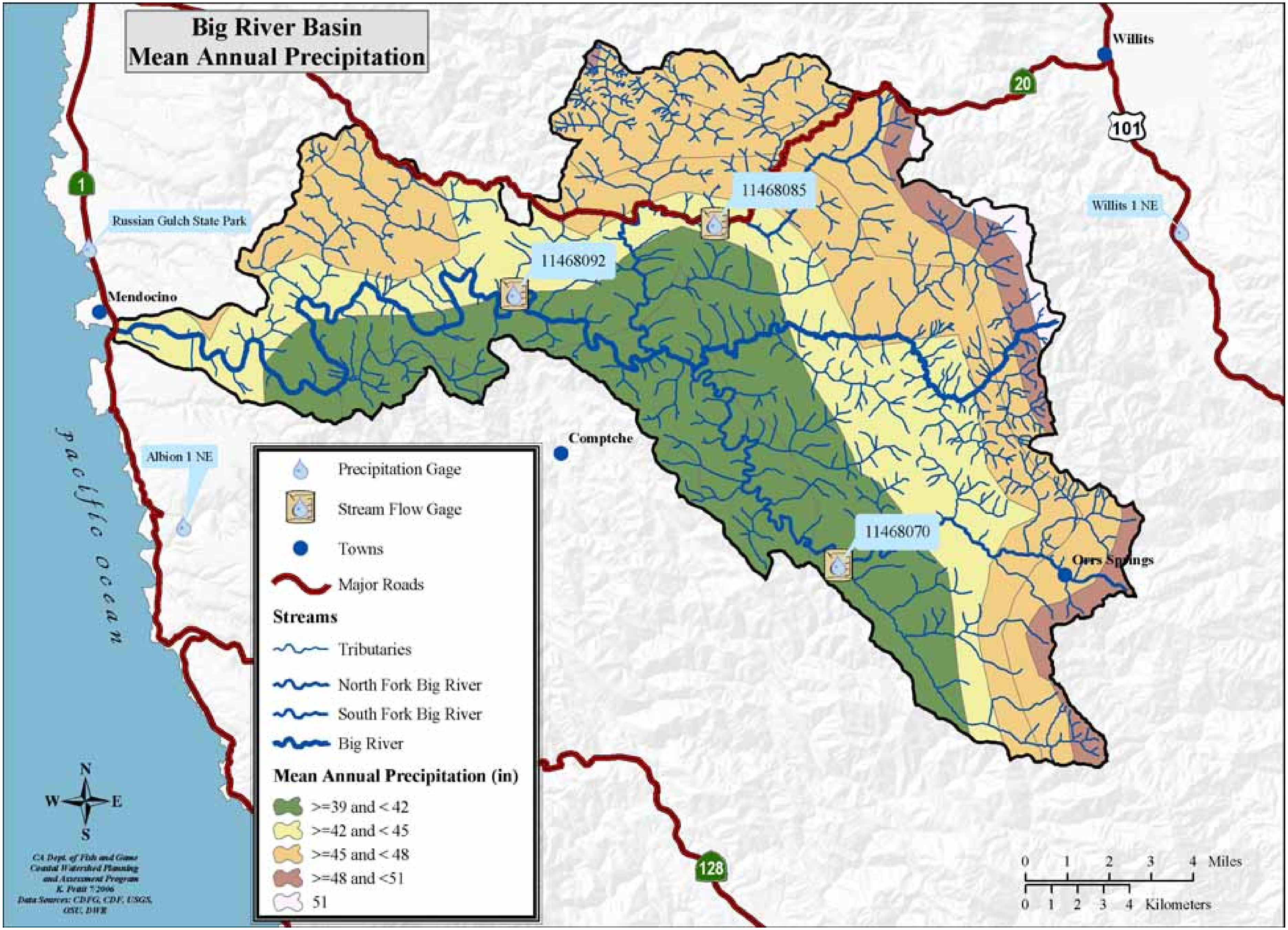


Figure 13. Big River Basin precipitation and nearby precipitation and stream flow gages.

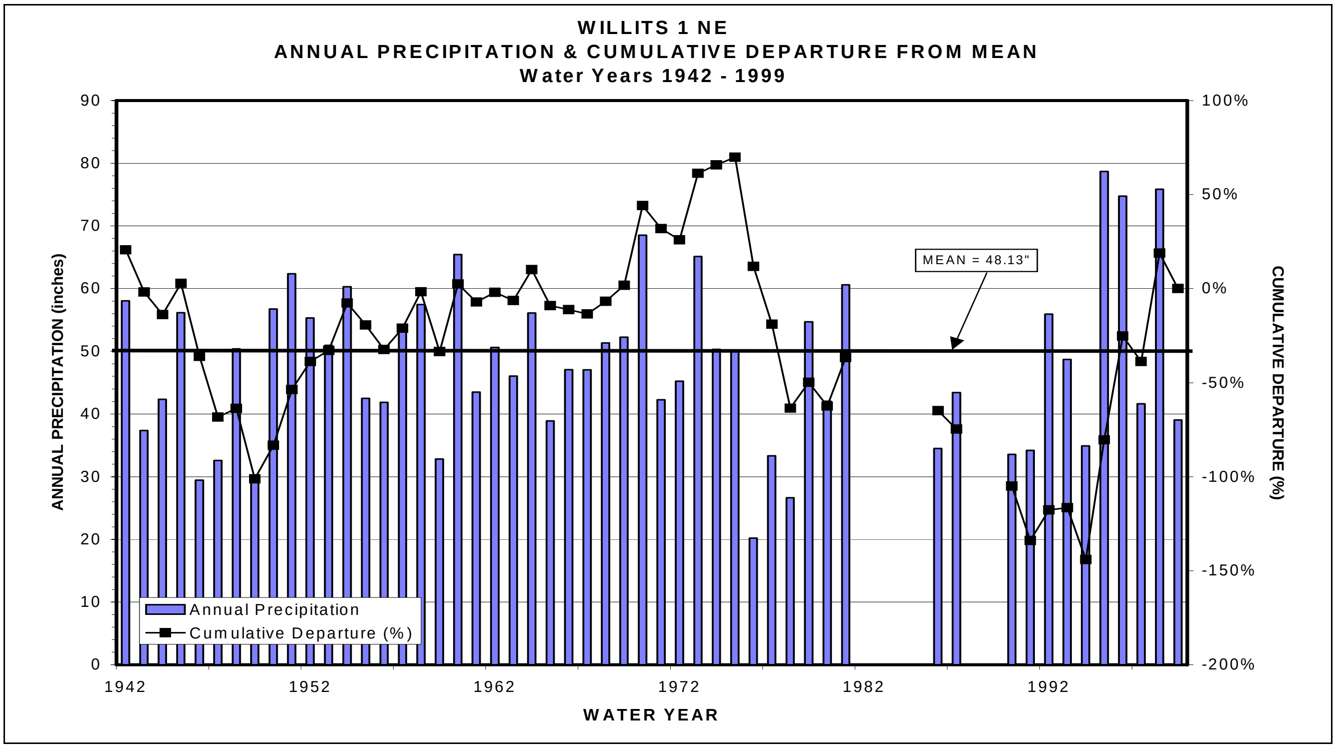


Figure 14. Annual precipitation and cumulative departure from the mean for the Willits 1 NE precipitation gage, DWR Station #F60 9685 00, for the period 1940—1999.

Hydrology

The Big River is a mid-sized coastal river with a catchment area of approximately 181.1 square miles. The mainstem becomes a fourth order stream downstream of the confluence with the North Fork Big River in the Middle Subbasin and most tributaries are intermittent or first or second order (Figure 15). North Fork Big River, South Fork Big River, and Daugherty Creek are third order streams.

The basin has many springs, most of which are cold. There is a hot spring at Orr Springs on South Fork Big River with water of 105°F (Fritz 1942).

In 1965, DWR reported that most Big River tributaries had permanent flow, though South Fork Big River usually became very low during the summer months. The mouth of the river was continuously open and had an excellent 6 mile long estuary. The mainstem Big River streambed was described as rather wide with sluggish flow throughout much of lower part of drainage. DWR estimated that flows required to maintain fishery resources were between 20 and 100 cfs, depending on the time of year (Table 14).

Table 14. DWR 1965 estimates of flow required to maintain fishery resources in the Big River.

Big River Basin Required Flows (cfs)			
Maintenance			Enhancement*
Nov 1 - April 30	May 1 - June 30	July 1 - Oct 31	Oct 1 - May 31
100	50	20	190

*Enhancement flows for June 1 to September 30 period not determined

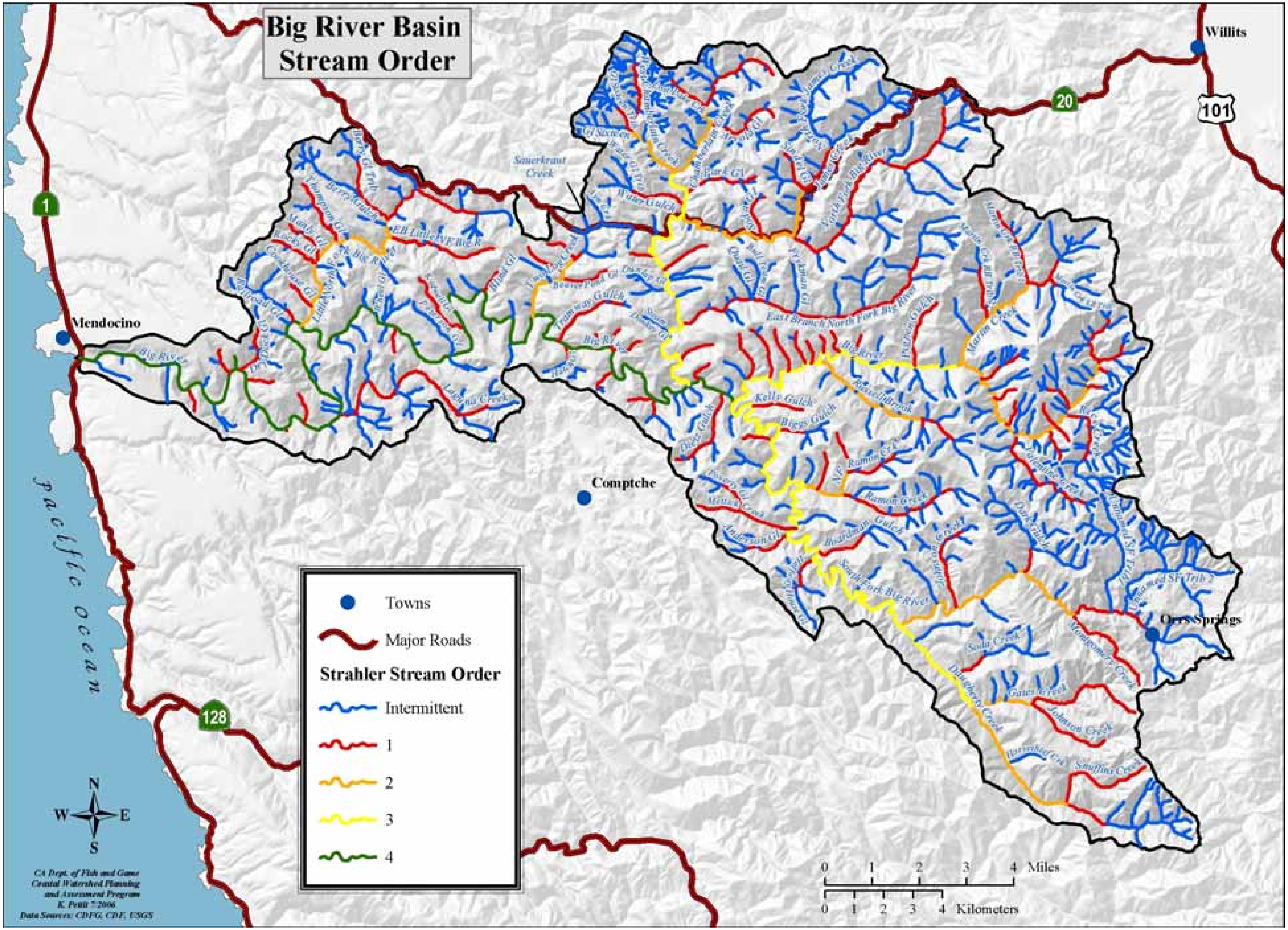


Figure 15. Stream order in the Big River Basin.

As part of a Fishery Improvement Study in 1973, USFWS (Perry 1973) measured stream flows at 20 transects in six streams and the mainstem Big River (Table 15, Figure 16). Measurements were taken bi-weekly from May 21 to July 19. In the mainstem Big River, stream flows ranged from 0.54 cfs in the headwaters in mid-July to 27.58 cfs just below the confluence with North Fork Big River in mid May. In the tributaries, stream flows ranged from 0.23 cfs in the upper reaches of North Fork Big River in mid July to 14.28 cfs in the lower reaches of North Fork Big River in mid May.

Table 15. Streamflow data collected by USFWS across the Big River Basin in 1973.

Transect	Date Measured and Flow (cfs)				
	May 21	June 5	June 19	July 5	July 19
Mainstem Big River					
Big River at Mendocino Woodlands	20.47	25.49	17.15	12.68	
Big River at Two Log Creek	21.75	19.87	--	10.44	--
Big River at South Fork Camp	27.58	22.74	16.14	12.83	9.71
Big River at Dietz Gulch	12.00	11.06	8.60	5.67	4.76
Big River at Wild Horse Opening	6.89	5.44	3.18	2.23	1.66
Big River at Upper Ranch Opening	4.72	3.32	2.67	1.64	1.37
Big River downstream from dam	2.19	1.98	1.33	1.13	0.51
Big River upstream from dam	1.04	1.33	0.83	0.57	0.54
Tributaries					
North Fork Big River downstream from East Branch North Fork Big River	14.28	9.66	8.78	5.69	--
East Branch North Fork Big River	1.16	0.93	0.90	0.67	0.46
North Fork Big River by Conservation Camp	6.73	5.22	4.16	2.95	2.41
Chamberlain Creek	--	3.18	2.26	1.50	1.12
James Creek	2.38	1.82	1.34	1.18	0.94
North Fork Big River upstream from James Creek	2.58	1.83	1.61	1.03	1.15
North Fork Big River upstream from dam	--	--	--	0.28	0.23
South Fork Big River at Biggs Gulch	10.15	6.85	--	3.37	--
South Fork Big River at Hansen School	8.63	4.14	2.55	2.31	1.45
South Fork Big River at Montgomery Creek	1.81	1.41	--	0.37	--
Martin Creek upstream from dam	2.09	1.10	1.05	0.60	0.49
Martin Creek downstream from dam	2.42	1.63	1.59	1.55	0.82

Mean Daily Discharge

Data from the Big Basin show that high flows during storms are of short duration, usually one to two days at most, and flows rapidly return to typical winter base flow within one week of peaks. Almost all significant runoff events occur between December and March (GMA 2001a).

Flow Duration

Flow duration analysis indicates that the South Fork Big River only exceeds 162 cfs 10% of the time, or 36 days per year on average, while 50% of the time flows are below 10 cfs. Flows exceed 850 cfs in the South Fork Big River only 1% of the time, or 3.6 days per year on average. It is thought that relatively little sediment transport occurs below 400 cfs, thus all of the geomorphic work accomplished by the river occurs in less than 5% of the time, with most concentrated in the top 1% of the flows (GMA 2001a).

Annual Runoff

The mean annual runoff for the 1952-1999 period was 268,700 acre-feet for the Big River downstream of Laguna Creek. Large volumes of runoff are often associated with both large flood years and years with high annual precipitation. The two largest annual runoff years were 1983 and 1974, almost 20% larger than the third largest runoff year, 1958 (Table 16). Three particularly dry periods stand out of the cumulative departure analysis, 1959-1964, 1976-1981, and 1987-1992 (GMA 2001a).

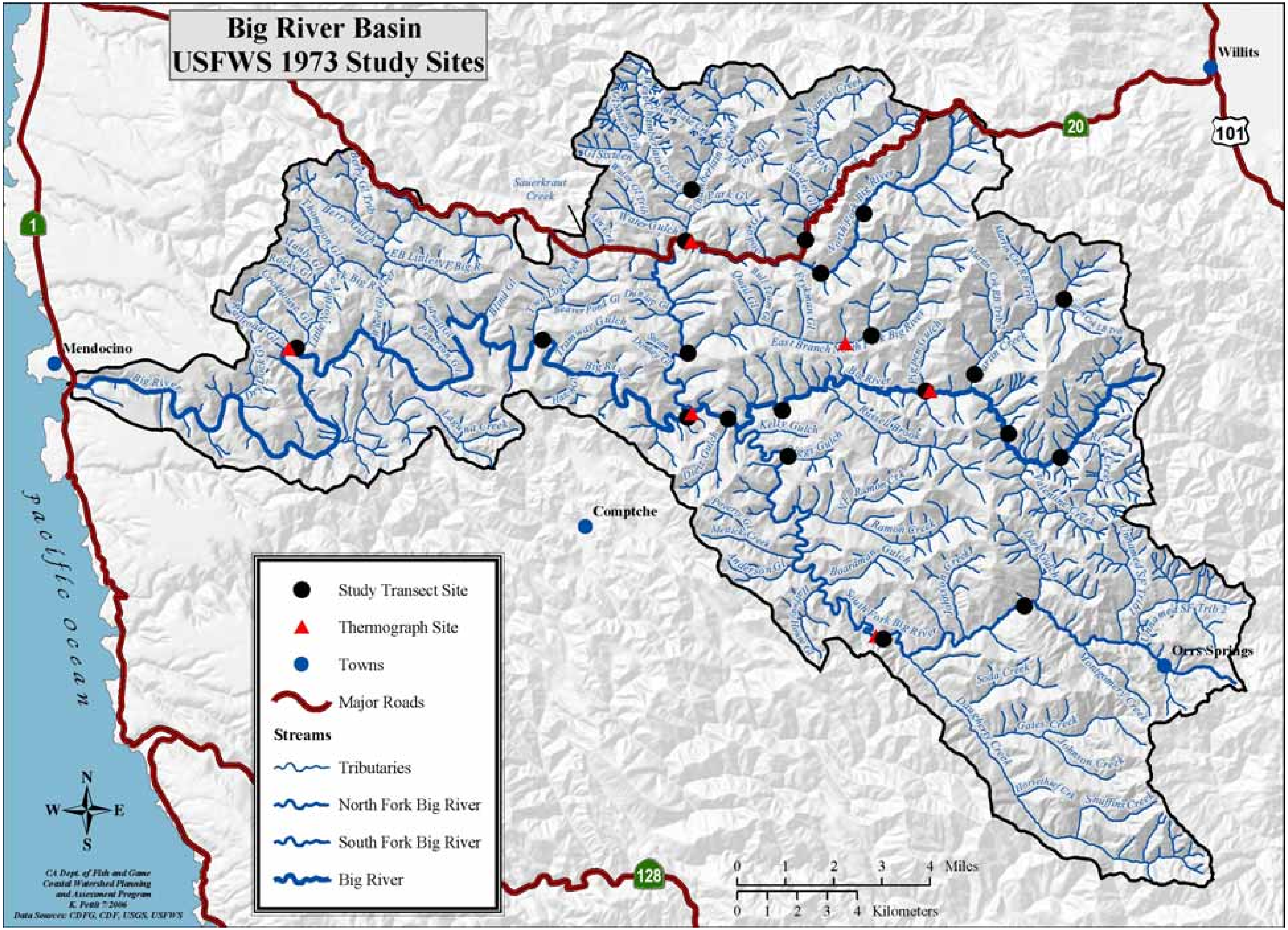


Figure 16. Map of 1973 USFWS study sites.

Table 16. Annual runoff and cumulative departure from mean Big River downstream of Laguna Creek.

Ordered Annual Runoff and Cumulative Departure Analysis			**Ranked Annual Runoff**		
Water Year	**Annual Runoff (acre-feet)**	**Cumulative Departure (acre-feet)**	**Rank**	**Water Year**	**Acre Feet**
1952	411,798	143,115	1	1983	605,738
1953	399,122	273,554	2	1974	604,938
1954	303,407	308,278	3	1958	496,178
1955	124,504	164,099	4	1998	490,197
1956	436,097	331,513	5	1982	441,812
1957	180,208	243,038	6	1995	438,182
1958	496,178	470,532	7	1956	436,097
1959	157,377	359,226	8	1965	415,298
1960	190,508	281,052	9	1952	411,798
1961	210,594	222,962	10	1993	401,344
1962	168,623	122,902	11	1953	399,122
1963	259,423	113,642	12	1969	367,778
1964	143,593	(11,448)	13	1986	347,194
1965	415,298	135,167	14	1996	331,960
1966	216,568	83,052	15	1997	329,279
1967	257,789	72,158	16	1971	327,536
1968	156,118	(40,407)	17	1999	327,081
1969	367,778	58,688	18	1970	325,966
1970	325,966	115,971	19	1975	322,231
1971	327,536	174,824	20	1954	303,407
1972	142,215	48,357	21	1978	298,910
1973	288,762	68,435	22	1973	288,762
1974	604,938	404,690	23	1984	277,042
1975	322,231	458,239	24	1963	259,423
1976	108,076	297,632	25	1967	257,789
1977	13,694	42,643	26	1980	256,537
1978	298,910	72,870	27	1966	216,568
1979	133,964	(61,849)	28	1989	216,206
1980	256,537	(73,995)	29	1961	210,594
1981	116,377	(226,301)	30	1960	190,508
1982	441,812	(53,173)	31	1957	180,208
1983	605,738	283,883	32	1985	173,447
1984	277,042	292,242	33	1962	168,623
1985	173,447	197,005	34	1959	157,377
1986	347,194	275,516	35	1968	156,118
1987	140,666	147,499	36	1990	145,129
1988	135,469	14,286	37	1964	143,593
1989	216,206	(38,192)	38	1972	142,215
1990	145,129	(161,745)	39	1987	140,666
1991	75,101	(355,327)	40	1988	135,469
1992	99,042	(524,967)	41	1979	133,964
1993	401,344	(392,306)	42	1955	124,504
1994	87,704	(573,286)	43	1981	116,377
1995	438,182	(403,786)	44	1976	108,076
1996	331,960	(340,509)	45	1992	99,042
1997	329,279	(279,913)	46	1994	87,704
1998	490,197	(58,399)	47	1991	75,101
1999	327,081	0	48	1977	13,694

After GMA 2001a
Mean 268,683 Maximum 605,738 Minimum 13,694
Note: Annual Runoff Data Derived from Synthetic Data

Peak Discharge

The largest recorded peak discharge for the South Fork Big River occurred in December 1964, when the river crested at 8,200 cfs (USGS). USGS peak discharge records are available for an 11-year period, 1961-1971 (Figure 17), and 1974.

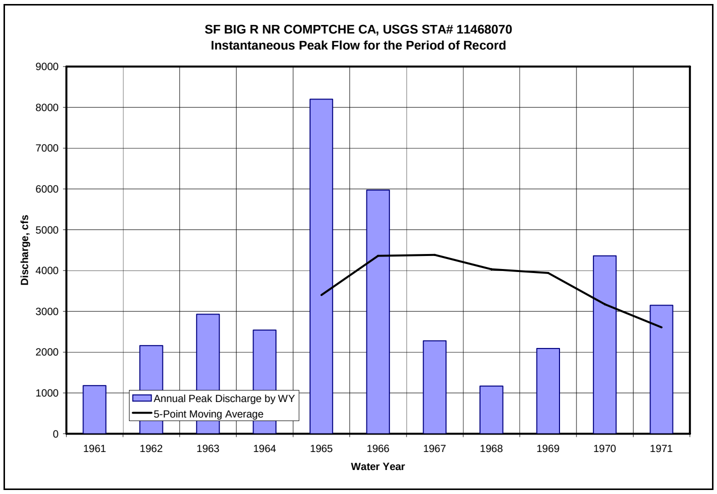


Figure 17. Annual instantaneous peak discharge and 5-year moving average for South Fork Big River near Comptche, USGS station #11468070, for Water Years 1961 – 1971.

In addition, GMA (2001) developed synthetic peak discharges for the South Fork Big River using peak correlation analysis between the Noyo River Basin and the Big River Basin in order to extend the record. Analysis showed that although the highest peak flows in the neighboring Noyo and Albion basins occurred during a January 1974 (water year 1974) storm event, this storm was not nearly as significant an event in the South Fork Big River. In fact, the correlation analysis estimated that the 1974 peak flow for the South Fork Big River should have been 68% larger than USGS data showed. No explanation for this disparity is currently available, although it indicates possible inaccuracies in available data. Precipitation intensity records for Fort Bragg are also inconsistent with the recorded magnitude of the 1974 peak discharge. A comparison of 1-day precipitation intensities with peak discharge indicates that 1-day precipitation does not appear to be the driving force behind Big River peak flows (GMA 2001a).

Significant storm flows, those in excess of 5,000 cfs, in the extended period of record occurred mostly in the months of December and January, with one event occurring in March 1986 (water year 1986). Peak discharges estimated for the entire Big River Basin based on a correlation with the Noyo record indicated that the January 1974 flood would have been the largest in the synthetic dataset, followed by December 1964 and January 1993 (Table 18) (GMA 2001a).

Flood Frequency

A flood frequency analysis by GMA (2001) for available data in the Big River Basin indicated that the January 1974 (5,250 cfs) flood would be about a 45-year event, while flows similar to December 1964 (2,540 cfs) would be about a 35-year event. The 2-year event is almost 12,000 cfs for the entire basin (Table 17).

Table 17. Mainstem Big River 3-parameter log-normal flood frequency analysis for the combined historic and synthetic 1952-2001 period of record (after GMA 2001a).

Return Period (years)	Computed Annual Maximum Peak Discharge(cfs)
2	11,900
5	22,100
10	30,100
20	38,700
50	51,000
100	61,300

A similar analysis by GMA (2001) for the South Fork Big River near Comptche site only indicated that the December 1964 flood would have been just smaller than a 50-year event, while the January 1974 flood would have been only a 10-year event.

Historic Floods

Although the Big River has a relatively short period of streamflow records, GMA (2001) was able to infer the dates of significant floods with regional data. Known large flood events in the region, many of which would also have occurred in Big River Basin, occurred in water years 1861, 1881, 1890, 1907, 1914, 1938, 1952, 1956, 1965, 1966, 1974, 1986, and 1993. The largest of these were likely to have been the 1861 and 1890 events, followed by the 1914, 1938, 1965, and 1974 events (not necessarily in that order by magnitude).

During the period of available synthetic streamflow records, 1974 stands out as a year with high peak flow and long duration of those flows (Table 19). This is similar to adjacent Noyo, Albion, and Caspar Creek basins, but considerably different from the Ten Mile basin and most coastal watersheds further north. In the Big River Basin, the January 1974 event appears to have been the most significant in the past 50, and perhaps 100, years.

Table 18. South Fork Big River USGS gage #11468070 peak discharges and annual maximums.

Rank	Water Year	Peak Discharge (cfs)	Probability	Recurrence Interval (years)
1	1965	8200	0.020	49.00
2	1993	7655	0.041	24.50
3	1956	7287	0.061	16.33
4	1966	5970	0.082	12.25
5	1952	5282	0.102	9.80
6	1974	5250	0.122	8.17
7	1986	5149	0.143	7.00
8	1970	4360	0.163	6.13
9	1953	4283	0.184	5.44
10	1995	4017	0.204	4.90
11	1960	3950	0.224	4.45
12	1954	3851	0.245	4.08
13	1983	3618	0.265	3.77
14	1997	3618	0.286	3.50
15	1982	3385	0.306	3.27
16	1971	3150	0.327	3.06
17	1963	2930	0.347	2.88
18	1996	2795	0.367	2.72
19	1958	2699	0.388	2.58
20	1980	2656	0.408	2.45
21	1964	2540	0.429	2.33
22	1975	2408	0.449	2.23
23	1967	2280	0.469	2.13
24	1962	2160	0.490	2.04
25	1969	2090	0.510	1.96
26	1998	1945	0.531	1.88
27	1973	1869	0.551	1.81
28	1990	1638	0.571	1.75
29	1985	1566	0.592	1.69
30	1978	1467	0.612	1.63
31	1959	1394	0.633	1.58
32	1989	1361	0.653	1.53
33	1984	1279	0.673	1.48
34	1972	1227	0.694	1.44
35	1957	1207	0.714	1.40
36	1955	1197	0.735	1.36
37	1961	1180	0.755	1.32
38	1968	1170	0.776	1.29
39	1988	1158	0.796	1.26
40	1976	1141	0.816	1.23
41	1981	984	0.837	1.20
42	2001	965	0.857	1.17
43	1994	800	0.878	1.14
44	1987	790	0.898	1.11
45	1979	774	0.918	1.09
46	1992	683	0.939	1.07
47	1991	510	0.959	1.04
48	1977	48	0.980	1.02

After GMA 2001a
Ranked with computed recurrence intervals based on the Weibull formula (historic and synthetic data)
Historic USGS data
GMA (2001) data
GMA (2001) synthetic data from peak correlation

Diversions, Dams, and Power Generation

There are five licensed, permitted, or pending water rights within the Big River Basin. This number does not include riparian users and other diversions that are not registered with the State Division of Water Rights. No major dams or power generating facilities are located within the basin.

Appropriative water right permits exist for a total of about 8.5 acre-feet per year of water from the Big River Basin, at a maximum diversion rate of about 16,820 gallons per day. Additionally, there is a right for one acre-foot per year for storage. The four appropriative water rights are for the South Fork Big River or an unnamed tributary to the South Fork, while the storage water right is located on a tributary to Laguna Creek in the Coastal Subbasin.

No major dams or power generating facilities are located within the Big River Basin. Four sites were considered for possible fisheries enhancement impoundments by US Bureau of Reclamation in 1973 (USBR 1973). The sites were located on the mainstem Big River, North Fork Big River, and Martin Creek.

Table 19. Big River data for assessing event magnitude. Data sources sorted and ranked with top 20 values listed.

Annual Runoff			**Peak Discharge**			**Annual Precipitation**				**1-Day Precipitation Intensity**				
Big River below Laguna Creek			**Big River near Mendocino**			**Willits**		**Fort Bragg 5N**		**Willits**			**Fort Bragg**	
Rank	Water Year	Annual Runoff (ac-ft)	Rank	Water Year	Peak Discharge (cfs)	Water Year	Annual Precipitation (inches)	Water Year	Annual Precipitation (inches)	Rank	Water Year	1-Day Precipitation (inches)	Water Year	1-Day Precipitation (inches)
1	1983	605,738	1	1974	47,900	1958	92.82	1998	77.31	1	1965	8.80	1953	4.15
2	1974	604,938	2	1965	43,200	1904	89.30	1983	62.47	2	1938	7.61	1939	4.05
3	1958	496,178	3	1993	41,600	1938	87.62	1941	60.32	3	1906	7.07	1995	3.84
4	1998	490,197	4	1956	39,600	1983	86.48	1995	58.61	4	1914	6.50	1979	3.78
5	1982	441,812	5	1966	34,600	1879	85.46	1909	58.52	5	1947	6.50	1990	3.78
6	1995	438,182	6	1952	28,800	1890	84.51	1958	58.02	6	1960	6.46	1938	3.70
7	1956	436,097	7	1986	28,100	1974	76.39	1915	55.85	7	1974	5.90	1937	3.62
8	1965	415,298	8	1970	23,900	1998	75.93	1974	54.84	8	1952	5.87	1969	3.58
9	1952	411,798	9	1953	23,400	1995	74.44	1938	53.29	9	1943	5.78	1958	3.52
10	1993	401,344	10	1995	22,000	1956	72.71	1914	52.61	10	1951	5.50	1966	3.52
11	1953	399,122	11	1960	21,600	1982	72.33	1993	51.54	11	1986	5.50	1965	3.49
12	1969	367,778	12	1954	21,100	1941	71.88	1969	50.62	12	1963	5.40	1915	3.42
13	1986	347,194	13	1983	19,800	1909	71.13	1942	50.53	13	1956	5.33	1996	3.30
14	1996	331,960	14	1997	19,800	1895	70.28	1921	50.52	14	1969	5.21	1998	3.30
15	1997	329,279	15	1982	18,500	1894	68.57	1904	50.43	15	1940	5.20	1971	3.23
16	1971	327,536	16	1969	16,700	1925	66.23	1925	49.78	16	1990	5.20	1993	3.23
17	1999	327,081	17	1971	16,300	1942	65.99	1997	49.71	17	1913	5.13	1913	3.10
18	1970	325,966	18	1996	15,300	1969	65.69	1953	48.36	18	1966	5.10	1956	3.07
19	1975	322,231	19	1958	14,800	1986	65.61	1978	47.95	19	1979	5.06	1994	3.06
20	1954	303,407	20	1980	14,600	1978	65.56	1956	47.41	20	1932	5.05	1997	3.06

After GMA 2001a
Peak Discharge was obtained by Correlation Analysis
Annual Runoff Data are Synthetic for all Years
Annual Precipitation and Intensity Data from Goodridge (1999)

Geology

The Big River Basin is mainly located on the coastal side of the Mendocino Range, which is the western-most mountain range of the northern California Coast Ranges Geomorphic Province. The topography of the basin varies from a relatively flat estuary and uplifted terraces, forming part of the Mendocino plateau (Fox 1983) on the western most portion, to the mountainous interior and eastern portion of the basin. The more subdued terrain of the western step-like marine terraces merges with the sharply dissected interior to the east. Erosional remnants of the plateau appear in the basin as scattered flat ridge tops and approximately accordant summits. Elevations range from near sea level in the western portion of the basin stepping up through a series of uplifted marine terraces to approximately 2,725 feet in the mountainous eastern portion.

The rocks of the Coast Ranges formed in deep ocean bottom and continental slope environments between about 140 and 28 million years ago (Harden 1998). Oceanic sediments and volcanic rocks were accreted to North America along the tectonic subduction zone that was present at that time (Blake and Jones 1974, 1981). The irregular folding and faulting of the rocks during this period of tectonic mixing created the resultant irregular relationship between varying rock types that is typical of the Franciscan Complex. Portions of the Franciscan Complex with similar geology are grouped into belts and further subdivided into terranes. The Coastal Terrane (broken formation) of the Cretaceous-Tertiary Coastal Belt of the Franciscan Complex forms the bedrock under most of basin with the eastern most portion composed of the more pervasively sheared and disrupted Jurassic-Tertiary Central Belt Franciscan mélange (Figure 18). Central Belt terrain generally underlies topographically subdued grassland or open forest. The Franciscan rocks are overlain by Tertiary marine sandstone in the southeastern portion of the basin.

Bedrock is locally overlain by surficial materials of marine and river terrace deposits, estuarine deposits and alluvium related to modern channel deposits, landslides, and beach and older dune sands. Several levels of alluvium and terrace deposits, present most notably in the western part of the watershed, and remnants of the Mendocino plateau in the interior indicate that much of this watershed has been uplifted relatively recently. This, coupled with the relatively flat, staircase like arrangement of terraces, incised preexisting drainages and u-shaped valleys indicate an early stage of maturity for the western portion of the watershed grading in to a fully mature topography on the eastern portion of the basin (Kilbourne 1986).

The geology and regional tectonics directly influence the nature of the slopes and the types and rates of landslides present. Landslide features are widespread in the watershed. The dominant form of mass wasting varies depending on the composition of the underlying rock. Generally, the Coastal Terrane Franciscan Complex has a greater clay component in the western part of Big River Basin than farther to the east. The degree of penetrative shearing is also more intense to the west. Finally, the cessation of watercourse incision due to sea level rise has more of an effect near the mouths of the streams than in the headwater areas. As a consequence, the slopes in the western part of the basin are less steep with more mature topography than they are to the east. Deep-seated rockslides (rotational/translational landslides) are more common in the middle and eastern portion of the basin than in the western most portions. Additionally, earthflows are more abundant in the eastern part of basin (underlain by mélange terrane) when compared with the areas to the west.

Bedrock

The entire basin is underlain by rocks of the Coastal Franciscan Complex except for a Tertiary age sandstone in the Greenough Ridge – Montgomery Woods State Park area. Within the basin, the Franciscan occurs as two distinct bedrock units: the relatively coherent (stable) Tertiary to Cretaceous age Coastal Belt terrane and the relatively incoherent (easily eroded) Tertiary to Jurassic age Central Belt terrane.

Coastal Belt Terrane

Rocks of the Franciscan Coastal Belt terrane are characterized by sandstone and interbedded siltstone and shale, with locally minor amounts of conglomerate present. Elsewhere chert, limestone, and greenstone are found. Coastal Belt rocks have been deformed by past tectonic activity. This has created a body of rock that has been broken up into coherent bedrock blocks of varying size (up to city blocks or larger) separated by shear zones and faulting; locally the bedrock is tightly folded.

Central Belt Terrane

Central Belt rocks crop out in the central area of the eastern margin of the basin. They underlie the subdued topography in portions of that area.

The Central Belt is a mélange characterized by blocks of bedrock, varying in size from fist size pieces to blocks up to city blocks or larger in size, in a highly sheared, mashed, and mangled clayey matrix. The blocks of bedrock can include sandstone, conglomerate, chert, greenstone, blueschist, limestone, eclogite, serpentine, amphibole, and ultramafic rocks. The subdued nature of the hillside topography overlying the central belt is a result of the weak nature of the sheared mélange matrix.

Tertiary Sandstone

These rocks crop out in the southeastern area of the Big River Basin. They are mapped to underlie Greenough Ridge and on to the southeast into Montgomery Woods State Park. These sandstones are well consolidated and interbedded with minor amounts of conglomerate and limestone. They are described as gently folded and thick bedded.

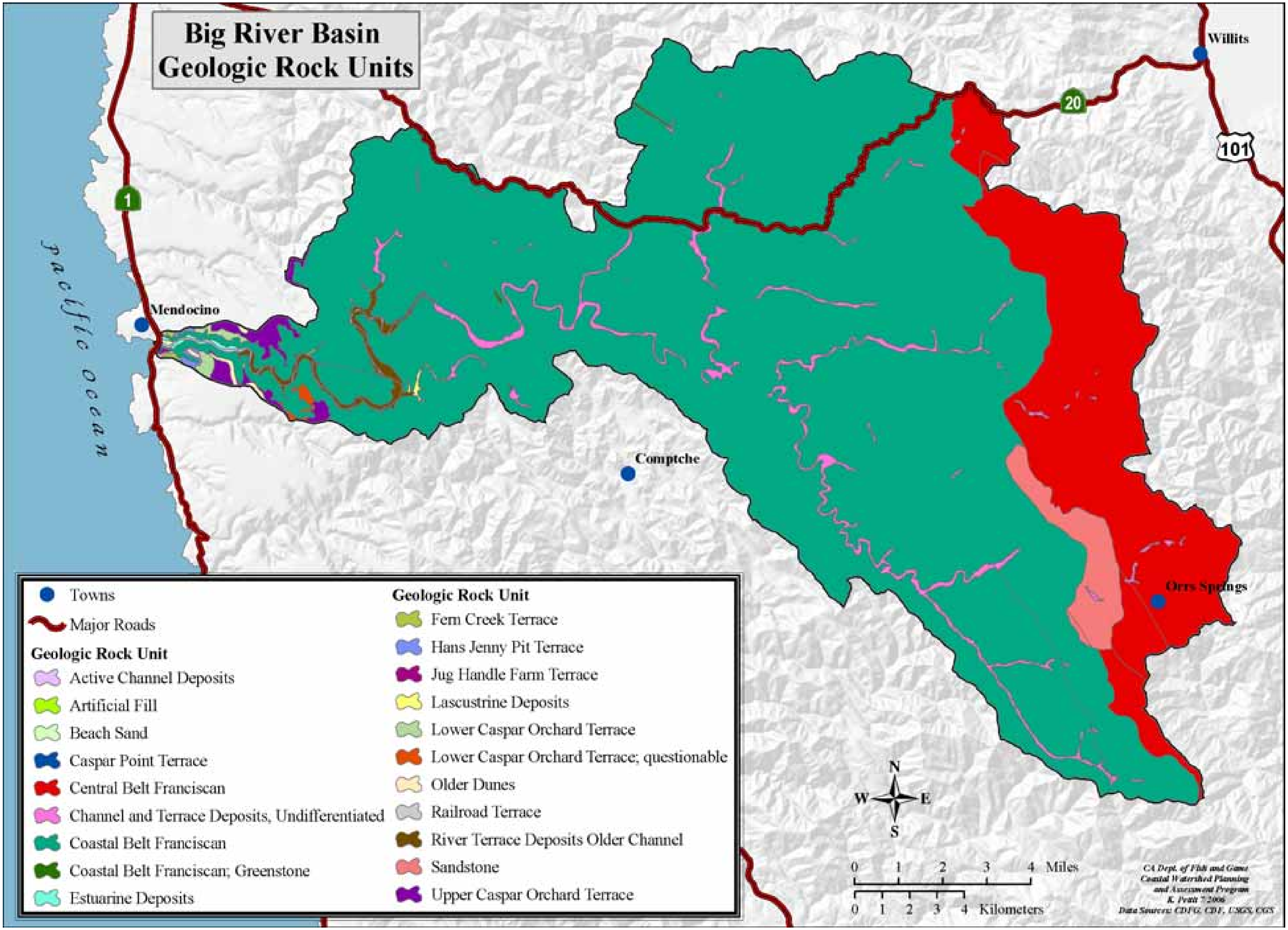


Figure 18. Geology of the Big River Basin.

Faulting, Seismicity, and Regional Uplift

The Big River Basin is located along the coastal side of the Mendocino Range, which lies along the active boundary between the Pacific and North American plates. The Pacific plate is moving northwards at a much faster pace than the North American plate, which is moving northwest. At present, most movement between the plates consists of the plates sliding past one another. The plate boundary also has a component of convergence - along which a series of northwest trending mountain ranges and active fault zones have developed. The primary active fault zone along the plate boundary is the San Andreas Fault located approximately four miles west of the mouth of Big River. This fault is a right-lateral strike slip fault and has been calculated to move 50 millimeters a year over the past three to four million years. Active uplift of the Coast Range continues at a rate of approximately 30 centimeters per 100 years in the Big River area (CGS 2004).

Slope Classes

A slope analysis of the basin was conducted by GMA (2001) using GIS data provided by the CDF. The Coastal, and to a lesser extent the Middle, subbasins contain a higher percentage of area of lower relief than the Inland Subbasin (Table 20). The Coastal and Middle subbasins have 44% and 37%, respectively, in slopes less than 31%, while the Inland Subbasin has 23% in this category. In the steeper slope classes, the Coastal and Middle subbasins have 19% and 25% with slopes exceeding 50%, respectively, and the Inland Subbasin has 34%.

Table 20. Slope classes in the Big River Basin.

Slope Class (%)	Coastal Subbasin		Middle Subbasin		Inland Subbasin		Big River Basin Total	
	Acres	%	Acres	%	Acres	%	Acres	%
0 -15	4,126	20	1,332	12	4,281	5	9,738	8
16 - 30	4,892	24	2,804	25	15,468	18	23,164	20
31 - 50	7,858	38	4,483	39	35,746	43	48,087	42
51 - 65	2,685	13	1,802	16	17,279	21	21,767	19
Over 65	1,209	6	1,001	9	10,891	13	13,101	11
Total	**20,770**	**100**	**11,422**	**100**	**83,664**	**100**	**115,856**	**100**

The low gradient valley floors and the small fragments of marine terraces in the Coastal Subbasin are seen in Figure 19, with the green colors of the lowest slope classes. Similarly, the red color for slopes exceeding 70% is visible in the headwaters areas, as well as the Lower South Fork PW, and at inner gorge locations along the narrow, incised drainages (GMA 2001a).

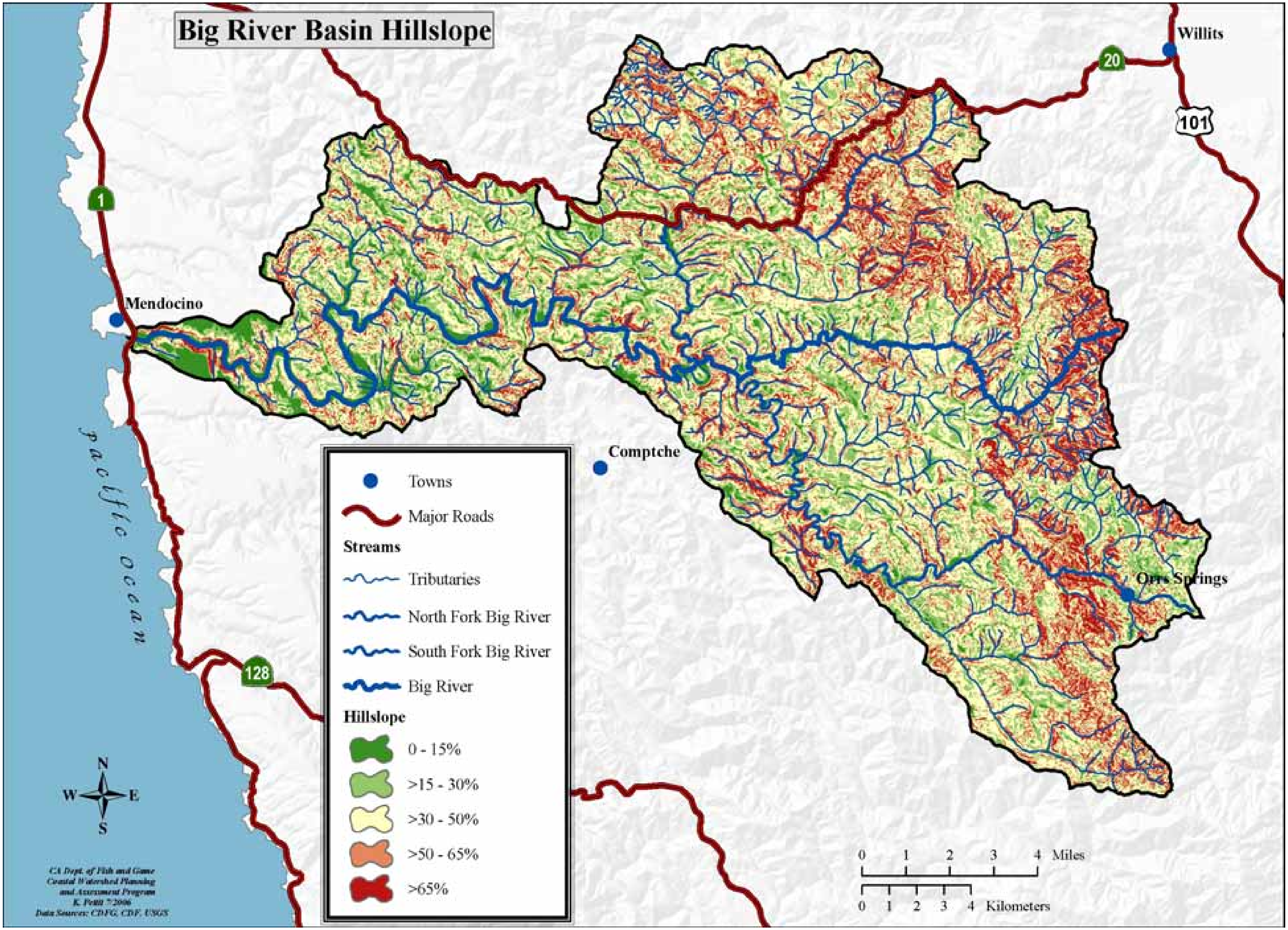


Figure 19. Slope class identification map.

Sediment Source Analysis

GMA (2001) conducted a sediment source analysis for the Big River Basin. Their sediment analysis consisted of three components:

- Evaluation of the dominant geomorphic processes that deliver sediment to stream channels;
- Measurement of parameters, such as landslide size/type/associated landuse, road length, and harvest areas from aerial photography;
- Selection of factors to complement, modify, and/or extend the photo-based measurements, thus allowing computation of results.

Sources of sediment in the basin include landsliding, surface erosion, and fluvial erosion.

Landsliding

Historic Analysis

GMA (2001) examined six sets of aerial photos from 1936, 1952, 1965, 1978, 1988, and 2000 for their landslide analysis. However, the photo set from 1936 was incomplete and is not discussed here (please see GMA 2001a for further details of 1936 data). They originally mapped 3,000 unique landsliding features across the basin and 488 features that were judged to be delivering sediment in more than one time period. GMA then eliminated questionable features and non-delivering landslides from further analysis. This resulted in a database of 2,037 unique landslide features across the basin.

Most mapped slides were debris slides. Landslides were most frequent in 1952 followed by 1965 (Table 21). Several large flood events, as measured by peak discharge, also occurred during these time periods. In addition, three of the highest 1-day precipitation intensities in the 102-year period of record occurred in the 1952 time period. Landsliding has been shown to be related to short term precipitation intensity in nearby Caspar Creek (Cafferata and Spittler 1998).

Table 21. Big River Basin number of delivering landslides by type and period.

Type	1952		1965		1978		1988		2000		Total all features	
	#	%	#	%	#	%	#	%	#	%	#	%
Debris Torrents	135	15.5	123	16.4	344	83.2	14	6.1	20	7.6	318	13.3
Earthflows	35	4.0	23	3.1	95	12.9	12	5.2	12	4.5	93	3.9
Rotational/ Translational	3	0.3	4	0.5	10	0.04		0.0		0.0	9	0.4
Slides	698	80.1	598	79.9	2220	3.6	203	88.6	232	87.9	1964	82.4
TOTALS:	**871**	**36.5**	**748**	**31.4**	**229**	**9.6**	**264**	**11.1**	**272**	**11.4**	**2384**	**100.0**

From GMA 2001a

GMA describes a trend of decreasing numbers of landslides since the peak number in 1952. Only 11.4% of all mapped slides occurred from 1989 through 2000. Higher slide frequencies appeared to coincide with periods of more intense landuse activities such as extensive timber harvest and road building following World War II. The decreased number of slides in recent years coincides with a period of reduced timber harvest and new forest management policies.

An examination of the landslide distribution amongst subbasins shows that the Inland Subbasin had the most slides in every period of study (Table 22). This is expected because of the Inland's larger area.

Table 22. Big River Basin number of delivering slides by study period and subbasin.

Subbasin	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total all periods	
	#	%	#	%	#	%	#	%	#	%	#	%
Coastal	106	12.2	77	10.3	10	4.4	23	8.7	32	11.8	248	10.4
Middle	49	5.6	69	9.2	22	9.6	25	9.5	30	11.0	195	8.2
Inland	716	82.2	602	80.5	197	86.0	216	81.8	210	77.2	1941	81.4
Total	**871**	**36.5**	**748**	**31.4**	**229**	**9.6**	**264**	**11.1**	**272**	**11.4**	**2,384**	**100**

GMA found that inner gorge slopes were not the most common origin for landslides across the basin. Analysts found that 22.2% (453) of the unique slides were inner gorge slides; 71.5% of these slides occurred before 1965 (Table 23). Most of the inner gorge landslides occurred in only three PWs, Lower South Fork, Middle Big

River, and the Lower North Fork PWs. This reflects the dominance of inner gorges in the main channels of the basin.

Table 23. Number and volume (in tons) of inner gorge landslides in the Big River Basin by subbasin and study period.

Subbasin	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		TOTAL	
	#	tons	#	tons	#	tons	#	tons	#	tons	#	tons
Coastal	19	70,044	19	44,827	4	4,825	3	7,056	4	7,643	49	134,396
Middle	12	41,006	33	129,430	12	23,799	10	21,874	5	3,465	72	219,574
Inland	139	417,083	102	262,451	20	35,069	25	52,848	46	49,530	332	816,980
Total	**170**	**528,134**	**154**	**436,708**	**36**	**63,692**	**38**	**81,778**	**55**	**60,639**	**453**	**1,170,951**

After GMA 2001a

Estimates of landslide volumes across the study periods showed a trend towards significantly reduced sediment volume delivered by landslides since 1989 compared to historic periods (GMA 2001a). Of the total volume of sediment delivered during the study period, 53% occurred from 1937 to 1952, 29% occurred from 1953 to 1965, and only 18% occurred after 1966. By 2000, the volume of slides was reduced to 6% of the 1937-2000 total. Most of the sediment volume was delivered in the Inland Subbasin (Table 24).

Table 24. Volume of delivering slides by study period by subbasin.

Subbasin	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	(% f or Entire Watershed For Entire Period)
Coastal	474,045	11.9	130,376	5.9	28,643	8.2	50,041	9.1	114,463	23.8	797,567	10.5
Middle	114,506	2.9	271,379	12.3	40,550	11.6	58,623	10.7	25,398	5.3	510,455	6.7
Inland	3,395,141	85.2	1,813,452	81.9	279,205	80.1	441,695	80.3	341,248	70.9	6,270,742	82.7
Total	**3,983,692**	**52.6**	**2,215,207**	**29.2**	**348,398**	**4.6**	**550,359**	**7.3**	**481,109**	**6.3**	**7,578,764**	**100**

After GMA 2001a

Similar to the trend in decreasing number of landslides in the period of study, GMA (2001) found a significant decrease in the volume delivered by landslides (Table 25).

Table 25. Number, total volume, and average volume of slides by period.

Category	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total
	#	%	#	%	#	%	#	%	#	%	
Number of slides	871	32.6	748	28.0	229	8.6	264	9.9	272	10.2	2,384
Total Volume (tons)	3,983,692	47.4	2,215,207	26.3	348,398	4.1	550,359	6.5	481,109	5.7	7,578,764
Average Volume (tons)	4,573		2,961		1,521		2,084		1,768		3,179

GMA 2001a

GMA calculated the average annual unit area volumes of sediment production by study period (2001) (Table 26). The overall sediment delivery from landsliding for the study period was estimated to be 664 tons/square mile/year. The lowest delivery for the entire basin was from 1966 to 1978, while the highest was from 1937 to 1952. This time period is not associated with any of the five largest storms during the study period; however, three of the seven highest 1-day precipitation intensities occurred. Following the 1965 period, there has been a decline in landslide delivery.

Table 26. Rate of delivering slides by study period by subbasin (tons/square mile/year for period).

Subbasin	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	Total
Coastal	912.5	308.9	67.9	154.1	293.8	389.9
Middle	400.9	1169.5	174.7	328.4	118.6	453.4
Inland	1,623.2	1067.1	164.3	337.9	217.5	761.2
Total	**1,375.2**	**941.2**	**148.0**	**304.0**	**221.4**	**664.3**

GMA 2001a

GMA (2001) investigated the Montgomery Woods State Reserve in greater detail than the rest of the basin in order to ascertain what natural background rates of landsliding might be for this area. The Reserve is small, but relatively undisturbed. GMA's study of background landsliding rates found no signs of recent mass wasting. GMA noted that their result could be confounded by the small area of the reserve and the underlying geology, Tertiary Sandstone, which is more stable than mélange and possibly more stable than the Coastal Belt of the Franciscan Formation.

Current Mapping

CGS finished a map of active and dormant landslides across the basin in 2005 (Figure 22). Historically active landslides have moved within approximately the past 150 years. Most landslides were in the Inland Subbasin and most landslides were dormant (Figure 20).

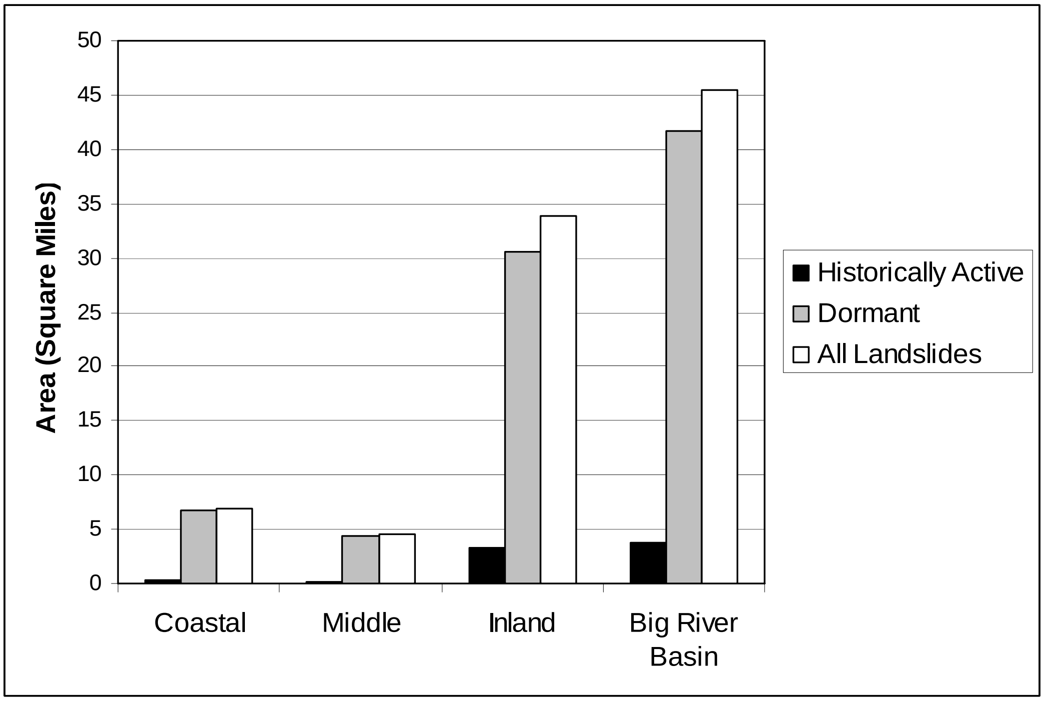


Figure 20. Map of historically active and dormant landslides across the Big River Basin (CGS 2005).

Landslide Potential

CGS completed a landslide potential map of the basin in 2005. Over 50% of the basin is in the high and very high landslide potential classes (Figure 20). The Coastal Subbasin has are higher percentage area in the very low and low landslide potential categories, while the Inland Subbasin has a higher percentage area in the higher landslide potential categories (Figure 21).

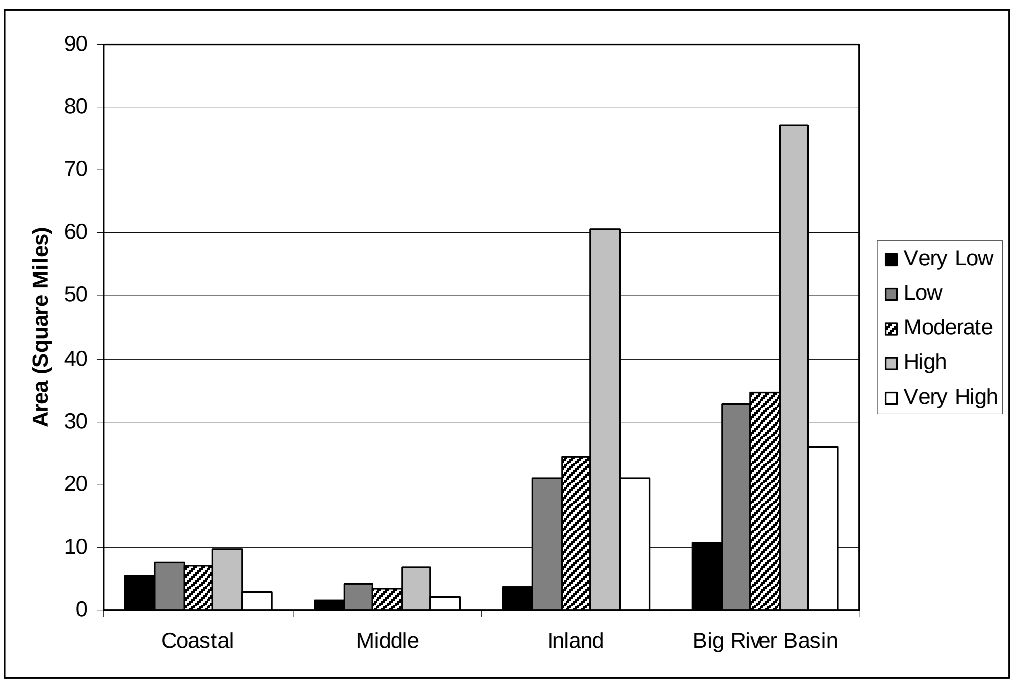


Figure 21. Area of each subbasin assigned to landslide potential categories (CGS 2005).

Fluvial Geomorphology

Channel Entrenchment

A CDF study of the Jackson Demonstration State Forest (JDSF) found that streams were often not connected to floodplains and off-channel areas (CDF 1999). Surveys by CDF showed that channels in North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, and James Creek PWs are particularly affected by channel entrenchment (GMA 2001a).

CGS mapped (2005) the location and length of inner gorges throughout the basin (Figure 23). Inner gorges are geomorphic features consisting of steep slopes adjacent to channels. These inner gorges have formed along 14.6% of the blueline streams across the basin and were most common along blueline streams in the Inland Subbasin (Table 27). To look at the distribution of inner gorges across the basin, the percentage of inner gorge length along blueline streams in each subbasin was compared to the percentage of total blueline stream. Inner gorges did not appear to be evenly distributed, with less in the Coastal and Inland subbasins and more in the Middle Subbasin.

Table 27. Inner gorges in the Big River Basin.

Subbasin	Length of Inner Gorges (miles)	% of Length Along Blueline Streams	% of Total Basinwide Inner Gorge Length	% of Blueline Stream in Basin
Coastal	21.4	<1	30.2	16.9
Middle	1.5	3.3	2.1	9.2
Inland	48.8	13.6	69.0	74.0
Big River Basin	70.8	14.6	100	100

CGS 2005

Bankfull Discharge

CGS (2004) estimated bankfull discharge at a cross-section on the mainstem Big River at RM 8.7 using various methodologies. Floodplain identifiers suggested that bankfull discharge at the cross-section was 83 feet wide and 8 feet in mean depth. The estimate for bankfull discharge that CGS found most reliable was 5,600 cfs. CGS's bankfull discharge estimates are less than the bankfull discharge estimated by GMA (2001) and used in their Sediment Source Analysis. Thus, the GMA estimates of sediment discharge may be significantly overestimated. However, due to the exploratory nature of CGS's study, GMA results should not be rejected at this time. Further studies of bankfull width need to be conducted (CGS 2004).

Alluvial Sediment Storage

GMA (2001) found that fluvial-induced changes in alluvial sediment storage from 1936 to 2000 were relatively small. Non-alluvial channel boundaries in steep valleys, together with entrenched channel geometry and stable banks due to dense streamside forests reduce sediment storage opportunities across the basin. GMA found that much of the sediment that reaches entrenched channels in the basin is flushed into low gradient areas of the lower mainstem Big River over relatively short periods of time.

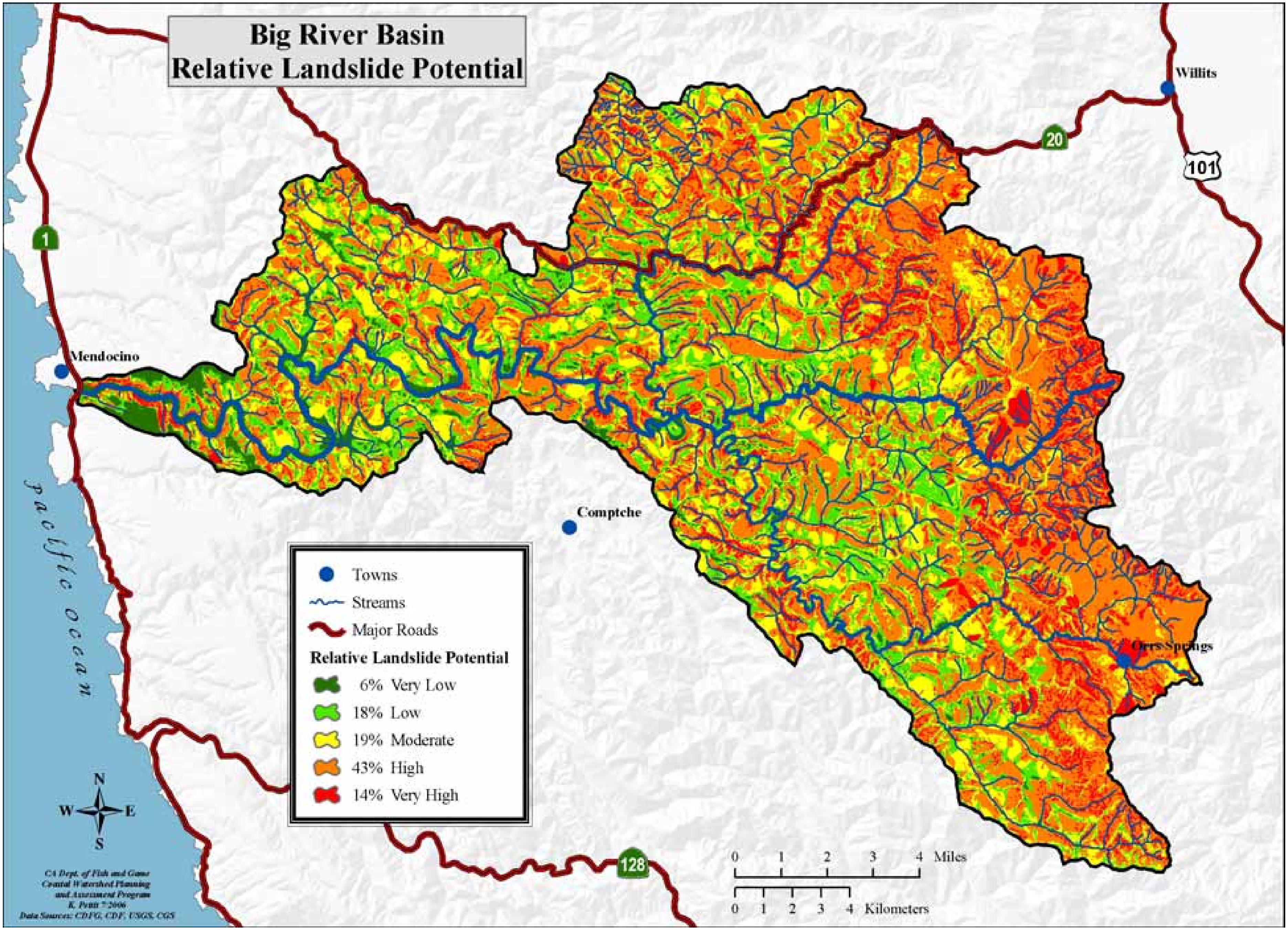


Figure 22. Landslide potential map for the Big River Basin (CGS 2005).

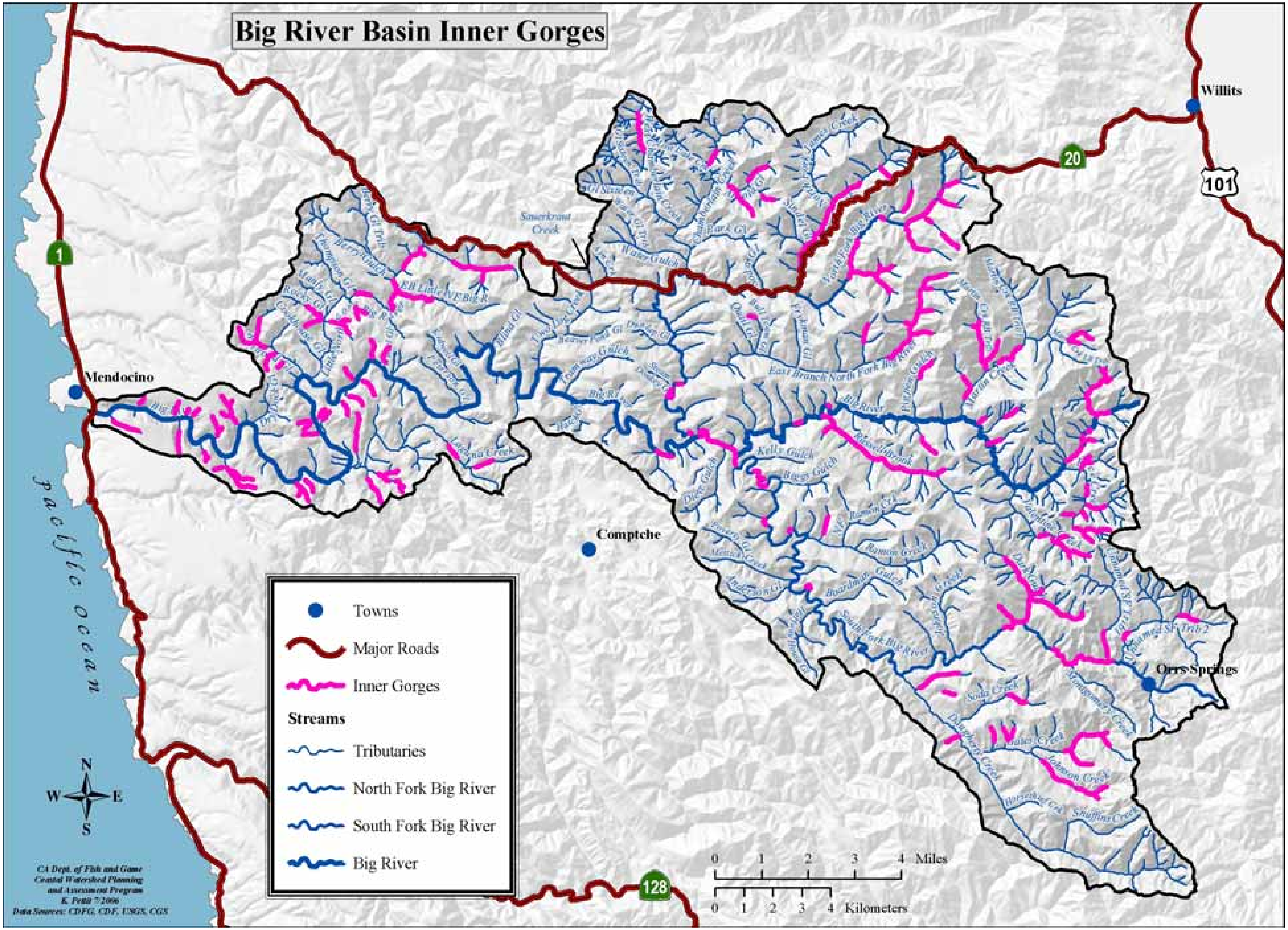


Figure 23. Inner gorges in the Big River Basin (CGS 2005).

Stream Gradient

CGS studied the distribution of stream gradients in the Big River Basin. Tributaries are steeper (>10%) than the main channels (Figure 24). The steeper gradients are source and transport reaches while the lower gradient channels are depositional reaches, which tend to accumulate and store channel sediment, including fine material trapped in interstices of gravel bars. These lower gradient reaches can become reaches of channel widening, decreased shading, and increased stream temperatures. The mainstem channel is especially low in gradient near the mouth of the Big River, <0.1%. Low-gradient reaches accumulate sediment and take longest to recover from channel disturbance.

Mappable Channel Features

CGS mapped and compiled fluvial features in several major channels within the Big River Basin from 1984 and 2000 air photos (Figure 25). General improvement between these years in the mainstem of the Big River, the North Fork, the South Fork, and Daugherty Creek were noted. Improvement was indicated by an overall net decrease in streamside erosion and accumulated bedload sediment (Figure 26). In spite of overall improvement, lower gradient reaches of the lower mainstem channel and estuary deteriorated, gaining elevated sediment. These are sites of accumulation and presumably aggradation. CGS (2004) found that deposition in estuary reaches is likely related to stream channels re-adjusting to a more natural discharge regime after the effects of splash damming (See the Coastal Subbasin for more details).

In 1984, CGS mapped 269 channel features of various lengths in major channels (Table 28). The features included both stable and unstable gravel bars, widened channels, and eroding banks. The total length of these mappable features was 26.5 miles, and 68% of the features by length indicated channel disturbance. Disturbance was represented by such things as lateral bars, mid-channel bars, eroding banks, and widened channels (about 18 miles in total length).

Between 1984 and 2000, major channel conditions generally improved as indicated by the decrease in the total number of mappable in-channel features from 269 to 221. The corresponding decrease in the total length of features was from 26.5 miles to 20.1 miles (Table 28). This represents a 24.2% reduction. Sixty-five percent (13 miles) of the mapped features in 2000 indicated channel disturbance. The net decrease in total mappable features was accompanied by, and partly accomplished by, the movement of bedload sediment to more stable in-channel features between 1984 and 2000.

Table 28. List showing number and total lengths in miles of mappable channel features in major channels, Big River Basin.

Date	Negative Sediment				All Sediment		Blue-Line Streams
	Length of Negative Sediments	% of Blue-Line Stream Network by Length	% of total Sediment Features by Length	# Negative Features	Length of All Sediments	# Total Features	Length in miles
Major Channels							
1984	17.9	3.7	67.7	219	26.5	269	485.9
2000	13.1	2.7	65.1	145	20.1	221	
North Fork							
1984	1.2	8.3	79.5	18	1.5	22	14.9
2000	1.1	7.6	62.1	13	1.8	22	
Mainstem Big River							
1984	12.0	28.2	63.5	113	18.9	155	42.6
2000	8.9	20.8	61.6	77	14.4	130	
South Fork							
1984	4.1	18.8	100.0	68	4.1	68	21.9
2000	2.5	11.6	74.6	48	3.4	63	
Daugherty Creek							
1984	2.1	23.8	95.8	25	2.2	26	8.7
2000	0.5	5.8	100.0	6	0.5	6	
Lower Mainstem							
1984	2.8	18.5	34.8	16	8.2	28	15.4
2000	5.3	34.7	66.5	24	8.0	40	

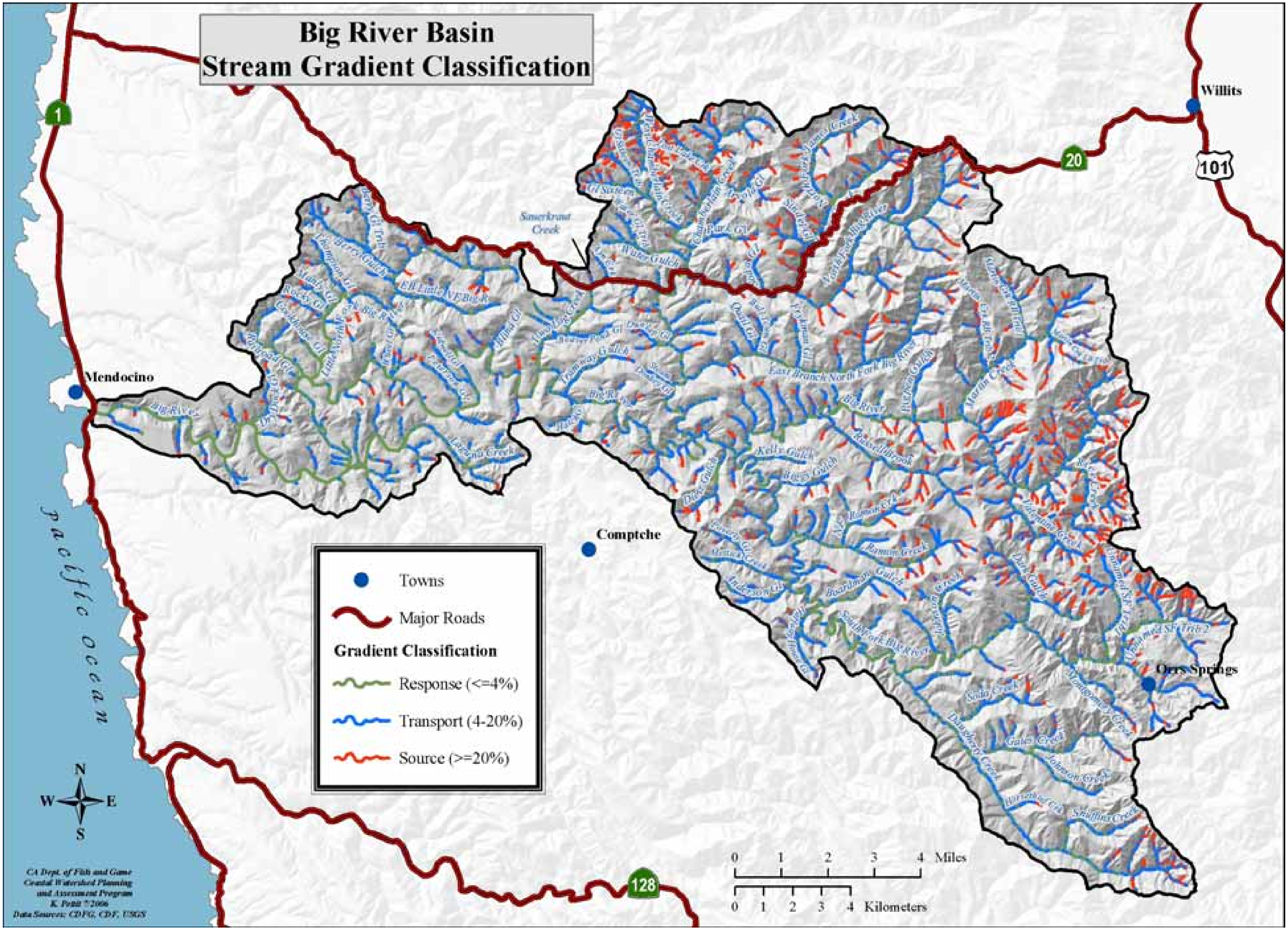


Figure 24. Stream gradients in the Big River Basin.

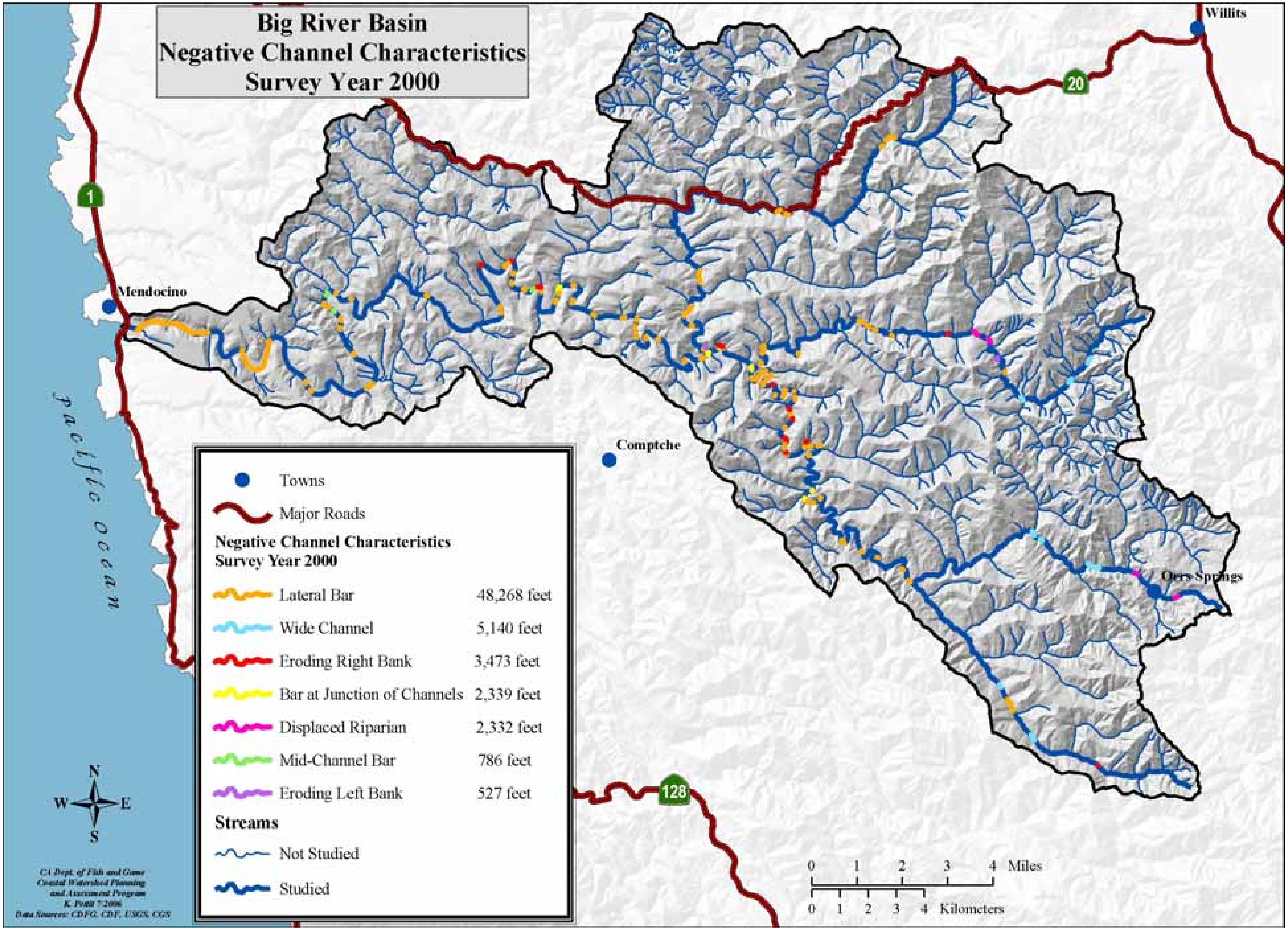


Figure 25. Mapped negative channel characteristics survey year 2000.

These characteristics may indicate excess sediment production, transport, and/or deposition in 2000 in major channels within the Big River Basin including the mainstem, North Fork, and South Fork Big River, and Daugherty Creek.

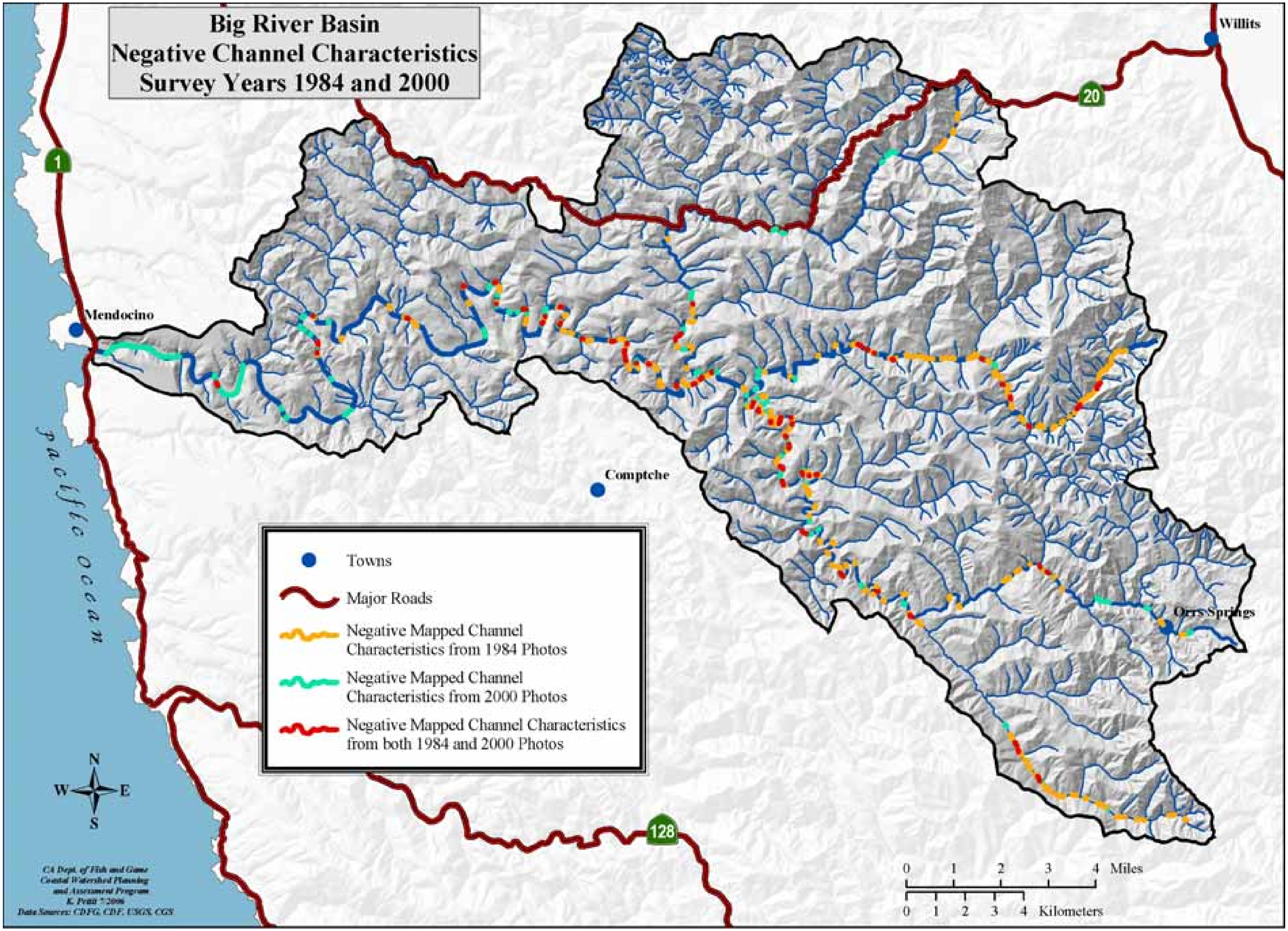


Figure 26. Mapped negative channel characteristics survey years 1984 and 2000.

These characteristics may indicate excess sediment production, transport, and/or deposition in 1984 and 2000 in major channels within the Big River Basin including the mainstem, North Fork, and South Fork Big River, and Daugherty Creek.

From 1984 to 2000, sediment accumulated preferentially in the lower 15 miles of the Big River where channel gradient is lowest. In the 1970s, a sand bar at the mouth of the Big River partially constricted water flow, and tidal water intruded into the channel 8.3 miles during the highest spring tides, making this the longest estuary in northern California at that time. CGS does not know the extent of vertical aggradation in the estuary nor does CGS know how the apparent accumulation of sediment in the estuary affected estuarine habitat between 1984 and 2000. Previous studies indicated that before 1984, the estuary was already greatly affected by accelerated deposition of sediment, which (1) created natural levees confining the channel, (2) cut off the marshes from salt water, (3) filled in sloughs, and (4) restricted the wetted area of the estuary. Previous studies suggested that the infilling of the estuary was accelerated in the late 1800s, concurrent with early timber harvest in the basin.

The mainstem channel is especially low in gradient near the mouth of the Big River. Such low-gradient reaches accumulate sediment and take longest to recover from channel disturbance. Major channel disturbances were probably caused by large storms during the 1950s through early 1980s, failures of older streamside roads, and downstream transport and accumulation of sediment stored in the mainstem and tributary channels. Areas of more unstable geology and more erodible geologic units tend to contribute more sediment to the stream network in tons per square mile. The disproportionate contribution from unstable areas is most apparent following large storms and wet years, such as 1983. Our 1984 photo mapping shows more mappable sediment stored in the channel. Further analysis of 1984 in-channel features with respect to hillslope geomorphology would show the spatial and temporal distribution of channel sediment with respect to geologic features.

Mainstem of the Big River

The mainstem channel generally improved above the estuary between 1984 and 2000. In 1984, mappable negative channel features occupied 28% of the blue-line stream length along the mainstem channel. In 2000, negative features occupied 21% (Table 28).

The lowest part of the mainstem channel accumulated sediment in the lowest gradient reach (<0.1%), within the Mouth of Big River PW (Figure 24). This area contains nearly one-third of the 43-mile total length of the mainstem channel, including about 8 miles of tidally influenced estuary.

Lower gradient stream reaches, such as the reach within the Mouth of the Big River Planning Watershed, take the longest to recover from channel disturbance. Their recovery rates are on the order of 50 years to centuries. In contrast, steeper tributary channels can take 5-10 years, or something on the order of decades, to recover from disturbance.

Vegetation

Prior to large scale timber harvest starting in the mid-1800s most of the Big River Basin supported mature coniferous forest, though original stands exist only in small areas today. Currently, redwood forests dominate the basin, but give way to Douglas-fir and oak woodlands in the upper elevations (Figure 27). Redwood in the Big River Basin typically occurs with Douglas-fir as a stand component, rather than occurring in pure stands. The Coastal Subbasin has the highest percentage of area in redwood-Douglas-fir stands (91%) and the Inland Subbasin has the least (68%), (Table 29).

Table 29. Acreage and proportion of area of vegetation classes in subbasins.

Class	Coastal		Middle		Inland		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Redwood - Douglas-fir	18,824	91	9,652	85	56,893	68	85,369	74
Douglas-Fir			219	2	10,991	13	11,210	10
Tan Oak, Madrone, Alder	363	2	1,032	9	4,521	5	5,916	5
White, Black or Live Oak & Bay Laurel			40		5,256	6	5,296	5
Blueblossom Ceanothus	645	3	150	1	62	0	857	1
Manzanita, Chamise, Scrub Oak					1,171	1	1,171	1
Bishop Pine, Pygmy Cypress, Willow	429	2			0	0	429	
Grass	283	1	180	2	4,749	6	5,212	4
Wet Meadows	31				0	0	31	
Water	176	1			0	0	176	
Barren / Rock	26		151	1	40	0	217	
Urban/Developed	2				0	0	2	
Totals	**20,779**	**100%**	**11,424**	**100%**	**83,683**	**100%**	**115,886**	**100%**

Douglas-fir does occupy some pure stands and, in an inverse ecological trend to redwood, the range is from none in the Coastal Subbasin to 13% of the area in the Inland Subbasin. In the Coastal and Middle subbasins the redwood-Douglas-fir type is predominant, but in the Inland Subbasin, redwood occupies the lower portion of the gulches and changes to drier species such as Douglas-fir and the oaks and grasslands up slope. Overall, hardwoods occupy about 20% of the basin and grasslands about 4%. Blueblossom (C*eanothus spp.*) and pampas grass are found in the Coastal and Middle subbasins and are usually a result of landscape disturbances.

Small sized trees that average 12-24 inches diameter at breast height (dbh) cover 62% of the basin (Table 30). Stands that average greater than 24-inch dbh trees cover 31.3% of the area, pole-sized trees cover 5.5%, and sapling-sized trees cover 0.9%. The Coastal Subbasin has the most acres of stands that average greater than 24-inch dbh trees, which may be a result of higher year-round precipitation. Most of the basin has a crown canopy density of over 80% (Table 31).

Table 30. Acres and percentage of vegetation in different size classes in the Big River Basin by subbasin.

Subbasins	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Coastal	413	2.1	653	3.3	9,071	46.2	9,162	46.7	317	1.6
Middle	64	0.6	317	2.9	7,647	69.9	2,872	26.2	42	0.4
Inland	476	0.6	4973	6.4	50763	65.4	20640	26.6	812	1.0
Total Big River Basin	**954**	**0.9**	**5,942**	**5.5**	**67,481**	**62.4**	**32,675**	**30.2**	**1,171**	**1.1**

Table 31. Density of vegetation in the Big River Basin by subbasin.

Subbasins	Percent Crown Canopy Density										Total Acres
	0%		10-69%		70%		80%		90%		
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	
Coastal	1,163	6	1,379	7	4,546	22	3,705	18	9,984	48	20,779
Middle	482	4	720	6	2,237	20	1,550	14	6,436	56	11,424
Inland	4,563	6	5,731	8	11,908	16	13,162	18	38,761	52	74,124
Total Big River Basin	**7,665**	**7**	**9,862**	**9**	**19,762**	**17**	**21,264**	**18**	**57,334**	**49**	**115,888**

Total density of all species - conifers and hardwoods. Most of the 0 percent density crown canopy is grasslands, water, and shrub species.

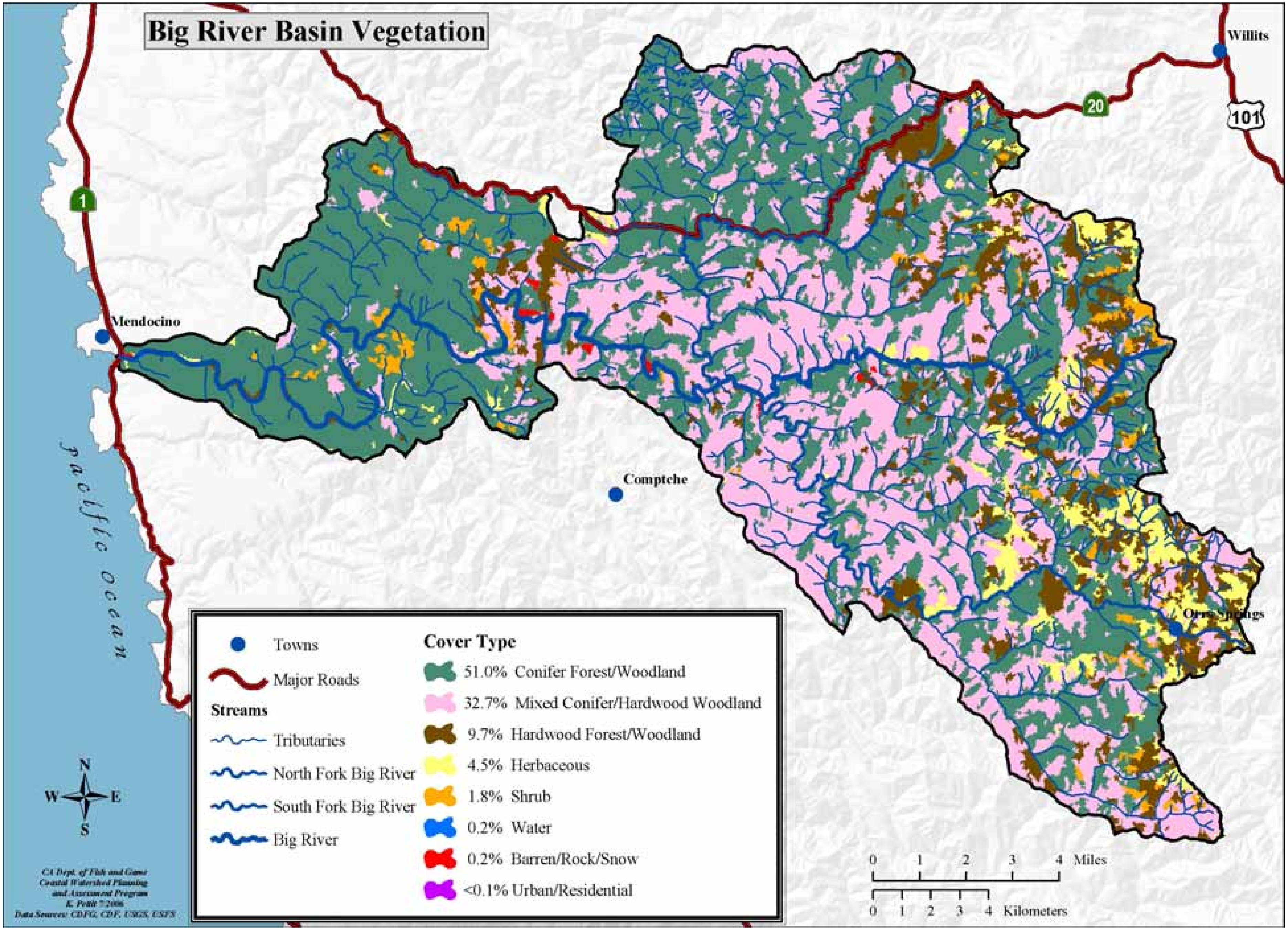


Figure 27. Big River Basin vegetation classes.

Fire History

Native Americans used fire as a land management tool. Specific practices and fire history are not known for all of the Big River Basin but information is available from research on the Jackson Demonstration State Forest (JDSF). This information indicates that redwood forests on the Mendocino Coast had a fire frequency of about 6 to 20 years during the 400 years prior to European settlement (Brown et al. 2003). Including surface fires, this burning interval is higher than previously reported in some studies, in part because of the tendency of redwood to obscure fire scarring. There was no clear trend of increasing fire frequency or intensity with increased distance inland from the coast. Most fires occurred during the late season of September through November when coastal fog generally dissipates and forest conditions are driest. These fires are thought to have been primarily started by Native Americans as a land management tool, clearing brush and providing a desirable landscape for their activities. As in the rest of the Big River Basin, JDSF wildfire activity ceased in the 1930s following the establishment of well-organized fire suppression forces.

There are five recorded wildfires in the Big River Basin in CDF records (Figure 28). The two largest were the 1931 Comptche wildfire and the 1950 Irene Peak wildfire. The Comptche fire was apparently ignited from slash piles and driven by high temperatures, low relative humidity, and strong northerly winds, the fire swept across the bordering Albion Basin and large sections of the Middle and Inland subbasins. There were actually several heads of the fire as residents frantically set back-fires to protect their property and families (Downie et al. 2003). Totaling about 29,600 acres, the fire destroyed homes and livelihoods, incinerated standing timber, the remains of the old log dams, railroad ties, trestles, and abandoned logging camps.

Current vegetation is the result of fire history in addition to timber harvesting and grazing. Interviews of nearby residents indicated that many ranchers burned the same areas every two or three years to keep the poison oak and brush down and logging slash was routinely burned after the original harvests. Management plans submitted by private landowners often state that range burning ceased in the 1960s.

Fire severity and hazard models generated by CDF indicate that fires have the ability to burn through large acreages and to severely damage both upslope and riparian areas. The fire hazard map (Figure 28) is strongly influenced by the current vegetation and proximity of residential housing.

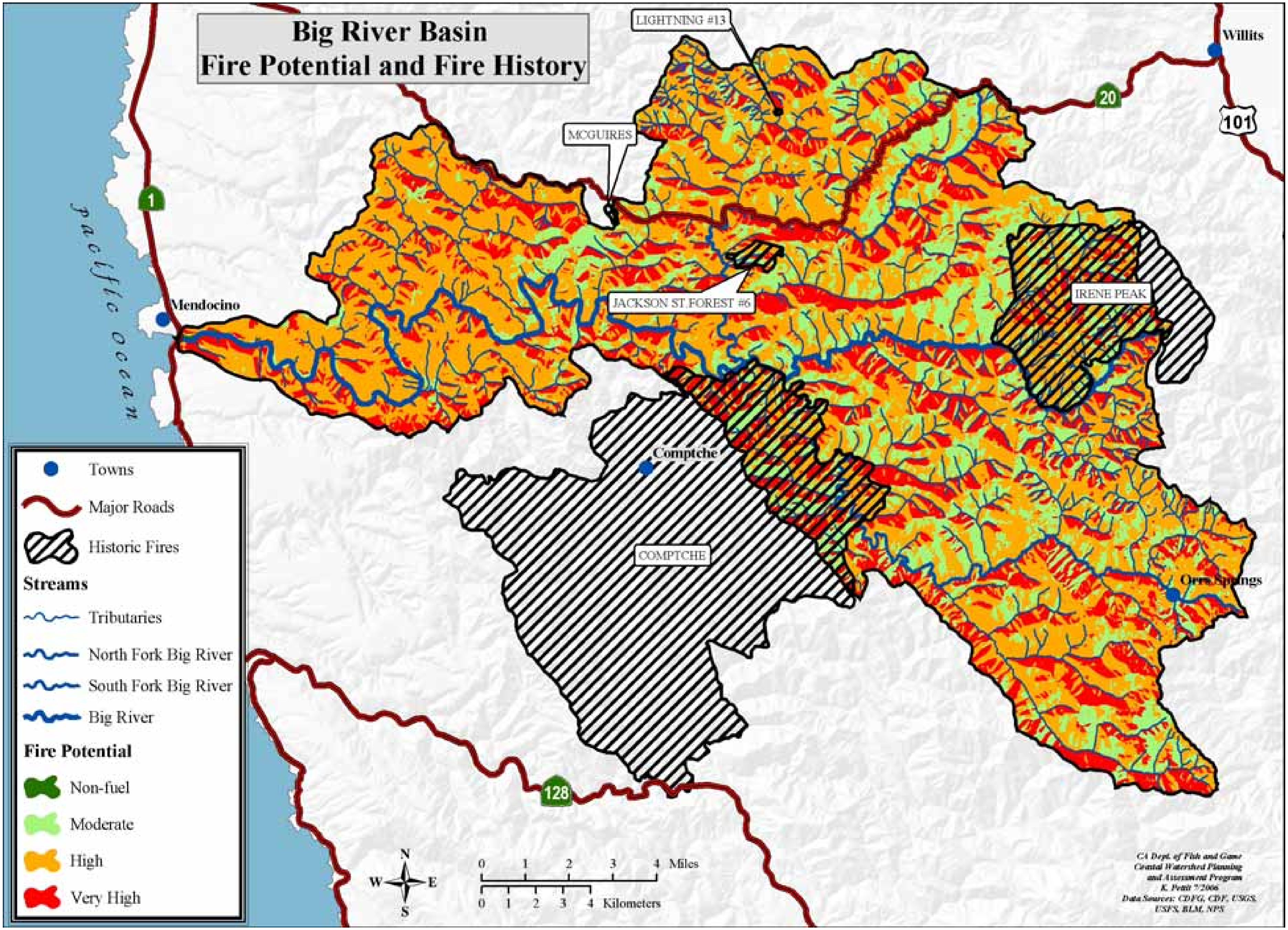


Figure 28. CDF recorded fires and fire hazard in the Big River Basin.

Population

There are no towns in the Big River Basin, though Mendocino, Little River, Comptche, and Willits are all within five miles of the watershed boundary. The total Big River Basin resident population estimated from the year 2000 census was 562 people (Table 32). Over half of the population lives in the Coastal Subbasin, which is close to the towns of Mendocino and Little River. The second most populous subbasin is the Inland, which includes Orr Springs. The town of Mendocino uses groundwater for domestic water needs. Population density across the basin is low, especially in the Inland Subbasin, which only has an estimated population of 197 across 131 square miles. The low population density and the use of groundwater mean that there is relatively little pressure throughout the basin from domestic diversion or consumption.

Table 32. Population and population density of the Big River Basin by subbasin.

Subbasin	Population	Area (Square Miles)	Population Density (Population/Square Mile)
Coastal	322	32.47	9.9
Middle	43	17.85	2.4
Inland	197	130.76	1.5
Total	**562**	**181.1**	**3.1**

Ownership

The Big River Basin is dominated by private land holdings, the largest three are owned by timber companies (MRC, Strategic Timber Trust, Hawthorne Timber Company) for a total of 29% of the basin, (Figure *29*). These companies are actively involved in managing the forest for silviculture. Weger is a family owned interest that also actively manages their forestland and is largest of the small landowners at 3% of the basin. Hawthorne Timber Company completed a land sale to the California State Parks system in 2002 creating the new 7,342-acre Big River State Park. State Park lands now comprise 7% of the basin. JDSF occupies 19% of the basin. JDSF is owned and managed by the State of California for the purpose of demonstrating forest management principles, recreation, and environmental conservation. It was acquired by the state from Caspar Lumber Company after much of the old growth had been harvested. Fifteen percent of the basin is owned privately in parcels varying from 40 to 1500 acres; 2% of the basin is in small private lots of up to 40 acres. Other than the town of Mendocino, there is relatively little human occupation in the watershed, with only scattered ranches and residences. Most of the smaller parcels are in the upper or east end of the basin and are dominated by grass or shrub lands.

Land Use

The earliest known inhabitants of the Big River were Pomo Native Americans. The Pomo village of Buldam was located near the present town of Mendocino. Little is known about this village, but the people there undoubtedly took advantage of the salmon runs in Big River, as well as the resources of the seashore and the coastal hills. The native populations along the coast were moderate in size and most of the Pomos lived in the Russian River Valley and at Clear Lake (Kroeber 1925).

Timber Harvest

Five key factors appear to have played a deciding role in how timber was harvested over time within the Big River and the North Coast in general: timber demand until the 1940s and after the mid 1940s, timber taxation, the first Forest Practices Act, the advent of the crawler tractor after World War II, and the modern Forest Practice Act in 1973.

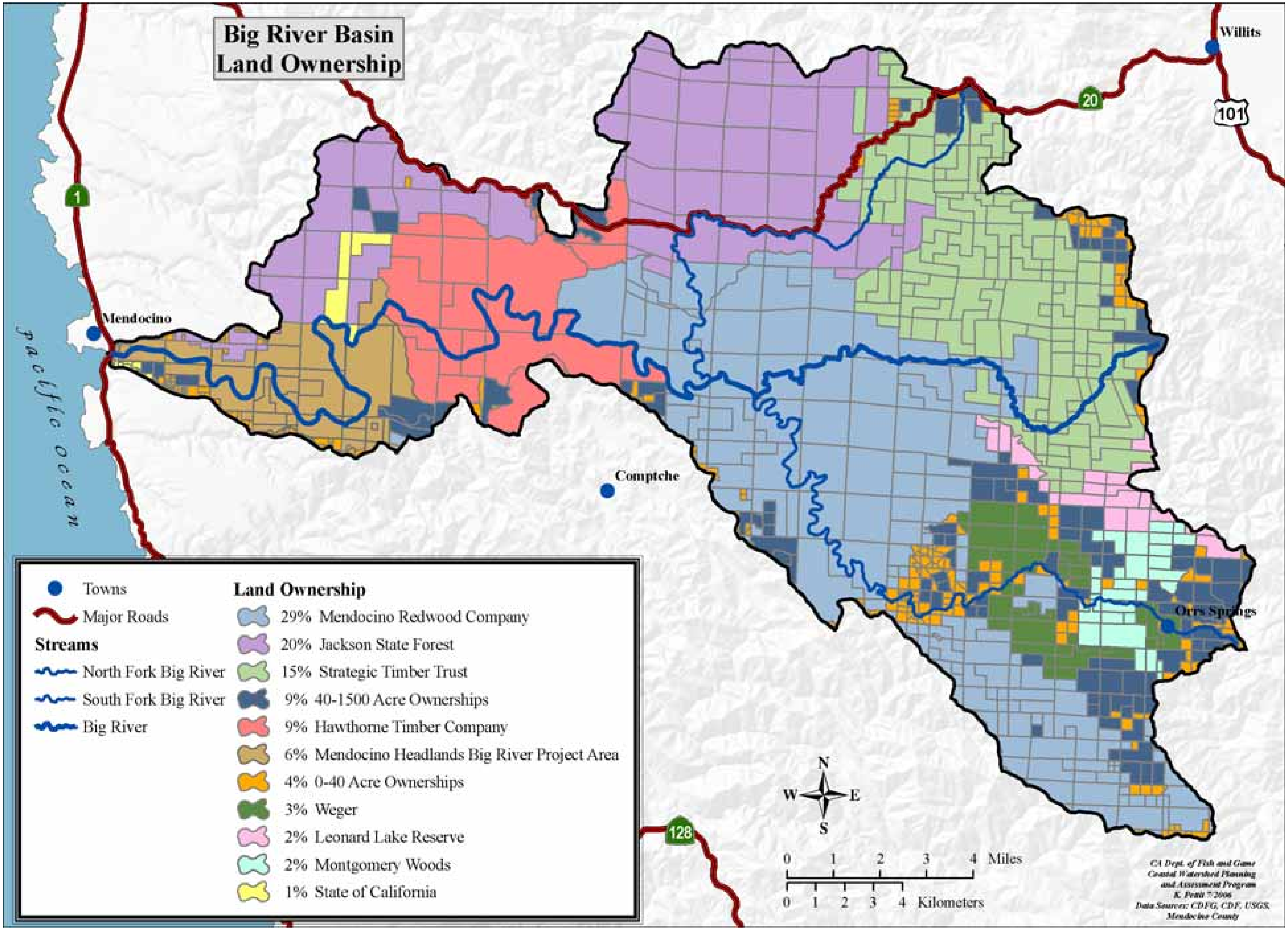


Figure 29. Big River Basin land ownership.

Following the discovery of gold in California in 1848, the demand for lumber in the state grew with the population. Logging in the Big River began in 1852 along the banks of the lower Big River around the time that the first mill was constructed in what was then known as Mendocino City. The mill was sited on the bluffs and an apron chute to load finished wood onto ships was constructed at the mill. Logs were kept in an enclosure at the mouth of the river, but this facility was continually being damaged by high river flows. In 1854, a new mill was built on the flat east of the present Highway 1.

In the early years, only those trees along the river that could be felled and then transported to the river via a rack and pinion device called a jackscrew were harvested. This pattern is evident in an aerial photograph taken in 1936, which shows a corridor of advanced second growth after the old growth had been removed along the river, trees grown back, and the old growth above the corridor was harvested in the 1920s. Loggers involved in these operations lived in large camps along wide flats on streambanks near the logging operations.

Cut-over streamside strips reforested quickly and by 1942 the basin contained some of the “finest redwood second growth in the state” (Fritz 1942). A University of California study in 1923 found 65-year old redwood second growth to contain 137,000 board-feet per acre.

Logging operations in the basin proceeded generally from the lower reaches in the early years, into the Little North Fork and Two Log Creek watersheds by the 1870s, then gradually into the headwaters over a period of 40-80 years. Logging in the South Fork began about 1888 (Jackson 1991). The early years of logging had one common theme, drag the log downhill to river, corduroy road, or track. The entire log was on the ground, thus it is called ground lead logging. Animals, primarily oxen, were used for yarding of logs until 1914 (Jackson 1991). The logs were usually dragged downhill and dumped into the river. Big River had 27 splash dams (Figure 30) that were then used to float logs downstream to the mill at the town of Mendocino.

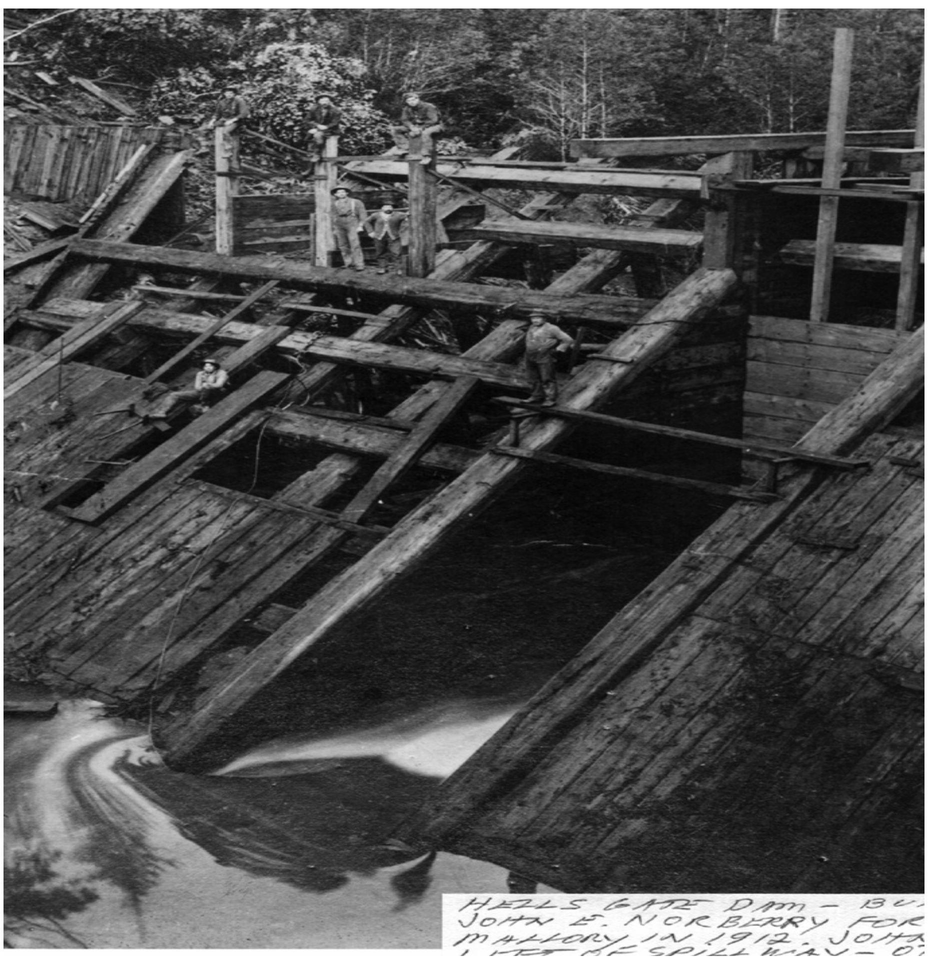


Figure 30. Hells Gate Splash Dam on the South Fork (1912).

Photo provided courtesy of the Mendocino Historical Society and the Held Poage Memorial Home and Research Library (from the Collection of Robert Lee).

Construction of splash dams began in about 1860 and continued through 1924. Some remained in use through 1937 (Jackson 1991) when the last raft of logs was floated down the North Fork Big River. The dams varied in size and construction methods, but ranged to as tall as 40 feet.

The last dam in the Big River was destroyed when it was burned by CDFG in 1972 or 1973 (Escola 2001). This was the Johnston dam on the upper mainstem Big River under Williams Peak. At the pleading of Escola, this dam had been preserved by the Resources Manager for Willits Redwood Company (present day Strategic Timber Trust) from destruction when they surveyed for a new road. Instead, WRC located the road above the dam. This dam was unique in that each joint in the construction of the dam had been ensured via mortise and tenons, or wood pins, so that the dam could later be easily disassembled and the logs transported to the mill and manufactured into lumber.

Big River was unique in that every log that went through the Mendocino Lumber Company mill came down the river, or at least through the estuary after being transported there via steam donkey and train. The last logs came through the mill in 1938 and were part of a cedar log raft that broke up in the ocean on the way down from Washington (Escola 2001). The company was the largest producer of lumber in Mendocino County until 1879.

CDFG, in conjunction with the Mendocino Lumber Company, built a fish ladder at the Hellsgate Dam on the South Fork Big River in 1927. The fish ladder was planned to allow coho salmon and steelhead trout access to spawning areas. In 1938, another fish ladder was added to the dam. The dam was later destroyed by fire in 1942 (Jackson 1991).

Steam donkeys were used beginning in the late 1800s until 1940 to move logs to the river or to a train line which ran up the lower portion of the mainstem. During the building of this track, a significant amount of hillside soil was pushed into the main channel to make room for the track bed and sidings, including one entire ridge cut back to make a wider turning radius (Jameson 2002). Other railroads were also built in the basin to aid in transporting logs (see page 92). Remnants of railroad trestles throughout the basin can still be seen today.

A log dump on RM 0.5 of the mainstem Big River operated from 1901 to 1936. Pilings were placed almost continuously between the piers and the millpond to assist in the transport of the logs to the mill and to prevent them from being swept out to sea.

From the 1880s to 1940s, entire slopes were clearcut of trees. Logs were dragged downslope to railroads and landings in stream bottoms resulting in major disturbance, including broadcast burning before yarding, massive stream filling and post-harvest debris sliding. In the 1930s and 40s there were massive attempts to convert timberland to grass for cattle grazing in the Middle and Inland subbasins.

The first tractor was used in the mainstem Big River in 1924, but tractors did not become heavily utilized until after World War II as they were big, bulky, and inefficient and could not compete with the steam donkeys. War requirements precluded further increase in use. Once the war ended, tractors became the principal means of skidding the large logs to the landings. Large skid trails were necessary due to the size of the equipment and logs. The large equipment and logs required the operator to put the blade down when going down hill to slow the tractor, resulting in more disturbance. Waterbreaks to curb erosion were rarely put in skid trails after logging.

During the initial tractor period logging arches were employed, which increased the size of these trails. The tractor-logging arch was developed on the Pacific Coast for skidding the large logs encountered there. It proved to be an effective tool for yarding logs in the redwood region. The arch was a large track or wheel mounted piece of equipment (Figure 31) pulled by a crawler tractor. In tractor arch operations, chokers were set to the log and the winch line of the tractor.

The logs were then winched up into the arch and the leading end hoisted clear of the ground. Due to the size of the tractor-arch combination there was a significant reduction in the maneuverability of the machine, resulting in an increase in the size of skid trails and landings. Each skid trail also needed a “turn around” for the tractor before it could connect to a turn of logs. These large, significant skid trails resulted in large cut banks, significant fills at low points and the increase in soil displacement. This combination of equipment, the manner of its use, and the disturbance almost certainly resulted in significant erosion and delivery of sediment to streams. Development of the integral arch eliminated the tractor arch operations, as the arch was now a part of the tractor and eliminated the need for a second piece of equipment.

Figure 31. Tractor arch operations.

Aerial photos and landscape photographs indicate that the yarding pattern during this period of logging was down the slope and drainage. Overall, ground disturbance was also increased due to the tractors' ability to construct large layouts in a relativity short amount of time. Layouts consisted of building a flat bed for the tree to fall into to cushion the blow and prevent it from breaking up upon impact. Not only was the layout made flat by moving the soil but mounds of soft soil were also pushed up along the lay to absorb the energy of the falling tree. A tractor-constructed layout was often up to 300 feet long and 20 feet wide. Once again, the harvesting practices of the day resulted in significant levels of soil disturbance.

From the 1940s to the 1970s, the predominant silvicultural method was the diameter limit cut because of the "Minimum Diameter Law" (Arvola 1977) and the "tax cut" because of the ad valorem timber tax. The Minimum Diameter Law required timber companies to leave standing timber for reforestation. This law prohibited the commercial cutting of coniferous trees of less than 18 inches in diameter unless a permit was received from the state, but was repealed in 1955. Standing timber was taxed on its assessed value on an annual basis until the time of the new timber yield tax law in 1977. The old tax law created an incentive to leave trees as the remaining timber was removed from the tax rolls once 70%of the volume had been harvested. The landowners would then move on to the next stand leaving 30%of the timber, usually the smallest. This was commonly called a "tax cut." Stands typically were entered several times as the remaining trees were harvested. Typically, they would harvest down to a 48-inch dbh in the first harvest then 24 to 36 and finally 18 to 20 inches until the original stand was harvested. Louisiana Pacific did one final cut, called the "shadow cut" of any tree over 12 inches regardless of age or vigor. Tractors were used almost exclusively without regard for watershed protections. The result was extreme damage due to roads, landings, and skid trails across very steep slopes and in virtually all skiddable watercourses accompanied by relatively high debris sliding post-harvest due to absence of erosion control and unprotected fill on steep slopes.

The post-war years and associated housing boom affected the Inland Subbasin more than the Coastal or Middle subbasins as most of the old growth already had been harvested there. The economic boom precipitated a need for Douglas-fir logs in significant amounts for the first time. Harvested lands resulted in areas that came back in vast tanoak stands, which are still evident today. Efforts at utilizing these hardwoods once they become large enough to saw have been met with some success, though landowners have been expending significant efforts and funds for years to reforest these areas with redwood and Douglas-fir.

The 1960s saw the first harvest of second growth focusing on the Coastal and Middle subbasins where the old growth had been harvested years before. Until 1973, the second growth was harvested by selection that removed half of volume, concentrating on larger trees using the same yarding systems as had been used in the old growth.

Harvesting of old growth timber was accomplished by stand replacing harvests or diameter limits cuts including seed tree cuts that removed the majority of the timber volume. These practices continued into the early 1970s. Timber harvest was occurring in the Big River Basin “practically to the bottom of small gullies, ravines, and stream courses. In some cases, ravines were completely blocked by bulldozing fill across them for passageways” (Perry 1974).

With the advent of the Forest Practice Act (1973), forestry experienced progressive improvement in road and yarding systems, but there were many landing failures from poor midslope roads in the 1970s and into 1980s. Landowners continued to selectively harvest the second growth until the 1980s, when clear cutting was instituted in the Coastal and Middle subbasins. Clear cutting constitutes 20 percent of the area harvested in the Coastal and Middle subbasins but less than 10 percent of all harvesting in the entire Big River Basin from 1980 to present.

Today a myriad of silvicultural practices are used to manage the young growth stands, resulting in more partial cutting with greater vegetation retention over the landscape and less disturbance in any one area (Figure 32). Clearcuts have been reduced in size from continuous, extensive areas to discrete units typically less than 30 acres in size. Buffers between even-aged management units were also required during this time period as part of the new rules.

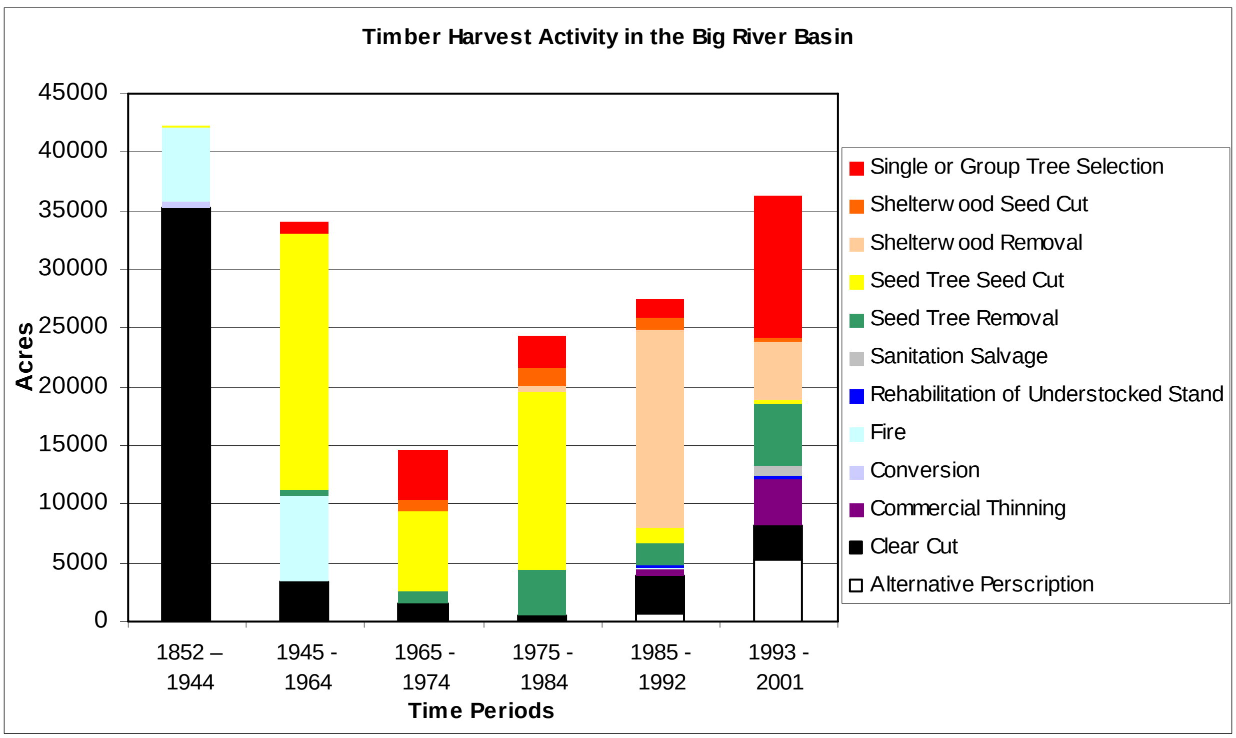


Figure 32. Acres of timber harvest activities in the Big River Basin.

Due to the gentle slopes in the Big River, tractor logging is currently the predominant method of harvest (Figure 33). Newer tractors are smaller and more nimble than those of the mid-20th century, resulting in less ground disturbance than occurred during logging of the earlier era. Modern cable yarding methods utilizing suspended cables with at least one end of the log off the ground were introduced in the 1980s.

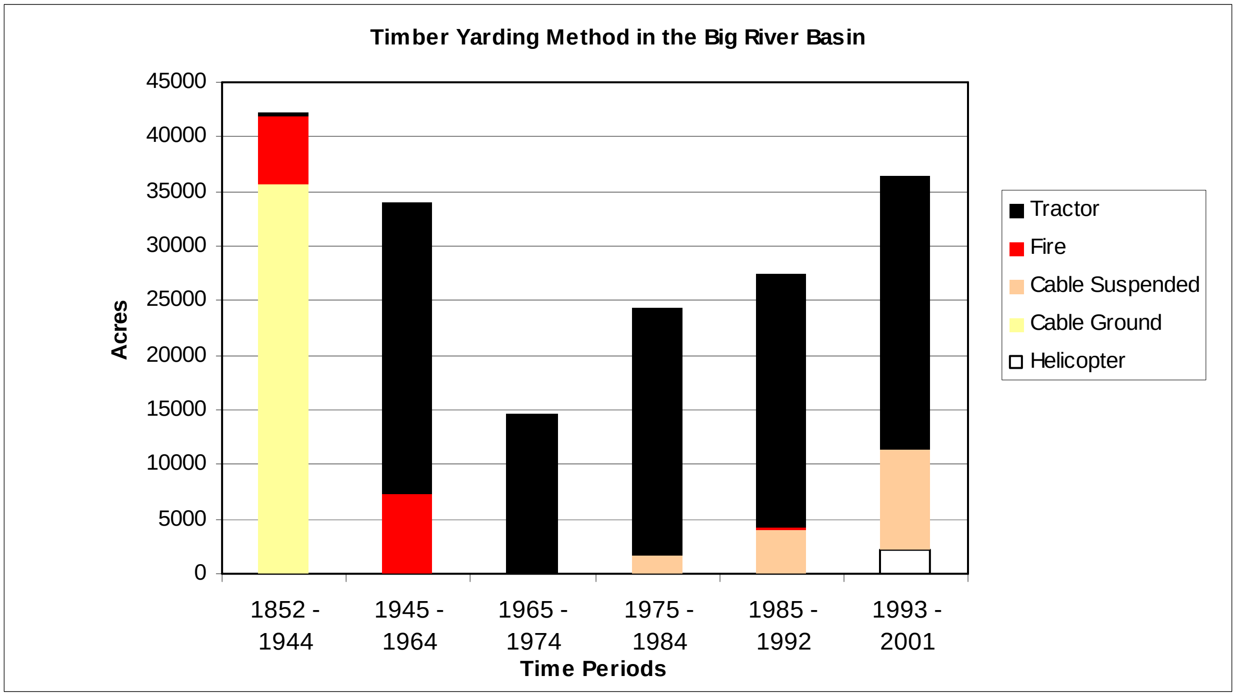


Figure 33. Acres of timber harvest yarding methods in the Big River Basin.

Along with the Forest Practices Act (1973), this technological change modified somewhat how timber was yarded within the drainage. There was an increase in the use of ridge top landings and mid-slope road construction. Whereas all logs were formerly yarded downhill to the creeks and river, it is now common to use suspended cables to log below roads and tractors above the roads. With the addition of stream protection zones in 1984 to the regulatory toolbox and refinements in 1993 these protection measures are quite visible on aerial photos.

While forest management practices have become less impactive in later years, the area harvested each year has increased. The Big River Basin is capable of growing well-stocked stands and producing high volumes of timber. As the stands cut during the original harvesting have grown back, harvesting is being repeated.

A significant number of acres have had activities more than once in the Big River Basin (Table 33). A third of the watershed area has seen activities only once since 1852; 79 percent or the acres have seen activities twice, 34 percent three times, and 8 percent have had activities four times. Fourteen percent of the area in the Big River has never had a fire, timber harvest, or been subjected to a conversion.

Table 33. Timber harvest in the Big River Basin.

Time Period	Acres Harvested	Percent of Basin Harvested
1852-1944	42,283	36.5
1945-1964	34,026	29.4
1965-1974	14,632	12.6
1975-1984	24,338	21.0
1985-1992	27,396	23.6
1993-2001	36,318	31.3
Total	**178,992**	

A CDF analyses of disturbance levels across the basin found that a total of 179,109 acres have had land use activity in the past 150 years. The first activity on 102,000 acres was in the high disturbance level category. Land use activities with high disturbance ratings were before 1985 (Figure 34). As much as ten times the timber volume per acre was removed during earlier logging of very large logs with heavy machinery and poor practices, resulting in very high impact to the watershed compared to after the Forest Practice Act. However, the more recent lower disturbance activities have been carried out over more acres per year in the basin.

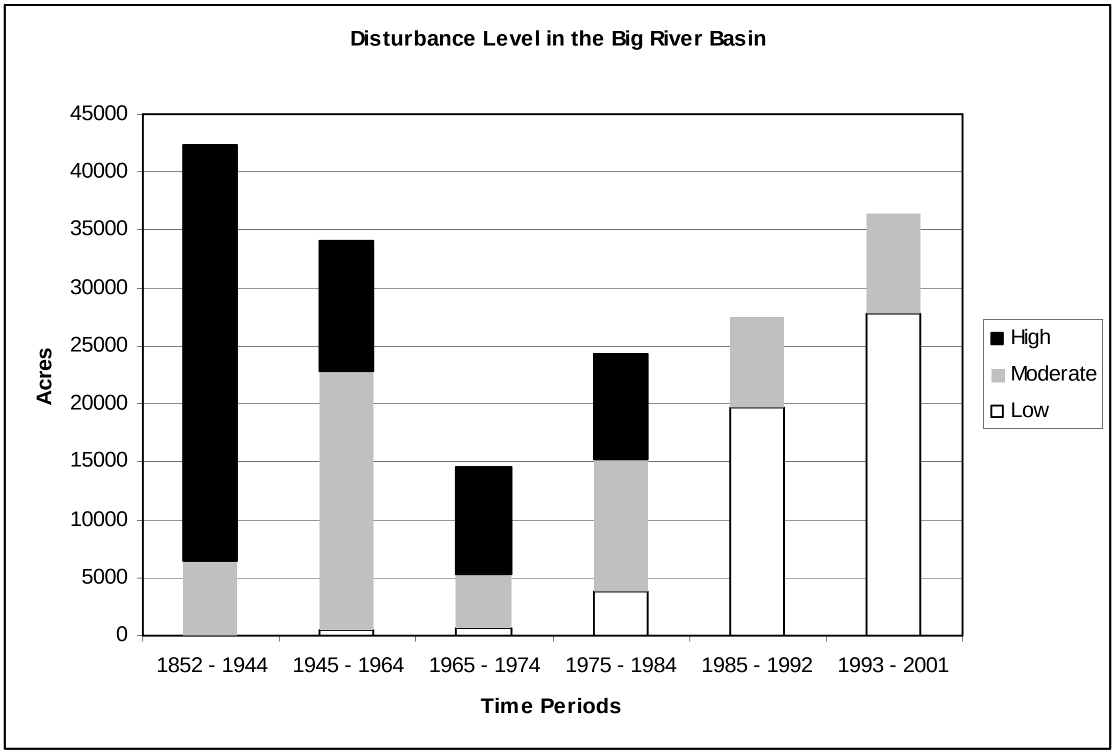


Figure 34. Disturbance level in the Big River Basin by time period and acres.

Roads

Truck roads and watercourse crossings in the basin date back to the late 1800s when the same alignment was first used by trains. Trucks were first used in the 1940s and railroad beds were converted to truck roads. Sixty four percent of roads were built before 1979, 32% are rocked surface from a local source, and 4% are paved. The paved roads are major highways or county roads. Road construction in the basin parallels timber harvest history, with an increase since 1989 as second growth timber came into maturity.

Historical roads in the basin are responsible for many legacy problems contributing sediment to watercourses today. With evolving changes in the Forest Practice Rules since the early 1970s, new harvest related road construction has to meet increasingly higher standards. These regulations cover construction activities such as operations on steep slopes, road alignment, road grades, erosion control, watercourse crossings, culvert installation, operations during the winter, and road maintenance. There are 1,242 miles of roads in the Big River Basin, which is 6.9 miles per square mile (Table 34, Figure 35).

Table 34. Truck roads in the Big River.

Period	Total Length in Miles				Length in Miles per Sq Mile			
Basin Wide	**Native**	**Paved**	**Rocked**	**Total**	**Native**	**Paved**	**Rocked**	**Total**
1852 - 1936	44.2	11.9	11.6	67.8	0.2	0.1	0.1	0.4
1937 - 1952	184.7	29.7	41.7	256.2	1.0	0.2	0.2	1.4
1953 - 1965	217.1	0.2	43.5	260.8	1.2	0.0	0.2	1.4
1966 - 1978	173.6		34.6	208.2	1.0		0.2	1.1
1979 - 1988	130.2		12.2	142.4	0.7		0.1	0.8
1989 - 2000	281.9	0.1	24.5	306.5	1.6	0.0	0.1	1.7
Total	**1,031.7**	**42.0**	**168.2**	**1,241.9**	**5.7**	**0.2**	**0.9**	**6.9**

Lengths are roads constructed in time period, not cumulative.

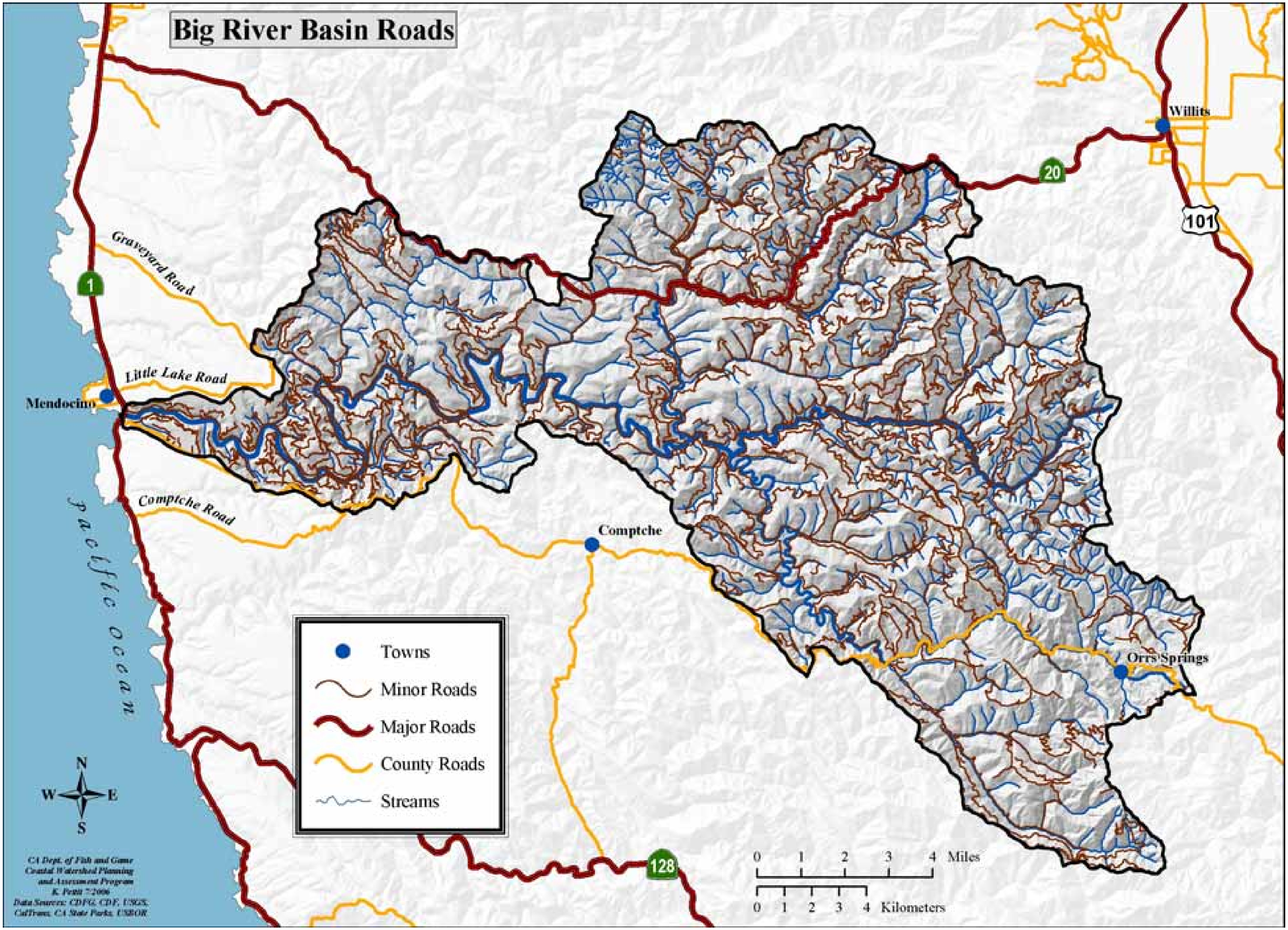


Figure 35. Roads in the Big River Basin.

Today, roads are being built to a higher standard, and larger and better watercourse crossings are being installed or upgraded. However, there is more partial stand harvesting and smaller harvest units today that will require more repeat use of existing roads. Many times historic roads were built, used for a particular harvest (typically very large units), then abandoned. On the surface leaving an area to stabilize may appear a good road practice, but the historical roads were built with no consideration for position on the slope, relation to a watercourse, minimum width or landing size, number of roads, diversion of water, or crossings that allow for water or fish passage. Construction on unstable ground was not even a serious consideration until the 1980s. Often, the easiest locations to build a road were in the creek bottoms and drag the logs down to the road. Long-term considerations were not legally required at the time, and we still experience legacy problems that continue to contribute sediment to watercourses today.

Historical roads are continually being upgraded, especially by the larger companies as they increase their level of stewardship in connection with harvesting timber. EPA noted (Geniella 1999) that the large landowners in the Eel River basin are bringing their roads up to a high standard, and the significant source of transportable sediment is due to the ranch and small landowners. This would appear to be true in the Big River as well.

Some of the techniques being used currently for abandonment of roads include the removal of watercourse crossings and re-contouring of the road prism (Figure 36, Figure 37 and Figure 39). Additionally, the number of roadside turnouts and large landings used for large old growth logging are being reclaimed (Figure 38).

Figure 36. Watercourse crossing at high risk of failing.

Figure 38. Reclaimed landing on mainline road.

Figure 37. Legacy watercourse crossing removal.

Figure 39. Abandoned road re-contoured to natural slope.

Railroads

Railroads were used in the basin for transporting harvested timber from 1885 to 1930. Locomotives were barged from the river's mouth to the middle of the estuary, where the railroad track began. The track extended upstream to the Little North Fork Big River, with branches into smaller tributaries (Figure 40). Other tracks were located in the Laguna Creek, Two Log Creek, and North Fork Big River watersheds. Some abandoned railroad grades were later converted into roads (GMA 2001a).

Public Lands

The relative remoteness, natural resources, and natural beauty of the Big River Basin have made it ideal for recreation, forestry demonstration, and conservation.

The National Park Service bought the 5,426-acre Mendocino Woodlands Recreation Demonstration Area (including 4,300 acres in the Big River Basin) in 1932 to provide a setting for activities that would introduce the public to the wonders of nature. A wood-and-stone campground facility, Camp I, was built in the Woodlands Area by the Works Progress Administration and the Civilian Conservation Corps (CCC) in 1936. Camp I was first occupied in July 1938 and gave birth to the Jack and Jill Family Camp in 1960- the first all African-American camp in the United States. The campground was one of 46 created across the country (including Camp David) during the 1930s.

In 1947, the Woodlands Area was transferred to the State of California explicitly for park, recreation, and conservation purposes. The Woodlands Area now consists of three parts: Mendocino Woodlands State Park (780 acres), a Special Treatment Area or STA in JSDF to create a buffer around the campground in the park (2,550 acres), and a part of JSDF (2,155 acres). The Woodlands Camp in the state park contains the group camping facility that is also a National Historic Landmark.

In 1942, University of California forestry professor Dr. Emmanuel Fritz suggested that California should create a state forest system to return timberlands to full productivity and thus ensure stable employment. The state Board of Forestry supported his ideas and a bill authorizing the state to purchase land for state forests was signed into law in May 1945. Fritz had proposed that the Big River Basin met the requirements for a state forest system particularly well (1942). Perceived advantages of the Big River Basin as a state forest included the high average site quality for timber, few large ownerships, large amount of second growth redwood, and high recreational opportunities. JSDF was purchased by the state in 1947 and includes 35.5 square miles of the basin.

In 1945, Robert Orr donated nine acres for the creation of a redwood reserve along Montgomery Creek in the Inland Subbasin. Since then, the Montgomery Woodlands State Reserve has grown to 1,142 acres and is reported to contain one of the world's tallest living trees. This coast redwood is 367 feet and 6 inches tall (112.0 meters) and has a diameter of 10 feet and 4 inches (3.14 meters). It is estimated to be over 1,000 years old. It was declared the tallest tree in 1996; however, a 370 foot (112.7 meters) tall tree was found in Humboldt Redwoods State Park in 2000 (Guiness World Records 2006). There is currently a proposal to expand the reserve by 1,240 acres.

In 1979, the USFWS commissioned an Environmental Assessment to help determine how a 3,000-acre parcel including the Big River Estuary could best be protected. The Big River was being considered for protection under the USFWS Unique and Nationally Significant Wildlife Ecosystem Program, which seeks to "identify, evaluate, and seek methods to assure protection and perpetuation of unique and nationally significant wildlife ecosystems." A large-scale inventory of potential sites in California identified 60 potential sites for protection. Of these, Big River was ranked as the sixth highest priority. Upcoming Timber Harvest Plans in the Big River Basin elevated the basin to the highest priority for protection in California. USFWS considered a variety of alternatives for protecting the Big River Estuary including no action, ecosystem management agreements, and USFWS acquisition. The Environmental Assessment concluded that the goals and objectives of the Unique Wildlife Ecosystem Program would be maximized with the USFWS acquisition alternative. However, this option was not realized at that time.

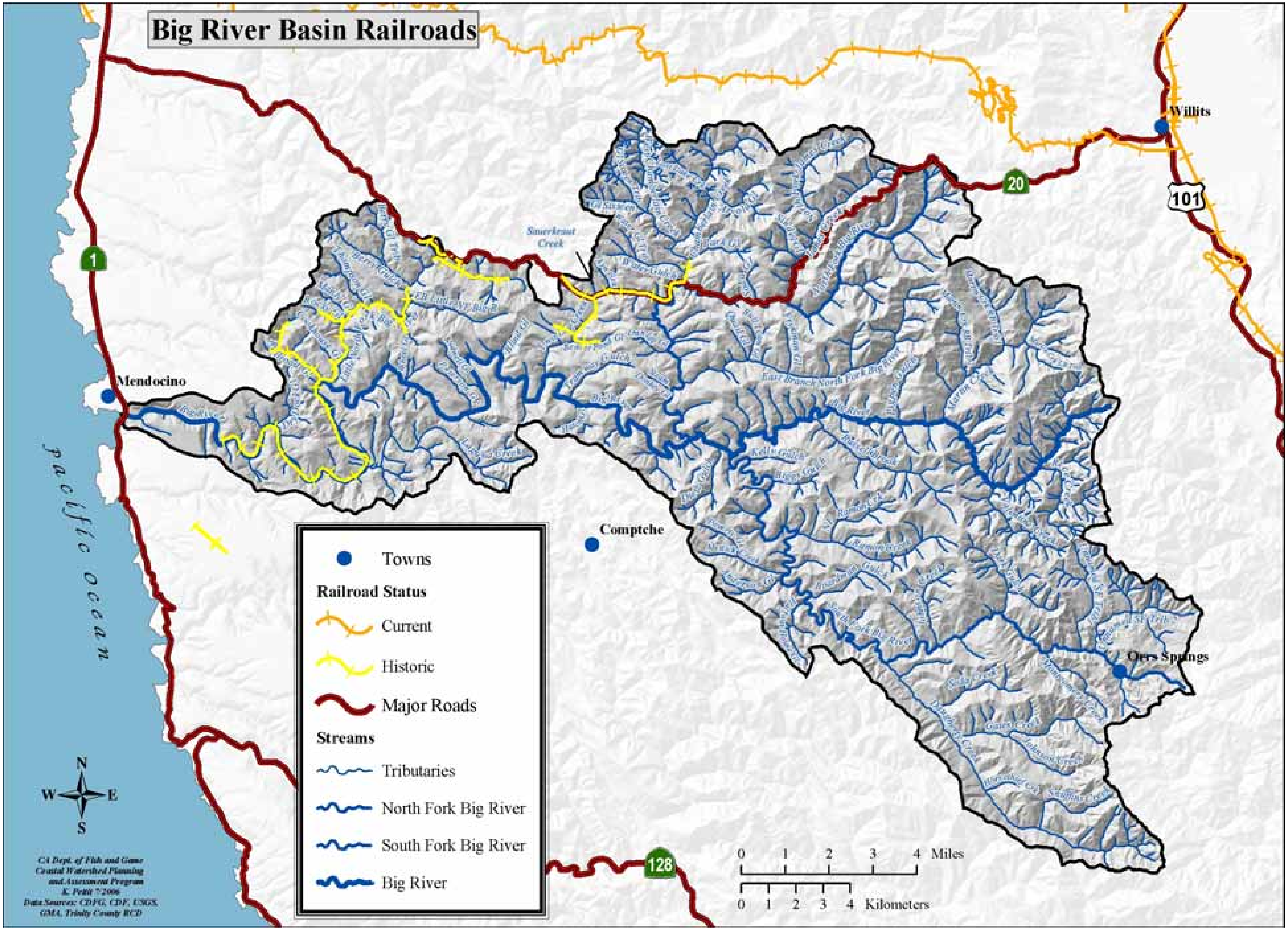


Figure 40. Big River Basin railroads.

In 1999, the Big River Estuary area was purchased by Hawthorne Timber Company. Local environmental activists and the Mendocino Land Trust protested prospective logging and Hawthorne Timber Company agreed to sell the land to the Trust for the estimated fair market value of the redwood timber on the land. The money was raised and the land was purchased by the Land Trust in 2002.

The Land Trust then deeded the land over to the California State Park system to create the Big River Unit of the Mendocino Headlands State Park. The addition of the 7,334-acre Big River Unit to the state park system created a 74,000-acre wildlife corridor linking coastal and inland habitats into the largest piece of connected public land entirely within Mendocino County. The acquisition also created 60,000 acres of contiguous public lands with more than 100 miles of joined trails.

Land Management

In 1997, the Big River Watershed Council submitted watershed guidelines for the Big River Basin to the National Marine Fisheries Service (NMFS). The purpose of the proposed guidelines was to provide NMFS with a set of guidelines to protect coho salmon and their habitat throughout the basin. The Watershed Council wrote guidelines in six categories:

- Protection of Key Watersheds:
    - No new roads should be built in roadless areas (over 5,000 acres);
    - Reduce existing road system and non-system road mileage outside road-less areas; no net increase in the amount of roads;
    - Watershed analysis is required prior to major management activities such as road building or timber harvest.
- Protection of Riparian Reserves:
    - Timber harvest is prohibited in riparian reserves;
    - Riparian reserves should not be included in calculations of timber base.
- Timber Harvest Restrictions:
    - All timber harvest is to be conducted in accordance with Institute for Sustainable Forestry Guidelines for sustainable forestry;
    - Timber harvest within a watershed or on a given ownership greater than 10 acres will be limited to 2% of inventory per year as described in the Mendocino County Forest Practices Rules;
    - Clearcutting is prohibited on all ownerships except for single-family residential purposes.
- Restriction of Use of Pesticides:
    - No pesticide spraying on wildlands or public or private roads or highways within wildlands within the Big River Basin (wildlands are all areas away from residential or business areas or the immediate area surrounding homes, businesses, or residential gardens or landscapes).
- Prohibition of Additional Water Appropriation:
    - There will be no additional drafting or allocation of water from any surface water source within the basin;
    - There will be no additional dams that will adversely affect any surface water source within the basin.
- Monitoring:
    - A specific program to monitor both the coho salmon population of Big River and the habitat at the watershed level will be developed and funded prior to authorization of further timber harvest on commercial forestlands within the basin;
    - Specific monitoring programs for site-specific monitoring of timber harvest areas to be done by qualified third parties will be designed and funded before additional timber harvest is authorized;
    - Monitoring plans will be approved by the Big River Watershed Council.

These guidelines are presented here for informational purposes and not meant to imply endorsement.

Water Quality

Water Temperature

With the exception of the Big River Estuary, continuous water temperature data were available for each subbasin, though not for every stream or year. Maps of sample locations are in the subbasin sections of this report. Water temperatures in the mainstem Big River were unsuitable in virtually every location tested, and the daily maximum temperatures measured sometimes exceeded the lethal threshold for salmonids if fish could not find thermal refuge.

Tributary samples in the Coastal Subbasin had fully suitable to moderately suitable water temperatures. It is likely that this is due, in large part, to the cooling marine influence in this subbasin. Overall, the water temperature in the Coastal Subbasin tributaries appear to be the most suitable in the Big River Basin. In addition, it is likely that the Little North Fork has some local cooling effect as it enters the mainstem Big River.

Tributaries in the Middle Subbasin had fully suitable to undetermined water temperatures. While the data in this subbasin are relatively sparse, it is likely that the marine influence in this subbasin and rapid re-growth of vegetation helps keep water temperatures relatively low. The tributaries that were monitored appear to be suitable for salmonids. It is likely that Two Log Creek has some local cooling effect as it enters the mainstem Big River.

Tributaries in the Inland Subbasin had fully suitable to fully unsuitable water temperatures. Generally, the tributaries that were monitored in the North Fork drainage appear suitable while tributaries in the South Fork and headwaters drainages appear to be unsuitable for salmonids.

The lower mainstem South Fork Big River had the highest daily water temperature (74°F) of any stream other than the mainstem Big River. It also appears that the upper mainstem Big River is one of the origins of the warm water seen downstream. Water leaves North Fork Big River with an MWAT of roughly 67°F; headwaters of Big River with an MWAT of roughly 66-68°F; and South Fork Big River with an MWAT of roughly 67-69°F.

Notable exceptions to general patterns in the Inland Subbasin are Lower Chamberlain Creek, most of the East Branch of the North Fork, the mainstem of the North Fork, one site in Montgomery Woods State Reserve, and tributaries dominated by groundwater. The mainstem North Fork is unusual in that it exhibits a rapid increase in water temperature upstream of the JDSF boundary, and then slowly declines until it leaves JDSF, and again shows a rapid increase near the confluence with the mainstem Big River. This may be due to naturally poor canopy or to commercial timber harvesting on either end of the North Fork. In any case, this should be investigated further. It also appears that the North Fork is one of the origins of the warm water seen downstream in the mainstem Big River. Conversely, the site in the Montgomery Reserve is a good example of what can be achieved with adequate canopy in the warmer interior portion of the basin.

Trends

In 1973, the USFWS (Perry 1974) recorded water temperatures at six sites in the Big River Basin as part of a Fisheries Improvement Study. Additional observations were also made of water temperatures in other sites. The study found that water temperatures in some streams exceeded 65°F almost every day from May through August with extreme high temperatures reaching the low 80s. Water temperatures in higher elevation tributaries without overstory cover along significant reaches of stream often exceeded 80°F. Researchers observed large numbers of fish grouped “in search of shade in pools.”

MWATs, MWMTs, and maximum temperatures calculated from continuous data loggers were compared to recent water temperature data at the similar locations. The site monitored in the Coastal Subbasin (mainstem Big River at the confluence with Little North Fork Big River) could not be matched exactly with a recent monitoring site. However, recent water temperatures at two nearby sites on the mainstem Big River were fully unsuitable while temperatures recorded in 1973 were moderately unsuitable.

The site monitored in the Middle Subbasin (mainstem Big River below the confluence with North Fork Big River) had moderately unsuitable water temperatures both in 1973 and during recent monitoring.

Four sites were monitored in the Inland Subbasin in 1973. Water temperatures in the North Fork Big River at the confluence with Chamberlain Creek decreased from fully unsuitable to undetermined or somewhat unsuitable while temperatures in the East Branch North Fork Big River increased from fully suitable to undetermined. One site monitored at the confluence of South Fork Big River and Daugherty Creek had moderately unsuitable water temperatures in both 1973 and during recent monitoring. The site monitored in mainstem Big River at Pig Pen Gulch showed a decrease in temperature from fully unsuitable to moderately unsuitable.

Since there were so few sample sites in 1973, no overall trends for the Big River Basin can be determined. However, increasing water temperatures in the East Branch North Fork Big River could be cause for concern while decreasing water temperatures in the North Fork Big River at Chamberlain Creek and mainstem Big River at Pig Pen Gulch may indicate recovery. Additionally, the differences could fall within the range of natural variation.

Sediment

A variety of sediment related field data have been collected in the Big River Basin, including pebble counts, V*, permeability, stream cross-sections, thalweg profiles, bulk sediment samples (McNeil), and turbidity and suspended sediment samples. Unfortunately, a large portion of these data are of limited duration or are not comparable to other data collected by others in the Big River Basin due to differing analysis techniques. Thus these data are not useful for trend analysis.

In the Coastal Subbasin, pebble counts, V*, bulk sediment samples, and turbidity samples were collected at various locations and times. Pebble count and V* measurements collected at one site in Berry Gulch during one year indicated excessive amounts of fine material in the stream. Bulk sediment samples collected in the Little North Fork indicate excessive sediment in sub-0.85 mm and sub-6.5mm size classes that generally exceed the TMDL limits for these size fractions.

A total of 88 useable turbidity samples were taken on the mainstem Big River, both upstream and downstream of the confluence with the Little North Fork Big River. Measurements indicate that 90% of all samples collected were at or below 52 NTU with a maximum recorded level of 600 NTU. The turbidity sampling conducted at these sites, combined with additional sampling, can eventually establish the range of background levels. Turbidity that is significantly elevated above background levels is not suitable for salmonids and can be an indicator of potential problems with suspended sediment.

In the Middle Subbasin, bulk sediment samples, stream cross-sections, thalweg profiles, and permeability measurements were collected at various locations and times. Bulk sediment samples collected in Two Log Creek indicate excessive sediment in sub-0.85 mm size class that generally exceeds the TMDL limits for this size fraction. Other bulk sediment data were collected by GMA and MRC. However, due to differing analysis techniques, these data are not comparable to each other or the TMDL limits. Permeability measurements on the mainstem Big River indicate low to moderate amounts of fine sediment when compared to similar sites at other locations in the Big River Basin. This is somewhat verified by the bulk sediment sample collected at the same location. Stream cross-sections and thalweg profiles were only collected during one year, so they are reported but not used in this assessment.

In the Inland Subbasin, bulk sediment, permeability, stream cross-sections, thalweg profiles, and suspended sediment and turbidity samples were collected at various locations and times. Bulk sediment samples collected at various locations in the North Fork and in Chamberlain Creek suggest a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek. Bulk sediment samples collected in the South Fork drainage indicate mostly mixed results with no trends evident.

Permeability measurements on the East Branch North Fork site indicate low to moderate amounts of fine sediment when compared to similar sites at other locations in the Big River Basin. This is somewhat verified by the bulk sediment sample collected at the same location. Permeability sampling also indicated significant fine material at the Daugherty and Ramon creek sites. The South Fork Big River site appeared to have less fine material and likely better spawning success. The permeability conclusions at Daugherty Creek, Ramon Creek, and South Fork Big River are somewhat supported by bulk sediment sampling at the same locations, particularly in the sub 0.85 mm size class.

Limited turbidity measurements indicated that at the nine tributary locations, turbidity varied between 2 and 811 NTU. The South Fork below Daugherty Creek had the highest average turbidity levels and the James Creek above the North Fork Big River site had the lowest turbidity levels. Limited turbidity and suspended sediment samples were collected on the mainstem Big River during winter flows. Measurements indicated that all of the turbidity samples were below 42 NTU, except one sample with a maximum recorded level of 240 NTU. There also appeared to be a strong correlation between turbidity and suspended sediment at all of the sites sampled.

Based on the information available for this assessment, sediment in the Big River Basin may be a limiting factor for aquatic organisms in some parts of the basin. Although elevated levels of fine sediment were found at some sample locations, comprehensive sampling throughout the basin has not been conducted.

Water Chemistry

Water chemistry sampling was generally limited in duration and even non-existent in some areas, including the Big River Estuary and the Middle Subbasin. In every subbasin where it was tested, sodium exceeded the applicable water quality criteria. On other occasions, there were unusual concentrations of boron, copper, aluminum, and zinc that exceeded water quality criteria. Boron concentrations in the South Fork Big River were particularly troubling because they were collected in 2001 with known methods. However, with the other metals, it is likely that they were artifacts of the sample collection method or location.

In February 2001, a tanker truck on Highway 20 spilled roughly 7,000 gallons of waste oil. Some of this waste oil discharged into a tributary to James Creek. Subsequent sampling indicated that petroleum constituents had reached James Creek. While it is likely that this event harmed some aquatic life, this site is in active cleanup and it is unlikely that this event will have a long-term effect on the local ecology.

It is unknown which, if any, of the pesticides and herbicides make their way into the stream channels from activities such as agriculture, timber harvesting, and right-of-way maintenance on County roads. This would depend on the method of application, solubility, and the persistence of these chemicals. However, this was not studied in this assessment due to the lack of sample data. A summary of select pesticides and herbicides used in Mendocino County (although not specifically the Big River Basin) in 2000 is given in the Water Quality Appendix. Further study of pesticides and herbicides is warranted to ensure that drinking water supplies and wildlife resources are protected in the Big River (and other watersheds).

Based on the information available for this assessment, water chemistry in the Big River Basin does not appear to be a limiting factor for aquatic organisms or a health hazard to humans. However, long-term sampling should be conducted to verify that the detected metals are, in fact, not in the surface water at the detected concentrations. Sodium concentrations should be looked at more carefully to determine the source of the sodium and if it is naturally occurring. No water quality information exists for the estuary, which is unique and should be studied further. Water quality sampling for pesticides and herbicides throughout the watershed is also recommended.

Riparian Conditions

Stream buffers were established on Class I/Perennial streams at 150 feet from the bank of the watercourse on both sides and 75 feet for Class II/Intermittent streams. Data used for analysis is the USGS 1:24,000 hydrography GIS data layer, upgraded within field watercourse designation from THPs digitized by CDF Santa Rosa GIS. There are 11,762 acres in the stream buffers, which includes barren areas composed of water and gravel bars in the lower reaches (Table 35). The 0% density class is occupied primarily by gravel bars, water, willows, and grasslands and is less than 1% of the watercourse buffer zone area.

Table 35. Acres by crown canopy density in watercourse buffer zone by subbasin.

Subbasins	Acres by Percent Crown Canopy Density										Acres in Buffer
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	
Coastal	297	2	18	84	5	9	7	454	407	1,172	2,455
Middle	15	6	2	10		2	3	255	222	589	1,104
Inland	161	67	13	164	79	66	45	1,266	1,827	4,513	8,203
Total Big River Basin	**474**	**74**	**34**	**258**	**85**	**77**	**55**	**1,975**	**2,456**	**6,274**	**11,762**

Table 36 presents the percent of area with canopy in the higher percentage ranges, 70% and above, which provide significant levels of stream shading and microclimate effect. In the entire Big River Basin, the area around the watercourses are well vegetated, as indicated by the 70–100% density class which accounts for 91% of the area. Also at the basin level, 74% of the buffer area is in 80% canopy density or better, and 53% of the area is in the 90-100% canopy closure class.

Table 36. Percentage of stream buffer area in higher canopy closure classes by subbasin.

Subbasins	Percent of Buffer Area by Crown Canopy Density				
	70%	80%	90%	70%+	80%+
Coastal	18	17	48	83	65
Middle	23	20	53	96	73
Inland	17	21	53	91	74
Total Big River Basin	**17**	**21**	**53**	**91**	**74**

Looking to canopy density at the subbasin level, the Coastal Subbasin has the lowest percentage of buffer area with canopy density in the higher classes: 83% of the area has 70% canopy density or higher and 64% has a density of 80% or higher. The Middle Subbasin has the greatest percentage of buffer area in the higher canopy density classes: 97% of the area in the 70% density or higher classes and 73% in the 80% density or higher classes. The Inland Subbasin runs a close second to the Middle Subbasin. These numbers are substantiated by high canopy densities found along stream reaches surveyed by CDFG and discussed in the *Fish Habitat Relationships* section below. These buffers are consistent with the associated stream channel widths.

As shown in Table 37, the majority of the trees in the watercourse buffer zone are small to medium/large, which are 12 to 40 inch dbh trees. Gravel bars, water, and grasslands do not have a tree size associated with them and are not included.

Small, medium/large and large trees (>12 inches dbh) could be recruited to streams as large woody debris. Overall, 91% of the buffer zone area in the basin is in these size classes. At the subbasin level, the percentage area in these three size classes is 94% to 95%.

Table 37. Acres by vegetation size class in watercourse buffer zone by subbasin.

Subbasins	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Coastal	77	3	42	2	969	45	1,020	47	50	2
Middle	0	0	44	4	735	67	303	27	6	1
Inland	21	0	374	5	4893	61	2571	32	183	2
Total Big River Basin	**99**	**1**	**460**	**4**	**6,596**	**56**	**3,894**	**33**	**239**	**2**

Fish Habitat Relationships

The Big River Basin supports populations of coho salmon, steelhead trout, and other valuable fishery resources. Coho salmon and steelhead trout enter the Big River Basin on their spawning migration during November or December, depending on stream flow conditions. Spawning takes place from November to March. The majority of juveniles move downstream to the ocean between March and June of each year.

In order to meet the needs of the life stages of anadromous salmonids, the Big River Basin must provide appropriate diverse stream flow regimes, suitable water quality, high quality gravel substrate for spawning and incubation of eggs, suitable in-channel and riparian conditions, and adequate food supplies within the fish bearing reaches throughout the basin. High quality instream and riparian habitat is most important for coho and steelhead as they spend a year or more rearing in streams.

The advent of timber harvesting in the Big River Basin in 1850 brought changes to stream channels across the basin due to land use activities. These changes from historic stream conditions resulted in reductions of salmonid habitat quality.

Identifying salmonid life history strategies at the basin and regional scales provides clues to the range of stream conditions and environmental requirements for fish. The fish are telling us what they need by displaying a range of behavioral patterns and they are telling us about the status of their habitat by their trends of abundance. Some species or life history strategies may already be lost or rarely observed due to changes from historic stream conditions. By gaining insight into the relationships between the diverse life history strategies, fishery population dynamics and status, and assessing stream habitat condition, we can make efficient recommendations for recovery of depressed populations.

A summary of the life history strategies and historic and current status of anadromous salmonid populations of Big River is provided in the CDFG Appendix. Further information on fisheries and habitat status of Big River is provided in each subbasin section.

Historic Conditions

There are approximately 52 named streams in the Big River Basin. In 1965, CDFG estimated that these streams provided 101 miles of coho salmon habitat and 137 miles of steelhead trout habitat (Table 38).

Table 38. Anadromous habitat in the Big River Basin in 1965 (from CDFG 1965).

Species	Miles of Stream			Total Stream Miles	Accessible to Anglers	
	Summer Stream Wetted Width in Feet					
	Up to 7	8 to 20	21 to 100		Miles	%
Coho Salmon	74	22	5	101	40	40
Steelhead Trout	110	22	5	137	40	29

In 1957, 1958, 1959, 1966, and 1979 CDFG conducted stream surveys on various tributaries in the three subbasins of the Big River Basin (Table 39). Many of the stream surveys coincided with the extensive logging across the Big River Basin. The results of past stream surveys were not quantitative and cannot be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions. The data from these stream surveys provide a snapshot of the conditions at the time of the survey. Summary tables appear in the subbasin sections of this report.

Surveys across the Big River Basin described a range of spawning habitat, pools, and shelter from poor to excellent. Good spawning habitat was reported in most surveyed streams in the Coastal and Middle subbasins. Pools were described as small, but abundant in most surveyed streams. Abundant deep pools were reported in North Fork and South Fork Big rivers. Shelter was described as good to excellent in most streams across the Basin.

Table 39. Streams surveyed by CDFG in the Big River Basin from 1957-1966.

Year	Coastal Subbasin	Middle Subbasin	Inland Subbasin	
Undated 1950s		Tramway Gulch Dietz Gulch	Kelly Gulch Biggs Gulch Mettick Creek	Anderson Gulch Boardman Gulch
1957			South Fork Big River	
1958			North Fork Big River East Branch North Fork Big River James Creek North Fork James Creek	South Fork Big River Unnamed Tributary to South Fork Big River #1 Unnamed Tributary to South Fork Big River #2
1959	Big River Little North Fork Big River Cookhouse Gulch Rocky Gulch Manly Gulch Thompson Gulch Berry Gulch	Two Log Creek	North Fork Big River East Branch North Fork Big River Water Gulch Ramon Creek Daugherty Creek Soda Creek Johnson Creek (Tributary to Gates Creek) Snuffins Creek	Johnson Creek Russell Brook Pig Pen Gulch Martin Creek East Fork Martin Creek Valentine Creek Rice Creek East Branch Rice Creek
1966		Two Log Creek Tramway Gulch	South Fork Big River Snuffins Creek Johnson Creek	

In 1965, DWR reported that although "there was considerable logging damage to these streams (in the Big and Noyo basins) in the past… stream clearance work recently completed by CDFG has removed logging debris from stream channels and provided access throughout the drainage to anadromous fish." The report also stated that the better spawning areas in the basin were mainly upstream from the confluence with Two Log Creek.

The California Fish and Game Plan of 1965 stated that damage to the basin from logging had been severe, although a stream clearance project helped rehabilitate the drainage. The plan reports that the Big River Basin was not supporting "the maximum runs of fish" and that limiting factors for salmonids were "siltation and erosion, probably resulting from poor forest practices." The plan recommends better land use programs and post-logging rehabilitation of streamside cover to improve fish runs.

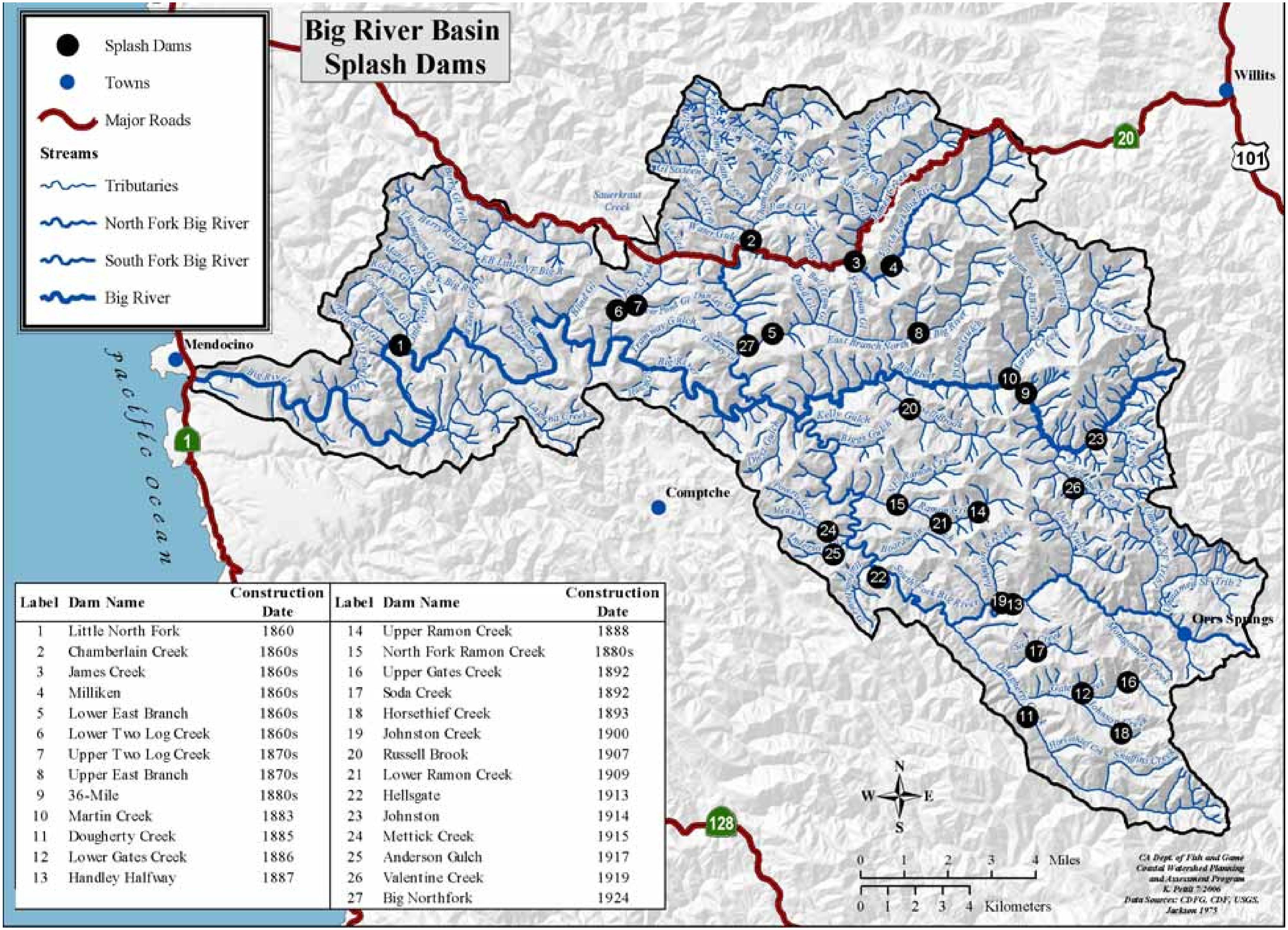
In 1973, USFWS conducted a Fishery Improvement Study in the Big River Basin (Perry 1974). USFWS found that the factors affecting fish resources in the basin in 1973 were mostly linked to timber harvesting activities:

> Cat-trails, skid roads, logging roads, and vegetation removal have contributed heavily to sediment clogging the spawning gravels. Though stream clearance projects have been undertaken, debris still presents physical barriers to migrating fish. Loss of streamside cover exposes the stream to solar radiation which increases the water temperatures to levels no longer tolerated by cold-water fishes.
>
> The stream has aggraded seriously in areas and would require reconstruction of pools and riffles. Summer flows appear adequate to support small populations of fingerlings and yearlings, provided pools, and streamside vegetation are improved.

USFWS stated that a watershed rehabilitation program would be needed to preserve and enhance existing spawning areas. Suggested rehabilitation measures included increasing summer flows in upstream rearing locations and creating additional pools. Due to Big River's potential for fishery enhancement, the basin was selected as a pilot project for a fishery improvement study. Results of this study are presented in the Water Quality and Fish History and Status sections of this report.

Effects of Historic Splash Dams

As discussed in the Land Use section of the Basin Profile, splash dam logging was used extensively throughout the Big River Basin. The basin had 27 splash dams (Figure 41).



Label	Dam Name	Construction Date
1	Little North Fork	1860
2	Chamberlain Creek	1860s
3	James Creek	1860s
4	Milliken	1860s
5	Lower East Branch	1860s
6	Lower Two Log Creek	1860s
7	Upper Two Log Creek	1870s
8	Upper East Branch	1870s
9	36-Mile	1880s
10	Martin Creek	1883
11	Dougherty Creek	1885
12	Lower Gates Creek	1886
13	Handley Halfway	1887
14	Upper Ramon Creek	1888
15	North Fork Ramon Creek	1880s
16	Upper Gates Creek	1892
17	Soda Creek	1892
18	Horsethief Creek	1893
19	Johnston Creek	1900
20	Russell Brook	1907
21	Lower Ramon Creek	1909
22	Hellsgate	1913
23	Johnston	1914
24	Mettick Creek	1915
25	Anderson Gulch	1917
26	Valentine Creek	1919
27	Big Northfork	1924

Figure 41. Splash dams on the Big River, built from 1860 to 1924, used until 1936.

When river flows were high during the winter season, dam flood gates were opened and the flood flows moved downstream and picked up logs that had been stacked in stream channels downstream. At some sites, logs were stored in the reservoir and released along with the water. Many of the dams were designed to operate in a synchronized fashion to maximize the flow of water in downstream reaches. The transport of logs downstream was called a log drive and usually occurred once per winter (GMA 2001a).

Before water was released from dams, the stream channels downstream from the dam all the way to the estuary were cleared of all obstructions and debris. Sometimes, logs moving downstream did get jammed, and one such jam on the Hellsgate reach of the South Fork Big River lasted for several years before it was cleared up. Most jams were quickly cleared, however (GMA 2001a).

These splash dam activities had a large impact upon stream channels across the Big River Basin that can still be seen today. South Fork Big River is heavily incised from flushing logs. Escola described the flushing of logs as intense snapping, popping and loud booms. In the fork where Anderson and Mettick Creeks come together, there resides a large boulder gouged by the pounding of the logs as they were flushed down the river. The Big River was "beat up the worst" (Escola 2001) of any of the coastal rivers due to the 80 years of driving logs down it.

Studies in the nearby Caspar Creek watershed of the effects of splash dams on channel geometry found post-splash damming channels to be deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD. The lack of LWD is also allowing sediment to move more quickly through the stream system and thus reach the estuary in greater quantities than pre-disturbance (Napolitano 1996, 1998 as cited in GMA 2001a). Channels within the Big River Basin share these characteristics (GMA 2001a). Another common effect of splash dam logging was displacement of main-channel gravels during log drives (Sedell et al. 1991).

Large Woody Debris Removal and Reduction

LWD shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids (Murphy and Meehan 1991). A lack of LWD in stream channels contributes to reduced pool frequency, depth, and overall habitat complexity. This reduces the quality of over-summering and over-wintering habitat for anadromous fishes. Where wood is lacking, stored sediments flush out, resulting in channel lowering and entrenchment. This disconnects channels from floodplains and reduces backwater habitats, which are thought to be important refuges for fish during strong winter storms.

Across the Big River Basin, past land use practices have removed LWD from stream channels. As discussed previously, the use of splash dam logging involved both the manual removal of LWD before dam waters were released and the flushing of remaining LWD by flood waters. Other logging practices also reduced LWD in streams by removing near-stream trees that would have otherwise been recruited into stream channels.

Additionally, there was a widespread program of LWD removal from low gradient (0-4 percent) stream channels in JDSF from the 1950s to the early 1990s. Stream channels in the Big River Basin cleared under this program include:

- Tramway Gulch
- Two Log Creek
- Berry Gulch
- East Branch Little North Fork Big River
- Laguna Creek
- James Creek
- Chamberlain Creek
- Water Gulch
- East Branch North Fork Big River
- North Fork Big River (CDF 1999, as cited in GMA 2001a)

CDFG also contracted various groups to clear LWD in streams in the 1980s and 1990s. Streams affected by these programs included:

- Russell Brook
- Ramon Creek
- Daugherty Creek
- Halfway House Gulch
- Mettick Creek
- Tramway Gulch
- East Branch North Fork Big River (MRC 2003)

The idea behind LWD removal was to re-establish fish passage around large wood jams that formed after logging activities. A secondary purpose was to allow sediment to flush from upstream of logjams where good spawning gravels were buried under fine sediment (Holman and Evans 1964). The apparent assumption underlying the removal of LWD was that sediment limits fisheries and that flushing it from the system will restore stream channels to equilibrium.

This strategy did not take into account that moderating sediment movement actually benefited downstream reaches by allowing them to at least retain patches of clean gravel for spawning. Additionally, large wood provided roughness elements to sort bed load and create scour. LWD removal programs also assumed that sediment supply would decrease, but instead, additional land use activities generated more sediment.

Current Conditions

The 52 named streams in the Big River Basin currently provide approximately 148 miles of anadromous salmonid habitat. The Big River Basin includes approximately 182 miles of low gradient streams and wetland habitat that is well suited to support coho salmon.

Recent habitat inventory surveys have been conducted on a total of 55 streams and three sections of the mainstem Big River (Table 40). In 2002, CDFG conducted 79.3 miles of habitat inventory surveys on 30 streams and two sections of the mainstem Big River. These surveys were completed under the direction of this assessment. Approximately 100.2 miles of current habitat inventory data existed prior to this effort. This included five streams and the mainstem Big River inventoried by Georgia Pacific in 1996, and 28 streams inventoried by CDFG from 1993 to 1998. Of these streams, seven were re-inventoried by CDFG in 2002. Tributary data presented in this report are from the most recent tributary inventories. Data from earlier inventories are summarized in the CDFG Appendix.

Across the Big River Basin, the Flosi et al. (1998) canopy cover target value was reached on most surveyed tributary streams. Only 15 surveyed tributaries, one in the Middle Subbasin and fourteen in the Inland Subbasin did not meet canopy cover targets. Two of these, the North and South forks of the Big River, are third order streams and thus expected to have lower canopy level observations due to wider channels. Surveys on the mainstem Big River also showed low canopy density. The mainstem is a fourth order river; however, so the target values do not apply.

Embeddedness target values were only reached on three tributaries and the mainstem Big River from Wheel Gulch to Blind Gulch and from Tramway Gulch to North Fork Big River. None of the surveyed tributaries in the Middle Subbasin reached target values for cobble 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 only met on Sauerkraut Creek and East Branch North Fork Big River.

Table 40. Summary of current (1995, 1996, 1997, 1998, and 2002) conditions.

Stream	Surveyed Length (miles).	% Canopy Density over the Surveyed Stream	% of Pool Tails with Cobble Embeddedness in Category 1	% Length of Surveyed Stream in Primary Pools	Shelter Cover Ratings
Target Values (Flosi et al 1998)		*>80%*	*>50%*	*>40%*	*>100*
Big River Basin	**154.1**				
Coastal Subbasin	**39.5**				
Big River	20.3	33	<1	36	45
Laguna Creek	1.9	87	1	30	61
Railroad Gulch	1.1	93	5	5	21
Little North Fork Big River	3.7	89	8	22	33
Rocky Gulch	0.2	100	57	2	33
Manly Gulch	0.7	92	23	1	18
Thompson Gulch	1.1	92	7	2	51
East Branch of the Little North Fork Big River	2.4	88	37	9	68
Berry Gulch	2.2	93	0	4	24
Berry Gulch Tributary	1.1	92	8	6	47
Big River (Wheel Gulch to Blind Gulch)	5.0	65	60	27	34
Middle Subbasin	**9.5**				
Kidwell Gulch	0.9	97	8	1	22
Two Log Creek	3.0	92	25	20	16
Sauerkraut Creek (Two Log Creek Tributary)	0.1	85	0	4	80
Ayn Creek (Two Log Creek Tributary)	0.3	80	0	3	58
Big River (Tramway Gulch to North Fork Big River)	4.7	56	53	35	66
Hatch Gulch	0.5	64	0	0	49
Inland Subbasin	**105.1**				
North Fork Big River	12.0	67	15	22	19
East Branch of the North Fork Big River	7.4	74	5	9	87
Chamberlain Creek	5.1	73	23	4	25
Water Gulch	1.9	94	2	13	41
Water Gulch Tributary	0.4	97	9	0	10
Park Gulch	1.0	97	6	2	64
West Chamberlain Creek	3.5	87	2	3	63
Gulch Sixteen	0.9	94	6.5	1	40
Gulch Sixteen Tributary	0.4	97	16	2	40
Arvola Gulch	0.9	84	3	2	33
Lost Lake Creek	0.9	93	15	1	17
Soda Gulch	0.7	98	0	0	8
James Creek	4.4	67	18	9	14
North Fork James Creek	2.4	80	11	7	50
South Fork Big River	20.5	78	27	24	27
Biggs Gulch	0.5	85	23	1	30
Ramon Creek	3.0	75	15	2	38
North Fork Ramon Creek	1.5	76	48	2	39
Mettick Creek	1.0	74	43	5	26
Poverty Gulch	0.1	69	0	0	38
Anderson Gulch	0.5	90	0	2	21
Boardman Gulch	1.3	87	0	1	51
Halfway House Gulch	0.2	84	67	10	30
Daugherty Creek	8.8	84	37	11	73
Soda Creek	1.7	83	74	3	27
Gates Creek	2.7	88	32	11	79
Johnson Creek (Gates Creek Tributary)	1.2	71	37	2	51
Horse Thief Creek	0.1	95	0	0	25
Snuffins Creek	1.3	81	18	1	38
Johnson Creek	0.9	71	37	1	51
Dark Gulch	1.4	77	16	2	26
Montgomery Creek	0.7	80	8	12	19
South Fork Big River Tributary #1	1.1	69	32	7	35
South Fork Big River Tributary #2	0.6	78	4	1	31
Russell Brook	4.1	83	1	2	36

Stream	Surveyed Length (miles).	% Canopy Density over the Surveyed Stream	% of Pool Tails with Cobble Embeddedness in Category 1	% Length of Surveyed Stream in Primary Pools	Shelter Cover Ratings
Martin Creek	3.7	81	15	11	24
Martin Creek Left Bank Tributary	0.6	90	11	2	26
Martin Creek Right Bank Tributary #1	1.5	83	0	2	26
Martin Creek Right Bank Tributary #2	0.6	86	0	6	34
Valentine Creek	1.8	84	15	2	19
Rice Creek	1.8	82	8	3	39

Based Upon Habitat Inventory Surveys from the Big River Basin, California. Condensed Tributary Reports are located in the CDFG Appendix.

Large Woody Debris

Large woody debris, or LWD, is an important component of stream habitats for anadromous salmonids. LWD shapes channel morphology, helps retain organic matter and provides essential cover for salmonids. MRC examined LWD in stream channels across their ownership (in the Middle and Inland Subbasins) in the Big River Basin and found a lack of LWD as well as a low recruitment potential for LWD (MRC 2003). LWD was low in major channels such as the mainstem Big River, North and South Forks Big River, and the East Branch North Fork Big River. For details, please see the Riparian Conditions and Fish Habitat Relationship sections of the Subbasin Profiles.

Fish Passage Barriers

Stream Crossings

Three stream crossings were surveyed in the Big River Basin as a part of the coastal Mendocino County culvert inventory and fish passage evaluation conducted by Ross Taylor and Associates (2001). Priority ranking of 24 culverts in coastal Mendocino County for treatment to provide unimpeded salmonid passage to spawning and rearing habitat placed the culvert on Johnson Creek at rank 5, the culvert on Dark Gulch at rank 7, and the culvert on the unnamed tributary to the South Fork of the Big River at rank 10. Since the culvert inventory was completed, the culverts on Johnson Creek and an unnamed tributary to South Fork Big River have been modified to improve fish passage.

Additional culverts that may pose problems for fish passage were noted by CDFG stream surveys, the CGS Geologic Report for the State Park, the MRC Watershed Analysis and in surveys documented by NMFS (Jones 2000). Please see the Subbasin Profiles for further details.

Culvert repair, upgrade, and improvement are an important part of stream restoration projects. In the Big River Basin, the CDFG North Coast Watershed Improvement Center includes culverts as a part of stream restoration and improvement efforts. They were able to supply information on recent culvert assessment and treatment contracts. Typically, following assessments like those done by Ross Taylor and Associates, the County or landowner follows up with improvement proposals to CDFG for funding support to implement recommendations. In the Big River Basin, some of the recommended treatments are currently proposed or being implemented.

Dry Channel

CDFG stream inventories found dry channels on 41 streams in the Big River Basin. Although the habitat typing survey only records the dry channel present at the point in time when the survey was conducted, this measure of dry channel can give an indication of summer passage barriers to juvenile salmonids. Dry channel conditions in the Big River Basin generally occur from late July through early September. Therefore, CDFG stream surveys conducted outside this period are less likely to encounter dry channel.

The amount of dry channel reported in surveyed stream reaches in the Big River Basin is 2.7% of the total length of streams surveyed. This dry channel was found in eight streams of the Coastal Subbasin, two streams of the Middle Subbasin, and 31 streams of the Inland Subbasin. Dry habitat units occurred near the mouth, in the middle reaches, and at the upper limit of anadromy of the tributaries.

Changes in Habitat Conditions from 1964 to 2001

Streams surveyed in the 1950s and 1960s and habitat inventory surveyed in the 1990s or 2002 were compared to indicate changes between past and current conditions. Data from 1960s stream surveys provided a snapshot of the conditions at the time of the survey. The results of past stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to indicate general trends.

Where habitat data were available from both older stream surveys and recent stream inventories it appeared that spawning habitat had mostly decreased across the Coastal Subbasin and remained constant across the Inland Subbasin. No general trend was seen in the Middle Subbasin.

It also appeared that pool habitat had mostly remained unchanged across the Coastal Subbasin and decreased in the Inland Subbasin. No general trend was seen in the Middle Subbasins.

Lastly, shelter appeared to have mostly remained unchanged in the Coastal Subbasin and decreased in the Inland subbasin, perhaps related to successful stream clearing projects. No general trend was seen in the Middle Subbasin.

For details, please see the Fish Habitat Relationship sections of the Subbasin Profiles and the CDFG Appendix.

Fish History and Status

Fishery resources of the Big River Basin include coho salmon and winter-run steelhead trout. Chinook salmon have been reported occasionally, but there are no current data on their distribution or population. CDFG attempted to establish a run of Chinook in the 1950s, but was not successful (DWR 1965). Other fish present in the Big River Basin include sticklebacks, lampreys, and sculpins (Table 41).

Many fish in the Big River Basin use the estuary during some part of their life history. Anadromous salmonids and Pacific lampreys pass through the estuary on migrations. Threespine stickleback, sculpins, surfperch, herring, eulachon, and topsmelt spawn or give birth within the estuary. Some steelhead trout, coho salmon, threespine stickleback, sculpin, starry flounder, Pacific halibut, and surfperch rear in the estuary (Britschgi and Marcus 1981).

Fishery resources of the Big River and its estuary were likely important food sources for the Pomo village that was once located near the town of Mendocino. The fishery resources also provided an important food supply to early European settlers of the Mendocino area.

As for most coastal streams, salmonid population data are limited for the Big River Basin. Anecdotal evidence and local opinion provide a case that salmonids were plentiful in the Big River Basin and experienced a decrease like other salmonid populations along the coast of California. Coho salmon have been documented in 31 tributaries and the mainstem Big River across the basin (Table 42). Steelhead trout have been documented in 51 tributaries and the mainstem Big River.

Table 41. Fishery resources of Big River.

Common Name	Scientific Name
Anadromous	
Coho Salmon	*Oncorhynchus kisutch*
Chinook Salmon	*Oncorhynchus tshawytscha*
Steelhead Trout	*Oncorhynchus mykiss*
Eulachon	*Thaleichthys pacificus*
Pacific Lamprey	*Lampetra tridentata*
Freshwater	
Coastrange Sculpin	*Cottus aleuticus*
Prickly Sculpin	*Cottus asper*
Sacramento Western Sucker	*Catostomus occidentalis occidentalis*
Pacific Brook Lamprey	*Lampetra pacifica*
Threespine Stickleback	*Gasterosteus aculeatus*
Marine or Estuarine Dependent	
Pacific Halibut	*Hippoglossus stenolepis*
Pacific Herring	*Clupea harengus pallasii*
Pacific Tomcod	*Microgadus proximus*
Topsmelt	*Atherinops affinis*
Bay Pipefish	*Sygnathus leptorhynchus*
Bocaccio	*Sebastes paucispinis*
Red-tail Surfperch	*Amphistichus rhodoterus*
Silver Surfperch	*Hyperprosopon ellipticum*

Common Name	Scientific Name
Striped Surfperch	*Embiotoca lateralis*
Pile Surfperch	*Damalichthys vacca*
Walleye Surfperch	*Hyperprosopon argentum*
Shiner Surfperch	*Cymatogaster aggregata*
White Surfperch	*Phanerodon furcatus*
Surf Smelt	*Hypomesus pretiosus*
Buffalo sculpin	*Enophrys bison*
Staghorn Sculpin	*Leptocottus armatus*
Starry Flounder	Platicthys stellatus
Amphibians	
Pacific Giant Salamander	*Dicamptodon tenebrosus*
Tailed Frog	*Ascaphus truei*
Red-legged Frog	*Rana aurora*
Foothill Yellow-Legged Frog	*Rana boylei*

Pers. comm. Harris and LeDoux CDFG, Wright CTM 2004, Grantham 2003, Britschgi and Marcus 1981.

Table 42. Documented salmonid presence across the Big River Basin.

Streams	Coho Salmon	Steelhead Trout	Unidentified Salmonids	Reference*
Coastal Subbasin				
Estuary channel Big River	X	X		SONAR 2001, 2002
Mainstem Big River	X	X		CDFG 1959, 2002; USFWS 1973; NMFS 1994-1996; CI 2001; HTC 1996
Laguna Creek			X	HTC 1996
Railroad Gulch	X	X		CEMR 1979; NMFS 1995-1997; HTC 1996; SONAR 2001
Little North Fork Big River	X	X		CDFG 1959, 1985, 1995; CEMR 1979; NMFS 1995-2000; SONAR 2001, 2002; HTC 1993-2002
Rocky Gulch	X			CDFG 1959, 1997
Manly Gulch			X	CDFG 1959, 1997
Thompson Gulch	X	X		CDFG 1959, 1985, 1997; CEMR 1979; NMFS1995-1997
East Branch Little North Fork Big River	X	X		NMFS 1967; CDFG 2002
Berry Gulch	X	X		CDFG 1959, 1997; NMFS 1995-1997
Berry Gulch Tributary	X	X		CDFG 1997
Middle Subbasin				
Mainstem Big River	X	X		CDFG 2002; MRC 1994-1996, 2000-2002
Kidwell Gulch		X		CDFG 2002
Two Log Creek	X	X		CDFG 1959, 1966, 1997, 1998, 2002; NMFS 1983, 1995-1997, 2000; CI 2001; MRC 1994-1996, 2000-2002; HTC 1993-2002
Saurkraut Creek				CDFG 1998
Ayn Creek		X		CDFG 1998
Beaver Pond Gulch				MRC 1995-1996, 2000-2002
Tramway Gulch	X	X		CDFG circa 1950, 1966; NMFS 1995-1996; MRC 1994-1996, 2000-2002
Hatch Gulch	X	X		CDFG 1988, HTC 1996, CDFG 1996
Dietz Gulch				CDFG circa 1950
Inland Subbasin				
North Fork Big River	X	X		CDFG 1958, 1959, 1985, 1996-1997; USFWS 1973; NMFS 1966, 1967, 1995-1997; CI 2001; MRC 1994-2002
Steam Donkey Gulch				MRC 1996, 2000-2001
East Branch North Fork Big River	X	X		CDFG 1958, 1959, 1966, 1998; CI 2001; USFWS 1973; CEMR 1979; NMFS 1995-1997; MRC 1994-1996, 2000-2002
Quail Gulch				MRC 1996
Bull Team Gulch	X	X		NMFS 1996; MRC 1996, 2000-2002
Frykman Gulch		X		MRC 2000-2002
Dunlap Gulch				MRC 1996, 2000-2002
Chamberlain Creek		X		NMFS 1980, 1995-1997; CDFG 1997; SONAR 2001
Water Gulch	X	X		CDFG 1959, 1997; NMFS 1981, 1995-1997
Water Gulch Tributary		X		CDFG 1995
Park Gulch		X		CDFG 1997; NMFS 1981, 1995-1997
West Chamberlain Creek		X		CDFG 1997; NMFS 1981, 1995-1997; SONAR 2001
Gulch Sixteen		X		CDFG 1997; NMFS 1995-1997
Gulch Sixteen Tributary				CDFG 1997
Arvola Gulch	X	X		CDFG 1997; NMFS 1980, 1995-1997
Lost Lake Creek		X		CDFG 1997; NMFS 1980, 1995-1997
Soda Gulch				CDFG 1997
James Creek		X		CDFG 1958, 1996; NMFS 1980, 1995-1997
North Fork James Creek		X		CDFG 1958, 1995; NMFS 1995-1997

Streams	Coho Salmon	Steelhead Trout	Unidentified Salmonids	Reference*
South Fork Big River	X	X		CDFG 1957/1958, 1966, 2002; USFWS 1973; NMFS 1995, 1996;CI 2001; MRC 1994-1996, 2000-2002
Kelly Gulch				CDFG circa 1950
Biggs Gulch				CDFG circa 1950, 2002
Noname Gulch				MRC 1995-1996, 2000-2001
Ramon Creek	X	X		CDFG 1959, 2002; NMFS 1995; CI 2001; MRC 1994-1996, 2000-2002; CDFG 2003
North Fork Ramon Creek	X	X		CDFG 2002; MRC 1994-1996, 2000-2002
Mettick Creek		X		CDFG circa 1950, 2002; NMFS 1994-1996; MRC 1994-1996, 2000-2002; CDFG 2003
Poverty Gulch				CDFG 2002
Anderson Gulch		X		CDFG circa 1950, 2002; NMFS 1994-1996; MRC 1994-1996, 2000-2002
Boardman Creek		X		CDFG circa 1950, 2002; MRC 1996, 2000-2002
Halfway House Creek		X		NMFS 1996; MRC 1996, 2000-2002
Daugherty Creek	X	X		CDFG 1959, 1993, 2002; NMFS 1996; CI 2001; MRC 1994-1996, 2000-2002
Soda Creek	X	X		CDFG 1959, 1988, 1993, 2002; NMFS 1995-1997; MRC 1994-1996, 2000-2002
Gates Creek	X	X		CDFG 1993, 2002; NMFS 1996; MRC 1994-1996, 2000-2002
Tributary to Gates Creek		X		MRC 2000
Johnson Creek (Tributary to Gates Creek)		X		CDFG 1959, 1993, 2002; NMFS 1996; MRC 1994-1996, 2000-2002
Horse Thief Creek				CDFG 2002
Snuffins Creek	X	X		CDFG 1959, 1966, 1993, 2002; NMFS 1996; MRC 1994-1996, 2000-2002
Johnson Creek		X		CDFG 1959, 1966, 2002; Jones 2000
Dark Gulch	X	X		NMFS 1958, 1999; CDFG 2002
Montgomery Creek				CDFG 2002
South Fork Tributary #1	X	X		CDFG 1958, 2002
South Fork Tributary #2	X	X		CDFG 1958, 2002
Mainstem Big River Headwaters	X	X		MRC 1994-1996, 2000-2002
Russell Brook	X	X		CDFG 1959, 2002; NMFS 1967, 1996; MRC 1994-1996, 2000-2002; CDFG 2003
Pigpen Gulch		X		CDFG 1959; NMFS 1967, 1994,-1996; MRC 1994-1996, 2000-2002
Martin Creek	X	X		CDFG 1959, 2002; NMFS 1967, 1994-1996; USFWS 1973; MRC 1994-1996, 2000-2002
Martin Creek Left Bank Tributary		X		CDFG 1959, 2002
Martin Creek Right Bank Tributary #1	X	X		CDFG 2002
Martin Creek Right Bank Tributary #2				CDFG 2002
Valentine Creek	X	X		CDFG 1959, 2002
Rice Creek		X		CDFG circa 1959, 2002; NMFS 1967
East Branch Rice Creek				CDFG 1959

All known surveys are listed, although salmonids may not have been detected in each survey. More details of individual surveys are available in subbasin sections and the CDFG Appendix.
* CDFG = Department of Fish and Game survey; CI = Department of Fish and Game Coho Inventory; CEMR = Center for Education and Manpower Resources; MRC = Mendocino Redwood Company Report; HTC = Hawthorne Timber Company; SONAR = School of Natural Resources at Mendocino High School; NMFS = National Marine Fisheries Service (Jones 2000)

Figure 42 and Figure 43 depict the documented current and estimated historic distributions of coho salmon and steelhead trout, respectively. Current ranges are based on documented presence reports by CDFG, MRC, HTC, SONAR, and NMFS. Salmonids may be present in sites where they have not been documented due to a lack of data or imperfect sample techniques.

The limits of the estimated historic range of steelhead trout, the most athletic of the Big River salmonids, was initially defined to be a perennial stream reach of 1000 feet or more with a gradient in excess of 10%. The limits of the coho salmon range estimates were defined as perennial reaches of 1000 feet or more with a gradient in excess of 5%. These estimates were based on 30 meter digital elevation model (DEM) analyses. The preliminary range estimates were then reviewed by a team of CDFG fishery biologists.

The preliminary estimates are not a definite indication that coho salmon and/or coho salmon were historically present in the indicated reaches, rather they indicate the possibility that salmonids were present. Additionally, the estimates do not conclusively prove that salmonids were not historically present in areas above the estimated gradient barriers. Other factors that affect salmonid distributions such as flow limitations, channel shape and size, and barriers such as waterfalls could not be incorporated into this gradient-based analysis. Additionally, the 30 meter DEM may not provide enough accuracy for this analysis.

Historical accounts indicate that salmon were plentiful and that salmon fishing was a common activity (Jackson 1991). One local newspaper accounts mentioned a haul of 79 salmon seined in the river and sold for 25 cents each in 1900 (Wynn 1989).

A 1955 CDFG memo (Evans) described the coho salmon fishery as depleted, with only two salmon seen in the past year. Fisheries biologists recommended stocking coho salmon to revive their populations along with stream improvement measures.

A DWR report in 1965 described excellent populations of steelhead and coho salmon in the Big River Basin. Creel census data collected by CDFG during January 1955 indicated that about 800 angler days were expended resulting in a catch of 450 steelhead. Based on these data, DWR estimated that the Big River had runs of about 6,000 steelhead and 2,000 coho salmon annually.

The 1965 CDFG Fish and Wildlife Plan estimated spawning runs of 6,000 coho salmon and 12,000 steelhead trout in the Big River Basin. This estimate was based on comparisons to nearby streams by local fish biologists. Salmon fishing in the basin was estimated to be 1,000 angler-days per year, while steelhead trout fishing was estimated to be 1,600 angler-days per year. An angler-day is one or more fishing expeditions by an angler within one 24-hour period. The fishing yields were estimated to be 400 salmon and 500 steelhead trout per year, or 0.4 salmon and 0.3 steelhead trout per angler-day.

Salmonids have been stocked in the Big River over the past 100 years. The earliest mention of stocking was from a 1904 Mendocino Dispatch Democrat article which mentioned that juvenile steelhead trout were stocked into James Creek. Although Big River was characterized as a primarily coho salmon and steelhead trout stream, CDFG also attempted to establish a run of Chinook salmon in the basin in the late 1940s and early 1950s. A 1955 CDFG memo described the coho salmon fishery as depleted and describes department efforts to stock Chinook salmon. Many unmarked Chinook fingerlings were released in the basin from 1949 through 1952 (Table 43). In addition, over 100,000 marked Chinook salmon fingerlings were released in 1950 as part of a larger study on the survival of stocked salmonids (Hallock et al. 1952). Only 14 of these marked fish were recovered, although an increase of Chinook salmon present was observed in the year that the recheck was made. This increase was attributed to the presence of straying Sacramento River and Umpqua River fish. Coho salmon eggs were stocked in South Fork Big River in January 1956.

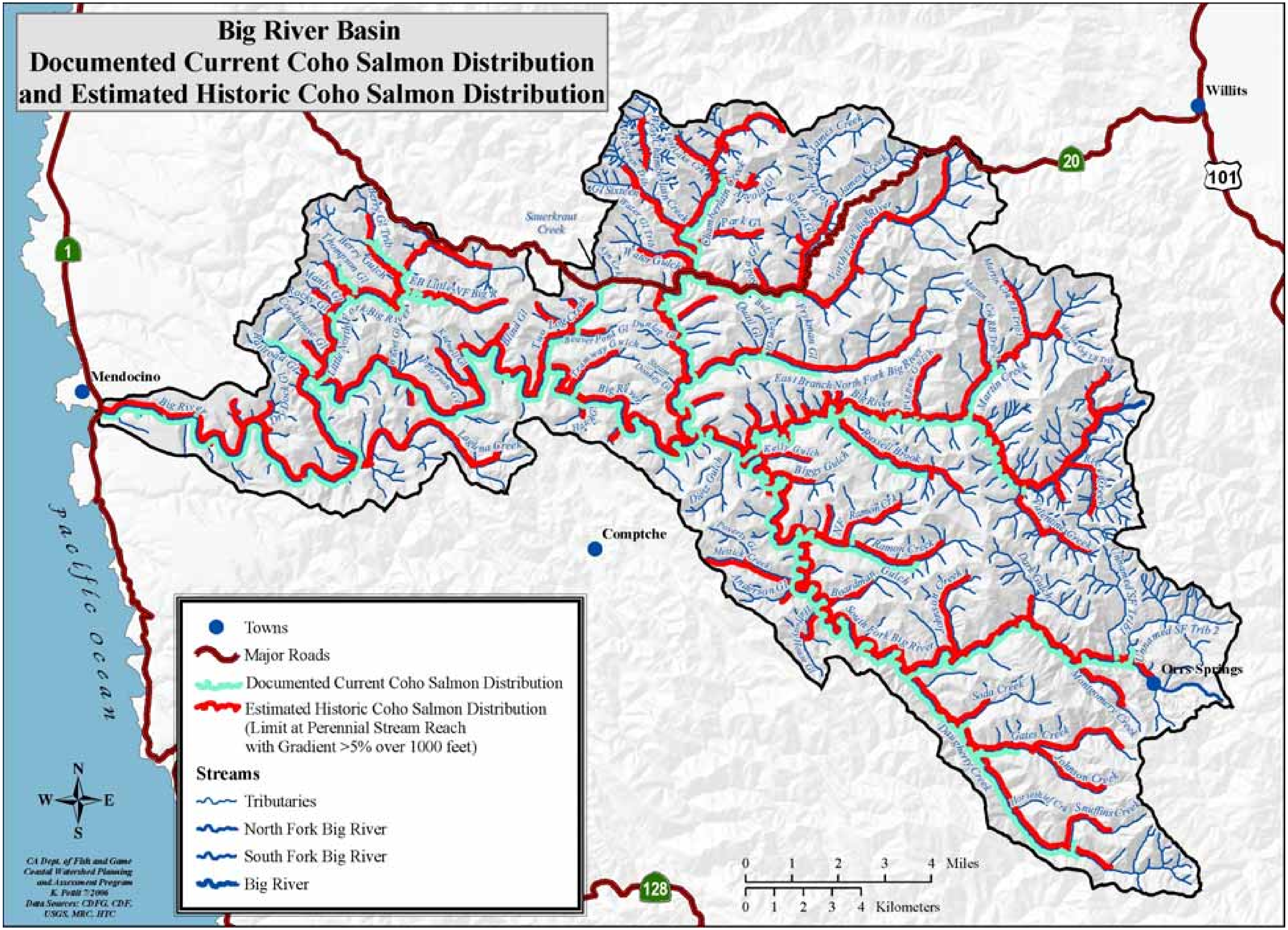


Figure 42. Coho salmon 2002 distribution based on CDFG and MRC surveys and estimated historic distribution based on a 30 meter digital elevation model in the Big River Basin.

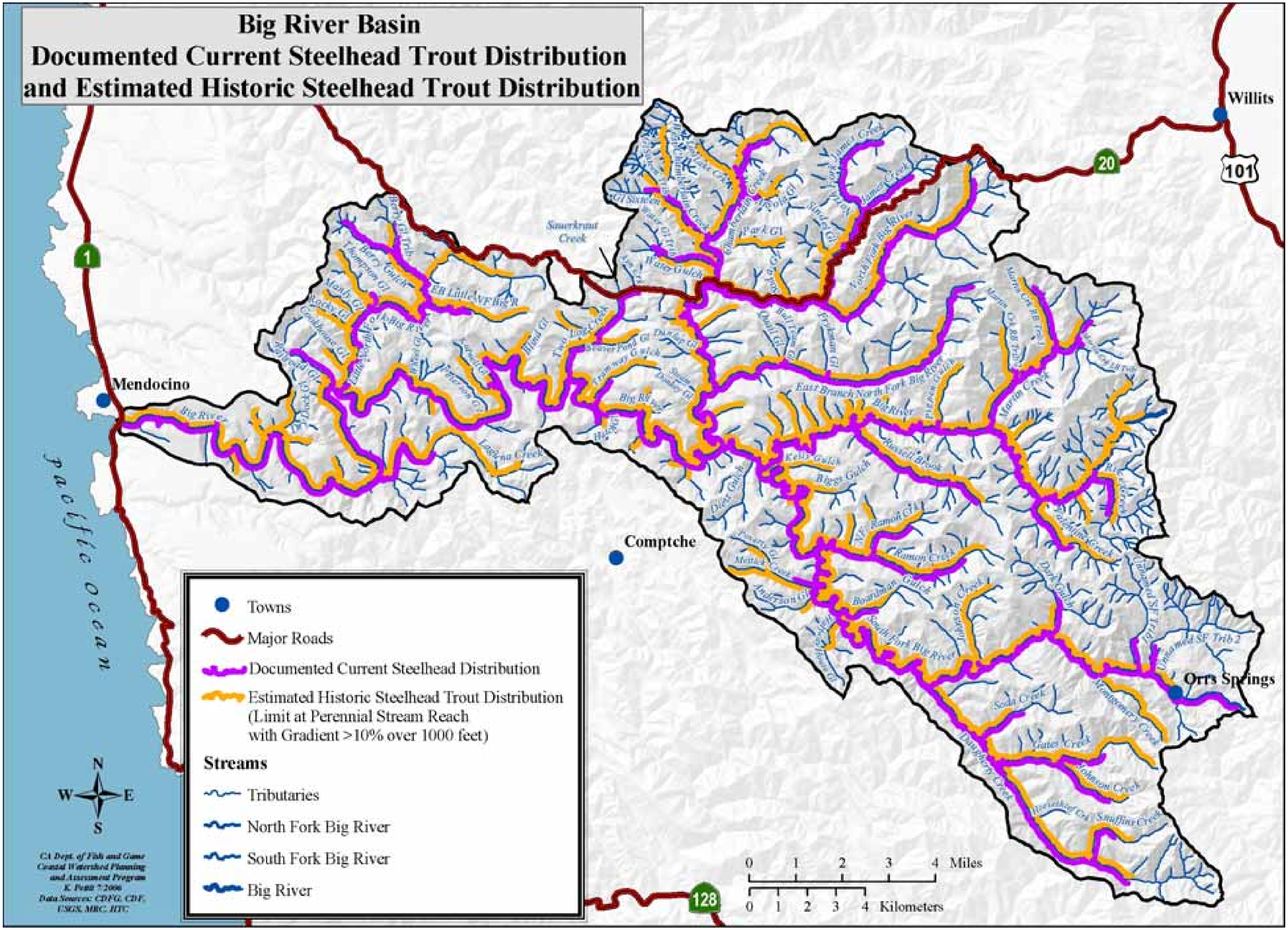


Figure 43. Steelhead trout 2002 distribution based on CDFG and MRC surveys and estimated historic distribution based on a 30 meter digital elevation model in the Big River Basin.

Table 43. Salmonid stocking in the Big River Basin.

Date	Where stocked	Number	Species	Source of Fish
1904	James Creek	Several thousand	Steelhead trout	Outlet Creek, Eel River Basin
1949-1952	Mainstem Big River	480,000	unmarked Chinook fingerlings	Mad River
1950	Mainstem Big River	132,734	marked Chinook fingerlings	Mad River
1956	South Fork Big River	200,000	Coho salmon eggs	NA
1973	Chamberlain Creek	100,000	Coho salmon	NA
1974	Mainstem Big River	100,000	Coho salmon	NA
1975	Mainstem Big River	90,000	Coho salmon	NA
1978	South Fork Big River	Many thousands	Coho salmon fingerlings	NA

CDFG conducted 40 stream surveys on 31 Big River tributaries in the 1950s and 1960s. Survey reports included drainage, stream condition, habitat suitability, stream obstruction, and fisheries descriptions. Salmonid presence and habitat characteristics were usually determined by direct stream bank observation. Survey reports concluded with recommendations for management. The Center for Education and Manpower Resources (CEMR) surveyed four streams in the Coastal and Inland subbasins in 1979 using the same protocols as CDFG. An additional 13 stream surveys and two electrofishing efforts conducted between 1958 and 1981 were documented by NMFS (Jones 2000). All surveys documented coho salmon and steelhead trout presence throughout the basin (Table 44).

Table 44. Coho salmon and steelhead trout presence reported in CDFG and CEMR stream surveys from 1950-1989.

Subbasin	Number of Streams Surveyed	Number of Streams where Coho Salmon were Reported*	Number of Streams where Steelhead Trout were Reported *
Coastal	5 (including mainstem Big River)	2	2
Middle	2	1	2
Inland	25	7	18

*These numbers do not include unidentified salmonid observations.

USFWS conducted field investigations of several streams across the Big River Basin associated with a Fisheries Improvement Study in 1973 (USBR 1974). Ten transects across the basin were electrofished to determine juvenile salmonid populations. Transects were 328 feet long (100 meters) and located in the mainstem Big River, North Fork Big River, East Branch North Fork Big River, South Fork Big River, and Martin Creek (Figure 16). Six sites were electrofished in July and all ten sites were electrofished in October. Steelhead trout were found in all transects and coho salmon were found in six transects (Table 45).

Table 45. USFWS electrofishing results from ten transects across the Big River Basin in 1973.

Subbasin	Number of Transects Surveyed	Number of Transects where Coho Salmon were Reported	Number of Transects Where Steelhead Trout Were Reported
Coastal	1	1	1
Inland	9	5	9

In 1973, the Salmon Restoration Association (SRA) started a small salmonid rearing pond on Chamberlain Creek (Maahs 1999). CDFG delivered 100,000 juvenile coho salmon and fish were fed by camp inmates at the Chamberlain Creek Conservation Camp. As air and water temperatures rose over the summer, it became clear that the pond was not large enough and stream flow into the pond was insufficient to meet dissolved oxygen needs and the project was halted.

In 1974, the SRA built a 345 feet long and 35 to 60 feet wide rearing pond along the mainstem Big River. The pond was planted with 100,000 coho salmon that year. Water temperatures over the summer were as high as 78°F and remained above 70°F for much of July and August. However, water flows were high enough to provide sufficient dissolved oxygen. Fish were flushed into the natural system with high flows on December 7. Although water temperatures in Big River were very high, another attempt at rearing coho salmon was made in the mainstem Big River pond in 1975 when 90,000 coho salmon were planted. Water temperature problems continued and the Big River rearing pond was abandoned.

In 1978, SRA estimated the spawning area available, potential for coho salmon, and runs present at that time in coastal Mendocino streams in a report describing salmonid restoration activities across the Mendocino coast (Maahs 1978). The Big River was estimated to have 75 miles of spawning area and the potential for 17,500 coho salmon. The 1978 coho salmon run was estimated to be 2,000.

CDFG conducted an extensive search of their records in 1979 and created an inventory of fish bearing streams in Mendocino County (Cherr and Griffin 1979). This inventory listed all the streams in the county and listed recorded fish species for streams where records were available. For this current assessment CDFG has utilized all of the primary sources identified by Cherr and Griffin.

From 1981-1987, SRA operated a coho salmon enhancement project on Johnson Creek in the South Fork Subbasin (Nielsen et. al 1991, Jones 2000). Fry were obtained from a hatchbox program on nearby Hollowtree Creek and the estimated capacity of the facility was 10,000 smolts per year (Sommarstrom 1984). About 2,500 coho salmon fry were reared and released in 1987 (Nielsen et. al 1991).

NMFS (Jones 2000) documented one stream survey, 32 electrofishing efforts, two carcass surveys, and one snorkel survey conducted between 1994 and 1997 across the basin. Coho salmon were found in 17 tributaries and the mainstem Big River and steelhead trout were detected in 32 tributaries and the mainstem Big River (Table 46).

Table 46. Coho salmon and steelhead trout presence documented by NMFS (Jones2000).

Subbasin	Number of Streams	# of streams with Coho Salmon Reported*	# of streams with Steelhead Trout Reported*
Coastal	5(including mainstem Big River)	5(including mainstem Big River)	5
Middle	2	1	2
Inland	26	11	25

*These numbers do not include unidentified salmonid observations.
From surveys, carcass surveys, electrofishing, and snorkel surveys between 1994 and 20007.

MRC has collected single-pass electrofishing or snorkel counts of 64 sites on 28 tributaries and the mainstem Big River in the Middle and Inland subbasins in the years 1994-1996, and 2000-2002 (MRC 2003). Sites were surveyed for the purpose of detecting the presence of fish species. These data do not enable the assessment of fish health or abundance, but do provide a look at fish community structure, and specifically the presence of coho salmon or other species. Coho salmon were found in 13 tributaries and the mainstem Big River and steelhead trout were detected in 23 tributaries and the mainstem Big River (Table 47). Not all study sites were sampled for multiple years, but in 13 study sites that were sampled for four years or more, coho salmon were only found in 2002.

Table 47. Coho salmon and steelhead trout presence reported in MRC stream surveys from 1990-2002.

Subbasin	Number of Study Sites	Number of Streams	Coho Salmon Reported*		Steelhead Trout Reported *	
			Number of Sites	Number of Streams	Number of Sites	Number of Streams
Middle	8	5 (including mainstem Big River)	5	3 (including mainstem Big River)	7	4 (including mainstem Big River)
Inland	56	25 (including mainstem Big River)	26	12 (including mainstem Big River)	51	21 (including mainstem Big River)

*These numbers do not include unidentified salmonid observations.

With the publication of the *California Salmonid Stream Habitat Restoration Manual* in 1991, stream survey methodologies used by CDFG became standardized and more quantitative. Georgia-Pacific (now Hawthorne Timber Company) surveyed seven streams in the Coastal and Middle subbasins in 1996 using CDFG protocols. These surveys documented coho salmon in one stream and steelhead trout in four (Table 48). Fifty-six tributary reports were completed by CDFG on 51 Big River tributaries from 1995 to 2002. Coho salmon were detected in 21 surveyed tributaries and two reaches of the mainstem Big River and steelhead trout were detected in 35 surveyed tributaries and two reaches of the mainstem Big River (Table 49).

Table 48. Coho salmon and steelhead trout presence reported in Georgia Pacific stream surveys in 1996.

Subbasin	Number of Streams Surveyed	Number of Streams Where Coho Salmon Were Reported*	Number of Streams Where Steelhead Trout Were Reported *
Coastal	5	1	3
Middle	2	0	1

*These numbers do not include unidentified salmonid observations.

Table 49. Coho salmon and steelhead trout presence reported in CDFG stream surveys from 1990-2003.

Subbasin	Number of Streams Surveyed	Number of Streams Where Coho Salmon Were Reported*	Number of Streams Where Steelhead Trout Were Reported *
Coastal	9 (including mainstem Big River)	8 (including mainstem Big River)	7 (including mainstem Big River)
Middle	3 (including mainstem Big River)	2 (including mainstem Big River)	3 (including mainstem Big River)
Inland	39	13	27

*These numbers do not include unidentified salmonid observations.

No recent studies estimate the populations of coho salmon and steelhead trout throughout the Big River Basin.

Fishing Interests and Constituents

Historically, sport fishing for coho salmon and steelhead trout has drawn local anglers to the Big River from November through February. A 1942 report to the State Board of Forestry estimated that there were 60 miles of streams within the basin accessible to spring trout and/or fall steelhead and salmon fishing (Fritz 1942). Before the 1960s, hundreds of small boats trolled for salmon in the Big River (Mendocino Coastal Streams Subcommittee of the Advisory Committee on Salmon and Steelhead Trout 1986).

A 1965 DWR report describes a fine winter steelhead fishery. Coho salmon usually supplied most of the catch in the early part of the season with the main steelhead trout runs occurring later and providing fishing through the end of the season. Summer fishing was not permitted in order to provide protected nursery areas for young fish prior to their migration to the ocean. The majority of ocean fishing along the Mendocino coast occurred in the summer and fall. Coho salmon were taken at sea in the commercial fishery; however, relatively few fish taken in sport and commercial fisheries at sea were produced in the Big River Basin. A 1978 coastal wetland survey (Dana 1978) describes hunting and sport fishing as common uses of the wetlands in the Big River Estuary.

The threatened and endangered status of coho salmon and steelhead trout currently restricts river sport fishing on Big Basin stocks. The winter salmon and steelhead fishery of the Big River below the confluence with Two Log Creek is managed as a catch and release fishery from November 1 to March 31. Only barbless hooks may be used. For up to date fishing regulations contact Department of Fish and Game Central Coast Region in Yountville, CA 95501 (707) 944-5500 or visit the CDFG website at www.dfg.ca.gov.

Restoration Programs

The CDFG Fisheries Restoration Grants Program has funded various projects in the Big River Basin (Figure 44). Projects can be grouped into six broad categories:

- Improve Fish Passage
- Decrease Erosion/Stream Sedimentation
- Big River Estuary Biodiversity Assessment
- Road Sediment Assessment/Planning
- Improve Instream Habitat
- Increase Stream Bank Stabilization/Protection
- Increase Stream Shading

More details of the restoration projects are in the subbasin sections of this report.

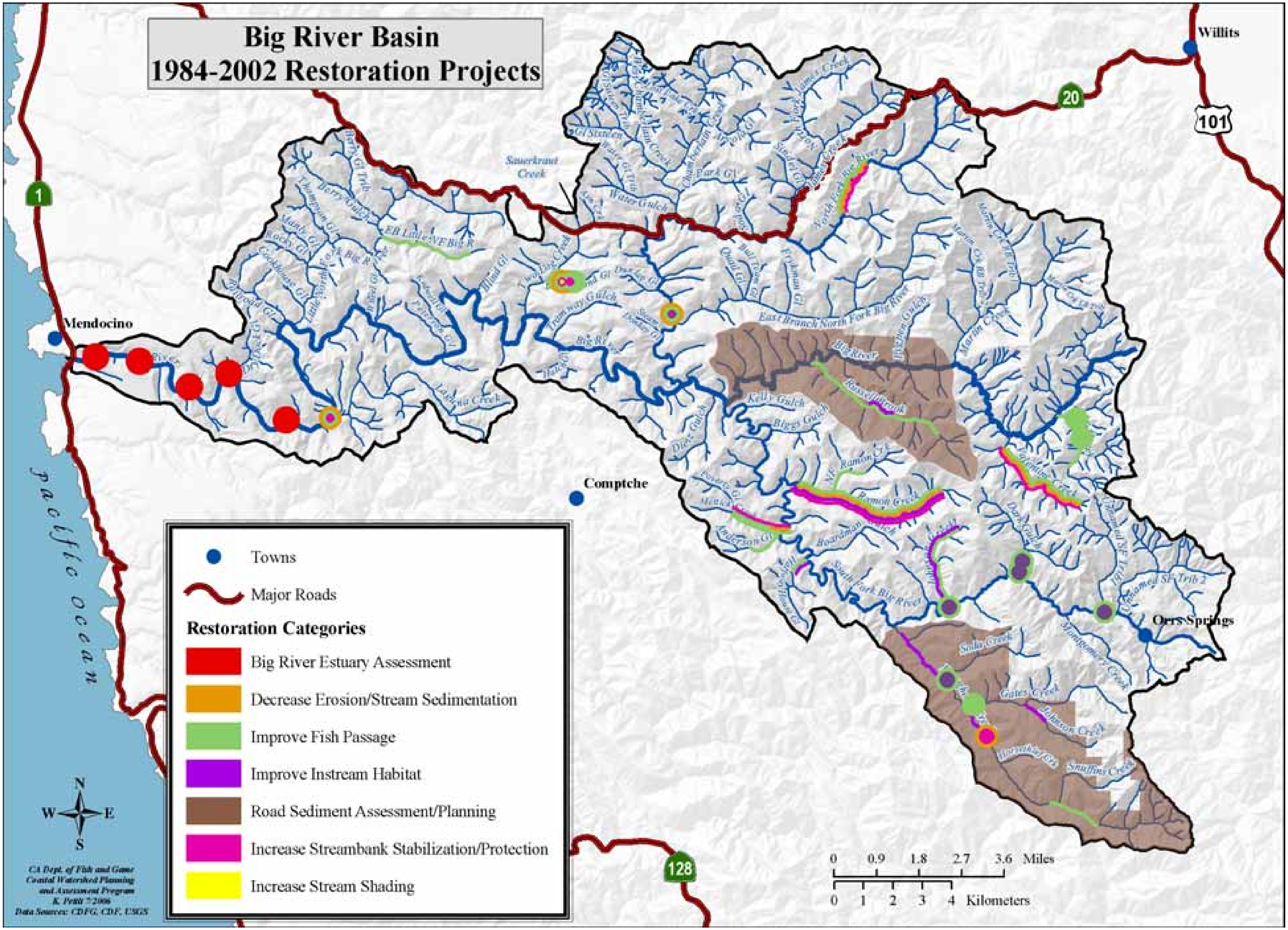


Figure 44. Restoration projects in the Big River Basin.

Special Status Species

Many plant and animal species in the Big River Basin have been found to have declining populations across their ranges and thus warrant special concern (Table 50). Species with declining populations are eligible to be listed under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA) for special attention. Detailed explanations of federal and state listings criteria are in the DFG Appendix. The lotus blue butterfly, Howell's spineflower, and coho salmon are listed as federally endangered, while coho salmon, marbled murrelets, American peregrine falcons, Northern Spotted Owls, Humboldt milk vetch, and Roderick's fritillary are state listed as endangered. The Big River Unit of Mendocino Headlands State Park supports an unusually high density, 0.78/square mile, of northern spotted owls. This density is among the highest recorded in California (Reid 2002).

Table 50. Special status species of the Big River Basin.

Common Name	Scientific Name	Federal Listing	State Listing
Invertebrates			
Pomo Bronze Shoulderband	*Helminthoglypta arrosa pomoensis*	Species of Concern	
Lotis Blue Butterfly	*Lycaeides argyrognomon lotis*	Endangered	
Fish			
Coho Salmon	*Oncorhynchus kisutch*	Endangered	Endangered
Steelhead Trout	*Oncorhynchus mykiss*	Threatened	
Chinook Salmon	*Oncorhynchus tshawytscha*	Threatened	
Amphibians			
Tailed Frog	*Ascaphus truei*	Species of Concern	Species of Special Concern
Foothill Yellow Legged Frog	*Rana boylii*	Species of Concern	Species of Special Concern
California Red Legged Frog	*Rana aurora draytonii*	Threatened	Species of Special Concern
Del Norte Salamander	*Plethodon elongatus*	Species of Concern	Species of Special Concern
Southern Torrent Salamander	*Rhyacotriton variegatus*	Species of Concern	Species of Special Concern
Reptiles			
Northwestern Pond Turtle	*Clemmys marmorata marmorata*	Species of Concern	Species of Special Concern
Birds			
Tricolored Blackbird	*Agelaius tricolor*	Species of Concern	Species of Special Concern
Sharp-shinned Hawk	*Accipiter striatus*		Species of Special Concern
Marbled Murrelet	*Brachyramphus marmoratus*	Threatened	Endangered
American Peregrine Falcon	*Falco peregrinus anatum*	De-listed	Endangered
Tufted Puffin	*Fratercula cirrhata*		Species of Special Concern
Osprey	*Pandion haliaetus*		Species of Special Concern
Northern Spotted Owl	*Strix occidentalis caurina*	Threatened	None
Mammals			
Red Tree Vole	*Arborimus pomo*		Species of Special Concern
Plants			
Pink Sand-Verbena	*Abronia umbellate spp beviflora*	Species of Concern	Special Plant
Blasdale's Bent Grass	*Agrostis blasdalei*	Species of Concern	Special Plant
Point Reyes Blennosperma	*Blennosperma nanum var. robustum*		Special Plant
Small Ground Cone	*Boschniakia hookeri*		Special Plant
Humboldt Milk Vetch	*Astragalus agnicidus*		Endangered
Thurber's Reed Grass	*Calamagrostis crassiglumis*		Special Plant
Coastal Bluff Morning-Glory	*Calystegia purpurata ssp. saxicola*		Special Plant
Swamp Harebell	*Campanula californica*	Species of Concern	Special Plant
California Sedge	*Carex californica*		Special Plant
Livid Sedge	*Carex livida*	Species of Concern	Special Plant
Lyngbye's Sedge	*Carex lyngbyei*		Special Plant
Deceiving Sedge	*Carex saliniformis*	Species of Concern	Special Plant
Green Sedge	*Carex viridula var. viridula*		Special Plant
Oregon Coast Indian Paintbrush	*Castilleja affinis ssp. littoralis*		Special Plant
Humboldt Bay Owl's-clover	*Castilleja ambigua ssp. humboldtiensis*		Special Plant
Mendocino Coast Indian Paintbrush	*Castilleja mendocinensis*	Species of Concern	Special Plant
Howell's Spineflower	*Chorizanthe howellii*	Endangered	Threatened
Whitney's Farewell-to-Spring	*Clarkia amoena ssp. whitneyi*		Special Plant
Round-Headed Chinese Houses	*Collinsia corymbosa*		Special Plant
Pygmy Cypress	*Cupressus goveniana ssp. pigmaea*	Species of Concern	Special Plant`
Supple Daisy	*Erigeron supplex*	Species of Concern	Special Plant
Menzies's Wallflower	*Erysimum menziesii ssp. menziesii*	Endangered	Endangered
Coast Fawn Lily	*Erythronium revolutum*		Special Plant
Roderick's Fritillary	*Fritillaria roderickii*	Species of Concern	Endangered
Pacific Gilia	*Gilia capitata ssp. pacifica*		Special Plant
Dark-eyed Gilia	*Gilia millefoliata*		Special Plant
Glandular Western Flax	*Hesperolinon adenophyllum*		Special Plant
Point Reyes Horkelia	*Horkelia marinensis*		Special Plant
Hair-Leaved Rush	*Juncus supiniformis*		Special Plant

Common Name	Scientific Name	Federal Listing	State Listing
Baker's Goldfields	*Lasthenia macrantha spp. bakeri*	Species of Concern	Special Plant
Coast Lily	*Lilium maritimum*	Species of Concern	Special Plant
Running-Pine	*Lycopodium clavatum*		Special Plant
Northern Microseris	*Microseris borealis*		Special Plant
Leafy-Stemmed Mitrewort	*Mitella caulescens*		Special Plant
Robust Monardella	*Monardella villosa ssp. globosa*		Special Plant
North Coast Phacelia	*Phacelia insularis var. continentis*		Special Plant
North Coast Semaphore Grass	*Pleuropogon hooverianus*	Species of Concern	Threatened
White Beaked-Rush	*Rhynchospora alba*		Special Plant
Great Burnet	*Sanguisorba officinalis*		Special Plant
Seacoast Ragwort	*Senecio bolanderi var. bolanderi*		Special Plant
Maple-Leaved Checkerbloom	*Sidalcea malachroides*	Species of Concern	Special Plant
Long-Beard Lichen	*Usnea longissima*		Special Plant
Marsh Violet	*Viola palustris*		Special Plant

Big River Basin General Issues

Public scoping meetings with Big River Basin residents and constituents and initial analyses of available data by watershed experts developed this working list of general issues and/or concerns:

- Water diversions have the potential to significantly reduce surface water flows of Big River and its tributaries. The potential for land development and increase in demand for water from the basin remains an issue of concern;
- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River and larger tributaries;
- There is concern that chemical and diesel spills in the basin are impairing stream conditions;
- There is concern that large amounts of sediments generated from road related failures have been and may be delivered to stream channels during major storms;
- Chronic fine sediment levels in many tributaries and the mainstem Big River are thought to be high;
- Estuary conditions are thought to be impaired by sediment;
- Fish habitat, including pool frequency, pool depth, shelter, large woody debris presence, cobble embeddedness, and fish passage are though to be unsuitable for salmonids throughout the basin;
- Timber harvest has been and continues to be the dominant land use in the Big River Basin;
- Landsliding related to roads, timber harvesting, and grassland is a concern;
- Long term effects to stream channels from splash dam logging throughout the basin are of concern;
- It is believed that there have been reductions in salmonid populations from historic levels;
- Sport and commercial fish harvests may have played a role in the reduction of numbers of Big River's salmonid populations;
- There is concern that the decline in the abundance of spawning salmon has likely caused a corresponding decrease in nutrients and organic matter available to streams;
- GMA (2001) may have over-estimated the bankfull width used in the Sediment Source Analysis (CGS 2004).

Integrated Analyses

The following section provides a picture of current watershed conditions for the freshwater lifestages of salmon and steelhead. Different watershed factors are analyzed together to examine their combined effects on stream channels. The interactions between geology, vegetation, landuse, water quality, and stream channels largely determine the quantity and quality of the freshwater habitat for salmon and steelhead.

Landsliding Interactions

As part of GMA's Sediment Source Analysis (2001), landuse was compared to landsliding activity. A landuse parameter combining occurrence in harvested areas, related to roads, and in areas of brush and grassland was used. GMA found that 33.0% of mapped debris torrents were in areas harvested more than 20 years ago and 27.0% were in areas harvested in the past 20 years (Table 51). Only 16.2% of debris torrents were road-related while 17.8% were in areas of brush or grassland. When examining all slides, GMA found that 60.0% were harvest-related, 30.3% were road-related, and 8.7% were found in brush and grassland areas. Additionally, slides related to road-fills were about five times more common than those related to road cuts.

Table 51. Occurrence of delivering debris torrents and slides by land use, 1952-2000.

A.

Land use	**Year**					**Total by land use**	**%**
Sub-type	**1952**	**1965**	**1978**	**1988**	**2000**		
Forest						0	0.0%
Harvest-related							
Clear cut		5	1			6	1.9%
Partial cut						0	0.0%
Harvested in last 20yr	48	27	2	3	5	85	27.0%
Harvest older than 20yr	49	43	6	5	1	104	33.0%
Skid trail		9	3	1		13	4.1%
Total:	***97***	***84***	***12***	***9***	***6***	***207***	***65.7%***
Road-related							
Road cut						0	0.0%
Road fill	14	15		9	13	51	16.2%
Railroad cut							
Railroad fill							
Total:	***14***	***15***	***0***	***9***	***13***	***51***	***16.2%***
Grassland	24	21	2	2	7	56	17.8%
Total by period	***135***	***120***	***14***	***20***	***26***	***315***	***100.0%***
% of total	***42.9%***	***38.1%***	***4.4%***	***6.3%***	***8.3%***	***100.0%***	

A. Debris Torrents
B. Slides

B.

Land use	**Year**					**Total by land use**	**%**
Sub-type	**1952**	**1965**	**1978**	**1988**	**2000**		
Forest	5	1				6	0.3%
Harvest-related							
Clear cut	3	9	1	5	9	27	1.4%
Partial cut	2	1				3	0.2%
Harvested in last 20yr	210	75	31	28	55	399	20.3%
Harvest older than 20yr	256	156	44	64	86	606	30.8%
Skid trail	5	59	41	31	6	142	7.2%
Total:	***476***	***300***	***117***	***128***	***156***	***1177***	***60.0%***
Road-related							
Road cut	35	26	11	23	18	113	5.7%
Road fill	114	201	63	61	42	481	24.5%
Railroad	1			1		2	0.1%
Total:	***150***	***227***	***74***	***85***	***60***	***596***	***30.3%***
Grassland	55	70	12	18	17	172	8.7%
Undetermined	7	4	2	1	1	15	0.7%
Total by period	***693***	***602***	***205***	***232***	***234***	***1966***	***100%***
% of total	***35.2%***	***30.6%***	***10.4%***	***11.8%***	***11.9%***	***100.0%***	

(GMA 2001a)

Overall, GMA (2001) found that 54.8% of sediment delivery from landsliding occurred in areas affected by timber harvest, 34.4% was related to roads, and 10.6% occurred in brush and grassland areas (Table 52 and Table 53). Most of the volume from brush and grasslands came from the Inland Subbasin, as most of the grassland in the basin occurs there.

Table 52. Volumes of delivering slides by land use by subbasin in tons.

Subbasin	Forest	Brush & Grassland	Harvest-Related					Road-Related	Total
			Partial or Clear Cut	Harvest (<20 Yrs)	Harvest (>20 Yrs)	Skid Trails	Total		
Coastal	0	54	24,622	208,728	290,705	3,881	527,937	264,967	792,958
Middle	0	25	6,759	35,973	154,730	29,439	226,900	283,213	510,139
Inland	11,070	788,704	52,656	1,228,518	1,713,858	347,079	3,342,111	2,024,512	6,166,397
Total	11,070	788,783	84,037	1,473,219	2,159,293	380,399	4,096,948	2,572,693	7,469,494
Percent of Total	0.1%	10.6%	1.1%	19.7%	28.9%	5%	54.8%	34.4%	

GMA 2001a

Table 53. Volumes of delivering slides by land use by subbasin as percentage of basin total.

Subbasin	Forest	Brush & Grassland	Harvest					Road-Related	Total
			Partial Or Clear Cut	Harvest (<20 Yrs)	Harvest (>20 Yrs)	Skid Trails	Total	Total	
Coastal	0.0%	0.0%	3.1%	26.3%	36.7%	0.5%	66.6%	33.4%	100.0%
Middle	0.0%	0.0%	1.3%	7.1%	30.3%	5.8%	44.5%	55.5%	100.0%
Inland	0.2%	12.8%	0.9%	19.9%	27.8%	5.6%	54.2%	32.8%	100.0%
Total	0.1%	10.6%	1.1%	19.7%	28.9%	5.0%	54.8%	34.4%	100.0%

GMA 2001a

In general, GMA found "a consistent pattern between road construction, harvest disturbance, and resulting sediment production from landslides" (2001). A time lag of 10-15 years seemed common between periods of intense landuse activity and sediment production. Overall, sediment production has decreased dramatically since 1965, due to a combination of less harvesting and improved timber harvest techniques following the Forest Practice Rules in 1973.

Harvest-related landsliding accounted for 54.8% of slide volumes across the Big River Basin, while road-related landsliding accounted for 34.4%. A high volume of sediment was associated with grasslands and brush in some PWs in the South Fork and headwaters drainages during some time periods. These high levels were thought to be related to landform adjustments in cleared areas and underlying Central belt or mélange terrain of the Franciscan formation.

Slope Interactions

An analysis of different timber harvest methods on slopes of varying percent showed that the highest proportion of land from 1852 to 2001 was tractor harvested on slopes from 31-50% (Table 54 and Table 55). More acres were harvested on slopes greater than 50% from 1993 to 2001 than any other study period. Most of these acres were harvested using tractor and cable suspended logging methods.

Table 54. Acreage harvested by slope of ground, period, and method.

Slope in Percent	Acres Harvested: Helicopter	Acres Harvested: Cable Ground	Acres Harvested: Cable Suspend	Acres Harvested: Tractor	Acres Harvested: Total	Proportion of Area: Helicopter	Proportion of Area: Cable Ground	Proportion of Area: Cable Suspend	Proportion of Area: Tractor	Proportion of Area: Total
1852 - 1944										
0 -15		5,331		137	5,468		14		0	15
16 - 30		7,827		375	8,202		21		1	22
31 - 50		13,894		695	14,589		37		2	39
51 - 65		5,695		316	6,012		15		1	16
Greater than 65		2,912		136	3,048		8		0	8
Total		**35,659**		**1,660**	**37,319**		**96**		**4**	**100**
1945 - 1964										
0 -15		7		1,355	1,362		0		5	5
16 - 30		19		4,718	4,737		0		19	19
31 - 50		32		11,356	11,388		0		45	45
51 - 65		12		5,169	5,181		0		20	20
Greater than 65		7		2,743	2,750		0		11	11
Total		**76**		**25,341**	**25,417**		**0**		**100**	**100**
1965 - 1974										
0 -15				876	876				6	6
16 - 30				2,947	2,947				20	20
31 - 50				6,636	6,636				45	45
51 - 65				2,777	2,777				19	19
Greater than 65				1,365	1,365				9	9
Total				**14,601**	**14,601**				**100**	**100**
1975 - 1984										
0 -15			72	1,186	1,258			0	5	5

Acres Harvested						Proportion of Area				
Slope in Percent	Helicopter	Cable Ground	Cable Suspend	Tractor	Total	Helicopter	Cable Ground	Cable Suspend	Tractor	Total
16 - 30			173	4,654	4,826			1	19	20
31 - 50			693	10,505	11,198			3	43	46
51 - 65			430	4,250	4,681			2	17	19
Greater than 65			305	2,026	2,330			1	8	10
Total			**1,672**	**22,620**	**24,293**			**7**	**93**	**100**
1985 - 1992										
0 -15			239	2,177	2,416			1	8	9
16 - 30			615	5,811	6,426			2	21	24
31 - 50			1,620	10,117	11,736			6	37	43
51 - 65			976	3,391	4,367			4	12	16
Greater than 65			606	1,585	2,192			2	6	8
Total			**4,056**	**23,081**	**27,137**			**15**	**85**	**100**
1993 - 2001										
0 -15	83		408	2,294	2,786	0		1	6	8
16 - 30	295		1,146	5,772	7,213	1		3	16	20
31 - 50	889		3,770	10,344	15,002	2		10	29	41
51 - 65	470		2,273	4,094	6,837	1		6	11	19
Greater than 65	369		1,546	2,470	4,385	1		4	7	12
Total	**2,105**		**9,143**	**24,974**	**36,223**	**6**		**25**	**69**	**100**

Table 55. Big River Basin ground disturbance by slope and harvest type, 1852-2001.

	Helicopter	Cable Suspend	Cable Ground	Tractor
Slope: 0-15%				
Acres Harvested	83	719	5,337	8,026
% Total Harvest Acres	0.1	0.4	3.2	4.9
Slope: 16-30%				
Acres Harvested	295	1,934	7,846	24,277
% Total Harvest Acres	0.2	1.2	4.8	14.7
Slope: 31-50%				
Acres Harvested	889	6,083	13,926	49,652
% Total Harvest Acres	0.5	3.7	8.4	30.1
Slope: 51-65%				
Acres Harvested	470	3,679	5,707	19,998
% Total Harvest Acres	0.3	2.2	3.5	12.1
Slope: >65%				
Acres Harvested	369	2,457	2,918	10,325
% Total Harvest Acres	0.2	1.5	1.8	6.3
Total Harvest Acres	2,105	14,872	35,734	112,278
% total Harvest Acres	1.3	9.0	21.7	68.1

Total Big River harvest/re-harvest acres = 164,989 acres, basin area = 115,886 acres. Blue categories have the lowest watershed disturbance impacts (6.4 %). Orange categories have medium watershed disturbance impacts (31.5 %). Magenta categories have the highest potential for surface erosion (62.2 %). Watershed disturbance destabilizes and/or compacts soil, re-routes drainages, and alters runoff rates and infiltration. These impact stream flows and water quality.

GMA (2001) examined the relationship between roads on various slope positions. They classified all the roads in the basin into riparian, mid-slope, or ridge-top (Table 56). Most of the roads in the basin are mid-slope, followed by riparian, and then ridge-top (Table 57). The proportion of roads in each location was similar in each subbasin. Only 22.7% of the riparian roads across the subbasin are either rocked or paved. Native riparian roads have a high potential for sediment contribution to the channel.

Table 56. Existing miles of roads in different road positions by types and subbasin (from GMA 2001a).

Subbasin	Riparian			Mid-Slope			Ridge			Total By Subbasin		
	Paved	Rocked	Native	Paved	Rocked	Native	Paved	Rocked	Native	Riparian	Mid-Slope	Ridge
Coastal Subbasin	0.5	9.5	41.2	7.5	29.4	111.5	2.4	7.0	39.5	51.2	148.4	48.9
Middle Subbasin	1.7	10.5	19.0	0.5	10.5	84.4	0.1	2.8	24.9	31.2	95.3	27.7
Inland Subbasin	10.3	34.8	168.7	14.7	57.3	392.3	2.7	8.2	150.3	213.9	464.3	161.2

Table 57. Big River Basin roads by location and surface type.

	Paved	Rocked	Un-surfaced
Ridgetop			
Miles	5.1	18	214.7
% Total Basin Miles	0.5	1.5	17
Mid-slope			
Miles	22.6	97.2	588.2
% Total Basin Miles	2.0	7.0	47.0
Riparian			
Miles	12.4	54.9	228.9
% Total Basin Miles	1.0	4.0	18.0

Total basin roads = 1242 miles, 6.9 miles/square mile. Blue categories have the lowest potential for road surface erosion (5%). Orange categories have medium potential for surface erosion (25%). Magenta categories have the highest potential for surface erosion (70%). Road surface erosion is a chronic source of fine sediment that can be delivered to streams, which is deleterious to fish habitat.

Road Interactions

GMA (2001) estimated road surface erosion across the basin from 1921 to 2000 (Table 58). Their analysis indicates that sediment production from roads has increased significantly with the increased amount of roads over the study period. Roads in 2000 were estimated to produce 92.7 tons of sediment per square mile per year across the basin, an increase over 1952 rates. Existing road surface erosion in 2000 was highest in the Middle Subbasin and lowest in the Inland Subbasin.

Table 58. Computed road surface erosion by study period by subbasin.

Subbasin	Computed Surface Erosion From Roads By Period (Tons/Yr)					Total By PW For Entire Period	% Total Watershed Road Surface Erosion	Entire Study Period Average Unit Area Road Surface Erosion	2000 Unit Area Road Surface Erosion
	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	(Tons)	(%)	(Tons/Mi2/Yr)	
Coastal	1176.2	1444.2	2001.8	2425.8	3200.9	127,122.5	19.2%	62.1	98.6
Middle	447.7	1068.2	1162.2	1357.8	1907.4	72,818.2	11.0%	64.7	106.9
Inland	2581.3	5888.5	8426.1	9527.6	11676.2	462,849.8	69.8%	56.2	89.3
Total	4,205.1	8,400.9	11,590.0	13,311.1	16,784.6	662,790.5	100.0%	58.1	92.7

GMA 2001a

GMA (2001) also estimated sediment production from skid roads. Overall surface erosion rates from harvest were found to be small (Table 59). The analysis suggested a peak in surface erosion at the time of high harvest rates using high-density tractor logging methods from 1953-1978. Smaller volumes of surface erosion have been produced by more extensive harvest areas since 1989 due to changing harvest techniques. Surface erosion from 1989 to 2000 was highest in the Inland Subbasin and lowest in the Middle Subbasin.

Table 59. Summary of surface erosion estimates from harvest areas by study period in tons.

Subbasin	1937-1952 Total	1953-1965 Total	1966-1978 Total	1979-1988 Total	1989-2000 Total	1921-2000 Total By Subbasin
Lower Big River	1,495	3,549	4,233	3,731	4,152	17,161
Middle Big River	783	10,180	762	2,381	1,881	15,986
Inland	20,816	39,006	72,641	17,743	9,244	159,450
Total	23,094	52,735	77,636	23,855	15,277	192,597

GMA 2001a

Road Crossings

Today there are 186 miles of roads in the watercourse buffer zone (Table 60). Seventy nine percent were built before 1979. While the data show 141 miles as native road surface, the Forest Practice Rules require that landowners that use roads for harvesting timber reduce the potential for sediment transport, so many are being surfaced with rock. Additionally, landowners are building midslope and ridge roads with improved standards to replace roads in the watercourse buffer zone.

Table 60. Length of truck roads in near proximity to watercourse.

Period	Total Length in Miles				Length in Miles per Sq Mile			
Basin Wide	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
pre - 1937	15.8	1.4	3.7	21.0	0.09	0.01	0.02	0.12
1937 - 1952	26.5	7.4	10.1	44.0	0.15	0.04	0.06	0.24
1953 - 1965	40.3	0.1	11.6	52.0	0.22		0.06	0.29
1966 - 1978	22.6		6.1	28.7	0.12		0.03	0.16
1979 - 1988	10.6		1.2	11.7	0.06		0.01	0.06
1989 - 2000	25.7		2.2	27.9	0.14		0.01	0.15
Total	**141.6**	**8.9**	**34.9**	**185.4**	**0.78**	**0.05**	**0.19**	**1.02**

Lengths are roads constructed in time period, not cumulative.

Fluvial Erosion

GMA (2001) estimated bank erosion and small streamside mass wasting across the basin and found little sediment from these sources. They found that most of the stream channels were incised and moderately stable.

Table 61. Bank erosion and small streamside mass wasting.

Subbasin	Bank Erosion and Small Streamside Mass Wasting		Total
	Class 1 (Tons/Year)	Class 2 (Tons/Year)	(Tons/Year)
Coastal	955	1,193	2,148
Middle	513	535	1,047
Inland	3,430	5,146	8,576
Total	Total (Tons/Yr):		11,771
% of stream miles	Total (Tons/Mi^2/Yr):		65.0

GMA 2001a

Stream Interactions

The products and effects of the watershed delivery processes examined in the geologic, slope, and landsliding Integrated Analyses tables are expressed in the stream habitats encountered by the organisms of the aquatic riparian community, including salmon and steelhead. Several key aspects of salmonid habitat in the Big River Basin are presented in the Stream Interactions Integrated Analysis. Channel and stream conditions are not necessarily exclusively linked to their immediate surrounding terrain, but may in fact be both spatially and temporally distanced from the sites of the processes and disturbance events that have been blended together over time to create the channel and stream's present conditions. Instream habitat data presented here were compiled from CDFG stream inventories described in more detail in the Fish Habitat Relationships sections of this report.

Pool Quantity and Quality

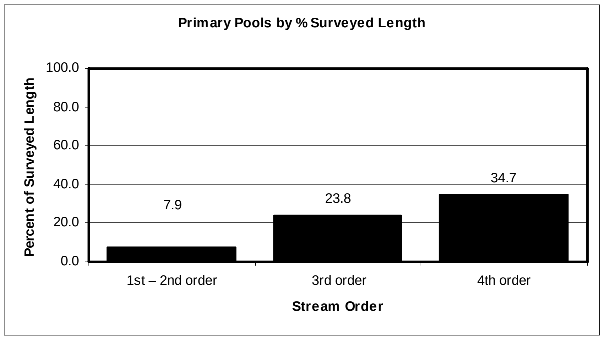


Figure 45. Primary pools in the Big River Basin.

Pools greater than 2.5 feet deep in 1st and 2nd order streams and greater than 3 feet deep in 3rd and 4th order streams are considered primary pools.

Significance: Primary pools provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30 – 55% of its length in primary pools to be suitable for salmonids.

Comments: The percent of primary pools by length in the Big River Basin is generally below target values for salmonids in lower order streams and appears to be suitable in fourth order streams.

Spawning Gravel Quality

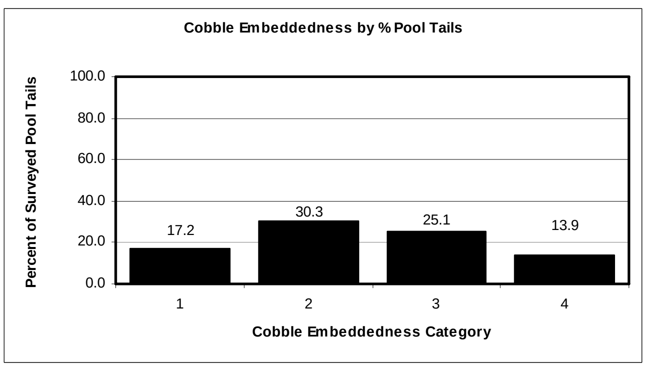


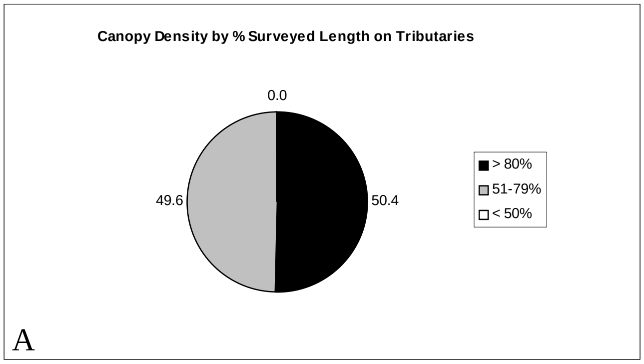
Figure 46. Cobble Embeddedness in the Big River Basin.

Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

Significance: Salmonids cannot successfully reproduce when forced to spawn in streambeds with a lack of suitably such as excessive silt, clays, and other fine sediment. Cobble embeddedness is the percentage of an average sized cobble piece at a pool tail out that is embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded, and category 4 is 76-100% embedded. Cobble embeddedness categories 3 and 4 are not within the fully supported range for successful use by salmonids.

Comments: Almost one half of pool tails within the Big River Basin have cobble embeddedness in categories 1 and 2, which meet spawning gravel target values for salmonids.

Shade Canopy



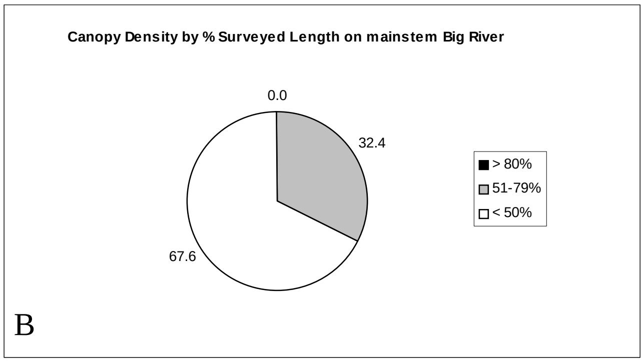


Figure 47. Canopy density in the Big River Basin. A. Tributaries. B. Mainstem Big River

Significance: Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey length is below target values and greater than 80% fully meets target values.

Comments: All of the surveyed tributary lengths within the Big River Basin have canopy densities greater than 50% and just over one half of those have canopy densities greater than 80%. This is above the canopy density target values for salmonids. Canopy density is lower on the mainstem Big River, as is expected on a fourth order stream with wide channels.

Pool Shelter

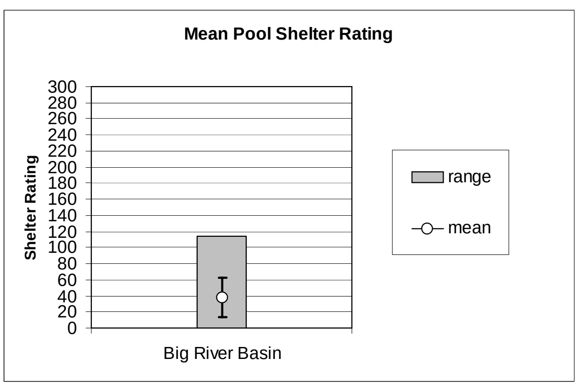


Figure 48. Pool shelter in the Big River Basin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

Significance: Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Comments: The average mean pool shelter rating in the Big River Basin is 37.9. This is below the shelter target value for salmonids.

Fish Passage

Table 62. Salmonid habitat artificially obstructed for fish passage.

Feature/Function		Significance	Comments
Type of Barrier	% of estimated historic coho salmon habitat currently inaccessible due to artificial passage barriers	Free movement in 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. Partial barriers exclude certain species and lifestages from portions of a watershed and temporary barriers delay salmonid movement beyond the barrier for some period of time. Total barriers exclude all species from portions of a watershed.	All of the 0.9% of estimated historic coho salmon habitat that is currently blocked by artificial barriers in the Big River Basin is blocked by a total barrier.
All Barriers	0.9		
Partial and Temporary Barriers	0.0		
Total Barriers	0.9		

N=3 Culverts in the Big River Basin

1998-2000 Ross Taylor and Associates Inventories and Fish Passage Evaluations of Culverts within the Coastal Mendocino County Road Systems

Table 63. Juvenile salmonid passage in the Big River Basin.

Feature/Function		Significance	Comments
Juvenile Summer Passage	Juvenile Winter Refugia	Dry Channel disrupts the ability of juvenile salmonids to move freely throughout stream systems.	Dry channel recorded in CDFG stream inventories in the Big River Basin has the potential to disconnect tributaries from the mainstem Big river and disrupt the ability of juvenile salmonids to forage and escape predation. This condition is most common in streams in the Inland Subbasin. Juvenile salmonids seek refuge from high winter flows, flood events, and cold temperatures in the winter. Intermittent side pools, back channels, and other areas of relatively still water that become flooded by high flows provide valuable winter refugia.
4.2 miles of surveyed channel dry	No Data		
2.7% of surveyed channel dry			

1993-2002 CDFG Stream Surveys, CDFG Appendix

Large Woody Debris

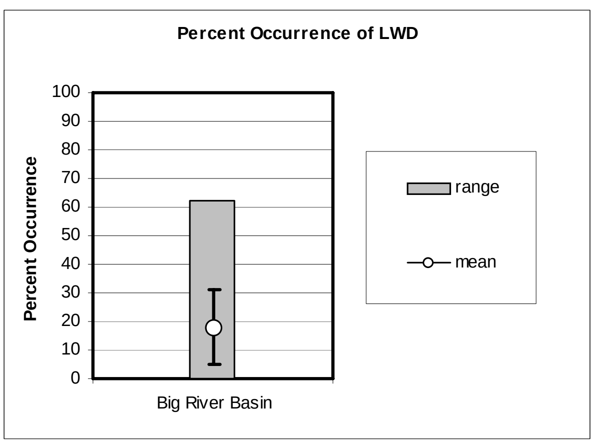


Figure 49. Large Woody Debris (LWD) in the Big River Basin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percentage occurrence of LWD.

Comments: The percent occurrence of LWD in a stream as calculated by CDFG in the Big River Basin represents a measure of the amount of woody debris that was found in the wetted width of a stream channel during stream surveys that can be used by fish for cover as compared to other types of fish cover present. The average percent occurrence of LWD for the Big River Basin is 17.9%. The dominant shelter type recorded in most stream reaches was boulders, while large woody debris was the second most common dominant shelter type. This average percent occurrence of LWD is about the same as in the neighboring Albion River Basin.

Although instream habitat conditions for salmonids varied a great deal across the 181 square mile Big River Basin, several generalities can be made. Canopy density is greater than 50% across almost the entire basin, and when reaches of the mainstem Big River are not considered, half of surveyed stream length has canopy densities greater than 80%. Additionally, 4.3 miles of surveyed stream (less than 3% of surveyed stream channel) were dry and less than 4% of estimated historic coho habitat was inaccessible due to artificial passage barriers. Cobble embeddedness values are approaching target values and the percent occurrence of large woody debris is higher than that found in Redwood Creek near Orick, the Mattole River, and the Gualala River, three other North Coast California watersheds in the NCWAP assessment effort. However, across the Big River Basin the percent of primary pools by survey length in lower order streams was below target values found in CDFG's *California Salmonid Stream Habitat Restoration Manual* and calculated by the EMDS system.

Stream Reach Condition EMDS

The anadromous reach condition EMDS evaluates the conditions for salmonids in a stream reach based upon water temperature, canopy cover, stream flow, and in channel characteristics. Data used in the Reach EMDS came from CDFG Stream Inventories. Currently, data exist in the Big River Basin to evaluate overall reach, canopy, in channel, pool quality, pool depth, pool shelter, and embeddedness conditions for salmonids. More details of how the EMDS functions are in the EMDS Appendix. EMDS calculations and conclusions are pertinent only to surveyed streams and are based on conditions present at the time of individual survey.

EMDS stream reach scores were weighted by stream length to obtain overall scores for subbasins and the entire Big River Basin. Weighted average reach conditions on surveyed streams in the Big River Basin as evaluated by the EMDS are somewhat unsuitable for salmonids (Table 64, Figure 50, Figure 51, Figure 52, and Figure 53). Suitable conditions exist for canopy across the Big River Basin when the mainstem Big River is not considered; for pool depth in the Coastal and Middle subbasins; and for embeddedness in the Middle Subbasin. Unsuitable conditions exist for pool quality and pool shelter across the Big River Basin.

Table 64. EMDS Anadromous Reach Condition Model results for the Big River Basin.

Subbasin	Reach	Water Temperature	Canopy	Stream Flow	In Channel	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Coastal Subbasin (excluding the mainstem Big River) (N =9)	- (-)	U (U)	- (+++)	U (U)	- (-)	- (--)	+ (--)	- (-)	-- (--)
Middle Subbasin (excluding the mainstem Big River) (N = 5)	- (-)	U (U)	+ (++)	U (U)	- (-)	- (--)	+ (--)	- (--)	+ (-)
Inland Subbasin (N = 41)	-	U	++	U	-	--	--	--	-
Overall (excluding the mainstem Big River) (N = 55)	- (-)	U (U)	+ (++)	U (U)	- (-)	-- (--)	- (--)	-- (--)	- (-)

Key:
\+ ++ +++ Highest Suitability
U Insufficient Data or Undetermined
\- -- --- Lowest Suitability
Results are given first for all surveyed reaches and then for only surveyed tributary reaches excluding the mainstem Big River in parentheses.

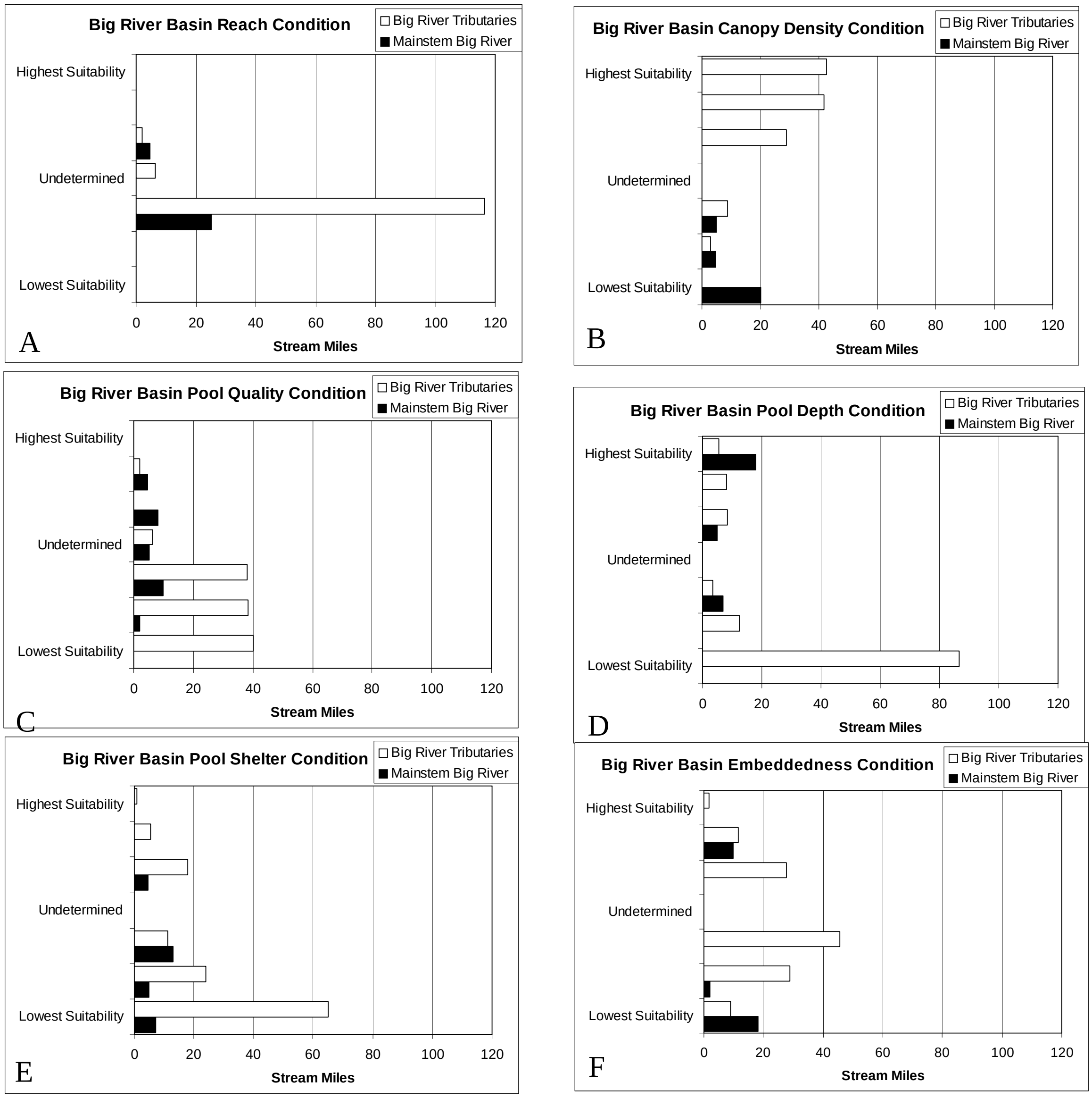


Figure 50. EMDS Reach Condition model results for the Big River Basin by surveyed stream miles.

A. Overall reach condition. B. Canopy density. C. Pool quality. D. Pool depth. E. Pool shelter. F. Cobble embeddedness.

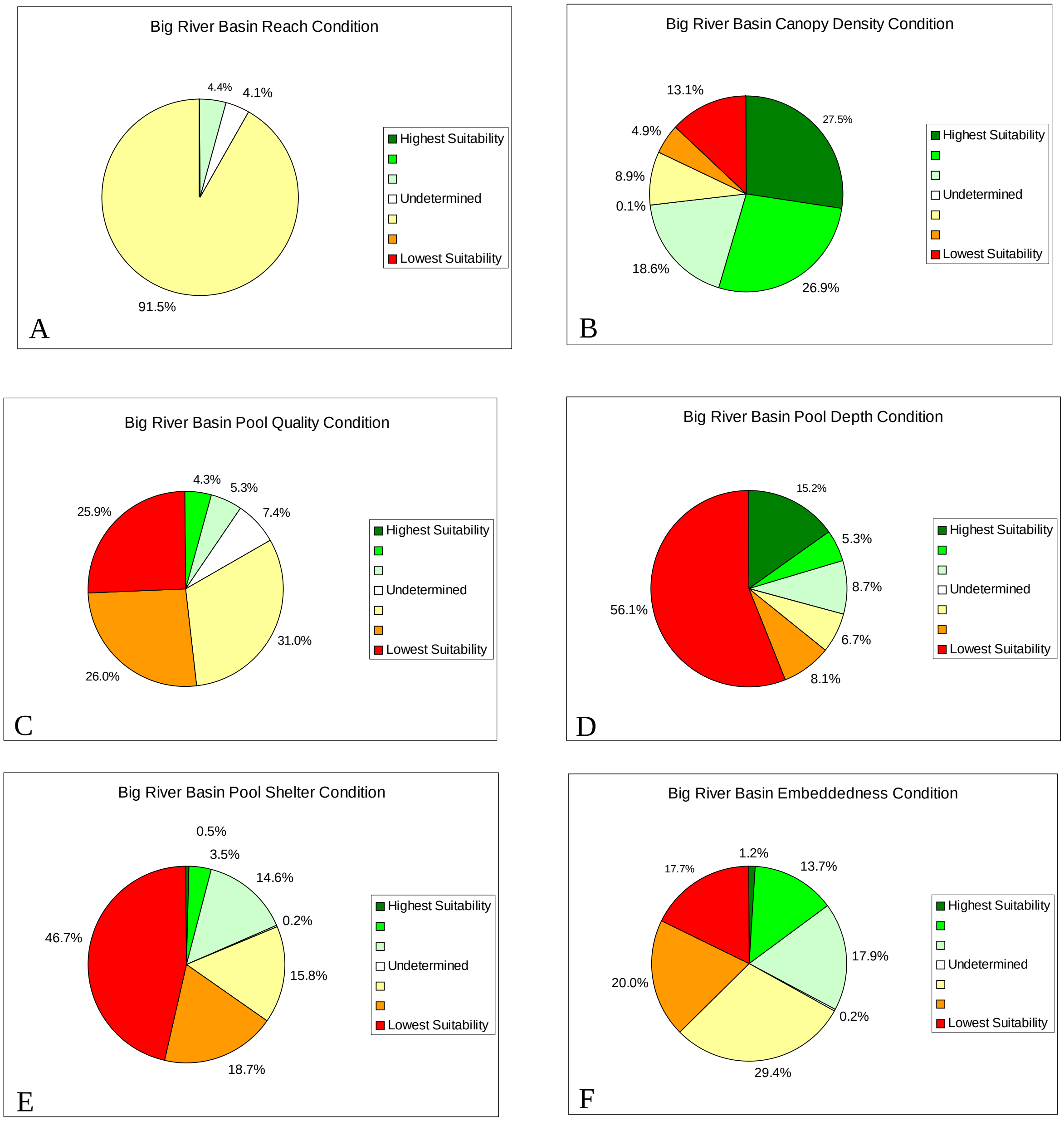


Figure 51. EMDS Reach Condition model results for the Big River Basin by percent surveyed stream miles.

A. Overall reach condition. B. Canopy density. C. Pool quality. D. Pool depth. E. Pool shelter. F. Cobble embeddedness.

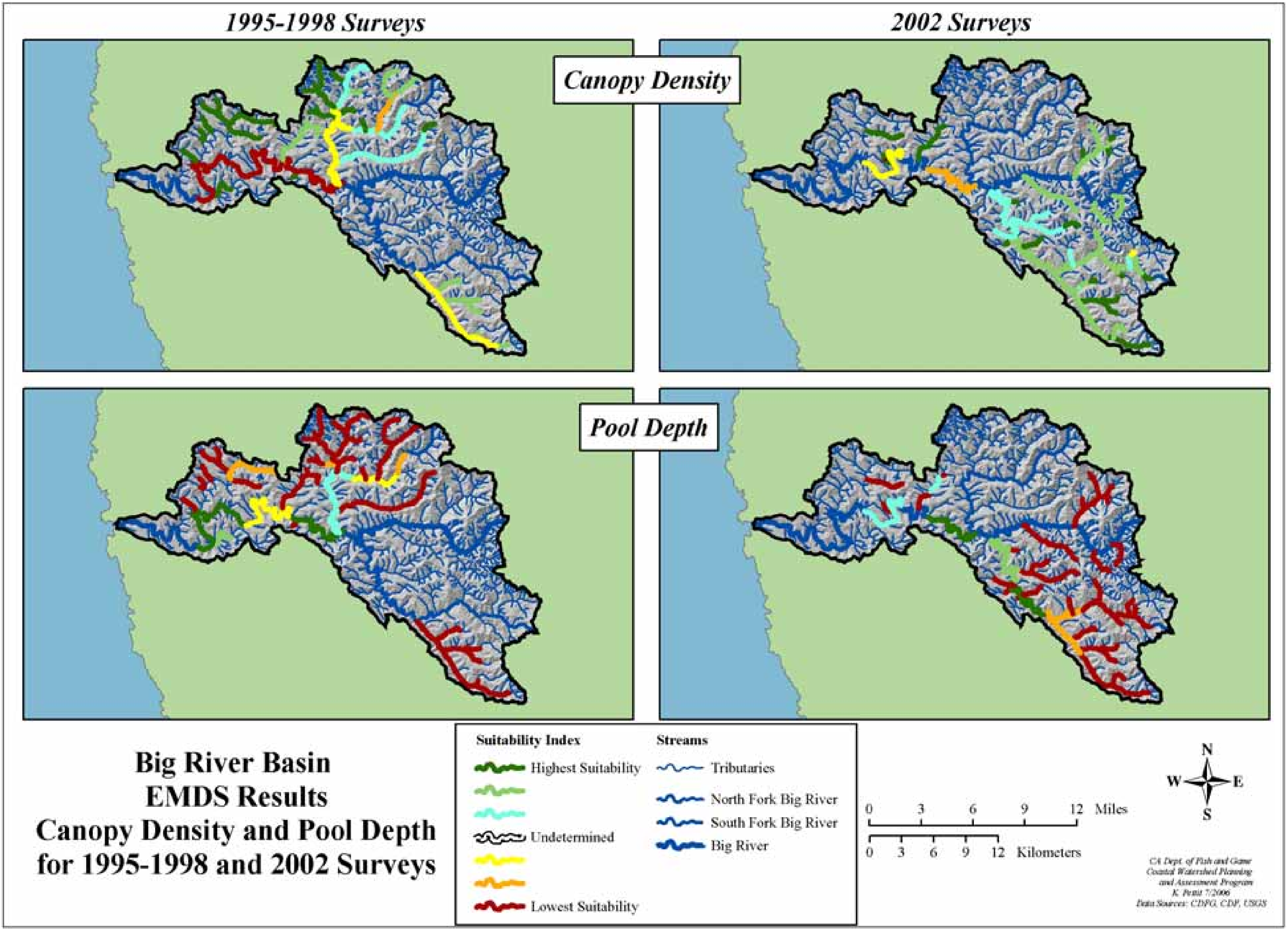


Figure 52. EMDS results for 1995-1998 and 2002 for canopy and pool depth.

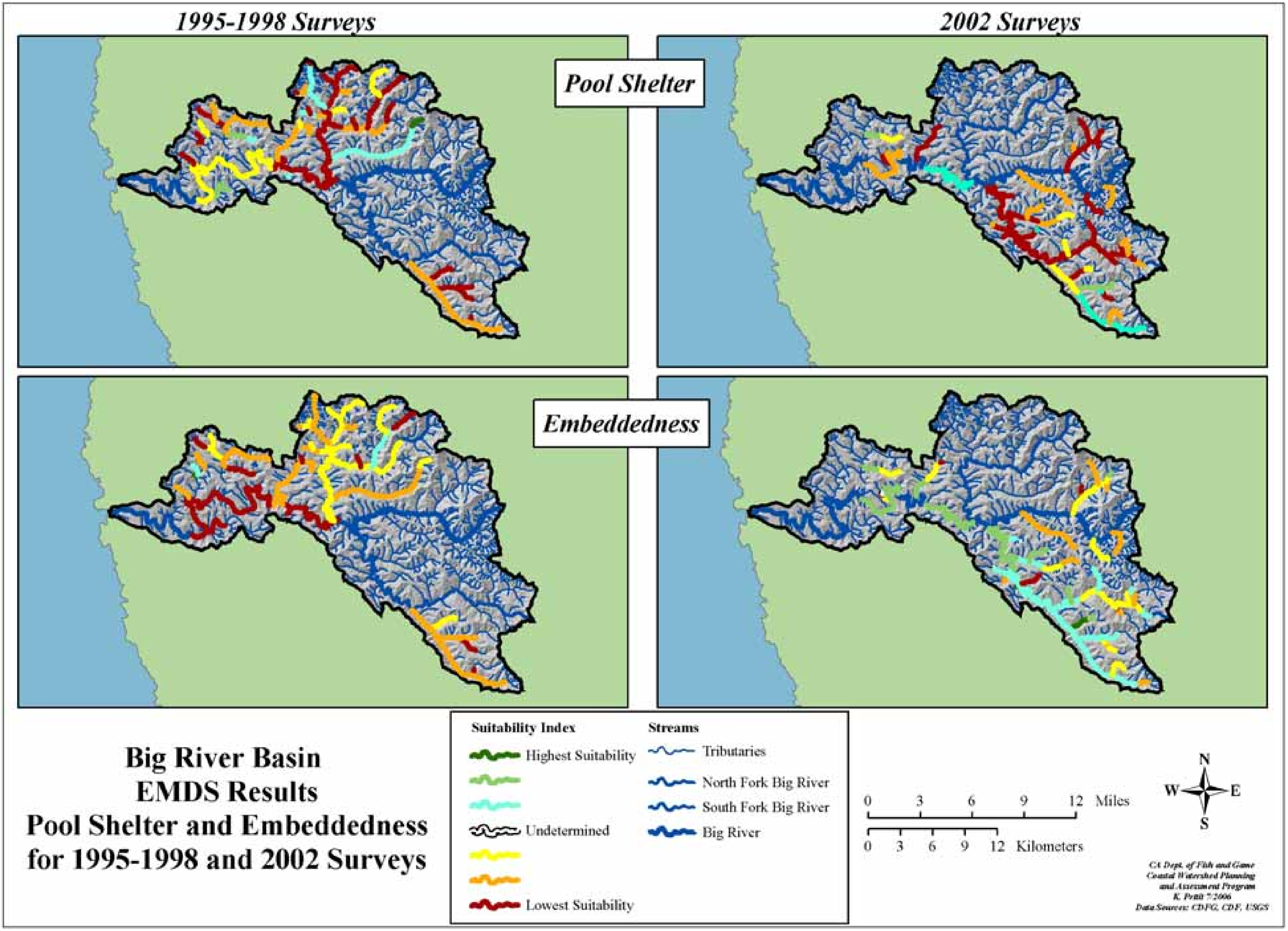


Figure 53. EMDS results for 1995-1998 and 2002 for Pool shelter and cobble embeddedness.

Analysis of Tributary Recommendations

In order to compare the occurrence of recommendations between the three subbasins in the Big River Basin, the three top ranking recommendations for each tributary were compiled. Each tributary was originally assigned anywhere from zero to ten recommendations, which were ranked in order of importance. Complete tributary recommendations for each subbasin can be found in each of the Subbasin Sections of this report.

The top three recommendations in each tributary were summed for each subbasin (Table 65). In terms of the most frequently given recommendations in each subbasin, the Coastal Subbasin had Roads and Cover recommendations for all nine tributaries and the mainstem surveyed, the Middle Subbasin had Roads and Cover recommendations for three out of five tributaries and the mainstem surveyed, and the Inland Subbasin had Roads recommendations for 24 out of 41 tributaries surveyed. Across the basin, the most frequently given recommendation was Roads.

Table 65. Occurrence of recommendations in first three ranks in surveyed streams.

Subbasin	# of Surveyed Tributaries	# of Surveyed Stream Miles	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Live-stock	Fish Passage
Coastal	9	39.5	4	9	0	2	5	9	0	0	0	1
Middle	5	9.5	2	3	1	1	2	3	0	1	0	0
Inland	41	105.1	20	24	7	8	20	21	1	4	0	5
Big River Basin	55	154.2	26	36	8	11	27	33	1	5	0	6

In order to further examine subbasin issues through the tributary recommendations given in CDFG stream habitat inventory surveys, the top three ranking recommendations for each tributary were collapsed into five different recommendation categories: Erosion/Sediment, Riparian/Water Temp, Instream Habitat, Gravel/Substrate, and Other (Table 66). When examining recommendation categories by number of tributaries, the most important Recommendation Category in the Coastal and Middle subbasins was Instream Habitat and in the Inland Subbasin was Erosion/Sediment (Table 67).

Table 66. How improvement recommendations were collapsed into recommendation categories in the Big River Basin.

Tributary Report Recommendation	Basin Wide Recommendation Category
Bank/Roads	Erosion/Sediment
Canopy/Temp	Riparian/Water Temp
Pool/Cover	Instream Habitat
Spawning Gravel/LDA	Gravel/Substrate
Livestock/Barrier	Other

Table 67. Distribution of basin wide recommendation categories in the Big River subbasins.

Subbasin	Erosion/Sediment	Riparian/Water Temperature	Instream Habitat	Gravel/Substrate	Other
Coastal	13	2	14	0	1
Middle	5	2	5	1	0
Inland	44	15	41	5	5
Big River Basin	62	19	60	6	6

However, comparing recommendation categories between subbasins could be confounded by the differences in the number of tributaries and the number of stream miles surveyed in each subbasin. Of the 55 tributaries and the mainstem Big River surveyed in the Big River Basin, 39.5 stream miles were in the Coastal Subbasin, 9.5 in the Middle Subbasin, and 105.1 in the Inland Subbasin. Therefore, the percentage of stream miles in each subbasin assigned to the various recommendation categories was calculated for each subbasin. The percentage of the total stream length in each subbasin assigned to each subbasin recommendation category was then calculated to compare between subbasins.

Instream Habitat is the most important recommendation category in the Middle and Inland subbasins, while Erosion/Sediment is most important in the Coastal Subbasin (Figure 54). In the Big River Basin as a whole, the most important recommendation category is Instream Habitat, followed Erosion/Sediment, Riparian Water Temp, Other, and Gravel/Substrate. Therefore, the highest priority rankings changed in all of the Big River subbasins when assessed by the number of tributaries or the percentage of stream miles. Additionally, the overall rankings of recommendation categories in the Big River Basin as a whole shifted in the different analyses. The most important recommendation category in the Coastal Subbasin changed from Instream Habitat to Erosion/Sediment when assessed by percentage of stream miles rather than number of tributaries. The most important recommendation category in the Inland Subbasin changed from Erosion/Sediment to Instream Habitat.

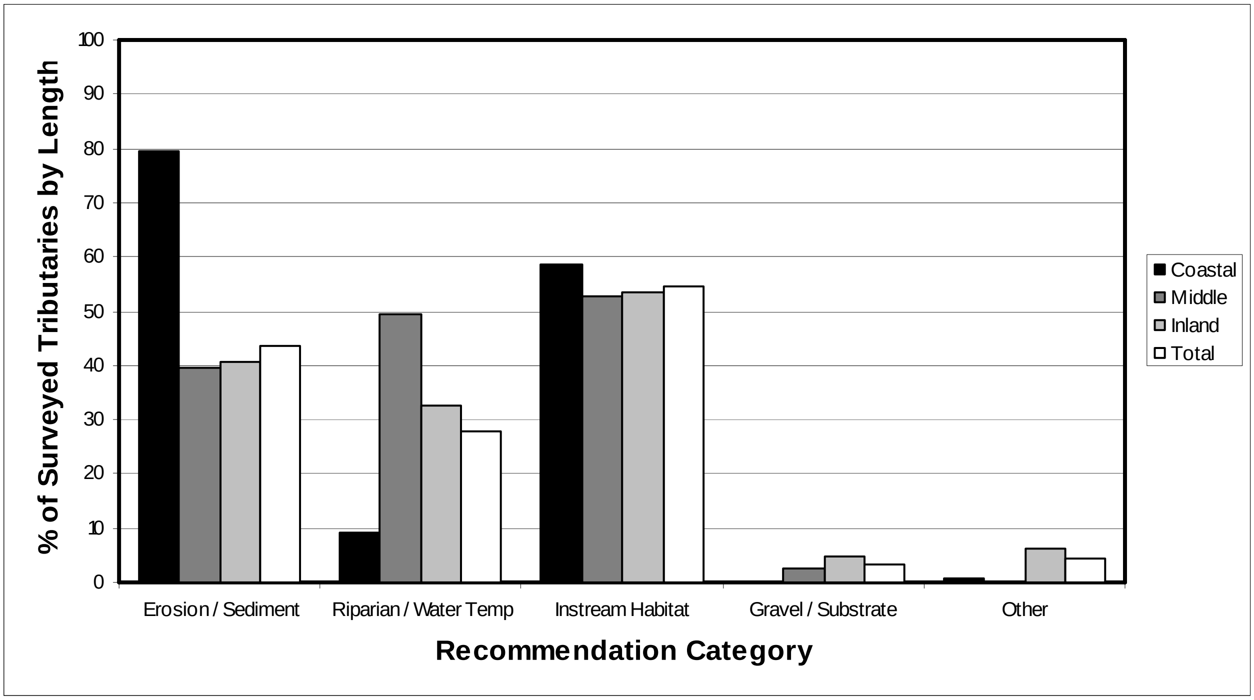


Figure 54. The percent of recommendation categories in Big River Basin surveyed streams.

The high number of Instream Habitat, Erosion/Sediment, and Riparian/Water Temperature recommendations across the Big River Basin indicates that high priority should be given to restoration projects emphasizing pools, cover, sediment reduction, and riparian replanting.

MRC Treatment Prescriptions

The MRC (2003) included specific land management actions or recommendations for protection of aquatic resources on their ownership in the basin (Table 68). These recommendations, or prescriptions, were linked to nine specific causal mechanisms. Each causal mechanism has the following associated with it:

- Resource Sensitive Area - area or topic addressed by the prescription
- Input Variable and Process - briefly states source variable or input to a sensitive resource
- Prescriptions - specific land management actions or recommendations

Recommendations are also linked to Mass Wasting Map units, which represent general areas of similar geomorphology, landslide processes, and sediment delivery potential for shallow-seated landslides. These units are interspersed throughout MRC's ownership and do not correlate to this assessment's subbasins (see MRC 2004 for definitions and a map of the Mass Wasting Units).

Table 68. Causal mechanisms and action prescriptions for the MRC ownership in the Big River Basin (MRC 2003).

Resource Sensitive Area	Input Variable and Process	Prescriptions
Mass Wasting Map Unit #1	Coarse and fine sediment from mass wasting and bank erosion	*MWMU 1 Road construction:* • If inner gorge topography, no new road or landing construction unless field reviewed and approved by a California Registered Geologist. • If not inner gorge topography, road construction shall be minimized. • If road construction must occur, the road must utilize the highest design standards to lower risk of mass wasting sediment delivery. *MWMU 1 Existing Roads:* • Existing roads and landings shall be abandoned when no longer needed. If abandoning is not feasible, then roads or landings shall be maintained at the design standards that lower risk of mass wasting sediment delivery. *MWMU 1 Tractor Yarding:* • Equipment exclusion zones on inner gorge slopes. • Equipment exclusion zones on non-inner gorge slopes except for existing roads or where alternative yarding method creates potential for greater sediment delivery. *MWMU 1 Skid Trail Construction or Reconstruction:* • No new tractor trail construction on inner gorge slopes, no new tractor trail construction or reconstruction on non-inner gorge slopes unless field reviewed and approved by a California Registered Geologist. *MWMU 1 timber harvest:* • MWMU 1 will receive no harvest on inner gorge slopes unless approved by a California Registered Geologist. • On other areas (non-inner gorge slopes) within MWMU 1, in addition to the riparian protections set as company policy, timber harvest must retain a minimum of 50% overstory canopy dispersed evenly across the slopes. • The MWMU 1 protections will extend from the edge of the watercourse transition line up to the break in slope of the inner gorge and 25 feet of additional slope distance after the break in slope of the inner gorge. • For those areas that do not have well defined inner gorge topography in MWMU 1 timber harvest must retain 50% canopy.
Mass Wasting Map Unit #2	Coarse and fine sediment from mass wasting	*MWMU 2 Road construction:* • If inner gorge topography, no new road or landing construction unless field reviewed and approved by a California Registered Geologist. • If not inner gorge topography, road construction shall be minimized. • If road construction must occur, the road must utilize the highest design standards to lower risk of mass wasting sediment delivery. *MWMU 2 Existing Roads:* • Existing roads and landings shall be abandoned when no longer needed. If abandoning is not feasible, then roads or landings shall be maintained at the design standards that lower risk of mass wasting sediment delivery. *MWMU 2 Tractor Yarding:* • Equipment exclusion zones on inner gorge slopes. Equipment exclusion zones on non-inner gorge slopes except for existing roads or where alternative yarding method creates potential for greater sediment delivery. *MWMU 2 Skid Trail Construction or Reconstruction:* • No new tractor trail construction on inner gorge slopes, no new tractor trail construction or reconstruction on non-inner gorge slopes unless field reviewed and approved by a California Registered Geologist. *MWMU 2 Timber Harvest:* • No harvest on inner gorge slopes unless approved by a California Registered Geologist. On other areas (non-inner gorge slopes) within MWMU 2, in addition to the riparian protections set as company policy, timber harvest must retain a minimum of 50% canopy (see footnote 1, page H-2) dispersed evenly across the slopes. • The MWMU 2 protections will extend from the edge of the watercourse transition line up to the break in slope of the inner gorge and 25 feet of additional slope distance after the break in slope of the inner gorge. • For those areas that do not have well defined inner gorge topography in MWMU 2 timber harvest must retain 50% canopy.

Resource Sensitive Area	Input Variable and Process	Prescriptions
Mass Wasting Map Unit #3	Coarse and fine sediment from mass wasting	*MWMU 3 Road construction:* • No new road construction across MWMU 3 unless field reviewed and approved by a California Registered Geologist unless it is the best road alternative2. *MWMU 3 Existing Roads:* • Existing roads and landings shall be abandoned when no longer needed. If abandoning is not feasible, then roads or landings shall be maintained at the design standards that lower risk of mass wasting sediment delivery. *MWMU 3 Tractor Yarding:* • Equipment limited to existing roads or stable trails3. *MWMU 3 Skid Trail Construction or Reconstruction:* • No new tractor trail construction or reconstruction unless field reviewed and approved by a California Registered Geologist. *MWMU 3 Timber Harvest:* • Retain 50% canopy (see footnote 1, page H-2) with trees dispersed evenly across slope. Tree retention shall be emphasized in the axis of headwall swales. Deviations from this default must be field reviewed and approved by a California Registered Geologist.
Rockslides (deep seated landslides)	Coarse and fine sediment from mass wasting	No harvest or new road construction will occur on active portions of rockslides with a risk for sediment delivery unless approved by a California Registered Geologist.
High and Moderate Erosion Roads*	Coarse and fine sediment from surface and point source erosion	The roads with a high erosion hazard rating should be given special attention for maintenance or erosion control. These roads should be considered high priority roads for rock surface, improved and increased road drainage relief, design upgrades, or decommissioning. The moderate erosion hazard roads should be given similar attention, but not as high a priority as the high erosion hazard roads. The roads in close proximity to watercourses in the Big River WAU will be assessed, where possible, for decommissioning based on road network connectivity and harvesting needs. Assessment or scheduling of road decommissioning will consider operational considerations of harvest scheduling, proximity and availability of equipment, magnitude of the problem, and accessibility to the site. The following roads have been identified, to date, for decommissioning: • Road DC-023 from DC0023-05 to SC-018 • Road DC-23-07 • Road SC-037 • Road SC-016-07 • Road SC-012 • Road M-150 • Road GC-018
Known High Treatment Immediacy Sites for Roads*	Sedimentation from surface and point source erosion	The known high treatment immediacy controllable erosion sites will be the highest priority for erosion control, upgrade, or modifications to existing design. These sites will be scheduled for repair based on operational considerations of harvest scheduling, proximity and availability of equipment, magnitude of the problem, and accessibility to the site.
Fish Passage Barriers from Culverts**	Barrier to fish migration	The 5 known culverts shall be removed or replaced with a drainage facility that will pass both juvenile and adult salmonids. All of these crossings should be a high priority for fish passage improvement. Other fish migration barriers likely exist and need to be investigated over time.
Riparian Areas	LWD recruitment	The company policies for streamside stand retention are considered to be appropriate at this time for LWD recruitment. Monitoring of LWD recruitment will be done to determine if this is correct. In the interim MRC will promote attempts to place LWD in stream channels to provide habitat structure. The stream locations with high instream LWD demand should be considered the highest priority for LWD placement. The moderate instream LWD demand segments would be next.
Canopy Closure over Class I and II Watercourses	Canopy closure and stream water temperature	The company policies for promoting streamside canopy and riparian management are considered to be appropriate at this time to improve stream canopy. Monitoring of stream temperatures and canopy will be done to determine if this is correct. Areas with unnaturally low canopy in the Big River WAU will have the following considerations for canopy improvement: • Tree planting along the river for restoration of riparian vegetation should be emphasized. • Restoration harvest within the Aquatic Management Zone will not remove trees providing effective shade. • Stream temperatures will be monitored to determine if temperatures are lowering as canopy grows in over time.

* See the MRC Road Hazard maps on pages 38 of the Middle Subbasin and 93 of the Inland Subbasin for locations of road sites.
** See Fish Passage Barriers sections on pages 23 of the Middle Subbasin and 57 of the Inland Subbasin for locations of culverts.

Refugia Areas

The NCWAP interdisciplinary team identified and characterized refugia habitat in the Big River Basin by using expert professional judgment and criteria developed for north coast watersheds. The criteria included measures 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. The team also used results from information processed by the CCWPAP EMDS at the stream reach scale.

The most complete data available in the Big River Basin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the CCWPAP team.

Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 69. Subbasin salmonid refugia area ratings in the Big River Basin.

Subbasin	Refugia Categories:				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
Coastal Subbasin		X				X	X
Middle Subbasin			X				X
Inland Subbasin			X				X

*Ratings in this table are done on a sliding scale from best to worst. Subbasin refugia ratings are aggregated from their tributary ratings. See page 45 for a discussion of refugia criteria.

Big River Basin Tributaries by Refugia Category:

High Quality Habitat, High Quality Refugia Tributaries:

None

High Potential Refugia Tributaries:

Railroad Gulch
Little North Fork Big River
Rocky Gulch
Thompson Gulch
East Branch Little North Fork Big River
Berry Gulch
Berry Gulch Tributary
Two Log Creek
Ayn Creek
Tramway Gulch
Hatch Gulch
North Fork Big River
East Branch North Fork Big River
Bull Team Gulch
Chamberlain Creek
Water Gulch
West Chamberlain Creek
Arvola Gulch
James Creek
South Fork Big River
Ramon Creek
North Fork Ramon Creek
Daugherty Creek
Soda Creek
Gates Creek
Snuffins Creek
Dark Gulch
South Fork Big River Tributary #1
South Fork Big River Tributary #2
Russell Brook
Martin Creek
Martin Creek Right Bank Tributary #1
Valentine Creek

Medium Potential Refugia Tributaries:

Big River Estuary
Big River mainstem in the Coastal, Middle, and Inland subbasins
Laguna Creek
Manly Gulch
Saurkraut Creek
Beaver Pond Gulch
Dunlap Gulch
Frykman Gulch
Water Gulch Tributary
Gulch Sixteen
Gulch Sixteen Tributary
Lost Lake Creek
North Fork James Creek
Biggs Gulch
Mettick Creek
Boardman Gulch
Halfway House Gulch
Johnson Creek (Tributary to Gates Creek)
Horse Thief Creek
Johnson Creek
Pig Pen Gulch
Martin Creek Left Bank Tributary
Martin Creek Right Bank Tributary #2
Rice Creek

Low Quality Habitat, Low Potential Refugia Tributaries:

Dry Dock Gulch
Cookhouse Gulch
Wheel Gulch
Peterson Gulch
Kidwell Gulch
Blind Gulch
Dietz Gulch
Steam Donkey Gulch
Quail Gulch
Park Gulch
Soda Gulch
Poverty Gulch
Anderson Gulch
Montgomery Creek

Data Limited and Critical Contributing Area

Occasionally, individual streams were missing data that would have provided a more complete picture for use in the refugia analysis. In these cases, only one or two of the factors used in the rating process were missing and this did not prevent refugia determination from being estimated. Where there were not enough data to give a stream a refugia rating, the site may have been listed as a critical contributing area based on the suitability of the habitat according to available data. All streams are lacking desired data.

Other Related Refugia Component Categories:

Potential Future Refugia (Non-anadromous)

None

Critical Contributing Area:

Big River Estuary

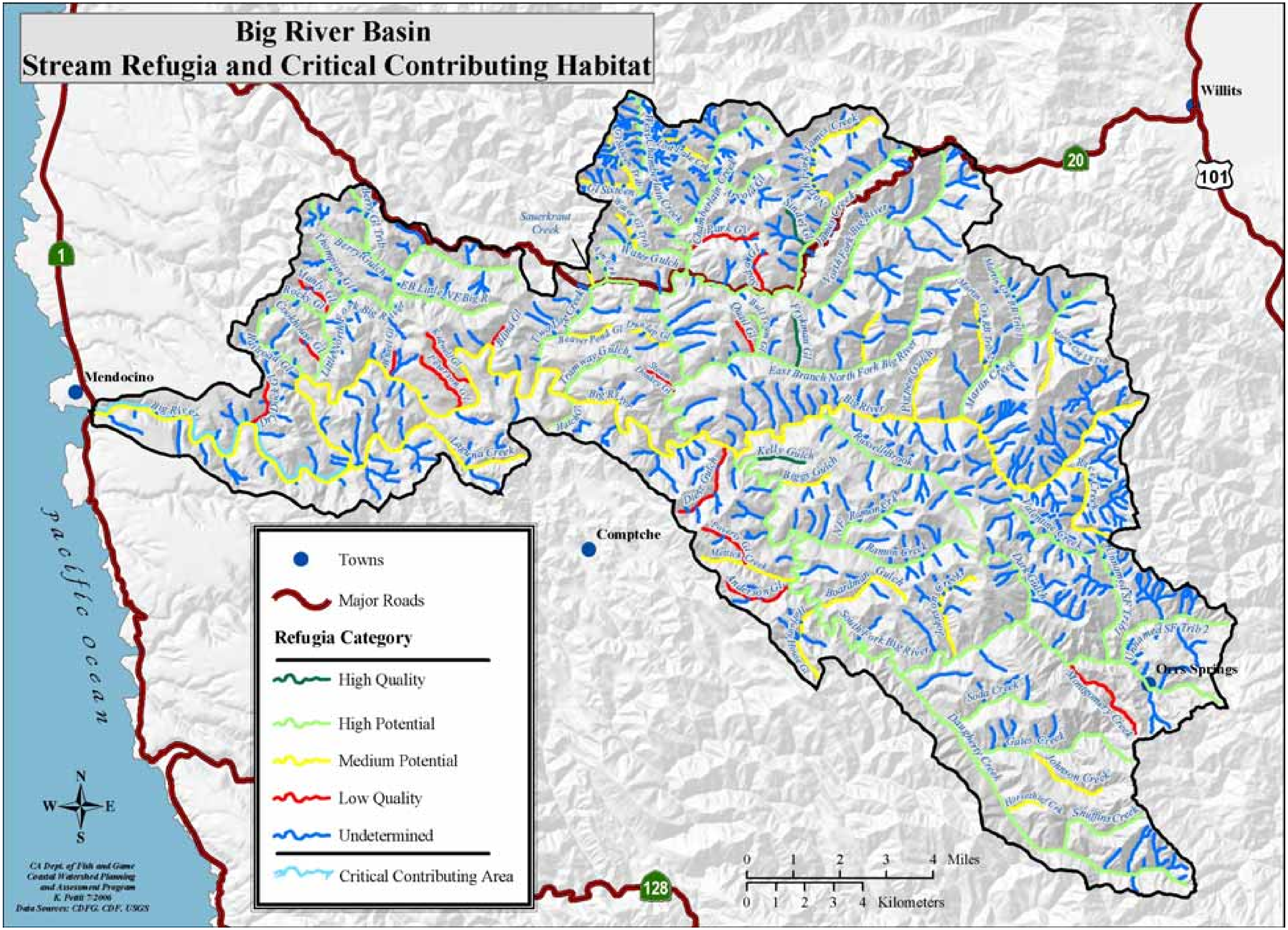


Figure 55. Stream refugia in the Big River Basin.

Responses to Assessment Questions

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

<u>Findings and Conclusions:</u>

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries Endangered Species Act listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast. Coho salmon in Mendocino County are currently listed as endangered under the California and federal Endangered Species Acts and steelhead trout are listed as threatened under the federal Endangered Species Act;
- Based on limited CDFG, USFWS, HTC, MRC, and SONAR presence surveys and surveys documented by NMFS, the distributions of coho salmon and steelhead trout do not appear to have changed since the 1960s;
- Steelhead trout were documented in more reaches surveyed by CDFG and MRC since 1990 than coho salmon;
- Thirty tributaries, the mainstem Big River, and the estuary had records of coho salmon and steelhead trout since 1990. Twenty additional tributaries recorded only steelhead trout.

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

<u>Findings and Conclusions:</u>

Flow/Water Quality

- Water temperatures at all seven monitoring sites along the mainstem of the Big River were unsuitable for salmonids;
- Water temperatures in tributaries across the basin showed that temperatures were generally suitable for salmonids in the Coastal and Middle subbasins and mixed in the Inland Subbasin. Water temperatures in the larger tributaries in the Inland Subbasin such as the North and South forks Big River were generally unsuitable for salmonids while water temperatures in the smaller tributaries were suitable;
- There have been very few water quality samples taken across the basin. Some sites show indications of exceeding NCRWQCB criteria for sodium, copper, specific conductance, total dissolved solids, aluminum, zinc, or boron. However, these findings are based on few sample sites and in some cases may be artifacts of the type of sampling procedure used.

Fish Passage

- Fish passage barriers have been identified in seven surveyed tributaries across the basin and several small tributaries along the estuary are blocked to fish passage by perched culverts;
- Areas of dry channel found during CDFG stream surveys may indicate fish passage problems in some tributaries during periods of low flow;
- Erosion/Sediment;
- Data collected in four tributaries in the basin indicated excessive amounts of fine sediment in the sub-0.85 mm and/or sub-6.5mm size classes, which would create unsuitable conditions for salmonids. However, much of the basin has not been evaluated for sediment delivery and deposition.

Riparian Condition

- Canopy cover was suitable for salmonids on all surveyed reaches within the basin except for James Creek and the mainstem Big River. The mainstem Big River has a larger, broader channel and floodplain and is expected to have relatively reduced canopy levels.

Instream Habitat

- A high incidence of shallow pools and a lack of cover and large woody debris indicate simplification of instream salmonid habitat in surveyed tributary reaches and the estuary.

Gravel/Substrate

- Cobble embeddedness values in many CDFG surveyed reaches were unsuitable for salmonid spawning success. Of surveyed pool tails, only 17.2% had cobble embeddedness less than 26%. In addition, the MRC characterized spawning gravels as fair quality on segments they surveyed;
- Permeability sampling in four locations throughout the basin indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonid in these sample sites.

Refugia Areas

- Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin tributaries where they have generally been rated as high potential refugia. Conditions in the Middle and Inland subbasins are mixed and generally rated as medium potential refugia.

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions?

Findings and Conclusions:

- The geology of the Big River Basin is primarily comprised of Coastal Belt Franciscan Complex. This portion of the Franciscan complex is relatively stable compared to the mélange terrane of the Central Belt, which is found only in the upper parts of the watershed. A small portion of Tertiary age sandstone is found in the Greenough Ridge - Montgomery Woods State Reserve area (EPA, 2001);
- The Coastal and Middle subbasins have much lower relief and longer slopes than the Inland Subbasin, which has a high percentage of area in higher slope classes;
- Redwood and Douglas fir forests have historically and continue to dominate the basin. Additional vegetation includes tan oak, madrone, alder, bishop pine, pygmy cypress, willow, grass, oak, bay laurel, alder oak, and blueblossom. Pre-European forests consisted of mostly large old-growth trees;
- A long history of wildfire has influenced the current vegetation of the Big River Basin, although the specifics of fire practices and history are unknown. However, fire was a natural and frequent occurrence. Prior to European settlement, the Mendocino Coast experienced a fire every 6-20 years during the last 200-400 hundred years (Brown 1999). In 1931, the Comptche fire swept across the eastern part of the basin, burning 10,733 acres, 9% of the basin;
- The basin has experienced a variety of natural disturbances such as earthquakes, flooding, droughts, and decadal climate shifts. Examples include a moderate earthquake that originated about two miles south of the Albion Basin during the mid to late 1800s, another strong earthquake that originated near Fort Bragg in 1898, and the distant San Francisco earthquake in 1906. Earthquakes often trigger landsliding;
- Landsliding has occurred across the entire basin. More landslides and more volume from landslides by area are found in the Inland Subbasin than the other two subbasins;
- Many of the tributaries in the basin are intermittent in their upper reaches and usually have summer and fall flows of less than 1 cfs.

How has land use affected these natural processes?

Findings and Conclusions:

- Historic timber harvest activities reduced riparian canopy, 86% of the basin has experienced one or more timber harvests. However, canopy is currently suitable along most surveyed tributary reaches across the basin;
- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times [61% of trees in 75-100 feet wide watercourse buffer zones have diameter at breast height (dbh) less than 24 inches]. The small diameter of near stream trees across the basin limits the

recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;

- Splash dam logging involving 27 splash dams across the basin before 1920 likely greatly accelerated erosion and widened stream channels across the basin. However, significant bed lowering along the lowermost reaches of Big River associated with splash dams is unlikely;
- Post splash damming channels are deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD and gravel;
- Early splash dam and barrier removal projects, starting in the 1950s, cleared many streams across the basin of timber-related woody debris. The lack of instream complexity seen today likely results from these past practices;
- A lack of LWD throughout the Big River Basin also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance;
- CGS found that channel narrowing, floodplain growth, and encroachment of forest vegetation on marshes seen since 1900 along the estuary is likely the result of a river channel reclaiming itself after the multiple decades of channel clearing, splash dam flooding, and battering by logs in transport;
- Historic sawmill complexes on the Big River flats reduced wetland habitat;
- Construction of near stream railroads in the Coastal and Middle subbasins and North Fork Big River and roads throughout the basin used fill that constricted stream channels and destabilized streambanks;
- From 1937 to 2000 the rate of landsliding across the basin was 664.3 tons/square mile/year (approximately 332 cubic yards or 33 truck loads). Rates were highest in the Inland Subbasin, followed by the Middle and Coastal subbasins, respectively;
- CGS photo mapping of stream channels in 1984 and 2000 found that negative channel features increased in the Mouth of Big River PW and decreased in the North and South forks Big River and Daugherty Creek, as expected between source and depositional reaches. The greatest reductions in negative channel features were seen in Daugherty Creek;
- There has been a significant increase in road building since 1989 across the basin, especially in the Coastal and Middle subbasins. However, new roads have been built to higher standards, on ridge-tops, and are paved; thus creating less of a sediment source;
- Roads and timber harvesting are listed in the NCRWQCB TMDL report as major sources of human-related sediment into the stream system. The effects from these activities are often spatially and temporally removed from their upland sources;
- County culverts located on three tributaries in the Inland Subbasin have been identified as total salmonid passage barriers by a Mendocino County roads study. Additionally, perched culverts have blocked fish passage to small tributaries along the estuary;
- The recent purchase of a large portion of the estuary and transfer to DPR for management as a park also will likely improve temperature and sediment conditions in the Coastal Subbasin as planned management improves roads and riparian zones.

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

<u>Findings and Conclusions:</u>

Based on the information available for this assessment, it appears that salmonid populations are currently being limited by:

- Low summer stream flows in tributaries in the Inland Subbasin;
- High water temperatures in the mainstem Big River;
- Fish passage barriers;
- Embedded spawning gravels;
- Reduced habitat complexity.

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

Flow and Water Quality Improvement Activities

- To minimize and reduce the effects of water diversions, take action to ensure compliance with state water laws to address seasonal diversion, off-stream reservoirs, bypass flows protective of coho salmon and other anadromous salmonids and the normal hydrograph, and avoidance of adverse impacts caused by water diversion;
- Discourage instream flow diversions in tributaries with cooler water temperatures for thermal refugia delivered to the warmer North and South forks and mainstem Big River in the summer;
- Land managers should work to reduce the temperature of water flowing into the Middle and Coastal subbasins. In order to do this, they should maintain and/or establish adequate streamside protection zones to increase shade and reduce heat inputs to Big River and its tributaries throughout the basin;
- Follow the procedures and guidelines outlined by NCRWQCB to protect water quality from ground applications of pesticides.

Fish Passage

- Consider modifying debris accumulations to facilitate fish passage where necessary;
- Adequately fund prioritization and upgrading of culverts to provide fish passage within the range of coho salmon and to pass 100-year flows and the expected debris loads.

Erosion and Sediment Delivery Reduction Activities

- To reduce sediment delivery to Big River, land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with landuse activities throughout the basin. Thirty-six CDFG stream surveys had road sediment inventory and control as a top tier tributary recommendation;
- Support and encourage existing and active road management programs undertaken by landowners throughout the basin;
- Map unstable soils and use soil mapping to guide land-use decisions, road design, THPs, and other activities that can promote erosion;
- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks;
- Limit unauthorized and impacting winter use of unsurfaced roads and recreational trails to decrease fine sediment loads;
- Develop erosion control projects similar to the North Fork Ten Mile River erosion control plan (Mendocino Department of Transportation 2001).

Riparian and Instream Habitat Improvement Activities

- Improve instream structure for juvenile escape and ambush cover. Thirty-one CDFG stream surveys and the mainstem Big River have increase escape cover as a top tier tributary recommendation;
- Add LWD to stream channels where appropriate/feasible to develop habitat diversity and to increase shelter complexity. In addition, there is a need to leave large wood on stream banks and in estuarine channels for potential recruitment into stream channels and the estuary;
- Maintain and improve existing riparian cover where needed;
- Encourage growth and retention of nearstream conifers;
- Ensure that any land management activities include protection and preservation of stream and riparian habitats and maintain or improve ecological integrity within the basin;
- Ensure that high quality habitat is protected from degradation. Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins;
- Consider the use of management strategies such as conservation easements to maximize potential benefits to aquatic habitats from near-stream forest protection.

Education, Research, and Monitoring Activities

- State Parks, CDFG, MRC, and HTC should continue and expand existing monitoring of anadromous salmonid populations to include some winter and spring fish sampling;
- Support stream gage installations and maintenance to establish a long term record of Big River hydrologic conditions;
- Additional investigations of the physical characteristics of Big River are needed to re-evaluate the Sediment Source Analysis. A regional curve of bankfull dimensions vs. drainage area should be developed for Mendocino County and used to validate CGS (2004) bankfull discharge estimates for Big River;
- Hillslope and in-stream monitoring proposed by the MRC in their Watershed Analysis (2003) should be carried out and additional monitoring programs throughout the basin should be planned with respect to MRC techniques;
- A study examining how sediment plugs moved downstream from historic splash dam locations over time on air photos is recommended;
- Continue water temperature monitoring at current locations and expand these efforts where appropriate;
- Further study of timberland herbicide use is recommended.

Subbasin Profiles and Synthesis

Coastal Subbasin

The Coastal Subbasin includes all of the watershed area of the mainstem Big River just below its confluence with Peterson Gulch (Figure 57). This encompasses all of the Big River Estuary. Stream elevations across the subbasin range from sea level to 40 feet at the boundary with the Middle Subbasin. The highest point is above Kidwell Gulch on the border with the Middle Subbasin, at 1,235 feet. The subbasin encompasses 32.5 square miles and occupies 17.9% of the total basin area. The Big River Estuary is large relative to the size of the basin, with tidal influence extending approximately 8.3 miles upstream from the ocean. The estuary is the longest undeveloped estuary in California (Warrick and Wilcox 1981). The mouth of the river is an opening along the north side of Mendocino Bay. The bay is protected by rocky headlands, which minimize wave-induced longshore sediment transport and help the mouth to remain open to the sea year round. The town of Mendocino lies just outside of the Big River Basin, north of the river mouth.

Climate

The climate of the Coastal Subbasin is characterized by a pattern of low-intensity rainfall in the winter and cool, dry summers with coastal fog. Average annual rainfalls range from 40 inches near the coast to 55 inches further inland. Air temperatures are moderated by the ocean influence and average 40 to 47°F.

Hydrology

The Coastal Subbasin is made up of three CalWater Units (Figure 57). There are 24.5 perennial stream miles in 14 perennial tributaries in this subbasin (Table 70). There are an additional 17.9 miles of the mainstem Big River. The mainstem Big River in the Coastal Subbasin is a fourth order system using the Strahler (1964) classification. The tributaries to the mainstem in this subbasin are first and second order streams with drainage areas ranging from less than one square mile to 14 square miles (Figure 56).

Table 70. Tributaries to the Big River in the Coastal Subbasin by river mile from 7.5 minute topographic maps.

CalWater Planning Watershed	River Mile	Bank (L,R)	Stream	Perennial (Miles)	Intermittent (Miles)	Stream Order
Mouth of Big River	0.4	R	Unnamed Tributary		0.9	Intermittent
	2.3	R	Unnamed Tributary		0.8	Intermittent
	3.2	R	Unnamed Tributary	0.6		1
	3.6	L	Unnamed Tributary		0.6	Intermittent
	4.1	R	Unnamed Tributary		1.3	Intermittent
	5.1	L	Unnamed Tributary	0.5	0.3	1
	5.3	L	Dry Dock Gulch	1.2	0.1	1
	5.6	L	Unnamed Tributary	0.5	0.4	1
	7.3	R	Unnamed Tributary	0.3	0.3	1
	8.0	L	Unnamed Tributary	0.5	0.3	1
Laguna Creek	9.2	R	Big River Laguna	5.6	0.8	1
Mouth of Big River	12.2	L	Railroad Gulch		2.7	1
Berry Gulch	12.4	L	Little North Fork Big River	8.4	0.1	2
			Unnamed Tributary to Little North Fork Big River/Cook House Gulch		1.0	1
			Rocky Gulch	0.5	0.7	1
			Manly Gulch		1.1	1
			Thompson Gulch	1.9		1
			East Branch Little North Fork Big River	1.1	1.7	1
			Berry Gulch	2.6	0.4	1
			Berry Gulch Tributary		1.8	1
Mouth of Big River	13.9	R	Unnamed Tributary	0.4	0.3	Intermittent
	14.4	R	Unnamed Tributary		0.6	Intermittent
	15.2	L	Unnamed Tributary		1.0	Intermittent
	15.8	L	Wheel Gulch		0.9	Intermittent
	15.9	R	Unnamed Tributary		0.5	Intermittent
	16.1	R	Unnamed Tributary	0.5	0.1	1
	17.9	R	Unnamed Tributary		1.3	Intermittent

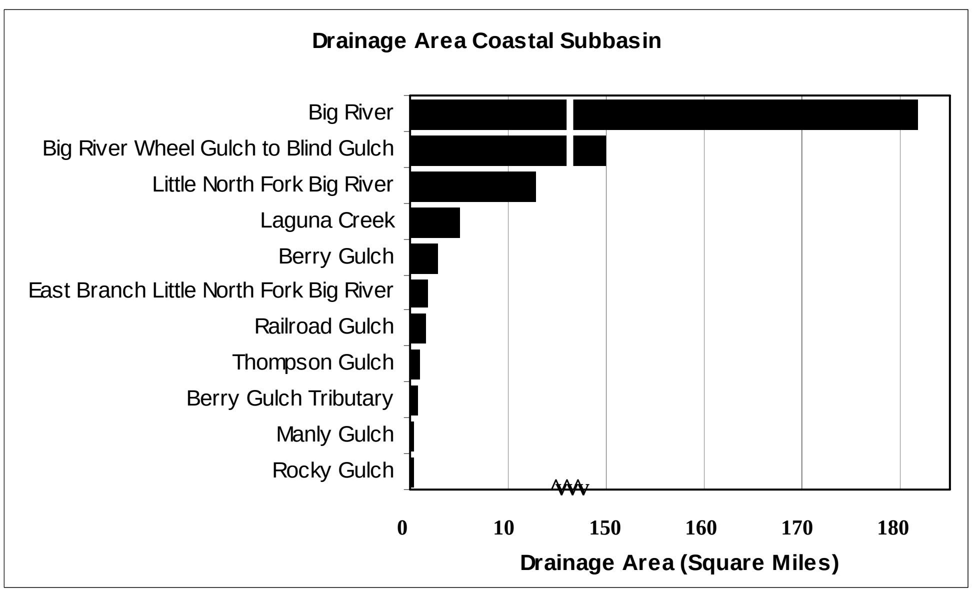


Figure 56. Drainage area of streams surveyed by CDFG in the Coastal Subbasin.

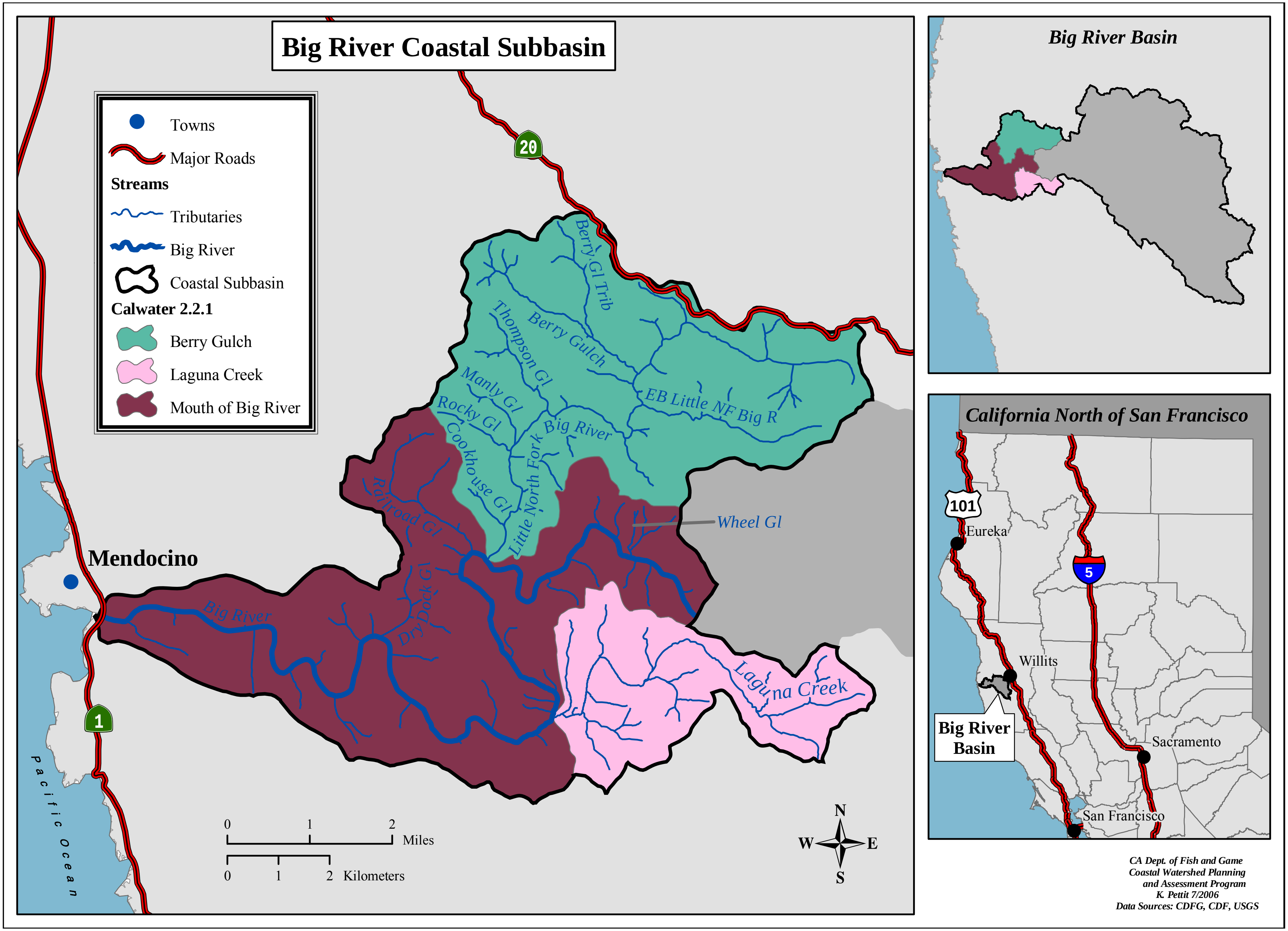


Figure 57. Coastal Subbasin and CalWater2.2a planning watersheds.

Estuary

The mouth of the Big River remains open year-round and forms a large estuary. Unlike many estuaries, Big River Estuary is not lagoonal but instead has a long linear channel. During high spring tides, the tidal influence extends up to 8.3 miles upstream, while during the winter tides extend 3 miles upstream (GMA 2001a). Crescent-shaped tidal flats alternate on either side of the channel corresponding with the alluvial deposits of the river (Marcus and Reneau 1981). Wetlands in the lower reaches of Coastal Subbasin tributaries suggest that the estuary may have extended further up-river in the past (GMA 2001a).

A coastal wetland survey of the estuary was completed by CDFG in 1978 (Dana). The study found the estuary consisted of approximately 106 acres under marine water at mean low tide and approximately 191 acres of marsh and mud flats. Associated marshes are salt (63 acres), brackish (33 acres), and freshwater (59 acres). There were about 15 acres of mudflats and 2 acres of eelgrass beds (*Zostera*). Hypersaline ponds that dry up occasionally during the summer were interspersed throughout the salt marshes. Riparian vegetation was permanent and consisted mainly of alders and willows (Dana 1978). A series of eight salt marsh flats border the lower three miles of the estuary (Figure 58, Marcus and Reneau 1981).

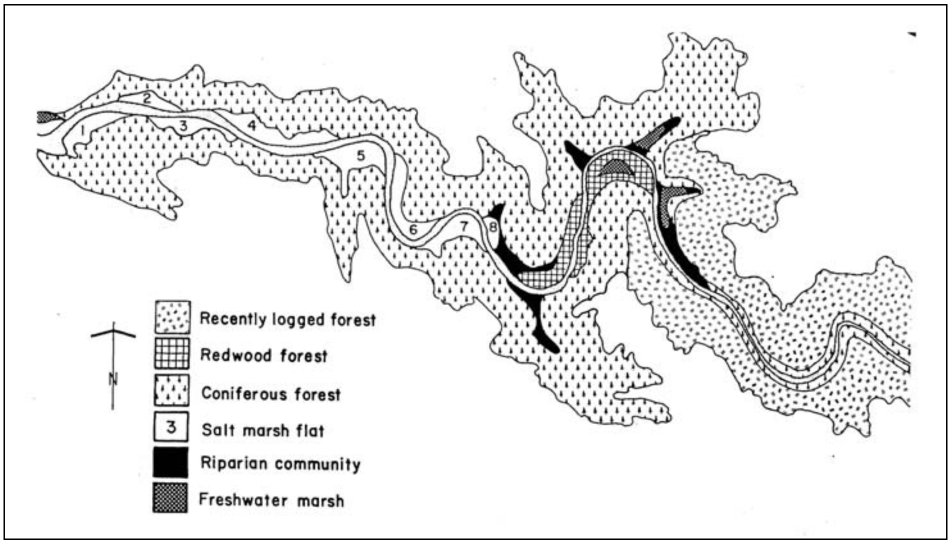


Figure 58. Map of salt marsh flats in the Big River Estuary in 1981 from Marcus and Reneau.

Upstream from the mouth, the floodplain narrows abruptly and adjacent slopes are vegetated with second growth redwood and mixed conifer forest. The hillslopes on either side of the river are steep, with occasional remnants of the river's former floodplain with stands of alder.

About eight miles inland the river is joined by Laguna Creek, where a large freshwater lagoon exists. This wetland is surrounded by freshwater marsh containing rushes (*Juncus*), cattails (*Typha*), and cowlily (*Nuphar*). Tidal influence in the summer extends as far as 8.5 miles upstream with ranges of two to four miles in the winter. Rockweed (*Fucus*), marine algae, has been found as far as four miles upriver (Dana 1978). More information about vegetation in and along the estuary is discussed in the Riparian Conditions section of this subbasin.

Many animal species are found in the estuary in addition to the salmonids that utilize the estuary as a migration corridor and as a nursery area for juveniles. Species of importance to fisherman include Dungeness crab, surfperch, flatfish, and surf smelt. Soft shell clams occur in intertidal flats. Old pilings in the estuary are covered in tunicates, nudibranches, barnacles, and mussels. Opossum shrimp (*Neomysis*) are found in the estuary and freshwater mollusks (*Goniobasis*) are found in the river (Dana 1978). More information about fish in the estuary is discussed in the Fish History and Status section of this subbasin.

Mammals found in the estuary include river otter, deer, mink, sea lions, and harbor seals. Sandflats at the mouth of Big River are used as rest areas by shorebirds that feed on invertebrates in the mudflats. Diving ducks, dabbling ducks, and black brant are also found. Virginia and sora rail are expected to occur in marsh areas. Woodduck nests were located in the Laguna Creek marsh in 1978, but no use was reported (Dana 1978). Twenty-four additional woodduck boxes were installed in Dry Dock Gulch and Laguna Creek in December

2002 and January 2003 (SONAR 2003). Boxes were checked for nesting success between March 11, and May 29, 2003. Two boxes out of nine were used at Dry Dock Gulch and eleven out of 15 were used at Laguna Gulch (Kight and Waldman 2003). Other birds observed in the estuary include uncommon pileated woodpeckers, osprey, great blue herons, and spotted owls (Dana 1978).

Geology

The Coastal Subbasin has a high percentage of area in low slope classes. The Big River Estuary is a drowned Pleistocene river valley that cuts through a Franciscan sandstone formation. The most recent parent material is sandstones, shales, and thick deposits of alluvium. The predominant soil type is Hugo, interspersed with Josephine and Empire (Soil-Vegetation Maps of California, and supplements, 1975, as cited in English 1979).

Landsliding

CGS (2004) examined landsliding in the Big River State Park as a part of their Engineering Resource Assessment. The entire park is underlain by Franciscan Coastal Belt geology. In the western part of the park, wave action has eroded the rocks and reduced their relief, marine terrace rocks have mantled the rock, and the Big River has caused incision. In the eastern section of the park, rocks have not been subject to wave action and thus have a much higher relief. Therefore, the western part of the park has steeper slopes, whereas the eastern part has longer slopes. Debris slide slopes are common in the steep streamside slopes next to the Big River and larger deep-seated landslides occur in the eastern upland sections of the park. The greatest amount of small active debris slides and small landslides occur in debris-slide slope areas. Inner gorges also occur along some of the eastern Big River tributaries within the park.

A GMA (2001) analysis of landslides across the entire subbasin by time period found that about 10% of the number of slides across the Big River Basin were in this subbasin. The Berry Gulch PW had the highest number of slides in the subbasin, while the period from 1937 to 1952 had the highest number of landslides.

Table 71. Coastal Subbasin number of delivering slides by study period and PW (GMA 2001a).

Planning Watershed	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total All Periods	
	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)
Mouth of Big River	24	22.6	27	35.1	2	20.0	1	4.3	16	50.0	70	28.2
Berry Gulch	64	60.4	44	57.1	8	80.0	17	73.9	9	28.1	142	57.3
Laguna Creek	18	17.0	6	7.8	0	0.0	5	21.7	7	21.9	36	14.5
Coastal Subbasin	**106**	**42.7**	**77**	**31.0**	**10**	**4.0**	**23**	**9.3**	**32**	**12.9**	**248**	**100**

Landslide volume estimates from the same time periods showed that 10.5% of sediment delivered to streams across the Big River Basin occurred in the Coastal Subbasin (GMA 2001a) (Table 72). The highest volumes of sediment in this subbasin were delivered in the Mouth of Big River PW.

Table 72. Volume of delivering slides by study period by PW in the Coastal Subbasin (GMA 2001a).

Subbasin	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	(%f or Entire Watershed For Entire Period)
Mouth of Big River	408,001	86.1	82,624	63.3	26,832	93.7	33,980	67.9	60,903	53.2	612,340	8.1
Berry Gulch	49,694	10.5	2,449	1.9	0	0.0	16,061	32.1	12,589	11.0	80,792	1.1
Big River Estuary	16,350	3.4	45,304	34.7	1,811	6.3	0	0.0	40,970	35.8	104,435	1.4
Total	474,045	59.4	130,376	16.3	28,643	3.6	50,041	6.3	114,463	14.4	797,567	10.5

The CGS (2005) landslide potential map classified 39% of the Coastal Subbasin in the high and very high potential categories (Table 73).

Table 73. Landslide Potential in the Coastal Subbasin.

Landslide Potential Category	Area (square miles)	% of Subbasin
Very Low	5.4	17
Low	7.6	23
Moderate	7.0	22
High	9.6	30
Very High	2.8	39

Fluvial Geomorphology

The Big River Estuary and immediate upstream area are comprised of:

- A series of oxbows and old river channels in the floodplain;
- Old river terraces next to the floodplain; and
- Ancient sea terraces occurring between 200-300 feet in elevation (English 1979).

The estuary is the repository of watershed sediment carried downstream by the river and sand carried upstream by the tide. Therefore, estuaries are sites of active sedimentation. During floods, high tide waters mix with slow, silt laden river water in the estuary - resulting in sediment deposition. Large river sediment loads cause greater deposition in the estuary. Consequently an examination of geomorphic patterns in an estuary can reflect erosional processes occurring in the watershed (Marcus and Reneau 1981).

A 1981 study of the historic sedimentation in the Big River Estuary found that the estuary has experienced a rapid sedimentation of its channel and salt marshes since the advent of logging in the watershed (Marcus and Reneau 1981). The study mapped the distribution of vegetation along the estuarine channel (Figure 58) and looked at historic photos as well. The estuary was also found to exhibit an unusual pattern of deposition. The most obvious indicator of accelerated sedimentation in the Big River Estuary was the occurrence of levees along the estuary channel. Levees form as silt laden flood waters are slowed along the edges of the channel. Coarser, heavier sediments settle out and form an embankment along tidal flats and estuary channels. The result is the storage of sediment in natural levees and on tidal flats.

Levees in the estuary extend along the channel to 1.7 miles above the river mouth and display a regular decrease in height. They vary in width from 40 feet in the upper estuary to 10 feet and less in the lower region. These levees record the transition in the estuary from primarily tidal influences (salt marsh and mudflat) to primarily river influences (floodplains).

The estuary channel has narrowed and the floodplain has grown at the expense of mudflat and subtidal areas as estuary banks have prograded. Blockage or reduction in tidal influence has occurred in the upper flats while a filling of sloughs and increase in mudflat height is found in the lower flats.

Marcus and Reneau used several examples to illustrate these estuarine processes:

> A railroad system was used to transport logs to the estuary during the early logging. A log dump located 3.8 miles upriver served as a spur of the railroad where logs could be dumped directly into the water. This log dump is shown in a historic photograph taken in the 1920s as standing in open water (Jackson 1975). The border of Flat 8 sloped gently away from the water. Today the pilings of this log dump stand adjacent to Flat 8, bordered by a levee 4 feet in height. The historic development of this levee records a major change in the hydraulic conditions of the estuary. Winter floods were not able to deposit enough sediment to build levees at the site of the log dump prior to 1900. Since the photograph was taken, levees have developed 2 miles further down the estuary.
>
> Once the logs were dumped into the estuary, they were rafted down to the sawmill at the mouth. To avoid stranding the logs on the tidal flats, rows of pilings were placed at the lower low tide line (Jackson 1975). Chains were stretched between these pilings and acted as a barrier to the floating logs. Presently in Flat 4, two sets of pilings occur, the outer one at approximately low tide line and the inner one trending back into the salt marsh. Two sets of pilings were installed during the logging operations before 1938 indicating that heavy sedimentation had extended the low tide line out into the channel, thus rendering the original set obsolete.
>
> The filling of these tidal sloughs by sediment is demonstrated by the presence of several barges, buried in Flat 4. These barges were used for transport in the estuary. The barges are 42 feet in width and were moored in the tidal slough, indicating the original slough was at least this wide. Presently the same slough is 7 feet in width and [one] barge is buried adjacent to the bank.

CGS photo mapping found that within the Mouth of Big River PW, the main channel gained negative channel features between 1984 and 2000, due to accumulation of sediment that was visible in plan view in relatively small-scale aerial photographs (Figure 59). The year 1984 showed 2.8 miles of negative channel features; 2000 showed 5.3 miles of negative channel features, consisting of lateral bars and a few mid-channel bars. The length of negative channel features grew significantly from 18.5% (1984) to 34.7% (2000) of the length of the blue-line stream representing the lower mainstem channel in the Mouth of Big River PW.

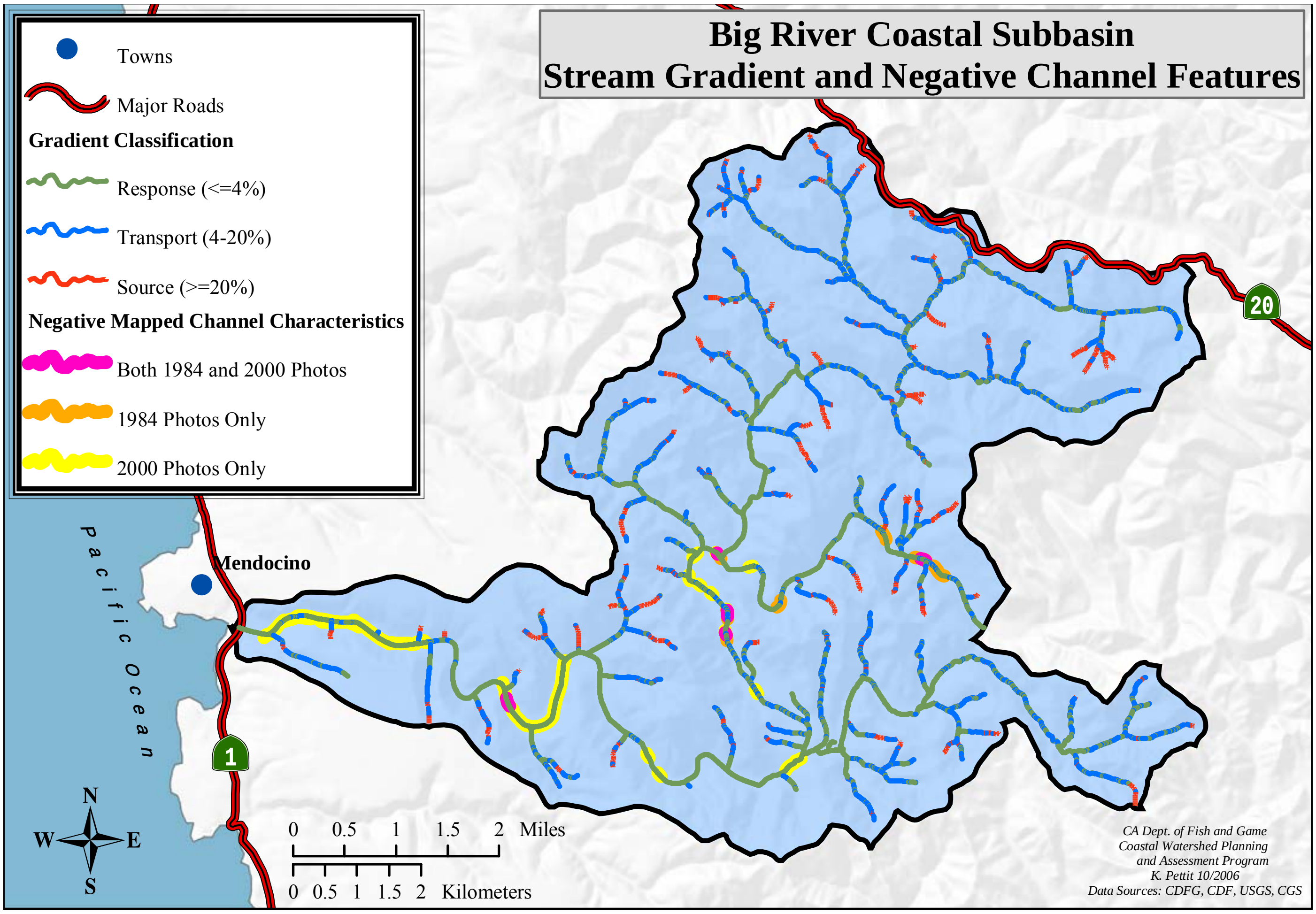


Figure 59. Map showing the relatively shallow gradient (<0.1%) of the lower Big River, where sediment appears to have accumulated between photo years 1984 and 2000.

CGS prepared an Engineering Geologic Resource Assessment for DPR in 2004. As part of their analysis, CGS identified stream channel conditions and sediment sources within the 7,315-acre Big River State Park. The Big River's gradient through the park is approximately 0.0475 percent, making the Big River a Rosgen type C channel. CGS was able to separate the channel in the park into four different reaches based on changes in sinuosity (Table 74). CGS found that from the mouth of Big River to RM 6.7, tidal influences and estuarine processes appear to mask fluvial processes. Reneau (1981) estimated that over 100 feet of sediment has accumulated in the estuary by the mouth of Big River over the past 9,000 years - or approximately 3 millimeters of sediment per year. This is considered the natural background sedimentation rate in the estuary.

Table 74. Channel reaches of different sinuousity and possible geologic/geomorphic controls within the Big River State Park (from CGS 2004).

RM	Reach Name	Sinuosity	Valley Flat/Flood Prone Width (feet)	Most Commonly Measured Widths (feet)	Possible Geologic and/or Geomorphic Controls
0.0-2.2	Tidal	1.06	350:1,000	600	Drowned river mouth where tidal and estuary processes (sedimentation) dominate
2.2-8.0	Meanders	1.66	300:850	550	Incised antecedent meanders
8.0-10.6	Wonder Plot	1.18	400:1,400	600-800	General linear trend at ~N40W that parallels the structural grain of folding and faulting along California's coastline
10.6-13.4	Woodlands	1.52	275:900	400-600	Return to antecedent meanders

Within the boundaries of the park, Big River meanders through a flat-floored valley with a bottom made up of alluvial sediment. About 85% of the river banks along the park are formed within this alluvial sediment, while the other 15% are eroded into steep valley floors underlain by colluviums or sandstone bedrock. The alluvial valley ranges from 275 to 1,400 feet wide at the confluence with Laguna Creek. The most common valley width within the park is 600 feet. The mainstem Big River is incised into the valley alluvium and has nearly vertical three to 20 foot high stream banks in most places. Banks are generally composed of weakly consolidated and uncemented silt and fine sand. When the stream banks exceed 6 feet in height, the banks slump and slough. Water levels in the late summer are between three and six feet in the tidal reach and between six and 20 feet in the upstream reaches below the valley flat (CGS 2004).

Old tidal mudflats and estuarine deposits of fine silt interlaminated with thin layers of peat have developed into salt marshes along the tidal reach. Upstream of this reach, mixed conifer forest has developed on valley flats composed of fine sand and silt deposited by the river. These valley flats are fluvial terraces and gently undulate to flat, slope down away from the channel, and usually contain a closed linear depression near the base of the adjacent hillslope. This is likely the result of natural levee formation (CGS 2004).

CGS (2004) examined silt lines on tree trunks on the fluvial terraces in the park. These lines are caused by regular inundation and have been described in historical accounts. Lines range from three to six feet above the terrace surface. Fritz (1923) described the lines in the Wonder Plot, a six-acre parcel of second growth redwoods set aside as a long term scientific experiment in redwood growth rates (Figure 60):

> The site is on a high river bench of fine silt that is reported to be inundated once every four or five years. The mud line on the trees is in many cases 7 feet off the ground.

Another description of the same plot in 1945 states:

> The sample plot, a square figure of one full acre, lies on a "flat" or a bench on the left bank of Big River. The soil is very deep silt, and, although about 20 feet above the bed of the river, is subject to inundation in occasional years. Mud lines on the trees indicate the level to have been 5 feet above the ground at the highest point of the plot.

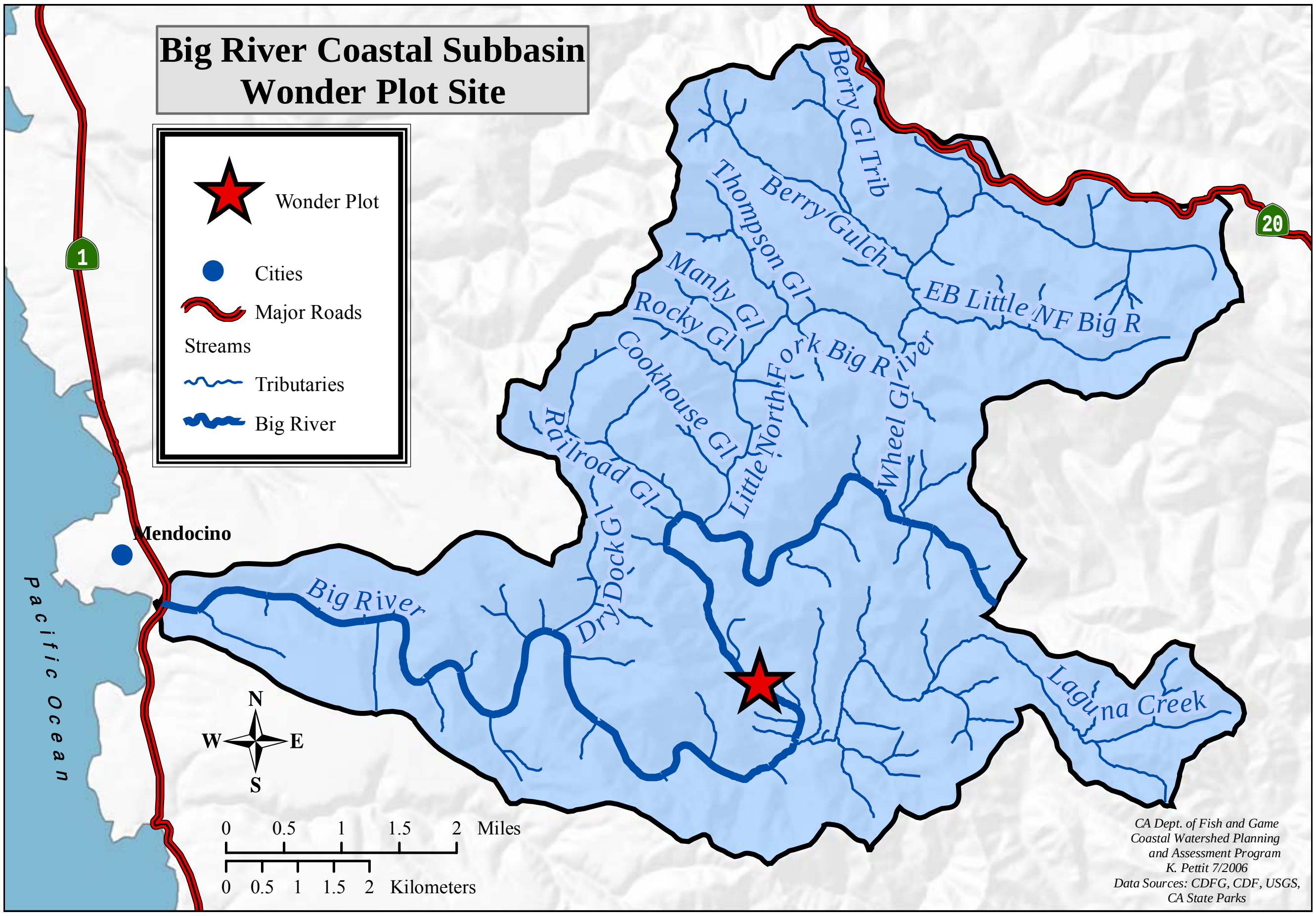


Figure 60. Wonder plot experimental site.

CGS (2004) surveyed a cross-section near the Wonder Plot, at RM 8.7. The cross-section showed the level of the terrace surface to be 25 feet above the river bed, with silt lines on tree trunks at four to five feet above the ground surface. Thus the observations made by CGS in 2004 were very similar to those made by Fritz in 1923 and 1945. This indicates that the topographic relationship between the terrace surface and the active channel has not changed substantially in the past 80 years during the period of intense timber harvesting throughout the upper watershed (CGS 2004).

However, other aspects of channel morphology have changed. The 40 to 50 years of splash dam logging across the basin likely had an effect on stream channels. Channel clearing, artificial flooding, and battering by logs in transport likely greatly accelerated erosion and widened the width of the channel (CGS 2004). However, significant bed lowering along the lowermost reaches of Big River associated with splash dams is considered unlikely (CGS 2004). The very shallow gradient of the river inhibits stream power and the close proximity of the ocean provides ultimate control of base level. The remains of old log pilings and the foundation of a pier or log deflection wall within the channel from the early 1900s also support this idea. If bed adjustments had occurred in this section of the river, such old structures in the river would have been destroyed by annual and high flows over the past century (CGS 2004).

CGS (2004) examined the channel narrowing phenomenon documented by Reneau (1981) for most of the 20th century. They found that Reaneau had failed to discuss his findings within the context of “a river channel reclaiming itself after the multiple decades of channel clearing, splash dam flooding, and battering by logs in transport” (CGS 2004). CGS found it likely that channel conditions of the early 1900s documented by Marcus and Reneau (1981) were in fact an artifact of the splash dam era and represented a much wider channel. Therefore, channel narrowing seen since 1900 likely represents the channel re-adjusting to a more natural discharge regime (CGS 2004).

Out of 21 stream reaches surveyed by CDFG in the Coastal Subbasin, the most common Rosgen channel type was F4 (Table 75). There were nine different channel types present.

Table 75. Channel types in surveyed streams of the Coastal Subbasin.

Stream	Reach	Survey Length (Miles)	Channel Type
Big River	1	8.1	F4
	2	5.0	F4
	3	1.9	F4
	4	1.8	F3
	5	3.5	B2
Laguna Creek	1	1.9	C3
Railroad Gulch	1	1.1	F4
Little North Fork Big River	1	3.7	G4
Rocky Gulch	1	0.1	E4
	2	0.1	A3
Manly Gulch	1	0.7	G4
Thompson Gulch	1	0.7	B4
	2	0.4	F4
East Branch Little North Fork Big River	1	0.9	A4
	2	1.5	B4
Berry Gulch	1	0.1	F3
	2	1.3	F4
	3	0.2	B2
	4	0.6	F4
Berry Gulch Tributary	1	1.1	F4
Big River Wheel Gulch to Blind Gulch	1	5.0	F4

Vegetation

Redwood-Douglas-fir forests cover 91% of the Coastal Subbasin, with the remainder made up mostly of various other tree species and blueblossom (*Ceanothus spp.*) shrubs (Table 76). Blueblossom is usually a result of a clearcut where slash has been burned as it reseeds through fire and prefers disturbed areas. Tree stands are mostly composed of small to medium/large trees (Table 77). Almost half of the subbasin is covered by trees with 90% crown canopy density, although 6% is not covered by canopy (Table 78).

Table 76. Acreage and proportion of area of vegetation classes in the Coastal Subbasin.

Class	Acres	%
Redwood - Douglas-fir	18,824	91
Douglas-fir		
Tan oak, Madrone, Alder	363	2
White, Black or Live oak & Bay laurel		
Blueblossom Ceanothus	645	3
Manzanita, Chamise, Scrub oak		
Bishop Pine, Pygmy cypress, Willow	429	2
Grass	283	1
Wet Meadows	31	
Water	176	1
Barren/Rock	26	
Urban/Developed	2	
Totals	**20,779**	**100%**

Table 77. Vegetation size class in the Coastal Subbasin by planning watershed.

Planning Watersheds	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Mouth of Big River	357	4.0	383	4.2	4,647	51.5	3,493	38.7	152	1.7
Berry Gulch	56	0.7	194	2.5	2,608	33.9	4,671	60.7	161	2.1
Laguna Creek	0	0.0	76	2.6	1,816	62.7	999	34.5	4	0.1
Total Coastal	**413**	**2.1**	**653**	**3.3**	**9,071**	**46.2**	**9,162**	**46.7**	**317**	**1.6**

Table 78. Density of vegetation in the Coastal Subbasin by planning watershed.

Planning Watersheds	Percent Crown Canopy Density										Total Acres
	0%		10-69%		70%		80%		90%		
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	
Mouth of Big River	511	5	585	6	1,866	20	2,310	24	4,270	45	9,542
Berry Gulch	304	4	518	6	2,197	27	943	12	4,032	50	7,993
Laguna Creek	349	11	279	9	482	15	452	14	1,683	52	3,244
Total Coastal	**1,163**	**6**	**1,379**	**7**	**4,546**	**22**	**3,705**	**18**	**9,984**	**48**	**20,779**

Total density of all species - conifers and hardwoods.
Most of the 0% density crown canopy is grasslands, water, and shrub species.

Fire and Fuels

Areas of high fuel rank dominate the Coastal Subbasin, with small discontinuous zones of very high fuel rank scattered throughout. There were no records of large wildfires in this subbasin.

Land Use

The Coastal Subbasin is composed of various sized parcels with smaller parcels clustered around the north and south boundaries near the mouth- close to the towns of Mendocino and Little River. The three largest landholders in this subbasin are California State Parks, JDSF, and Hawthorne Timber Company, LLC.

Interest in purchasing lands around the Big River Estuary for conservation purposes first came under serious consideration in the late 1970s when USFWS prepared an environmental assessment to examine options for protecting the area. In 2002, a local citizens' group purchased a 7,334-acre parcel in the Big River Basin from the Hawthorne Timber Company. Money was raised from public agencies and private donations. The Mendocino Land Trust acted as the lead organization in the fund raising effort. On July 1, 2002, this parcel, known as the Big River Unit, was added to Mendocino Headlands State Park. This new State Park unit makes up 32% of the Coastal Subbasin.

The Big River acquisition includes 50 miles of mainstem Big River and its tributaries. It includes the entire tidal estuary and 1,500 acres of wetlands. The Big River property is connected to Van Damme State Park on the south, and JSDF and Russian Gulch State Park to the north. This created 60,000 acres of connected wildlife corridors and trail systems. Mendocino Headlands State Park is currently managed for preserving biological diversity, protecting valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation. A preliminary management plan for the new state park unit has been developed.

A CDFG coastal wetland survey conducted in 1978 (Dana) recommended that the estuary be managed with a watershed management plan including three key elements:

- Protection of habitat elements such as riparian woodland, marshes, snags, and nesting trees;
- Avoidance of erosion through proper timber harvest techniques, such as no clear-cutting along the floodplain or immediate watershed, proper operation of equipment on steep slopes, erosion control at stream crossings, and post-timber clean-ups;
- Not increasing recreational activities.

California State Parks also owns and manages the 720-acre Mendocino Woodlands State Park. This land is surrounded by a 2550-acre special treatment area managed by CDF.

JDSF owns 32% of the Coastal Subbasin area. The State of California owns and manages JDSF for demonstrating forest management principles, recreation, and environmental conservation.

Highway 1 crosses the Big River near its mouth across a high bridge. The current bridge was built in 1960. Prior to the current bridge, a series of five low bridges were built at various times, each with a slightly different abutment. The first bridge was completed in 1860. Today's high bridge was built to replace the flood prone lower bridge.

Big River Flat, east of present Highway 1, near the mouth of the river is currently an unpaved parking lot. In the past, however, this flat was the site of a timber mill complex. The complex included a mill, mill hands' cabins, and several family dwellings. Four lumber companies operated mills at the complex or in the town of

Mendocino: California Lumber Manufacturing Co., Mendocino Mill Co., Mendocino Saw Mills, and the Mendocino Lumber Co.

The estuary was used extensively as a mill pond from the 1850s to 1938. Logs were transported downstream via splash-damming or railroads and stored in the estuary. Booms were built along the low-tide lines to keep logs from getting stranded as the tides changed.

In 1852 surveying began for a railroad across the beach at the mouth of Big River. The railroad was used as a tramway between the mill, built in 1854, and the east end of the Big River beach. Logs were stored at an enclosure in the river until they were milled. A second mill, closer to the log enclosure, was built in 1855. Timber framed piers were built in the river 3.5 miles upstream from the mill for stopping logs going downstream in 1858.

The second mill burned down in 1863 (Figure 61). It was rebuilt immediately and the need for large timbers for rebuilding induced the logging company to reserve nearby large trees in Reserve Gulch. In 1889 the mill was shut down temporarily to institute a new sawdust disposal system at the instigation of the County's Fish Commissioner. The commissioner ordered the closure to stop the sumping of waste products into the river. A new sawdust disposal system was constructed, which moved sawdust to a burning area away from the mill and river.

Figure 61. The ruins of Big River Mill after it burned in 1863.

In 1900, the paddleboat Maru was launched at the mill. The Maru was used to maneuver logs around the Big River Estuary. On April 18, 1906 the mill was heavily damaged by the San Francisco earthquake and was out of commission for a month. In 1926 the last of four piers of the old boom were removed from the river after the log storage area had filled with debris after 60 year of holding logs. A new boom was constructed. The mill closed on November 30, 1938 and was eventually dismantled.

Additional land uses in the Coastal Subbasin include a canoe rental facility located on the south bank of Big River near the Highway 101 Bridge (Dana 1978) and six gravel quarries (2005b). One recent quarry located on the left bank of the mainstem Big River at approximately RM 0.6 extracted and processed up to 8,000 cubic yards of rock per year from 1992 to 2002 (Mendocino County Department of Planning and Building Services 1992a and b) but was closed when DPR acquired the property.

Forest Management

Timber harvesting has dominated the history of the Coastal Subbasin for the past 150 years. Almost the entire subbasin was harvested by 1944 (Table 79). Hawthorne Timber Company currently owns 22% of the subbasin. Additionally, timber companies previously owned and harvested land now owned and managed by State Parks and JDSF.

Table 79. Timber harvest in the Coastal Subbasin.

Time Period	Acres Harvested	Percent of Subbasin Harvested
1852-1944	19,470	93.7
1945-1964	1,363	6.6
1965-1974	2,299	11.1
1975-1984	2,030	9.8
1985-1992	6,278	30.2
1993-2001	8,071	38.8
Total	**39,512**	**190**

Early timber harvest activities across the subbasin consisted of clear cuts and conversion of land, while most recent harvests are single or group tree selections (Figure 62). Yarding methods have also changed over time, from predominantly cable ground before World War II, to tractor yarding in the post war years, and increasingly towards cable suspended since 1985 (Figure 63).

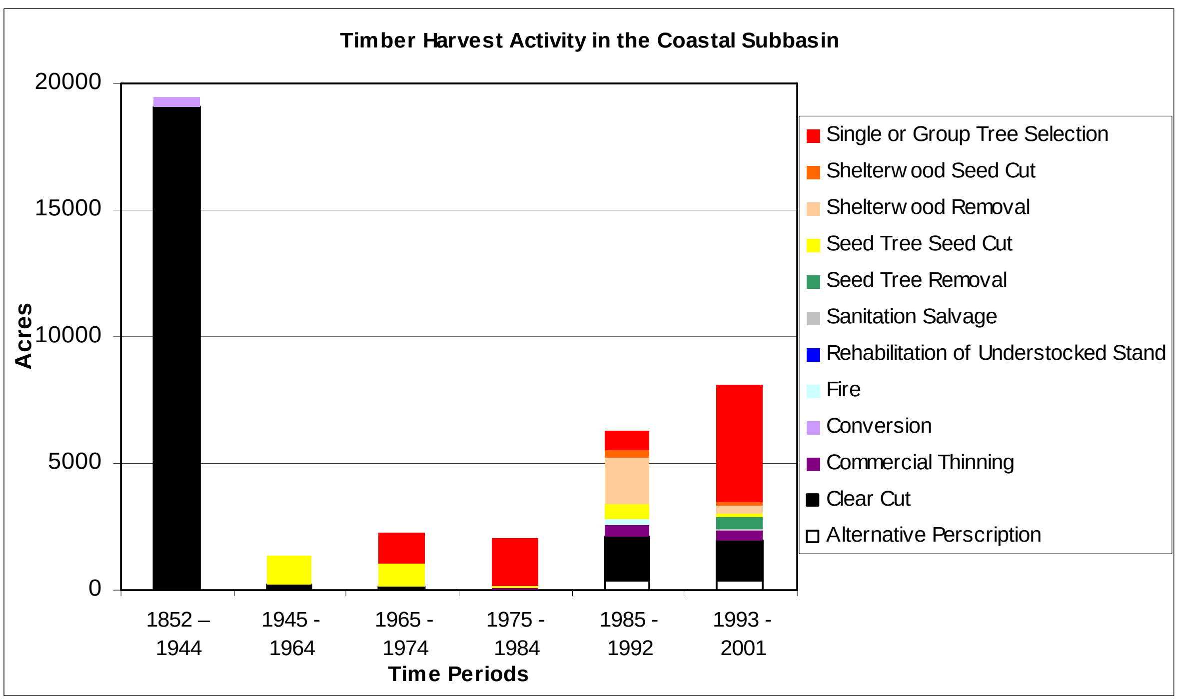


Figure 62. Acres of timber harvest activities in the Coastal Subbasin.

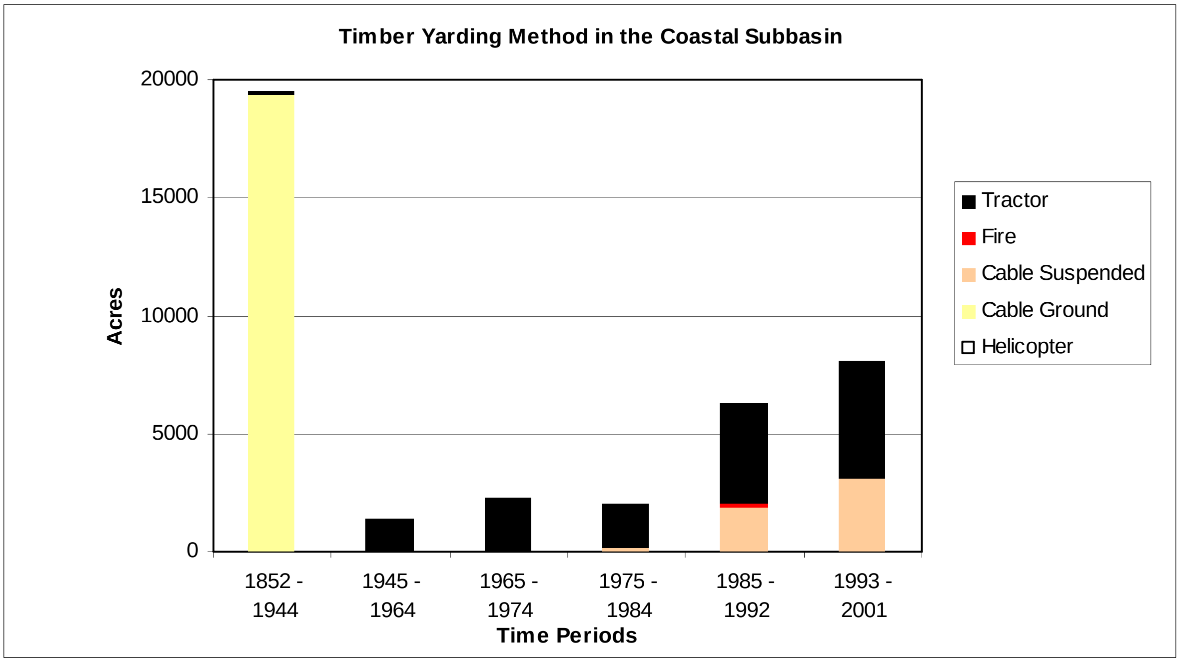


Figure 63. Acres of timber harvest yarding methods in the Coastal Subbasin.

GMA (2001) calculated the harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, for 1937-1951, 1952-1964, 1965-1977, 1978-1987, and 1988-2001. The harvest density was 51 acre/acre for 1989 to 2000 (or 51% of the watershed). This was the most intense harvesting during any of the time periods studied. Over the entire study period, an estimated 133% of the Coastal Subbasin was harvested, with roughly 38% of that happening from 1989-2000. The percentage harvest exceeds 100% in part because some areas were harvested multiple times. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 23% was clear-cut and 77% partial cut, with less than one percent skid trails.

The remains of giant stumps, railroad beds, splash dams, and booms from the heydays of logging throughout the Big River Basin are still present in the estuary.

A CDF analysis of disturbance levels across this subbasin found high disturbance level activities on many acres before 1944 (Figure 64). Activities appeared to decrease from 1944 to 1984, when moderate level activities were present over more acres than high disturbance activities. After 1985, all activities were low or moderate disturbance, but occurred over more acres than the time period from 1945 through 1984.

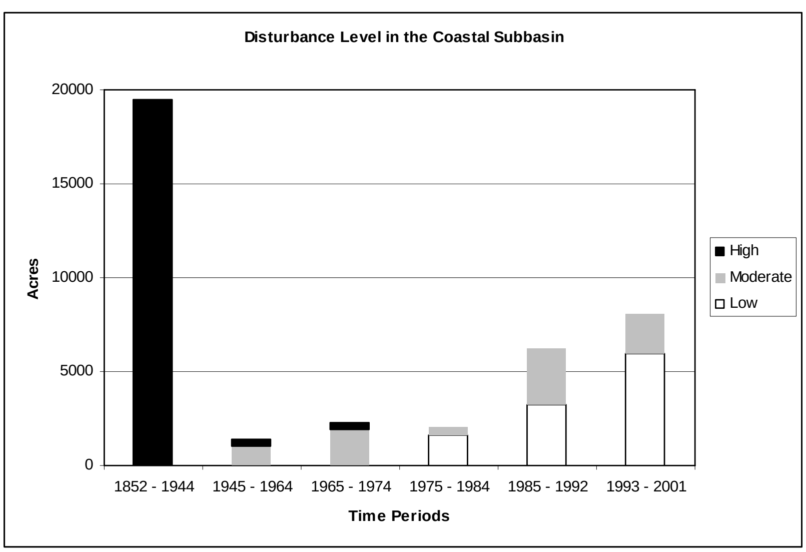


Figure 64. Acres by disturbance level in the Coastal Subbasin.

Roads

The Coastal Subbasin has a total of 248.4 miles of roads, the vast majority of which are not paved (Table 80). Overall road density is 7.7 miles per square mile and was estimated to be 4% paved and 96% rocked or native. A logging road parallels the river near the mouth and provides access to the estuary. Road construction has been at its highest levels since 1989, with increased timber harvest of second growth.

Table 80. Length of truck roads by period and road surface.

Period	Total Length in Miles				Length in Miles per Sq Mile			
	Native	**Paved**	**Rocked**	**Total**	**Native**	**Paved**	**Rocked**	**Total**
Up thru 1936	33.3	8.3	7.2	48.8	1.0	0.3	0.2	1.5
1937 - 1952	22.1	1.7	6.6	30.3	0.7	0.1	0.2	0.9
1953 - 1965	19.1	0.2	3.2	22.5	0.6	0.0	0.1	0.7
1966 - 1978	26.9		9.2	36.2	0.8		0.3	1.1
1979 - 1988	27.9		10.9	38.8	0.9		0.3	1.2
1989 - 2000	62.9	0.1	8.8	71.8	1.9	0.0	0.3	2.2
Total	**192.2**	**10.3**	**45.9**	**248.4**	**5.9**	**0.3**	**1.4**	**7.7**

Lengths are roads constructed in time period, not cumulative.

Water Quality

Estuary

During periods of low flow and high tide, the estuarine influence on the Big River can extend approximately 8.3 miles from the mouth of the Big River to roughly the confluence of Laguna Creek. For the water quality assessment, the boundaries of the Big River estuary were not specifically delineated, but were treated as a subset of the Coastal Subbasin. This area is discussed separately because of the estuarine influence on water quality in this portion of the Big River Basin. Larger features included in the Big River estuary are the mouth of the Big River, and Dry Dock Gulch.

There was no information available for temperature in the Big River Estuary, probably reflective of the difficulty in sampling estuarine areas with ever-changing physical and chemical conditions. Physical-chemical information is also largely lacking, as noted by the presence of only two sampling events, once each during 1993, and 1994, in an unnamed tributary to the Big River.

Sediment

Turbidity samples were available for one small, unnamed tributary in the Big River Estuary. It should be noted that there are not sufficient turbidity data to make more than broad statements about this constituent. In the two samples collected, the turbidity levels in the water were very low, ranging from 0.8 to 6.0 NTU. However, more sampling is needed to begin to characterize the turbidity conditions in this stream.

Water Column Chemistry

Overall, little is known about water quality in the Big River Estuary. Searches for available water quality data revealed only two water quality sampling locations: at the Highway 1 Bridge and in what appears to be a small unnamed tributary near the mouth of the Big River (Table 81). The Highway 1 bridge sampling location was established in a WDR permit issued to the California Department of Transportation for water quality monitoring during bridge retrofit activities. However, no data associated with this permit were discovered and it is unclear if any water quality monitoring has occurred to date.

The sampling associated with the unnamed tributary to the Big River (R.M. 0.4) occurred as part of routine testing for California Department of Health Services in a cistern well that is now inactive. A cistern well is a shallow well, typically set in a creek or spring that primarily draws surface water. In this case, the description of the source was a “cistern well, creek diversion.” Based on the water quality and the fact that this site was used as a drinking water source, it is most likely not representative of the more saline water found in the Big River Estuary. Therefore, because of the limited amount of data associated with this site and unknowns about data quality, data from the cistern well were used for screening purposes only.

The cistern well was operated by the Big River Vista Mutual Water Company and was sampled on three occasions; once in 1988, 1993, and 1994. The well itself was physically located approximately 0.5 miles upstream from the Highway 1 Bridge, along what appears to be an intermittent stream on the south bank of the Big River.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria.

Basic water chemistry data, including specific conductance, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. Dissolved oxygen and total dissolved solids were not sampled at this site. The summary data for basic water quality at the Vista Mutual Water Company site are shown below.

Table 81. Basic water chemistry, Big River Estuary.

Parameter	Count All	Count Detects	Min.	Date Min[1]	Max.	Date Max	Average.	WQ Objectives	
								MIN	MAX
Site Name, Location: Vista Water Company, unnamed tributary to Big River estuary									
pH, Lab (pH units)	2	2	6.3	1/26/93	6.3	1/26/93	NA	6.5	8.5
Specific Conductance (µS/cm)	2	2	115	1/26/93	117	6/8/94	NA	NA	300[2] / 195[3]

[1] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).
[2] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[3] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

As can be seen in Table 81, the pH of the water was detected at 6.3 in both sampling events, which is lower than the minimum Basin Plan water quality objective. Specific conductance appeared to be within the acceptable range in both samples.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during the sampling events. This includes alkalinity, chloride, iron, sodium, and sulfate. However, unlike the constituents shown in Table 81, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. These constituents and the most conservative applicable criteria are shown in Table 82.

Table 82. General water column chemistry, Big River Estuary.

Parameter	Count All	Count Detects	Min.	Max.	Average	Criteria	Criteria Exceeded?	Comments on Criteria[1]
Site Name, Location: Vista Water Company, unnamed tributary to Big River estuary								
Total Alkalinity (mg/L as CaCO3)	2	2	7.0	14.0	NA	≥ 20 mg/L	Yes	Protection of freshwater aquatic life
Chloride, Dissolved (mg/L)	2	2	29.0	32.0	NA	≤ 106 mg/L	No	Protection of agricultural water uses
Iron, Dissolved (µg/L as Fe)	2	1	0	120.0	NA	≤ 300 µg/L	No	Secondary California MCL for drinking water
Sodium, Dissolved (mg/L as Na)	2	2	17.0	17.0	NA	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[2]
Sulfate, Dissolved (mg/L as SO4)	2	1	0	3.7	NA	≤ 250 mg/L	No	Secondary California MCL for Drinking Water

[1] See the Water Column Chemistry section for description of criteria.
[2] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 82, most of the constituents did not exceed their respective criteria, with the exception of sodium and total alkalinity (which was below the criteria). No other criteria were found in Marshack (2000) relating to either sodium or total alkalinity. It is not clear if these water samples were filtered or not filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations. Finally, with only two samples collected on what appears to be a small intermittent stream near the mouth of the Big River, these results are only a beginning of the sample set that is needed to characterize the surface water in this tributary. Therefore, these values are useful as screening values only and additional sampling should occur if the water quality in this tributary is to be characterized.

Total hardness was also reported in the water quality sampling, but does not have water quality criteria at this time. However, it can affect the toxicity of metals to aquatic life and is therefore important beyond just being a basic water quality indicator. Samples for total hardness as calcium carbonate ($CaCO_3$) were collected on two occasions. The first sample, collected on January 26, 1993, was reported to be 20 mg/L. The second sample, collected on June 8, 1994, was reported to be 18 mg/L.

No anthropogenic chemicals were detected in any of the samples.

Estuary Discussion

As seen in the preceding sections, there is very little water quality information available for the estuarine reaches and its associated tributaries to the Big River. The lack of data for water temperature, in-stream sediment, as well as the data results from the physical-chemical water sampling during 1996 and 1997 in the unnamed tributary to Big River by the Vista Water Co. are insufficient to fully characterize historical and/or future water quality conditions, either in the tributary or those portions of the Big River Estuary that may be influenced by tributary runoff.

Tributaries and Mainstem

Water temperature information for the Coastal Subbasin is fairly complete, particularly for subbasin tributaries, due to participation by local landowners such as Hawthorne Timber Company (HTC) and the CDF at JSDF.

Recent bulk sediment records, along with older V* and pebble counts conducted in 1992 were available. GMA was responsible for a portion of the bulk sediment data that was gravimetrically analyzed. HTC also collected bulk sediment data but used volumetric collection and analytical methods, the same method prescribed for those watersheds having TMDLs in place or under consideration by the Regional Water Board.

Mainstem Big River physical-chemical information is fairly representative, with sampling conducted by the Regional Water Board through the efforts of the SWAMP during two sampling events in 2001 in the mainstem below the Little North Fork. Joint Regional Water Board and USGS sampling also occurred in the mainstem upstream of the Little North Fork from 1959-1988. Unlike the mainstem Big River, there were no physical-chemical sampling records uncovered during the data-gathering phase of the assessment for subbasin tributaries.

Water Temperature

Continuous water temperature data logging devices were deployed by HTC and JDSF at a total of twelve (12) locations in the Coastal Subbasin (Figure 65). In general, water temperature was monitored in one or more locations in the subbasin during the years 1993 to 2001.

There are a total of four monitoring sites on the Little North Fork (JSF 541, JSF 542, HTC BIG10, and HTC BIG8). These monitoring sites are all located in the upper and middle reaches of the Little North Fork. JSF 541 was monitored for two years, JSF 542 was monitored for two years, HTC BIG10 was monitored for seven years, and HTC BIG8 was monitored for seven years. Based on data from these sites, the water temperature varies between fully suitable with a minimum observed MWAT of 57ºF, to moderately suitable with a maximum observed MWAT of 61ºF. As would be expected, the water temperatures appear to gradually increase further downstream, as evident in Figure 66. None of the tributaries that were monitored appear to significantly alter the water temperatures in the Little North Fork. This includes the East Branch Little North Fork (HTC BIG9), which was monitored for six years, Berry Gulch (JSF 543), which was monitored for two years, and Thompson Gulch (JSF 544) which was monitored for one year. Based on the data from these sites, the maximum observed MWATs varied from 57-60°F. Furthermore, most of the Little North Fork and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence. As listed in Table 83, the sites which exhibited the highest diurnal fluctuations were HTC BIG8, HTC BIG9, and HTC BIG10. These three sites also appear to have a downward trend in the MWAT values, which may reflect re-growth of canopy. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of these sites in approximately 1989. A 1994 Landsat map (KRIS Big River) shows open areas and small trees near these monitoring sites, but a map of the change in vegetation between 1994 and 1998 did not indicate a loss or gain of vegetation.

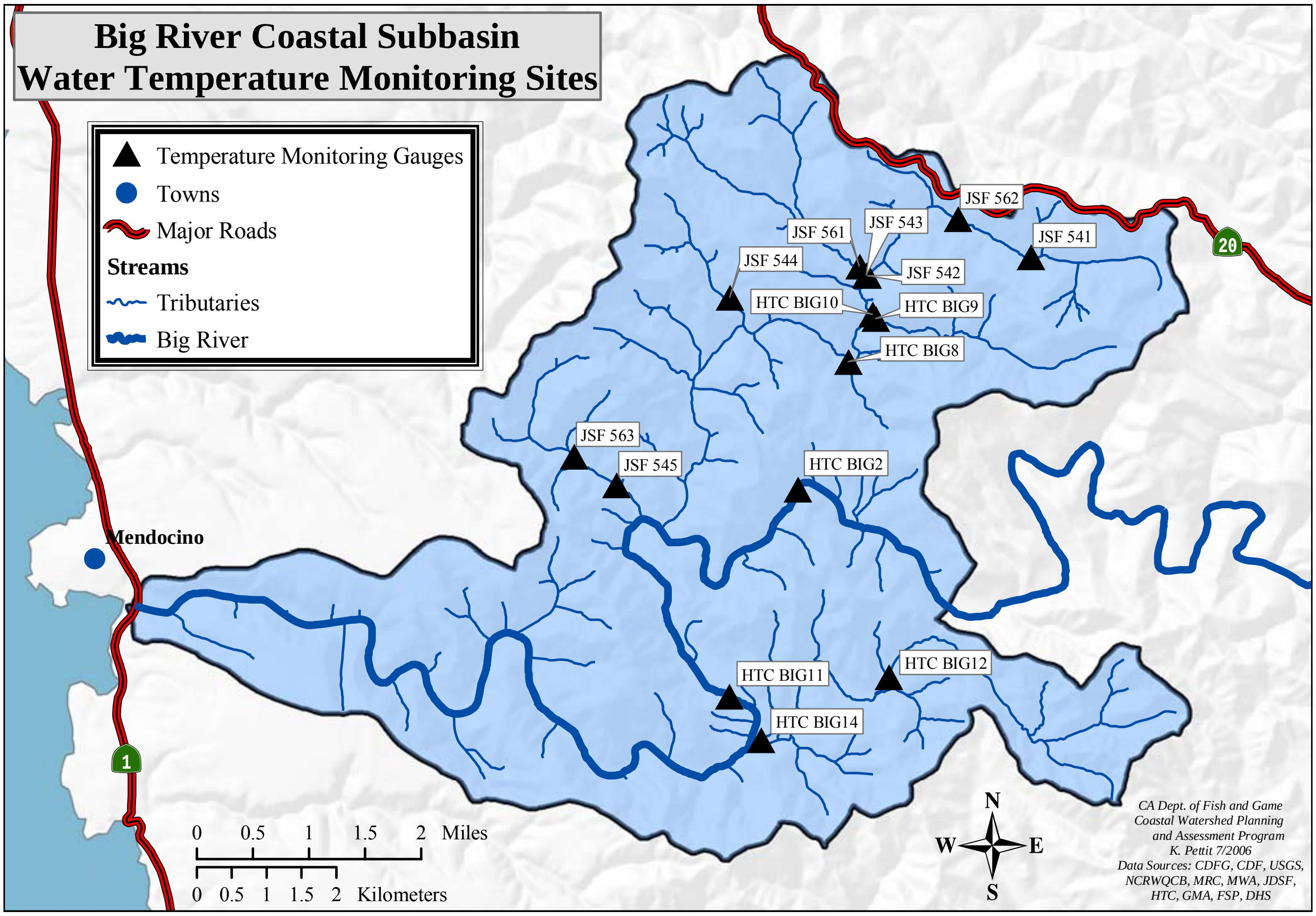


Figure 65. Water temperature monitoring sites, Coastal Subbasin.

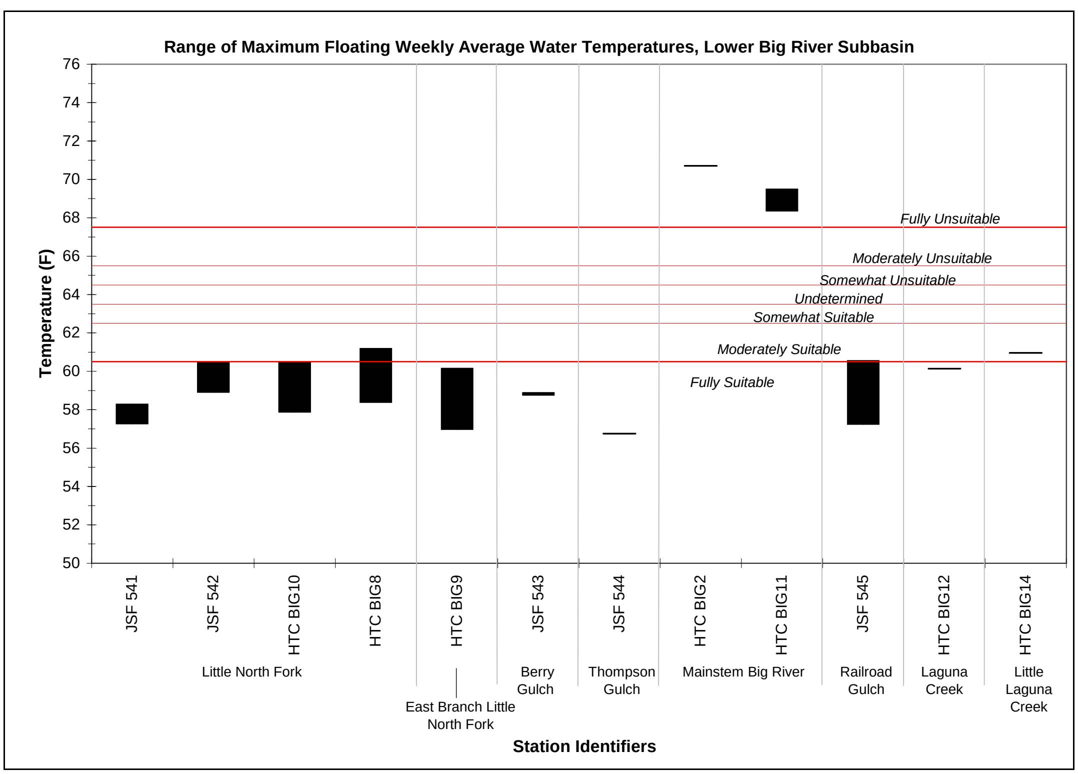


Figure 66. Range of MWATs, Coastal Subbasin.

Table 83. Water temperature summary, Coastal Subbasin.

Site	Max MWAT	MWAT Trend	Range of max diurnal Fluctuations		Seasonal Max	Years of Data
Fully Suitable (50-60°F)						
JSF 544	57	NA	2.5	2.5	58	1
JSF 541	58	1.0	2.8	3.1	60	2
JSF 543	59	-0.2	4.8	4.8	61	2
HTC BIG 12	60	NA	4.0	4.0	62	1
HTC BIG 9	60	-3.2	4.7	7.2	64	6
JSF 542	60	0.9	4.8	5.6	62	2
HTC BIG 10	60	-2.6	4.3	6.8	65	7
Moderately Suitable (61-62°F)						
JSF 545	61	0.6	4.5	5.0	62	3
HTC BIG 14	61	NA	5.7	5.7	64	1
HTC BIG 8	61	-2.8	6.2	8.1	66	7
Somewhat Suitable (63°F)						
--	--	--	--	--	--	--
Undetermined (64°F)						
--	--	--	--	--	--	--
Somewhat Unsuitable (65°F)						
--	--	--	--	--	--	--
Moderately Unsuitable (66-67°F)						
--	--	--	--	--	--	--
Fully Unsuitable (68°F)						
HTC BIG 11	70	-1.2	7.9	9.5	75	2
HTC BIG 2	71	NA	9.9	9.9	76	1

The one site in Railroad Gulch (JSF 545), a tributary to the mainstem Big River, was monitored for three years. During the three years monitored, the water temperature varied between fully suitable with a minimum observed MWAT of 57°F to moderately suitable with an observed MWAT of 61ºF. Diurnal fluctuations were minimal and there was no apparent trend in MWAT values. Available THP maps (KRIS Big River) of Railroad Gulch indicate no harvesting near the stream during the period of 1987-1999.

Laguna Creek, a tributary to the mainstem Big River, was also monitored at one location (HTC BIG12) in the middle portion of the stream for one year. During the one year monitored, the water temperature was fully suitable with a maximum observed MWAT of 60ºF. A tributary to Laguna Creek, Little Laguna Creek, was monitored at one location (HTC BIG14) in the lower portion of the stream for one year. During the one year monitored, the water temperature was moderately suitable with a maximum observed MWAT of 61ºF. Based on the available data, it appears as though Little Laguna Creek has no significant effect on the water temperature of Laguna Creek. Diurnal fluctuations were minimal and there was insufficient data to establish a trend at either site.

There are a total of two monitoring sites on mainstem Big River (HTC BIG2 and HTC BIG11). One site is located before the confluence with the Little North Fork (HTC BIG2) and was monitored for one year. The other site is located above the confluence with Laguna Creek (HTC BIG11) and was monitored for two years.

The monitoring site above the confluence with the Little North Fork (HTC BIG2) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 71ºF. In addition, the maximum water temperature recorded was 76ºF, over the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.9ºF) at this site also suggest moderate to poor cover and/or low flows.

The monitoring site on the mainstem Big River above Laguna Creek (HTC BIG11) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 75ºF, the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (7.9-9.5°F) suggest poor canopy and/or flow conditions.

USFWS monitored one site on the mainstem Big River at the confluence with the Little North Fork Big River in 1973 (Perry 1974). This site was approximately halfway between the two more recent monitoring sites (HTC BIG2 and HTC BIG11). The 1973 monitoring site recorded water temperatures that were moderately unsuitable with a MWAT of 67ºF. In addition, the maximum water temperature recorded was 74ºF, close to the lethal limit for salmonids (75ºF). Comparison of 1973 data with recent monitoring along the mainstem Big River appears to show an increase in water temperature. However, the 1973 monitoring site was at the confluence with the Little North Fork Big River, which recent data have shown to have cooler water than the mainstem Big River and may be exerting a cooling influence.

Sediment

There is not sufficient data to make more than broad statements about turbidity in the Coastal Subbasin (Table 84). Of the 87 samples collected with the Hach turbidimeter, 90% of the samples were equal to or less than 51.6 NTU, with a maximum recorded value of 600 NTU. In addition, at the SWAMP station located downstream of the Little North Fork Big River confluence, one turbidity sample was collected that had turbidity level of 0.19 NTU.

Another set of 96 turbidity samples collected at the same location indicated that 90% of the samples were equal to or less than 40 ppm as SiO_2, with a maximum recorded value of 340 ppm as SiO_2. However, Hellige turbidity samples (measured as ppm as SiO_2) cannot be directly compared to the other turbidity measurements.

Table 84. Turbidity summary, Coastal Subbasin.

Parameter	Count All	Count Detects	Min.	Date Min[1]	Max.	Date Max	Average	50th Percentile	90th Percentile
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River									
Turbidity, Hellige (ppm as Silicon Dioxide)	96	94	0	9/16/70	340.0	1/23/69	20.7	3.0	40.0
Turbidity, HACH Turbidimeter (NTU)	87	76	0	5/4/72	600.0	2/13/75	33.4	1.0	51.6
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River									
Turbidity (NTU)	1	1	0.19	06/28/01	0.19	06/28/01	NA	NA	NA

[1] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

Turbidity that is significantly elevated above background levels can impede the ability of salmonids to feed and can be an indicator of potential problems with suspended sediment. This in turn may point to potential problems with heavy sediment loads. The turbidity sampling conducted at these sites, combined with additional sampling, can eventually establish the range of background levels.

Pebble counts and V* measurements were conducted by Chris Knopp (Knopp 1993) in Berry Gulch, a tributary to the Little North Fork Big River in 1992. Berry Gulch was selected as a "highly disturbed watershed," indicating that it exhibited large areas of disturbed soil, unpaved, low-slope roads, inconsistent or poor stream course protection, and inconsistent avoidance of unstable terrain during the last 40 years. This site was one of 21 sites chosen by Knopp that were highly disturbed.

The pebble count conducted in Berry Gulch had a median pebble size that was calculated to be 28 mm. This value is significantly lower than the 69 mm median particle size from the combined "index yes" and "index no" streams (Knopp 1993). However, even when compared to the median pebble sizes from the other highly disturbed streams measured by Knopp (1993), Berry Gulch was significantly lower. For example, the average of all median pebble sizes in highly disturbed streams was 38 mm compared to the 28 measured at Berry Gulch. For salmonids, the smaller the median pebble size, the more potentially detrimental during the early life stages.

V* is a measure of fine sediments that occupy the scoured residual volume of a pool. This is measured as the depth of the sediment layer in a pool from the apparent bottom of the pool to the armor layer beneath the loose sediment. As the amount of sediment in transport increases, the amount of sediment deposition in pools should increase. For the reach measured in Berry Gulch, the V* was calculated to be 38%. In other words, 38% of the scoured residual pool volume was filled with sediment. The target value for this measurement is less than an average of 21% or maximum of less than 45% sediment for Franciscan formations. While a measurement of 38% is on the high side, it is only one measurement during one year. Further sampling is necessary to confirm the results of this measurement.

In 1996 and 1997, the Hawthorne Timber Company collected McNeil samples at one site in the Coastal Subbasin (BIG 8), located on the Little North Fork Big River below the confluence with the East Branch Little North Fork. These McNeil core samples were collected using a volumetric method, and are therefore directly comparable to the Big River TMDL targets. In general, four McNeil cores were collected at each of the two riffles sampled. A summary of McNeil data collected at BIG 8 is shown in Table 85. Raw data were not available for this assessment.

Table 85. Bulk sediment data summary (volumetric), LNF Big River (HTC).

Site Name	Site Location	Year	Sieve Size (mm)	Median Percent Less Than
BIG 8	Little North Fork Big River	1996	4.0	32.8%
			0.85	18.3%
		1997	4.0	28.1%
			0.85	17.1%

Based on the summary data shown in Table 85, the sediment in the sub 6.5 mm size class exceeded the Big River TMDL target of ≤ 30% in 1996 and may have exceeded it in 1997. Because a 4-mm sieve was used, the comparison was made with the 4-mm value instead of 6.5 mm. Therefore, for comparisons to the TMDL target, it is conservative. The sediment in the sub 0.85 mm size class exceeded the Big River TMDL target of ≤ 14% in both 1996 and 1997. In both size classes, the sediment values improved from 1996 to 1997. However not enough data are available and the apparent improvement could be due to sample variability.

In 2001, Graham Matthews & Associates collected McNeil core samples in the Coastal Subbasin at one site located approximately 150 feet downstream of the confluence with Railroad Gulch. However, since the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment.

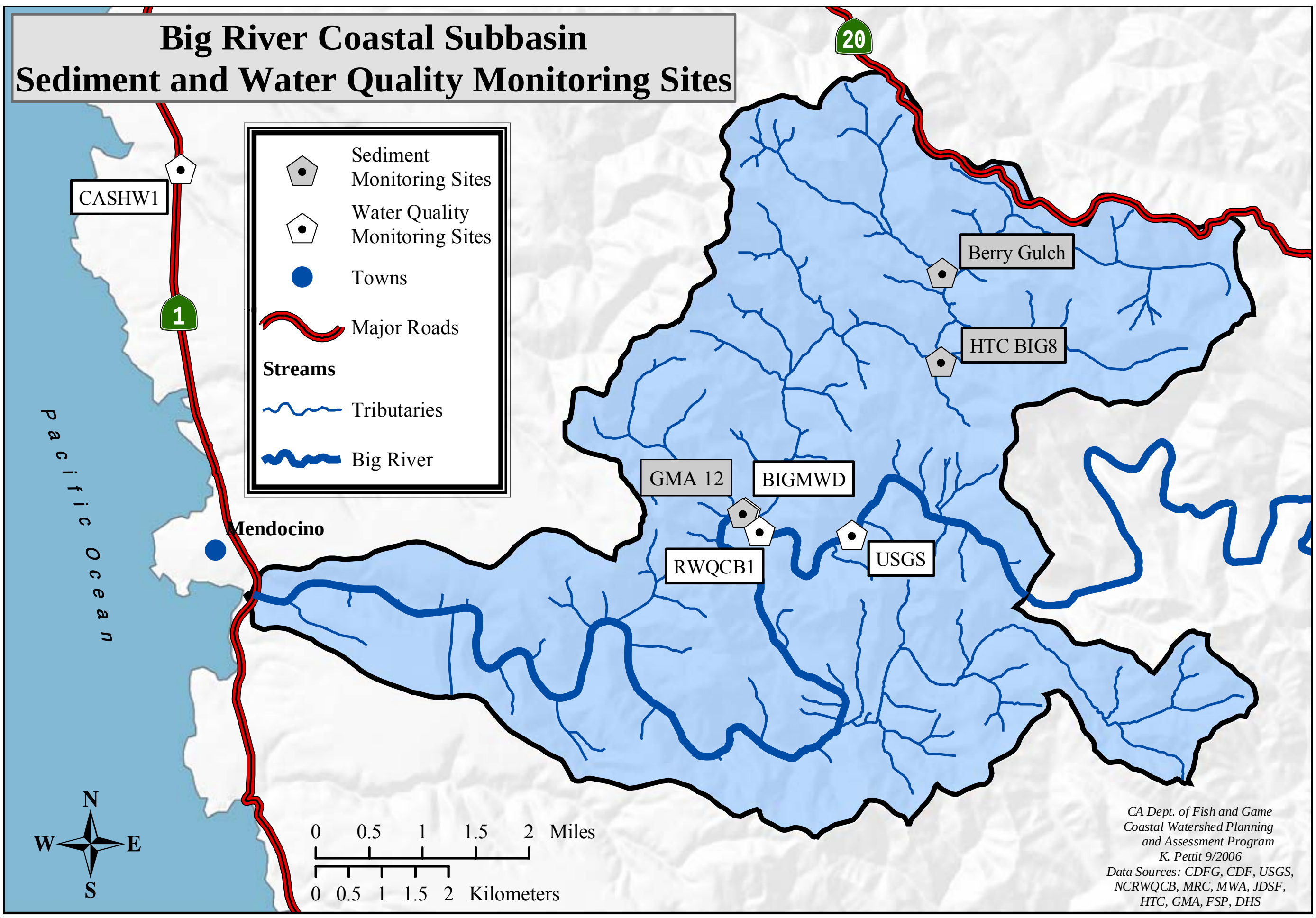


Figure 67. In-stream sediment and water quality monitoring sites, Coastal Subbasin.

Water Column Chemistry

Water chemistry data were collected at three closely spaced surface water locations in the Coastal Subbasin. The first sampling site is located on the Big River, immediately downstream of the confluence with the Little North Fork of the Big River. This site was sampled by the Regional Water Board (under the SWAMP program) on two occasions in 2001. The second sampling site is located on the Big River, immediately upstream of the Little North Fork of the Big River confluence near the Mendocino Woodlands. Established by the Regional Water Board in 1959, it was generally sampled monthly until about 1966 and then typically sampled every two months from 1968 until 1988. The third surface water-sampling site, located approximately 1.5 miles upstream from the Regional Water Board site, was sampled by the USGS. Originally established in 1960, it was generally sampled monthly through 1966, and then once in 1977.

Other than what appears to be one short unnamed tributary, there are no streams converging with the Big River between the Regional Water Board and USGS locations, and therefore the water chemistry should be similar and comparable between these sites. Thus, these data sets were combined and treated as a single data set for this assessment.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria.

Basic water chemistry data, including specific conductance, total dissolved solids, dissolved oxygen, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. The summary data for basic water quality at all sites in the Coastal Subbasin are shown in Table 86.

Table 86. Basic physical water parameters, Coastal Subbasin.

Parameter	Count All	Count Detects	Min.	Date Min	Max.	Date Max	Average	WQ objectives	
								Min	Max
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River									
Dissolved Oxygen, Field (mg/l)	2	2	8.96	06/28/01	9.38	05/10/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	2	2	8	05/10/01	8	05/10/01	NA	6.5	8.5
pH, Field (pH units)	2	2	7.79	06/28/01	7.81	05/10/01	NA	6.5	8.5
Specific Conductance (uS/cm)	1	1	190	06/28/01	190	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (uS/cm)	2	2	195	06/28/01	203	05/10/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/l)	**2**	**2**	**110**	**05/10/01**	**140**	**06/28/01**	**NA**	**NA**	**190[3] / 130[4]**
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River									
Dissolved Oxygen (mg/L)	207	207	4.5	10/13/82	13.0	1/5/67	10.1	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	269	269	0.76	12/5/60	8.4	6/4/65	7.4	6.5	8.5
pH, Lab (pH units)	135	135	7.0	1/6/59	8.4	6/4/65	7.8	6.5	8.5
Specific Conductance (uS/cm)	202	202	76.0	2/13/75	292.0	6/12/63	182.6	NA	300[3] / 195[4]
Specific Conductance, Field (uS/cm)	95	95	79.0	2/13/75	581.0	8/30/77	184.6	NA	3003 / 195[4]
Total Dissolved Solids (mg/l)	**9**	**9**	**107.0**	**5/7/63**	**136.0**	**9/13/63**	**123.8**	**NA**	**190[3] / 130[4]**

[1] Value represents the 90th percentile lower limit. 90% of the values in a calendar year must be equal to or greater than the 90% lower limit.
[2] Value represents the 50th percentile (median) lower limit. 50% of the monthly means in a calendar year must be equal to or greater than the 50% lower limit.
[3] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.
[4] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

Given the limited data that are available, it does not appear any of the basic water column chemistry parameters at the site downstream of the confluence with the Little North Fork (SWAMP BIGMWD) are significantly outside of the range of Basin Plan water quality objectives.

At sites upstream of the Little North Fork (RWQCB 1 and USGS), two dissolved oxygen points, and one pH data point fall outside of the numeric Basin Plan water quality objectives. However, given that these skewed data points are from a data set of 207 and 269 points, respectively, it is unlikely that these are significant. The specific conductance and total dissolved solids values appear to be within the numeric Basin Plan water quality objectives.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during sampling events. This includes alkalinity, ammonia, boron, chloride, copper, iron, nitrate, sodium, sulfate, turbidity, and zinc. However, unlike the constituents shown in Table 86, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. These constituents and the most conservative applicable criteria are shown in Table 87.

Table 87. General water column chemistry, Coastal Subbasin.

Parameter	Count All	Count Detects	Min.	Max.	Average	Criteria	Criteria exceeded?	comments on CRITERIA[1]
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River								
Total Alkalinity (mg/L as CaCO3)	2	2	82	84	NA	≥ 20 mg/L	No	Protection of freshwater aquatic life
Boron (µg/L)	2	2	250	330	NA	≤ 630 µg/L	No	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	6.5	6.5	NA	≤ 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	2	0	NA	NA	NA	≤ 7.0 µg/L	No	Protection of freshwater aquatic life with a hardness of 75 mg/L[2]
Iron (µg/L)	2	1	0	190	NA	≤ 300 µg/L	No	Secondary California MCL for drinking water
Nitrate/Nitrite as N (mg/L)	2	0	NA	NA	NA	≤ 10 mg/L	No	Primary US EPA MCL for drinking water
Sodium (mg/L)	2	2	12	12	NA	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO4 (mg/L)	1	1	7.1	7.1	NA	≤ 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	2	0	0	0	NA	≤ 93 µg/L	No	Protection of freshwater aquatic life with a hardness of 75 mg/L[2]
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River								
Total Alkalinity (mg/L as CaCO3)	103	103	30.0	103.0	76.8	≥ 20 mg/L	No	Protection of freshwater aquatic life
Chloride, Dissolved (mg/L)	136	136	1.0	19.0	7.1	≤ 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	7	2	0	10.0	NA	≤ 6.8 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 73 mg/L[2]
Iron, Dissolved (µg/L as Fe)	8	4	0	130.0	36.3	≤ 300 µg/L	No	Secondary California MCL for drinking water
Nitrate, Dissolved (mg/L as NO3)	44	34	0	1.7	0.35	≤ 10 mg/L	No	Primary US EPA MCL for drinking water
Sodium, Dissolved (mg/L as Na)	201	201	4.5	17.0	10.4	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate, Dissolved (mg/L as SO4)	37	37	0.8	15.0	6.4	≤ 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	7	3	0	70.0	22.9	≤ 90 µg/L	No	Protection of freshwater aquatic life with a hardness of 73 mg/L[2]

[1] See the Water Column Chemistry section for description of criteria.
[2] See text below for details on derivation of criteria.
[3] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 87, all of the constituents that have numeric criteria did not exceed their respective criteria, with the exception of sodium at both sites and copper at the site upstream of the Little North Fork (RWQCB 1 & USGS). No other criteria were found in Marshack (2000) relating to sodium or copper. It should also be noted that in the downstream site (SWAMP BIGMWD), alkalinity was speciated into carbonate, bicarbonate, and hydroxide alkalinity. At SWAMP BIGMWD, the alkalinity was entirely bicarbonate alkalinity. In the upstream water samples (RWQCB 1 & USGS), it is not clear if the water samples were filtered or not filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations of dissolved sodium in the water column. While this should be investigated further, it is probable that sodium in the water is naturally occurring and not anthropogenic pollution. All of these sites are also outside of the estuary area, and therefore should not be saline.

Some constituents, including copper and zinc, vary in toxicity depending on the hardness of the water and therefore have hardness dependant criteria. At the upstream sampling sites (RWQCB1 & USGS), a total of 199 samples were analyzed for hardness with an average hardness of 73 mg/L as calcium carbonate ($CaCO_3$). This value was used to determine the toxicity criteria for copper and zinc. However, it should be noted that the sampling for hardness and these metals did not necessary coincide.

On two occasions, dissolved copper concentrations were reported as 10 µg/L, with the remaining five samples reported as zero. Presumably, the sample detections reported as zero were in fact “non-detects,” below some unknown detection limit less than 10 µg/L. Given an average hardness of the 73 mg/L, the maximum one-hour average concentration of dissolved copper is 10 µg/L. Based on the two positive detections out of a total of seven samples, copper concentrations at the upstream sites appear to be at or below the criteria to protect freshwater aquatic life.

Surface water at the downstream site (SWAMP BIGMWD) was also analyzed for copper on two occasions. Hardness at this site averaged 75 mg/L. Copper samples were reported as "non-detect," at or above the laboratory detection limit of 10 µg/L. Therefore, if copper did exist in the downstream samples, the concentrations were below the detection limits.

Dissolved zinc concentrations were reported as 30, 60, and 70 µg/L at the upstream sites (RWQCB 1 & USGS), with the remaining four samples reported as zero. Presumably, the sample detections reported as zero were in fact "non-detects", below some unknown detection limit less than 30 µg/L. Given an average hardness of 73 mg/L, the criteria for the maximum one-hour average concentration of dissolved zinc is 90 µg/L. Based on the three positive detections out of a total of seven samples, zinc concentrations in the Big River appear to be below the criteria to protect freshwater aquatic life.

Surface water at the downstream site (SWAMP BIGMWD) was also sampled for zinc on two occasions. Both samples were reported as "non-detect" at or above the laboratory detection limit of 20 µg/L. Therefore, if zinc did exist in the downstream samples, the concentrations were below the detection limits.

Other constituents, such as ammonia, vary in toxicity depending on the temperature and pH of the water. Ammonia was only sampled at the downstream site (SWAMP BIGMWD) on two occasions. On both occasions, no ammonia (as nitrogen) was detected at or above the laboratory detection limit of 0.05 mg/L.

Phosphorus and chlorophyll-a were also reported, but neither have specific numeric criteria at this time. However, they are broken out separately because they are a significant constituent of water quality.

Phosphorus can enter surface water bodies through fertilizer run-off or from the natural weathering of rocks in some watersheds. Phosphorus is a biostimulatory substance for algae, and excessive amounts can lead to algae blooms which can impact other aquatic life by negatively affecting dissolved oxygen concentrations. The summary data for phosphorus samples are shown in Table 88.

Table 88. Phosphorus summary, Coastal Subbasin.

Parameter	Count All	Count Detects	Min.	Date Min[1]	Max.	Date Max	AvG.
Site Name, Location: SWAMP BIGMWD, Mainstem Big River downstream of LNF Big River							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	0	0	NA	0	NA	NA
Site Name, Location: RWQCB 1 & USGS, Mainstem Big River upstream of LNF Big River							
Total Phosphorus (mg/L as P)	4	4	0.03	5/5/76	0.07	2/5/86	0.04
Orthophosphate, Dissolved (mg/L as P)	19	17	0	5/13/64	0.07	9/5/61	0.02

Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically)

There are not sufficient data to make more than broad statements about phosphorus. However, there was not an apparent problem with elevated phosphorus levels in the samples that were collected at the upstream sites (RWQCB 1 & USGS). Although both phosphorus and orthophosphate samples were collected at the downstream site (SWAMP BIGMWD) on two occasions for each analyte, it was not detected at or above the laboratory detection limits of 0.05 mg/L.

Chlorophyll-a was also sampled once at the downstream site (SWAMP BIGMWD) and was detected with a concentration of 0.00071 mg/L. Chlorophyll-a is a measurement of the chlorophyll in the suspended algae in the water column. High chlorophyll-a content, which directly relates to high algal concentrations in freshwater, can be an indicator of nutrient contamination of the surface water (such as in fertilizer run-off). However, there are no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

In the upstream sites (RWQCB1 & USGS), total and fecal coliform bacteria were detected at a maximum most probable number (MPN) of 900/100 ml and 30/100 ml, respectively. While total coliform bacteria can come from a variety of sources, the presence of the fecal coliform subset in aquatic environments indicates that the water has been contaminated with the fecal material of humans or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste.

The Basin Plan water quality objective for fecal coliform states that “the median fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed 50/100 ml, nor shall more than ten percent of total samples during any 30-day period exceed 400/100 ml” (RWQCB 2001). While not directly comparable, fecal coliform appears to be within the water quality objective.

Discussion

Collectively, temperature data show that the Coastal Subbasin is mostly unsuitable for MWATs in the mainstem and also when peak maximum temperature thresholds are considered. However, there were only three thermograph records at two stations along the mainstem. Big River tributary temperature records are nearly all suitable for both seasonally sampled MWATs and peak maximum temperatures. Both temperature metrics for the Coastal Subbasin reflect similar findings in all of the other subbasins for the mainstem and its tributaries.

Bulk sediment sampling was conducted during 1996 and 1997 by HTC and in 2001 by GMA in the Little North Fork and the mainstem Big River, respectively. The Little North Fork bulk sample results, except for the 1997 <6.4 mm = 28.1%, were unsuitable. Both GMA results are above thresholds for incubation and survival to emergence of salmonids from their redds. However, one result that was 14.5% was barely below threshold for salmonid incubation in fine sediment <0.85 mm = 14%. As noted in the tables for GMAs bulk sampling the gravimetric method used is not recognized as an acceptable methodology under current and/or prospective TMDLs for the North Coast Region to characterize subsurface spawning gravel suitability.

The data results from the two days of physical-chemical sampling during 2001 by the Regional Water Board under the SWAMP are insufficient to fully characterize historical and/or future water quality conditions in the lower Big River. The more extensive data sets from 1959-1988 are useful to reasonably extrapolate that, for the most part, physical chemical conditions of the mainstem Big River for some distance upstream from the Little North Fork are suitable. The single exceedance for copper appears to be an isolated incident, considering the 29 years that sampling took place. Excess sodium analyses were also experienced in other subbasins and in all likelihood sodium is a naturally occurring mineral in isolated reaches of the mainstem and tributary watercourses.

Riparian Conditions

There are 2,455 acres in the Coastal Subbasin in stream buffers, which includes the areas between the water and gravel bars in the lower reaches (Table 89). Across the subbasin, the area around the watercourses is well vegetated, as indicated by the 70 to 100% density class which accounts for 83% of the area (Table 89) Also 64% of the buffer area is in 80% canopy density or better, and 48% of the area is in the 90-100% canopy closure class. These numbers are substantiated by high canopy densities found along stream reaches surveyed by CDFG and discussed in *Fish Habitat Relationships*.

Table 89. Density of riparian vegetation in the Coastal Subbasin by planning watershed.

Planning Watersheds	Acres by Percent Crown Canopy Density										Acres in Buffer
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	
Mouth of Big River	241	1		68	5	3	3	221	264	500	1,308
Berry Gulch	12		17	8			3	208	88	473	809
Laguna Creek	44		2	8		6	1	25	55	199	338
Total Coastal	**297**	**2**	**18**	**84**	**5**	**9**	**7**	**454**	**407**	**1,172**	**2,455**

Table 90. Percentage of stream buffer area in higher canopy closure classes in the Coastal Subbasin.

Planning Watersheds	Percent of Buffer Area by Crown Canopy Density				
	70%	80%	90%	70%+	80%+
Mouth of Big River	17	20	38	75	58
Berry Gulch	26	11	58	95	69
Laguna Creek	7	16	59	83	75
Total Coastal	**18**	**17**	**48**	**83**	**64**

As shown in Table 91, the majority of the trees in the watercourse buffer zone are small to medium/large, which are 12 to 40 inch dbh trees. Small, medium/large and large trees (>12 inches dbh) could be recruited to streams as large woody debris. Overall, 94% of the buffer zone area in the basin is in these size classes. At the PW level, the percentage area in these three size classes varies from 73% in the Mouth of Big River PW to 98% in the Berry Gulch PW.

Table 91. Acres and percentage of vegetation size classes in the watercourse buffer zone in the Coastal Subbasin.

Planning Watersheds	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Mouth of Big River	77	6	35	3	550	42	384	29	21	2
Berry Gulch	0	0	6	1	244	30	518	64	29	4
Laguna Creek	0	0	1	0	176	52	118	35	0	0
Total Coastal	**77**	**3**	**42**	**2**	**969**	**39**	**1,020**	**42**	**50**	**2**

The long estuary is flanked by mudflats, eelgrass beds, wetlands, and riparian forests. A Mendocino High School of Natural Resources (SONAR) survey of plants found in a mudflat in the estuary in 2002 found 28 species (Table 92Table 92). The valley flat in the first 2.2 river miles supports salt marshes, which are covered by high river flows and saturated at high tide. Upstream of this reach, the valley flat is well vegetated with mixed conifer forest (CGS 2004).

Table 92. Mendocino High School of Natural Resources estuary study plant species list for mud flat #1 (after SONAR 2002).

Scientific Name	Common Name
Atriplex triangularis	Fat-hen saltweed
Carex obnuta	Slough sedge
Castilleja ambigua humboldtinensis	Humboldt Bay owl's clover
Conioselinum pacificum	Hemlock-parsley
Cotula coronopifolia	Brass buttons
Cuscuta salina	Dodder
Deschampsia cespitosa cespitosa	Tufted hairgrass
Distichli spicata	Saltgrass
Eleocharis macrostachya	Spike rush
Frankenia salina	Alkali heath
Galium trifidum pacificum	Bedstraw
Grindelia stricta stricta	Gum weed
Holcus lanatus	Velvet grass
Hordeum brachyantherum	Barley
Jaumea carnosa	Fleshy jaumea
Juncus mexicanus	Mexican rush
Oenanthe sarmentosa	Water parsley
Plantago maritime	Beach plantain
Polygonum punctatum	Dotted smartweed
Potentilla anserine pacifica	Silverweed
Pucinellia pumila	Dwarf alkali grass
Rumex salicifolius	Willow dock
Salicornia virginica	Pickleweed
Scirpus cernuus	Low bulrush
Scirpus microcarpus	Small-fruit bulrush
Trifolium wormskioldii	Cows clover
Triglochin matima	Seaside arrow grass
Typha latifolia	Cat-tail

Changes in the vegetative composition of mud flats surrounding the Big River Estuary have occurred at the same time as the levee build-up and siltation of slough systems discussed in the Fluvial Geomorphology section. Rapid vegetative succession from salt tolerant plants to non salt-tolerant plants has occurred as tidewater inflow to mudflats has been blocked. This successional scheme is unusual for salt marshes and represents a significant loss of wetland habitat in the estuary (Marcus and Reneau 1981, Seacat et al. 1981).

Big River's estuarine flats contain branched drainage sloughs that were formed by tidal erosion (Figure 58). These slough channels are the only conduit for tidewater inflows to the estuarine flats; however, the flats are not completely flooded by tidewater. Therefore, the distribution of slough channels and their proportionate area within each flat is directly related to saline influence to each marsh. Channel systems are extensive in the lower three flats and are reduced to non-functional in the upper flats (Marcus and Reneau 1981). These changes in slough channels and vegetation are likely related to stream channels re-adjusting to a more natural discharge regime after the effects of splash damming.

Vegetation patterns in the estuary are related to these slough channel systems. Various plant associations, or vegetation types, defined by their dominant plant species (e.g. pickleweed, rushes) have developed in the estuarine flats (Table 93Table 93). Salt marsh plants are specifically adapted for saline soils and when saline inflows are reduced to marsh soils, as in the upper estuarine flats, salt-loving plants are replaced by other vegetation types.

Table 93. Freshwater and salt marsh plant associations (from Seacat et al. 1981).

Vegetation Type	**Species Composition**	
	Scientific Name	**Common Name**
Pickleweed	*Salicornia virginica*	Pickleweed*
	Triglochin striata	Arrow grass*
	Jaumea carnosa	
	Cuscuta salina	Parasitic dodder
Rushes	*Juncus lesueurii*	Rush*
	Distichlis spicata	Salt grass
	Gramineae spp.	Grasses
	Holcus lanatus	Velvet grass
	Hierochloe occidentalis	Vanilla grass
Alders	*Alnus rubra*	Red alder
	Salix lasiolepis	Willow
Coastal scrub	*Baccharis pilularis*	Coyote brush*
	Lupinus rivularis	Lupine*
	Rubus ursinus	California blackberry*
	Anaphalis margaritacea	Pearly everlasting*
	Senecio jacobaea	Ragwort
	Foeniculum vulgare	Sweet fennel
	Erechtites arguta	Fire weed
	Rumex crassus	Dock
	Carex salinaeformis	Sedge
	Orthocarpus castillejoides	Owl's clover
	Pteridium aquilinum	Bracken fern
	Rhus diversiloba	Poison oak
	Convolvulus occidentalis	Morning glory
	Geranium molle	Cranesbill
	Gentiana amarella	Felwort
Freshwater or brackish water marsh species	*Typha latifolia*	Cattails*
	Scirpus robustus	Bulrush*
	Cicuta douglasii	Water hemlock
	Torilis arvensis	Hedge parsley
	Juncus effusus	Rush
	Scirpus arnuus	Bulrush
	Carex obnupta	Slough sedge
	Plantago hirtella	Plantain
	Potentilla egedei	Pacific silverweed

*indicates dominant species

The various flats along the estuary have distinctly different vegetation. Marcus and Reneau (1981) found that vegetation had changed substantially over time as well in their study of historic photos:

> Historic photographs (circa 1900) of Flat 1 reveal a mudflat with no vegetation of any type. Presently about half of this flat is covered with halophytic plants indicating a substantial rise in height of the flat. In addition this flat was across the channel from the logging mill pond. A row of old pilings still crosses its reaches diagonally. These pilings are the remnants of a wingdam, built in 1884 and used to direct the river's current toward the mill to flush sawdust and other debris (Jackson 1975). If the placement of these pilings in 1884 was such as to direct current movements then it may be assumed that they were placed in areas covered by water most of the time. At present, these pilings can have no effect on channel water currents, for they are located in a slough surrounded by islands of vegetation.

Marcus and Reneau found an unusual change in the Big River Estuary's salt marsh succession: the direct replacement of rushes by alder and coastal scrub. Usually, salt marsh is replaced by freshwater marsh. In Big River, wetlands were being replaced by riparian woodlands.

Once slough systems are reduced and marshes are isolated from tidal influences, their productive capacity is lost. Opportunities for juvenile estuarine fish, benthic invertebrates, and algal blooms usually common in the backwaters of tidal sloughs are greatly reduced. The long-term effects upon Big River Estuary of this sedimentation and loss of salt marsh is not known (Marcus and Reneau 1981). However, Marcus and Reneau failed to take the effects of historic splash dam logging into account during their analyses. Therefore, it is important to look at their findings whilst remembering that a more natural discharge regime is re-establishing itself since the end of splash damming.

Fish Habitat Relationship

Estuaries and coastal lagoons are critical habitats for anadromous salmonids. The mixing of sea and fresh waters creates conditions well suited for the anadromous life history strategies of salmonids. Salmonids 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 salmonids with an important area to acclimate to changes in salinity as they move between the freshwater and marine environments. Estuaries also are important nursery grounds due to high productivity of nutrients and relative isolation from predators.

During seaward migrations, all juvenile salmonids utilize at least a brief estuarine residence while they undergo physiological adaptations to salt water and imprint on their natal stream. Juvenile salmonids may also extend their estuarine residency to utilize the sheltered, food rich environments before entering the ocean. 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 members of their cohort (Reimers 1973; Nicholas and Hankin 1988). Estuarine reared salmonids may be at an advantage because they enter the ocean at a larger size or during conditions that are more favorable. Entering the ocean at a larger size may be advantageous by allowing juvenile salmonids to avoid predation or by increasing the variety and number of their prey items.

Salmonid utilization of the estuarine environment is a strategy that adds diversity to juvenile salmonid life history patterns and increases the odds for survival of a species encountering a wide range of environmental conditions in both the freshwater and marine environment. Additionally, an extended estuarine residency may be especially beneficial for salmonids from rivers where low summer flows or warm water temperatures severely limit summer rearing habitat. These benefits are enhanced by the estuary retaining its connection with cool, nutrient rich seawater, maintaining adequate depth and subsurface shelter complexity, and containing enough vegetation density (both in and out of the water), to supply temperature moderation, nutrition and cover.

Past Conditions

CDFG conducted stream surveys on six tributaries and the mainstem Big River in the Coastal Subbasin from 1959 to 1966. Three stream surveys were also conducted by the Center for Education and Manpower Resources (CEMR) in 1979. The results of the historic stream surveys are not quantitative and cannot be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions. The data from these stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair and poor were based upon the opinion of the biologist or scientific aid conducting the survey.

Surveys describe some good spawning habitat, abundant smaller pools, and good cover in Railroad Gulch and the Little North Fork Big River (Table 94). However, the surveyed tributaries to the Little North Fork Big River were described as having poor salmonid habitat. Many debris jams were described on the Little North Fork Big River. A 1958 CDFG flyover survey (Elwell) of four tributaries found no significant fish passage barriers.

Table 94. Habitat comments from surveys conducted in the Coastal Subbasin from 1959-1979.

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
Mainstem Big River	7/27/1959	Mostly poor to fair spawning areas with a few areas approaching good; Pools uncommon in the lower half of the river, becoming more common in the upper half of the river, averaging 10 feet long, 4 feet wide, and 10 inches deep; the lower 2/3 of the river very open, with only undercut bank and log jams for cover; the upper 1/3 of this river area more contained and large boulders and some riparian growth afford fair shelter	Many barriers; many log jams, scattered debris, and slash; old flush dam located one mile above the mouth of Valentine Creek a complete barrier with a 14 foot drop in the streambed; log jam barrier 0.4 miles upstream of the mouth of Rice Creek; boulder-log jam barrier 0.7 miles upstream of the mouth of Rice Creek; Log and dirt filled jam and barrier 0.9 miles upstream of the mouth of Rice Creek; Anadromy ends at a 12 foot high natural rock falls
Laguna Creek	10/16/1958 (flyover)	Appeared to have little fisheries value due to marshy characteristics	
Railroad Gulch	1979 (Center for Education and Manpower Resources)	A few pockets of good spawning gravel observed, totaling 100 yards; many small pools, totaling 50% of stream, but few that were more than 2 feet deep; good shelter, behind numerous logs and boulders	Culvert at mouth 72 feet long, blocked at upper end by log and small debris; in swamp many logs would prevent easy passage; 1.25 mile upstream a few small jams at 100 yard intervals; limited passage 1.5 mile upstream 100 feet above 35 foot culvert crossing road are 4 foot falls with 4 foot pool below; 100 yards above this another small falls with jam; difficult passage follows; after this, road crosses river with old wooden culvert which is caving in; 200 yards above this, total blockage with fallen tree stump; 100 yards above this more falls
Little North Fork Big River	10/16/1958 (flyover)	Appeared to have considerable fisheries value as a spawning and nursery stream	Streambed in the lower end of the drainage not visible. Old logging debris noted in the upper end of the drainage
	3/8/1959	The lower stream has several miles of very good spawning gravels, the upper stream might be of some value if it were cleaned up; pools are common and abundant; shelter is common throughout, mostly pools, logs and undercut banks; there are very few large boulders and very little low-growing riparian growth	Although there are many extensive log-jams, are not barriers because of the tendency of the stream to flood around them; a beaver dam across the main channel near the mouth; this dam, except for seepage, has closed the main stream channel; this has forced the water into at least four separate meandering channels, and is flooding the canyon; the resultant cutgrass and cattails make it difficult to see that there is more than a swamp here; anadromous fish must find this a difficult egress; many down stream migrants must be lost in drying pools and side streams; there is a concrete dam before the 5th tributary
	4/2/1979 (Center for Education and Manpower Resources)	95% gravel bottom; suitable spawning areas for salmon and trout throughout the stream; mostly good spawning gravel with some silt from erosion of old road following stream; riffles 50%, pools 45%, cascades 5%; good shelter caused by old logging debris and logs and overhanging banks; resting pools intermittently up to 6 feet deep all along stream; temperature 40°F	Log jam #1, 2 miles upstream from swamp, 40-50feet wide, 90feet long, 10feet high, appears to be a floater although further collection of upstream debris could make it impassable in near future; the jam causes water to divert into bank with some resultant erosion; silt build-up on upper side of jam; log jam #2 is ½ mile from the first jam, 100feet long, 75feet wide, 6-8feet high, again it is barely passable for fish with further debris probable near future blockage; with removal of strategic pieces on upstream part of jam it could be fully passable and would stop further erosion and silt deposit into the stream; log jam #3 is 1/3 mile above 2nd jam, 40feet long, 30feet wide, 10feet high with passage under logs; just above swampy area near fork with Big River were fallen logs causing some blockage
Unnamed Tributary to Little North Fork Big River/Cook House Gulch	3/8/1959 - Note in the Little North Fork Big River Survey	Not of sufficient value to justify a survey; mouth not seen; area flooded with water impounded by a beaver dam	

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
Rocky Gulch	3/8/1959 - Note in the Little North Fork Big River Survey	May have been a good, small spawning tributary; may still supply some spawning near the mouth; however, has been destroyed by gravel taking operations a few hundred feet above the mouth	
Manly Gulch	3/8/1959 - Note in the Little North Fork Big River Survey	Mud bottom, swampy, and probably dry during the summer	
Thompson Gulch	3/8/1959 - Note in the Little North Fork Big River Survey	May provide some spawning near its mouth	About 100 yards upstream from mouth there is a 3 foot falls
	4/15/1979 (Center for Education and Manpower Resources)	Substrate medium to small gravel overall (60%), although perhaps 10% more than 3 inches; 50% of stream suitable for steelhead spawning, 10% for salmon spawning; numerous pools below the many small falls on this stream, although few are deeper than 3 feet; good shelter, behind logs and undercut banks; temperature at mouth 49°F	7 log jams and 6 main falls; several impassable.
Berry Gulch	10/16/1958 (flyover)	Streambed not visible due to heavy conifer cover	
	3/8/1959 - Note in the Little North Fork Big River Survey	Insignificant at its mouth; flow negligible	

Current Conditions

Habitat Inventory Surveys

CDFG stream inventories were conducted for 39.7 miles on 21 reaches of nine tributaries and the mainstem Big River in the Coastal Subbasin since 1993 (Table 95, Figure 68). Additionally, the East Branch Little North Fork Big River was surveyed in 1996 as well as 2002. Stream attributes that were collected during stream inventories included canopy cover, embeddedness, percent pools, pool depth, and pool shelter.

Table 95. Surveyed streams in the Coastal Subbasin.

Stream	Survey Date	Reach	Survey Length (Miles)
Big River	July 1996	1	8.1
	July 1996	2	5.0
	July 1996	3	1.9
	July 1996	4	1.8
	July 1996	5	3.5
Laguna Creek	July 1996	1	1.9
Railroad Gulch	October 1996	1	1.1
Little North Fork Big River	October 1995	1	3.7
Rocky Gulch	September 1997	1	0.1
	September 1997	2	0.1
Manly Gulch	June 1997	1	0.7
Thompson Gulch	June 1997	1	0.7
	June 1997	2	0.4
East Branch Little North Fork Big River	June 2002	1	0.9
	June 2002	2	1.5
Berry Gulch	June 1997	1	0.1
	June 1997	2	1.3
	June 1997	3	0.2
	June 1997	4	0.6
Berry Gulch Tributary	June 1997	1	1.1
Big River Wheel Gulch to Blind Gulch	July-August 2002	1	5.0

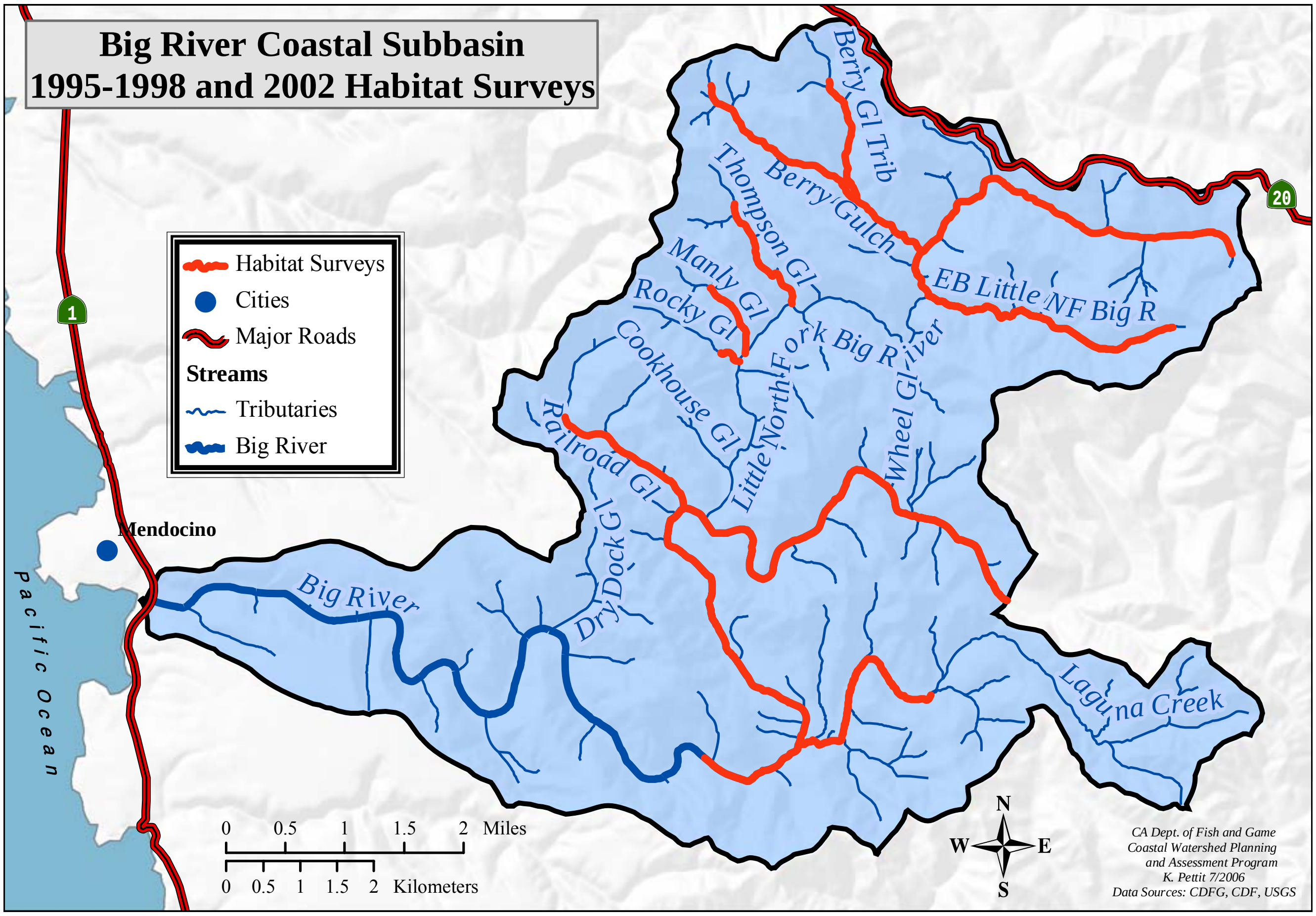


Figure 68. CDFG surveyed streams in the Coastal Subbasin.

Stream attributes tend to vary with stream size. For example, larger streams generally have more open canopy and deeper pools than small streams. This is partially a function of wider stream channels and greater stream energy due to higher discharge during storms. Surveyed streams in the Coastal Subbasin ranged in drainage area from 0.4 to 181.0 square miles.

Canopy cover, and relative canopy cover by coniferous versus deciduous trees were measured at each habitat unit during CDFG stream surveys. Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Furthermore, canopy levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel, as well as the insulating capacity of the stream and riparian areas during winter.

In general, the percentage of stream canopy cover increases as drainage area, and therefore channel width, decrease. Deviations from this trend in canopy may indicate streams with more suitable or unsuitable canopy relative to other streams of that subbasin. The surveyed tributary reaches of the Coastal Subbasin show percent canopy levels that meet target values for maintaining water temperature to support anadromous salmonid production (Figure 69). Canopy data collected on the lower mainstem of Big River, where the stream is fourth order, cannot be compared to target values. Rocky Gulch has the highest canopy cover values of Coastal Subbasin.

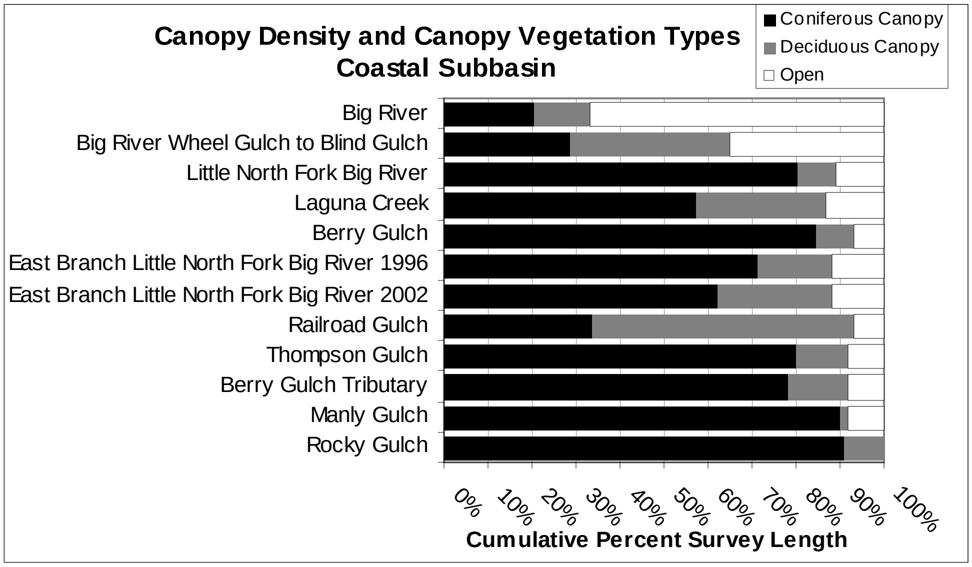


Figure 69. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Coastal Subbasin.

Averages are weighted by unit length to give the most accurate representation of the percent of a stream under each type of canopy. Streams are listed in descending order by drainage area (largest at the top).

Cobble embeddedness was measured at each pool tail crest during CDFG stream surveys. Embeddedness values in the Coastal Subbasin generally do not meet target values for successful salmonid egg and embryo development. However, Figure 70 illustrates how stream reaches rated as unsuitable overall may actually have some suitable spawning gravel sites distributed through the stream reach. Additionally, cobble embeddedness meets target values in Rocky Gulch, Manly Gulch, and the mainstem Big River from Wheel Gulch to Blind Gulch.

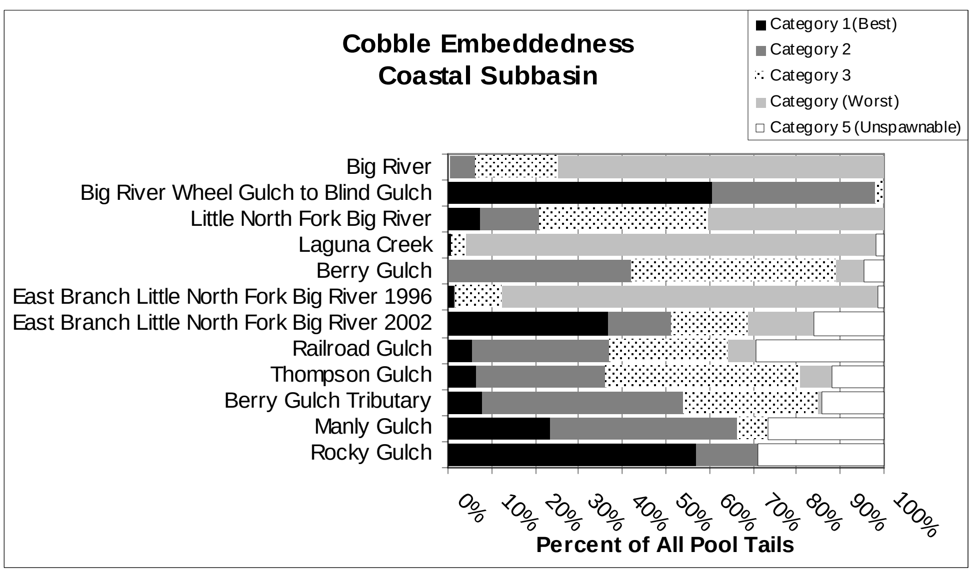


Figure 70. Cobble embeddedness categories as measured at every pool tail crest in surveyed streams in the Coastal Subbasin.

Cobble embeddedness is the % of an average sized cobble piece at a pool tail out that is embedded in fine substrate: Category 1 = 0-25% embedded, Category 2 = 26-50% embedded, Category 3 = 51-75% embedded, Category 4 = 76-100%, and Category 5 = unsuitable for spawning due to factors other than embeddedness (e.g. log, rocks). Streams are listed in descending order by drainage area (largest at the top).

Pool, flatwater, and riffle habitat units observed were measured, described, and recorded during CDFG stream surveys. During their life history, salmonids require access to all of these types of habitat. A balanced proportion of these habitat types is desirable. Most of the surveyed Coastal Subbasin streams have greater than

20% pool habitat by length (Figure 71). Dry units were measured and indicate a lack of habitat for fish. Culverts were also measured on four streams.

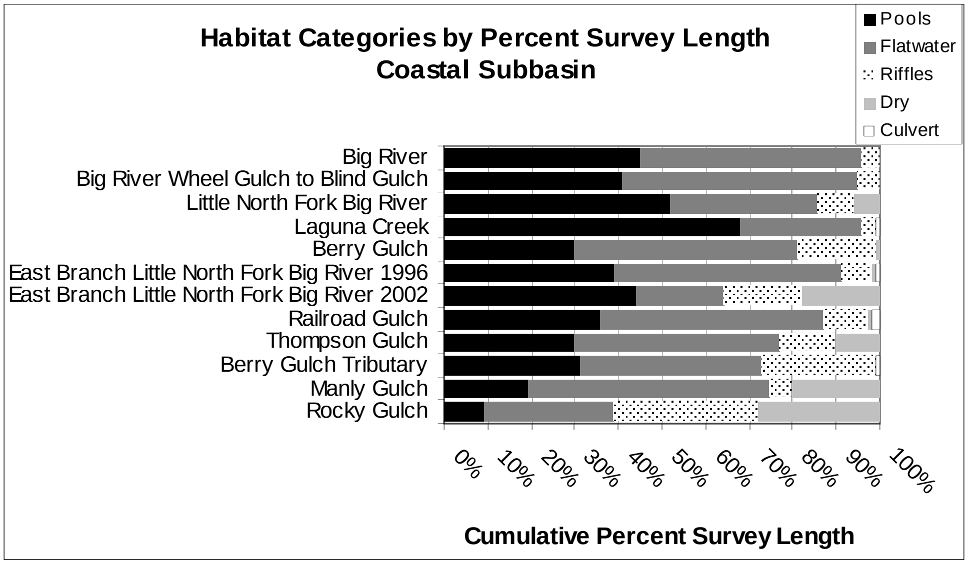


Figure 71. The percentage of pool habitat, flatwater habitat, riffle habitat, dewatered channel, and culverts by survey length in the Coastal Subbasin.

Streams are listed in descending order by drainage area (largest at the top).

Pool depths were measured during CDFG surveys. Primary pools are determined by a range of pool depths, depending on the order (size) of the stream. A reach must have 30 – 55% of its length in primary pools for its stream class to meet target values for supporting salmonids. Generally, larger streams have deeper pools. Deviations from the expected trend in pool depth may indicate streams with more suitable or unsuitable pool depth conditions relative to other streams of that subbasin. Most surveyed tributaries in this subbasin have less than 20% pools greater than two feet deep by length (Table 96). The mainstem Big River has the most pool habitat with maximum depth greater than two feet.

Table 96. Percent length of a survey composed of pools in the Coastal Subbasin.

Stream	Drainage Area (Sq. Mi.)	Stream Order	Percent Pools by Survey Length	Percent Pools > 2.0 by Survey Length	Perce3nt Pools >2.5 by Survey Length	Percent Pools >3.0 by Survey Length	Percent Pools >4.0 by Survey Length
Big River	181.0	4	44.9	44.3	44.1	43.5	36.3
Big River Wheel Gulch to Blind Gulch	149.2	4	39.9	39.9	39.9	37.6	27.2
Little North Fork Big River	12.8	2	52.4	32.7	21.7	10.3	2.8
Laguna Creek	5.1	1	68.2	38.7	29.5	21.1	8.4
Berry Gulch	2.8	1	27.3	10.8	4.4	2.8	0.3
East Branch Little North Fork Big River 2002	1.8	1	43.6	20.5	8.6	2.2	0.2
East Branch Little North Fork Big River 1996	1.8	1	39.7	15.4	7.7	2.3	0.0
Railroad Gulch	1.7	1	28.5	9.8	5.5	3.2	0.5
Thompson Gulch	1.1	2	29.5	4.7	1.9	1.4	0.5
Berry Gulch Tributary	0.9	1	33.8	10.7	6.0	5.1	5.1
Manly Gulch	0.5	1	19.4	4.2	1.3	0.9	0.0
Rocky Gulch	0.4	1	8.8	2.6	1.7	1.7	0.0

Streams are listed in descending order by drainage area (largest at the top).

Pool shelter was measured during CDFG surveys. Pool shelter rating illustrates relative pool complexity, another component of pool quality. Ratings range from 0-300. Shelter scores greater than 100 meet target values for supporting salmonids. Pool shelter ratings in the Coastal Subbasin do not meet target values (Figure 72).

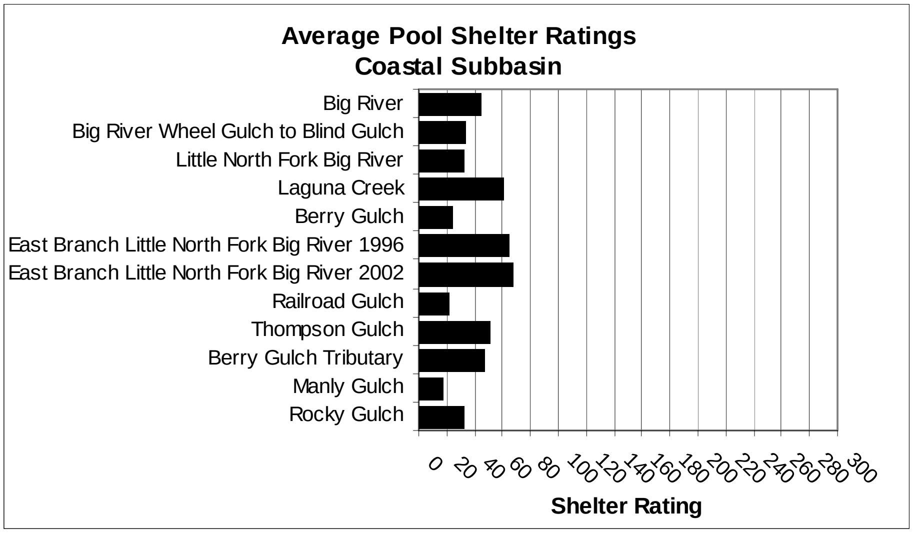


Figure 72. Average pool shelter ratings from CDFG stream surveys in the Coastal Subbasin.

Streams are listed in descending order by drainage area (largest at the top).

Pool shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered by nine different cover types was made during stream surveys. The mean percent of pool shelter cover in each cover type was calculated for each surveyed stream. The predominant pool cover types in most Coastal Subbasin tributaries are woody debris, undercut banks, and root masses (Table 97).

Table 97. Mean percent of shelter cover types in pools for surveyed tributaries in the Coastal Subbasin.

Stream	Undercut Banks	Small Woodsy Debris	Large Woody Debris	Rootmass	Terrestrial Vegetation	Aquatic Vegetation	Whitewater	Boulders	Bedrock Ledges
Big River	9.4	25.3	16.3	23.6	2.7	0.1	0.0	8.3	14.3
Big River Wheel Gulch to Blind Gulch	6.2	15.3	16.8	22.4	19.6	12.2	0.0	6.1	1.2
Little North Fork Big River	3.0	21.2	39.4	4.0	19.2	3.0	0.0	4.0	6.1
Laguna Creek	30.0	19.0	11.0	5.0	24.0	3.0	0.0	8.0	0.0
Berry Gulch	25.4	8.1	29.1	5.4	0.7	7.4	1.1	11.3	11.5
East Branch Little North Fork Big River 1996	10.5	12.3	50	10	5	0	0.8	0.5	11
East Branch Little North Fork Big River 2002	17.5	21.4	30.4	5.3	5.6	12.5	0.8	5.1	0.6
Railroad Gulch	2.2	55.0	27.2	0.0	0.0	14.4	0.0	1.1	0.0
Thompson Gulch	35.8	28.6	16.4	4.4	9.2	0.0	2.8	3.6	0.0
Berry Gulch Tributary	14.6	28.9	42.1	2.9	7.9	1.1	2.5	0.0	0.0
Manly Gulch	0.0	24.2	5.0	14.2	49.2	0.0	0.0	7.5	0.0
Rocky Gulch	27.0	7.0	0.0	33.0	33.0	0.0	0.0	0.0	0.0

Streams are listed in descending order by drainage area (largest at the top).

Fish Passage Barriers

Stream Crossings

Although no stream crossings were surveyed in the Coastal Subbasin as a part of the coastal Mendocino County culvert inventory and fish passage evaluation conducted by Ross Taylor and Associates (2001), CDFG stream surveys noted culverts on four tributaries, Little North Fork Big River, Railroad Gulch, Berry Gulch, and Berry Gulch Tributary (Table 98).

Table 98. Culverts described on streams inventoried by CDFG in the Coastal Subbasin.

Stream Name	Number of Culverts	Feet of Culvert
Little North Fork Big River	2	104
Railroad Gulch	1	86
Berry Gulch	2	94
Berry Gulch Tributary	1	65

Additionally, in the stream tributary report for Manly Gulch in 1997 a recommendation was given to create a channel under the main road to connect Manly Gulch to Little North Fork Big River. Winter access problems for adult fish at a non-existent channel at Camp Three (near the mouth of the stream) may be stopping Manly Gulch from being utilized for habitat by salmonids. The available habitat is sufficient for use by steelhead and coho.

CGS (2004) identified five watercourse crossings on Class I streams in Big River State Park (Table 99) (Figure 73). Only the culvert on Dry Dock Gulch was found to be a fish barrier. This culvert's outlet is high above Big River, creating a high jump for adult fish. The culvert also backs up water into a large pond covered by lily pads. Though this pond creates wetland habitat, it is unclear if it would occur naturally without the presence of the culvert. In addition, there were 10 Class I or II tributaries entering the estuary channel with high priority for remediation. These streams have not been surveyed for fish presence.

Table 99. CGS evaluated watercourse crossings of Class I streams in Big River State Park (CGS 2004).

Stream Name	Road Name	Type of Crossing	Length of Culvert (feet)	Comments
Dry Dock Gulch	M 1.0	Culvert	>25	Large Class I drains directly into Big River, outlet fill slopes eroded to nearly vertical by river erosion, crossing disconnects stream from Big River, fish barrier, culverts set high backing stream up into lily pad lake
Little North Fork Big River	M 14.0	Bridge	50	Bridge is currently passable with ATV, but should be further evaluated for structural integrity prior to allowing heavier vehicles to travel
Scooter Gulch	L 1.0	Culvert	35	Much ground disturbance, culvert bottom is rusted out, and no low-flow connectivity through this culvert
Unnamed Tributary to Big River	L 4.0	Bridge	50	Bridge site is currently passable with an ATV, but should be further evaluated for structural integrity prior to allowing heavier vehicles to travel
Big River	LB 1.0			Historic bridge crossing site across Big River. Wet crossing possible on ATV during lowest flows; Ranked high priority because of historic/future importance of this site as a bridge crossing. Currently there is no crossing and relatively minor sediment delivery

Dry Channel

CDFG stream inventories were conducted for 39.7 miles on 21 reaches of nine tributaries and the mainstem Big River in the Coastal Subbasin. A main component of CDFG Stream Inventory Surveys is habitat typing, in which the amount and location of pools, flatwater, riffles, and dry channel is recorded. Although the habitat typing survey only records the dry channel present at the point in time when the survey was conducted, this measure of dry channel can give an indication of summer passage barriers to juvenile salmonids. Dry channel conditions in the Big River Basin generally become established from late July through early September. Therefore, CDFG stream surveys conducted outside this period are less likely to encounter dry channel.

Dry channel disrupts the ability of juvenile salmonids to move freely throughout stream systems. Juvenile salmonids need well-connected streams to allow free movement to find food, escape from high water temperatures, escape from predation, and migrate out of their stream of origin. The amount of dry channel reported in surveyed stream reaches in the Coastal Subbasin is 2.3% of the total length of streams surveyed. This dry channel was found in eight streams (Figure 73 and Table 100). Dry habitat units occurred near the mouth of two tributaries, in the middle reaches of five tributaries, and at the upper limit of anadromy in three tributaries. Dry channel at the mouth of a tributary disconnects that tributary from the mainstem Big River, which can disrupt the ability of juvenile salmonids to access tributary thermal refugia in the summer. Dry channel in the middle reaches of a stream disrupts the ability of juvenile salmonids to forage and escape predation. Lastly, dry channel in the upper reaches of a stream indicates the end of anadromy.

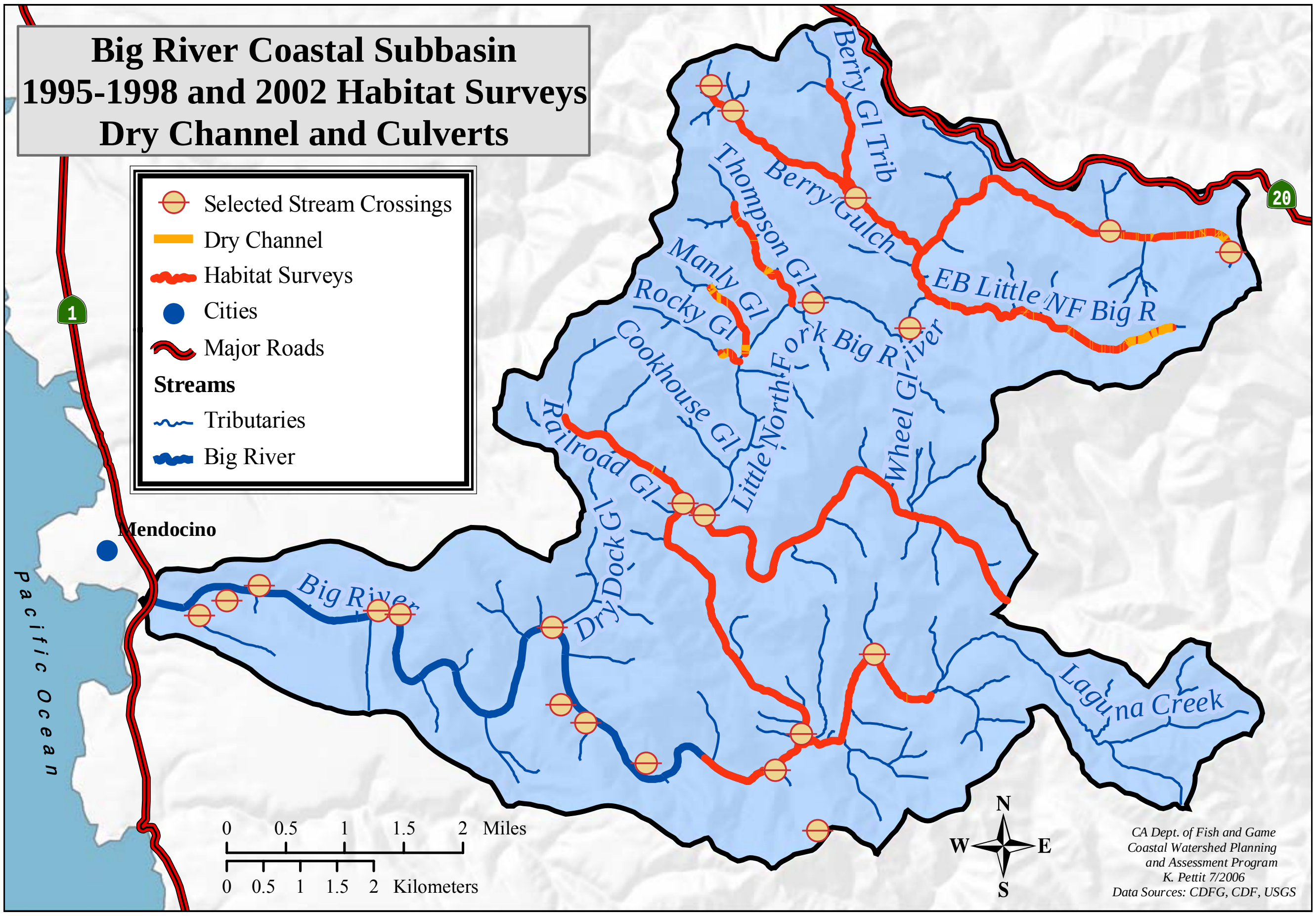


Figure 73. Dry and wetted channel and culverts reported during CDFG stream surveys in the Coastal Subbasin.

Table 100. Dry channel recorded in CDFG stream surveys in the Coastal Subbasin.

Stream	Survey Period	# of Dry Units	Dry Unit Length (ft)	% of Survey Dry Channel
Big River	July 1996	0	0	0.0
Laguna Creek	July 1996	1	32	0.3
Railroad Gulch	October 1996	1	57	1.0
Little North Fork Big River	October 1995	39	1,121	5.8
Rocky Gulch	September 1997	3	312	28.4
Manly Gulch	June 1997	9	729	20.5
Thompson Gulch	June 1997	5	328	5.7
East Branch of the Little North Fork Big River	June 2002	22	2,194	17.7
Berry Gulch	June 1997	2	82	0.7
Berry Gulch Tributary	June 1997	0	0	0.0
Big River (Wheel Gulch to Blind Gulch)	July - August 2002	0	0	0.0

Restoration Programs

The CDFG Fisheries Restoration Grants Program has funded various projects in the Coastal Subbasin (Table 101). Projects include research, education, bank stabilization, and log jam removal.

Table 101. Restoration projects in the Coastal Subbasin.

Name	Years	Project Leader	Project
Big River Estuary Biodiversity Assessment	2001-2002	Mendocino Unified School District	Survey, study, research, education, training, workshops
Big River Restoration Project (near confluence with Laguna Creek)	1989-1991	Center for Education and Manpower Resources	Stream bank stabilized, log jam removed, grass planted
East Branch Little North Fork Log Jam Barrier Modification Projects	1984-1986	North coast Salmon Habitat Restoration Group	Log jams removed

DPR has proposed several restoration projects on their newly acquired lands in the Big River State Park. The main focus of the work will be road improvements to decrease sediment input to streams and remove fish passage barriers. Projects include road decommissioning, conversion of roads to recreational trails, skid trail stabilization and removal, road resurfacing, and removing debris from clogged culverts (DPR 2005a and b). In addition, Barber (2003 Draft) completed an Erosion Prevention and Implementation Plan for Mendocino Woodlands, which is in the Little North Fork Big River watershed. This plan prioritized corrective treatments for road and trail related sediment sources.

Changes in Habitat Conditions from 1960 to 2001

Streams surveyed in the 1950s and 1960s and habitat inventory surveyed in the 1990s or 2002 were compared to indicate changes between historic and current conditions. Data from 1960s stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor are based on the judgment of the biologist or scientific aid who conducted the survey. The results of historic stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to show general trends.

Where habitat data were available from both older stream surveys and recent stream inventories it appeared that spawning habitat increased in two streams, decreased in one, and remained similar in others (Table 102). Pool habitat increased in the mainstem Big River, but decreased or remained similar elsewhere. Shelter decreased in two streams and remained similar in other streams.

Table 102. Comparison between historic habitat conditions with current habitat inventory surveys in the Coastal Subbasin.

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of Changes from Historic to Current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
Big River	ND*	NA	Poor to fair	Unsuitable	Uncommon	Suitable	Only undercut banks and log jams for cover	Unsuitable	Pool habitat increased
Laguna Creek	ND	Fully suitable	ND	Fully unsuitable	ND	Suitable	ND	Suitable	ND
Railroad Gulch	ND	Fully suitable	Few pockets of good spawning gravel	Unsuitable	Many small pools, few more than 2 feet deep	Fully unsuitable	Good	Fully unsuitable	Pool habitat and shelter decreased
Little North Fork Big River	ND	Fully suitable	Very good in lower stream	Unsuitable	Common and abundant	Unsuitable	Common throughout	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
Rocky Gulch	ND	Fully suitable	May provide some near mouth	Fully suitable	ND	Fully unsuitable	ND	Unsuitable	ND
Manly Gulch	ND	Fully suitable	Mud bottom	Suitable	ND	Fully unsuitable	ND	Fully unsuitable	Spawning habitat increased
Thompson Gulch	ND	Fully suitable	May provide some near mouth	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	Habitat similar between years
East Branch Little North Fork Big River	ND	Fully suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Suitable	ND
Berry Gulch	ND	Fully suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Berry Gulch Tributary	ND	Fully suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Big River Wheel Gulch to Blind Gulch	ND	Unsuitable	Poor to fair	Suitable	Uncommon	Suitable	Only undercut banks and log jams for cover	Unsuitable	Spawning habitat and pool habitat increased

*ND is no data available

Fish History and Status

Historically, the Coastal Subbasin supported runs of coho salmon, and steelhead trout. CDFG stream surveys were conducted for six tributaries and the mainstem Big River in the Coastal Subbasin from 1959 to 1966 (Table 103). The USFWS electrofished one transect in the mainstem Big River by Mendocino Woodlands State Park in 1973 (Perry 1974). Three stream surveys were also conducted by the CEMR in 1979. Out of the seven streams surveyed in the 1950s and 1960s, steelhead trout were found in the mainstem Big River and East Branch Little North Fork Big River, coho salmon were found in the Little North Fork Big River and East Branch Little North Fork Big River, and unidentified salmonids were found in two streams. USFWS found both coho salmon and steelhead trout in the mainstem Big River in 1973. Out of three streams surveyed in the 1979, steelhead trout were found in none and unidentified salmonids were reported in the Little North Fork Big River. Few salmonids were reported in these surveys.

Table 103. Summary of all electrofishing, snorkel survey, carcass survey, and bank observation surveys conducted in the Coastal Subbasin.

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
Estuary channel Big River	2001	SONAR	Snorkel Survey	Present	Present	
	2002	SONAR	Snorkel Survey			Present
Mainstem Big River	1959	CDFG	Visual Observation		Present	
	1973	USFWS	Electrofishing	Present	Present	
	1994	NMFS	Electrofishing		Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing	Present	Present	
	1996	HTC	Visual Observation		Present	
	2001	CDFG	Coho Inventory	Present		
Laguna Creek	1996	HTC	Visual Observation			Present
Railroad Gulch	1979	CEMR	Visual Observation			
	1995	CDFG	Electrofishing	Present		
		NMFS	Electrofishing	Present		
	1996	HTC	Electrofishing	Present	Present	
		CDFG	Carcass Survey	Present	Present	
		NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
Tributary to Railroad Gulch	1996	HTC	Electrofishing			
Little North Fork Big River	1959	CDFG	Visual Observation	Present		
	1979	CEMR	Visual Observation			
	1985	CDFG	Carcass Survey			
	1993	HTC	Electrofishing		Present	
	1994	HTC	Electrofishing		Present	
	1995	HTC	Electrofishing		Present	
		CDFG	Electrofishing	Present	Present	
		CDFG	Carcass Survey	Present	Present	
		NMFS	Electrofishing	Present	Present	
	1996	CDFG	Carcass Survey	Present	Present	
		HTC	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
	1997	HTC	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
	1998	HTC	Electrofishing		Present	
	1999	HTC	Electrofishing		Present	
		NMFS	Carcass Survey			Present
	2000	HTC	Electrofishing		Present	
		NMFS	Carcass Survey			Present
	2001	HTC	Electrofishing		Present	
		SONAR	Carcass Survey	Present	Present	
	2002	SONAR	Carcass Survey	Present	Present	
Rocky Gulch	1997	CDFG	Electrofishing	Present		
Manly Gulch	1997	CDFG	Electrofishing			Present
	1997	CDFG	Visual Observation			Present
Thompson Gulch	1979	CEMR	Visual Observation			
	1995	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing			
	1997	NMFS	Electrofishing		Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
		CDFG	Electrofishing	Present	Present	
East Branch Little North Fork Big River	1967	NMFS	Visual Observation	Present	Present	
	1985	CDFG	Carcass Survey			
	1986	CDFG	Electrofishing	Present	Present	
	1996	CDFG	Carcass Survey	Present	Present	
	2002	CDFG	Electrofishing	Present	Present	
Berry Gulch	1986	CDFG	Electrofishing	Present	Present	
	1995	CDFG	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing	Present	Present	
	1997	CDFG	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present	Present	
Berry Gulch Tributary	1997	CDFG	Electrofishing	Present	Present	
Big River from Wheel Gulch to Blind Gulch	2002	CDFG	Snorkel Survey	Present	Present	

* CDFG = Department of Fish and Game survey; CI = Department of Fish and Game Coho Inventory; CEMR = Center for Education and Manpower Resources; MRC = Mendocino Redwood Company Report; HTC = Hawthorne Timber Company; SONAR = School of Natural Resources at Mendocino High School; NMFS = National Marine Fisheries Service (Jones 2000)

Hawthorne Timber Company and CDFG studies have continued to document the presence of coho salmon and steelhead trout in the Coastal Subbasin.

Georgia Pacific began electrofishing surveys on the Little North Fork Big River as part of a monitoring program in 1993. The monitoring has been continued by the Hawthorne Timber Company. The sample site was electrofished annually and coho salmon and steelhead trout were consistently detected (Figure 74). Steelhead trout numbers show consistent multi-year class populations.

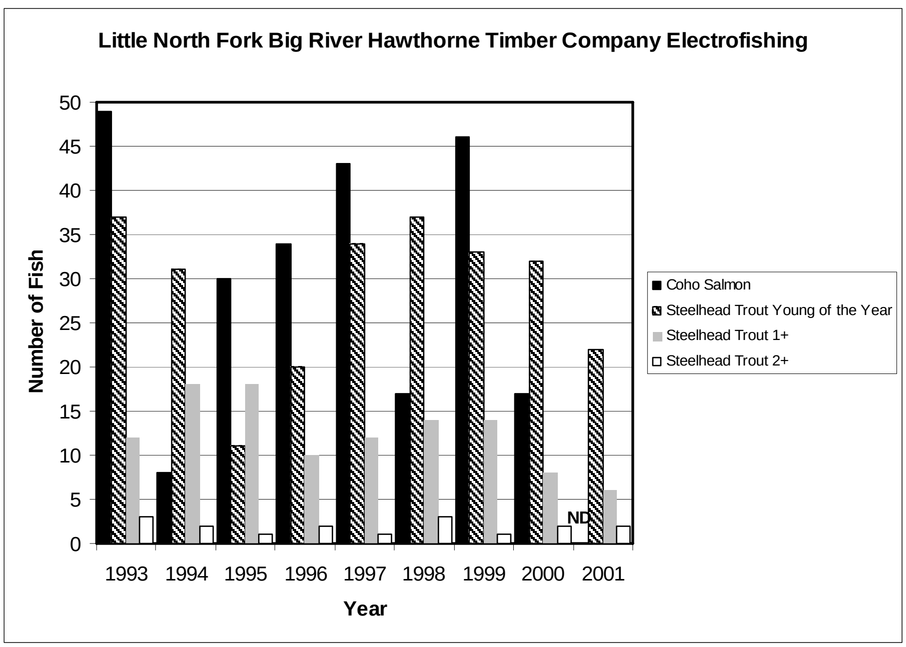


Figure 74. Electrofishing results from 1993-2001 for the Little North Fork Big River.

Surveys by Georgia-Pacific and Hawthorne Timber Company.

Georgia Pacific also used visual observation and electrofishing to detect salmonids during stream surveys conducted in mainstem Big River and three tributaries in 1996. Coho salmon were detected in Railroad Gulch, steelhead trout were detected in mainstem Big River and Railroad Gulch, and unidentified salmonids were detected in Laguna Creek.

Electrofishing documented by NMFS (Jones 2000) in five streams from 1995 to 1997 found coho salmon and steelhead trout in mainstem Big River, Railroad Gulch, Little North Fork Big River, Thompson Gulch, East Branch Little North Fork Big River, and Berry Gulch.

Carcass surveys conducted by CDFG in Little North Fork Big River detected 30 redds in 1995 and 26 redds in 1996. Numerous live coho salmon and coho salmon carcasses were also observed. A carcass survey in 1996 in Railroad Gulch found 26 redds, six live coho salmon, and one coho salmon carcass. The School of Natural Resources at Mendocino High School conducted carcass surveys in Railroad Creek in 2001 and Little North Fork Big River in the winters of 2001-2002 and 2002-2003 (SONAR 2001-2002, Sharples 2003). No fish or redds were observed in Railroad Creek. Thirty-three coho salmon and one steelhead trout were found in both years in Little North Fork Big River. Twenty six redds were observed in the 2001-2002 season and 16 redds were observed in the 2002-2003 season.

The 2001 CDFG Coho Inventory found coho salmon present in mainstem Big River. Snorkel surveys of the Big River Estuary conducted by the School of Natural Resources at Mendocino High School in 2001 and 2002 detected coho salmon and steelhead trout, as well as unidentified salmonids and surfperch (Clapsadle et al. 2001).

CDFG stream inventory surveys conducted across the subbasin also detected coho salmon and steelhead trout from 1995 through 2002. Coho salmon were detected in seven surveyed tributaries and the mainstem Big River from Wheel Gulch to Blind Gulch. Steelhead trout were detected in six surveyed tributaries and the mainstem Big River from Wheel Gulch to Blind Gulch. More detailed summaries of stream surveys and fisheries studies in the Coastal Subbasin are provided in the CDFG Appendix.

Coastal Subbasin Issues

From the various disciplines' assessments and constituent input, the following issues were developed for the Coastal Subbasin. These must be considered in context of the Big River Basin's Franciscan mélange geology, the many low gradient depositional reaches in this subbasin, and the 8.3 mile long Big River Estuary. In the Coastal Subbasin:

- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River;
- There is concern that road related failures are contributing large amounts of sediments to stream channels during major storms;
- There is evidence of channel narrowing and increased sediment deposition in the estuary; however, the channel could simply be recovering from the effects of extensive splash damming throughout the basin;
- Estuary conditions are thought to be impaired by sediment;
- Excessive amounts of fine material in streams are a concern;
- A large section of the Coastal Subbasin has recently become State Park and management decisions affecting this land are in progress.

Coastal Subbasin Integrated Analysis

The following section provides a dynamic, spatial picture of watershed conditions for the freshwater lifestages of salmon and steelhead. Different watershed factors are analyzed together to examine their combined effects on stream channels. The interactions between geology, vegetation, landuse, water quality, and stream channels indicate the quantity and quality of the freshwater habitat for salmon and steelhead.

Landsliding Interactions

GMA (2001) calculated the unit volume of delivering landslides, comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas, to be 292 tons/square mile/year for 1989-2000. In the Coastal Subbasin, it was reported that 100% of the landslides occurred in timber harvest areas or were related to roads (Figure 75). Of the delivering landslides from harvest related activities and roads, it was estimated that 66% were related to roads and 34% were related to timber harvesting (including skid trails). Results over the entire study period (1937-2000) showed that 33% of the delivering landslides were road related, 67% were related to timber harvesting (including skid trails), and none were related to grassland areas or unmanaged forest.

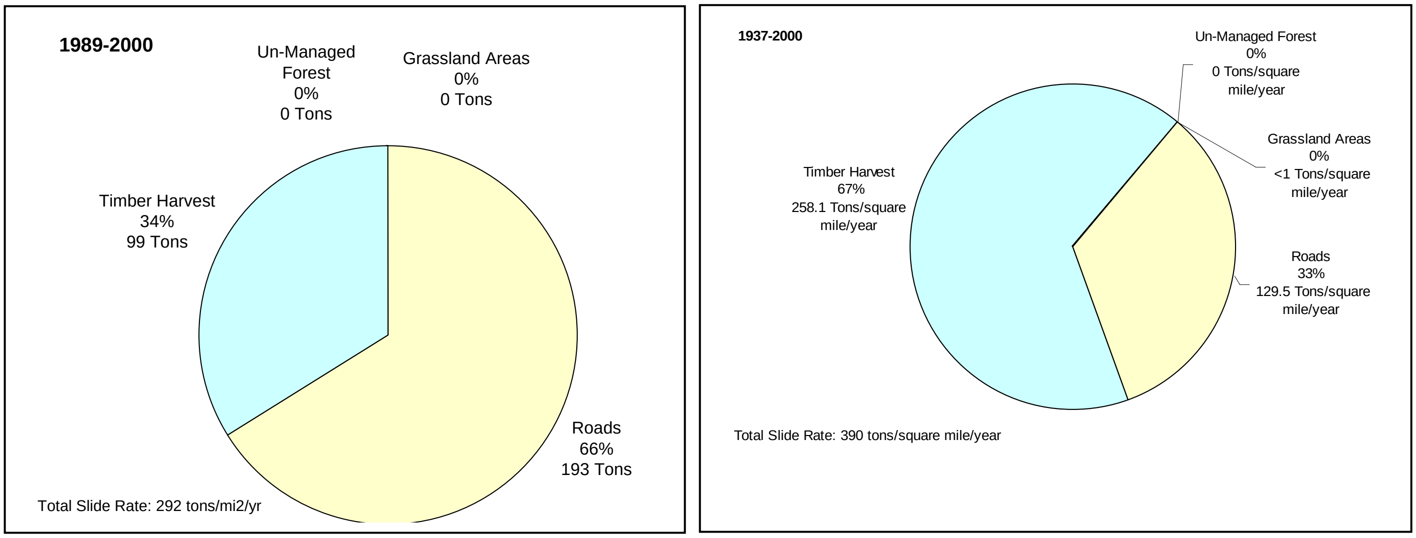


Figure 75. Delivering landslides by category, Coastal Subbasin (GMA 2001a).

Thus, when comparing the 1989-2000 time period to that of the entire study period, the percentage of delivering landslides due to roads versus timber harvesting was reversed. This switch in the primary cause of delivering landslides may be the result of timber harvesting methods that are less disruptive, or it may be the result of years of building roads that are now triggering more landslides. It is important to note that the total estimated slide rate decreased from 390 (1937-2000) to 292 tons/square mile/year (1989-2000), a moderate drop in sediment input by landslides.

When examining the three PWs in the Coastal Subbasin, the Berry Gulch PW had a higher percentage of harvest-related sediment delivered by landslides, while the Laguna Creek PW had a slightly higher percentage of sediment related to roads (Table 104).

Table 104. Volumes of delivering slides by land use by PW for 1937-2000 in the Coastal.

PW	Forest	Brush & Grassland	Harvest-Related					Road-Related	Total
			Partial Or Clear Cut	Harvest (<20 Yrs)	Harvest (>20 Yrs)	Skid Trails	Total		
Mouth of Big River	0 0.0%	0 0.0%	0 0.0%	14,367 6.7%	102,000 47.6%	1,389 0.6%	130,547 60.9%	83,928 39.1%	214,476
Berry Gulch	0 0.0%	54 <0.1%	9,410 1.9%	172,052 34.6%	165,187 33.2%	2,492 0.5%	349,141 70.2%	148,496 29.8%	497,692
Laguna Creek	0 0.0%	0 0.0%	2,421 3.0%	22,309 27.6%	23,518 29.1%	0 0.0%	48,248 59.7%	32,544 40.3%	80,792
Coastal Subbasin	0 **0.0%**	54 **<0.1%**	11,831 **1.5%**	208,727 **26.3%**	290,706 **36.7%**	3,882 **0.5%**	527,937**66** **.6%**	264,969 **33.4%**	792,960

Subbasin in tons and percentage of subbasin total (GMA 2001a).

All three PWs had a peak in sediment production in 1952 (Table 105). The highest peak sediment production was 345,779 tons in 1952 in the Berry Gulch Big PW. Harvest-related landslides provided more volume in the peak year for all PWs.

In the 2000 study period, sediment production from landslides ranged from 12,589 tons in the Laguna Creek PW to 63,653 tons in the Mouth of Big River PW. Harvest related landslides provided more volume in Laguna Creek and roads in Mouth of Big River and Berry Gulch.

Sediment production related to landsliding showed varying trends in different PWs from 1937 to 2000. All three PWs showed a decrease in sediment production from in 1965 and 1978, as they all showed peaks in sediment volume in 1952. Harvest-related landslides provided the most sediment in 1952 in all three PWs, Laguna Creek PW in 2000, and in Berry Gulch PW in 1978. Road-related sediment volumes appear to have gained relative importance in all PWs after 1965. The Mouth of Big River PW showed a decrease in sediment production from 1978 to 1988, while the other two PWs showed increases in this study period. In the last study period (1988 to 2000) sediment volume related to landslides decreased in the Laguna Creek PW and increased in the other PWs.

Table 105. Volume of delivering slides by land use, PW, and year in the Coastal Subbasin.

Year	PW	Forest	Brush & Grassland	Harvest-Related					Road-Related	Study Period Total
				Partial or Clear Cut	Harvest (< 20 Years)	Harvest (> 20 Years)	Skid Trail	Total		
1952	Mouth of Big River				1,775	64,026	0	65,800	12,366	78,166
1965					47	26,993	1,372	40,641	28,463	69,104
1978					1,635	106	0	1,741	1,811	3,552
1988					0	0	0	0	0	0
2000					10,910	10,876	17	22,364	41,288	63,653
Total:		0	0	0	14,367	102,000	1,389	130,547	83,928	214,476
1952	Berry Gulch		54	907	155,500	135,320		291,728	53,997	345,779
1965					4,817	22,561		27,377	27,794	55,172
1978				8,062		2,164	2,492	12,718	12,478	25,196
1988					5,637	4,220		9,857	24,017	33,874
2000				440	6,097	923		7,460	30,210	37,670
Total:		0	54	9,410	172,052	165,187	2,492	349,141	148,496	497,692
1952	Laguna Creek				13,395	23,133		36,528	13,166	49,694
1965					1,380	386		1,766	683	2,449
1978								0		0
1988				1,201				1,201	14,860	16,061
2000				1,220	7,534			8,754	3,835	12,589
Total:		0	0	2,421	22,309	23,518	0	48,248	32,544	80,792

It should be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 75). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 292 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 35% of the total sediment input by all categories of landslides.

When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 76 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails. Based on these preliminary comparisons, it appears as though landsliding related to roads and timber harvesting needs to be addressed to meet the TMDL load allocation goals. Roads, in particular, seem to be a significant problem, but one that can be addressed with relative ease compared to landslides and other large natural disturbances.

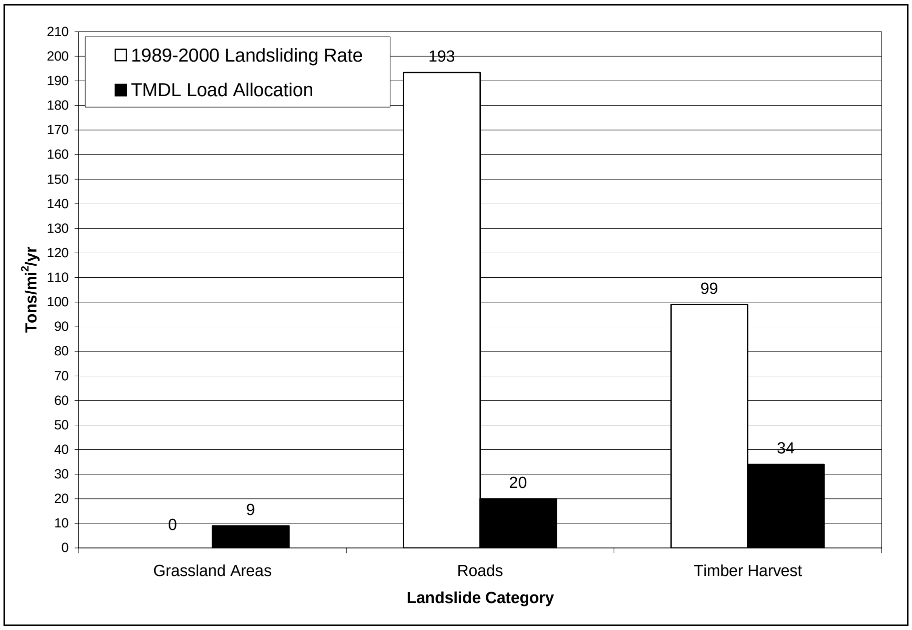


Figure 76. Landslide rate vs. TMDL load allocations, Coastal Subbasin (GMA).

Slope Interactions

An analysis of different types of roads on slopes of varying percent showed that most road miles are on slopes from 31 to 50% in this subbasin (Table 106). When GMA (2001) grouped slopes into categories, they found that most of the roads are mid-slope, followed by riparian, and then ridge-top (Table 107). An estimated 21% of roads are located in the riparian zone. The proportion of roads in each location was similar in each PW (Table 108).

Table 106. Length of truck roads by side slope and road surface.

Side Slope in Percent	Total Length in Miles				Miles per Square Mile				Proportion of Length			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
0 -15	50	4	16	71	1.5	0.1	0.5	2.2	20	2	7	28
16 - 30	55	5	11	70	1.7	0.1	0.3	2.1	22	2	4	28
31 - 50	65	1	13	79	2.0	0.0	0.4	2.4	26		5	32
51 - 65	17	0	4	22	0.5	0.0	0.1	0.7	7		2	9
Greater than 65	6		2	8	0.2		0.0	0.2	2		1	3
Total	**193**	**10**	**46**	**249**	**5.9**	**0.3**	**1.4**	**7.7**	**77**	**4**	**18**	**100**

Table 107. Coastal Subbasin roads by location and surface type.

	Paved	Rocked	Un-surfaced
Ridgetop			
Miles	2.4	7.0	39.5
% Total Basin Miles	1.0	2.8	15.9
Mid-slope			
Miles	7.5	29.4	111.5
% Total Basin Miles	3.0	11.8	44.9
Riparian			
Miles	0.5	9.5	41.2
% Total Basin Miles	0.2	3.8	16.6

Blue categories have the lowest potential for road surface erosion (6.8%). Orange categories have medium potential for surface erosion (27.9%). Magenta categories have the highest potential for surface erosion (65.3%). Road surface erosion is a source of fine sediment that can be delivered to streams, which is deleterious to fish habitat. Total subbasin roads = 248.4 miles, 7.7 miles/square mile.

Table 108. Existing miles of road in different road positions by types and PW in the Coastal Subbasin (from GMA 2001a).

Planning Watershed	Riparian			Mid-Slope			Ridge			Total By PW		
	Paved	Rocked	Native	Paved	Rocked	Native	Paved	Rocked	Native	Riparian	Mid-Slope	Ridge
Mouth of Big River	0.5	9.5	41.2	7.5	29.4	111.5	2.4	7.0	39.5	51.2	148.4	48.9
Berry Gulch		1.9	15.3	1.6	6.3	42.1	1.2	1.9	14.5	17.2	50.1	17.6
Laguna Creek		2.3	5.6	1.9	3.8	18.4	0.2	0.3	8.6	7.9	24.1	9.1

Road Interactions

GMA (2001) estimated that road surface erosion across the Coastal Subbasin increased significantly from 1937 to 2000, coinciding with an increased amount of roads, (Table 109). Roads in 2000 were estimated to produce 98.6 tons of sediment per square mile per year across the subbasin, an increase over 1936 rates. Existing road surface erosion in 2000 was highest in the Mouth of Big River PW and lowest in the Laguna Creek PW.

Table 109. Computed road surface erosion by study period by PW in the Coastal Subbasin (GMA 2001a).

PW	Computed Surface Erosion From Roads By Period (Tons/Yr)					Total By PW For Entire Period	% Total Watershed Road Surface Erosion	Entire Study Period Average Unit Area Road Surface Erosion	2000 Unit Area Road Surface Erosion
	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	(Tons)	(%)	(Tons/Mi2/Yr)	
Mouth of Big River	664.7	749.1	1047.4	1190.1	1505.6	64,500.5	9.7%	68.7	101.0
Berry Gulch	416.4	566.3	786.8	959.8	1227.2	48,834.5	7.4%	62.0	98.3
Laguna Creek	95.1	128.9	167.6	275.9	468.1	13,787.5	2.1%	42.9	92.3
Coastal Subbasin	1176.2 (36.7%)	1444.2 (45.1%)	2001.8 (62.5%)	2425.8 (75.8%)	3200.9 (100.0%)	127,122.5	19.2%	62.1	98.6

GMA (2001) estimated that sediment production from skid roads across the subbasin was small (Table 110). The analysis suggested a peak in surface erosion at the time of high harvest rates using high-density tractor logging methods from 1953-1978. Surface erosion from 1989 to 2000 was almost the same in the Berry Gulch and Laguna Creek PWs and twice that in the Mouth of Big River PW.

Table 110. Summary of surface erosion estimates from harvest areas by study period in the Coastal Subbasin (GMA 2001a).

PW	1937-1952 (Tons)	1953-1965 (Tons)	1966-1978 (Tons)	1979-1988 (Tons)	1989-2000 (Tons)	1921-2000 Total by PW or SW (Tons)
Mouth of Big River	0.0	526.5	2,551.2	1,791.1	2,026.9	6,895.7
Berry Gulch	1,495.4	2,586.2	1,681.7	484.6	1,052.3	7,300.2
Laguna Creek	0.0	436.4	0.0	1,455.7	1,072.8	2,964.8
Coastal Subbasin	1,495.4	3,549.1	4,232.9	3,731.4	4,152.0	17,160.6

As can be seen in Figure 77, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1937-2000) is likely due to continued road building through the years which has resulted in greater road surface area. CGS (2004) evaluated sediment yield from existing roads and culverts for the 3,715-acre Big River State Park.

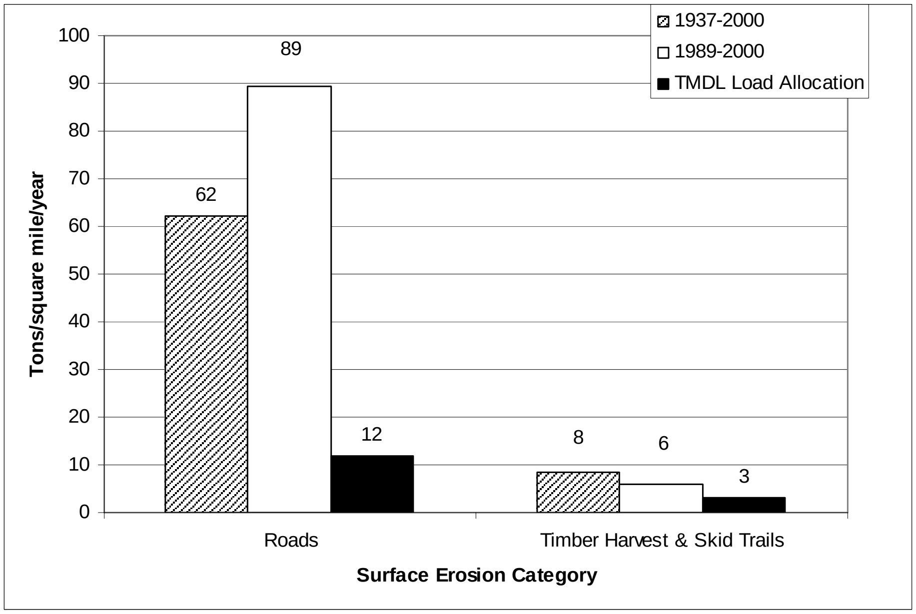


Figure 77. Surface erosion rate vs. TMDL load allocations, Coastal Subbasin (GMA 2001a).

Road Crossings

Today there are 38 miles of roads in the watercourse buffer zone (Table 111). Seventy five percent were built before 1979 (Table 112). While the data show 31 miles as native road surface, the Forest Practice Rules require that landowners that use roads for harvesting timber reduce the potential for sediment transport, so many are being surfaced with rock. There are almost 21 streams crossings per square mile in this subbasin (Table 113).

Table 111. Length of truck roads in near proximity to watercourse in miles by watercourse classification and road classification in the Coastal Subbasin.

Watercourse Class	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
w/i 150' of FPR Class I or USGS Perennial	22.3	0.2	4.8	27.2	0.69	0.01	0.15	0.84
w/i 75' of FPR Class II or USGS Intermittent	5.2	0.2	1.2	6.5	0.16	0.01	0.04	0.20
w/i 25' of FPR Class III	3.4	0.0	0.9	4.3	0.11		0.03	0.13
Total	**30.9**	**0.4**	**6.8**	**38.1**	**0.95**	**0.01**	**0.21**	**1.17**

Table 112. Length of truck roads in near proximity to watercourse in miles by period of construction and road classification in the Coastal Subbasin.

Period	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
pre - 1937	13.2	0.3	2.4	15.9	0.41	0.01	0.07	0.49
1937 - 1952	3.0		2.1	5.1	0.09		0.06	0.16
1953 - 1965	3.7	0.1	0.6	4.4	0.11		0.02	0.13
1966 - 1978	2.2		0.9	3.2	0.07		0.03	0.10
1979 - 1988	2.7		0.5	3.2	0.08		0.01	0.10
1989 - 2000	6.1		0.4	6.5	0.19		0.01	0.20
Total	**30.9**	**0.4**	**6.8**	**38.1**	**0.95**	**0.01**	**0.21**	**1.17**

Table 113. Number of watercourse truck road crossings by watercourse and road classification in the Coastal Subbasin.

Watercourse Class	Total Crossings				Crossings per Square Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
FPR Class I or CFF Perennial	49	2	13	64	1.5	0.1	0.4	2
FPR Class II or CFF Intermittent	120	1	37	158	3.7	0	1.1	4.9
FPR Class III	372	3	81	456	11.5	0.1	2.5	14
Total	**541**	**6**	**131**	**678**	**16.7**	**0.2**	**4**	**20.9**

Fluvial Erosion

GMA (2001) estimates of bank erosion and small streamside mass wasting found little sediment from these sources.

Table 114. Bank erosion and small streamside mass wasting in the Coastal Subbasin.

Planning Watershed	Bank Erosion and Small Streamside Mass Wasting		Total
	Class 1 (Tons/Year)	Class 2 (Tons/Year)	(Tons/Year)
Mouth of Big River	457.35	555.62	1012.97
Berry Gulch	364	425	789
Laguna Creek	134	212	346
Coastal Subbasin	955	1,193	2,148

GMA 2001a

Stream Interactions

The products and effects of the watershed delivery processes examined in the geologic, slope, and landsliding Integrated Analyses tables are expressed in the stream habitats encountered by the organisms of the aquatic riparian community, including salmon and steelhead. Several key aspects of salmonid habitat in the Big River Basin are presented in the Stream Interactions Integrated Analysis. Channel and stream conditions are not necessarily exclusively linked to their immediate surrounding terrain, but may in fact be both spatially and temporally distanced from the sites of the processes and disturbance events that have been blended together over time to create the channel and stream's present conditions. Instream habitat data presented here were compiled from CDFG stream inventories described in more detail in the Fish Habitat Relationships sections of this report.

Primary Pools

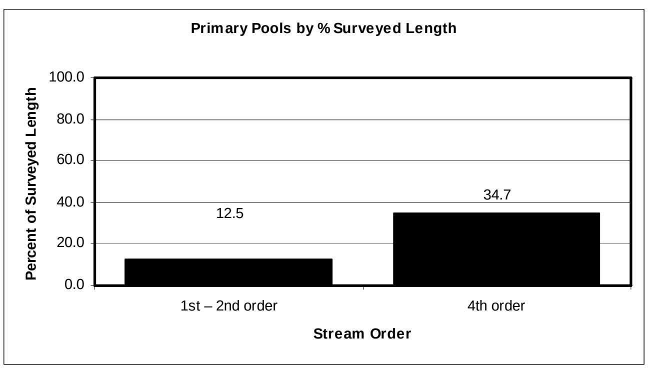


Figure 78. Primary pools in the Coastal Subbasin.

Pools greater than 2 feet deep in 1st and 2nd order streams and greater than 3 feet deep in 3rd and 4th order streams are considered primary pools.

Significance: Primary pools provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30-55% of its length in primary pools to be suitable for salmonids. In first and second order streams, a primary pool is described as being at least two feet deep. In third and fourth order streams, a primary pool is described as being at least three feet deep.

Comments: The percent of primary pools by length in the Coastal Subbasin is generally below target values for salmonids in lower order streams and appears to be suitable in fourth order streams. This subbasin has the highest percent of primary pools in first and second order streams surveyed of any of the Big River Subbasins.

Spawning Gravel Quality

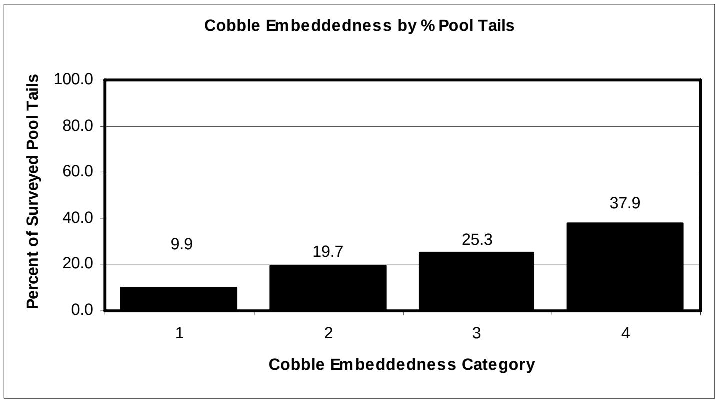


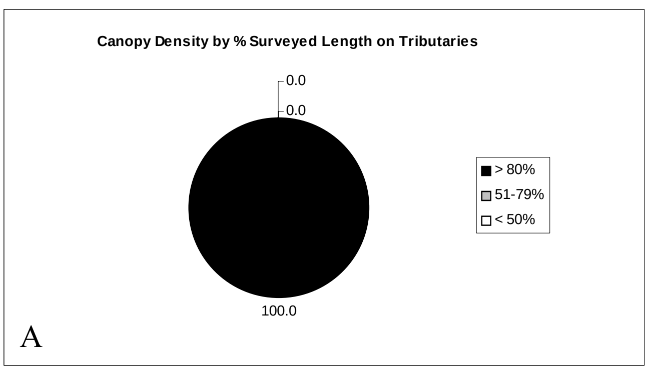
Figure 79. Cobble embeddedness in the Coastal Subbasin.

Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

<u>Significance:</u> Successful salmonid egg and embryo survival diminishes when spawning occurs in streambeds with excessive silt, clay, and other fine sediment. Cobble embeddedness is the percentage of an average sized cobble at a pool tail out embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded and category 4 is 76%-100% embedded. Cobble embeddedness categories 3 and 4 are not within the suitable range for successful use by salmonids. Category 5 describes pool tail outs with unspawnable substrate such as bedrock, log sills, or boulders.

<u>Comments:</u> More than one half of the surveyed stream lengths within the Coastal Subbasin, where the mainstem Big River is primarily a depositional reach, have cobble embeddedness in categories 3 and 4, which does not meet spawning gravel target values for salmonids. This subbasin has the highest percent of unsuitable cobble embeddedness values in surveyed streams of the Big River Subbasin.

Shade Canopy



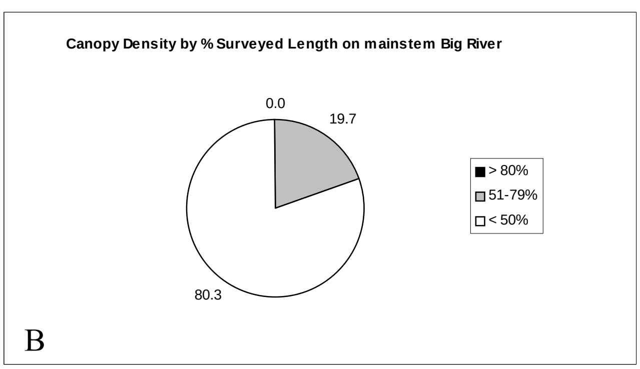


Figure 80. Canopy density in the Coastal Subbasin. A. Tributaries. B. Mainstem Big River.

<u>Significance:</u> Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey length is unsuitable and greater than 80% is fully suitable.

<u>Comments:</u> All of the surveyed tributary lengths within the Coastal Subbasin have canopy densities greater than 80%. This is above the canopy density target values for salmonids. The mainstem Big River has lower canopy density values, as is expected on a forth order stream.

Fish Passage

Table 115. Juvenile salmonid passage in the Coastal Subbasin.

Feature		Significance	Comments
Juvenile Summer Passage	Juvenile Winter Refugia		
0.9 Miles of Surveyed Channel Dry	No Data	Dry channel disrupts the ability of juvenile salmonids to move freely throughout stream systems.	Dry channel recorded in the Coastal Subbasin during stream surveys has the potential to disrupt the ability of juvenile salmonids to forage and escape predation in eight tributaries. Juvenile salmonids seek refuge from high winter flows, flood events, and cold temperatures in the winter. Intermittent side pools, back channels, and other areas of relatively still water that become flooded by high flows provide valuable winter refugia.
2.3% of Surveyed Channel Dry			

1993-2002 CDFG Stream Surveys, CDFG Appendix

Pool Shelter

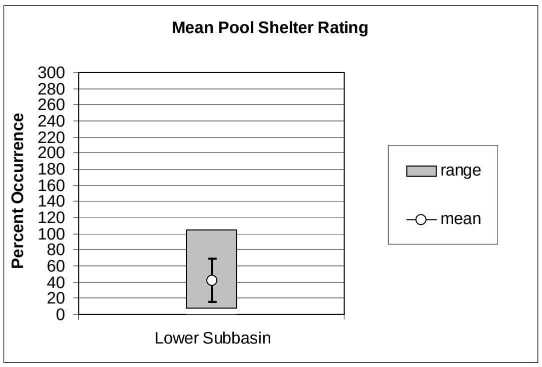


Figure 81. Pool shelter in the Coastal Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

Significance: Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Comments: The average mean pool shelter rating in the Coastal Subbasin is 41.9. This is below the shelter target value for salmonids, but is the highest of the Big River subbasins.

Large Woody Debris

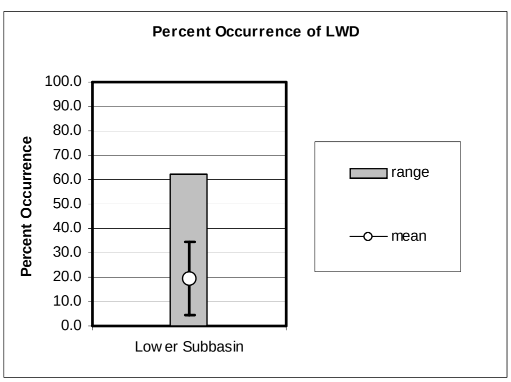


Figure 82. Large Woody Debris (LWD) in the Coastal Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percent occurrence of LWD.

Comments: A 19.5 average percent occurrence of large woody debris is low compared to the range of values recorded throughout the entire Big River Basin, which is 0 to 62. The dominant shelter types recorded in most stream reaches were large woody debris, small woody debris, and terrestrial vegetation.

Although instream habitat conditions for salmonids varied across the Coastal Subbasin, several generalities can be made. Instream habitat conditions were generally good within this subbasin at the time of CDFG surveys. The percentage of primary pools by survey length was the most suitable for salmonids of any of the Big River Subbasins. Canopy density levels appear low in this subbasin, but the large proportion of surveyed stream length on the mainstem Big River (a fourth order stream) accounts for the low canopy density. All of the tributary reaches surveyed in this subbasin have canopy densities greater than 80%. However, embeddedness values were generally below target values as found in CDFGs California Salmonid Stream Habitat Restoration Manual and calculated by the EMDS. The percent occurrence of large woody debris was in the lower range of values recorded in the Big River Basin. In addition, dry channel occurred in 0.9 miles of surveyed stream (2.3% of the surveyed stream length).

Stream Reach Conditions EMDS

The anadromous reach condition EMDS evaluates the condition for salmonids in a stream reach based upon instantaneous water temperature, riparian vegetation, stream flow, and in channel characteristics. Data used in the Reach EMDS come from CDFG habitat inventory surveys. Currently, data exist in the Big River Basin to evaluate overall reach, water temperature, canopy, in channel, pool quality, pool depth, pool shelter, and embeddedness conditions for salmonids. Details on how the EMDS system calculates habitat variables are in the EMDS Appendix. EMDS calculations and conclusions are pertinent only to surveyed streams and are based on conditions present at the time surveyed.

EMDS stream reach scores were weighted by stream length to obtain overall scores for tributaries and the entire Coastal Subbasin. Weighted average reach conditions on surveyed streams in the Coastal Subbasin as evaluated by the EMDS are somewhat unsuitable for salmonids (Table 116, Figure 83). Suitable conditions exist for canopy across the subbasin except for the mainstem Big River. Laguna Creek has suitable conditions for pool quality, pool depth, and pool shelter. Suitable conditions also exist for pool quality and pool depth in Big River; pool shelter in East Branch Little North Fork Big River; and embeddedness in Rocky Gulch, Manly Gulch, and Big River from Wheel Gulch to Blind Gulch.

One tributary, East Branch Little North Fork Big River, had two years of data, 1996 and 2002. A comparison of the two years data shows an increase in the suitability of canopy and cobble embeddedness and a decline in the suitability of pool shelter.

Table 116. EMDS Anadromous Reach Condition Model results for the Coastal Subbasin.

Stream		Reach	Water Temperature	Canopy	Stream Flow	In Channel	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Coastal Subbasin (excluding the mainstem Big River)		- (-)	U (U)	- (+++)	U (U)	- (-)	- (--)	+ (--)	- (-)	-- (--)
Big River		-	U	---	U	-	+	++	-	--
Laguna Creek		+	U	+++	U	+	++	++	++	---
Railroad Gulch		-	U	+++	U	-	---	---	---	--
Little North Fork Big River		-	U	+++	U	-	--	--	--	--
Rocky Gulch		-	U	+++	U	-	--	---	--	+++
Manly Gulch		-	U	+++	U	-	---	---	---	+
Thompson Gulch		-	U	+++	U	-	--	---	-	--
East Branch of the Little North Fork Big River	1996	-	U	+	U	-	-	---	++	--
	2002	-	U	+++	U	-	-	---	+	-
Berry Gulch		-	U	+++	U	-	--	---	--	--
Berry Gulch Tributary		-	U	+++	U	-	--	---	--	-
Big River (Wheel Gulch to Blind Gulch)		-	U	-	U	-	-	+	--	++

Key: + ++ +++ Highest Suitability
U Insufficient Data or Undetermined
- -- --- Lowest Suitability

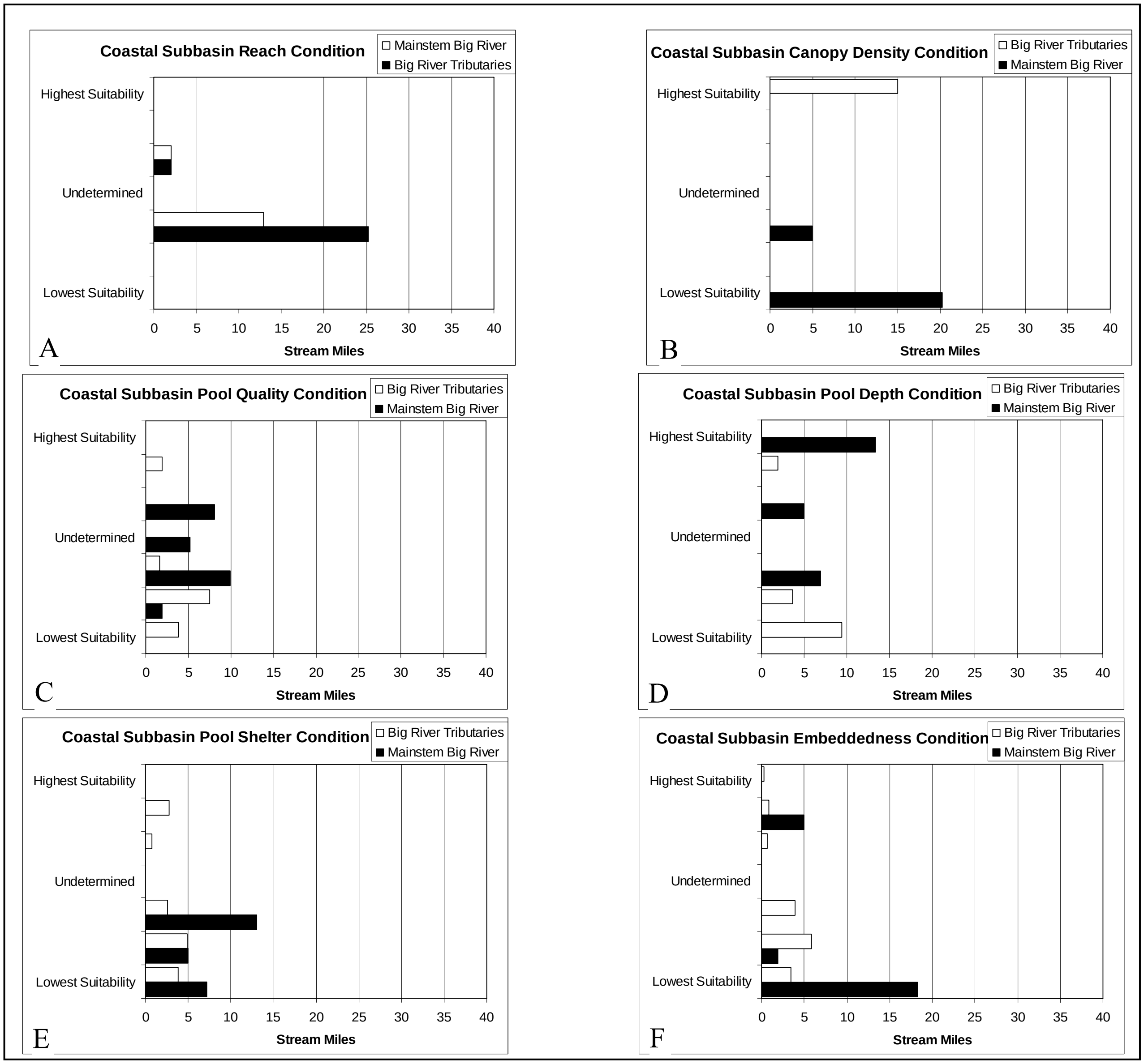


Figure 83. EMDS Reach Condition model results for the Coastal Subbasin by surveyed stream miles.

In streams with multiples years of data, the most current year was used. A. Overall reach condition. B. Canopy density. C. Pool quality. D. Pool depth. E. Pool shelter. F. Cobble embeddedness.

Analysis of Tributary Recommendations

CDFG inventoried 39.5 miles on nine tributaries and the mainstem Big River in the Coastal Subbasin. A CDFG biologist selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFG habitat inventories (Table 117). More details about the tributary recommendation process are given in the Big River Synthesis Section of the Watershed Profile.

Table 117. Ranked tributary recommendations summary in the Coastal Subbasin based on CDFG stream inventories.

Stream	# of Surveyed Stream Miles	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Big River	20.3	1	2	4			3		5		
Laguna Creek	1.9	2	3			1	4		5		
Railroad Gulch	1.1		2			3	1				
Little North Fork Big River	3.7	3	1				2				
Rocky Gulch	0.2		2				1				
Manly Gulch	0.7		3				2				1
Thompson Gulch	1.1		2			3	1				
East Branch of the Little North Fork Big River	2.4		4		1	2	3				
Berry Gulch	2.2		2		4	3	1				
Berry Gulch Tributary	1.1		2				1				
Big River Wheel Gulch to Blind Gulch	5.0	3		4	1		2				

Temp = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Bank** = 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** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

In order to further examine Coastal Subbasin issues through the tributary recommendations given in CDFG stream surveys, the top three ranking recommendations for each tributary were collapsed into five different recommendation categories: Erosion/Sediment, Riparian/Water Temp, Instream Habitat, Gravel/Substrate, and Other (Table 118). When examining recommendation categories by number of tributaries, the most important recommendation category in the Coastal Subbasin is Instream Habitat.

Table 118. Top three ranking recommendation categories by number of tributaries in the Coastal Subbasin.

Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	13
Riparian / Water Temp	Canopy / Temp	2
Instream Habitat	Pool / Cover	15
Gravel / Substrate	Spawning Gravel / LDA	0
Other	Livestock / Barrier	1

However, when comparing recommendation categories in the Coastal Subbasin by number of tributaries could be confounded by the differences in the number of stream miles surveyed on each tributary. Therefore, the number of stream miles in the subbasin assigned to various recommendation categories was calculated (Figure 84). When examining recommendation categories by number of stream miles, the most important recommendation categories in the Coastal Subbasin shift to Erosion/Sediment, Instream Habitat, and Riparian/Water Temperature. These comprise the top tier of recommended improvement activity focus areas.

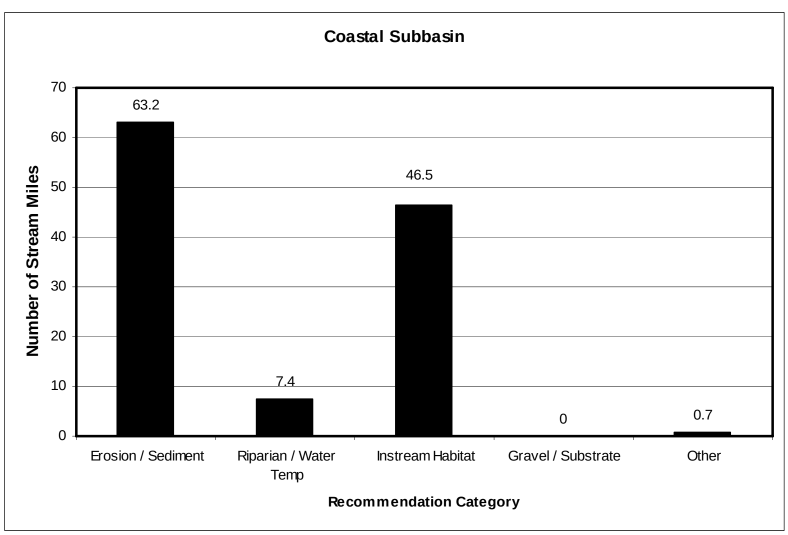


Figure 84. Recommendation categories by stream miles in the Coastal Subbasin.

The high number of Erosion/Sediment, Instream Habitat, and Riparian/Water Temperature recommendations across the Coastal Subbasin indicates that high priority should be given to restoration projects emphasizing sediment reduction, pools, cover, and riparian replanting.

Sediment Source Restoration Sites Within the Big River State Park

CGS evaluated approximately 36 miles of roads (44% of the length of roads) and 129 watercourse crossings (55% of potential crossing locations) within the Big River State Park. They prioritized roads and watercourse crossings for site remediation into three categories: high, moderate, and low (Figure 87). High priority sites were those that require immediate attention, moderate sites should be further investigated in the near-future, and low priority sites will probably require little more than regular maintenance.

Most of the roads evaluated were given a low priority ranking, with 26% receiving a moderate priority ranking, and 8% receiving a high priority ranking (Figure 85). High and moderate priority road segments are concentrated along riparian and mid-slope roads.

Most of the watercourse crossings evaluated were given a high priority ranking, with 27% receiving a moderate priority ranking, and 16% receiving a low priority ranking (Figure 86). All of the Class I stream crossings were given a high priority. Class I streams generally convey a substantial volume of perennial streamflow and have a great potential to deliver sediment to actual or potentially fish-bearing streams. All of the Class II stream crossings were given a high or moderate priority ranking. Class II streams transmit intermittent to perennial flow at a lower discharge than Class I streams and are positioned farther from actual or potential fish bearing streams. Class III streams were given varying priority rankings, though more were given high and moderate rankings than low rankings. Class III streams transmit intermittent or ephemeral flows, generally only following rainfall. They are typically positioned furthest from actual or potential fish bearing streams.

Since CGS's study was purposefully conducted in areas with the most significant erosion and/or mass wasting problems or potential for such problems, their results are biased towards sites with existing and potential problems. A randomly selected group of study sites would likely have found a larger range of conditions. However, these results indicate that roads and watercourse crossings have the greatest potential for erosion and sediment delivery within the park boundaries and will help pin-point high priority restoration sites.

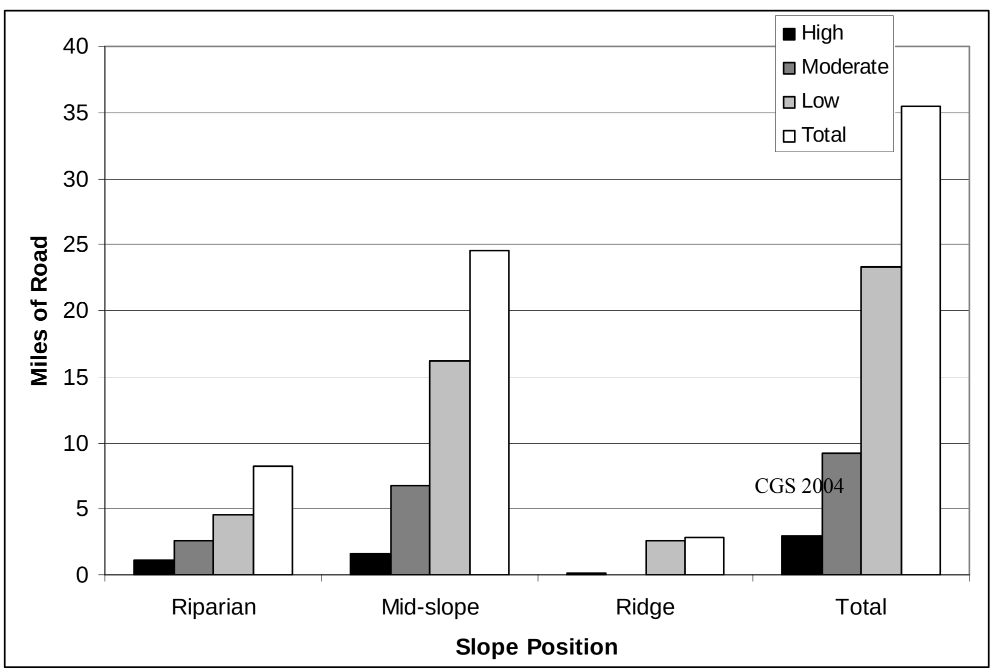


Figure 85. Miles of roads classified by slope position and priority ranking in Big River State Park.

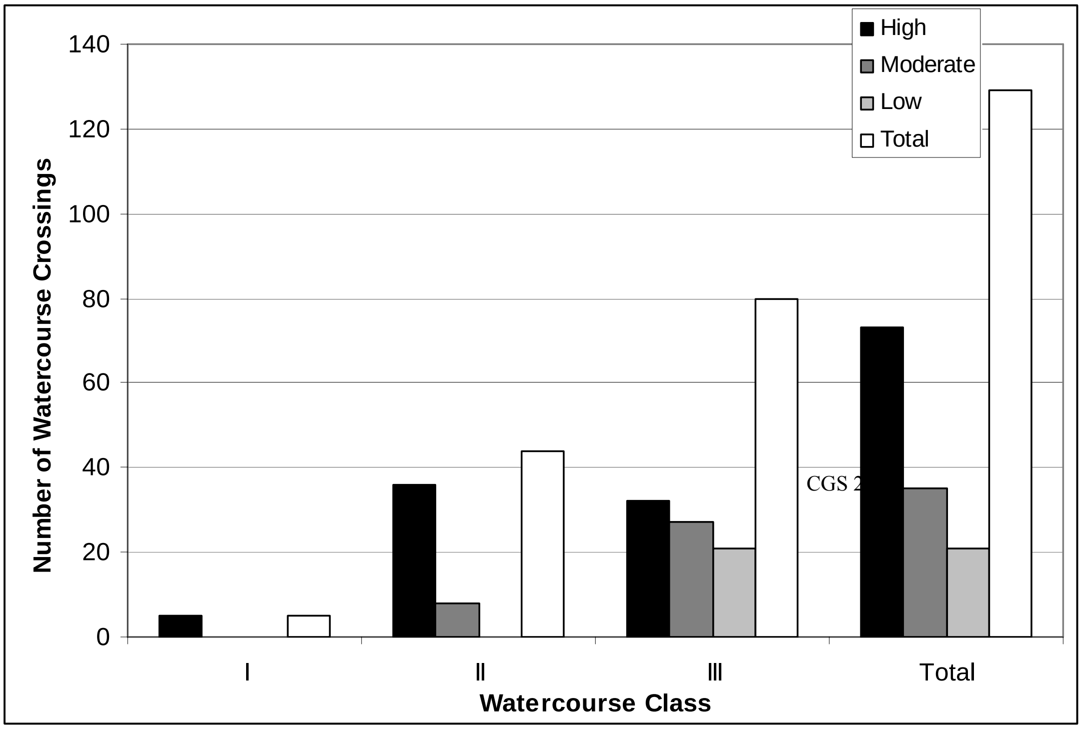


Figure 86. Number of watercourse crossings evaluated by watercourse class and priority ranking in Big River State Park.

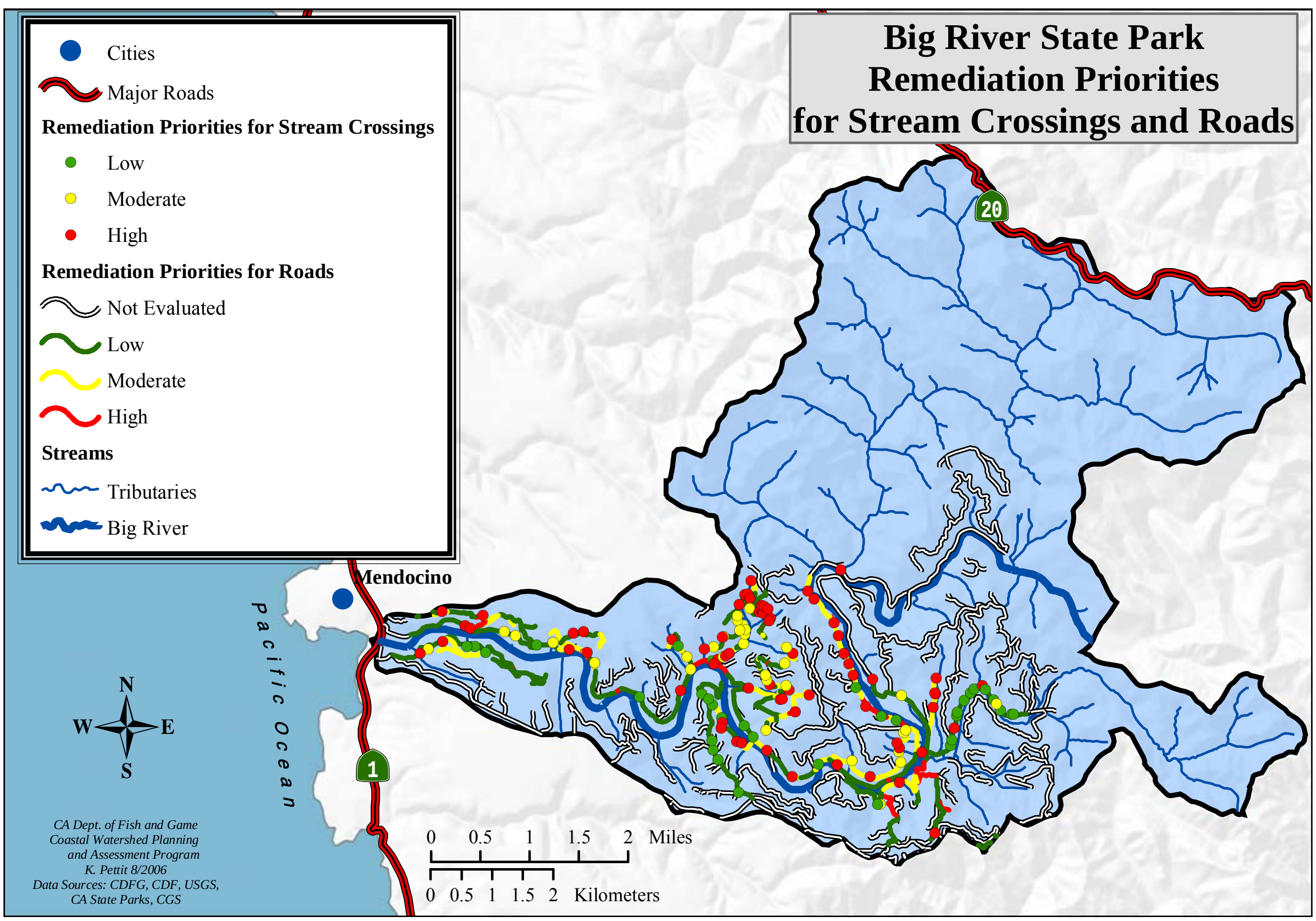


Figure 87. Map of roads and watercourse crossings prioritized by restoration by CGS in Big River State Park (CGS 2004).

Refugia Areas

The NCWAP interdisciplinary team identified and characterized refugia habitat in the Coastal Subbasin by using professional judgment and criteria developed for north coast watersheds. The criteria included measures 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. The team also used results from information processed by the NCWAPs EMDS at the stream reach scale.

The most complete data available in the Coastal Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the NCWAP team.

Salmonid habitat conditions in the Coastal Subbasin on surveyed streams are generally rated as high potential refugia. The Big River Estuary and the Little North Fork Big River provide the best salmonid habitat in this subbasin, while Cookhouse Gulch and Wheel Gulch provide low quality refugia. Additionally, the estuary, mainstem, and Little North Fork Big River serve as critical contributing areas. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 119. Tributary salmonid refugia area ratings in the Coastal Subbasin.

Stream	Refugia Categories*				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
Big River Estuary			X			X	X
Big River			X			X	X
Dry Dock Gulch				X			
Laguna Creek			X				X
Railroad Gulch		X					X
Little North Fork Big River		X				X	X
Cookhouse Gulch				X			X
Rocky Gulch		X					X
Manly Gulch				X			X
Thompson Gulch		X					X
East Branch of the Little North Fork Big River		X					X
Berry Gulch		X					X
Berry Gulch Tributary		X					X
Wheel Gulch				X			X
Subbasin Rating		X					X

*Ratings in this table are done on a sliding scale from best to worst. See page 45 in the Introduction and Overview section for a discussion of refugia criteria.

Responses to Assessment Questions

What are the history and trends of the sizes, range, and relative health and diversity of salmonid populations within the Coastal Subbasin?

Findings and Conclusions:

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast;
- Based on limited CDFG, USFWS, HTC, and SONAR presence surveys and surveys documented by NMFS since the 1960s, the distributions of coho salmon and steelhead trout do not appear to have changed;
- Reaches surveyed by CDFG since 1990 that contained salmonids usually had both coho salmon and steelhead trout present;
- Six tributaries, the mainstem Big River, and the estuary had records of coho salmon and steelhead trout since 1990. One additional tributary also recorded only coho salmon.

What are the current salmonid habitat conditions in this subbasin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Erosion/Sediment

- Pebble counts and V* measurements in one sampled tributary (Berry Gulch) and McNeil samples in the Little North Fork indicated excessive amounts of fine material in these streams. This could indicate unsuitable conditions for salmonids.

Riparian/Water Temperature

- There are no temperature data for the Big River Estuary; however, it is expected that the water temperatures in the mainstem Big River quickly cool once they reach the estuary due to the marine influence;
- Water temperatures at monitoring sites on the mainstem of the Big River in this subbasin were fully unsuitable in all years monitored with high diurnal fluctuations (7.9-9.9°F) and high maximum temperatures (75-76°F). This could indicate unsuitable conditions for salmonids in the mainstem upstream of the estuary;
- Most of the Little North Fork Big River and tributary monitoring sites exhibited low diurnal fluctuations suggesting good shading, and/or good flow conditions and/or a tempering marine influence. This indicates suitable conditions for salmonids;
- It is probable that the Little North Fork has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream with wide channels.

Instream Habitat

- In the estuary, escape and ambush cover are unsuitable for salmonids;
- A high incidence of shallow pools, and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in all nine surveyed tributary reaches;
- Areas of dry channel found during CDFG stream surveys on eight streams may indicate fish passage problems in some tributaries.

Gravel Substrate

- Cobble embeddedness values in most surveyed reaches were unsuitable for salmonid spawning success.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as high potential refugia;
- The Big River Estuary and the Little North Fork Big River provide the best salmonid refugia in this subbasin;
- The estuary, mainstem Big River, and Little North Fork Big River serve as critical contributing areas.

Other

- Winter access problems for adult fish at a non-existent channel near the mouth of Manly Gulch may be stopping it from being utilized for habitat by salmonids;
- Small tributaries along the estuary are blocked to fish passage by perched culverts;
- There are no water chemistry data for the estuary and little data for this subbasin as a whole;
- Water chemistry data available from a small stream near the estuary, but not related to the water chemistry in the estuary itself, indicated that alkalinity and sodium appeared to be below the minimum water quality criteria;

- Basic water chemistry on the mainstem Big River both upstream and downstream of the Little North Fork appear to be within applicable numeric Basin Plan water quality objectives. However, sodium at the mainstem sites upstream and downstream of the Little North Fork confluence exceeds its criteria. Additionally, copper exceeds its criteria at sites upstream of the Little North Fork. However, these findings may be artifacts of the type of sampling procedure used;
- Total and fecal coliform was detected on the mainstem at the sites upstream of the Little North Fork confluence. It appears as though the levels detected are not hazardous for humans.

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions in this subbasin?

Findings and Conclusions:

- Many of the tributaries in this subbasin are intermittent in their upper reaches and usually have summer and fall flows less than 1 cfs;
- This subbasin is underlain by Franciscan Coastal Belt geology. The western part of the subbasin has much lower relief and longer slopes than the eastern part. Debris slide slopes are common in the steep streamside slopes next to the Big River and larger deep-seated landslides occur in the eastern upland sections. Inner gorges also occur along some of the eastern Big River tributaries;
- About 10% of the slides found across the Big River Basin and 10% of sediment delivered in the basin were in this subbasin. The Little North Fork PW had the highest number of slides while the Lower Big River PW had the highest volumes of sediment delivered;
- Redwood and Douglas fir forest has historically and continues to dominate this subbasin. Additional vegetation includes tan oak, madrone, alder, bishop pine, pygmy cypress, willow, and blueblossom. Pre-European forests consisted of mostly large old-growth trees. Today, trees averaging 12-24 inches dbh cover 46% of the subbasin and trees averaging greater than 24-inch dbh cover 48%;
- The estuary is bordered by mudflats, eelgrass beds, and salt marshes as well as permanent riparian vegetation consisting mainly of alders and willows. Studies of the estuary and air photos document encroachment of forest vegetation on marshes and a decrease in marsh vegetation along the estuary over the past 100 years;
- Air photo analysis of the Big River Estuary since 1936 shows that the channel has narrowed and the floodplain has grown at the expense of mudflat and subtidal areas as estuary banks have prograded. Blockage or reduction in tidal influence has occurred in the upper flats while a filling of sloughs and increase in mudflat height is found in the lower flats;
- CGS found that the topographic relationship between the terrace surface and the active channel at the Wonder Plot (RM 9) has not changed substantially in the past 80 years;
- CGS found that channel narrowing seen since 1900 in the lower Big River is likely the result of a river channel reclaiming itself after the multiple decades of channel clearing, splash dam flooding, and battering by logs in transport;
- Photo mapping of channel fluvial features of the Mouth of Big River PW between 1984 and 2000 found that the main channel of Big River gained negative channel features due to accumulation of sediment. The length of negative channel features grew significantly from 18.5% (1984) to 34.7% (2000) of the length of the lower mainstem channel in this PW.

How has land use affected these natural processes?

Findings and Conclusions:

- Over 40 years of splash dam logging across the basin before 1920 likely greatly accelerated erosion and widened the width of the channels across the basin, though significant bed lowering along the lowermost reaches of Big River associated with splash dams is unlikely;
- Early splash damming and barrier removal projects starting in the 1950s cleared many streams in this subbasin of timber-related woody debris. The lack of instream complexity seen today likely resulted from these past practices;

- Construction of near stream railroads and roads constricted stream channels and destabilized streambanks throughout this subbasin;
- Most of the existing roads in Big River State Park are in satisfactory condition, but will deteriorate within five to ten years without annual maintenance, introducing sediment into stream channels;
- Wetland habitat was reduced by historic sawmill complexes on the Big River flats;
- Historic timber harvest activities reduced riparian canopy; however, canopy is currently suitable along surveyed tributary reaches in this subbasin;
- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times (50% of trees in watercourse buffer zones have dbh less than 24 inches). The small diameter of near stream trees across this subbasin limits the recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;
- A lack of LWD throughout the Big River Basin also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance.

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

- Based on the information available for this subbasin, it appears that salmonid populations are currently being limited by reduced habitat complexity, high water temperatures in the mainstem Big River, and embedded spawning gravels.

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

<u>Recommendations:</u>

Flow and Water Quality Improvement Activities

- Protect instream flows in Little North Fork Big River, Railroad Gulch, and Laguna Creek for thermal refugia from the warmer mainstem Big River in the summer.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated that nine out of eleven surveyed tributaries in this subbasin had road sediment inventory and control as a top tier tributary recommendation;
- Continue to support and encourage current and future road management programs undertaken by California State Parks;
- California State Parks should follow the recommendations of CGS (2004) in treating identified sediment sources on roads and road crossings within Big River State Park;
- All roads within Big River State Park and their associated watercourse crossings required for public safety, existing easements, future restoration effort success, and public access must be maintained to high standards (CGS 2004);
- Encourage the use of appropriate Best Management Practices for all land use and development activities to minimize erosion and sediment delivery to streams. For example, low impact yarding systems should be used in timber harvest operations on steep and unstable slopes to reduce soil compaction, surface disturbance, and resultant sediment yield;
- California Department of Parks and Recreation should consult with appropriate resource professionals to assist in transitioning industrial timberlands on the Big River State Park to self-sustaining forest (CGS 2004).

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the main channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated that all nine surveyed tributaries and the mainstem Big River have increase escape cover as a top tier tributary recommendation;

- Leave large wood in estuarine channels, on the beach, and on stream banks for potential recruitment into the estuary;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the Big River Estuary, mainstem Big River, Little North Fork Big River, Railroad Gulch, East Branch Little North Fork Big River, Berry Gulch Tributary, and Rocky, Thompson, and Berry gulches;
- Create a channel under the main road to connect Manly Gulch to Little North Fork Big River to address winter access problems for adult fish at the non-existent channel at Camp Three.

Education, Research, and Monitoring Activities

- Conduct surveys of ten small tributaries entering the estuary through blocked culverts in the Big River State Park to determine if they provide salmonid habitat;
- Establish monitoring stations to track instream sediment along the estuary;
- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- Assess water temperature and dissolved oxygen in the estuary as there is currently no data on these indicators;
- Establish long-term water chemistry monitoring stations in the lower mainstem Big River. If there are indications of problems, monitoring should be implemented in tributaries as necessary to determine the source of the problem;
- Encourage the involvement of SONAR in fish and habitat monitoring activities.

Subbasin Conclusions

The Coastal Subbasin contains the Big River Estuary, which is of major importance to fish and wildlife along the Mendocino coast. The estuary provides a large area of wetlands that are essential habitat to many species including salmonids. Salmon and steelhead habitat conditions in the estuary, the mainstem Big River, and the tributaries of the Coastal Subbasin are generally in the early stages of recovery from past disturbance and suitable for salmonid production. Reduced habitat complexity, high water temperatures in the mainstem Big River, and embedded spawning substrate are limiting factors to salmonid populations in some parts of the subbasin.

There are many opportunities for improvements in conditions, especially with the recent creation of the Big River State Park. Water temperature monitoring, road maintenance and decommissioning, and adding LWD to improve channel complexity are examples of appropriate improvement activities that can be initiated in the park. However, aquatic and channel conditions at the most downstream section of a river system are a response to watershed products transported from throughout the basin. Fine sediment and warm water are two watershed products most deleterious to the estuary's fisheries. As such, long term improvements in the estuary must be produced by careful watershed stewardship throughout the Big River Basin.

Middle Subbasin

Mainstem Big River in 2002, Photo by Steve Cannata

The Middle Subbasin includes the watershed area of the mainstem Big River just above its confluence with Peterson Gulch up until its confluence with the South Fork Big River, not including the North Fork Big River (Figure 88). Stream elevations range from 40 feet at boundary with the Coastal Subbasin to 210 feet at the confluence with the North Fork Big River. The highest point in the subbasin is above Dietz Gulch at approximately 1,560 feet. The Middle Subbasin is the smallest of the three Big River Subbasins at 17.9 square miles and occupies 9.9% of the total basin area. Most of the subbasin is owned by Hawthorne Timber Company and Mendocino Redwood Company and is managed for timber production.

Climate

The Middle Subbasin has average annual rainfall ranging from 55 inches closer to the coast to 65 inches farther inland. Temperatures are typically cooler in the winters and warmer in the summers than in the Coastal Subbasin, although the marine influence still moderates temperatures and prevents extremes. Temperatures average from 40 to 45°F.

Hydrology

The Middle Subbasin is made up of two CalWater Units (Figure 88). There are 11.8 perennial stream miles in 14 perennial tributaries in this subbasin. There are an additional 14.2 miles of the mainstem Big River (Table 120). The mainstem Big River in the Middle Subbasin is a fourth order river using the Strahler (1964) classification. The tributaries to the mainstem in this subbasin are first and second order streams with drainage areas ranging from less than one square mile to just over five square miles (Figure 89).

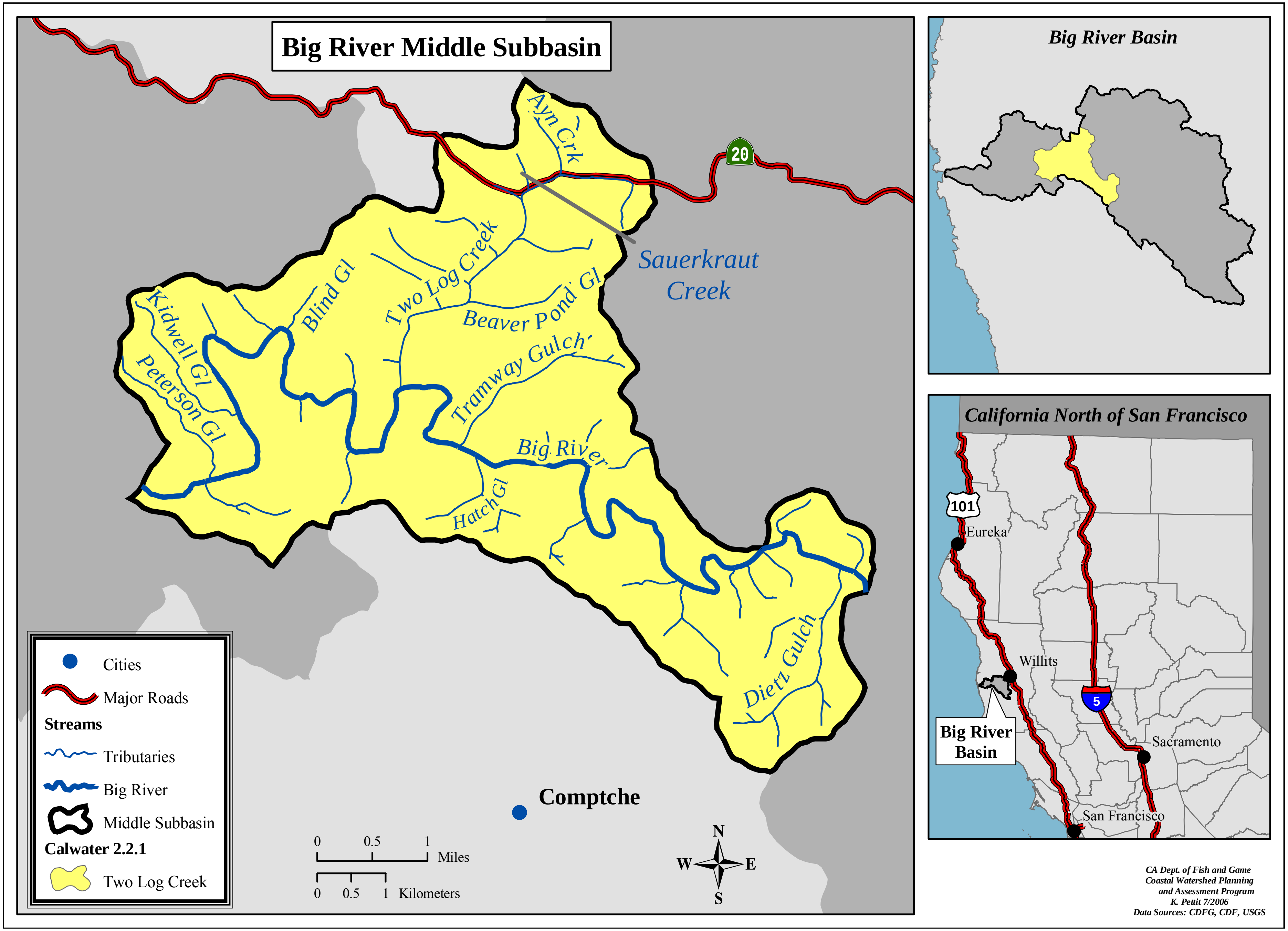


Figure 88. Middle Subbasin and CalWater 2.2a planning watersheds.

Table 120. Tributaries to the Big River in the Middle Subbasin by river mile from 7.5 minute topographic maps.

CalWater Planning Watershed	R.M.	Bank (L,R)	Stream	Perennial (Miles)	Intermittent (Miles)	Stream Order
Two Log Creek	17.6	L	Peterson Gulch		1.7	Intermittent
	19.1	L	Kidwell Gulch	1.9		1
	20.1	L	Unnamed Tributary		0.5	Intermittent
	20.9	L	Unnamed Tributary		0.6	Intermittent
	21.0	L	Blind Gulch	0.5	0.2	1
	21.9	R	Unnamed Tributary		0.9	Intermittent
	22.5	L	Unnamed Tributary		0.4	Intermittent
	23.1	R	Unnamed Tributary	0.5	0.1	Intermittent
	24.1	L	Two Log Creek	2.5	2.0	2
			Saurkraut Creek		0.4	Intermittent
			Ayn Creek		0.8	Intermittent
	25.5	L	Tramway Gulch	1.7	0.6	1
	25.7	R	Unnamed Tributary/Hatch Gulch	1.0	0.4	1
	26.5	L	Unnamed Tributary	0.5	0.1	1
	26.8	L	Unnamed Tributary	0.5	0.2	1
	26.9	L	Unnamed Tributary	0.4	0.1	1
	27.4	R	Unnamed Tributary	0.6	0.1	1
	29.4	R	Unnamed Tributary	0.4	0.3	1
	29.4	R	Unnamed Tributary	0.8	0.4	1
	31.2	L	Unnamed Tributary	0.3	0.3	1
	32.0	R	Dietz Gulch	0.1	3.6	1
	32.1	L	Unnamed Tributary		0.6	Intermittent

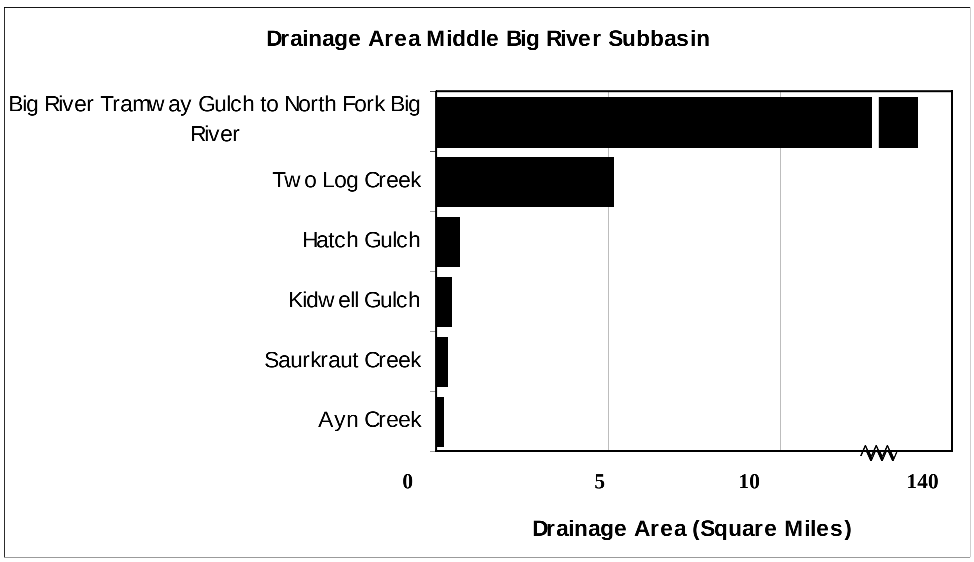


Figure 89. Drainage area of streams surveyed by CDFG in the Middle Subbasin.

Geology

The Middle Subbasin has a high percentage of area in low slope classes. The predominant geologic type is Coastal Belt Franciscan.

Landsliding

A GMA (2001) analysis of landslides by time period found that about 8.2% of the number of slides across the entire basin were in the Middle Subbasin. The period from 1953 to 1965 had the highest number of landslides (Table 121).

Table 121. Middle Subbasin number of delivering slides by study period and PW (GMA 2001a).

Planning Watershed	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total All Periods	
	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)
Two Log Creek	49	25.1	69	35.4	22	11.3	25	12.8	30	15.4	195	100

Landslide volume estimates from the same time periods showed that 6.7% of sediment delivered to streams across the Big River Basin occurred in the Middle Subbasin (GMA 2001a) (Table 122). The period from 1953 to 1965 had the highest volume of sediment delivered.

Table 122. Volume of delivering slides by study period by PW in the Middle Subbasin (GMA 2001a).

Planning Watershed	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%f or Entire Watershed For Entire Period
Two Log Creek	114,506	22.4	271,379	53.2	40,550	7.9	58,623	11.5	25,398	5.0	510,455	6.7

The CGS (2005) landslide potential map classified 49% of the Middle Subbasin in the high and very high potential categories (Table 123).

Table 123. Landslide Potential in the Middle Subbasin.

Landslide Potential Category	Area (Sq. Miles)	% of Subbasin
Very Low	1.6	9
Low	4.2	23
Moderate	3.3	18
High	6.8	38
Very High	2.0	11

RC Ownership

The MRC Watershed Analysis found a total of 257 landslides in the MRC ownership of the Middle Subbasin. Of that total, 220 were shallow-seated landslides (debris slides, torrents, or flows) and 37 were deep-seated landslides (rockslides) (Table 124). Most landslides in the study period occurred in the 1970s.

Table 124. Shallow-seated landslide summary for lands under MRC ownership in the Middle Subbasin.

Planning Watershed	Number of Landslides			
	1970s	1980s	1990s	Total
Two Log Creek	84	57	79	220

MRC 2003

The majority of landslides in the MRC ownership are debris slides and rockslides. Only about 4% of shallow landslides observed were debris flows and debris torrents while none were earth flows (Table 125).

Table 125. Percent of landslides by type and PW for lands under MRC ownership in the Middle Subbasin.

Planning Watershed	Debris Slides	Debris Torrents	Debris Flows	Rockslides	Earth Flows
Two Log Creek	81%	3%	1%	16%	0%

MRC 2003

MRC also delineated Mass Wasting Map Units across their ownership, to represent general areas of similar geomorphology, landslides processes, and sediment delivery potential for shallow-seated landslides. For more details, see the Geology Appendix.

MRC found that 89% of the shallow-seated landslides within their ownership in the Middle Subbasin delivered sediment to a watercourse. A total of 154,042 tons of mass wasting sediment delivery was estimated for the study period, or 97 tons/square mile/year. Over their entire ownership, MRC found that 34% of mass wasting sediment delivery occurred in the 1970s, 19% occurred in the 1980s, and 48% occurred in the 1990s. The relatively high amounts of sediment delivered in the 1990s are thought to be related to high rainfall events in the 1990s.

Fluvial Geomorphology

Out of 12 stream reaches surveyed by CDFG in the Middle Subbasin, the most common Rosgen channel types were B4 and G4 (Table 126). There were seven different channel types present.

Table 126. Channel types in surveyed streams of the Middle Subbasin.

Stream	Reach	Survey length (Miles)	Channel Type
Kidwell Gulch	1	0.6	F4
	2	0.2	B4
	3	0.1	A4
Two Log Creek	1	1.4	B4
	2	0.1	B3
	3	1.3	B4
	4	0.1	G1
	5	<0.1	G6
Saurkraut Creek	1	0.1	G4
Ayn Creek	1	0.3	G4
Big River Tramway Gulch to North Fork Big River	1	4.7	F4
Hatch Gulch	1	0.5	G4

Of the seven stream segments surveyed by MRC in this subbasin, the most common Rosgen channel type was F4 (Table 127). There were six channel types present. MRC measured various stream channel characteristics and grouped channels across their ownership into different geomorphic units. MRC plans to use the geomorphic unit classification to examine habitat-forming processes within the channels.

Table 127. Channel Types in streams surveyed by the MRC on their ownership in the Middle Subbasin.

Stream	Segment	Survey Length (Miles)	Channel Type
Big River	BT1	0.3	F4
	BT2	0.3	F4
Two Log Creek	BT4	0.1	Cb4,F4
	BT4(2)	0.1	F4
Beaver Pond Gulch	BT5	0.0	B4,G4
Tramway Gulch	BT12	0.0	E4,C4
Dietz Gulch	BT26	0.1	E4,C4

MRC 2003

Vegetation

Redwood-Douglas-fir forests cover 85% of the Middle Subbasin, with the remainder made up mostly of tan oak, madrone, and alder (Table 128). Almost 70% of tree stands are composed of small trees (Table 129) and just over half of the subbasin is covered by trees with 90% crown canopy density (Table 130).

Table 128. Acreage and proportion of area of vegetation classes in the Middle Subbasin.

Class	Acres	%
Redwood - Douglas-fir	9,652	85
Douglas-Fir	219	2
Tan Oak, Madrone, Alder	1,032	9
White, Black or Live Oak & Bay Laurel	40	0
Blueblossom Ceanothus	150	1
Manzanita, Chamise, Scrub Oak	0	0
Bishop Pine, Pygmy Cypress, Willow	0	0
Grass	180	2
Wet Meadows	0	0
Water	0	0
Barren / Rock	151	1
Urban/Developed	0	0
Totals	**11,424**	**100%**

Table 129. Vegetation size class in the Middle Subbasin.

Planning Watershed	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Two Log Creek	64	0.6	317	2.9	7,647	69.9	2,872	26.2	42	0.4

Table 130. Density of vegetation in the Middle Subbasin.

Planning Watershed	Percent Crown Canopy Density										Total Acres
	0%		10-69%		70%		80%		90%		
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	
Two Log Creek	482	4	720	6	2,237	20	1,550	14	6,436	56	11,424

Total density of all species - conifers and hardwoods. Most of the 0 percent density crown canopy is grasslands, water, and shrub species.

Fire and Fuels

Areas of high and very high fuel rank dominate the Middle Subbasin, with areas of moderate fuel rank in the higher elevations. The 1931 Comptche fire burned 1,851 acres in the southwest corner of the subbasin and the smaller 2000 McGuire fire burned 14 acres along the northern border.

Land Use

The Middle Subbasin is composed mostly of large sized parcels owned by the Hawthorne Timber and Mendocino Redwood companies. A small section of the JDSF and some 40-1,500 acre parcels make up the remainder of the subbasin.

On September 16, 1874, Daniel Milliken closed his logging camp at the Piers. He then opened a hand logging camp (no animals) at Two Log (Crossing) Creek. Indian trails had crossed that tributary at two different places, hence the original name.

The predominant landuse in this subbasin is timber harvest. Recently, some of the timber land has been considered for sale to conservation groups (Eilperin 2006). An additional land use is rock quarries. A rock quarry in the Two Log Creek watershed was mined in 2000, resulting in the deposition of sediment into the Creek (EPA 2001).

Forest Management

For the past 250 years timber harvest has dominated the history of the Middle Subbasin. Almost 75% of the subbasin was harvested by 1944 (Table 131). Hawthorne Timber Company and Mendocino Redwood Company currently own 90% of the subbasin.

Table 131. Timber harvest in the Middle Subbasin.

Time Period	Acres Harvested	Percent of Subbasin Harvested
1852-1944	8,256	72.3
1945-1964	2,794	24.5
1965-1974	1,241	10.9
1975-1984	715	6.3
1985-1992	4,580	40.1
1993-2001	4,316	37.8
Total	**21,903**	

Early timber harvest activities across the subbasin consisted mostly of clear cuts and fire, while recent harvests are a mix of harvest techniques including single or group tree selections, shelterwood removal, seed tree removal, and commercial thinning (Figure 90). Yarding methods have also changed over time, from predominantly cable ground before World War II, to tractor yarding in the post war years, and increasingly towards cable suspended and helicopter since 1985 (Figure 91).

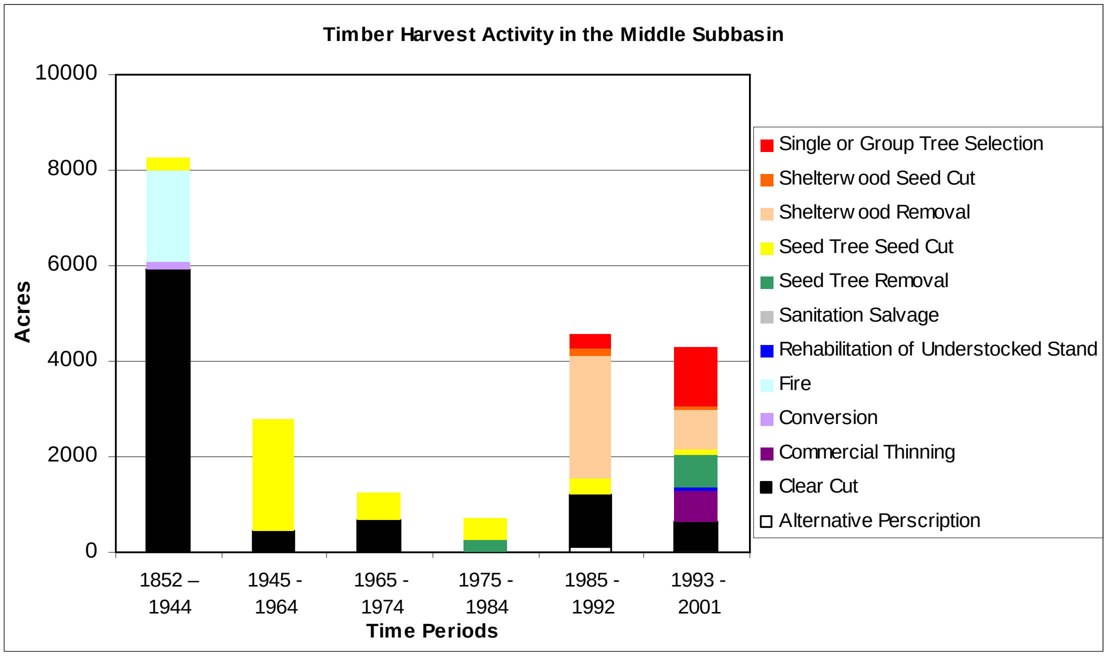


Figure 90. Acres of timber harvest activities in the Middle Subbasin.

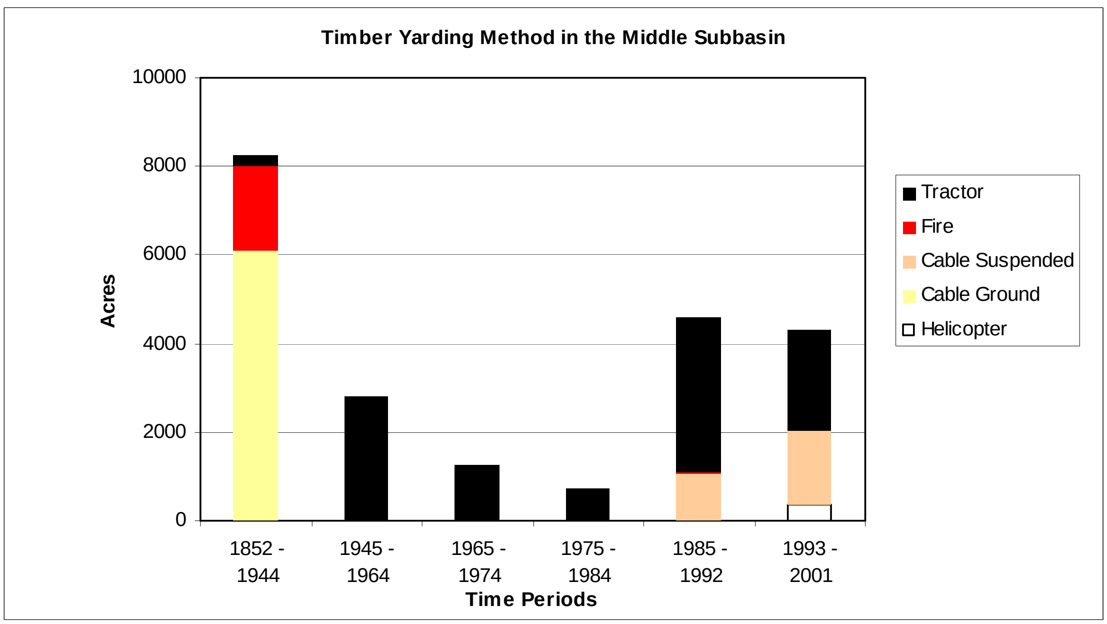


Figure 91. Acres of timber harvest yarding methods in the Middle Subbasin.

GMA (2001) calculated the harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, for 1937-1951, 1952-1964, 1965-1977, 1978-1987, and 1988-2001. The most intense harvesting occurred from 1989 to 2000 when 41% of the watershed was harvested. Over the entire study period, an estimated 113% of the Middle Subbasin was harvested, with roughly 36% of that happening from 1989-2000. The percentage harvest exceeds 100% because some areas were harvested multiple times. Of the harvesting that occurred in the 1989-2000 time period, it was reported that approximately 18% was clear-cut and 80% partial cut, with 2% skid trails.

A CDF analysis of disturbance levels across this subbasin found high disturbance level activities occurring on more acres before 1974 (Figure 92). Activities after 1974, shifted to low and moderate disturbance levels, but occurred over more acres per year than in the past.

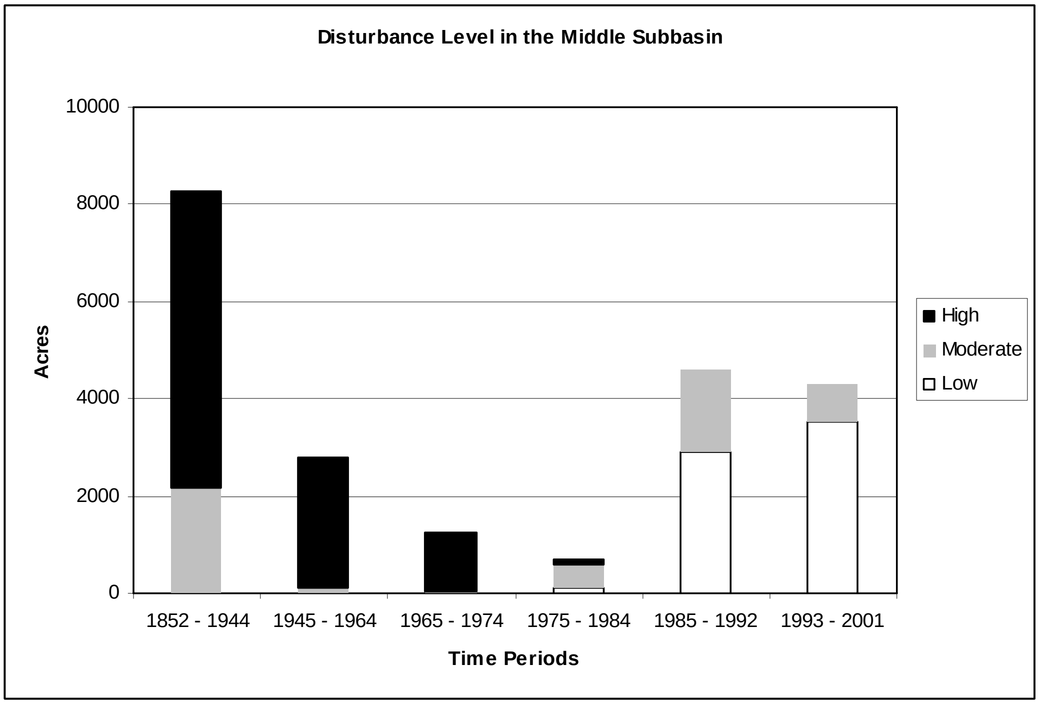


Figure 92. Acres by disturbance level in the Middle Subbasin.

Roads

The Middle Subbasin has a total of 154.2 miles of roads, the vast majority of which are not paved (Table 132). This is the lowest total number of road miles of the three Big River subbasins. However, overall road density is 8.6 miles per square mile, which is the highest of all the subbasins. Road construction has increased since 1988, with increasing timber harvest.

Table 132. Length of truck roads by period and road surface.

Period	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
Up thru 1936	7.0	2.2	4.3	13.5	0.4	0.1	0.2	0.8
1937 - 1952	17.2		2.4	19.7	1.0		0.1	1.1
1953 - 1965	26.1		14.8	40.9	1.5		0.8	2.3
1966 - 1978	6.6		0.8	7.4	0.4		0.0	0.4
1979 - 1988	19.4		0.2	19.5	1.1		0.0	1.1
1989 - 2000	51.9		1.3	53.2	2.9		0.1	3.0
Total	**128.3**	**2.2**	**23.8**	**154.2**	**7.2**	**0.1**	**1.3**	**8.6**

Lengths are roads constructed in time period, not cumulative.

Water Quality

In the Middle Subbasin temperature monitoring records were available for the Big River mainstem and nearly all of the major tributaries due largely to participation by Mendocino Redwood Co. (MRC), Hawthorne Timber Company (HTC), and the CDF at JDSF. Sediment records were available for bulk, permeability, and, though not represented in the IA tables, by a sediment source analysis conducted by Graham Mathews Associates (GMA). GMA also performed subsurface sediment (gravel) permeability measurements at one station in the mainstem below the North Fork Big River. D50 (pebble counts) were completed at four cross sections in the mainstem below the North Fork Big River, however, the counts were only conducted at the head's of riffles and therefore not comparable to traditionally conducted pebble counts that encompass the length and width of entire riffles. Physical-chemical water quality data were completely lacking.

Temperature

Continuous water temperature data logging devices were deployed by HTC and MRC at a total of nine (9) locations in the Middle Subbasin (Figure 94). With the exception of 1997, water temperature was monitored in one or more locations in the Middle Subbasin during the years 1993 to 2001.

During the initial data review, the several potential issues with the water temperature data were noted. Data were reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the Middle Subbasin, all but three of the available water temperature data sets met the data quality criteria and were used for this assessment.

The three data sets that were not used were excluded because either the period of record was too short or the loggers began recording too late or stopped recording too early. In each of these cases, there is evidence that the peak temperatures and MWATs were missed based on more complete records at other sites during the same season.

There are a total of three monitoring sites on Two Log Creek (HTC BIG5, HTC BIG4, and MRC 76-2). These monitoring sites are all located in the middle and lower reaches of Two Log Creek. HTC BIG5 was monitored for one year, HTC BIG4 was monitored for five years, and MRC 76-2 was monitored for two years. Based on data from the middle Two Log Creek (HTC BIG5) site, the water temperature was fully suitable with a maximum observed MWAT of 60ºF (Figure 93). Data collected at the two lower Two Log Creek Sites (HTC BIG4 and MRC 76-2), indicated water temperatures between fully suitable with a minimum observed MWAT of 58ºF and undetermined with a maximum observed MWAT of 64ºF. The only tributary to Two Log Creek that was monitored was Beaver Pond Gulch (MRC 76-20), which was monitored for one year. Based on these data, the water temperatures at this site were fully suitable with a maximum MWAT of 56°F. This may contribute to lower water temperatures in Two Log Creek if flows are sufficient. However, based on the flat peaks in the thermograph for MRC 76-20, the temperatures recorded may be more representative of a thermally stratified pool or a site with a significant groundwater component. It does appear that Two Log Creek does provide some cooling effect to the mainstem Big River.

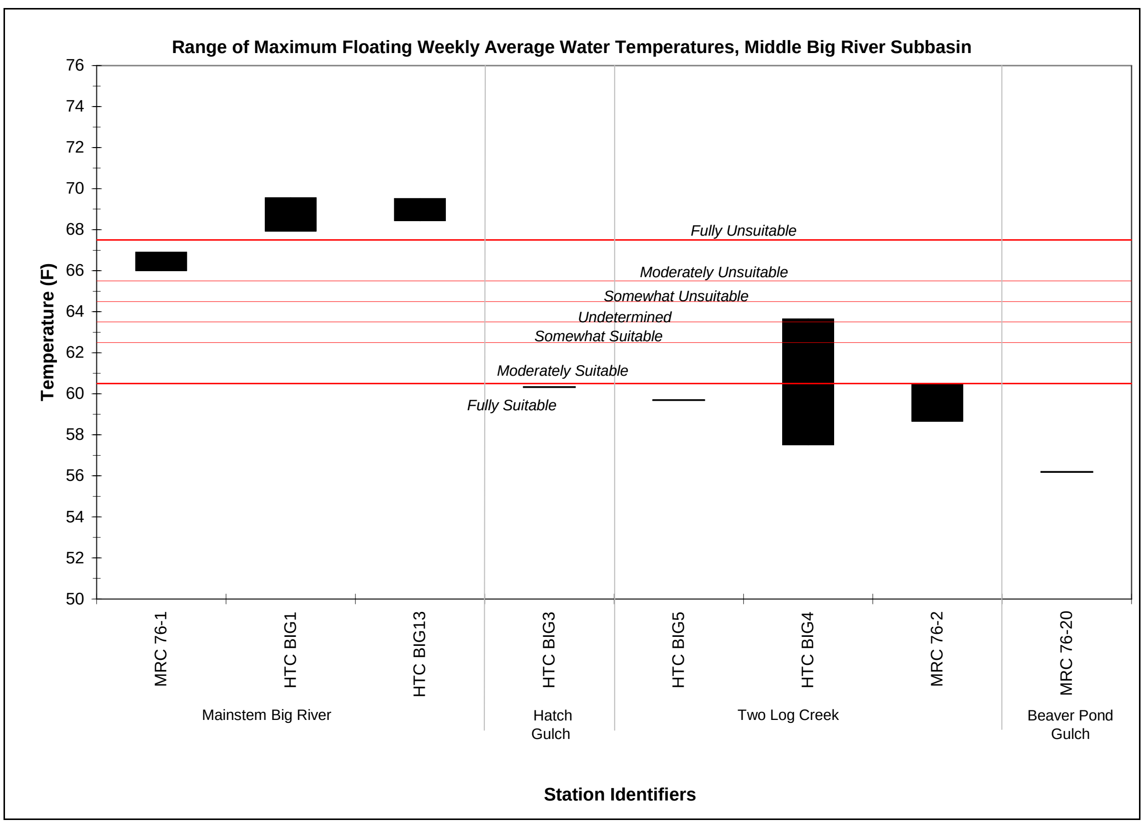


Figure 93. Range of MWATs, Middle Subbasin.

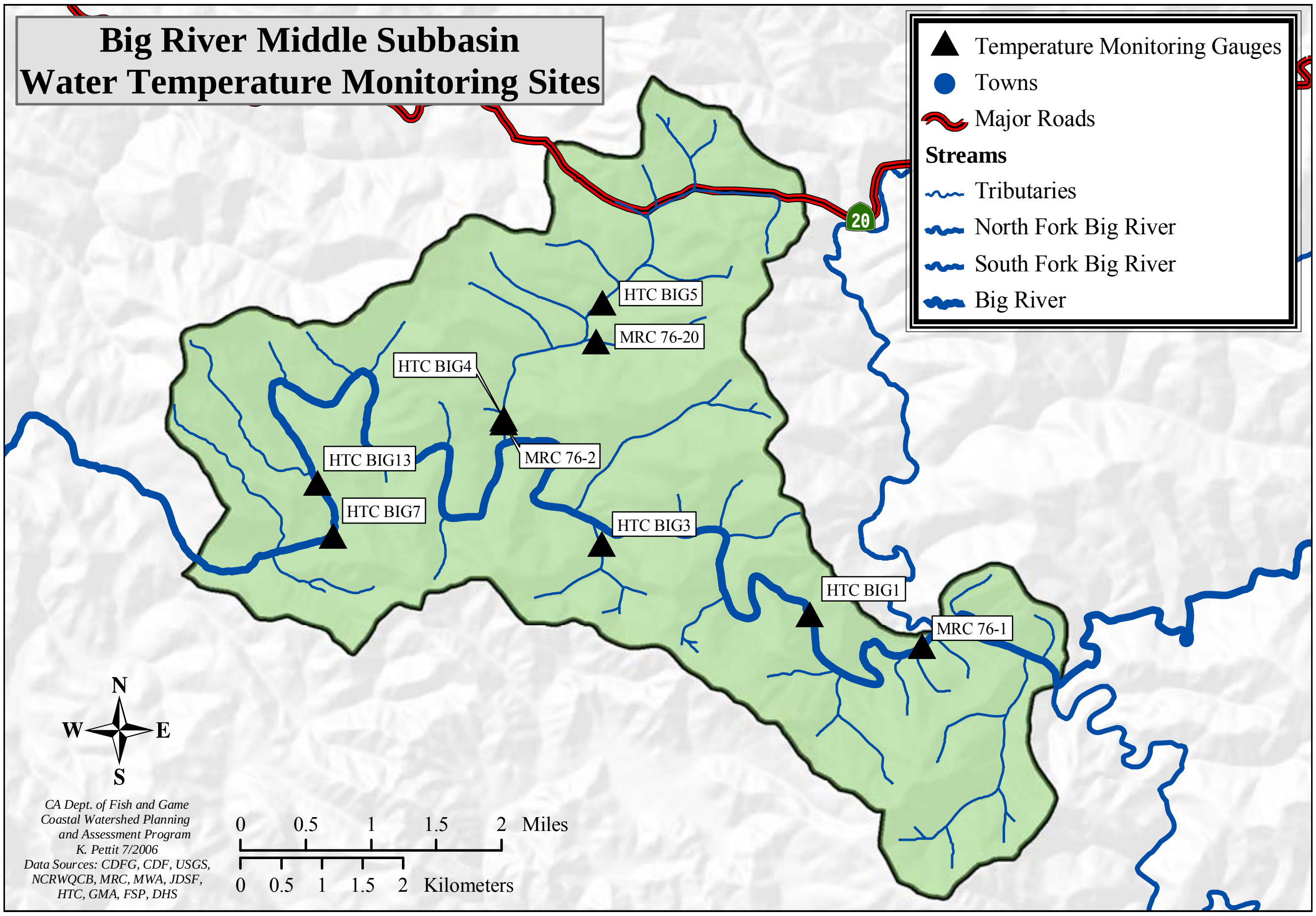


Figure 94. Water temperature monitoring sites, Middle Subbasin.

With the existing information, there is no apparent trend in water temperatures in Two Log Creek as it moves downstream. This is evident in Figure 93. However, large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites (MRC 76-2 and HTC BIG4). In addition, there also appears to be a downward trend in MWATs at the lower Two Log Creek sites, which may reflect canopy re-growth. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of these sites in approximately 1988 and 1993. A 1994 Landsat map (KRIS Big River) shows open areas and small trees near these monitoring sites, but a map of the change in vegetation between 1994 and 1998 did not indicate a loss or gain of vegetation. However, this relationship should be explored further in the Big River Synthesis Report.

There are a total of three monitoring sites on mainstem Big River (MRC 76-1, HTC BIG1, and HTC BIG13). One site is located after the confluence with the North Fork (MRC 76-1) and was monitored for three years. The next site downstream is located between the North Fork and Two Log Creek (HTC BIG1) and was monitored for seven years. The last site is located below the confluence with Two Log Creek (HTC BIG13) and was monitored for three years.

The monitoring site below the confluence with the North Fork (MRC 76-1) recorded water temperatures that were moderately unsuitable with a maximum observed MWAT of 67ºF. In addition, the maximum water temperature recorded was 73ºF, slightly below the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.7-12.8ºF) at this site also suggest poor cover and/or low flows.

USFWS monitored one site on the mainstem Big River at the confluence with the North Fork Big River in 1973 (Perry 1974). The monitoring site recorded water temperatures that were moderately unsuitable with a MWAT of 66ºF. In addition, the maximum water temperature recorded was 81ºF, over the lethal limit for salmonids (75ºF). Comparison of 1973 data with recent monitoring at the same location (MRC 76-1) appears to show average water temperatures remaining similar.

The monitoring site on the mainstem Big River between the North Fork and Two Log Creek (HTC BIG1) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 76ºF, above the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (7.5-11.4°F) suggest poor canopy and/or flow conditions.

The monitoring site on the mainstem Big River below Two Log Creek (HTC BIG13) recorded water temperatures that were fully unsuitable with a maximum observed MWAT of 70ºF. In addition, the maximum water temperature recorded was 77ºF, above the lethal limit for salmonids (75ºF). The diurnal fluctuations at this site (10.8-11.1°F) suggest poor canopy and/or flow conditions.

A site on Hatch Gulch (HTC BIG3), a tributary to the mainstem Big River between the North Fork and Two Log Creek (but below HTC BIG1), was monitored for one year. Monitoring at this site recorded water temperatures that were fully suitable with a maximum observed MWAT of 60ºF. The diurnal fluctuations at this site were minimal. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River.

In general, water temperatures appear to increase between MRC 76-1 and HTC BIG1. While there are no significant tributaries between these sites, it appears that poor canopy in the vicinity of MRC 76-1 may be contributing to the apparent rise in water temperature. Available THP maps (KRIS Big River) indicate that harvesting occurred in the vicinity of this site in approximately 1997. A 1994 Landsat map (KRIS Big River) shows open areas and small trees near these monitoring sites, and a map of the change in vegetation between 1994 and 1998 indicated a loss of vegetation in the area. However, this relationship should be explored further in the Big River Synthesis Report.

The summary values for each of the monitoring sites in the middle Big River are presented in Table 133.

Table 133. Water temperature summary, Middle Subbasin.

SITE	MAX MWAT	MWAT Trend	range of max diurnal fluctuations		Seasonal Max	Years of Data
Fully Suitable (50-60ºF)						
MRC 76-20	56	NA	4.2	4.2	57	1
HTC BIG5	60	NA	3.9	3.9	62	1
HTC BIG3	60	NA	5.6	5.6	62	1
MRC 76-2	60	-1.8	6.7	7.6	64	2
Moderately Suitable (61-62ºF)						
—	—	—	—	—	—	—
Somewhat Suitable (63ºF)						
—	—	—	—	—	—	—
Undetermined (64ºF)						
HTC BIG4	64	-2.2	6.7	12.0	68	5
Somewhat Unsuitable (65ºF)						
—	—	—	—	—	—	—
Moderately Unsuitable (66-67ºF)						
MRC 76-1	67	0.9	9.7	12.8	73	31
Fully Unsuitable (68ºF)						
HTC BIG13	70	-1.1	10.8	11.1	77	3
HTC BIG1	70	-1.5	7.5	11.4	76	7

1 Only 2 years diurnal.

Sediment

In 1996 and 1997, the Hawthorne Timber Company collected McNeil samples at one site in the Middle Subbasin (BIG 4), located on Lower Two Log Creek (Figure 95). In 2001, GMA collected McNeil core samples at two locations (GMA 10 and GMA 11). MRC collected McNeil core samples in one location in 2000 (MRC S5), including permeability measurements, thalweg profiles, and stream cross-sections.

The HTC McNeil core samples were collected using a volumetric method, and are therefore directly comparable to the Big River TMDL targets. In general, four McNeil cores were collected at each of the two riffles sampled. A summary of McNeil data collected at BIG 4 is shown in (Table 134). Raw data were not available for this assessment.

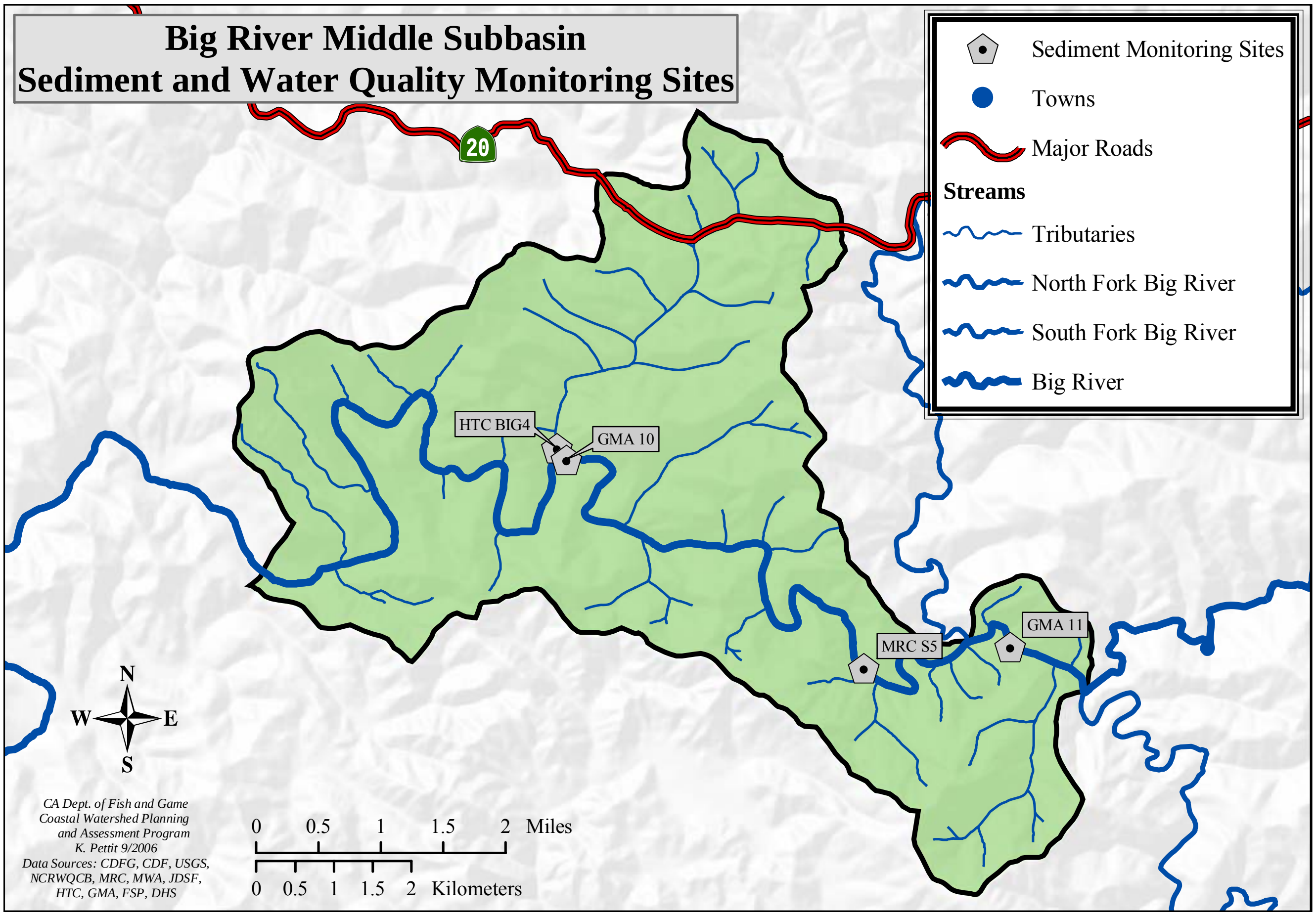


Figure 95. In-stream sediment and water quality monitoring sites, Middle Subbasin.

Table 134. Bulk sediment data summary (volumetric), Two Log Creek (HTC).

Site Name	Site Location	Year	Sieve Size (mm)	Median Percent Less Than
BIG 4	Lower Two Log Creek	1996	4.0	29.8%
			0.85	18.3%
		1997	4.0	27.0%
			0.85	20.2%

Based on the summary data shown in Table 134, the sediment in the sub 6.5 mm size class may have met the Big River TMDL target of ≤ 30% in 1996 and 1997. Because a 4-mm sieve was used, the comparison was made with the 4-mm value instead of 6.5 mm. Therefore, the actual percentage less than 6.5 mm is likely somewhat higher. The sediment in the sub 0.85 mm size class exceeded the Big River TMDL target of ≤ 14% in both 1996 and 1997. In the sub 0.85 mm size class, the amount of fine sediment appeared to increase between 1996 and 1997. However not enough data are available to establish a trend and it could be due to sample variability.

In 2001, GMA collected McNeil core samples in the Middle Subbasin at two sites. One site is located on the Big River, just upstream of the confluence with Two Log Creek (GMA 10). The other site is also located on the Big River, downstream of the confluence with the South Fork Big River and upstream of the confluence with the North Fork Big River (GMA 11). In all size classes, more fine sediment was present at the mainstem Big River site above Two Log Creek (GMA 10) than was present at the site above the confluence with the North Fork Big River (GMA 11). However, because the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment.

MRC also collected McNeil core samples at one site in the Middle Subbasin in 2000. The site is located below the confluence with the North Fork Big River on the mainstem of the Big River (MRC S5). As with the GMA McNeil data, MRC also collected the McNeil cores using the gravimetric method. As a result, these data were not comparable to Big River TMDL target for fine sediment.

MRC also recorded permeability measurements at pool tail-outs in the same stream segments where bulk sediment samples, cross-sections, and thalweg profiles were collected. In the stream segments measured, a total of 25 or 26 median permeability values were recorded. The 25^{th}, 50^{th}, and 75^{th} percentile values for each of these stream segments were then plotted. The mainstem Big River site (MRC S5) had moderate median permeability values. Using the empirical formula (McBain and Trush 2000), this stream segment was expected to have roughly 31-38% survival to emergence. The McNeil sample collected in the same stream segment also suggests relatively good fine sediment conditions when compared to other MRC samples in other subbasins.

Discussion

Collectively, temperature data at the thirteen stations monitored show that the Big River Mainstem is unsuitable for salmonids when MWATs are considered, and nine out of thirteen temperature records are suitable when peak seasonal maximum temperature thresholds are considered. Tributaries to the mainstem had seven of ten MWAT records in the Middle Subbasin that were found suitable for salmonids. All of the seasonal peak maximum temperatures, ten records, were found suitable for salmonids during those seasons monitored.

Bulk sediment sampling results by MRC and GMA at three stations using the gravimetric method in the Big River mainstem were found to be suitable for salmonids when referenced to the thresholds for fine sediment <0.85 mm of 14% and < 6.4 mm at 30%. HTCs bulk sampling results, calculated using the volumetric method, showed that gravel size classes were barely within suitable criteria for survival to emergence, but exceeded that for egg incubation within stream locations where it is likely salmonids would build redds. Gravel permeability was only conducted in the Big River mainstem below the NF Big River. The results of the permeability data were calculated to have a 22% survival to emergence for salmonids. Interestingly, data gathered by Kondolf, 2001, calculate a 50% survival to emergence of salmonids when percent fines <0.85mm = 14%; at this site for this metric all of the <0.85 mm sediment sizes (three samples) were below this 14% threshold but, through permeability calculations, would have a survival to emergence expectation of 22%, less than half of Kondolf's calculations.

Riparian Conditions

There are 1,104 acres in the Middle Subbasin in stream buffers, which includes the areas between the water and gravel bars in the lower reaches (Table 135). Across the subbasin, the area around the watercourses is well vegetated, as indicated by the 70 to 100% density class which accounts for 97% of the area (Table 136). Also 73% of the buffer area is in 80% canopy density or better, and 53% of the area is in the 90-100% canopy closure class. These numbers are substantiated by high canopy densities found along stream reaches surveyed by CDFG and discussed in *Fish Habitat Relationships*.

Table 135. Density of riparian vegetation in the Middle Subbasin by planning watershed.

Planning Watersheds	Acres by Percent Crown Canopy Density										Acres in Buffer
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	
Two Log Creek	15	6	2	10		2	3	255	222	589	1,104

Table 136. Percentage of stream buffer area in higher canopy closure classes in the Middle Subbasin.

Planning Watersheds	Percent of Buffer Area by Crown Canopy Density				
	70%	80%	90%	70%+	80%+
Two Log Creek	23	20	53	97	73

As shown in Table 137, 67% of the trees in the watercourse buffer zone are small, which are 12 to 24 inch dbh trees. Small, medium/large and large trees (>12 inches dbh) could be recruited to streams as LWD. Overall, 95% of the buffer zone area in the basin is in these size classes.

Table 137. Acres by vegetation size class in watercourse buffer zone in the Middle Subbasin.

Planning Watersheds	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Two Log Creek	0	0	44	4	735	67	303	27	6	1

MRC examined LWD recruitment potential on their ownership in the Middle Subbasin. They found that LWD recruitment potential is poor in their ownership (Figure 96). An exception is the Two Log Creek watershed, where most stands have high or moderate recruitment potential ratings. Past harvesting in riparian areas has lead to small-sized, open stands composed of mixed conifer hardwood species.

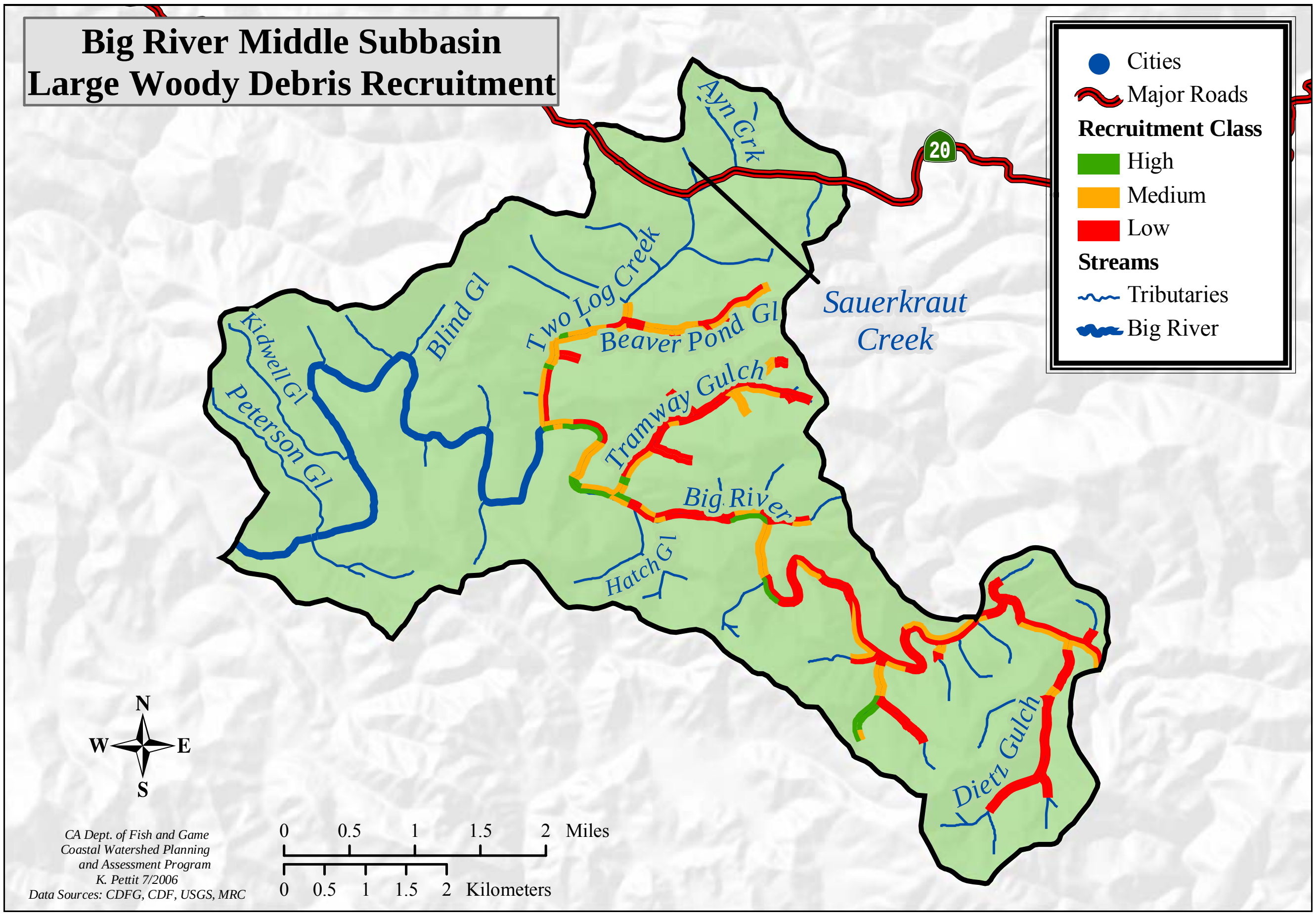


Figure 96. Map of LWD recruitment potential classes on MRC ownership in the Middle Subbasin (MRC 2003).

Fish Habitat Relationship

Past Habitat Conditions

CDFG stream surveys were conducted for three tributaries in the Middle Subbasin from 1950 to 1966. The results of the historic stream surveys are not quantitative and can not be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions. The data from these stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair and poor were based upon the opinion of the biologist or scientific aid conducting the survey.

Surveys describe good spawning habitat, shallow pools, and good cover in Two Log Creek and Tramway Gulch (Table 138). Many debris jams were described on both streams as well. A 1958 CDFG flyover survey of two tributaries found no significant fish passage barriers.

Table 138. Habitat comments from surveys conducted in the Middle Subbasin from 1950-1966.

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
Two Log Creek	10/16/1958 (flyover)	Streambed not visible due to heavy conifer cover	
	7/28/1959	Substrate mostly gravel with some rubble and bedrock with occasional patches of sand; good spawning, stream has long stretches of adequate spawning gravel present throughout; pools average 10 feet long and 6 feet wide and 1 foot deep, range from 6 feet deep to 1 foot deep; good shelter in the form of heavy to tree shade and undercut banks; average water temperature 54°F	17 log jams; many barriers
	6/20/1966	Pool substrate mostly fine gravel with some coarse gravel; pools upstream have more fine gravel and less sand; riffle substrate generally fine gravel with a little coarse gravel; pool areas from poor to good - appears to be more shallow riffle area than pool area; normal pool 2 feet deep; fair shelter provided by undercut banks, tree stumps, log jams, logs, a few large rocks, and some overhanging terrestrial plants; water temperatures ranged from 60-65°F	No barriers observed; two log jams near the mouth
Dietz Gulch	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)	Appeared unimportant to fish life	
Tramway Gulch	10/16/1958 (flyover)	Streambed not visible due to heavy canopy cover	
	Undated (1950s?)	Substrate mostly gravel, some sand, little rubble; good spawning areas, extensive stretches of gravel throughout; small, fairly frequent pools, average size 6 feet long and 2 feet wide and 6 inches deep; Good shelter provided by undercut banks, logs, and some rocks; average water temperature 58°F	Infrequent old log jams, only partial barriers
	8/5/1966	The first half mile of stream presently suitable for spawning steelhead; average pools are 15 inches deep; an occasional pool was 2 feet deep; pool frequency is less than that of riffles; pools caused by log jams, current, undercut banks, single logs wedged crosswise to the direction of flow, and a few scattered boulders and some bedrock; 1:2 pool to riffle ratio; shelter adequate in first half mile; water temperature 59°F	First log jam not presently a total barrier, but may silt in soon- approximately 100 yards above mouth; first complete total barrier approximately 2-300 yards above first jam- very small jam but evidently stopped spawners as no fry could be observed above, consists of some silted in logs that the adults apparently cannot pass over; upstream from total barrier- large log jam, another total barrier, water drops about 12 to 15 feet over silted in jam; above there are several small jams; however, are in logged area and stream intermittent

Current Conditions

Habitat Inventory Surveys

CDFG stream inventories were conducted for 9.4 miles on 13 reaches of five tributaries and the mainstem Big River in the Middle Subbasin since 1993 (Table 139, Figure 97). Additionally, the Two Log Creek was surveyed in 1996 through 1998 as well as 2002. Stream attributes that were collected during stream inventories included canopy cover, embeddedness, percent pools, pool depth, and pool shelter.

Table 139. Surveyed streams in the Middle Subbasin.

Stream	Survey Date	Reach	Survey Length (Miles)
Kidwell Gulch	June 2002	1	0.6
	June 2002	2	0.2
	June 2002	3	0.1
Two Log Creek	June 2002	1	1.4
	June 2002	2	0.1
	June 2002	3	1.3
	June 2002	4	0.1
	June 2002	5	<0.1
Saurkraut Creek	July 1998	1	0.1
Ayn Creek	July 1998	1	0.3
Big River Tramway Gulch to North Fork Big River	July 2002	1	4.7
Hatch Gulch	July 1996	1	0.5

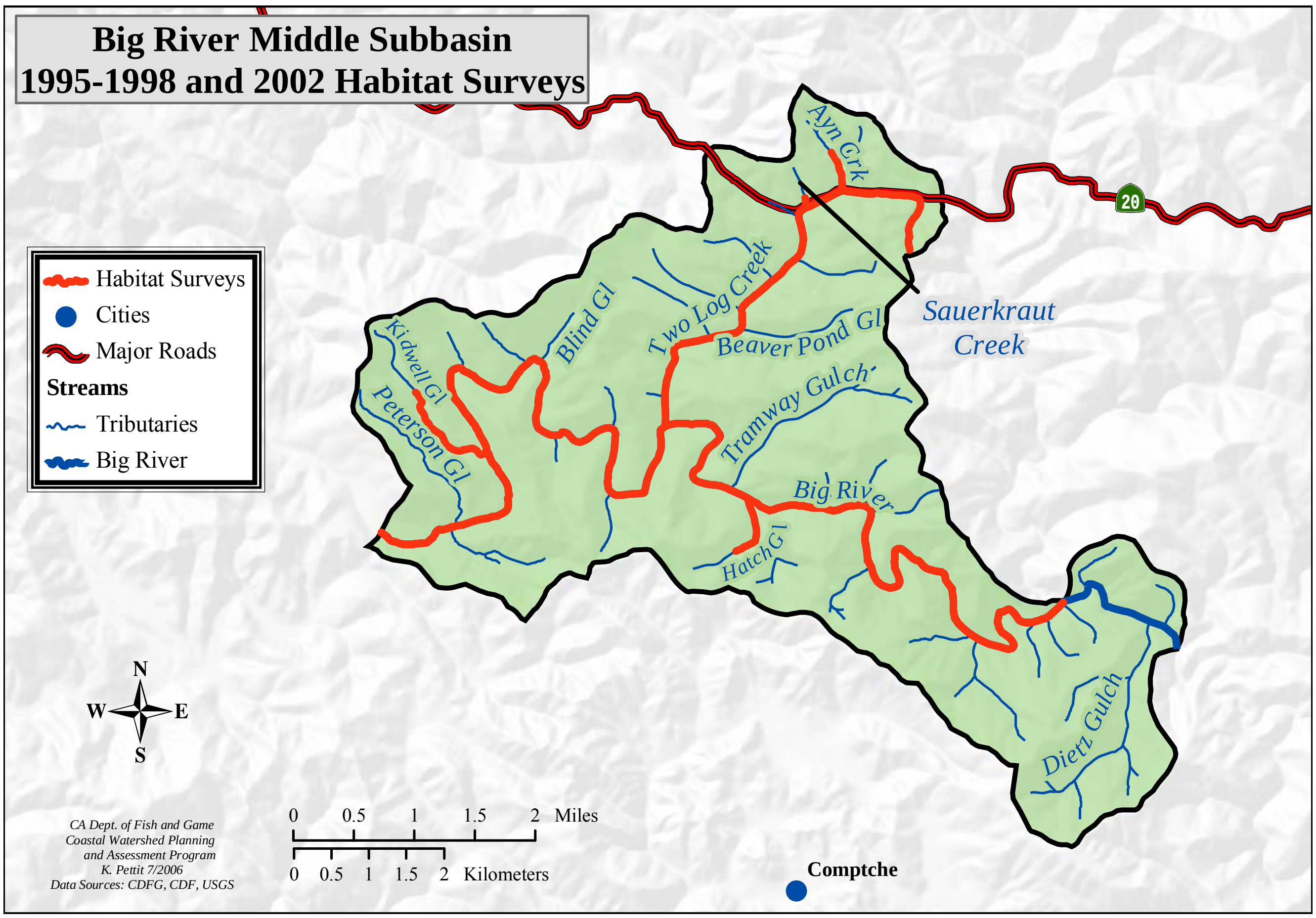


Figure 97. CDFG surveyed streams in the Middle Subbasin.

Stream attributes tend to vary with stream size. For example, larger streams generally have more open canopy and deeper pools than small streams. This is partially a function of wider stream channels and greater stream energy due to higher discharge during storms. Surveyed streams in the Middle Subbasin ranged in drainage area from 0.2 to 137.7 square miles (Table 140).

Canopy cover, and relative canopy cover by coniferous versus deciduous trees were measured at each habitat unit during CDFG stream surveys. Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Furthermore, canopy levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel, as well as the insulating capacity of the stream and riparian areas during winter.

In general, the percentage of stream canopy cover increases as drainage area, and therefore channel width, decrease. Deviations from this trend in canopy may indicate streams with more suitable or unsuitable canopy relative to other streams of that subbasin. All of surveyed tributary reaches of the Middle Subbasin except for Hatch Gulch showed percent canopy levels that meet target values for maintaining water temperature to support anadromous salmonid production (Figure 98). Surveyed reaches of the mainstem Big River did not meet target values; however, as the mainstem Big River is a fourth-order river in this subbasin, the target values do not apply. Kidwell Gulch has the highest canopy cover values of Middle Subbasin.

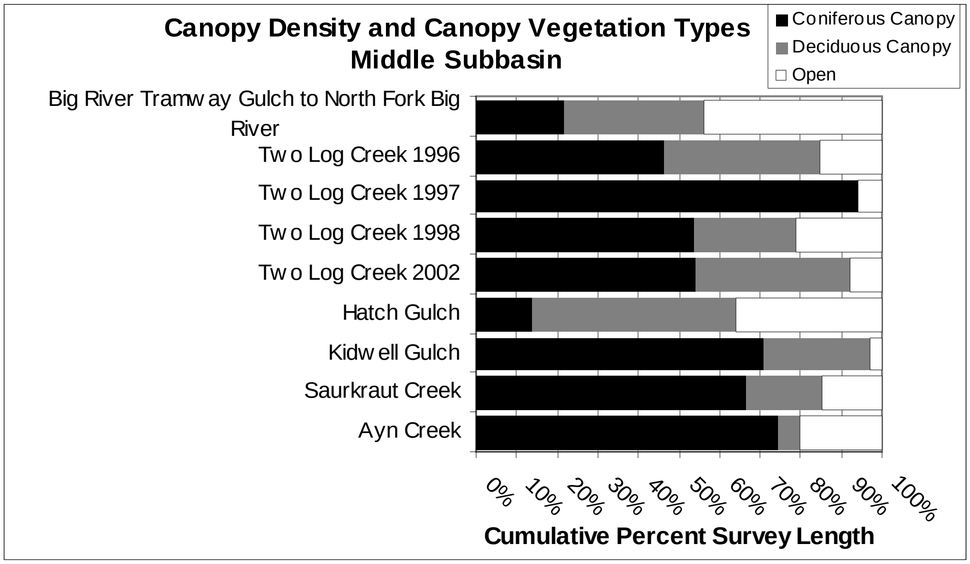


Figure 98. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Middle Subbasin.

Averages are weighted by unit length to give the most accurate representation of the percent of a stream under each type of canopy. Streams are listed in descending order by drainage area (largest at the top).

Cobble embeddedness was measured at each pool tail crest during CDFG stream surveys. Embeddedness values in the Middle Subbasin generally do not meet target values for successful salmonid egg and embryo development. However, Figure 99 illustrates how stream reaches rated as unsuitable overall may actually have some suitable spawning gravel sites distributed through the stream reach. Additionally, cobble embeddedness meets target values in Sauerkraut Creek and the mainstem Big River from Tramway Gulch to North Fork Big River.

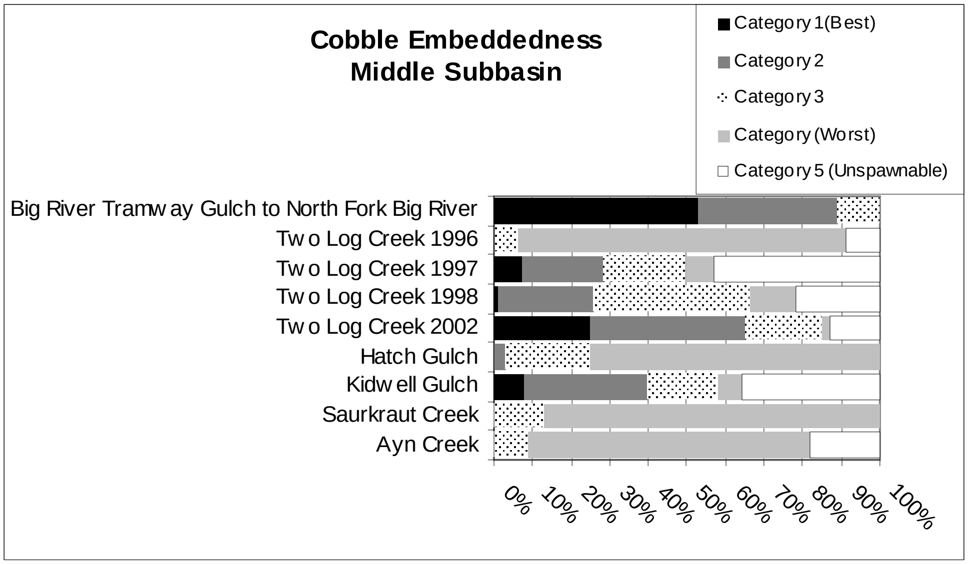


Figure 99. Cobble embeddedness categories as measured at every pool tail crest in surveyed streams in the Middle Subbasin.

Cobble embeddedness is the % of an average sized cobble piece at a pool tail out that is embedded in fine substrate: Category 1 = 0-25% embedded, Category 2 = 26-50% embedded, Category 3 = 51-75% embedded, Category 4 = 76-100%, and Category 5 = unsuitable for spawning due to factors other than embeddedness (e.g. log, rocks). Streams are listed in descending order by drainage area (largest at the top).

Pool, flatwater, and riffle habitat units observed were measured, described, and recorded during CDFG stream surveys. During their life history, salmonids require access to all of these types of habitat. A balanced proportion of these habitat types is desirable. Most of the surveyed Middle Subbasin streams have greater than 20% pool habitat by length (Figure 100). Dry units were measured, and obviously indicate poor conditions for fish. Several culverts were also measured on Ayn Creek.

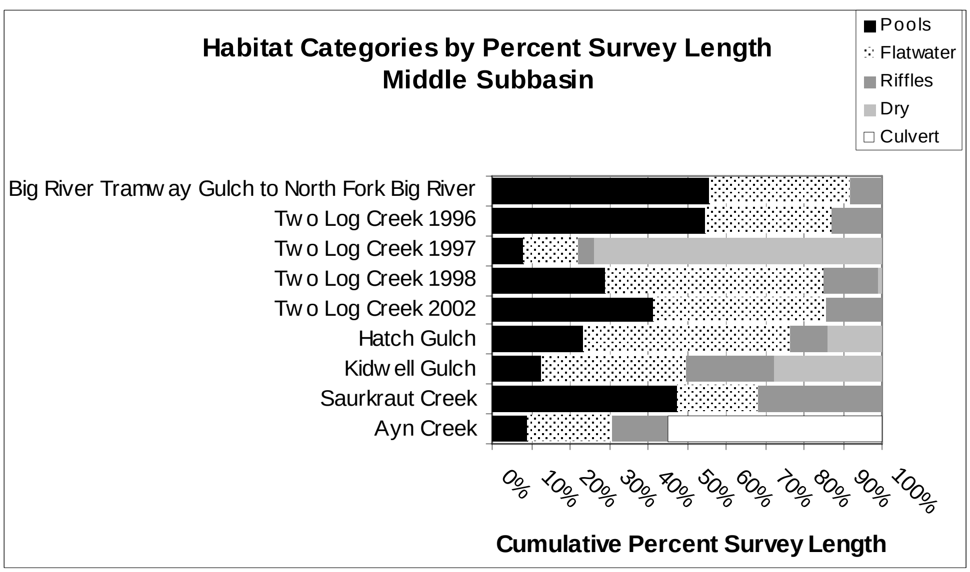


Figure 100. The percentage of pool habitat, flatwater habitat, riffle habitat, dewatered channel, and culverts by survey length in the Middle Subbasin.

Streams are listed in descending order by drainage area (largest at the top).

Pool depths were measured during CDFG surveys. Primary pools are determined by a range of pool depths, depending on the order (size) of the stream. A reach must have 30 – 55% of its length in primary pools for its stream class to meet target values for supporting salmonids. Generally, larger streams have deeper pools. Deviations from the expected trend in pool depth may indicate streams with more suitable or unsuitable pool depth conditions relative to other streams of that subbasin. Most surveyed tributaries in this subbasin have less than 20% pools greater than two feet deep by length (Table 140). The mainstem Big River from Tramway Gulch to North Fork Big River has the most pool habitat with maximum depth greater than two feet.

Table 140. Percent length of a survey composed of pools in the Middle Subbasin. Streams are listed in descending order by drainage area.

Stream	Drainage Area (Sq. Miles)	Stream Order	Percent Pools by Survey Length	Percent Pools >2.0 by Survey Length	Percent Pools >2.5 by Survey Length	Percent Pools >3.0 by Survey Length	Percent Pools >4.0 by Survey Length
Big River Tramway Gulch to North Fork Big river	137.7	4	57.0	56.5	55.4	49.3	35.4
Two Log Creek 1996	5.2	2	54.9	25.4	17.1	12.2	3.8
Two Log Creek 1997	5.2	2	7.3	0.8	0.0	0.0	0.0
Two Log creek 1998	5.2	2	27.2	19.2	13.4	8.2	1.8
Two Log Creek 2002	5.2	2	41.5	28.4	19.9	11.4	1.6
Hatch Gulch	0.7	1	24.0	24.0	0.0	0.0	0.0
Kidwell Gulch	0.5	1	13.4	1.1	0.8	0.5	0.0
Saurkraut Creek	0.3	1	47.6	9.1	3.9	0.0	0.0
Ayn Creek	0.2	1	9.3	3.0	3.0	1.3	0.0

Pool shelter was measured during CDFG surveys. Pool shelter rating illustrates relative pool complexity, another component of pool quality. Ratings range from 0-300. Shelter scores greater than 100 meet target values for supporting salmonids. Pool shelter ratings in the Middle Subbasin only meet target values in Sauerkraut Creek (Figure 101).

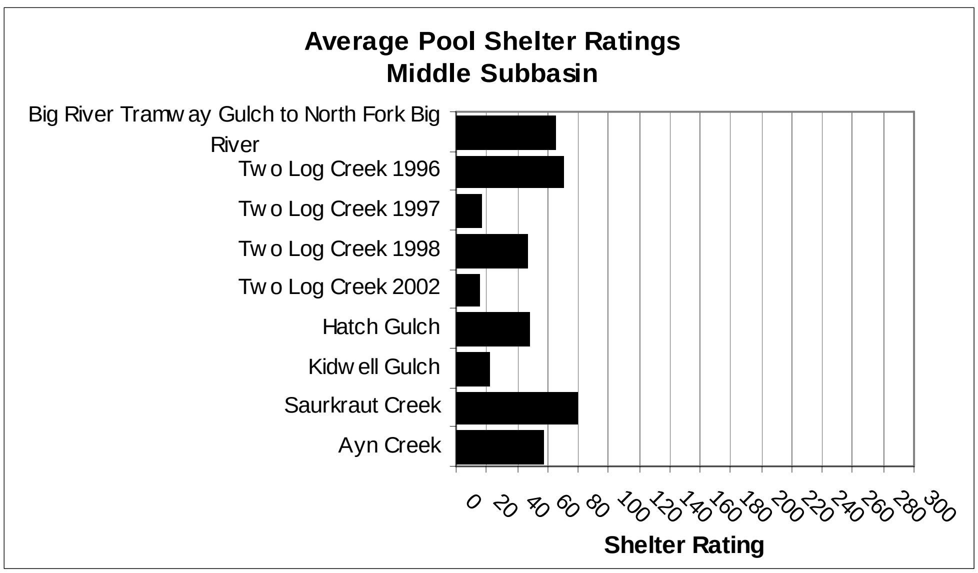


Figure 101. Average pool shelter ratings from CDFG stream surveys in the Middle Subbasin.

Streams are listed in descending order by drainage area.

Pool shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered by nine different cover types was made during stream surveys. The mean percent of pool shelter cover in each cover type was calculated for each surveyed stream. The predominant pool cover types in most Middle Subbasin tributaries are undercut banks, woody debris, root masses, and terrestrial vegetation (Table 141).

Table 141. Mean percent of shelter cover types in pools for surveyed tributaries in the Middle Subbasin. Streams are listed in descending order by drainage area.

Stream	Undercut Banks	Small Woody Debris	Large Woodsy Debris	Root Mass	Terrestrial Vegetation	Aquatic Vegetation	Whitewater	Boulders	Bedrock Ledges
Big River Tramway Gulch to North Fork Big River	9.9	9.4	10.3	11.3	15.6	23.8	0.1	9.1	11.1
Two Log Creek 1996	34.84	19.19	4.35	8.71	6.13	0.0	0.32	11.61	14.84
Two Log Creek 1997	15.0	32.5	22.5	0.0	17.5	0.0	0.0	12.5	0.0
Two Log Creek 1998	33.1	7.3	10.6	14.1	9.7	2.5	2.8	6.3	13.6
Two Log Creek 2002	34.7	10.3	1.8	20.8	4.1	6.2	5.9	15.6	0.6
Hatch Gulch	1.7	0.0	86.7	0.0	0.0	0.0	1.7	6.7	3.3
Kidwell Gulch	20.2	32.5	43.1	0.0	2.1	0.4	1.3	0.4	0.0
Saurkraut Creek	16.7	16.7	30.0	0.0	30.0	0.0	0.0	6.7	0.0
Ayn Creek	8.0	30.0	46.0	0.0	2.0	0.0	8.0	6.0	0.0

MRC Habitat Surveys

MRC inventoried and assessed salmonid habitat along seven stream segments on four tributaries and the mainstem Big River across their ownership in the Middle Subbasin in 2000 (Table 142).

Table 142. Surveyed stream segments on MRC ownership in the Middle Subbasin (MRC 2003).

Stream Segment	Segment ID	Survey Length (feet)
Big River	BT1	1766
Big River	BT2	1628
Two Log Creek	BT4	480
Two Log Creek	BT4(2)	494
Beaver Pond Gulch	BT5	224
Tramway Gulch	BT12	218
Dietz Gulch	BT26	328

Canopy Closure

Canopy closure measured on stream segments across the MRC's ownership in the Middle Subbasin ranged from less than 40% on the mainstem Big River to greater than 90% on all the tributaries surveyed (Figure 102). Low canopy density is expected on higher order streams such as Big River.

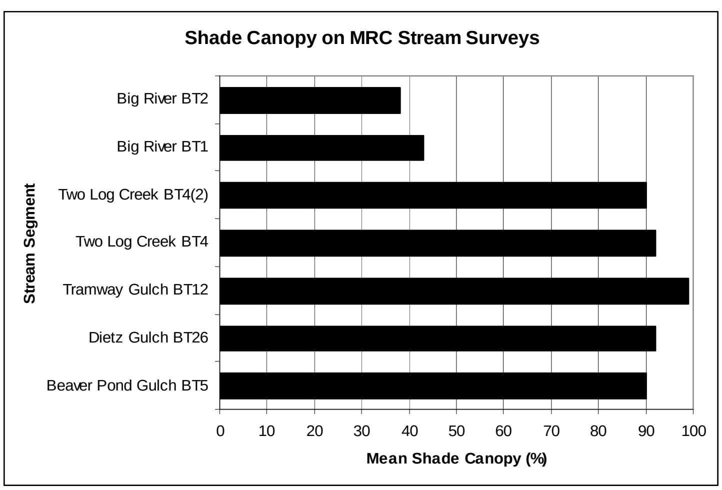


Figure 102. Stream Canopy closure on stream segments in the MRC ownership of the Middle Subbasin (MRC 2003).

Pools

The number of pools measured on stream segments across the MRC's ownership in the Middle Subbasin ranged from five to seven (Table 143). The percentage of pools with mean residual pool depths greater than 3 feet was less than 50% in all segments surveyed. Most pools were bank forced.

Table 143. Pool characteristics measured on stream segments in the MRC ownership of the Middle Subbasin (MRC 2003).

Stream	Segment	% Pool:Riffle: Flatwater by stream length	Total # of pools	Pool Spacing (reach length/bank full/#pools)	Shelter rating	Mean residual pool depth (feet)	% of all pools with residual depth ≥3 ft.	Key LWD + rootwads / 328 ft. with Debris Jams	Pool Mechanism			
									Free	LWD forced	Boulder forced	Bank forced
MRC 'Good' Target		>50%pools	NA	≤ 2.9	>120	NA	>50%	>6.6 in streams >40 feet BFW >3.9 in streams <40 feet BFW	NA			
Big River	BT1	34:10:56	5	4.6	66	1.8	14	0	2	2	0	1
Big River	BT2	48:41:11	7	3.0	71	2.9	30	0	0	0	0	7
Two Log Creek	BT4	60:37:3	5	4.4	55	1.6	16	0.7	0	3	0	2
Two Log Creek	BT4(2)	81:19:0	7	3.5	83	1.4	14	1.3	2	3	0	2
Beaver Pond Gulch	BT5	50:50:0	5	3.8	136	0.7	0	2.9	1	2	0	2
Tramway Gulch	BT12	49:51:0	5	5.5	41	0.7	0	1.5	0	3	0	2
Dietz Gulch	BT26	49:51:0	6	6.6	20	1.0	0	0	2	0	0	4

Spawning Gravel

The amount of spawning gravel measured on stream segments across the MRC's ownership in the Middle Subbasin ranged from 1.5 to greater than 3% (Table 144); the target of greater than three percent was reached on three stream segments. MRC characterized spawning gravels as fair quality on all segments surveyed.

Table 144. Spawning gravel characteristics measured on stream segments in the MRC ownership of the Middle Subbasin.

Stream	Segment	Spawning gravel quantity (%)	% Embeddedness	Sub-surface fines	Gravel Quality	% Over-wintering substrate
MRC 'Good' Target		>3%	<25%	1.0-1.6	1.0-1.6	>40% of units cobble or boulder dominated
Big River	BT1	>3	25-50	Fair	Fair	0
Big River	BT2	>3	25-50	Fair	Fair	0
Two Log Creek	BT4	>3	25-50	Fair	Fair	0
Two Log Creek	BT4(2)	1.5-3	>50	Fair	Fair	10
Beaver Pond Gulch	BT5	1.5-3	>50	Poor	Fair	60
Tramway Gulch	BT12	1.5-3	>50	Fair	Fair	11
Dietz Gulch	BT26	1.5-3	>50	Poor	Fair	0

MRC 2003

Large Woody Debris

MRC (2003) examined LWD loading and demand in 7 stream segments across their ownership in the Middle Subbasin (Table 145). Only one segment on Beaver Pond Gulch made the MRC target value for key LWD. The target value set was 3.3 pieces of LWD per 100 meters for streams with bankfull widths greater than 45 feet; 3.9 with bankfull widths 35-45 feet; 4.9 with bankfull widths 15-35 feet; and 6.6 with bankfull widths less than 15 feet.

Table 145. MRC LWD survey results in the Middle Subbasin (MC 2003).

Stream	# of Segments Surveyed	Pieces of Functional LWD		Total Volume of LWD		Key LWD	Jams	
		Number Including Jams	Number per 328 feet (including jams)	Cubic Yards (including jams)	Cubic Yards per 328 feet (including jams)	Number Including Jams	% of LWD pieces in jams	% of volume in jams
Big River	2	42	3.9-4.2	44.3	1.8-6.6	0	0	0
Two Log Creek	2	28	9.3-9.6	27.9	7.2-11.5	3	0	0
Beaver Pond Gulch	1	49	71.8	33.2	48.6	7	37	60
Tramway Gulch	1	9	13.5	7.3	10.9	1	0	0
Dietz Gulch	1	5	5.0	1.2	1.2	0	0	0

Although debris jams were scarce, they did contain a significant portion of the LWD present when they occurred. MRC also found that a considerable amount of the LWD observed was at least partially buried and thus could not be quantified. LWD was dominated by redwood, which is more stable than hardwood species.

Nearly all surveyed segments contained LWD that was not recently recruited to the stream. It did not appear that much LWD had been contributed within the past ten years. Low recruitment in recent years could be a result of timber harvest practices.

MRC gave surveyed stream segments in the Middle Subbasin low quality LWD ratings (Figure 103, Table 146). Only Tramway Gulch was rated marginal. Combined with the low LWD recruitment potential discussed in the Riparian Conditions section, the low quality LWD ratings across the MRC ownership show that much of the streams are badly in need of LWD. Major channels, such as the mainstem Big River are especially in need of LWD.

Table 146. Instream LWD quality ratings for major streams and sections of streams in MRC ownership in the Middle Subbasin.

Stream	Instream LWD Quality Rating
Big River in Two Log Creek PW	Deficient
Two Log Creek	Deficient
Tramway Gulch	Marginal

MRC 2003

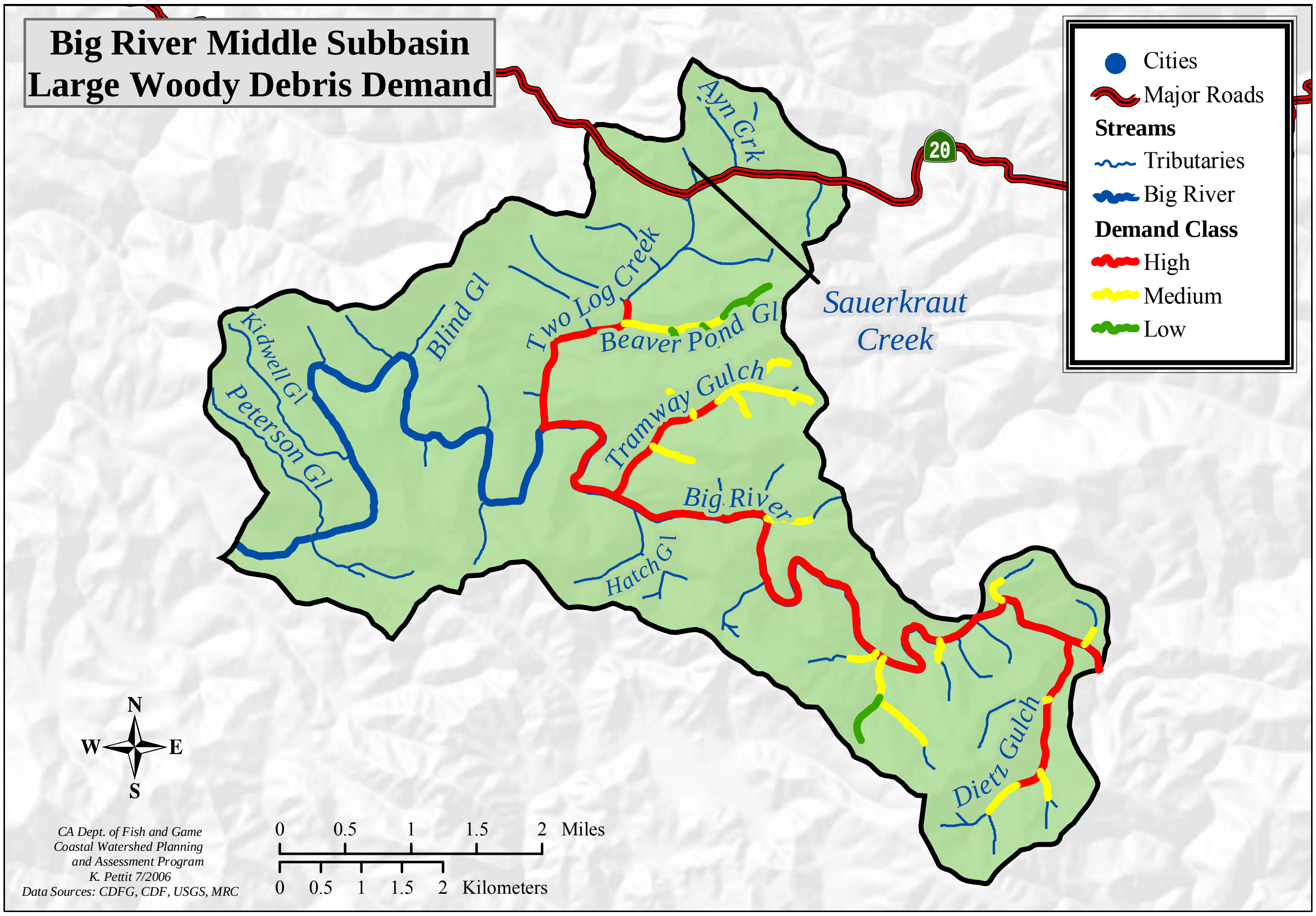


Figure 103. Map of instream LWD demand in MRC ownership in the Middle Subbasin (MRC 2003).

Fish Passage Barriers

Stream Crossings

Although no stream crossings were surveyed in the Middle Subbasin as a part of the coastal Mendocino County culvert inventory and fish passage evaluation conducted by Ross Taylor and Associates (2001), CDFG stream surveys noted culverts on one tributary, Ayn Creek.

Dry Channel

CDFG stream inventories were conducted for 9.4 miles on 13 reaches of five tributaries and the mainstem Big River in the Middle Subbasin. A main component of CDFG Stream Inventory Surveys is habitat typing, in which the amount and location of pools, flatwater, riffles, and dry channel is recorded. Although the habitat typing survey only records the dry channel present at the point in time when the survey was conducted, this measure of dry channel can give an indication of summer passage barriers to juvenile salmonids. Dry channel conditions in the Big River Basin generally become established from late July through early September. Therefore, CDFG stream surveys conducted outside this period are less likely to encounter dry channel.

Dry channel disrupts the ability of juvenile salmonids to move freely throughout stream systems. Juvenile salmonids need well-connected streams to allow free movement to find food, escape from high water temperatures, escape from predation, and migrate out of their stream of origin. The amount of dry channel reported in surveyed stream reaches in the Middle Subbasin is 3.5% of the total length of streams surveyed. This dry channel was found in two streams (Figure 104,

Table 147). Dry habitat units occurred in the middle reaches and at the upper limit of anadromy in both tributaries. Dry channel in the middle reaches of a stream disrupts the ability of juvenile salmonids to forage and escape predation. Lastly, dry channel in the upper reaches of a stream indicates the end of anadromy.

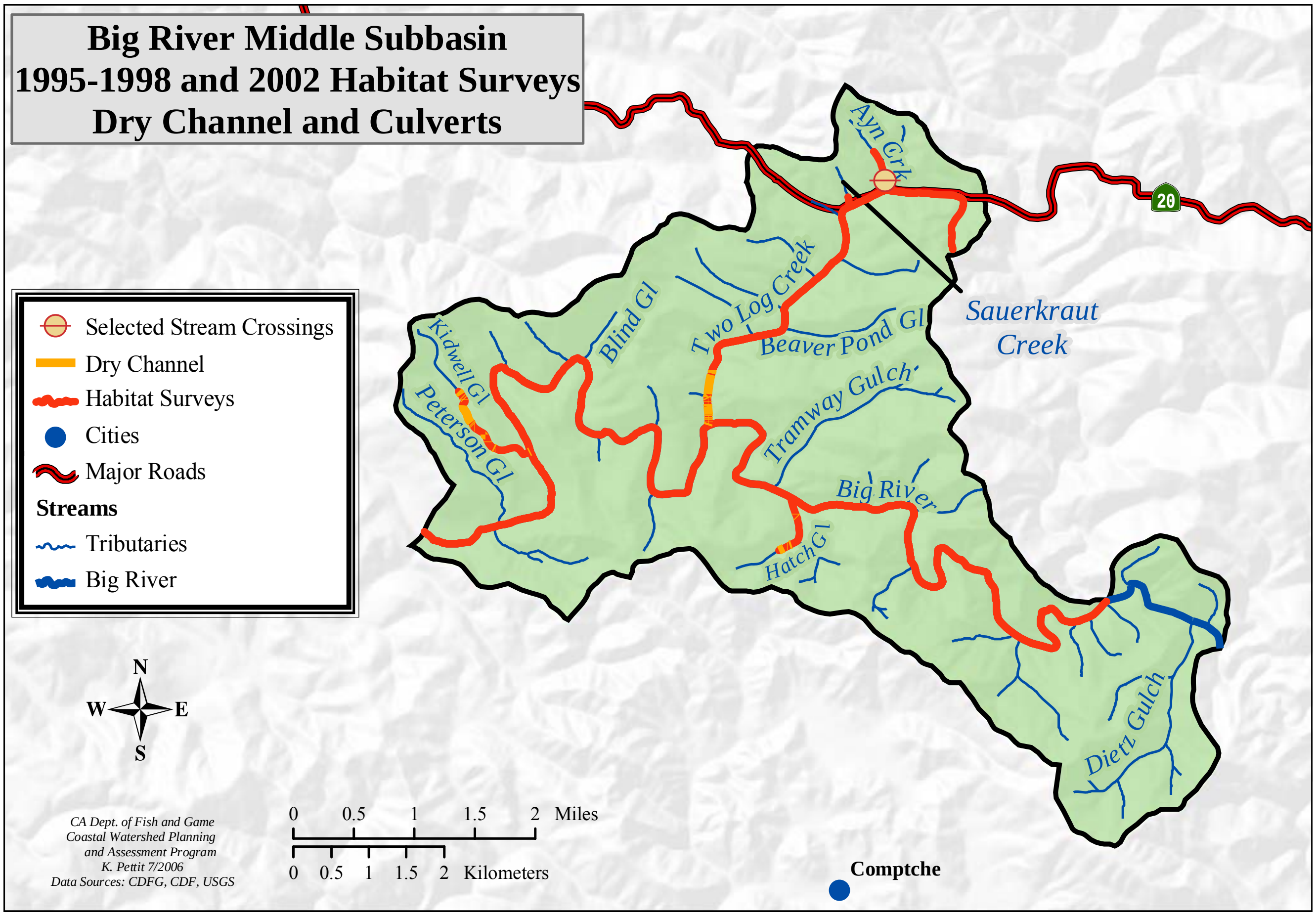


Figure 104. Dry and wetted channel and culverts reported during CDFG stream surveys and culverts reported by MRC (2004) in the Middle Subbasin.

Table 147. Dry channel recorded in CDFG stream surveys in the Middle Subbasin.

Stream	Survey Period	# of Dry Units	Dry Unit Length (ft)	% of Survey Dry Channel
Kidwell Gulch	June 2002	13	1343	27.7
Two Log Creek	June 2002	0	0	0.0
Saurkraut Creek (Two Log Creek Tributary)	July 1998	0	0	0.0
Ayn Creek (Two Log Creek Tributary)	July 1998	0	0	0.0
Big River (Tramway Gulch to North Fork Big River)	July 2002	0	0	0.0
Hatch Gulch	July 1996	5	391	13.6

Restoration Programs

The CDFG Fisheries Restoration Grants Program funded a project on Beaver Pond Gulch in the Middle Subbasin. The project leader was the E-Center and it was carried out from 2000 to 2001. The project details included:

- Fish barrier removed, log jam removed;
- Fish barrier removed, stream bank stabilized: log revetment installed, log jam removed, conifers planted;
- Fish barrier removed, stream bank stabilized: log revetment installed, log jam removed;
- Road ditch and drainage culvert maintenance (removing debris) log jam removal, fish barrier removal, bank stabilization, and road maintenance.

HTC has carried out a large woody debris restoration program on their ownership in Two Log Creek in recent years. Large wood has been added to the creek in various locations and configurations. Some of the wood was anchored and some not anchored. All wood was labeled with inventory tags so it can be tracked in the case of displacement by storm flows.

Changes in Habitat Conditions from 1960 to 2001

Streams surveyed in the 1950s and 1960s and habitat inventory surveyed in the 1990s or 2002 were compared to indicate changes between historic and current conditions. Data from 1960s stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor are based on the judgment of the biologist or scientific aid who conducted the survey. The results of historic stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to show general trends.

Habitat data were available from both older stream surveys and recent stream inventories for Two Log Creek and the mainstem Big River (Table 148). It appeared that spawning habitat and pool habitat increased in the mainstem Big River and remained similar Two Log Creek. Shelter decreased in Two Log Creek and increased in the mainstem Big River.

Table 148. Comparison between historic habitat conditions with current habitat inventory surveys in the Middle Subbasin.

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of Changes from Historic to Current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
Kidwell Gulch	ND*	Suitable	ND	Unsuitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND
Two Log Creek	ND	Fully Suitable	Good	Suitable	Average one foot deep, range from six to one foot deep	Unsuitable	Good	Unsuitable	Shelter decreased
Saurkraut Creek	ND	Fully Suitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND	Suitable	ND
Ayn Creek	ND	Suitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND	Unsuitable	ND
Tramway Gulch	ND	ND	Good	ND	Small, fairly frequent pools	ND	Good	ND	ND
Big River Tramway Gulch to North Fork Big River	ND	Unsuitable	Poor to fair	Suitable	Uncommon	Fully Suitable	Only undercut banks and log jams for cover	Suitable	Spawning habitat, pool habitat, and shelter increased
Hatch Gulch	ND	Fully Suitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND	Suitable	ND

*ND= No Data
If more than one year of historic data were available, the oldest data were used.

Fish History and Status

Historically, the Middle Subbasin supported runs of Chinook salmon, coho salmon, and steelhead trout. CDFG stream surveys were conducted for three tributaries in the Middle Subbasin from 1959 to 1966 (Table 149). Coho salmon and steelhead trout were observed in Two Log Creek in 1959; however, only steelhead trout were observed in 1966. No salmonids were described in Tramway and Dietz gulches in the 1950s surveys. A 1966 survey of Tramway Gulch detected about 20 steelhead trout per habitat unit near the mouth of the stream.

Table 149. Summary of all electrofishing, snorkel survey, and bank observation surveys conducted in the Middle Subbasin.

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified salmonids
Kidwell Gulch	2002	CDFG	Electrofishing		Present	
Two Log Creek - Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing	Present	Present	
	1996	MRC	Electrofishing	Present	Present	
	2000	MRC	Electrofishing	Present	Present	
	2001	MRC	Electrofishing	Present	Present	
	2002	MRC	Snorkel Survey	Present	Present	
Two Log Creek - Middle	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing			
	2000	MRC	Electrofishing	Present	Present	
	2001	MRC	Electrofishing	Present		
Two Log Creek - Upper	2002	MRC	Electrofishing	Present	Present	
Two Log Creek	1959	CDFG	Visual Observation	Present	Present	
	1966	CDFG	Visual Observation		Present	
	1983	CDFG	Electrofishing	Present	Present	
	1993	HTC	Electrofishing		Present	
	1994	HTC	Electrofishing		Present	
	1995	HTC	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present	Present	
	1996	HTC	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present	Present	
	1997	HTC	Electrofishing		Present	
		CDFG	Electrofishing	Present		
		NMFS	Electrofishing	Present	Present	
	1998	CDFG	Electrofishing	Present	Present	
		HTC	Electrofishing		Present	
	1999	HTC	Electrofishing		Present	
	2000	HTC	Electrofishing		Present	
		NMFS	Snorkel Survey	Present	Present	
	2001	HTC	Electrofishing		Present	
	2002	CDFG	Electrofishing	Present	Present	
Saurkraut Creek	1998	CDFG	Visual Observation			
Ayn Creek	1998	CDFG	Visual Observation			
		CDFG	Electrofishing		Present	
Beaver Pond Gulch - Lower	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing			
Beaver Pond Gulch - Upper	1995	MRC	Electrofishing			
	1996	MRC	Electrofishing			
	2000	MRC	Electrofishing			
Big River-Below Tramway Gulch	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Electrofishing	Present	Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Tramway Gulch	circa 1950	CDFG	Visual Observation			
	1966	CDFG	Visual Observation	Present		
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	2001	CDFG	Coho Inventory			
Tramway Gulch - Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified salmonids
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing	Present	Present	
Tramway Gulch - Upper	1994	MRC	Electrofishing			
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing			
Big River from Tramway Gulch to North Fork Big River	2002	CDFG	Snorkel Survey	Present	Present	
Hatch Gulch	1988	CDFG	Electrofishing	Present	Present	
	1996	CDFG	Snorkel Survey		Present	
		HTC	Visual Observation			Present
Dietz Gulch	circa 1950	CDFG	Visual Observation			
Big River-Below North Fork Confluence	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2002	MRC	Snorkel Survey		Present	

*CDFG = Department of Fish and Game survey; CI = Department of Fish and Game Coho Inventory; CEMR = Center for Education and Manpower Resources; MRC = Mendocino Redwood Company Report; HTC = Hawthorne Timber Company; SONAR = School of Natural Resources at Mendocino High School; NMFS = National Marine Fisheries Service (Jones 2000)

CDFG, Hawthorne Timber Company, and MRC studies have continued to document the presence of coho salmon and steelhead trout in the Middle Subbasin.

CDFG electrofishing surveys of Two Log Creek in 1983 and Hatch Gulch Creek in 1988 found both coho salmon and steelhead trout.

Electrofishing and snorkel surveys documented by NMFS (Jones 2000) found steelhead trout and coho salmon in Two Log Creek from 1995 to 1997 and 2000. Electrofishing also found steelhead trout in Tramway Gulch in 1995 and 1996.

Georgia Pacific began electrofishing surveys on the Two Log Creek as part of a monitoring program in 1993. The monitoring has been continued by the Hawthorne Timber Company. The sample site was electrofished annually and steelhead trout young of the year and 1+ were consistently detected (Figure 105). No steelhead trout 2+ were detected. Coho salmon were detected in each year except for 1994.

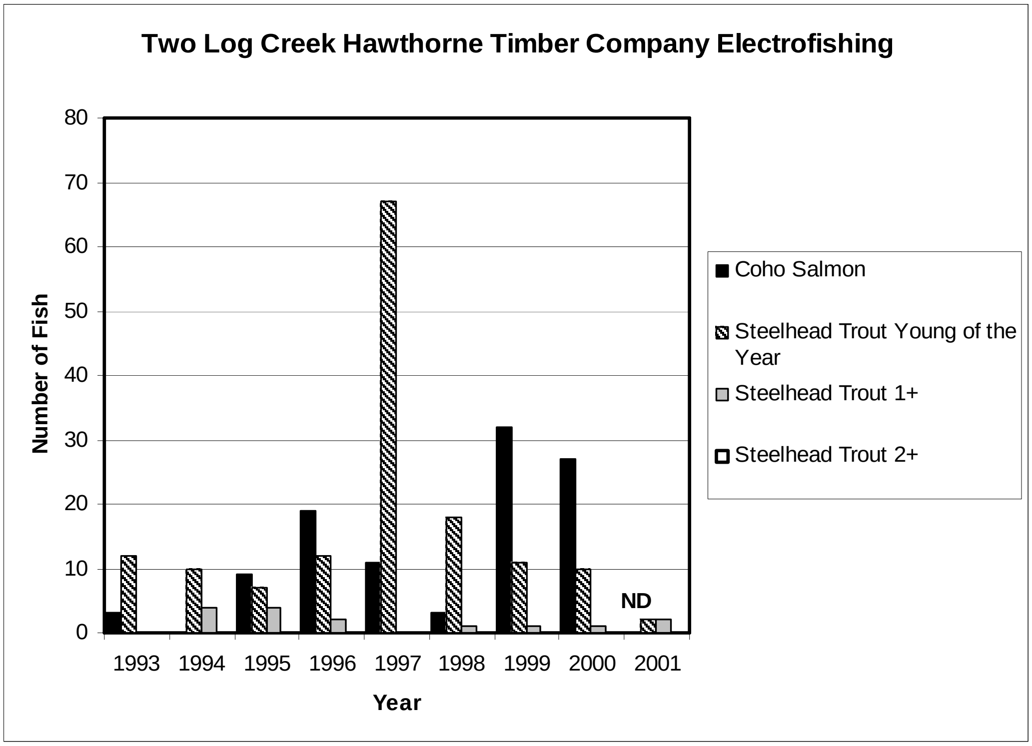


Figure 105. Electrofishing results from 1993-2000 for Two Log Creek (surveys by Georgia-Pacific).

MRC has collected single-pass electrofishing or snorkel counts of many sites in the Middle Subbasin in the years 1994-1996, and 2000-2002. The sites were surveyed for the purpose of detecting the presence of fish species. These data do not enable the assessment of fish health or abundance, but do provide a look at fish community structure, and specifically the presence of coho or other species. Coho salmon were found in Two Log Creek and mainstem Big River below Tramway Gulch consistently, while they were found in Tramway Gulch only in 2002 (Table 149). Steelhead trout were detected in Two Log Creek, mainstem Big River below Tramway Gulch, Tramway Gulch, and mainstem Big River below North Fork Big River consistently. No salmonids were detected in Beaver Pond Gulch.

Georgia Pacific used streamside visual observation and electrofishing to detect salmonids during stream surveys conducted in Two Log Creek and Hatch Gulch in 1996. Steelhead trout were detected in Two Log Creek but no salmonids were detected in Hatch Gulch.

A 1996 CDFG snorkel survey in Hatch Gulch did detect steelhead trout. Visual observations as a part of 1998 CDFG stream inventory surveys in Saurkraut Creek and Ayn Creek did not detect salmonids, though an electrofishing survey in Ayn Creek detected steelhead trout. The 2001 CDFG Coho Inventory did not detect coho salmon in Tramway Gulch.

CDFG stream inventory surveys in Two Log Creek found coho salmon in 1997, 1998, and 2002 and steelhead trout in 1998 and 2002. Steelhead trout were also detected in Kidwell Gulch and mainstem Big River from Tramway Gulch to North Fork Big River in 2002, but coho salmon were only found in mainstem Big River in these surveys. More detailed summaries of stream surveys and fisheries studies in the Middle Subbasin are provided in the CDFG Appendix.

Middle Subbasin Issues

From the various disciplines' assessments and constituent input, the following issues were developed for the Middle Subbasin. These must be considered in context of the Big River Basin's Franciscan mélange geology and the many low gradient depositional reaches in this subbasin.

- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River;
- There is concern that road related failures are contributing large amounts of sediments to stream channels during major storms;
- Moderate to high levels of fine material in streams are a concern.

Middle Subbasin Integrated Analysis

The following section provides a dynamic, spatial picture of watershed conditions for the freshwater lifestages salmon and steelhead. Different watershed factors are analyzed together to examine their combined effects on stream channels. The interactions between geology, vegetation, landuse, water quality, and stream channels indicate the quantity and quality of the freshwater habitat for salmon and steelhead.

Landsliding Interactions

GMA (2001) calculated the unit volume of delivering landslides, comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas, to be 119 tons/square mile/year for 1989-2000. In the Middle Subbasin, it was reported that 100% of the landslides occurred in timber harvest areas or were related to roads (Figure 106, Table 150). Of the delivering landslides from harvest related activities and roads, it was estimated that 41% were related to roads and 59% were related to timber harvesting (including skid trails). Results over the entire study period (1937-2000) showed that 56% of the delivering landslides were road related, 44% were related to timber harvesting (including skid trails), and none were related to grassland areas or unmanaged forest.

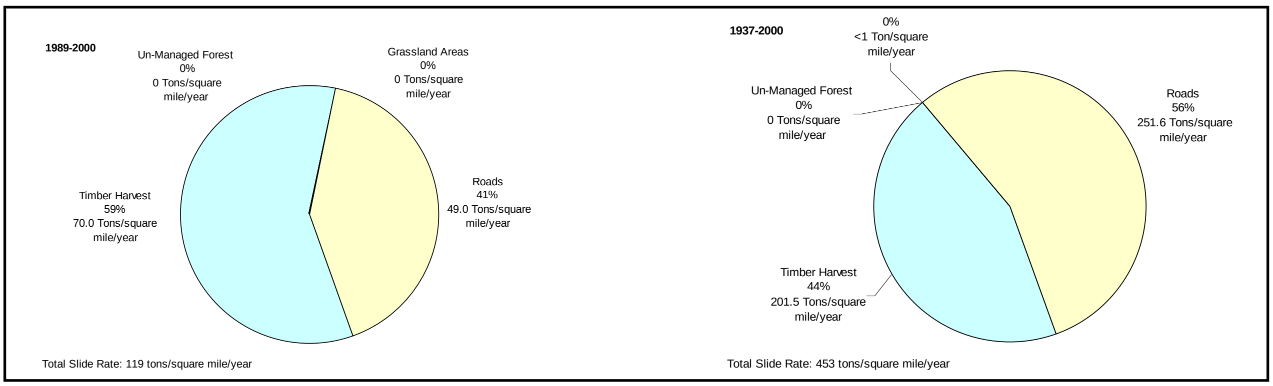


Figure 106. Delivering landslides by category, Middle Subbasin (GMA 2001a).

Table 150. Volumes of delivering slides by land use by PW for entire study period in the Middle Subbasin in tons and percentage of subbasin total (GMA 2001a).

PW	Forest	Brush & Grassland	Harvest-Related					Road-Related	Total
			Partial Or Clear Cut	Harvest (<20 Yrs)	Harvest (>20 Yrs)	Skid Trails	Total		
Middle Big River	0 0.0%	25 <0.1%	6,759 1.3%	35,973 7.1%	154,730 30.3%	29,439 5.8%	226,900 44.5%	283,213 55.5%	510,139

Thus, when comparing the 1989-2000 time period to that of the entire study period, the percentage of delivering landslides due to roads increased while those due to timber harvesting decreased. This may primarily be the result of timber harvesting methods that are less disruptive, or it may be the result of years of building roads that are now triggering more landslides. It is important to note that the total estimated slide rate decreased from 453 (1937-2000) to 119 tons/square mile/year (1989-2000), a substantial drop in sediment input by landslides.

The Middle Subbasin was harvested intensely fairly early, and extensive landslides related to early harvests were observed. Since the 1952 study period, sediment production from landslides related to all landuse has decreased (Table 151).

Table 151. Volume of delivering slides by land use, PW, and year in the Middle Subbasin in tons.

Year	Forest	Brush & Grassland	Harvest-Related					Road-Related	Study Period Total
			Partial Or Clear Cut	Harvest < 20 Years	Harvest > 20 Years	Skid Trail	Total		
1952	0	0	0	15,545	88,386	0	103,931	10,575	114,506
1965	0	25	2,651	2,446	33,645	25,824	64,566	206,788	271,379
1978	0	0	0	4,964	20,353	1,118	26,435	13,798	40,233
1988	0	0	3,663	3,056	7,781	2,498	16,998	41,625	58,623
2000	0	0	445	9,961	4,564	0	14,971	10,427	25,398
Total:	0	25	6,759	35,974	154,730	29,439	226,900	283,213	510,139

GMA 2001a

It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 106). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural "background" landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 119 tons/mi^2/yr. This would indicate that background landslides may have contributed roughly 43% of the total sediment input by all categories of landslides.

When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 107 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails. Based on these preliminary comparisons, it appears as though landsliding related to roads and timber harvesting need to be addressed to meet the TMDL load allocation goals. Grassland areas are not a significant problem.

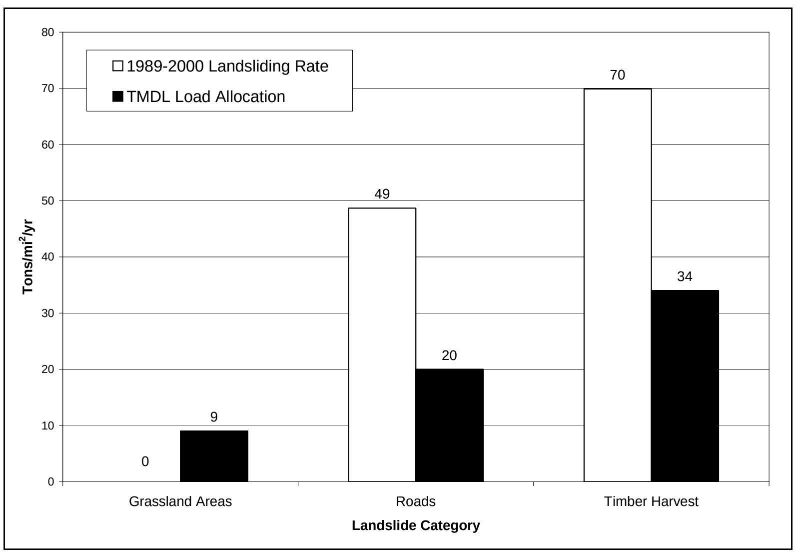


Figure 107. Landslide rate vs. TMDL load allocations, Middle Subbasin (GMA).

The MRC Watershed Analysis found that of the 257 shallow-seated landslides observed in the MRC ownership of the Middle Subbasin, 136, or 53%, were road-associated. Road associated mass wasting was found to have contributed about 98,000 tons (490 tons/square mile/year) in the study period. This is 64% of the total mass wasting sediment inputs for the MRC ownership in the Middle Subbasin. Road associated mass wasting was a major sediment source.

Slope Interactions

An analysis of different types of roads on slopes of varying percent showed that most road miles are on slopes from 31 to 50% in this subbasin (Table 152). When GMA (2001) grouped slopes into categories, they found that most of the roads are mid-slope, followed by riparian, and then ridge-top (Table 153). It was estimated that 20% of roads are located in the riparian zone.

Table 152. Length of truck roads by side slope and road surface.

Side Slope in Percent	Total Length in Miles				Miles per Sq Mile				Proportion of Length			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
0 -15	19	1	5	24	1.1	0.0	0.3	1.4	12		3	16
16 - 30	38	1	5	44	2.1	0.1	0.3	2.5	25	1	3	29
31 - 50	47	0	7	55	2.6	0.0	0.4	3.1	30		5	35
51 - 65	17	0	3	21	1.0	0.0	0.2	1.2	11		2	13
Greater than 65	7		3	11	0.4		0.2	0.6	5		2	7
Total	**129**	**2**	**24**	**155**	**7.2**	**0.1**	**1.3**	**8.7**	**83**	**1**	**15**	**100**

Table 153. Middle Subbasin roads by location and surface type.

	Paved	Rocked	Un-surfaced
Ridgetop			
Miles	0.1	2.8	24.9
% Total Basin Miles	0.1	1.8	16.1
Mid-slope			
Miles	0.5	10.5	84.4
% Total Basin Miles	0.3	6.8	54.7
Riparian			
Miles	1.7	10.5	19.0
% Total Basin Miles	1.1	6.8	12.3

Total subbasin roads = 154.2 miles, 8.6 miles/square mile
Blue categories have the lowest potential for road surface erosion (2.2%). Orange categories have medium potential for surface erosion (24.3%). Magenta categories have the highest potential for surface erosion (73.8%). Road surface erosion is a source of fine sediment that can be delivered to streams, which is deleterious to fish habitat

The MRC Watershed Analysis found that about 88% of field observed shallow landslides inventoried on MRC land in the Middle Subbasin were initiated on slopes greater than or equal to 60% gradient. About 75% of shallow landslides initiated on slopes greater than or equal to 70% gradient. Of the field observed landslides occurring on slopes with gradients less than 70%, all were road related. This suggests that few landslides are occurring on slopes less than 70% gradient unless triggered by a road or skid trail.

Shallow-seated landslides were in the greatest concentration in inner gorge and steep streamside areas. Combined, these two locations accounted for 58% of the shallow-seated landslides; 17% inner gorge and 41% steep streamside slopes. Headwall swells accounted for 10%, and the remainder occurred in midslope areas, often as a result of roads, landings, and skid trails.

In the MRC's ownership, low slope class roads make up 47% of all the contributing road area (Table 154). Low slope class roads delivered 810 tons/year, compared to 1010 tons/year for middle slope class roads and 180 tons/year on high slope class roads. This indicates the importance of monitoring low and mid-sloped roads.

Table 154. Surface and point source erosion estimates by slope class for MRC ownership in the Middle Subbasin.

PW	Low-Slope			Mid-Slope			High-Slope		
	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)
Two Log Creek	6.0	47%	810	5.3	42%	1010	1.3	11%	180

MRC 2004

Road Interactions

GMA (2001) estimated that road surface erosion across the Middle Subbasin increased significantly from 1937 to 2000, coinciding with an increased amount of roads (Table 155). Roads in 2000 were estimated to produce 106.9 tons of sediment per square mile per year across the subbasin, an increase over 1952 rates.

Table 155. Computed road surface erosion by study period by PW in the Middle Subbasin.

PW	Computed Surface Erosion From Roads By Period (Tons/Yr)					Total By PW For Entire Period	% Total Watershed Road Surface Erosion	Entire Study Period Average Unit Area Road Surface Erosion	2000 Unit Area Road Surface Erosion
	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	(Tons)	(%)	(Tons/Mi2/Yr)	
Two Log Creek	447.7 (23.5%)	1068.2 (56.0%)	1162.2 (60.9%)	1357.8 (71.2%)	1907.4 (100.0%)	72,818.2	11.0%	64.7	106.9

GMA 2001a

GMA (2001) estimated that sediment production from skid roads across the subbasin was small (Table 156). The analysis suggested a peak in surface erosion at the time of high harvest rates using high-density tractor logging methods from 1953-1978.

Table 156. Summary of total surface erosion estimates in tons from harvest areas by study period.

Planning Watershed	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	1937-2000 Total
Two Log Creek	782.5	10,179.8	761.5	2,380.7	1,881.4	15,985.9

GMA 2001a

As can be seen in Figure 108, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both also exceed the TMDL load allocation for surface erosion. In particular, surface erosion related to roads appears to be a significant problem. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1937-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

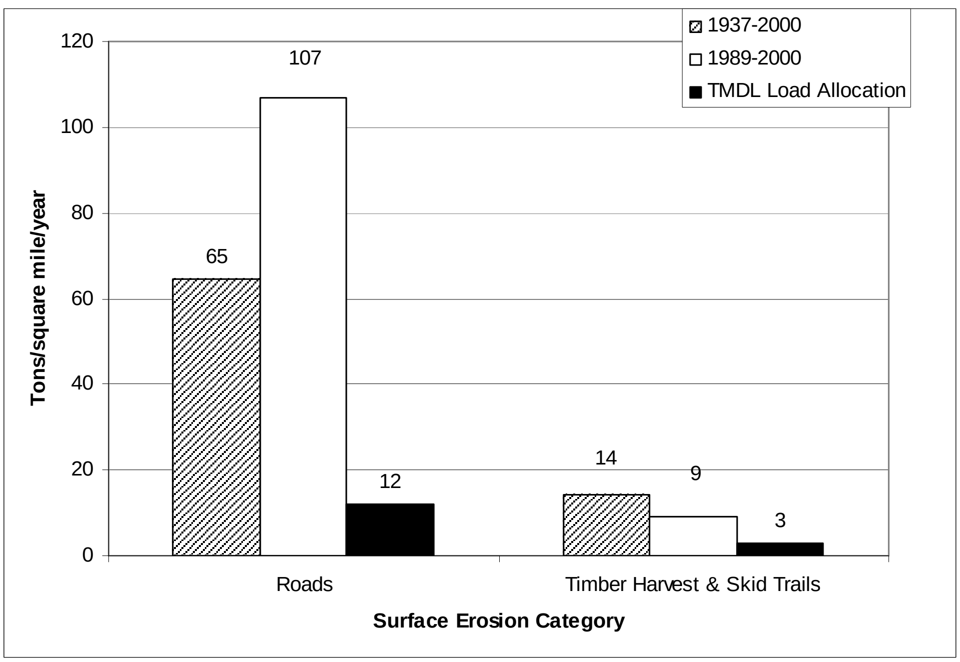


Figure 108. Surface erosion rate vs. TMDL load allocations, Middle Subbasin (GMA).

Roads within MRC's ownership in the Middle Subbasin were estimated to generate 300 tons/square mile/year of sediment from road associated surface and point erosion (MRC 2003) (Table 157). The surface erosion rate was higher than the point source erosion rate.

Table 157. Road associated surface and point source erosion estimates for MRC ownership in the Middle Subbasin.

PW	Total Road Associated Erosion (tons/year)	MRC owned acres	Road Associated Erosion Rate (tons/square mile/year)	Surface Erosion Rate (tons/square mile/year)	Point Source Erosion Rate (tons/square mile/year)
Two Log Creek	2000	4275	300	220	80

MRC 2003

MRC found that the high level of tractor based yarding used for timber harvest in the 1940s, 1950s, and 1960s on their ownership produced a high level of sediment delivery (Table 158 and Figure 109). However, the widespread geographic extent of skid trails in the 1970s and 1980s produced the most total skid trail area and the highest sediment delivery rates. The peak in sediment delivery rate from skid trails in the Middle Subbasin occurred in the 1970s. Skid trail delivery rates diminished across the MRC ownership in the 1990s with less harvest activity and stricter regulations.

Table 158. Skid trail use in acres for MRC ownership in the Middle Subbasin.

Planning Watershed	1940s	1950s	1960s	1970s	1980s	1990s
Two Log Creek	233	525	1663	2379	2129	133

MRC 2003

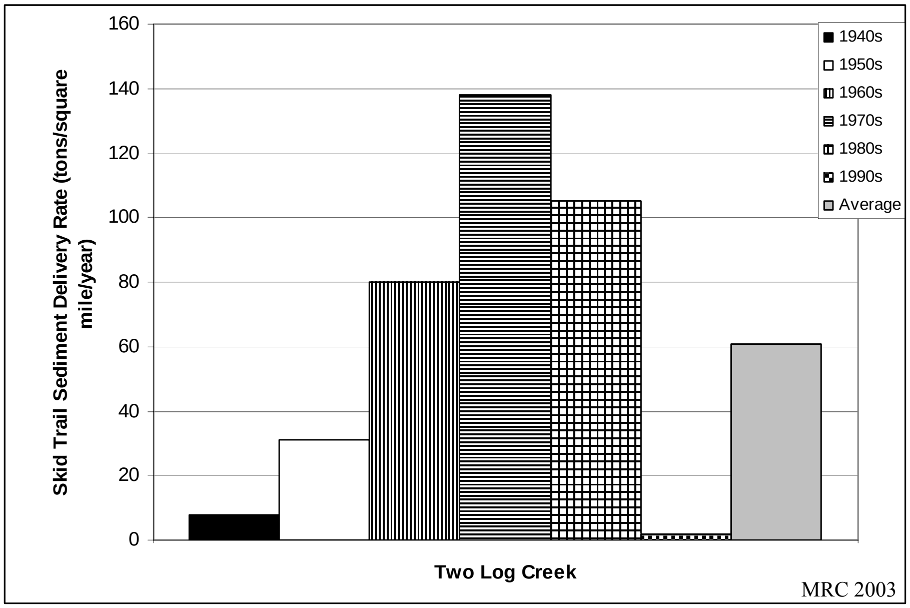


Figure 109. Skid trail sediment delivery estimates for MRC ownership in the Middle Subbasin.

MRC (2003) estimated the total sediment inputs for their ownership in the Middle Subbasin. The average estimated sediment input for the past 30 years was 1150 tons/square mile/year (Table 159). Road associated erosion was the dominant sediment contributing process in the MRC ownership in the Middle Subbasin, making up 54% of the sediment inputs. When skid trail erosion is included in road-associated erosion totals the percentage increases to 76%.

Table 159. Estimated sediment inputs by input type for the MRC ownership.

PW	Road Surface Erosion	Road Point Source Erosion	Road Associated Mass wasting	Hillslope Mass wasting	Skid Trail Erosion	Total
Two Log Creek	220	80	320	280	250	1150

Averaged from 1970-2000. MRC 2003.

Road Crossings

Today there are 20.4 miles of roads in the watercourse buffer zone (Table 160). Seventy eight percent were built before 1979 (Table 161). While the data show 12.5 miles as native road surface, the Forest Practice Rules require that landowners that use roads for harvesting timber reduce the potential for sediment transport, so many are being surfaced with rock. There are almost 21 streams crossings per square mile in this subbasin (Table 162).

Table 160. Length of truck roads in near proximity to watercourse by watercourse classification and road classification.

Watercourse Class	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
w/in 150' of FPR Class I or USGS Perennial	5.1	0.6	5.3	11.0	0.29	0.04	0.30	0.62
w/in 75' of FPR Class II or USGS Intermittent	5.0	0.2	1.4	6.6	0.28	0.01	0.08	0.37
w/in 25' of FPR Class III	2.4	0.0	0.3	2.8	0.14		0.02	0.16
Total	**12.5**	**0.9**	**7.1**	**20.4**	**0.70**	**0.05**	**0.40**	**1.14**

Table 161. Length of truck roads in near proximity to watercourse by period of construction and road classification.

Period	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
pre - 1937	1.6	0.9	1.4	3.8	0.09	0.05	0.08	0.21
1937 - 1952	2.0		0.3	2.3	0.11		0.02	0.13
1953 - 1965	4.0		5.2	9.2	0.22		0.29	0.51
1966 - 1978	0.6		0.0	0.7	0.04			0.04
1979 - 1988	0.8			0.8	0.05			0.05
1989 - 2000	3.5		0.2	3.7	0.19		0.01	0.20
Total	**12.5**	**0.9**	**7.1**	**20.4**	**0.70**	**0.05**	**0.40**	**1.14**

Table 162. Number of watercourse truck road crossings by watercourse and road classification in the Middle Subbasin.

Watercourse Class	Total Crossings				Crossings per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
FPR Class I or CFF Perennial	9		11	20	0.5	0	0.6	1.1
FPR Class II or CFF Intermittent	64	2	14	80	3.6	0.1	0.8	4.5
FPR Class III	217	6	43	266	12.2	0.3	2.4	14.9
Total	290	8	68	366	16.2	0.4	3.8	20.5

Fluvial Erosion

GMA (2001) estimates of bank erosion and small streamside mass wasting found little sediment from these sources.

Table 163. Bank erosion and small streamside mass wasting.

Planning Watershed	Bank Erosion and Small Streamside Mass Wasting		Total Tons/Year
	Class 1 (Tons/Year)	Class 2 (Tons/Year)	
Two Log Creek	513	535	1,047

GMA 2001a

Stream Interactions

The products and effects of the watershed delivery processes examined in the geologic, slope, and landsliding Integrated Analyses tables are expressed in the stream habitats encountered by the organisms of the aquatic riparian community, including salmon and steelhead. Several key aspects of salmonid habitat in the Big River Basin are presented in the Stream Interactions Integrated Analysis. Channel and stream conditions are not necessarily exclusively linked to their immediate surrounding terrain, but may in fact be both spatially and temporally distanced from the sites of the processes and disturbance events that have been blended together over time to create the channel and stream's present conditions. Instream habitat data presented here were compiled from CDFG stream inventories described in more detail in the Fish Habitat Relationships sections of this report.

Primary Pools

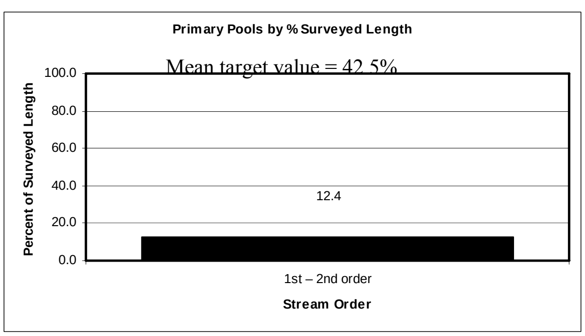


Figure 110. Primary Pools in the Middle Subbasin.

Pools greater than 2 feet deep in 1st and 2nd order streams and greater than 3 feet deep in 3rd and 4th order streams are considered primary pools.

Significance: Primary pools provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30-55% of its length in primary pools to be suitable for salmonids. In first and second order streams, a primary pool is described as being at least two feet deep. In third and fourth order streams, a primary pool is described as being at least three feet deep.

Comments: The percent of primary pools by length in the Middle Subbasin is generally below target values for salmonids.

Spawning Gravel Quality

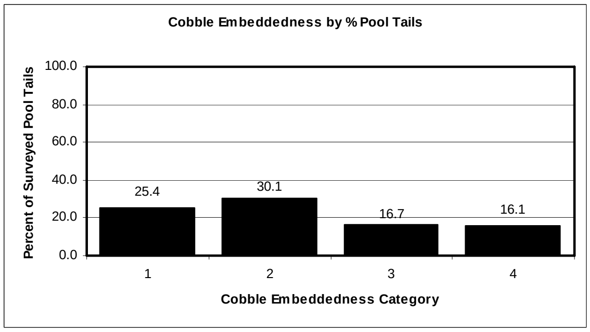


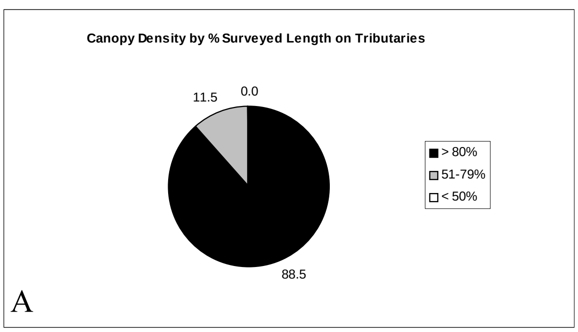
Figure 111. Cobble Embeddedness in the Middle Subbasin.

Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included

Significance: Successful salmonid egg and embryo survival diminishes when spawning occurs in streambeds with excessive silt, clay, and other fine sediment. Cobble embeddedness is the percentage of an average sized cobble at a pool tail out embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded and category 4 is 76%-100% embedded. Cobble embeddedness categories 3 and 4 are not within the suitable range for successful use by salmonids. Category 5 describes pool tail outs with unspawnable substrate such as bedrock, log sills, or boulders.

Comments: More than one half of the surveyed stream lengths within the Middle Subbasin have cobble embeddedness in categories 1 and 2, which meets spawning gravel target values for salmonids. This subbasin has the highest percent of suitable cobble embeddedness values in surveyed streams of the Big River Subbasins.

Shade Canopy



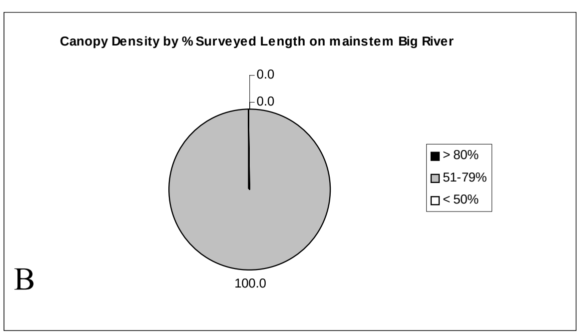


Figure 112. Canopy Density in the Middle Subbasin.

A. Tributaries. B. Mainstem Big River

Significance: Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey length is unsuitable and greater than 80% is fully suitable.

Comments: All of the surveyed tributaries within the Middle Subbasin have canopy densities greater than 50% and over 80% of the surveyed lengths have canopy densities greater than 80%. This is above the canopy density target values for salmonids. Canopy density on the mainstem Big River is lower, as is expected on a forth order stream.

Fish Passage

Table 164. Juvenile salmonid passage in the Middle Subbasin.

Feature/Function		Significance	Comments
Juvenile Summer Passage	**Juvenile Winter Refugia**	Dry channel recorded in the Middle Subbasin during stream surveys has the potential to disrupt the ability of juv3enile salmonids to forage and escape predation in three tributaries. Juvenile salmonids seek refuge from high winter flows, flood events, and cold temperatures in the winter. Intermittent side pools, back channels, and other areas of relatively still water that become flooded by high flows provide valuable winter refugia.	
0.3 Miles of surveyed channel dry	No Data		
3.5% of survey channel dry			

1993-2002 CDFG stream surveys, CDFG Appendix

Pool Shelter

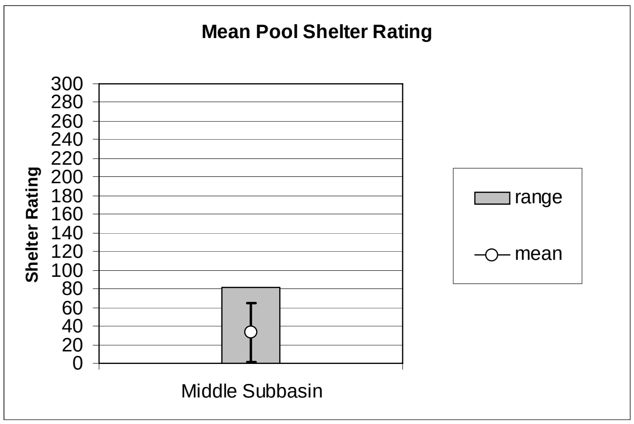


Figure 113. Pool shelter in the Middle Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

<u>Significance:</u> Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

<u>Comments:</u> The average mean pool shelter rating in the Middle Subbasin is 33.1. This is below the shelter target value for salmonids.

Large Woody Debris

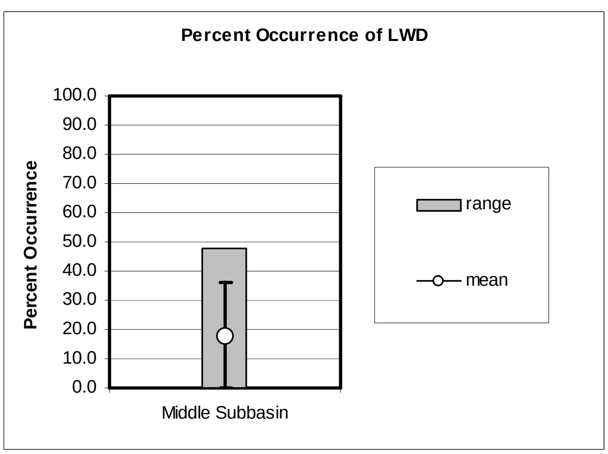


Figure 114. Large Woody Debris (LWD) in the Middle Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

<u>Significance:</u> Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percent occurrence of LWD.

<u>Comments:</u> A 17.9 average percent occurrence of large woody debris is low compared to the range of values recorded throughout the entire Big River Basin, which is 0 to 62. The dominant shelter types recorded in most stream reaches were boulders, large woody debris, and undercut banks.

Although instream habitat conditions for salmonids varied across the Middle Subbasin, several generalities can be made. Instream habitat conditions were generally good within this subbasin at the time of CDFG surveys. Cobble embeddedness was the most suitable for salmonids of any of the Big River Subbasins. Canopy density levels were above 50%, additionally, when surveyed reaches of the mainstem Big River were not considered, 88.5% of surveyed tributary length had canopy densities greater than 80%. However, the percentage of primary pools by survey length was generally below target values as found in CDFGs California Salmonid Stream Habitat Restoration Manual and calculated by the EMDS. Additionally, the percent occurrence of large woody debris was in the lower range of values recorded in the Big River Basin. In addition, dry channel occurred in 0.3 miles of surveyed stream (3.5% of the surveyed stream length).

Stream Reach Conditions EMDS

The anadromous reach condition EMDS evaluates the conditions for salmonids in a stream reach based upon water temperature, canopy cover, stream flow, and in channel characteristics. Data used in the Reach EMDS come from CDFG Stream Inventories. Currently, data exist in the Big River Basin to evaluate overall reach, canopy, in channel, pool quality, pool depth, pool shelter, and embeddedness conditions for salmonids. More details of how the EMDS functions are in the EMDS Appendix. EMDS calculations and conclusions are pertinent only to surveyed streams and are based on conditions present at the time of individual survey.

EMDS stream reach scores were weighted by stream length to obtain overall scores for tributaries and the entire Middle Subbasin. Weighted average reach conditions on surveyed streams in the Middle Subbasin as evaluated by the EMDS are somewhat unsuitable for salmonids (Table 165, Figure 115). Suitable conditions exist for canopy across the entire subbasin. Big River from Tramway Gulch to North Fork Big River has suitable conditions for pool quality, pool depth, pool shelter, and embeddedness. Suitable conditions also exist for pool shelter in Hatch Gulch, and embeddedness in Two Log Creek.

One tributary, Two Log Creek, had four years of data, 1996, 1997, 1998, and 2002. A comparison of EMDS results from 1998 and 2002 shows an increase in the suitability of canopy, pool depth, and cobble embeddedness.

Table 165. EMDS Anadromous Reach Condition Model results for the Middle Subbasin.

Stream		Reach	Water Temperature	Canopy	Stream Flow	In Channel	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Middle Subbasin (excluding the mainstem Big River		- **(-)**	**U** **(U)**	+ **(++)**	**U** **(U)**	- **(-)**	- **(--)**	+ **(--)**	- **(--)**	+ **(-)**
Kidwell Gulch		-	**U**	++	**U**	-	---	---	---	-
Two Log Creek	1998	-	**U**	++	**U**	-	--	---	--	--
	2002	-	**U**	+++	**U**	-	--	--	--	+
Saurkraut Creek (Two Log Creek Tributary)		-	**U**	+++	**U**	-	-	---	+	---
Ayn Creek (Two Log Creek Tributary)		-	**U**	++	**U**	-	--	---	-	---
Big River (Tramway Gulch to North Fork Big River)		+	**U**	--	**U**	+	++	+++	+	++
Hatch Gulch		-	**U**	+++	**U**	-	-	---	+	---

Key:
+++ ++ + Highest Suitability
U: Insufficient Data or Undetermined
- -- --- Lowest Suitability

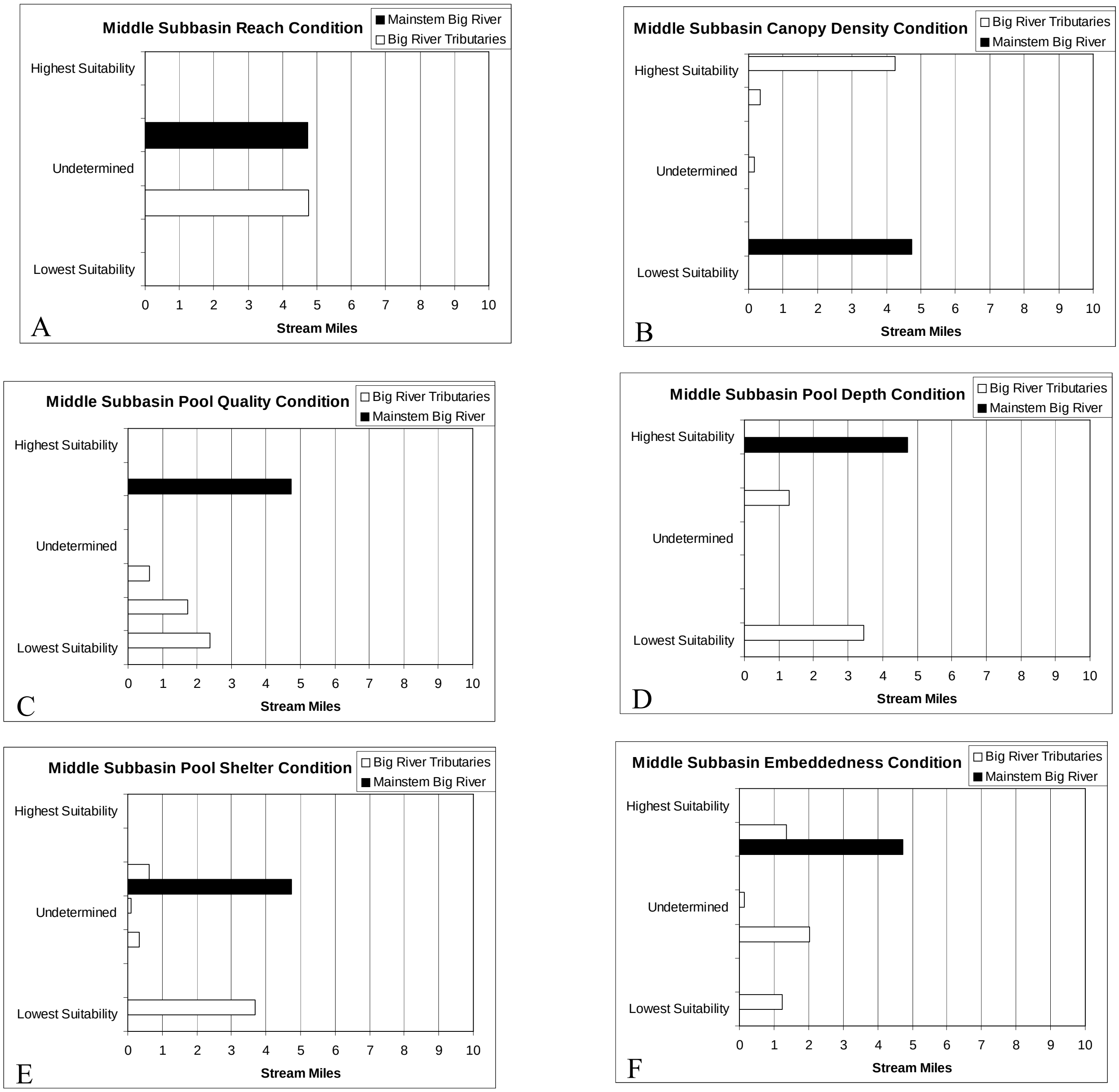


Figure 115. EMDS Reach Condition model results for the Middle Subbasin by surveyed stream miles.

In streams with multiples years of data, the most current year was used. A. Overall reach condition. B. Canopy density. C. Pool quality. D. Pool depth. E. Pool shelter. F. Cobble embeddedness.

MRC Road Hazard Map

MRC classified the roads in their ownership into three erosion hazard classes (Figure 116). MRC aimed to identify current problems, consider reconstruction, and prioritize maintenance through this process. Below is a brief summary of erosion hazard classes:

- High Road Erosion Hazard Class - Highest amount of recent deliverable surface erosion to watercourses and a high potential for future deliverable erosion;
- Moderate Road Erosion Hazard Class - Moderate amounts of recent deliverable surface erosion to watercourses and low potential for future deliverable erosion;
- Low Road Erosion Hazard Class - Low amounts of recent deliverable surface erosion to watercourses and low potential for future deliverable erosion.

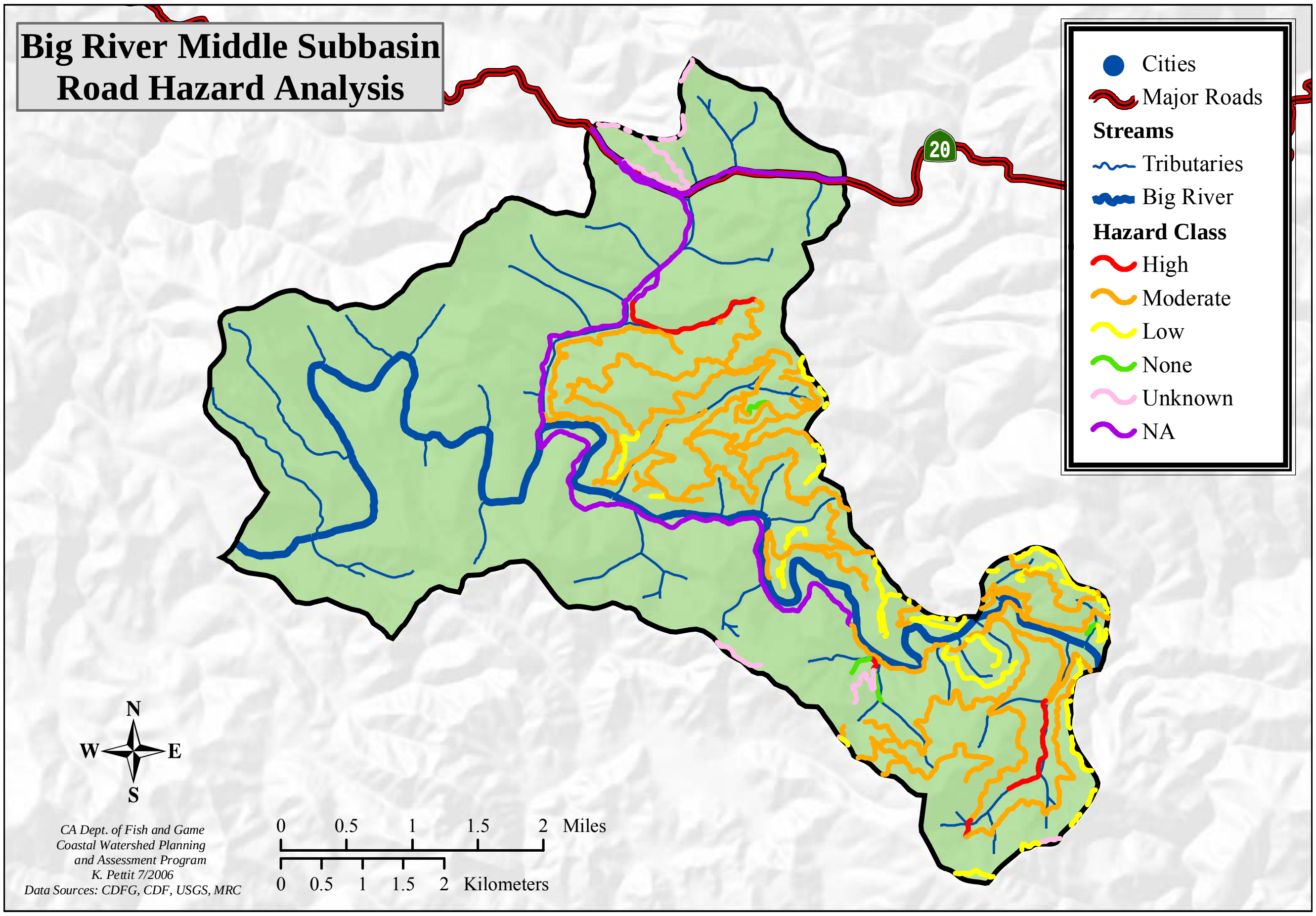


Figure 116. MRC roads erosion hazard classes in the Middle Subbasin.

Analysis of Tributary Recommendations

CDFG inventoried 9.5 miles on five tributaries and the mainstem Big River in the Middle Subbasin. A CDFG biologist selected and ranked recommendations for each of the inventoried streams, based upon the results of these standard CDFG habitat inventories (Table 166). More details about the tributary recommendation process are given in the Big River Synthesis Section of the Watershed Profile.

Table 166. Ranked tributary recommendations summary in the Middle Subbasin based on CDFG Stream Inventories.

Stream	# of Surveyed Stream Miles	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
Kidwell Gulch	0.9		3			1	2		4		
Two Log Creek	3.0	2	3				1				
Sauerkraut Creek	0.1		1								
Ayn Creek	0.3										
Big River Tramway Gulch to North Fork Big River	4.7			2	1		3				
Hatch Gulch	0.5	3	4			1		5	2		

Temp = summer water temperatures seem to be above optimum for salmon and steelhead; **Pool** = pools are below target values in quantity and/or quality; **Cover** = escape cover is below target values; **Bank** = 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** = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; **Fish Passage** = there are barriers to fish migration in the stream.

In order to further examine Middle Subbasin issues through the tributary recommendations given in CDFG stream surveys, the top three ranking recommendations for each tributary were collapsed into five different recommendation categories: Erosion/Sediment, Riparian/Water Temp, Instream Habitat, Gravel/Substrate, and Other (Table 167). When examining recommendation categories by number of tributaries, the most important recommendation categories in the Middle Subbasin are Erosion/Sediment and Instream Habitat.

Table 167. Top Three ranking recommendation categories by number of tributaries in the Middle Subbasin.

Target Issue	Related Table Categories	Count
Erosion/Sediment	Bank/Roads	5
Riparian/Water Temp	Canopy/Temp	2
Instream Habitat	Pool/Cover	5
Gravel/Substrate	Spawning Gravel/LDA	1
Other	Livestock/Barrier	0

However, comparing recommendation categories in the Middle Subbasin by number of tributaries could be confounded by the differences in the number stream miles surveyed on each tributary. Therefore, the number of stream miles in each subbasin assigned to the various recommendation categories was calculated (Figure 117). When examining recommendation categories by number of stream miles, the most important recommendation categories in the Middle Subbasin are Instream Habitat, Riparian/Water Temperature, and Erosion/Sediment. These comprise the top tier of recommended improvement activity focus areas.

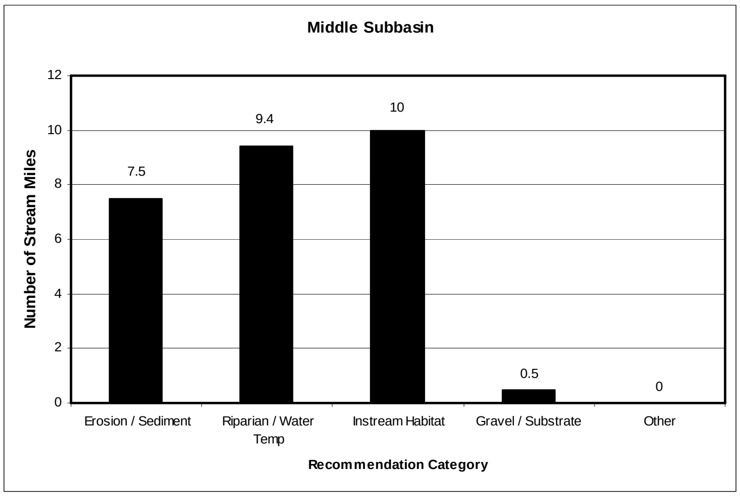


Figure 117. Recommendation categories by stream miles in the Middle Subbasin.

The high number of Instream Habitat, Riparian/Water Temp, and Erosion/Sediment recommendations across the Middle Subbasin indicates that high priority should be given to restoration projects emphasizing pools, cover, riparian replanting, and sediment reduction.

Refugia Areas

The NCWAP interdisciplinary team identified and characterized refugia habitat in the Middle Subbasin by using expert professional judgment and criteria developed for north coast watersheds. The criteria included measures 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. The team also used results from information processed by the NCWAPs EMDS at the stream reach scale.

The most complete data available in the Middle Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the NCWAP team.

Salmonid habitat conditions in the Middle Subbasin on surveyed streams are generally rated as medium potential refugia. Additionally, the mainstem Big River serves as a critical contributing area. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 168. Tributary Salmonid Refugia Area Ratings in the Middle Subbasin.

Stream	Refugia Categories*:				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
Big River		X				X	X
Peterson Gulch				X			X
Kidwell Gulch				X			X
Blind Gulch				X			X
Two Log Creek		X					X
Saurkraut Creek			X				X
Ayn Creek		X					X
Beaver Pond Gulch			X				X
Tramway Gulch		X					X
Hatch Gulch		X					X
Dietz Gulch				X			X
Subbasin Rating			X				X

*Ratings in this table are done on a sliding scale from best to worst. See page 45 in Program Introduction and Overview for a discussion of refugia criteria.

Responses to Assessment Questions

What are the history and trends of the sizes, range, and relative health and diversity of salmonid populations within the Middle Subbasin?

Findings and Conclusions:

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast;
- Based on limited CDFG, USFWS, MRC, and HTC presence surveys and surveys documented by NMFS since the 1960s, the distributions of coho salmon and steelhead trout do not appear to have changed;
- Two tributaries and the mainstem Big River had records of coho salmon and steelhead trout since 1990. Two additional tributaries also recorded only steelhead trout.

What are the current salmonid habitat conditions in this subbasin? How do these conditions compare to desired conditions?

Findings and Conclusions:

Erosion/Sediment

- McNeil samples in Two Log Creek indicated excessive amounts of fine material in this stream. This could indicate unsuitable conditions for salmonids.

Riparian/Water Temperature

- All of the water temperature monitoring sites on the mainstem Big River had MWATs that varied from moderately to fully unsuitable (67-70°F) with maximum daily temperatures (73-77°F) in excess of the lethal limit for salmonids. High diurnal fluctuations were also recorded (7.5-12.8°F), suggesting poor canopy and/or low flows;
- Data from lower Two Log Creek indicated water temperatures were between fully suitable, with a minimum observed MWAT of 58 F, and undetermined with a maximum observed MWAT of 64 F. However, large diurnal temperature fluctuations (6.7-12.0°F) were recorded at both lower Two Log Creek sites, which may indicate poor canopy and/or low flows;
- The only monitored tributary to Two Log Creek, Beaver Pond Gulch, had fully suitable water temperatures, but based on the thermograph, the monitoring device may have been placed in a thermally stratified pool or a site with a significant groundwater component;
- Hatch Gulch had fully suitable water temperatures with minimal diurnal fluctuations. It is likely that Hatch Gulch provides some cooling effect to the mainstem Big River;

- It is also probable that Two Log Creek has a cooling effect on the mainstem Big River. However, the magnitude of that effect is unknown as it is dependant on the temperature differentials and flows;
- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin, but unsuitable on surveyed reaches of the mainstem Big River as expected on a larger order stream.

Instream Habitat

- A high incidence of shallow pools, and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in surveyed reaches of Kidwell Gulch, Two Log Creek, and the mainstem Big River between Tramway Gulch and the North Fork Big River;
- Areas of dry channel in Kidwell and Hatch gulches found during CDFG stream surveys may indicate fish passage problems.

Gravel Substrate

- Cobble embeddedness values in Hatch Gulch, and Saurkraut and Ayn creeks were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on all seven segments they surveyed;
- Permeability sampling in the Big River below the North Fork Big River indicated low to moderate amounts of fine material. This could indicate suitable to somewhat unsuitable conditions for salmonids.

Refugia Areas

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- Two Log Creek provides the best salmonid refugia in this subbasin;
- The mainstem Big River serves as critical contributing area.

Other

- There are no water chemistry data for this subbasin.

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions in this subbasin?

Findings and Conclusions:

- Many of the tributaries in this subbasin are intermittent in their upper reaches and usually have summer and fall flows less than 1 cfs;
- This subbasin is underlain by Franciscan Coastal Belt geology and has a high percentage of area in lower slope classes;
- About 12% of the slides found across the Big River Basin and 10% of sediment delivered in the basin were in this subbasin;
- Redwood and Douglas fir forest has historically and continues to dominate this subbasin. Additional vegetation includes tan oak, madrone, alder, and blueblossom. Pre-European forests consisted of mostly large old-growth trees. Today, trees averaging 12-24 inches dbh cover 70% of the subbasin and trees averaging >24-inch dbh cover 27%.

How has land use affected these natural processes?

Findings and Conclusions:

- Two splash dams on Two Log Creek and numerous splash dams upstream of this subbasin likely greatly accelerated erosion and widened the width of the channels in Two Log Creek and the mainstem Big River in this subbasin;
- Early splash damming and barrier removal projects starting in the 1950s cleared Two Log Creek and Tramway Gulch of timber-related woody debris. The lack of instream complexity seen today likely results from these past practices;

- Construction of near stream roads throughout this subbasin and railroads along Two Log Creek constricted stream channels and destabilized streambanks;
- Roads and timber harvesting are listed in the Total Maximum Daily Loads as major sources of human-related sediment into the fluvial system. Many of the effects from these activities are spatially and temporally removed from their upland sources;
- Historic timber harvest activities reduced riparian canopy; however, canopy is currently suitable along surveyed tributary reaches in this subbasin;
- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times (71% of trees in watercourse buffer zones have dbh less than 24 inches). The small diameter of near stream trees across this subbasin limits the recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;
- A lack of LWD also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance.

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

- Based on the information available for this subbasin, it appears that salmonid populations are currently being limited by reduced habitat complexity, high water temperatures in the mainstem Big River, and embedded spawning gravels.

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

<u>Recommendations:</u>

Flow and Water Quality Improvement Activities

- Protect instream flows in Two Log Creek and Hatch Gulch for thermal refugia from the warmer mainstem Big River in the summer.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Saurkraut Creek have road sediment inventory and control as a top tier tributary improvement recommendation.

Riparian and Instream Habitat Improvement Activities

- Where feasible, add LWD to develop habitat diversity in the mainstem channel and to increase shelter complexity for salmonids. CDFG stream surveys indicated Kidwell Gulch, Two Log Creek, and Big River from Tramway Gulch to North Fork Big River have increase escape cover as a top tier tributary recommendation;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the mainstem Big River, Two Log Creek, Ayn Creek, and Tramway and Hatch gulches.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River;
- In lower Two Log Creek, both MRC and HTC have temperature monitoring sites in nearly the same location. It may be more effective if one company monitored the site and shared the information with the other while the second monitoring device is deployed at another location.

Subbasin Conclusions

The Middle Subbasin represents a transition zone between the Coastal and Inland subbasins - moving from a heavily marine influenced climate and gentler slopes to larger temperature fluctuations throughout the year and steeper slopes. Although this subbasin is small, just under 10% of the land mass of the Big River Basin, it contains Two Log Creek, an important fish-bearing tributary. Salmon and steelhead habitat conditions in the Middle Subbasin are generally degraded, but support some salmonid production.

This subbasin appears to be impacted by reduced habitat complexity, high water temperatures in the mainstem Big River, and embedded spawning gravels. In addition, this subbasin has a comparatively dense network of roads that provide potential sources of fine sediment input to streams. Historical accounts indicate that stream conditions were favorable for salmonids in the past and certain habitat factors remain favorable in some of the tributaries. Accordingly, there are opportunities for stream improvements and a need to restore areas of stream refugia. Examples of habitat improvement activities include increasing channel complexity, monitoring stream temperatures, road improvements and erosion proofing, and mitigation of stream bank erosion. The natural variability of stability and erodability of the geologic terrains should be considered before project implementation and appropriate best management practices should be followed to minimize erosion and sediment delivery to streams. Current landowners and managers interested and motivated to eliminate impacts related to land use and accelerate a return to the stable, beneficial conditions for salmonids are encouraged to do so, enlisting the aid and support of agency technology, experience, and funding opportunities.

Inland Subbasin

Upper South Fork Big River Watershed, Photo by Bill Lydgate in KRIS. May 2001

The Inland Subbasin includes the entire watershed area of the North Fork Big River, South Fork Big River, and the entire watershed area of the Big River above the confluence with the South Fork Big River (Figure 118). Stream elevations range from 200 feet at the confluence of the mainstem Big River with North Fork Big River to approximately 1300 feet in the headwaters of the tributaries. The highest point in the subbasin is Irene Peak at 2,836 feet. The subbasin encompasses 130.8 square miles, occupying 72.2% of the total basin area. Most of the subbasin is owned by MRC, Strategic Timber Trust, and JDSF and is managed for timber production. There are also a large number of smaller privately owned parcels near the western border and the small hamlet of Orr Springs lies near the headwaters of the South Fork Big River.

Climate

The Inland Subbasin has average annual rainfalls ranging from 45 inches in lower elevations to 65 inches at higher elevations and towards the northeastern border. The wettest part of the subbasin is the North Fork drainage. Temperatures are typically cooler in the winters and warmer in the summers than in coastal areas. Temperatures range from below freezing to over 90°F seasonally and average 40-51°F.

Hydrology

The Inland Subbasin is made up of 12 CalWater Units (Figure 118). There are 144.4 perennial stream miles in 58 perennial tributaries in this subbasin (Table 169). There are an additional 15.7 miles of the mainstem Big River. North Fork Big River, Chamberlain Creek, South Fork Big River, Daugherty Creek, and the mainstem Big River below the confluence with South Fork Big River are third order streams using the Strahler (1964) classification. The other tributaries and the mainstem Big River above the confluence with South Fork Big River are first and second order streams. Drainage areas range from less than one square mile to over 50 square miles for the South Fork Big River (Figure 119).

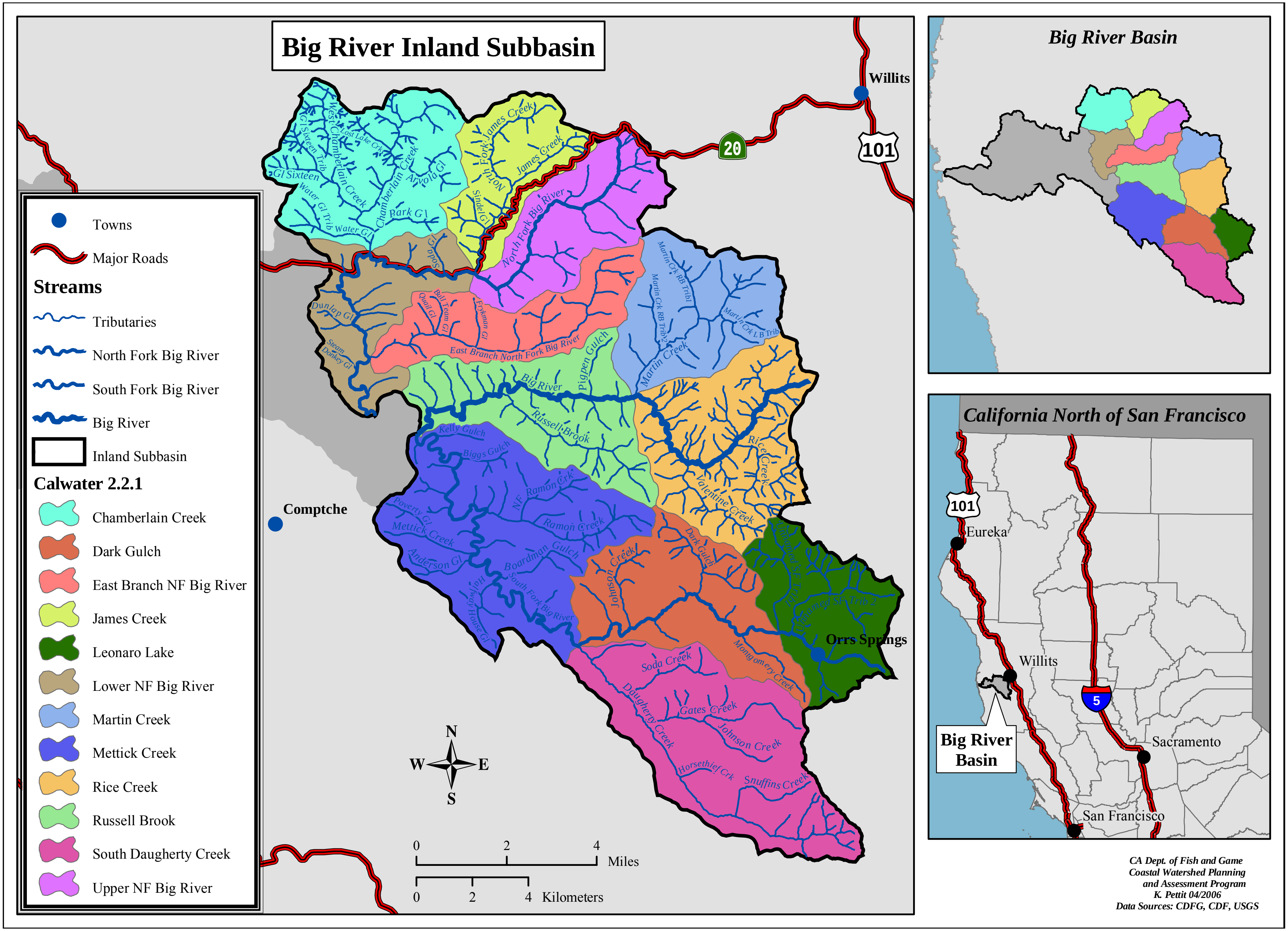


Figure 118. Inland Subbasin and CalWater 2.2a planning watersheds.

Table 169. Tributaries to the Big River in the Inland Subbasin by river mile from 7.5 minute topographic maps.

CalWater Planning Watershed	R.M.	Bank (L,R)	Stream	Perennial (Miles)	Intermittent (Miles)	Stream Order
	30.9	L	North Fork Big River	17.2	0.6	3
East Branch North Fork			East Branch North Fork Big River	7.4	1.4	1
Chamberlain Creek			Chamberlain Creek	6.0		3
			Water Gulch	1.2	1.2	1
			Water Gulch Tributary		1.0	Intermittent
			Park Gulch	0.8	0.6	1
			West Chamberlain Creek	4.0	0.1	2
			Gulch Sixteen	1.8	1.0	1
			Gulch Sixteen Tributary	2.4	0.1	1
			Arvola Gulch	1.2	0.9	1
			Unnamed Tributary to Chamberlain Creek/Lost Lake Creek	0.3	1.0	1
Lower North Fork Big River			Unnamed Tributary to North Fork Big River/Soda Gulch	1.1		1
James Creek			James Creek	2.8	2.8	2
			Sindel Gulch	0.8	0.3	1
			North Fork James Creek		3.6	Intermittent
	32.4	R	South Fork Big River	23.6	2.0	3
Mettick Creek			Kelly Gulch	1.2		1
			Biggs Gulch	0.1	1.2	1
			Ramon Creek	4.8		2
			North Fork Ramon Creek	2.1	0.3	2
			Bowman Gulch		1.1	Intermittent
			Mettick Creek	2.4		1
			Poverty Gulch	1.1	0.3	1
			Anderson Gulch	1.8	0.2	1
			Boardman Gulch	2.5	0.2	1
			Halfway House Gulch	1.5	0.6	1
South Daugherty Creek			Daugherty Creek	7.7	2.3	3
			Soda Creek	1.0	1.9	1
			Gates Creek	3.1	1.7	2
			Johnson Creek	1.9	0.3	1
			Horse thief Creek		1.0	Intermittent
			Snuffins Creek	2.0	0.9	1
Dark Gulch			Johnson Creek	2.4	0.3	1
			Dark Gulch	0.5	2.1	1
			Montgomery Creek	2.1	0.6	1
Leonaro Lake			Unnamed Tributary South Fork Big River #1		3.3	Intermittent
			Unnamed Tributary South Fork Big River #2		3.3	Intermittent
Russell Brook	33.4	L	Unnamed Tributary		0.7	Intermittent
	33.4	L	Unnamed Tributary	1.0	0.3	1
	34.0	L	Unnamed Tributary	1.2	0.2	1
	35.1	L	Unnamed Tributary	1.1		1
	35.6	L	Unnamed Tributary	0.6	0.2	1
	35.7	L	Unnamed Tributary	0.5	0.1	1
	36.0	R	Russell Brook	4.8	0.2	2
	36.3	L	Unnamed Tributary	0.4		1
	36.9	L	Unnamed Tributary	0.6		1
	37.3	L	Unnamed Tributary	0.6		1
	37.3	R	Unnamed Tributary		0.6	Intermittent
	37.7	L	Unnamed Tributary		0.7	Intermittent
	38.0	R	Unnamed Tributary		0.4	Intermittent
	38.5	R	Unnamed Tributary		0.4	Intermittent
	38.9	L	Pigpen Gulch	1.0	0.9	1
	39.0	R	Unnamed Tributary		1.0	Intermittent
	39.7	L	Unnamed Tributary		0.5	Intermittent
	39.8	R	Unnamed Tributary		0.7	Intermittent
Martin Creek	40.1	L	Martin Creek	5.2	0.2	1
			Martin Creek Right Bank Tributary #2	0.4	1.4	1
			Martin Creek Right Bank Tributary #1	3.2		1
			Martin Creek Left Bank Tributary		1.6	Intermittent
	40.7	L	Unnamed Tributary		0.6	Intermittent

CalWater Planning Watershed	R.M.	Bank (L,R)	Stream	Perennial (Miles)	Intermittent (Miles)	Stream Order
	40.9	L	Unnamed Tributary	1.2	0.3	1
	41.0	R	Unnamed Tributary		0.5	Intermittent
	41.4	L	Unnamed Tributary		1.1	Intermittent
	41.7	L	Unnamed Tributary	0.6	0.1	1
	42.1	R	Unnamed Tributary		0.7	Intermittent
	42.4	R	Unnamed Tributary		0.6	Intermittent
	42.6	L	Unnamed Tributary	0.5	0.2	1
	42.8	R	Unnamed Tributary		0.3	Intermittent
	42.9	L	Unnamed Tributary		1.1	Intermittent
Rice Creek	43.0	R	Valentine Creek	4.5	0.3	1
	43.3	L	Unnamed Tributary		0.6	Intermittent
	43.5	R	Unnamed Tributary		0.4	Intermittent
	43.9	R	Unnamed Tributary	0.6	0.2	1
	44.1	R	Unnamed Tributary	0.4	0.1	1
	44.2	L	Unnamed Tributary	0.5	0.1	1
	44.6	R	Rice Creek	2.8	0.3	1
	44.6	L	Unnamed Tributary		0.4	Intermittent
	44.7	L	Unnamed Tributary		0.4	Intermittent
	44.8	L	Unnamed Tributary	1.1	0.4	1
	45.5	R	Unnamed Tributary	0.4	0.1	1
	45.6	L	Unnamed Tributary		0.5	Intermittent
	45.7	L	Unnamed Tributary		0.5	Intermittent
	46.0	L	Unnamed Tributary		0.4	Intermittent
	46.2	R	Unnamed Tributary	0.6	0.1	1
	46.4	R	Unnamed Tributary	0.9	0.3	1
	46.8	L	Unnamed Tributary	0.4	0.3	1
	47.0	L	Unnamed Tributary		0.3	Intermittent
	47.2	L	Unnamed Tributary		0.2	Intermittent
	47.6	L	Unnamed Tributary	0.3	0.2	1

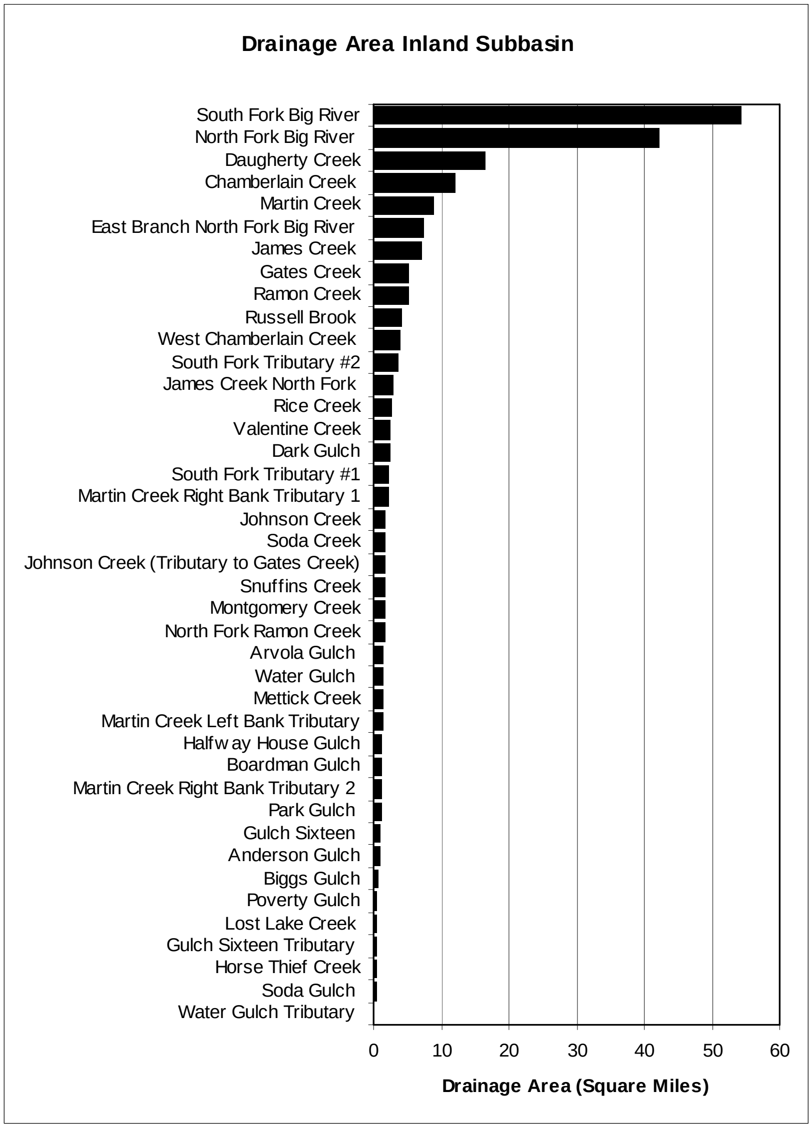


Figure 119. Drainage area of streams surveyed by CDFG in the Inland Subbasin.

Geology

The Inland Subbasin has a high percentage of area in higher slope classes. The Upper Mainstem Big PW has noticeably steeper slopes than the other PWs, with 49.1% of its slopes exceeding 50%, and 17.5% exceeding 70%. The Chamberlain Creek, Upper North Fork Big, Martin Creek, Daugherty Creek, and Middle South Fork PWs all have 36-40% of their slopes in excess of 50% (GMA 2001a).

The subbasin is underlain by rocks of the Coastal Belt Franciscan in the western part and Central Belt Franciscan in the eastern edge with a section of Tertiary age sandstone in the Greenough Ridge – Montgomery Woods State Park area.

Landsliding

A GMA (2001) analysis of landslides by time period found that about 81% of the number of slides across the entire basin were in the Inland Subbasin. The high percentage is due to the fact that this subbasin has over half of the area of the basin. The South Daugherty Creek PW had the highest number of slides in the subbasin, with the Rice Creek and Mettick Creek PWs second and third highest, respectively. The entire South Fork drainage was a high producer of landslides, producing 36% of all slides mapped in the entire Big River Basin. The period from 1937 to 1952 had the highest number of landslides.

Table 170. Inland Subbasin number of delivering slides by study period and PW.

Planning Watershed	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total All Periods	
	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)	(#)	(%)
Upper North Fork Big River	31	4.3	16	2.7	9	4.6	16	7.4	9	4.3	81	4.2
James Creek	28	3.9	45	7.5	13	6.6	15	6.9	8	3.8	109	5.6
Chamberlain Creek	70	9.8	59	9.8	17	8.6	10	4.6	12	5.7	168	8.7
East Branch North Fork Big	39	5.4	20	3.3	10	5.1	9	4.2	17	8.1	95	4.9
Lower North Fork Big River	51	7.1	33	5.5	3	1.5	6	2.8	7	3.3	100	5.2
Leonaro Lake	52	7.3	24	4.0	9	4.6	9	4.2	7	3.3	101	5.2
Dark Gulch	48	6.7	91	1.5	25	12.7	18	8.3	20	9.5	202	10.4
South Daugherty Creek	90	12.6	119	19.8	33	16.8	58	26.9	36	17.1	336	17.3
Mettick Creek	86	12.0	61	10.1	24	12.2	15	6.9	44	21.0	230	11.8
Rice Creek	128	17.9	90	15.0	26	13.2	34	15.7	11	5.2	289	14.9
Martin Creek	41	5.7	25	4.2	16	8.1	14	6.5	16	7.6	112	5.8
Russell Brook	52	7.3	19	3.2	12	6.1	12	5.6	23	11.0	118	6.1
Inland Subbasin	**716**	**36.9**	**602**	**31.0**	**197**	**10.1**	**216**	**11.1**	**210**	**10.8**	**1941**	**100**

GMA 2001a

Landslide volume estimates from the same time periods showed that 82.7% of sediment delivered to streams across the Big River Basin occurred in the Inland Subbasin (GMA 2001a) (Table 171). The highest volumes of sediment in this subbasin were delivered in the Chamberlain Creek PW.

Table 171. Volume of delivering slides by study period by PW in the Inland Subbasin.

Subbasin	1937-1952		1953-1965		1966-1978		1979-1988		1989-2000		Total	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	(%f or Entire Watershed For Entire Period)
Upper North Fork Big River	37,093	1.1	29,175	1.6	10,906	3.9	39,165	8.9	8,164	2.4	124,503	1.6
James Creek	144,596	4.3	116,547	6.4	20,580	7.4	53,885	12.2	2,535	0.7	338,143	4.5
Chamberlain Creek	804,189	23.7	222,892	12.3	28,398	10.2	9,666	2.2	12,200	3.6	1,077,345	14.2
East Branch North Fork Big	137,107	4.0	70,162	3.9	17,748	6.4	44,179	10.0	24,765	7.3	293,961	3.9
Lower North Fork Big River	120,861	3.6	73,891	4.1	2,424	0.9	8,881	2.0	6,900	2.0	212,957	2.8
Leonaro Lake	828,480	24.4	69,078	3.8	14,494	5.2	40,489	9.2	16,365	4.8	968,906	12.8
Dark Gulch	95,223	2.8	288,421	15.9	31,898	11.4	18,120	4.1	17,304	5.1	450,966	6.0
South Daugherty Creek	359,000	10.6	320,909	17.7	19,781	7.1	90,227	20.4	40,900	12.0	830,817	11.0
Mettick Creek	207,219	6.1	124,382	6.9	45,865	16.4	20,331	4.6	56,836	16.7	454,633	6.0
Rice Creek	403,490	11.9	271,868	15.0	34,857	12.5	54,666	12.4	65,068	19.1	829,949	11.0
Martin Creek	123,057	3.6	188,716	10.4	42,901	15.4	32,005	7.2	47,655	14.0	434,334	5.7
Russell Brook	134,826	4.0	37,411	2.1	9,352	3.3	30,082	6.8	42,558	12.5	254,229	3.4
Total	**3,395,141**	**54.1**	**1,813,452**	**28.9**	**279,204**	**4.5**	**441,696**	**7.0**	**341,250**	**5.4**	**6,270,743**	**82.7**

GMA 2001a

The CGS (2005) landslide potential map classified 62% of the Inland Subbasin in the high and very high potential categories (Table 172).

Table 172. Landslide Potential in the Inland Subbasin.

Landslide Potential Category	Area (square miles)	% of Subbasin
Very Low	3.8	3
Low	20.9	16
Moderate	24.4	19
High	60.7	46
Very High	21.1	16

MRC Ownership

During MRC's Watershed Analysis, a total of 1,290 landslides were identified in the MRC ownership of the Inland Subbasin. Of that total, 884 were shallow-seated landslides (debris slides, torrents, or flows) and 406 were deep-seated landslides (rockslides) (Table 173). The Mettick Creek PW had the most shallow-seated landslides and most of these occurred in the 1970s. Over the whole MRC ownership in the subbasin, most landslides in the study period occurred in the 1990s.

Table 173. Shallow-seated landslide summary for lands under MRC ownership in the Inland Subbasin.

PW	Number of Landslides			
	1970s	1980s	1990s	Total
East Branch North Fork Big River	13	22	31	66
Rice Creek	6	1	6	13
Lower North Fork Big River	17	24	18	59
Mettick Creek	159	117	137	413
Dark Gulch	6	1	1	8
Russell Brook	27	45	83	155
South Daugherty	36	35	99	170
Total	**264**	**245**	**375**	**884**

MRC 2003

The majority of landslides in the MRC ownership are debris slides and rockslides. Only about 6% of shallow landslides observed were debris flows and debris torrents while none were earth flows (Table 174).

Table 174. Percent of landslides by type and PW for lands under MRC ownership in the Inland Subbasin.

PW	Debris Slides	Debris Torrents	Debris Flows	Rockslides	Earth Flows
East Branch North Fork Big River	47%	2%	4%	47%	0%
Rice Creek	7%	0%	0%	24%	0%
Lower North Fork Big River	73%	0%	1%	25%	0%
Mettick Creek	64%	3%	3%	30%	0%
Dark Gulch	54%	0%	8%	38%	0%
Russell Brook	57%	3%	7%	33%	0%
South Daugherty	67%	3%	2%	29%	0%
Total	**62%**	**2%**	**4%**	**31%**	**0%**

MRC 2003

MRC also delineated Mass Wasting Map Units across their ownership, to represent general areas of similar geomorphology, landslides processes, and sediment delivery potential for shallow-seated landslides. For more details, see the Geology Appendix.

MRC found that 87% of the shallow-seated landslides within their ownership in the Inland Subbasin delivered sediment to a watercourse. A total of 628,226 tons of mass wasting sediment delivery was estimated for the study period, or 394 tons/square mile/year. Over their entire ownership, MRC found that 34% of mass wasting sediment delivery occurred in the 1970s, 19% occurred in the 1980s, and 48% occurred in the 1990s. The relatively high amounts of sediment delivered in the 1990s are thought to be related to high rainfall events in the 1990s. Within their ownership in the Inland Subbasin, the highest sediment delivery rate was in the Mettick Creek PW.

Fluvial Geomorphology

The North Fork of the Big River was the least impacted of the major channels studied in photo years 1984 and 2000. Only 8.3% (1984) and 7.6% (2000) of the blue-line stream length was impacted in the two photo years.

The South Fork of the Big River improved between photo years. In 1984, nearly 19% of the blue-line stream length was impacted; in photo year 2000, less than 12% of the length of blue line stream was impacted.

Daugherty Creek, a tributary to the South Fork of the Big River, showed the greatest improvement in channel conditions between photo years 1984 and 2000. A higher proportion of this stream contains steeper channel gradients than the other major channels described above. Daugherty Creek's blue-line stream length is about 8.7 miles. The gradient of lower Daugherty Creek ranges from 0.1% up to 2%; middle Daugherty Creek ranges from 1% to 4% in gradient; and upper Daugherty Creek is steeper than 4% and the headwaters are steeper than 10%.

In 1984, nearly 24% of the length of Daugherty Creek was impacted by stream disturbance features, including parts of the headwaters channel, with a gradient above 10%. This suggests recent disturbance, probably in 1983. In photo year 2000 less than 6% of the blue-line channel was impacted, mostly in the lower half of the tributary in reaches having gradients below 4%.

Out of 73 stream reaches surveyed by CDFG in the Inland Subbasin, the most common Rosgen channel types was F4 (Table 175) There were 17 different channel types present.

Table 175. Channel types in surveyed streams of the Inland Subbasin.

Stream	Reach	Survey Length (Miles)	Channel Type
North Fork Big River	1	7.1	F4
	2	3.5	F4
	3	1.4	F4
East Branch North Fork Big River	1	6.6	B4
	2	0.8	A4
Chamberlain Creek	1	1.5	F4
	2	3.6	F4
Water Gulch	1	1.0	B4
	1	0.9	E4
Water Gulch Tributary	1	0.4	B4
Park Gulch	1	1.0	F4
West Chamberlain Creek	1	3.3	F4
	1	0.2	A4
Gulch Sixteen	1	0.8	F4
	2	0.1	F4
Gulch Sixteen Tributary	1	0.4	F4
Arvola Gulch	1	0.9	F4
Lost Lake Creek	1	0.9	G4
Soda Gulch	1	0.7	G3
James Creek	1	2.8	F3
	2	1.6	F3
James Creek North Fork	1	2.4	F4
South Fork Big River Part 1	1	6.3	F3
	2	5.4	F3
South Fork Big River Part 2	1	3.5	C3
	2	3.3	F3
	3	1.2	B1
	4	0.8	C2
Biggs Gulch	1	0.5	F4
Ramon Creek	1	1.6	B4
	2	1.4	F3
	3	0.9	B3
North Fork Ramon Creek	1	1.5	F4
Mettick Creek	1	1.0	B4
Poverty Gulch	1	0.1	E3
Anderson Gulch	1	0.5	F3
Boardman Gulch	1	1.2	B4
	2	<0.1	B3
Halfway House Gulch	1	0.2	F4
Daugherty Creek	1	0.8	B4
	2	2.7	F4
	3	2.5	F3
	4	2.0	F2
	5	0.8	A3
Soda Creek	1	0.6	B4
	2	0.1	F4
	3	0.6	B4
	4	0.4	G4
Gates Creek	1	0.2	F4
	2	2.2	B4
	3	0.3	A4
Johnson Creek (Tributary to Gates Creek)	1	0.4	B4
	2	0.1	F4
	3	0.7	G4
Horse Thief Creek	1	0.1	F4
Snuffins Creek	1	1.3	G4
Johnson Creek	1	0.9	F4
Dark Gulch	1	1.4	B3
Montgomery Creek	1	0.2	F2
	2	0.1	B2
	3	0.4	F6
Unnamed Tributary 1 to South Fork Big River	1	0.7	F3
	2	0.1	B2
	3	0.3	B4
Unnamed Tributary 2 to South Fork Big River	1	0.6	C4
Russell Brook	2	4.1	B3
Martin Creek	1	3.5	B2
	1	0.2	F2
Martin Creek Left Bank Tributary	1	0.6	B3
Martin Creek Right Bank 1 Tributary	1	1.5	B3
Martin Creek Right Bank 2 Tributary	1	0.6	B4
Valentine Creek	1	1.8	B3
Rice Creek	1	1.8	F4

Of the 37 stream segments surveyed by MRC in this subbasin, the most common Rosgen channel type was F4 (Table 176). There were nine channel types present. MRC measured various stream channel characteristics and grouped channels across their ownership into different geomorphic units. MRC plans to use the geomorphic unit classification to examine habitat-forming processes within the channels. MRC also established five long term monitoring stations where thalweg profiles, cross sections, and particle size distribution will be studied over time. These sites are on the mainstem Big River, East Branch North Fork Big River, Ramon Creek, Daugherty Creek, and South Fork Big River.

Table 176. Channel types in streams surveyed by the MRC on their ownership in the Inland Subbasin.

Stream	Segment ID	Survey Length (Miles)	Channel Type
East Branch North Fork Big River	BE1	0.2	F4
	BE2	0.1	F4
Bull Team Gulch	BE8	0.0	G4
Frykman Gulch	BE14	0.0	B4
Big River in Rice Creek PW	BI1	0.2	F4
North Fork Big River	BL1	0.2	F4
	BL3	0.2	F4
Steam Donkey Gulch	BL7	0.0	A1
Dunlap Gulch	BL12	0.1	A3
South Fork Big River	BM1	0.2	F4
	BM3	0.2	F4
	BM5	0.2	F4
Ramon Creek	BM25	0.1	F4
	BM26	0.1	F4
	BM27	0.1	F4
North Fork Ramon Creek	BM31	0.1	F4
	BM32	0.1	G4,B4
Mettick Creek	BM54	0.1	G1
	BM55	0.1	
Boardman Gulch	BM59	0.0	A3,A1,G4
Halfway House Gulch	BM64	0.1	A1,A4,G4
South Fork Big River Tributary	BM76	0.0	F4,G4
Big River in Russell Brook PW	MR1	0.2	F4
	BR2	0.2	F4
	BR4	0.2	F4
Russell Brook	BR5	0.1	B4,G4
	BR6	0.1	F4,G4
	BR7	0.1	G4,F4
Wildhorse Gulch	BR9	0.1	
Pig Pen Gulch	BR29	0.0	G4
Daugherty Creek	BS1	0.2	F4
	BS3	0.1	G3,B3
	BS5	0.1	B4,G4
Soda Creek	BS15	0.1	G4
Gates Creek	BS23	0.1	G3,B3
Johnson Creek	BS24	0.1	B4,G4
Snuffins Creek	BS49	0.1	G4

MRC 2003

Vegetation

Redwood-Douglas-fir forests cover 68% of the Inland Subbasin, with the remainder made up mostly of Douglas-fir, grass, oak, bay laurel, tan oak, madrone, and alder (Table 177). The North Fork drainage has the most acres of Redwood-Douglas-fir forest and the upper drainage has the most Douglas-fir forest. Oak, bay laurel, and grasslands are concentrated in the South Fork and upper drainages. Sixty-five percent of tree stands are composed of small trees (Table 178) and just under half of the subbasin is covered by trees with 90% crown canopy density (Table 179). Seven percent of the basin has no canopy cover. The North Fork drainage has more tree stands composed of medium/large trees and less areas with no canopy cover than the other two drainages within the subbasin. The upper drainage has the least amount of area covered by 90% canopy density.

Table 177. Acreage and proportion of area of vegetation classes in the Inland Subbasin.

Class	North Fork		South Fork		Upper		Inland	
	Acres	%	Acres	%	Acres	%	Acres	%
Redwood - Douglas-fir	23,971	86	21,684	63	11,238	54	56,893	68
Douglas-Fir	1,855	7	4,952	14	4,184	20	10,991	13
Tan Oak, Madrone, Alder	1,359	5	1,661	5	1,501	7	4,521	5
White, Black or Live Oak & Bay Laurel	253	1	2,881	8	2,122	10	5,256	6
Blueblossom Ceanothus			50	0	12	0	62	0
Manzanita, Chamise, Scrub Oak	98	0	516	1	557	3	1,171	1
Bishop Pine, Pygmy Cypress, Willow								
Grass	304	1	3,105	9	1,340	6	4,749	6
Wet Meadows								
Water								
Barren / Rock			10	0	30	0	40	0
Urban/Developed								
Totals	**27,840**	**100%**	**34,859**	**100%**	**20,984**	**100%**	**83,683**	**100%**

Table 178. Vegetation size classes in the Inland Subbasin by planning watershed.

PW	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Chamberlain Creek		0	52	0.7	3,687	47	4,003	51	107	1.4
East Branch North Fork Big River	6	0.1	201	4	3,669	72.7	1,173	23.2		0
James Creek		0	95	2.1	3,083	69.2	1,273	28.6	3	0.1
Lower North Fork Big River		0	104	2.1	2,489	50.4	2,222	45	128	2.6
Upper North Fork Big River		0	266	5.2	3,543	68.9	1,309	25.5	22	0.4
Dark Gulch	50	0.8	480	7.8	3,543	57.3	1,720	27.8	391	6.3
Leonaro Lake	34	1	389	11.2	1,946	55.8	1,015	29.1	102	2.9
Mettick Creek	9	0.1	497	4.3	8,634	74.5	2,445	21.1		0
South Daugherty Creek	57	0.6	1,094	11	7,266	73.2	1,486	15	24	0.2
Martin Creek	55	1	766	14.4	3,400	64	1,065	20.1	25	0.5
Rice Creek	218	3.1	716	10.2	4,687	67	1,362	19.5	9	0.1
Russell Brook	47	0.7	311	4.6	4,816	71.4	1,566	23.2	1	0
Total Inland	**476**	**1**	**4971**	**6**	**50763**	**65**	**20639**	**27**	**812**	**1**

Total density of all species - conifers and hardwoods. Most of the 0 percent density crown canopy is grasslands, water, shrub species.

Table 179. Density of vegetation in the Inland Subbasin by planning watershed.

PW	Percent Crown Canopy Density										Total Acres
	0%		10-69%		70%		80%		90%		
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	
Chamberlain Creek	12	0	57	1	1,851	24	1,105	14	4,836	62	7,863
East Branch North Fork	107	2	371	7	958	19	1,169	23	2,552	49	5,156
James Creek	1	0	144	3	760	17	1,423	32	2,128	48	4,456
Lower North Fork	7	0	146	3	905	18	923	19	2,969	60	4,950
Upper North Fork	275	5	711	13	840	16	1,479	27	2,112	39	5,416
Dark Gulch	966	14	638	9	822	11	931	13	3,793	53	7,151
Leonaro Lake	1,840	35	1,276	24	490	9	722	14	998	19	5,325
Mettick Creek	139	1	716	6	1,577	13	2,001	17	7,292	62	11,724
South Daugherty Creek	733	7	952	9	1,469	14	1,860	17	5,645	53	10,659
Martin Creek	629	11	1,264	21	681	11	1,311	22	2,056	35	5,940
Rice Creek	1,041	13	1,026	13	1,323	16	1,688	21	2,953	37	8,033
Russell Brook	270	4	460	7	1,304	19	1,397	20	3,579	51	7,011
Total Inland	**6,020**	**7**	**7,761**	**9**	**12,980**	**16**	**16,009**	**19**	**40,913**	**49**	**83,684**

Total density of all species - conifers and hardwoods. Most of the 0 percent density crown canopy is grasslands, water, and shrub species.

Fire and Fuels

Areas of high and very high fuel rank dominate the Inland Subbasin, with larger bands of very high fuel rank along the border of the North Fork and upper drainages, through the middle of the upper drainage, and along the southern border of the subbasin. The 1931 Comptche fire burned 4,234 acres in the southern part of the subbasin and the 1950 Irene Peak fire burned 6,929 acres in the eastern part. A 1951 fire burned 322 acres in the JDSF and a smaller 2003 fire burned 10 acres near the northern border.

Land Use

The Inland Subbasin is composed mostly of large sized parcels owned by JDSF, MRC, Strategic Timber Trust, and Weger Timber Company. Smaller parcels cluster around the western boundary near town of Willits and the hamlet of Orr Springs.

Montgomery Woodlands State Reserve makes up an additional 3% of the subbasin. The reserve started with a nine-acre donation by Robert Orr in 1945, and has since been enlarged to 1,142 acres by purchases and donations from the Save-The-Redwoods League. The reserve includes 700 acres of redwood trees and many trails. It has excellent groves of both a magnificent old-growth coastal redwood grove and a fern forest. A recent land acquisition by the Save the Redwoods League will double the size of the park, adding 1,240 acres (Geneilla 2006).

The Pacific Forest Trust holds a conservation easement on 4,000 acres along the western border of the Big River Basin called the Leonard Lake Preserve. The preserve straddles four to five miles of the watershed boundary and about 33% of it lies within the Big River Basin. The conservation easement allows for a limited amount of timber harvest, maintenance of existing roads, and some horse grazing. The land cannot be further developed, however.

Cattle and sheep grazing were historically common in the grassland areas within the subbasin and still occur in some areas.

Forest Management

May 6, 1885 Alfred R. Johnston granted a land patent for 160 acres of timberland on Daugherty Creek. (In his 20 years on the upper South Fork, he was to establish 7 known logging camps, and built or operated 7 logging dams).

Timber harvesting has played an important role in the history of the Inland Subbasin for the past 250 years. Harvests increased dramatically in the post World War II years and have increased again since 1973 (Table 180). Timber harvest in the upper drainage has been especially high recently, with 50.4% of the drainage harvested from 1993 to 2001. MRC, Strategic Timber Trust, and Weger currently own 62% of the subbasin.

Table 180. Timber harvest in the Inland Subbasin.

Time Period	North Fork		South Fork		Upper		Inland Subbasin	
	Acres Harvested	Percent of Subbasin Harvested	Acres Harvested	Percent of Subbasin Harvested	Acres Harvested	Percent of Subbasin Harvested	Acres Harvested	Percent of Subbasin Harvested
1852-1944	5,884	21.1	6,760	19.4	1,912	9.1	14,556	17.4
1945-1964	12,418	44.6	7,389	21.2	10,060	47.9	29,867	35.7
1965-1974	8,917	32.0	2,410	6.9	2,765	13.2	14,092	16.8
1975-1984	13,434	48.3	4,422	12.7	3,736	17.8	21,592	25.8
1985-1992	5,427	19.5	5,054	14.5	6,057	28.9	16,538	19.8
1993-2001	6,041	21.7	7,323	21.0	10,567	50.4	23,931	28.6
Total	**49,122**		**33,359**		**35,097**		**117,578**	

Early timber harvest activities across the subbasin consisted of clear cuts and fire, while most recent harvests are single or group tree selections, shelterwood removal, seed tree removal, commercial thinning, and alternative prescription (Figure 120). Many acres of the subbasin underwent conversion from 1945 to 1964. Use of fire for harvesting was largely concentrated in the South Fork drainage prior to 1944 and the upper drainage from 1945-1964. Seed tree seed cut harvest was used more often in the North Fork drainage from 1945 to 1975 than the other drainages.

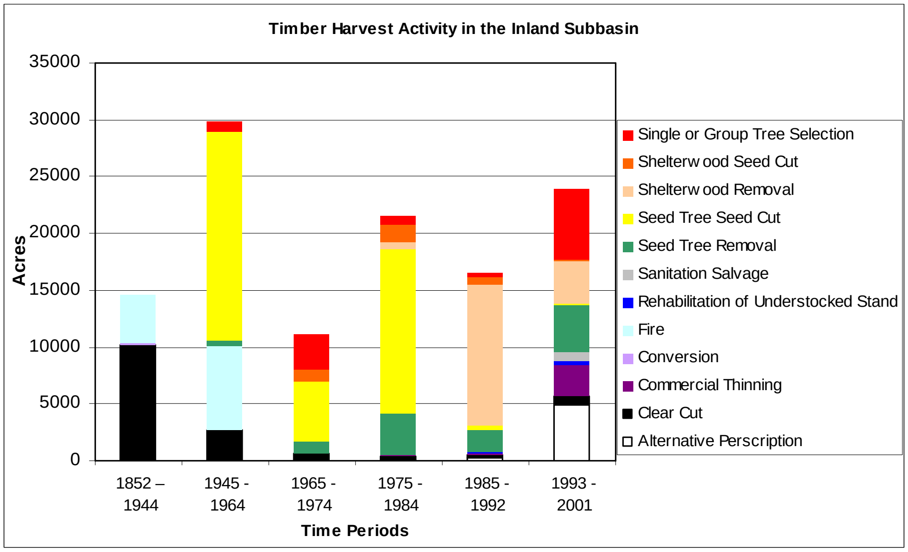


Figure 120. Acres of timber harvest activities in the Inland Subbasin.

Yarding methods have also changed over time, from predominantly cable ground and fire before World War II to tractor yarding in the post war years, and increasing cable suspended and helicopter since 1975 (Figure 121). Helicopter yarding has been concentrated in the South Fork and upper drainages.

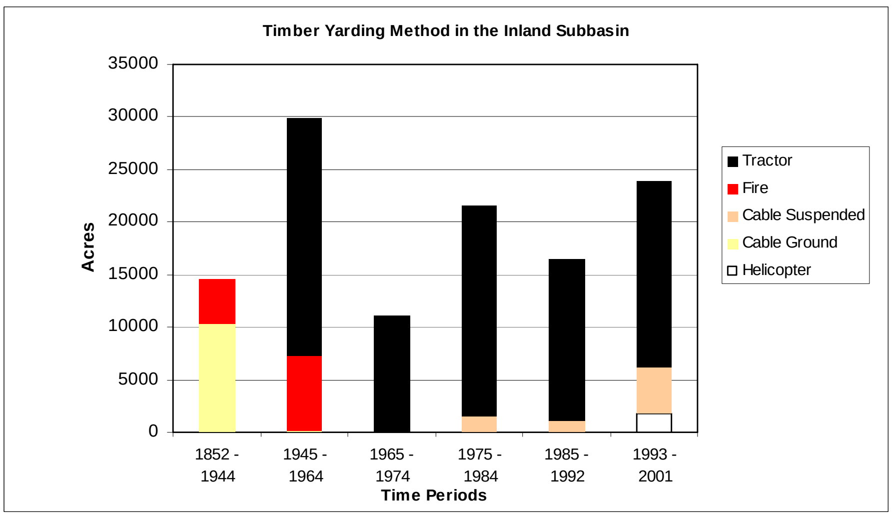


Figure 121. Acres of timber harvest yarding methods in the Inland Subbasin.

GMA (2001) calculated the harvest density, a measure of the acres of timber harvested in a given time period divided by the total acreage in the watershed, for 1937-1951, 1952-1964, 1965-1977, 1978-1987, and 1988-2001. The harvest density was 34 acre/acre for 1989 to 2000 (or 34% of the watershed). This was the most intense harvesting during any of the time periods studied. Over the entire study period, an estimated 102% of the Inland Subbasin was harvested. The percentage harvest exceeds 100% in part because some areas were harvested multiple times.

A CDF analyses of disturbance levels across this subbasin found that land use activity over the past 150 years has generally shifted from high disturbance activities to low and moderate disturbance activities (Figure 122). The rate of activities in recent years appears to have increased.

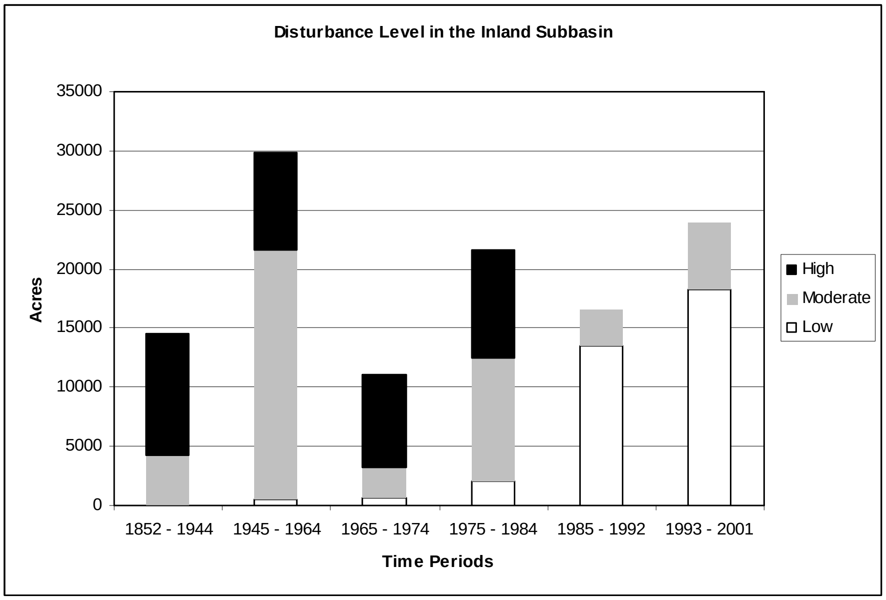


Figure 122. Acres by disturbance level in the Inland Subbasin.

Roads

The Inland Subbasin has a total of 839.2 miles of roads, the vast majority of which are made of native material (Table 181). There are very few paved roads throughout the subbasin and none at all in the upper drainage. Overall road density is 6.4 miles per square mile, the lowest of the three Big River subbasins. Road densities within the subbasin ranged from 5.8, 6.6, and 7.1 miles per square mile in the South Fork, North Fork, and upper drainages, respectively. Road construction peaked from 1937 to 1952 and decreased until 1988. Construction has increased since 1988, with increased timber harvest.

Table 181. Length of truck roads in the Inland Subbasin by period and road surface.

Period	Total Length in Miles				Length in Miles per Sq Mile			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
Up thru 1936	3.9	1.4	0.1	5.4				
1937 - 1952	145.5	28	32.8	206.2	1.1	0.2	0.3	1.6
1953 - 1965	171.9		25.5	197.4	1.3		0.2	1.5
1966 - 1978	140		24.7	164.7	1.1		0.2	1.3
1979 - 1988	83		1.1	84.1	0.6			0.6
1989 - 2000	167.1		14.3	181.6	1.3		0.1	1.4
Total	711.3	29.5	98.5	839.2	5.4	0.2	0.8	6.4

Lengths are roads constructed in time period, not cumulative

Water Quality

There is a fairly complete record of water temperature information for the North Fork and South Fork drainages of the Inland Subbasin. This is due to more widespread accessibility to subbasin watercourses and broad participation by local landowners, particularly MRC and CDF at JDSF. The headwaters drainage only has water temperature data for the northern portion due to participation by the MRC and the CDF at JDSF.

Physical-chemical information is largely lacking, as noted by the presence of only four sampling events by the Dept. of Health Services (DHS) and the NCRWQCB.

Sediment records were available for bulk, permeability and by a sediment source analysis conducted by GMA. GMA and MRC were largely responsible for most of the sediment data. D50s (pebble counts) were also conducted by MRC in a number of watercourses, however, they were completed only at the head's of riffles and therefore are not comparable to more traditionally conducted pebble counts that encompass the length and width of entire riffles. A single turbidity-suspended sediment sampling event was also conducted during 2001 by GMA at the Big River Mainstem downstream from Russell Brook.

Temperature

Continuous water temperature data logging devices were deployed by MRC, JSF, and MWA at a total of 50 locations in the Inland Subbasin. However, one site on the lower North Fork (MRC 75-4) apparently had no raw data associated with it or it was not made available for this assessment. Therefore, there were a total of 49 active sites in this subbasin with summary values for one additional site. Water temperature was monitored in one or more locations in the Inland Subbasin during the years 1990 to 2001.

During the initial data review, the several potential issues with the water temperature data were noted. Data were reviewed according to the criteria established in the Water Quality Criteria section, with the intent that only data that appeared representative of stream conditions were used. In the Inland Subbasin, all but five of the available water temperature data sets met the data quality criteria and were used for this assessment. It should be noted, however, that the MWA sites were typically positioned at the bottom of pools to assess thermal refugia. Therefore, data from these loggers may not represent average water temperature conditions in their respective thermal reaches.

Since there were so many sampling locations across the Inland Subbasin (Figure 123), results are presented by drainage: North Fork Big River, South Fork Big River, and headwaters.

North Fork Drainage

There are a total of nine monitoring sites on the North Fork of the Big River (FSP 5238, FSP 5220, JSF 527, JSF 528, JSF 529, JSF 530, JSF 531, JSF 532, and MRC 75-4). These monitoring sites are all located throughout all of the reaches in the North Fork and were recording temperatures for the following durations: two years at FSP 5238, two years at FSP 5220, one year at JSF 527, three years at JSF 528, one year at JSF 529, three years at JSF 530, one year at JSF 531, three years at JSF 532, and one year at MRC 75-4.

In the upper reaches of the North Fork (FSP 5238 and FSP 5220), the water temperature was somewhat suitable with an observed maximum MWAT of between 63 and 64°F. The North Fork then enters JDSF, and the first monitoring site (JSF 527) that is encountered is near the forest boundary. At this site (JSF 527), water temperature was moderately unsuitable with an observed maximum MWAT of 66°F. The reason for this temperature jump is unclear. However, it could be due to any one or more of the following: the influences of a small unnamed tributary between the monitoring sites, a lack of canopy or flow in the vicinity of JSF 527, or the placement of the FSP temperature probes not following the standard protocol used by JSF. Based on a 1994 Landsat vegetation map (KRIS Big River), the position in the watershed (e.g. headwaters) and the diurnal temperature fluctuations at the FSP sites, it is likely that the canopy and/or flow are poor at these sites. While the canopy appears to be good at JSF 527, the large temperature jump is likely due to a particularly exposed section of stream immediately upstream which heats the water quickly, possibly combined with a different protocol for probe placement.

After entering JDSF, the temperatures in the North Fork remain relatively high, but generally appear to decline downstream. Two probes were place on either side of the confluence with James Creek, JSF 528, and JSF 529. Water temperatures at these sites were moderately unsuitable, with a maximum observed MWAT of 66°F before the confluence with James Creek to somewhat unsuitable with an MWAT of 65°F. This, combined with temperature data from James Creek, suggests that James Creek has somewhat of a cooling effect on the North Fork. There are two monitoring sites on James Creek (JSF 534 and JSF 567) and one on the North Fork of James Creek (JSF 533). Water temperatures at the North Fork James Creek site (JSF 533) were fully suitable with a maximum observed MWAT of 59°F. Farther down on James Creek, the next monitoring site (JSF 534) had water temperatures that were moderately unsuitable, with an observed MWAT of 61°F. In the lower portion of James Creek, the next site (JSF 567) had water temperatures that were somewhat suitable, with an observed MWAT of 63°F. At these sites, diurnal fluctuations ranged from good to poor (6.2-11.5°F).

The next group of monitoring sites on the North Fork was placed on either side of the confluence with Chamberlain Creek (JSF 530 and JSF 531). Water temperatures at these sites were somewhat unsuitable to undetermined, with an observed maximum MWAT of 65°F before the confluence and an observed MWAT of 64°F after the confluence. This, combined with temperature data from Chamberlain Creek suggests that Chamberlain Creek has a somewhat cooling effect on the North Fork.

USFWS monitored one site on the North Fork Big River at the confluence with Chamberlain Creek in 1973 (Perry 1974). The monitoring site recorded water temperatures that were fully unsuitable with a MWAT of 72ºF. In addition, the maximum water temperature recorded was 83ºF, over the lethal limit for salmonids (75ºF). Comparison of 1973 data with recent monitoring at the same location (JSF 530 and JSF 531) appears to show that water temperatures have decreased significantly since 1973.

There are six monitoring sites on Chamberlain Creek (JSF 536, JSF 557, JSF 537, JSF558, JSF 538, and JSF 539) and one on West Chamberlain Creek (JSF 540). Water temperatures at the West Chamberlain Creek site (JSF 540) were fully suitable with a maximum observed MWAT of 59°F. In the headwaters of Chamberlain Creek, JSF 536 is the first monitoring site. JSF 536 had water temperatures that were fully suitable, with a maximum observed MWAT of 58°F. The next monitoring site downstream is JSF 557, which is located immediately before the confluence with Arvola Gulch. The observed water temperatures at this site, while significantly higher than JSF 536, were still fully suitable with an observed MWAT of 60°F. The monitoring site immediately downstream of the confluence with Arvola Gulch (JSF 537), exhibited water temperatures that were fully suitable to moderately suitable with a maximum observed MWAT of 61°F. Based on the observed Chamberlain Creek stream temperatures upstream and downstream of Arvola Gulch and temperature monitors in upper and lower Arvola Gulch, it appears that Arvola Gulch has little or no effect on Chamberlain Creek water temperatures. Both sites in Arvola Gulch (upper and lower) appeared to have essentially the same water temperature in the year monitored. Water temperatures in Arvola Gulch were moderately suitable with observed MWATs of 61°F at both sites.

Immediately downstream of the paired monitoring sites on Chamberlain Creek around the confluence with Arvola Gulch, is JSF 558. Water temperatures at this site were moderately suitable with an observed MWAT of 61°F, which is essentially the same as that seen in JSF 536 (immediately upstream). The next monitoring site on Chamberlain Creek (JSF 538) is placed immediately after the confluence with West Chamberlain Creek. Water temperatures at this site were moderately suitable with an observed MWAT of 61°F. It is uncertain what effect West Chamberlain Creek has on Chamberlain Creek, but it appears as though West Chamberlain Creek has little effect or possibly a slight cooling effect.

Water Gulch, a tributary to Chamberlain Creek, converges with Chamberlain Creek between West Chamberlain Creek and the confluence with the North Fork. The monitoring site located in Water Gulch (JSF 560) exhibited water temperatures that were fully suitable, with a maximum observed MWAT of 58°F. The thermograph from this site suggests that that the monitoring location may have a significant groundwater component and/or possibly a thermally stratified pool, especially in August and September. This is indicated by the atypical "flat" fluctuations. While the site at Water Gulch is much cooler than Chamberlain Creek, it is unknown what effect, if any, Water Gulch may have on the water temperature in Chamberlain Creek after the confluence.

The final site in lower Chamberlain Creek (JSF 539) appears to have substantially higher water temperatures than JSF 538. Water temperatures at this site were moderately suitable to somewhat suitable, with a maximum observed MWAT of 63°F. Based on a 1994 Landsat vegetation map (KRIS Big River), it may be that the elevated temperatures seen at this site are due to a large clearing in this portion of Chamberlain Creek.

After the paired monitoring sites on either side of the confluence with Chamberlain Creek, the next North Fork site is JSF 532. Water temperatures at this site were undetermined to somewhat unsuitable, with a maximum observed MWAT of 65°F. However, given the range of fluctuations in the MWAT at this site, it does not appear to be substantially different from JSF 531 (the site upstream of it).

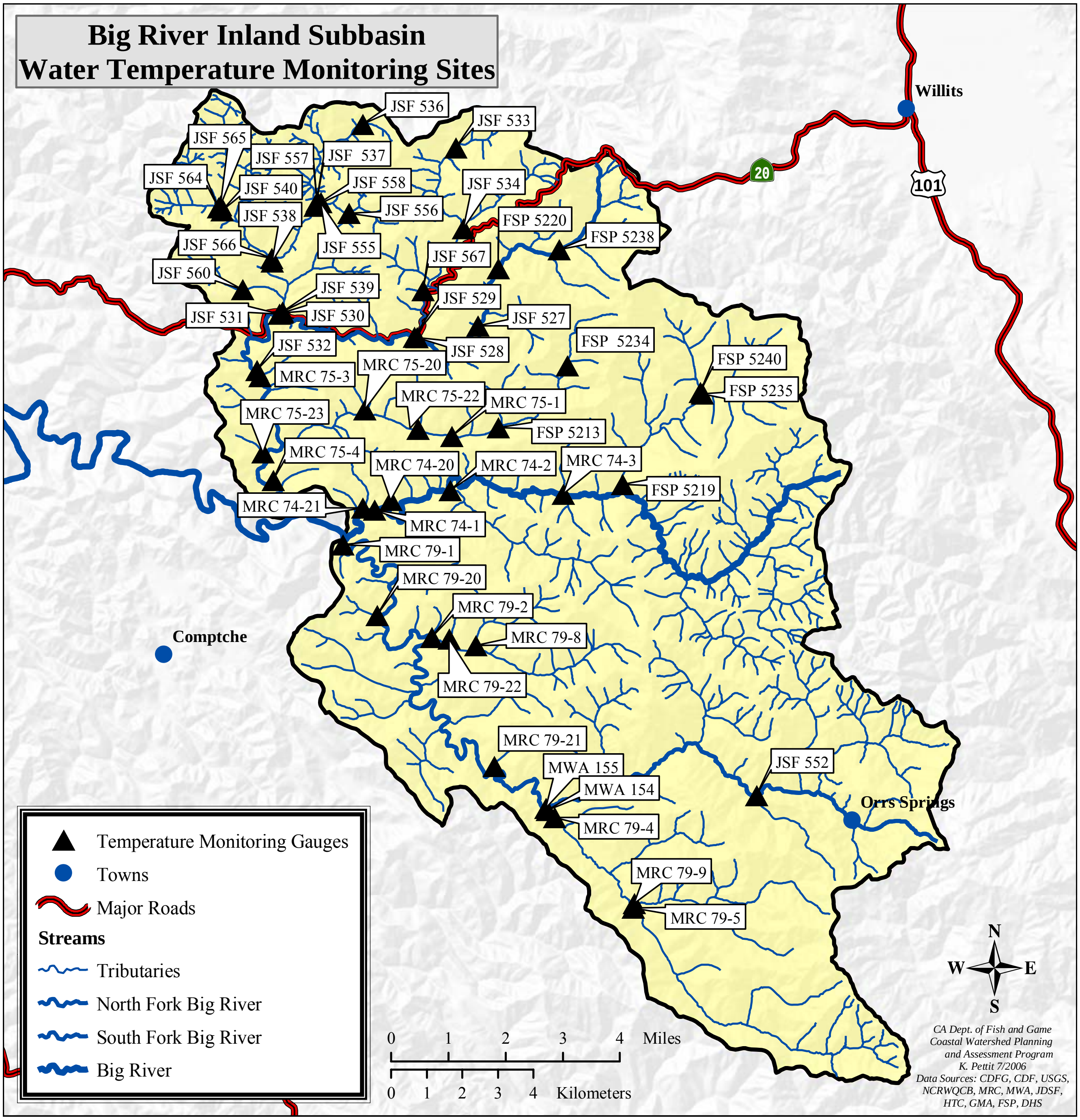


Figure 123. Water temperature monitoring sites, Inland Subbasin.

The East Branch of the North Fork, a tributary to the North Fork, has four water temperature monitoring sites (FSP 5234, FSP 5213, MRC 75-1, and MRC 75-3). These sites are spread along the length of the East Branch of the North Fork and were monitored for two years, two years, six years, and two years, respectively. The first site in upper East Branch of the North Fork (FSP 5234), had water temperatures that were fully suitable with an observed maximum MWAT of 60°F. Further downstream, located in the middle portion of the East Fork of the North Fork, are FSP 5213 and then MRC 75-1. FSP 5213 had water temperatures that were moderately suitable to somewhat suitable, with a maximum observed MWAT of 63°F. MRC 75-1 had water temperatures that were moderately suitable to somewhat unsuitable, with a maximum observed MWAT of 65°F. However, the MWATs at MRC 75-1 appear to have a downward trend.

USFWS monitored one site on the middle reach of the East Branch North Fork Big River in 1973 (Perry 1974). The monitoring site had recorded water temperatures that were fully suitable with a MWAT of 59ºF. In addition, the maximum water temperature recorded was 64ºF, well below the lethal limit for salmonids (75ºF).

Comparison of 1973 data with recent monitoring at a similar location (MRC 75-1) appears to show that water temperatures have increased since 1973.

A site in lower Frykman Gulch (MRC 75-22), a tributary to the East Branch North Fork, was monitored for one year. The confluence of this tributary is downstream of MRC 75-1. The thermograph from MRC 75-22 suggests that the monitoring probe at this site was in a stratified pool and/or a location that is significantly influenced by groundwater. This is evident by the atypical diurnal fluctuations and flat peaks. The water temperatures at this site were fully suitable with a maximum observed MWAT of 56°F. It is unclear if Frykman Gulch contributes a significant amount of flow to the East Branch of the North Fork, and thus it is not known if it provides any cooling effect.

The last site on the East Branch of the North Fork, near the confluence with the North Fork, is MRC 75-3, which was monitored for two years. Water temperatures at this site were moderately suitable to undetermined, with a maximum observed MWAT of 64°F. While there is a substantial difference in the observed MWATs at this site (-2.9°F) between 1997 and 2001, there is insufficient information to determine if there is a possible trend. This drop could be due to climatic conditions, differences in placement of the monitoring probe, or some alteration of the canopy. A review of available THP maps (KRIS Big River) did not indicate any harvesting at this location during the late 1990s.

After the confluence with the East Branch of the North Fork, the next tributary to the North Fork that was monitored is Steam Donkey Gulch (MRC 75-23). This site was monitored for one year. Inspection of the thermograph for this site suggests that the probe was placed either in a stratified pool or in a location with a significant groundwater influence, particularly in the middle to late summer. Water temperatures at this site are fully suitable, with an observed MWAT of 56°F. It is unclear what, if any, contribution of cooler water Steam Donkey Gulch makes to the North Fork. However, based on the thermograph, it is suspected that flows are minimal, particularly in the middle to late summer.

The final site on the North Fork, downstream of the confluence with Steam Donkey Gulch, is MRC 75-4. This site was monitored for one year. Water temperatures at this site are moderately unsuitable, with an observed MWAT of 67°F. However, the maximum diurnal temperature fluctuations are low (5.4°F). Unlike the North Fork sites in the JDSF, water temperatures at this site did not follow a downward trend, and in fact MRC 75-4 had the highest recorded MWAT in the North Fork subbasin. However, it should be noted that this site was only monitored in 1992, while the other upstream sites were monitored during different years. Therefore, it is possible that 1992 was an abnormally hot year.

Nevertheless, a 1994 Landsat vegetation map (KRIS Big River) indicates a substantially younger forest on the North Fork downstream of the JSF boundary. With the low diurnal fluctuations recorded at MRC 75-4, it is suspected that there is a significant amount of flow to give the water some thermal buffering capacity. The predominance of small trees in the reaches upstream of MRC 75-4 would also suggest significant solar exposure. It is unknown if the vegetation shown in the 1994 Landsat map was essentially the same in 1992. However, presuming it was, this may be the reason for the relatively high MWAT observed at MRC 75-4. In any case, further monitoring is necessary to conclusively make any connections.

As shown in Figure 124, water temperatures in the North Fork are apparently dropping as the water moves downstream. However, this only seems to apply to sites within the JDSF. Of the portions of the North Fork outside of JDSF, the limited amount of water temperature data appears to show upward spikes in water temperature. In general, the 1994 Landsat vegetation map (KRIS Big River), indicates younger forests outside of the JDSF boundaries, with a preponderance of tree sizes in the sapling through small/medium tree size. There also appears to be more areas without trees. Available THP maps (KRIS Big River) also indicate that a large portion of the land outside of JSF has been harvested in some manner in the 1990's. While more years' of data are needed to confirm this pattern, the limited amount of data from a large number of monitoring sites suggest that the North Fork is significantly heated on the private lands surrounding JDSF.

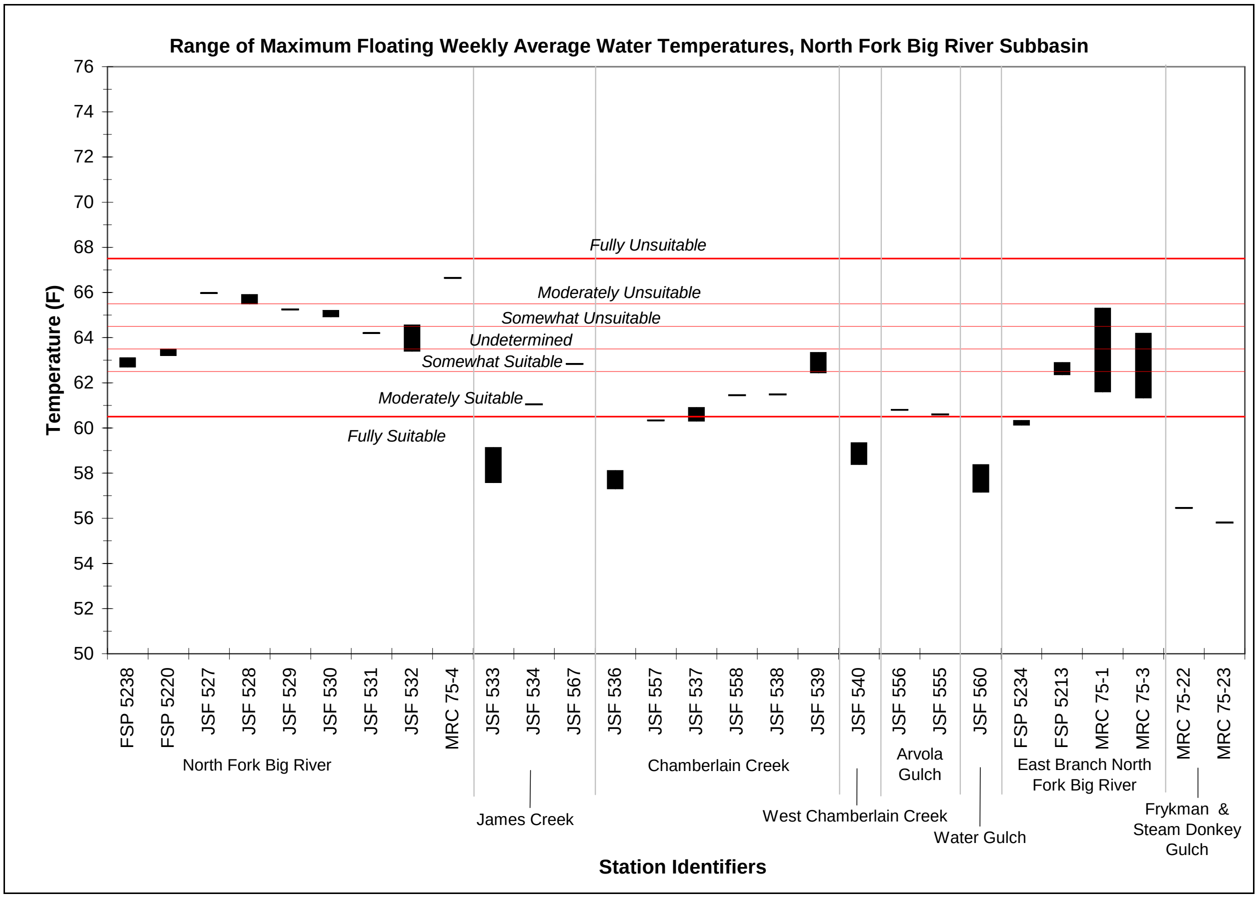


Figure 124. Range of MWATs in the North Fork drainage.

South Fork Drainage

The most extensively monitored locations in the Inland Subbasin were the South Fork Big River above the confluence with the Big River (MRC 79-1) and lower Daugherty Creek (MRC 79-4 and MWA 154). These sites were monitored for five, six, and three years, respectively. Three other sites, including Montgomery Creek (JSF 552), Lower Ramon Creek (MRC 79-2), and the South Fork Big River below Daugherty Creek (MWA 155) were monitored for three years each. The remaining sites were monitored for one year, with the exception of Lower Gates Creek (MRC 79-9), which was monitored for two years.

There are a total of three monitoring sites on Daugherty Creek (MRC 79-4, MRC 79-5, and MWA 154). Lower Daugherty Creek was monitored at two locations: one site (MRC 79-4) was monitored for six years, and the other nearby site (MWA 154) was monitored for three years. Based on data from these Lower Daugherty Creek sites, the water temperature varies between moderately suitable with a minimum observed MWAT of 62ºF, to moderately unsuitable with a maximum observed MWAT of 67ºF. In general the water temperatures at MRC 79-4 are higher than those observed at MWA 154, as seen in Figure 125. This is probably due to the fact that MWA typically deploys their temperature monitors in areas of thermal refugia, such as the bottom of a pool. However, even with the data logger deployed to capture thermal refugia, water temperature exceeded the fully supportive range.

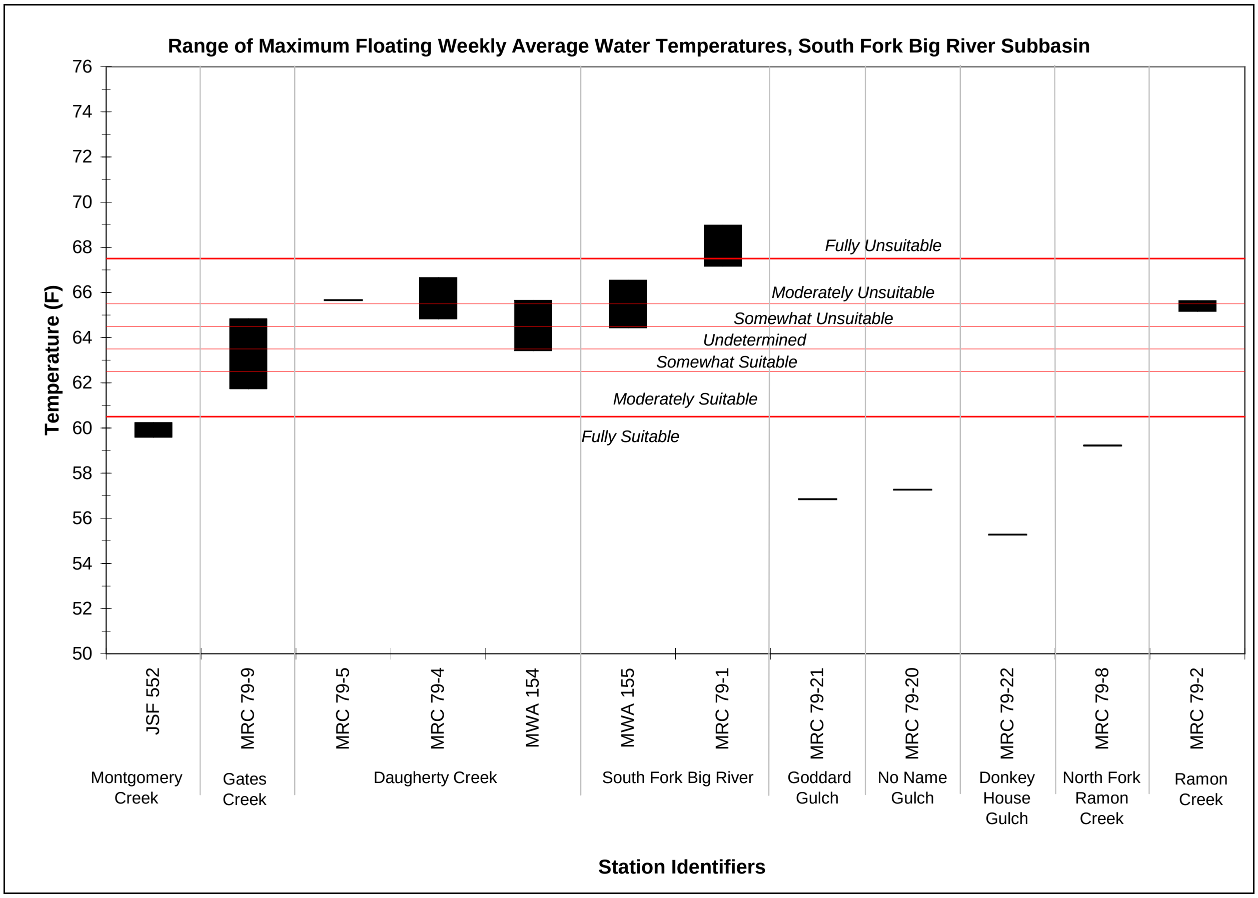


Figure 125. Range of MWATs in the South Fork drainage.

The one site in Upper Daugherty Creek (MRC 79-5) was only monitored during one year. The data from this site suggest that the MWATs are similar to those observed in Lower Daugherty Creek, as MRC 79-5 was within the range of MWATs observed in Lower Daugherty Creek. However, further monitoring is necessary to confirm this relationship. In any case, during the one year monitored, the water temperature was moderately unsuitable with an observed MWAT of 66ºF.

On the whole, both upper and lower Daugherty Creek exhibited relatively large diurnal temperature fluctuations (7.6-11.3ºF), indicating possible low flow and/or poor canopy conditions. Based on 1994 Landsat vegetation images (KRIS Big River), it appears as though much of Daugherty Creek has small trees within the riparian corridors, which may contribute to increased solar exposure and the large diurnal temperature fluctuations observed.

Gates Creek, a tributary to Daugherty Creek, was also monitored at one location (MRC 79-9) in the lower portion of the stream for two years. During the two years monitored, the water temperature varied between moderately suitable with a minimum observed MWAT of 62ºF, to somewhat unsuitable with a maximum observed MWAT of 65ºF. By comparing the range of MWATs in Lower Gates Creek against the single year of monitoring in Upper Daugherty Creek (MRC 79-5), it appears that Gates Creek may have a cooling effect on Daugherty Creek. However, more data must be collected in both sites to confirm this relationship. In addition, as with the sites on Daugherty Creek, the site at Lower Gates Creek experienced large diurnal fluctuations (9.6-9.9ºF) suggesting low flow and/or poor canopy conditions. Based on 1994 Landsat vegetation images (KRIS Big River), it appears as though much of Gates Creek has small trees within the riparian corridors, which may contribute to increased solar exposure and the large diurnal temperature fluctuations observed.

There are a total of two monitoring sites on South Fork Big River (MRC 79-1 and MWA 155). One site is located below the confluence with the mainstem Big River (MRC 79-1) and was monitored for five years. The other site is located below the confluence with Daugherty Creek (MWA 155) and was monitored for three years.

The monitoring site above the confluence with the mainstem of the Big River (MRC 79-1) recorded water temperatures between moderately unsuitable with a minimum observed MWAT of 67ºF, to fully unsuitable with a maximum observed MWAT of 69ºF. In addition, the maximum water temperature recorded was over 74ºF, close to the lethal limit for salmonids (75ºF). The diurnal fluctuations (7-11ºF) at this site also suggest moderate to poor cover and/or low flows.

The monitoring site on the South Fork Big River below Daugherty Creek (MWA 155) recorded water temperatures between undetermined with a minimum observed MWAT of 64ºF, to moderately unsuitable with a maximum observed MWAT of 67ºF. While, in general, the diurnal fluctuations were slightly lower at this site than MRC 79-1, it still averaged around 8ºF suggesting moderate canopy and/or flow conditions. By comparing MWATs at this MWA 155 against MRC 79-1 (see Figure 125), it is apparent that MWA 155 is cooler, with no overlap in the MWAT ranges. However, this could be due to one of several factors: MWA 155 was placed in an area of thermal refugia and would be expected to be lower than the average temperature in that thermal reach; MRC 79-1 is significantly lower in the watershed than MWA 155, increasing the possibility of solar heating.

USFWS monitored one site on the South Fork Big River at the confluence with Daugherty Creek in 1973 (Perry 1974). The monitoring site recorded water temperatures that were undetermined with a MWAT of 64ºF. In addition, the maximum water temperature recorded was 71ºF. Comparison of 1973 data with recent monitoring at the same location (MWA 155) appears to show that water temperatures have remained similar since 1973.

Montgomery Creek (JSF 552), Lower Goddard Gulch (MRC 79-21), and Lower No Name Gulch (MRC 79-20) are all tributaries to the South Fork Big River. Montgomery Creek and Lower Ramon Creek were monitored for three years each, and the other streams were monitored for one year. During the years monitored, the Montgomery Creek (JSF 552) site recorded water temperatures that were entirely within the fully suitable range with a maximum observed MWAT of 60ºF. This suggests good stream flow and/or good stream shading.

Lower No Name Gulch (MRC 79-20) and Lower Goddard Gulch (MRC 79-21), tributaries to the South Fork of the Big River, both exhibited stream temperatures well within the fully suitable range for salmonids in the one year monitored. These sites had observed MWATs of 57ºF and 57ºF, respectively. However, the thermographs for Lower Goddard Gulch suggest that the data loggers were placed in an area dominated by groundwater, and/or the monitors were placed in a thermally stratified pool. By contrast, based on the thermographs for Lower No Name Gulch, it appears though the stream was flowing until early August, at which time it may have become isolated and dominated by groundwater. This is evident by diurnal temperature fluctuations that gradually become essentially flat.

Both Lower Donkey House Gulch (MRC 79-22) and Lower North Fork Ramon Creek (MRC 79-8), tributaries to Ramon Creek, exhibited stream temperatures within the fully suitable range for salmonids in the one year monitored. These sites had observed MWATs of 55ºF and 59ºF, respectively. The site on the North Fork Ramon Creek (MRC 79-8) appeared to have moderate diurnal fluctuations (8ºF), which would suggest moderate shading and/or stream flow along the thermal reach. By inspection of the thermograph, it appears as though this stream continued to flow during the year monitored and probably had some cooling effect on Ramon Creek. However, Lower Donkey House Gulch (MRC 79-22) appeared to have little to no flow for a large part of the summer in what appears to be a groundwater dominated flow regime. The temperature monitor may have been placed in a relatively deep pool which may thermally insulate it from the normal diurnal temperature fluctuations. Conversely, water temperatures observed in Lower Ramon Creek (MRC 79-2) were somewhat unsuitable with a minimum observed MWAT of 65ºF, to moderately unsuitable with a maximum observed MWAT of 66ºF. The large diurnal temperature fluctuations (8-14ºF) in this site in Lower Ramon Creek indicate moderate to poor shading or low stream flows.

Headwaters Drainage

There are a total of two monitoring sites on Martin Creek (FSP 5235 and FSP 5219). These monitoring sites are all located in the upper and lower reaches of Martin Creek. FSP 5235 was monitored for one year, and FSP 5219 was monitored for two years. Based on data from the upper Martin Creek (FSP 5235) site, the water temperature was somewhat suitable with a maximum observed MWAT of 63ºF. Based on data collected at the lower Martin Creek site (FSP 5219), the water temperature was somewhat unsuitable maximum observed MWAT of 65ºF. The only tributary to Martin Creek that was monitored was an un-named tributary (FSP 5240) in upper Martin Creek, which was monitored for two years. Based on this data, the water temperatures at this site varied between somewhat suitable with a minimum MWAT of 63ºF and undetermined with a maximum MWAT of 64°F.

There are a total of two monitoring sites on mainstem Big River (MRC 74-3 and MRC 74-1). One site is located on the mainstem between Martin Creek and Russell Brook (MRC 74-3) and was monitored for four years. The second mainstem site is located between Russell Brook and the South Fork Big River (MRC 74-1) and was monitored for four years.

The monitoring site between Martin Creek and Russell Brook (MRC 74-3) recorded water temperatures that were undetermined to moderately unsuitable with a maximum observed MWAT of 66ºF. In addition, the maximum water temperature recorded was 73ºF, slightly below the lethal limit for salmonids (75ºF). The diurnal fluctuations (9.2-14.8ºF) at this site also suggest poor cover and/or low flows.

USFWS monitored one site on the mainstem Big River at the confluence with Pig Pen Gulch in 1973 (Perry 1974). The monitoring site recorded water temperatures that were fully unsuitable with a MWAT of 69ºF. In addition, the maximum water temperature recorded was 79ºF, above the lethal limit for salmonids (75ºF). Comparison of 1973 data with recent monitoring at the same location (MRC 74-3) appears to show that water temperatures have decreased since 1973.

The monitoring site between Russell Brook and the South Fork Big River (MRC 74-1) recorded water temperatures that were moderately unsuitable to fully unsuitable with a maximum observed MWAT of 68ºF. In addition, the maximum water temperature recorded was 75ºF, which is the lethal limit for salmonids (75ºF). The diurnal fluctuations (10.8-12.9ºF) at this site also suggest poor cover and/or low flows.

Water temperatures at several tributaries that feed into the mainstem Big River below Martin Creek were also monitored. These include Russell Brook (MRC 74-2), Johnston Gulch (MRC 74-20), and Wildhorse Gulch (MRC 74-21). These sites were monitored for four years, one year, and one year, respectively. The monitoring site on Russell Brook (MRC 74-2) recorded water temperatures that were fully suitable to moderately suitable, with a maximum observed MWAT of 62ºF. The diurnal fluctuations (6.7-8.4ºF) at this site suggest moderate to poor cover and/or low flows. The monitoring site on Johnston Gulch (MRC 74-20) recorded water temperatures that were fully suitable, with a maximum observed MWAT of 58ºF. The monitoring site on Wildhorse Gulch (MRC 74-21) recorded water temperatures that were fully suitable, with a maximum observed MWAT of 58ºF. The diurnal fluctuations at each of these sites are minimal.

As would be expected, there appears to be an upward trend in water temperatures as the water moves lower in the both the mainstem Big River and Martin Creek (Figure 126). While there is insufficient information to determine if the un-named tributary to Martin Creek has an effect on the water temperatures in Martin Creek, it appears as though Russell Brook does provide some cooling effect to the mainstem Big River. The two other tributaries that were monitored were significantly cooler than the mainstem Big River. However, they were only monitored for one year and the thermographs from these sites indicate that they may have been in stratified pools or possibly a groundwater dominant regime. In either case, it is unknown how much flow they contribute to the mainstem Big River and thus if they provide any cooling effect.

Available THP maps (KRIS Big River) indicate that harvesting occurred in large portions of the Martin Creek watershed from 1989-1999. A 1994 Landsat map (KRIS Big River) shows many open areas and small trees near many of the monitoring sites, which may be contributing to the large diurnal fluctuations and generally higher water temperatures.

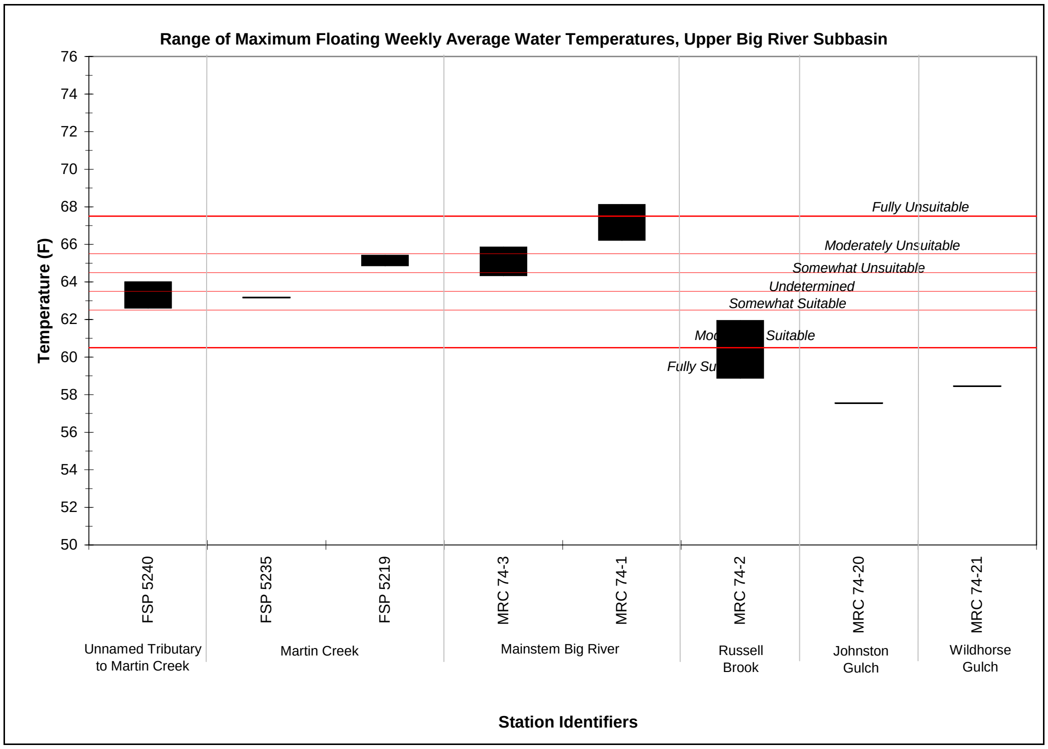


Figure 126. Range of MWATs in the headwaters drainage.

Summary

In summary, out of 47 sample sites in the Inland Subbasin, 27 had suitable water temperatures and 17 had unsuitable water temperatures (Table 182). Many of the unsuitable water temperatures recorded were on larger streams such as the North and South forks of Big River, Daugherty Creek, and mainstem Big River.

Table 182. Water temperature summary, Inland Subbasin.

Stream	Site ID	Maximum MWAT	MWAT Trend	Range of maximum diurnal fluctuations		Seasonal Maximum	Years of Data
Fully Suitable (50-60ºF)							
Donkey House Gulch	MRC 79-22	55	NA	3.5	3.5	55	1
Frykeman Gulch	MRC 75-22	56	NA	3.5	3.5	57	1
Steam Donkey Gulch	MRC 75-23	56	NA	3.5	3.5	58	1
Goddard Gulch	MRC 79-21	57	NA	2.1	2.1	58	1
No Name Gulch	MRC 79-20	57	NA	7.7	7.7	61	1
Chamberlain Creek	JSF 536	58	-0.8	3.6	4.5	60	3
Water Gulch	JSF 560	58	-1.2	3.4	3.9	61	2
Johnson Gulch	MRC 74-20	58	NA	2.8	2.8	59	1
Mainstem Big River	MRC 74-21	58	NA	4.1	4.1	60	1
James Creek	JSF 533	59	1.0	6.2	8.2	63	4
West Chamberlain Creek	JSF 540	59	-0.1	5.0	5.9	62	3
North Fork Ramon Creek	MRC 79-8	59	NA	7.5	7.5	63	1
East Branch North Fork Big River	FSP 5234	60	0.2	4.8	5.6	63	2
Chamberlain Creek	JSF 557	60	NA	6.1	6.1	64	1
Montgomery Creek	JSF 552	60	0.4	4.5	4.6	63	3
Moderately Suitable (61-62ºF)							
James Creek	JSF 534	61	NA	8.3	8.3	66	1
Chamberlain Creek	JSF 537	61	-0.6	6.5	7.4	65	2
Chamberlain Creek	JSF 538	61	NA	7.9	7.9	65	1
Arvola Gulch	JSF 555	61	NA	7.0	7.0	64	1
Arvola Gulch	JSF 556	61	NA	9.2	9.2	67	1
Chamberlain Creek	JSF 558	61	NA	9.8	9.8	69	1
Russell Brook	MRC 74-2	62	-0.6	6.7	8.4	66	4[1]
Somewhat Suitable (63ºF)							
James Creek	FSP 5213	63	-0.6	9.0	10.3	69	2
North Fork Big River	FSP 5238	63	0.4	9.1	11.1	70	2
Chamberlain Creek	JSF 539	63	-0.9	7.4	8.5	69	3

Stream	Site ID	Maximum MWAT	MWAT Trend	Range of maximum diurnal fluctuations		Seasonal Maximum	Years of Data
James Creek	JSF 567	63	NA	11.5	11.5	69	1
Martin Creek	FSP 5235	63	NA	12.4	12.4	72	1
Undetermined (64ºF)							
North Fork Big River	FSP 5220	64	0.3	8.3	11.0	71	2
North Fork Big River	JSF 531	64	NA	8.0	8.0	70	1
James Creek	MRC 75-3	64	-2.9	9.3	11.8	69	2
Unnamed tributary to Martin Creek	FSP 5240	64	1.4	11.0	15.0	75	2
Somewhat Unsuitable (65ºF)							
North Fork Big River	JSF 529	65	NA	9.7	9.7	71	1
North Fork Big River	JSF 530	65	-0.3	8.0	8.4	71	3
North Fork Big River	JSF 532	65	0.6	5.8	6.9	68	4
James Creek	MRC 75-1	65	-2.9	8.7	13.7	72	6
Gates Creek	MRC 79-9	65	-3.1	9.6	9.9	71	2
Martin Creek	FSP 5219	65	-0.6	11.7	12.4	72	2
Moderately Unsuitable (66-67ºF)							
North Fork Big River	JSF 527	66	NA	11.2	11.2	74	1
North Fork Big River	JSF 528	66	-0.4	9.5	10.2	71	3
Ramon Creek	MRC 79-2	66	0.0	8.3	13.6	73	3
Daugherty Creek	MRC 79-5	66	NA	10.0	10.0	70	1
Daugherty Creek	MWA 154	66	-1.1	7.6	8.6	70	3
Mainstem Big River	MRC 74-3	66	1.5	9.2	14.8	73	4
North Fork Big River	MRC 75-4	67	NA	5.4	5.4	70	1
South Fork Big River	MWA 155	67	-0.4	7.5	8.3	71	3
Daugherty Creek	MRC 79-4	67	-0.6	9.0	11.3	73	6
Fully Unsuitable (68ºF)							
Mainstem Big River	MRC 74-1	68	1.6	10.8	12.9	75	4[2]
South Fork Big River	MRC 79-1	69	-1.8	6.8	10.6	74	5

[1] Only 3 years of diurnal
[2] Only 2 years of diurnal

Sediment

Turbidity and Suspended Sediment

Turbidity that is significantly elevated above background levels can impede the ability of salmonids to feed and can be an indicator of potential problems with suspended sediment. This in turn may point to potential problems with heavy sediment loads. While the information collected in the Inland Subbasin is useful preliminary data, consistent long-term sampling is needed to determine the condition of these sites with respect to suspended sediment concentrations.

There were ten turbidity/suspended sediment sites established by GMA in the Inland Subbasin in 2000 and 2001 in support of the US EPA TMDL. Additional turbidity samples were collected at the Chamberlain Creek Conservation Camp under the DHS community water supply testing program and on the North Fork Big River immediately below the confluence with Chamberlain Creek under the SWAMP program at the Regional Water Board. Turbidity samples were also collected by the Regional Water Board under the SWAMP program at one location in 2001.

Ten stations were sampled by GMA for sediment and turbidity (Figure 127). In general, these sites were designed to be located closely to MRC sediment sampling sites. At the suspended sediment/turbidity locations, background conditions cannot be established due to the lack of data. Of the data that does exist, all of the samples were collected during the winter. Overall, turbidity was reported between 1.6 and 811 NTU. Each of these sites has limited data associated with them and the sample times at the various sites do not necessarily correspond. However, of the data reported, James Creek above the North Fork Big River site had the lowest average turbidity levels and the South Fork Big River below Daugherty Creek had the highest average turbidity levels (Table 183). Of all of the turbidity monitoring sites, the South Fork below Daugherty Creek (GMA 14) also had the highest spikes in turbidity.

Table 183. Turbidity samples in the Inland Subbasin.

Site	Site #	# of Samples	Dates Sampled	Range of Turbidity Values (NTU)		Average Turbidity (NTU)
				Low	High	
Chamberlain Creek above North Fork Big River	GMA1	13	February 2000 January 2001 February 2001 March 2001	5.2	114.0	38.7
North Fork Big River above Chamberlain Creek	GMA2	17	January 2000 February 2000 January 2001 February 2001 March 2001	1.6	214.0	52.1
James Creek above North Fork Big River	GMA3	4	February 2000 January 2001 February 2001	17.6	37.3	25.0
East Branch North Fork Big River above North Fork Big River	GMA4	7	February 2000 January 2001 February 2001 March 2001	5.4	65.9	32.3
North Fork Big River above Big River	GMA5	9	February 2000 January 2001 February 2001 March 2001	4.7	72.8	31.2
South Fork Big River above Big River	GMA7	7	January 2001 February 2001 March 2001	2.33	381.7	94.5
South Fork Big River above Daugherty Creek	GMA8	9	February 2001 March 2001	13.7	811.0	170.8
South Fork Big River below Daugherty Creek	GMA14	8	February 2001 March 2001	12.6	777.0	177.7
Daugherty Creek above South Fork Big River	GMA9	9	February 2001 March 2001	13.1	158.0	51.7
Big River above South Fork Big River	GMA6	7	January 2001 February 2001 March 2001	3.8	240.0	58.0

Suspended sediment and turbidity appear to be closely related at each of these sites. With the small sample set available for this site, the coefficient of determination (r^2) value is between 0.83 and 0.99. This indicates that there is probably very good correlation between turbidity and suspended sediment at all of these sites. While turbidity and suspended sediment concentrations did not correlate well with flow, it was found that the suspended sediment load did correlate well with flow at these sites (GMA, 2001).

As stated previously, DHS, NCRWQCB, and SWAMP also collected turbidity data. The turbidity sample taken at the sample sites did not exhibit significant levels of turbidity (Table 184). However, each measurement only represented one sample.

Table 184. Turbidity summary, Chamberlain Creek, North Fork Big River, and South Fork Big River (DHS and SWAMP).

Parameter	Count All	Count DetectS	Min.	Date Min[1]	Max.	Date Max
Chamberlain Creek Site (DHS)						
LAB TURBIDITY (NTU)	1	1	6.6	2/14/96	6.6	2/14/96
North Fork Big River Site (SWAMP BIGH20)						
Turbidity (NTU)	1	1	0.34	06/28/01	0.34	06/28/01
Site Name, Location: SWAMP SFBIGD, South Fork Big River Below Daugherty Creek						
Turbidity (NTU)	1	1	0.23	06/28/01	0.23	06/28/01

[1] Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).Bulk Sediment.

Figure 127. In-stream sediment and water quality monitoring sites, North Fork Big River Subbasin.

Bulk Sediment

MRC collected McNeil core samples in four locations in 2000 (MRC S4), including permeability measurements, thalweg profiles, and stream cross-sections. GMA also collected McNeil core samples in 2001 at most of the turbidity/suspended sediment sampling sites sampled for turbidity. No McNeil sample was collected at the James Creek site above the North Fork (GMA 3) or South Fork Big River below Daugherty Creek (GMA 14). However, additional sample sites included North Fork above James Creek, South Fork Big River above the Big River (GMA 7), South Fork Big River above Daugherty Creek (GMA 8), and Daugherty Creek above the South Fork Big River (GMA 9). When possible, GMA locations also coincided with MRC McNeil sampling sites. However, because the core samples were collected using the gravimetric method (dry sieve), it is not comparable to the Big River TMDL target for fine sediment. These data are only comparable to other data collected using the gravimetric method.

The subsurface streambed material in the North Fork Big River shows large increases in the amount of fine sediment between James Creek and Chamberlain Creek (GMA 13 to GMA 2). Lower Chamberlain Creek (GMA 1) and the lower East Branch North Fork Big River (GMA 4) appear to contribute moderate amounts of fine sediment in the sub 5.6 mm and 0.85 mm size classes to the North Fork Big River. However, based on limited sampling, both tributaries appear to have less fine sediment in these size classes than found in the North Fork Big River immediately above the confluence with Chamberlain Creek. At the lower end of the subbasin, the North Fork Big River site (GMA 5) shows a decrease in fine sediment in all size classes compared to any of the measured tributaries and mainstem North Fork samples, except the one sample collected upstream of James Creek (GMA 13).

The observed changes in fine sediment may be due to fine sediment coming from James Creek into the North Fork Big River. At the bottom of the North Fork Big River (GMA 5), it appears as though sub 5.6 mm sediment is significantly lower than observed in any of the sediment sampling locations except for the single site on the North Fork Big River upstream of James Creek (GMA 13). This may be due to a lag in the downstream transport of fine sediment or to higher flows in this area more effectively transporting fine sediment out of this reach of the North Fork. At all of the sediment sampling sites, the observed differences may also be due in part to normal sample variability.

In 2000, MRC also collected McNeil core samples at one site in the North Fork Subbasin (MRC S4). The MRC site is located in the lower portion of the East Branch North Fork Big River. Like the GMA samples, these sediment samples were collected using the gravimetric method and are therefore not directly comparable to the Big River TMDL target for fine sediment. However, they are unfortunately also not comparable to the GMA samples because the GMA samples do not include surface particles.

There is substantially less fine sediment in nearly all of the size classes at the Daugherty Creek site (GMA 9) than at the other two South Fork Big River sites (GMA 7 and GMA 8). By looking at the GMA data, it appears there is a significant amount of fine sediment in all sub 5.6 mm size classes in the South Fork Big River above the confluence with Daugherty Creek. By the bottom of the subbasin, the one GMA sample in the South Fork Big River suggests that the fine sediment moving through this area is somewhat less than found upstream of Daugherty Creek. However, inspection of the MRC data collected the previous year (2000) at nearby sites indicate that the MRC Daugherty Creek site (MRC S1) contained more fine sediment than either the South Fork site (MRC S3) or the Ramon Creek site (MRC S2). As a group the MRC samples do not necessarily support the pattern seen with the GMA samples only one year later.

Permeability

MRC also recorded permeability measurements at pool tail-outs in the same stream segments where bulk sediment samples, cross-sections, and thalweg profiles were collected. In the each of the stream segments measured, a total of 25 or 26 median permeability values were recorded. The 25^{th}, 50^{th}, and 75^{th} percentile values for each of these stream segments were then plotted.

The East Branch North Fork Big River site (MRC S4) had generally low to moderate median permeability values. Using the empirical formula (McBain and Trush 2000), this stream segment was expected to have roughly 10-35% survival to emergence. The McNeil sample collected in the same stream segment also suggests relatively good fine sediment conditions when compared to other MRC samples in other subbasins.

The Daugherty Creek (MRC S1) and Ramon Creek (MRC S2) stream segments each had very low median permeability values. Using the empirical formula (McBain and Trush 2000), these stream segments were expected to have roughly 12-17% and 0-2% survival to emergence, respectively. The South Fork Big River (MRC S3) stream segment was expected to have roughly 22-47% survival to emergence. Based on this one year of data (2000), the South Fork Big River stream segment (MRC S3) had significantly better streambed gravel permeability than either the Daugherty Creek (MRC S1) or Ramon Creek (MRC S2) stream segments. Both MRC S1 and MRC S2 had substantial amounts of fine sediment in the streambed gravel interstitial spaces, and it is likely that spawning success in these stream segments was relatively poor. Conversely, MRC S3 appeared have less fine material plugging the interstitial spaces and was more likely to support successful spawning. To some degree, particularly in the sub-0.85 mm size class, the MRC bulk sediment samples appear to support this conclusion.

Water Chemistry

The Inland Subbasin contained three water quality sampling sites. One water quality sampling site was a community water system at the CDF Chamberlain Creek Conservation Camp under DHS purview. The intake to the drinking water system (the sampling point) is on lower Chamberlain Creek, immediately above the confluence with the North Fork Big River.

SWAMP sampled water quality on the North Fork Big River below the confluence with Chamberlain Creek and the South Fork Big River below the confluence with Daugherty Creek (SWAMP SFBIGD). A creek diversion (surface water) system is operated by CDF at the Chamberlain Creek Conservation Camp that has been typically sampled two to three times a year from 1991 through 2000 (last available data). The source water was not sampled in 1992, 1994, 1995, and 1998. Both SWAMP sampling sites were sampled on two occasions in 2001.

No water column chemistry data were found in the headwaters drainage.

The analysis of water column chemistry is divided into parameters with numeric water quality objectives in the Basin Plan, parameters with narrative water quality objectives in the Basin Plan (which can be quantified using numeric criteria found in the literature), and other important parameters that may have applicable narrative water quality objectives, but no available numeric criteria.

Basic water chemistry data, including dissolved oxygen, specific conductance, total dissolved solids, and hydrogen ion concentration (pH) were compared to numeric water quality objectives in the Basin Plan. Dissolved oxygen and total dissolved solids were not sampled at the Chamberlain Creek site. The summary data for basic water quality at the Inland Subbasin sites are shown in Table 185.

Table 185. Basic physical water parameters, Inland Subbasin.

Parameter	Count All	Count DetectS	Min.	Date Min*	Max.	Date Max	Avg.	W.Q. Objectives	
								MIN	MAX
Site Name, Location: CDF Chamberlain (DHS), lower Chamberlain Creek									
pH, Lab (pH units)	1	1	7.9	2/14/96	7.9	2/14/96	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	134	2/14/96	134	2/14/96	NA	NA	300[3] / 195[4]
Site Name, Location: SWAMP BIGH20, North Fork Big River									
Dissolved Oxygen, Field (mg/L)	2	2	9.86	06/28/01	10.33	05/10/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH, Lab (pH units)	2	2	8.3	05/10/01	8.46	06/28/01	NA	6.5	8.5
pH, Field (pH units)	2	2	8.22	05/10/01	8.38	06/28/01	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	220	06/28/01	220	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (µS/cm)	2	2	209	05/10/01	226	06/28/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/L)	2	2	140	05/10/01	150	06/28/01	NA	NA	190[3] / 130[4]
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek									
Dissolved Oxygen, Field (mg/L)	2	2	9.34	06/28/01	10.82	05/09/01	NA	7.0 / 7.5[1] / 10.0[2]	NA
pH (pH units)	2	2	8.3	06/28/01	8.36	05/09/01	NA	6.5	8.5
pH, Field (pH units)	2	2	8.14	06/28/01	8.3	05/09/01	NA	6.5	8.5
Specific Conductance (µS/cm)	1	1	300	06/28/01	300	06/28/01	NA	NA	300[3] / 195[4]
Specific Conductance, Field (µS/cm)	2	2	263	05/09/01	297	06/28/01	NA	NA	300[3] / 195[4]
Total Dissolved Solids (mg/L)	2	2	160	05/09/01	170	06/28/01	NA	NA	190[3] / 130[4]

Date on which the minimum value occurred is the first date that the value occurred. For example, if there were several "non-detects", represented here as a zero, the date given is the first instance of non-detect (chronologically).

[1] Value represents the 90th percentile lower limit. 90% of the values in a calendar year must be equal to or greater than the 90% lower limit.

[2] Value represents the 50th percentile (median) lower limit. 50% of the monthly means in a calendar year must be equal to or greater than the 50% lower limit.

[3] Value represents the 90th percentile upper limit. 90% of the values in a calendar year must be equal to or less than the 90% upper limit.

[4] Value represents the 50th percentile (median) upper limit. 50% of the monthly means in a calendar year must be equal to or less than the 50% upper limit.

The pH of the water at the Chamberlain Creek site (CDF Chamberlain) was reported at 7.9, which is within the Basin Plan water quality objective. Specific conductance appeared to be within or slightly below the acceptable range in the one sample collected. However, in all cases, the amount of data available for this site, combined with unknown data quality, limit the data to screening purposes only.

At the North Fork Big River site (SWAMP BIGH20), water samples for pH, total dissolved solids, and specific conductance were collected for laboratory analysis. Additional measurements of dissolved oxygen, pH, and specific conductance were taken in the field. Each of these constituents appeared to be within the acceptable range in both samples.

Keeping in mind the limited data that are available, specific conductance and total dissolved solids measurements were relatively high in the South Fork Big River sample site compared to Basin Plan water quality objectives.

Narrative water quality objectives in the Basin Plan apply to a variety of metals and other constituents that were detected during the sampling events. This includes alkalinity, aluminum, ammonia, barium, boron, chloride, copper, iron, sodium, sulfate, and zinc. Unlike the constituents shown in Table 185, the numeric criteria for these parameters are derived from the literature to support the narrative water quality objectives. The constituents and the most conservative applicable criteria are shown in Table 186.

Table 186. General water column chemistry, Inland Subbasin.

Parameter	Count All	Count Detects	Min.	Max.	Avg.	Criteria	Criteria exceeded?	Comments on Criteria[1]
Site Name, Location: CDF Chamberlain (DHS), lower Chamberlain Creek								
Alkalinity, Total (mg/L as $CaCO_3$)	1	1	54	54	NA	≥ 20 mg/L	No	Protection of freshwater aquatic life
Aluminum (µg/l)	3	2	0	1300	NA	≤ 87 µg/L	Yes	Protection of freshwater aquatic life
Barium (µg/l)	3	1	0	21	NA	≤ 1000 µg/L	No	Primary California MCL for drinking water
Chloride (mg/l)	1	1	14	14	NA	≤ 106 mg/L	No	Protection of agricultural water uses
Copper (µg/l)	1	1	190	190	NA	≤ 4.0 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 39 mg/L[2]
Iron (µg/l)	1	1	140	140	NA	≤ 300 µg/L	No	Secondary California MCL for drinking water
Sodium (mg/l)	1	1	9.7	9.7	NA	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate (mg/l)	1	1	4.1	4.1	NA	≤ 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/l)	1	1	88	88	NA	≤ 53 µg/L	Yes	Protection of freshwater aquatic life with a hardness of 39 mg/L[2]
Site Name, Location: SWAMP BIGH20, North Fork Big River								
Alkalinity, Total (mg/L)	2	2	90	98	NA	≥ 20 mg/L	No	Protection of freshwater aquatic life
Boron (µg/L)	2	2	240	300	NA	≤ 630 µg/L	No	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	8.1	8.1	NA	≤ 106 mg/L	No	Protection of agricultural water uses
Copper (µg/L)	2	0	0	0	NA	≤ 7.6 µg/L	No	Protection of freshwater aquatic life with a hardness of 83 mg/L[2]
Iron (µg/L)	2	0	0	0	NA	≤ 300 µg/L	No	Secondary California MCL for drinking water
Sodium (mg/L)	2	2	12	13	NA	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO_4 (mg/L)	1	1	6.3	6.3	NA	≤ 250 mg/L	No	Secondary California MCL for drinking water
Zinc (µg/L)	2	0	0	0	NA	≤ 101 µg/L	No	Protection of freshwater aquatic life with a hardness of 83 mg/L[2]
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek								
Ammonia as N (mg/L)	2	1	0	0.24	NA	≤ 1.39 mg/L	No	Ambient water quality for ammonia, US EPA[2]
Boron (µg/L)	2	2	1000	2400	NA	≤ 630 µg/L	Yes	IRIS reference dose for drinking water, US EPA
Chloride (mg/L)	1	1	9.9	9.9	NA	≤ 106 mg/L	No	Protection of agricultural water uses
Sodium (mg/L)	2	2	16	19	NA	≤ 2 mg/L	Yes	SNARL for drinking water toxicity other than cancer risk, US EPA[3]
Sulfate as SO_4 (mg/L)	1	1	9.7	9.7	NA	≤ 250 mg/L	No	Secondary California MCL for Drinking Water
Total Alkalinity (mg/L)	2	2	110	130	NA	≥ 20 mg/L	No	Protection of freshwater aquatic life
Zinc (µg/L)	2	1	0	21	NA	≤ 123 µg/L	No	Protection of freshwater aquatic life with a hardness of 105 mg/L[2]

[1] See the Water Column Chemistry section for description of criteria.
[2] See text below for details on derivation of criteria.
[3] Assumes a relative source contribution of 10% from drinking water and 90% from other dietary sources.

As can be seen in Table 186, several constituents, including aluminum, copper, sodium, and zinc exceeded their numeric criteria at the Chamberlain Creek site (CDF Chamberlain). At the North Fork Big River site (SWAMP BIGH20), neither copper nor zinc was detected at or above the detection limits for the analytical method used, which were 10 µg/L and 20 µg/L, respectively. However, sodium was detected at similar concentrations at both sites; all of which were above the water quality criteria. The aluminum concentration at the lower Chamberlain Creek site (CDF Chamberlain) exceed all of the applicable primary and secondary MCLs, including the US EPA MCL (20-200 µg/l), the California primary MCL (1,000 µg/l), and the California secondary MCL (200 µg/l). No other criteria were found in Marshack (2000) relating to sodium, copper, or zinc.

At the Chamberlain Creek site (CDF Chamberlain), it is not clear if the water samples were filtered or not-filtered, and how they were collected and analyzed. Each of these factors could affect the extent to which the sample results are representative of the true concentrations. It is unclear if the metals in the water are naturally occurring or anthropogenic pollution from the CDF camp. While samples collected for DHS are generally located at the system intake, it is also possible that the sample is from some other point in the water system. In addition, with only one to three samples, these results are only a beginning of the sample set that is needed to characterize the surface water in Chamberlain Creek and the North Fork Big River. Therefore, these values are useful as screening values only and additional sampling should occur to adequately characterize the water quality.

Boron and sodium exceeded their numeric criteria at the South Fork Big River site (SWAMP SFBIGD). In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l). However, with only one to two samples, these results are only a beginning of the sample set that is needed to characterize the surface water in South Fork Big River. Therefore, additional sampling should occur to adequately characterize the water quality and determine the source(s) of constituents that exceed their criteria.

It should also be noted that at the North Fork Big River and South Fork Big River sites, alkalinity was speciated into carbonate, bicarbonate, and hydroxide alkalinity. At these sites, the alkalinity was almost entirely bicarbonate alkalinity, with small amounts of other alkalinity at levels below the detection limits. Samples for total hardness as calcium carbonate ($CaCO_3$) were also collected on one occasion at the Chamberlain Creek site, two times at the North Fork Big River site, and at the South Fork Big River site. The sample collected at the Chamberlain Creek site (CDF Chamberlain) on February 14, 1996 was reported to be 39 mg/L. The samples collected at the North Fork Big River site (SWAMP BIGH20) on May 10, 2001 and June 28, 2001 was 82 and 85 mg/L, respectively. The samples collected for hardness on May 9, 2001 and June 28, 2001 were 100 and 110 mg/L, respectively. These values were used to determine the water quality criteria for the metals such as copper and zinc, whose toxicity depends on the hardness of the water.

Water samples were also collected for ammonia at the North Fork Big River and South Fork Big River sites. Of the two samples collected from the North Fork Big River, one of the samples, collected on June 28, 2001 contained 0.12 mg/L of ammonia nitrogen. Ammonia in the other water sample was not detected at or above the analytical detection limit of 0.05 mg/L. Of the two samples collected on the South Fork Big River, one sample collected on May 9, 2001 contained 0.24 mg/L of ammonia nitrogen. Ammonia in the other water sample was not detected at or above the analytical detection limit of 0.05 mg/L.

The toxicity of ammonia to freshwater organisms depends on several factors, including the water temperature and pH. During sample collection, the pH was measured at 8.3 and 8.38 and the water temperature was measured at 61.2 and 61.0°F. Based on these values, the water quality criteria for ammonia is approximately 1.17 mg/L at North Fork Big River and 1.39 mg/L at South Fork Big River (US EPA 1999). This criterion is for a 30-day average concentration with fish in the early life stages present. Therefore, ammonia was detected but did not exceed the numeric criteria. Nitrate/Nitrite nitrogen was also sampled for, but was not detected at or above the analytical detection limit of 0.05 mg/L.

Turbidity, phosphorus, and chlorophyll-a were also reported, but none have specific numeric criteria at this time. However, they are broken out separately because they are significant constituents of water quality. Turbidity, for the purposes of this assessment, is considered a sediment related parameter and is discussed in the Turbidity and Suspended Sediment section.

Phosphorus can enter surface water bodies through fertilizer run-off or from the natural weathering of rocks in some watersheds. Phosphorus is as a biostimulantory substance for algae, and excessive amounts can lead to algae blooms which can impact other aquatic life by negatively affecting dissolved oxygen concentrations. The summary data for phosphorus samples collected at the North Fork Big River and South Fork Big River sites are shown in Table 187. No samples for phosphorus were collected at the Chamberlain Creek site (CDF Chamberlain).

Table 187. Phosphorus summary, Inland Subbasin.

Parameter	Count All	Count DetectS	Min.	Date Min	Max.	Date Max	Avg.
Site Name, Location: SWAMP BIGH20, North Fork Big River							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	1	0	06/28/01	0.058	05/10/01	NA
Site Name, Location: SWAMP SFBIGD, South Fork Big River below Daugherty Creek							
Phosphorus (mg/L)	2	0	0	NA	0	NA	NA
Orthophosphate as P (mg/L)	2	0	0	NA	0	NA	NA

There are not sufficient data to make more than broad statements about phosphorus. However, there was not an apparent problem with elevated phosphorus levels in the samples. However, orthophosphate was detected on one occasion in the North Fork Big River. Orthophosphate, one of several species that together make up total phosphorus, is believed to be the more bio-available variety to plants such as algae. However, there is no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

Chlorophyll-a was also sampled once at the North Fork Big River and South Fork Big River sites and was detected with a concentration of 0.00078 mg/L in the North Fork Big River. Chlorophyll-a is a measurement of the chlorophyll in the suspended algae in the water column. High chlorophyll-a content, which directly relates to high algal concentrations in freshwater, can be an indicator of nutrient contamination of the surface water (such as in fertilizer run-off). However, there are no water quality criteria for this constituent and therefore it is used primarily to screen for other potential water quality problems.

On February 27, 2001, a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on Highway 20 at mile marker 21.76 (measured from the Highway 1/Highway 20 intersection at Fort Bragg). While some of the liquid remained on the roadway and adjacent unpaved shoulders, a portion of it ultimately discharged to a tributary to James Creek. In an attempt to stop continued discharge of pollutants to James Creek, a dam was constructed on the tributary. However, testing at various locations along the un-named tributary and James Creek itself (RWQCB 2-RWQCB 10) indicated that some of the constituents discharged to James Creek. This included 1,2,4-trimethylbenzene, toluene, xylene, tetrachlorethene, methyl tert-butyl ether (MtBE), petroleum hydrocarbons in the diesel and motor oil ranges, and others. Many of these compounds exceeded their numeric water quality criteria, but the event was episodic and has been in active cleanup. Because of the active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on wildlife.

Discussion

Collectively, temperature data show that monitored sites in the Inland Subbasin are mostly unsuitable for MWATs but, conversely, are suitable when seasonal maximum temperature thresholds are considered.

The North Fork mainstem was unsuitable for MWATs but suitable when maximum temperature thresholds are considered. Most of the tributaries to the North Fork Big River had a majority of stations with suitable MWATs and, like the mainstem, all of the seasonal maximum temperatures were within the fully suitable range. In the South Fork drainage, the majority of unsuitable MWATs were located in the South Fork Big River and Daugherty Creek mainstems while tributary reaches were suitable for seven of twelve records analyzed. The mainstem Big River was unsuitable for salmonids when MWATs were considered but suitable when peak seasonal maximum temperature thresholds were considered. Four of seven tributaries in the headwaters drainage had seasonal MWAT records that were suitable for salmonids. In the eleven headwaters drainage tributaries monitored, all of the peak maximum temperatures were suitable for salmonids.

The predominance of suitable maximum seasonal temperatures in the Inland Subbasin follows similar patterns present in the other Big River Subbasins. Perhaps this is due, in part, to the proximity of most of the Big River Basin to the Pacific Ocean and the moderating influence of associated coastal marine weather, dominated during most of the mid- to late summer season by foggy, overcast conditions. Water temperatures also reflect overall habitat and geological conditions documented by the CDFG and, whose results generally show more sheltered streams located in narrow valleys and canyons, respectively, that provide a greater degree of solar protection to subbasin streams.

Bulk sediment sampling records had mixed results, with the smaller fraction threshold of ≤0.85mm found to be largely suitable for salmonid egg incubation, while gravel ≤6.4 mm were shown to be marginally suitable to unsuitable for the survival to emergence of salmonids from their redds in those stream reaches sampled. Gravel permeability sampling largely agrees with the bulk sampling data, particularly in Lower Ramon Creek, when extrapolated as a surrogate for fine sediment (matrix) particles lodged between larger (framework) gravel.

The data results from the 1996 physical-chemical sampling did show criteria/threshold exceedences for aluminum, copper, and zinc during 1996 DHS investigations at Chamberlain Creek, and also sodium during the DHS 1996 and SWAMP 2001 sampling events. The SWAMP site that was in the North Fork Big River, just downstream from the confluence of Chamberlain Creek, did not have elevated levels of metals in analyzed samples. In all likelihood sodium is naturally occurring in specific watershed tributaries. A single elevated analyses for a particular metal may be naturally occurring in local streams, but when all three metals exceed established criteria in the water sampled, anthropogenic sources become suspect. Further sampling and site characterization would be necessary to determine if the three metals present in DHS water sampling at Chamberlain Creek are related to past and/or present activities at the CDF Chamberlain Creek Conservation Camp. The data results from the two days of physical-chemical sampling in South Fork Big River during 2001, even though boron and sodium exceeded specific thresholds, are insufficient to fully characterize historical and/or future trends of chemical water quality conditions in the South Fork Big River.

Riparian Conditions

There are 8,202 acres in the Inland Subbasin in stream buffers, which includes the areas between the water and gravel bars in the lower reaches (Table 188). Across the subbasin, the area around the watercourses is well vegetated, as indicated by the 70 to 100% density class which accounts for 93% of the area (Table 189). Also 77% of the buffer area is in 80% canopy density or better, and 55% of the area is in the 90-100% canopy closure class. The PW with the lowest percent of its stream buffers covered by greater than 70% canopy density was Leonaro Lake. These numbers are substantiated by high canopy densities found along stream reaches surveyed by CDFG and discussed in *Fish Habitat Relationships*.

Table 188. Density of riparian vegetation in the North Fork Subbasin by planning watershed.

Planning Watersheds	Acres by Percent Crown Canopy Density										Acres in Buffer
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	
Chamberlain Creek	4		7	2	3			223	125	621	984
East Branch North Fork				14				68	159	219	459
James Creek	1			12				50	144	203	409
Lower North Fork	2			2	1	4	1	131	120	281	542
Upper North Fork	3	4		9	7	1	1	62	129	259	476
Dark Gulch	25	2		7	9	3	1	112	114	375	649
Leonaro Lake	75	27	3	21	36	16	17	64	101	135	495
Mettick Creek	7	6	2	26	1	12	3	187	295	775	1,314
South Daugherty Creek	15	1	1	10	6	4	5	84	204	501	830
Martin Creek	9	13	1	36	5	16	7	61	113	274	535
Rice Creek	15	4		22	6	1	7	121	187	451	814
Russell Brook	5	9		5	6	9	2	103	138	419	695
Total Inland	**161**	**66**	**14**	**166**	**80**	**66**	**44**	**1,266**	**1,829**	**4,513**	**8,202**

Table 189. Percentage of stream buffer area in higher canopy closure classes in the North Fork Subbasin.

Planning Watersheds	Percent of Buffer Area by Crown Canopy Density				
	70%	80%	90%	70%+	80%+
Chamberlain Creek	23	13	63	98	76
East Branch North Fork	15	35	48	97	82
James Creek	12	35	50	97	85
Lower North Fork	24	22	52	98	74
Upper North Fork	13	27	54	95	82
Dark Gulch	17	18	58	93	75
Leonaro Lake	13	20	27	61	48
Mettick Creek	14	22	59	96	81
South Daugherty Creek	10	25	60	95	85
Martin Creek	11	21	51	84	72
Rice Creek	15	23	55	93	78
Russell Brook	15	20	60	95	80
Total Inland	**15**	**22**	**55**	**93**	**77**

As shown in Table 190, the majority of the trees in the watercourse buffer zone are small to medium/large, which are 12 to 40 inch dbh trees. Small, medium/large and large trees (>12 inches dbh) could be recruited to streams as LWD. Overall, 95% of the buffer zone area in the subbasin is in these size classes. The percentage area in these three size classes is highest in the North Fork drainage and lowest in the headwaters and South Fork drainages. At the PW level, the percentage varies from 76% in the Leonaro Lake PW to 99% in the Chamberlain Creek and James Creek PWs.

Table 190. Acres by vegetation size class in watercourse buffer zone in the Inland Subbasin.

Planning Watersheds	Sapling (<6 inches dbh)		Pole (6-11 inches dbh)		Small Tree (12-24 inches dbh)		Medium/Large Tree (24-40 inches dbh)		Large Tree (>40 inches dbh)	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Chamberlain Creek	0	0	8	1	429	44	511	52	33	3
East Branch North Fork Big River	0	0	13	3	314	68	132	29		0
James Creek	0	0	4	1	261	64	144	35		0
Lower North Fork Big River	0	0	11	2	233	43	248	46	48	9
Upper North Fork Big River	0	0	36	8	287	60	146	31	3	1
Total North Fork	**0**	**0**	**71**	**2**	**1,524**	**53**	**1,181**	**41**	**85**	**3**
Dark Gulch	4	1	21	3	314	48	212	33	73	11
Leonaro Lake	3	1	42	8	257	52	97	20	22	4
Mettick Creek	0	0	45	3	905	69	357	27	0	0
South Daugherty Creek	0	0	50	6	543	65	220	27	1	0
Total South Fork	**6**	**0**	**159**	**5**	**2,019**	**61**	**886**	**27**	**97**	**3**
Martin Creek	6	1	73	14	324	61	121	23	1	0
Rice Creek	7	1	52	6	551	68	189	23	0	0
Russell Brook	1	0	20	3	475	68	194	28	0	0
Total Headwaters	**15**	**1**	**144**	**7**	**1,350**	**66**	**504**	**25**	**1**	**0**
Total Inland	**21**	**0**	**375**	**5**	**4893**	**61**	**2571**	**32**	**181**	**2**

MRC examined LWD recruitment potential on their ownership in the Inland Subbasin. They found that LWD recruitment potential is quite poor in their ownership (Figure 128). An exception is the East Branch of the North Fork Big River watershed, where most stands have high or moderate recruitment potential ratings. Past harvesting in riparian areas has lead to small-sized, open stands composed of mixed conifer hardwood species.

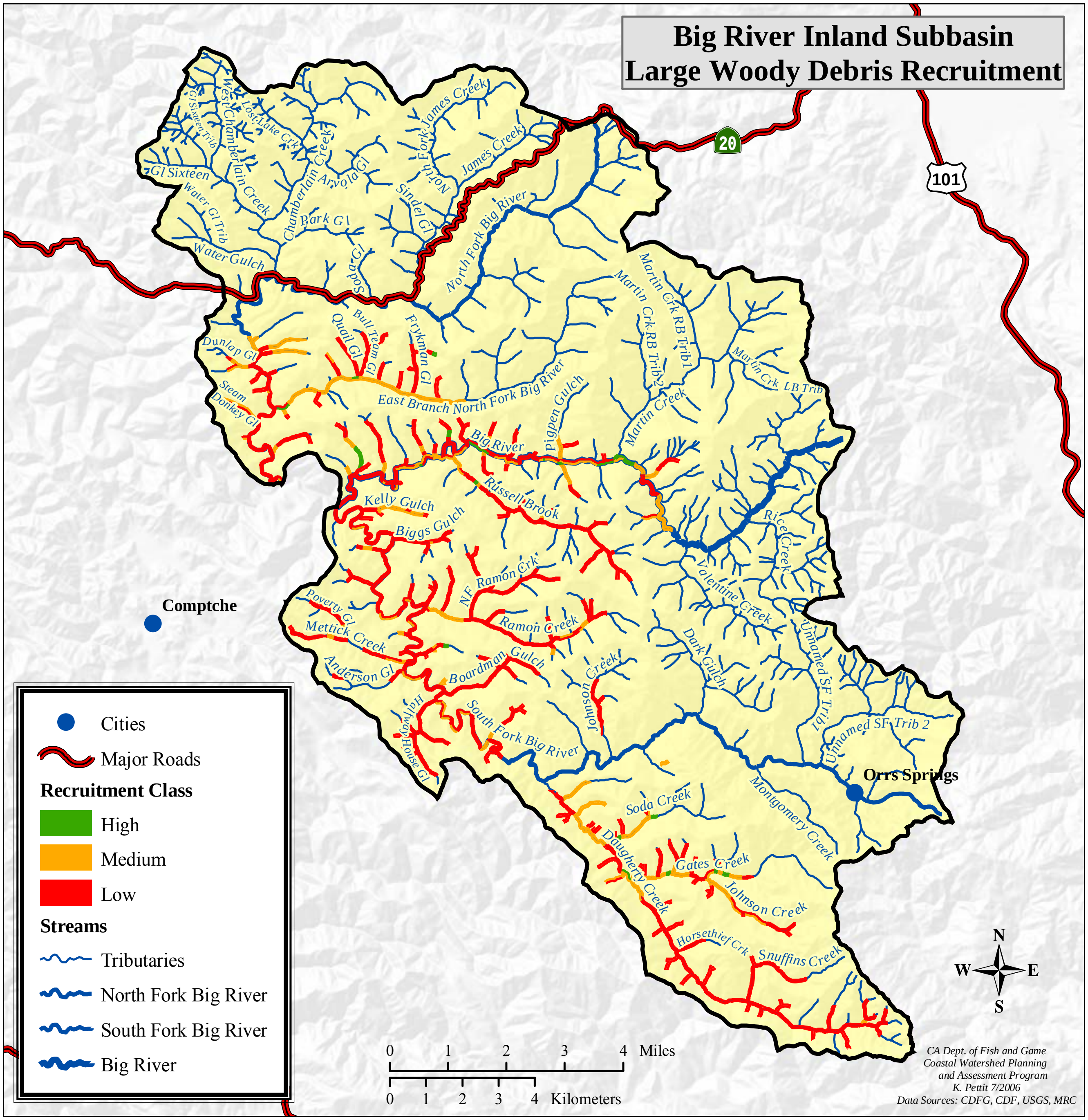


Figure 128. Map of LWD recruitment potential classes on MRC ownership in the Inland Subbasin (MRC 2003).

Fish Habitat Relationship

Past Habitat Conditions

CDFG stream surveys were conducted for 26 tributaries in the Inland Subbasin from 1950 to 1979. One stream survey was also conducted by the Center for Education and Manpower Resources in 1979. The results of the historic stream surveys are not quantitative and can not be used in comparative analyses with current habitat inventories; however, they do provide a description of habitat conditions. The data from these stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair and poor were based upon the opinion of the biologist or scientific aid conducting the survey.

Surveys mostly describe a range of spawning habitat, pools, and cover from poor to excellent (Table 191). Spawning gravel in most streams was described as excellent to fair. However, spawning gravel in James Creek, Snuffins Creek, Pig Pen Gulch, and the two unnamed tributaries to South Fork Big River was reported as scarce or poor. Pool development was described as excellent in South Fork Big River. Pools in most streams were described as common, but not deep. Shelter in most streams was described as good to excellent though shelter in Rice Creek and East Branch Rice Creek was reported as poor.

Many debris jams were described on most surveyed streams. A 1958 CDFG flyover survey of 25 tributaries and the mainstem Big River found possible fish passage barriers on South Fork Big River, Mettick Creek, Anderson Gulch, Daugherty Creek, Montgomery Creek, South Fork Big River Tributary #1, mainstem Big River, and Martin Creek. The flyover also reported extensive damage caused by logging in Chamberlain Creek, James Creek, Johnson Creek, Dark Gulch, Montgomery Creek, and South Fork Big River tributaries #1 and #2.

Table 191. Habitat comments from surveys conducted in the North Fork Subbasin from 1958-1979.

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
North Fork Big River	10/16/1958 (flyover)	Appears to have considerable fisheries value as a spawning and nursery area for anadromous fishes	Eight log jams noted in the six miles between the mouth of James Creek and the headwaters
	10/16/1958	Substrate predominantly gravel and small rubble throughout; very good to excellent spawning areas; very good pool development, some pools average 10 feet deep; very good shelter, mainly in the form of undercut banks, rock, and streamside vegetation	Two log jams may develop into barriers; 1. approximately 200 feet below TS-3 road bridge crossing- four cut logs jammed in narrow gorge section, serious barrier to fish life could result; 2. approximately ¼ mile above North Fork Camp- small amount of debris piled up against large log lying across the channel (10 feet above the streambed level), no barrier at present, potential barrier
	8/4/1959	Substrate gravel, sand, rubble, and bedrock; good spawning areas above tributary #6; good pool development, range from 2 - 4 feet deep; good shelter provided by undercut banks, boulders, and heavy tree shade; water temperatures 57-60°F	Many log jams and barriers; 10 complete barriers
East Branch North Fork Big River	10/16/1958 (flyover)	The entire stream could not be observed due to dense conifer canopy	One large log jam was observed approximately three miles above the mouth
	11/3/1958	Substrate gravel and rubble; excellent spawning areas throughout 1 mile lower section; medium sized pools scattered throughout the one mile section; good shelter provided by under cut banks and rock	One barrier observed 50 feet above the mouth of the stream; not a barrier at present, but may become a barrier in the future
	7/30/1959	Excellent spawning in the middle and upper sections; good pool development, average 6 feet wide, 10 feet long, 2 feet deep; excellent shelter provided by heavy tree shade, rocks, and undercut banks	Many log jams and partial barriers
	8/29/1966	Section 1: Few spawning areas, very little gravel, mainly boulders; pools frequently excellent, average 1 foot deep; good shelter , provided by logs, roots, boulders, and undercut banks; Section 2: spawning areas plentiful, gravels very good, silt is a problem; pools frequently good, average size 1 foot deep; good shelter, provided by logs, roots, boulders, and undercut banks; Section 3: spawning gravels present, could be good if winter flow is high enough to remove silt; pools frequently poor, average size 0.5 foot deep; shelter poorer than sections 1 and 2, provided by logs, roots, boulders, and undercut banks; water temperature 55°F	7 log jams, all major barriers to fish passage
	3/26/1979 (Center for Education and Manpower Resources)	Excellent quality gravel for spawning in the first 1 mile upstream, then increasing quantities of silt; 80% pools, some up to 4 feet deep, often more than 2 feet deep; numerous logs, pools, and boulders provide shelter; water temperature 49-50°F	8 main log jams; 1 impassable, and several with limited passage
Chamberlain Creek	10/16/1958 (flyover)	The majority of the 8 miles of stream surveyed has been removed from fisheries production through needlessly poor logging practices	
Water Gulch	10/16/1958 (flyover)	Unimportant to fish life	
	10/1959	At present, of no use to fish life; possibly could be of importance to fish life after stream clearance	
James Creek	10/16/1958 (flyover)	Practically the entire 8 miles of previously good salmon and steelhead stream has been lost to the fishery due to extensive logging damage and erosion through CDF road building activities	

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
	11/30/1958	Poor spawning areas due to siltation and logging debris, spawning areas present are probably inaccessible due to existing barriers; pools common to scarce, range from 1 to 4 feet deep, average 2 feet deep; mostly excellent shelter	Filled with log-debris jams; not a 100 feet section of streambed that is free of logs; trees and slash actually fill the streambed for a considerable distance
North Fork James Creek	12/9/1958	Substrate mostly gravel-rubble and rubble-gravel, some silt in the lower section of the creek and some mud in the bottom near the headwaters; comparatively large areas of medium to good spawning gravels in the upper reaches; pools common throughout, averaging 1-2 feet deep; good to excellent shelter provided by undercut bank, riparian growth, and fallen trees	Many log jams throughout; most appear to be partial barriers, but could become permanent barriers in the future; all jams are natural windfalls
South Fork Big River	8/8/1957 10/16/1958 11/8/1958	Substrate predominantly gravel, rubble, with some bedrock; generally good to excellent spawning areas; excellent pool development, large and frequent pools; very good shelter provided by logs, brush, and undercut banks	Seven logjams that are complete or partial barriers
	10/16/1958 (flyover)		The nine miles of stream above the mouth are completely free of all obstructions to fish life; the remaining eight miles of stream contain 7 log jams or other barriers to fish life
	8/25/1966	Section 1: Good spawning gravels; excellent pool frequency, very large pools; good shelter. Section 2: abundant spawning areas; excellent pool frequency, fairly large pools; good shelter. Section 3: poor spawning area due to heavy silt, and a great deal of rubble; good pool frequency, smaller pools; good shelter. Section 4: poor spawning area due to a great deal of bedrock and silt; poor pool frequency, small pools; poor shelter. Water temperature 74°F at Orr Springs	No logjams that could be considered barriers
Kelly Gulch	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)	Appeared unimportant to fish life	
Biggs Gulch	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)	Appeared unimportant to fish life	
Ramon Creek	10/16/1958 (flyover)		The entire four miles of stream appears clear of obstructions to fish life
	8/11/1959	Substrate primarily gravel with some bedrock, sand, and organic debris; about 75% of the stream is extremely good for spawning fish; good pool development, up to 3 feet deep; fair to good shelter provided by overhanging trees, log jams, undercut banks, and some large boulders; average water temperature 64°F	Logjams
Mettick Creek	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)		Full of old logging debris
Anderson Gulch	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)		Full of old logging debris
Boardman Gulch	circa 1950	Poor and short sections for fisheries	
	10/16/1958 (flyover)		Appeared unimportant to fish life

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
Daugherty Creek	10/16/1958 (flyover)	Appeared to have potential as an excellent salmon and steelhead spawning and nursery stream	The entire streambed was not visible due to heavy canopy cover; three log-debris jams noted in the lower and mid-sections of the stream and extensive logging debris in the stream bottom in the headwaters section
	8/10/1959 (downstream)	Substrate gravel and rubble, with occasional areas of bedrock; good to fair spawning areas; pools averaged 8 inches deep and were well developed; good to fair shelter provided by pools, undercut banks, and large rubble; water temperatures ranged from 58-62°F	Many log jams and barriers resulting from logging.
	8/10/1959 (upstream)	Substrate silt, gravel, boulder, rubble, bedrock and sand, heavily silted in upper areas; no-existent spawning areas in valley and upper forks, fair spawning areas in north tributary and remainder of stream; pools common in gorge and canyon and uncommon in valley, averaged 8 inches deep; good shelter provided by stream side growth; average water temperature 62°F	Many log jams and barriers.
Soda Creek	8/11/1959	Substrate gravel, bedrock, rubble, and silt in the upper area and behind barrier; good spawning areas throughout middle and upper areas, upper area only has a few scattered spots of gravel due to siltation; abundant pools averaging 1 foot deep; good shelter provided by overhanging streamside growth and trees; average water temperature 58°F	Many jams and barriers; natural rock falls barrier 75 yards upstream from the mouth.
Gates Creek	10/16/1958 (flyover)	Appeared to have excellent potential as a salmon and steelhead spawning and nursery stream	
Johnson Creek (tributary to Gates Creek)	10/16/1958 (flyover)	Appeared to be a good spawning and nursery stream for anadromous fish	
	8/7/1959	Substrate gravel with rubble, sand, boulder and bedrock; good spawning areas throughout except for a few poor areas; good pool development, average 1 foot deep; good shelter throughout provided by stream side trees and overhanging limbs and roots; average water temperature 57°F	Several logjams and barriers
	8/9/1966	Average bottom very little fine and coarse rubble, very little bedrock, moderate amount of coarse gravel, great deal of fine gravel; pool: riffle ratio 1:3, pools shallow; most pools open and devoid of hiding places, shelter not very good; water temperature 59°F	No barriers present; some logjams present in upper headwater areas.
Snuffins Creek	8/10/1959	Substrate gravel, silt, sand and small amounts of rubble, heavy concentration of silt found in the upper area; fair to poor spawning areas throughout, lower section has fine gravel, middle section has gravel to silt, upper section has some gravel and heavy silting; pools uncommon and poor, average 4 inches deep; fair to good shelter; average water temperature 59°F	Many logjams
	6/9/1966	Since the gravel in the stream bed is fairly loose, and this years fry is present in the stream, it appears that spawning areas are not a problem in the stream; the gravel particle size necessary for steelhead spawning is present in most all riffle areas, and the tail of pools; pools are not too common (1/ 100 feet approximately); pools appear to be in fair shape; average pool 7 inches deep; few pools were observed that were two feet deep; frequency of pools was 25% or less; poor shelter provided by log jams, single logs, and tree roots from large redwood stumps; water temperature 62°F	At least five log jams from the stream mouth to the first total barrier to upstream migration; first total barrier 0.1 mile above the mouth of the stream; first 5 or so jams are not barriers at present, but they will probably silt in during next winters rain; another total barrier located at the second bridge crossing; similar barrier 100 feet above the bridge; 8 log jams were removed in 1966 which improved two miles of stream
Johnson Creek	10/16/1958 (flyover)	Appeared to have been extensively logged	

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
	7/8/1959	Spawning areas fair throughout; good pool development of medium sized pools throughout, becoming uncommon in the extreme upper section; excellent shelter provided by undercut banks, rocks, streamside vegetation, and fallen rocks; average water temperature 57°F	Several logjams and barriers
Dark Gulch	10/16/1958 (flyover)	The entire stream completely lost to the fishery from poor logging practices	
Montgomery Creek	10/16/1958 (flyover)	The entire stream removed from fisheries production through poor logging practice	Stream choked with old logging debris
Unnamed Tributary to the South Fork Big River #1	10/16/1958 (flyover)	Fisheries value considerably reduced through poor logging practices	Partial barriers in the form of log debris exist throughout the entire stream
	11/8/1958	Generally fair to poor spawning areas scattered throughout the entire stream, best in the lower ¾ mile; pools fair in the lower mile, and poor above; shelter provided by logging debris and undercut banks.	Considerable logging debris constituting some partial barriers
Unnamed Tributary to the South Fork Big River #2	10/16/1958 (flyover)	Fisheries value considerably reduced through logging; of minor importance to fish life	
	11/8/1958	Substrate mostly silt, some scattered gravel sections throughout; fair spawning areas present, but generally scarce; pools small and infrequent; shelter adequate and fair.	Three log barriers and other small debris.
Big River	10/16/1958 (flyover)		A large wooden dam located approximately one mile above the mouth of Valentine Creek appeared to block off approximately five miles of the Big River headwaters to anadromous fish
Russell Brook	10/16/1958 (flyover)	Appeared to be a good spawning and nursery stream	The entire four miles of stream surveyed were free from log jams and debris
	8/5/1959	Substrate gravel, rubble, and sand with some amounts of bedrock; fair to good spawning areas; good pool development, average 2 feet deep; excellent shelter provided by overhanging tree limbs and foliage; average water temperature 58°F	Log jams, but no barriers to fish
Pig Pen Gulch	10/16/1958 (flyover)	Not visible due to heavy canopy cover	
	5/29/1959	Spawning areas poor throughout, no desirable spawning areas in upper headwaters, and fair to poor spawning areas in middle and lower sections; good pool development, abundant pools, average 1 foot deep; abundant shelter provided by riparian growth, heavy horsetail and undercut banks	Logging debris and two barriers
Martin Creek	10/16/1958 (flyover)	Appeared to have considerable fisheries value	Three large log jams noted in the lower section of the stream, with a considerable amount of debris above
	8/3/1959	Gravel, rubble, sand, and silt bedrock substrate; fair to good spawning areas, none to poor in the upper and headwater sections, fair in the middle section, good in the lower section; abundant pools throughout, 6 inches to 7 feet deep; excellent shelter provided by riparian growth, undercut banks, and log jams; average water temperature 59°F	Many jams and barriers
Martin Creek Left Bank Tributary	8/3/1959	The east fork has only occasional spawning areas throughout ranging from fair to poor; the north fork of the east fork was fair to poor spawning gravel in the lower half with occasional fair to poor areas in the upper half; in the East Fork pools were common throughout, average 6 inches deep; in the north fork, pools were common in the upper half to uncommon in the lower half; shelter is good on the East Branch except for a few areas where logging operations have opened up the cover; shelter in the north fork is excellent; water temperatures ranged from 56-65°F	Many log jams and barriers

Tributary	Date Surveyed	Habitat Comments	Barrier Comments
Valentine Creek	10/16/1958 (flyover)	Appeared to be a good spawning and nursery stream	Lower mile free from obstruction and upper mile not visible due to heavy conifer canopy cover
	7/29/1959	Poor to fair spawning areas throughout most of the stream; abundant pools, 5-8 inches deep; good to excellent shelter provided by boulders, undercut banks, tree roots, and riparian growth; water temperatures ranged from 60-70°F	1 log jam; 1 fallen in flush dam
Rice Creek	10/16/1958 (flyover)	Full of old logging debris, fisheries value appeared negligible	
	Approx. 1959	Fair spawning areas in lower section, poor to non existent spawning areas in the upper section; poor pool development in the lower section, average 1 foot deep; lower section open with no shelter, middle and upper sections covered with riparian growth and logging debris; average water temperature 71°F	4 log jams and barriers
East Branch Rice Creek	7/28/1959	Extremely small gravel present, considered poor spawning; poor pool development, average 2 feet by 3 feet by 6 inches; poor to fair shelter in the form of riparian growth, undercut banks, logging debris, and rocks, many areas open due to poor past logging practices; average water temperature 62°F	Many log jams and barriers

Current Conditions

Habitat Inventory Surveys

CDFG stream inventories were conducted for 106.0 miles on 73 reaches of 41 tributaries in the Inland Subbasin since 1993 (Table 192, Figure 129). Additionally, the North Fork Big River was surveyed in 1996 as well as 1997, and Daugherty Creek, Gates Creek, Soda Creek, Johnson Creek (tributary to Gates Creek), and Snuffins Creek were surveyed in 1993 as well as 2002. Stream attributes that were collected during stream inventories included canopy cover, embeddedness, percent pools, pool depth, and pool shelter.

Table 192. Surveyed streams in the Inland Subbasin.

Stream	Survey Date	Reach	Survey Length (Miles)
North Fork Big River	August/September 1997	1	7.1
	August	2	3.5
	August	3	1.4
East Branch North Fork Big River	June 1998	1	6.6
	June 1998	2	0.8
Chamberlain Creek	July 1997	1	1.5
	July 1997	2	3.6
Water Gulch	July 1997	1	1.0
	July 1997	1	0.9
Water Gulch Tributary	July/August 1997	1	0.4
Park Gulch	June 1997	1	1.0
West Chamberlain Creek	June 1997	1	3.3
	June 1997	1	0.2
Gulch Sixteen	July 1997	1	0.8
	July 1997	2	0.1
Gulch Sixteen Tributary	July 1997	1	0.4
Arvola Gulch	July 1997	1	0.9
Lost Lake Creek	July 1997	1	0.9
Soda Gulch	September 1997	1	0.7
James Creek	October 1996	1	2.8
	October 1996	2	1.6
James Creek North Fork	July/August 1997	1	2.4
South Fork Big River Part 1	June 2002	1	6.3
	June 2002	2	5.4
South Fork Big River Part 2	August/September 2002	1	3.5
	September 2002	2	3.3
	September 2002	3	1.2
	September 2002	4	0.8
Biggs Gulch	June 2002	1	0.5
Ramon Creek	June 2002	1	1.6
	June 2002	2	1.4
	June 2002	3	0.9
North Fork Ramon Creek	June 2002	1	1.5
Mettick Creek	June/July 2002	1	1.0
Poverty Gulch	July 2002	1	0.1
Anderson Gulch	August 2002	1	0.5
Boardman Gulch	June 2002	1	1.2
	June 2002	2	<0.1
Halfway House Gulch	June 2002	1	0.2
Daugherty Creek	July 2002	1	0.8
	July 2002	2	2.7
	July 2002	3	2.5
	July 2002	4	2.0
	July 2002	5	0.8
Soda Creek	May 2002	1	0.6
	May 2002	2	0.1
	May 2002	3	0.6
	May 2002	4	0.4
Gates Creek	May/June 2002	1	0.2
	May/June 2002	2	2.2
	May/June 2002	3	0.3

Stream	Survey Date	Reach	Survey Length (Miles)
Johnson Creek (Tributary to Gates Creek)	May 2002	1	0.4
	May 2002	2	0.1
	May 2002	3	0.7
Horse Thief Creek	June 2002	1	0.1
Snuffins Creek	July/August 2002	1	1.3
Johnson Creek	July/August 2002	1	0.9
Dark Gulch	August 2002	1	1.4
Montgomery Creek	July 2002	1	0.2
	July 2002	2	0.1
	July 2002	3	0.4
Unnamed Tributary 1 to South Fork Big River	July 2002	1	0.7
	July 2002	2	0.1
	July 2002	3	0.3
Unnamed Tributary 2 to South Fork Big River	July 2002	1	0.6
Russell Brook	July 2002	2	4.1
Martin Creek	July 2002	1	3.5
	July 2002	1	0.2
Martin Creek Left Bank Tributary	July 2002	1	0.6
Martin Creek Right Bank 1 Tributary	July 2002	1	1.5
Martin Creek Right Bank 2 Tributary	July 2002	1	0.6
Valentine Creek	July/August 2002	1	1.8
Rice Creek	August 2002	1	1.8

Stream attributes tend to vary with stream size. For example, larger streams generally have more open canopy and deeper pools than small streams. This is partially a function of wider stream channels and greater stream energy due to higher discharge during storms. Surveyed streams in the Inland Subbasin ranged in drainage area from 0.4 to 54.3 square miles (Figure 142).

Canopy cover, and relative canopy cover by coniferous versus deciduous trees were measured at each habitat unit during CDFG stream surveys. Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Furthermore, canopy levels provide an indication of the potential present and future recruitment of large woody debris to the stream channel, as well as the insulating capacity of the stream and riparian areas during winter temperature to support anadromous salmonid production (Figure 130). Water Gulch tributary, Gulch Sixteen tributary, and Park Gulch had the highest canopy cover values of Inland Subbasin. Streams with canopy densities under 70% by length were Poverty Gulch, South Fork Tributary #1, James Creek, and North Fork Big River. North Fork Big River is a third order stream, however, and therefore not expected to have high canopy density.

In general, the percentage of stream canopy cover increases as drainage area, and therefore channel width, decrease. Deviations from this trend in canopy may indicate streams with more suitable or unsuitable canopy relative to other streams of that subbasin. Twenty-seven of the surveyed tributaries of the Inland Subbasin show percent canopy levels that meet target values for maintaining water temperature.

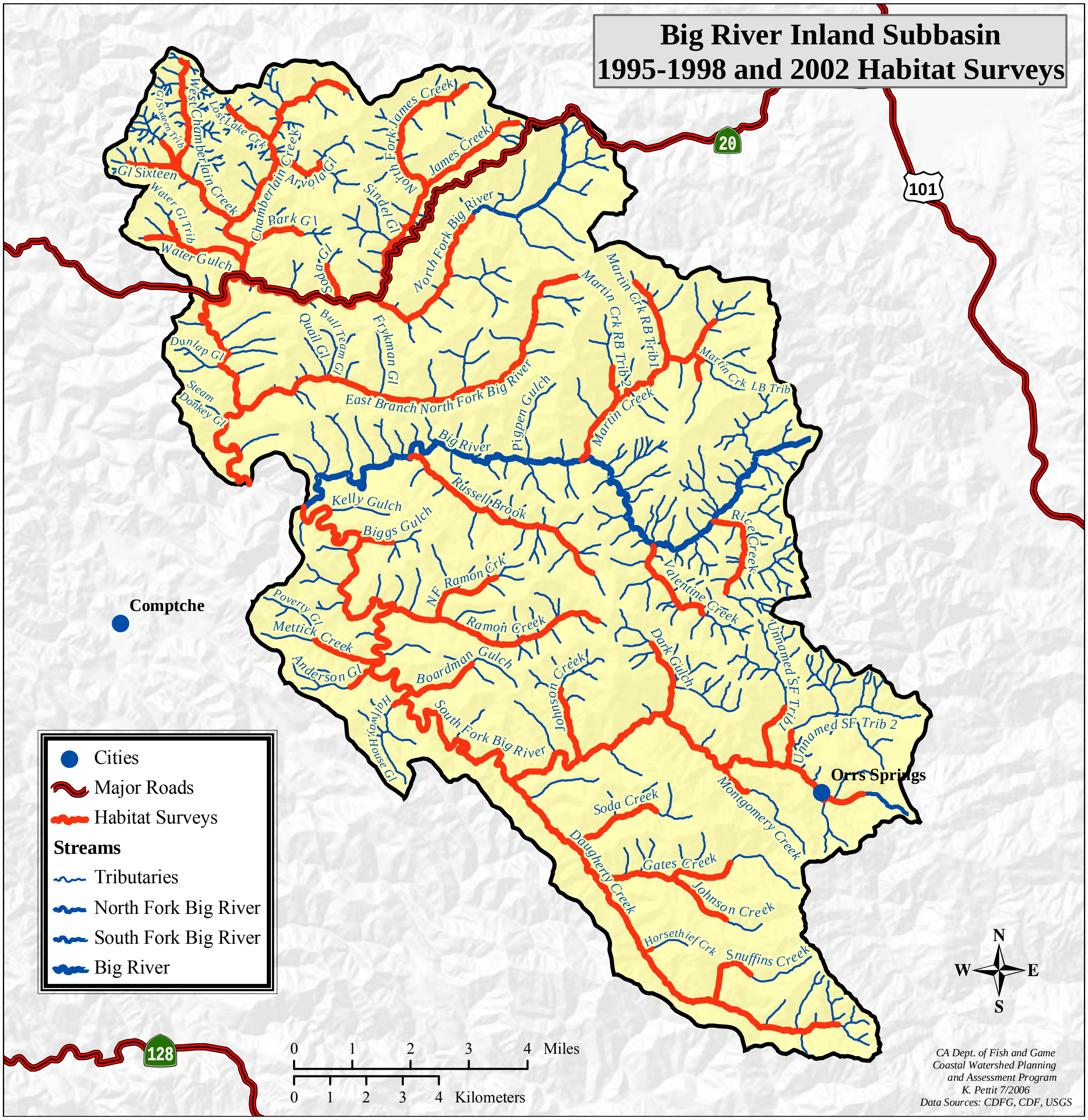


Figure 129. CDFG surveyed streams in the Inland Subbasin.

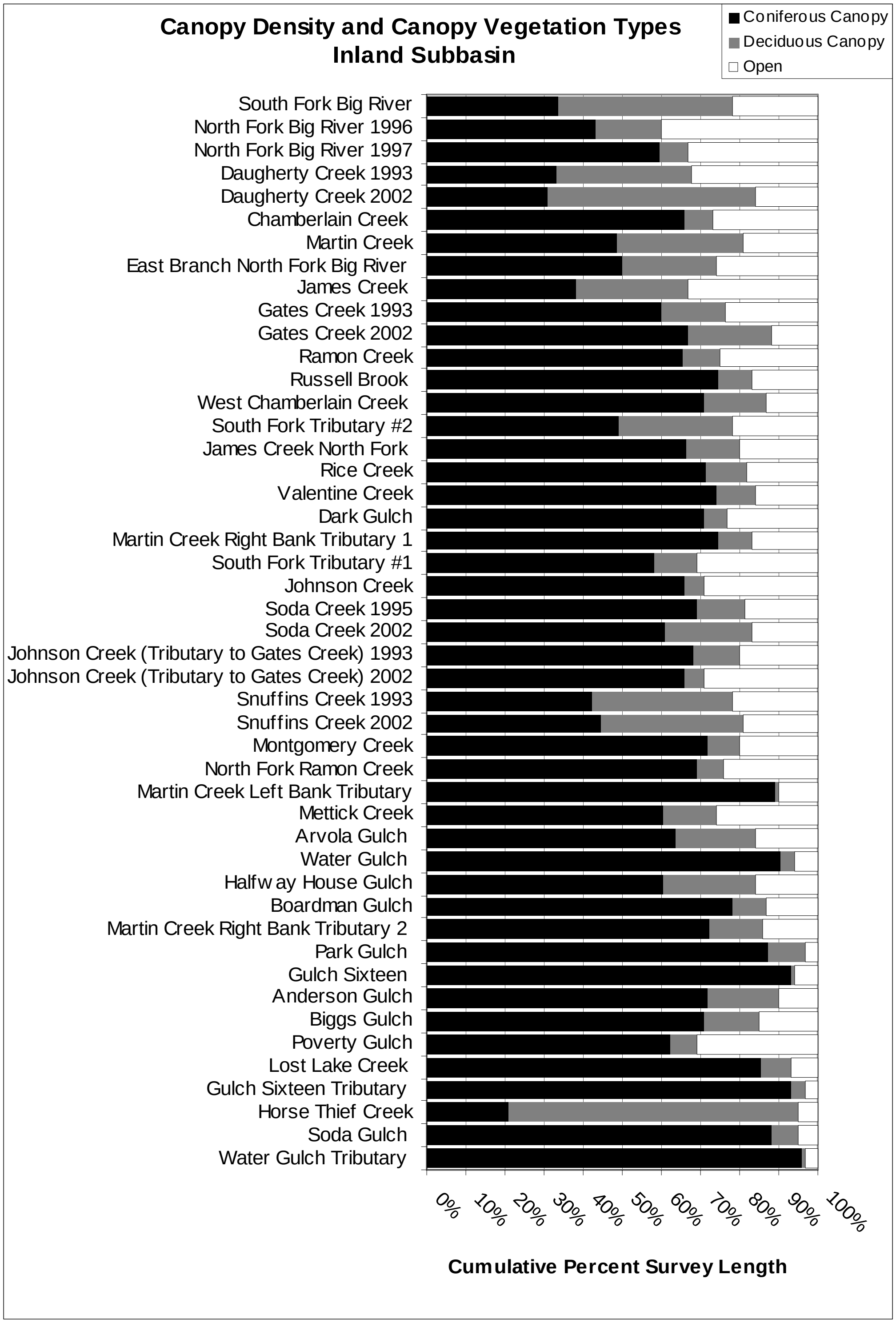


Figure 130. The relative percentage of coniferous, deciduous, and open canopy covering surveyed streams in the Inland Subbasin.

Averages are weighted by unit length to give the most accurate representation of the percent of a stream under each type of canopy. Streams are listed in descending order by drainage area (largest at the top).

Cobble embeddedness was measured at each pool tail crest during CDFG stream surveys. Embeddedness values in the Inland Subbasin generally do not meet target values for successful salmonid egg and embryo development. The percent of pool tail-outs with category 1 cobble embeddedness only exceeded 50% in Halfway House Gulch and Soda Creek. The percent of pool tail-outs with category 1 or 2 cobble embeddedness exceeded 50% in 21 tributaries. Martin Creek had no pool tail-outs with category 1 or 2 embeddedness ratings and Boardman Gulch only had 8% of its pool tail-outs with category 1 or 2 cobble embeddedness. Figure 131 illustrates how stream reaches rated as unsuitable overall may actually have some suitable spawning gravel sites distributed through the stream reach.

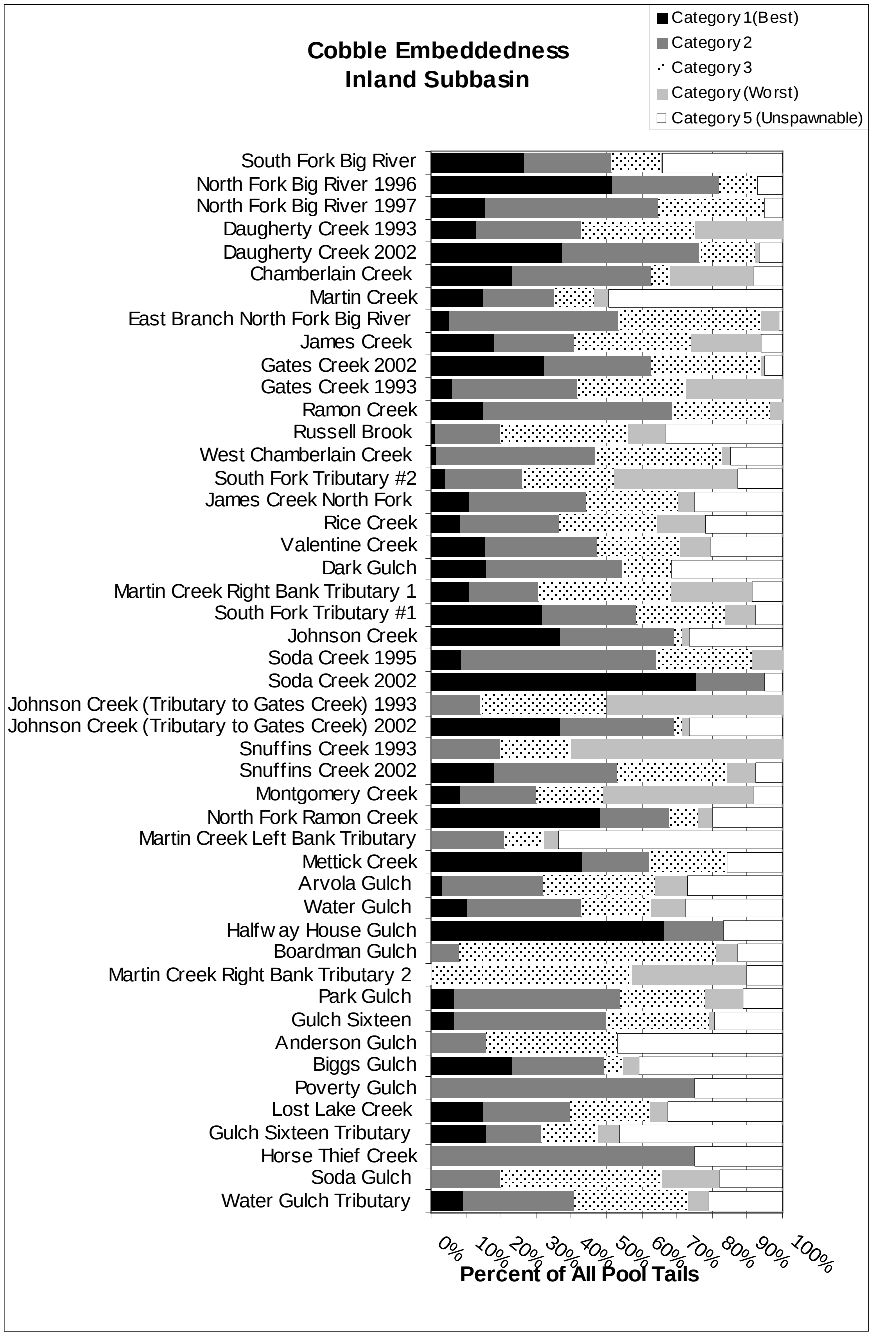


Figure 131. Cobble embeddedness categories as measured at every pool tail crest in surveyed streams in the Inland Subbasin.

Cobble embeddedness is the % of an average sized cobble piece at a pool tail out that is embedded in fine substrate: Category 1 = 0-25% embedded, Category 2 = 26-50% embedded, Category 3 = 51-75% embedded, Category 4 = 76-100%, and Category 5 = unsuitable for spawning due to factors other than embeddedness (e.g. log, rocks). Streams are listed in descending order by drainage area (largest at the top).

Pool, flatwater, and riffle habitat units observed were measured, described, and recorded during CDFG stream surveys. During their life history, salmonids require access to all of these types of habitat. A balanced proportion of these habitat types are desirable. Eight of the surveyed Inland Subbasin streams have greater than 30% pool habitat by length (Figure 132). Only Gates Creek and North Fork Big River had 40% pool habitat by length. Horse Thief Creek had the least pool habitat by length with only 6%. Dry units measured obviously indicate poor conditions for fish and are discussed further in the Fish Passage Barriers section.

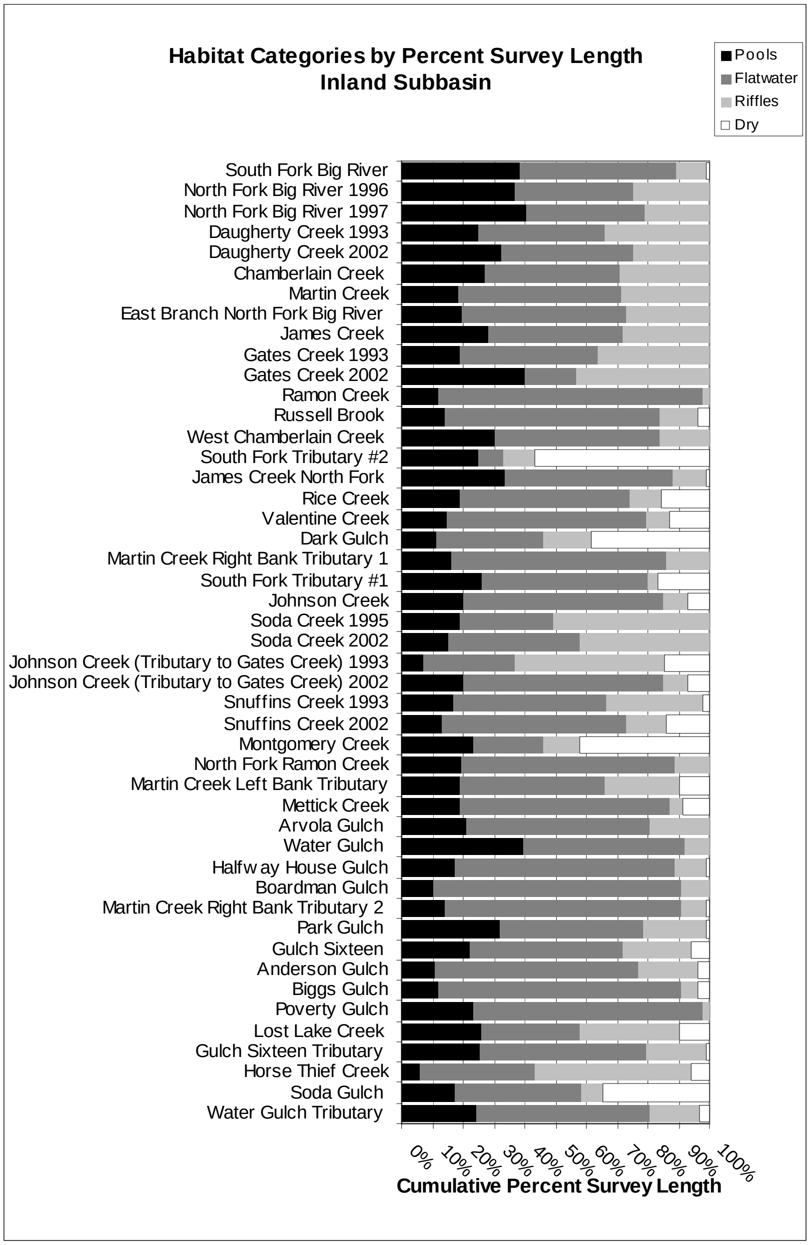


Figure 132. The percentage of pool habitat, flatwater habitat, riffle habitat, dewatered channel, and culverts by survey length in the Inland Subbasin.

Streams are listed in descending order by drainage area (largest at the top).

Pool depths were measured during CDFG surveys. Primary pools are determined by a range of pool depths, depending on the order (size) of the stream. A reach must have 40% of its length in primary pools for its stream class to meet target values for supporting salmonids. Generally, larger streams have deeper pools. Deviations from the expected trend in pool depth may indicate streams with more suitable or less suitable pool depth conditions relative to other streams of that subbasin.

Only North Fork and South Forks Big River have greater than 30% of their surveyed lengths in pools greater than two feet deep (Table 193) In addition, Daugherty Creek has greater than 20% of its surveyed lengths in pools greater than two feet deep. All other surveyed tributaries have less than 20% of their survey length in pools greater than 2 feet deep. Five surveyed tributaries had less than 2% pool habitat with maximum depth greater than two feet by length: Johnson Creek (tributary to Gates Creek), Snuffins Creek, Poverty Gulch, Horse Thief Creek, and Soda Gulch.

Table 193. Percent length of a survey composed of pools in the Inland Subbasin.

Stream	Drainage Area (Square Miles)	Stream Order	Percent pools by survey length	Percent pools >2.0 by survey length	Percent pools >2.5 by survey length	Percent pools >3.0 by survey length	Percent pools >4.0 by survey length
South Fork Big River	54.3	3	37.6	33.4	29.4	24	13.2
North Fork Big River 1996	42.1	3	37.3	25.4	18.7	12	5.3
North Fork Big River 1997	42.1	3	40.7	37.7	30.1	22.2	7.1
Daugherty Creek 1993	16.6	3	48.8	17	11.3	5.9	1.8
Daugherty Creek 2002	16.6	3	32.6	24.6	15.4	11.5	3.6
Chamberlain Creek	12.0	3	25.4	16.4	9.3	4.4	1.1
Martin Creek	9.0	1	18.7	14.8	10.7	6.4	2.5
East Branch North Fork Big River	7.3	1	18.8	15.6	9.1	5.3	0
James Creek	7.1	2	27.9	14.9	9.5	5.7	2.3
Gates Creek 1993	5.3	2	18.7	11.7	6.2	2.3	0.2
Gates Creek 2002	5.3	2	40.1	19.8	11.3	7	2.1
Ramon Creek	5.3	2	11.8	5.6	2.2	0.7	0.1
Russell Brook	4.1	1	14.1	5.4	2.1	0.8	0.2
West Chamberlain Creek	4.0	2	29.6	9.8	3.1	0.8	0.1
South Fork Tributary # 2	3.6	1	24.7	5.3	0.9	0.9	0
North Fork James Creek	3.0	1	29.3	11.3	7	4.1	0.7
Rice Creek	2.6	1	18.4	5	3.3	1.8	0.5
Valentine Creek	2.5	1	14.9	3.9	2	1.2	0
Dark Gulch	2.4	1	11.3	3.4	1.5	0.7	0.1
South Fork Tributary # 1	2.2	1	25.6	16.7	6.6	3.4	2.5
Martin Creek Right Bank 1 Tributary	2.2	1	15.9	3.3	2.1	0.9	0
Johnson Creek	1.8	1	14.8	5.2	1.4	0.3	0
Soda Creek 1995	1.8	1	19.3	5.2	1.9	0.8	0
Soda Creek 2002	1.8	1	15.1	5.8	2.9	1.8	0
Johnson Creek (Tributary to Gates Creek) 1993	1.7	1	6.6	0.3	0	0	0
Johnson Creek (Tributary to Gates Creek) 2002	1.7	1	14	5	2.3	0.2	0
Snuffins Creek 1997	1.7	1	16.5	6.9	3.4	2.3	1.1
Snuffins Creek 2002	1.7	1	14.2	1.8	0.5	0.3	0
Montgomery Creek	1.6	1	22.7	18.5	12.2	11.7	0
North Fork Ramon Creek	1.6	2	19.3	3.4	1.8	0	0
Arvola Gulch	1.5	1	20.5	2.9	1.7	0.3	0
Water Gulch	1.5	1	39.3	18.6	13.4	9.2	0
Mettick Creek	1.5	1	18.8	8.6	4.9	4.9	0
Martin Creek Left Bank Tributary	1.5	1	19.1	6.1	1.7	1.7	0
Halfway House Gulch	1.3	1	17.2	12.9	10.4	3.2	0
Boardman Gulch	1.2	1	10.3	3.7	0.9	0.4	0
Martin Creek Right Bank 2 Tributary	1.2	1	14	6.7	6.3	0	0
Park Gulch	1.1	1	31.8	5.5	1.5	0.4	0
Gulch Sixteen	1.0	1	22.1	2.9	0.6	0	0
Anderson Creek	0.9	1	10.7	6.4	2.1	1	0
Biggs Gulch	0.6	1	12.3	3.6	1.1	0	0
Poverty Gulch	0.6	1	23.2	0	0	0	0
Lost Lake Creek	0.4	1	10.8	2.2	1.3	0.5	0.3
Gulch Sixteen Tributary	0.4	1	22.5	5.4	2.1	0	1
Horse Thief Creek	0.4	1	6.4	0	0	0	0
Soda Gulch	0.4	1	16.8	1	0.4	0	0
Water Gulch Tributary	0.4	1	24.1	14.2	0	0	0

Streams are listed in descending order by drainage area (largest at the top)

Pool shelter was measured during CDFG surveys. Pool shelter rating illustrates relative pool complexity, another component of pool quality. Ratings range from 0-300. Shelter scores greater than 100 meet target values for supporting salmonids. Pool shelter ratings in the Inland Subbasin did not meet target values in (Figure 133). The highest pool shelter ratings were in East Branch North Fork Big River, Daugherty Creek, and Gates Creek. The lowest pool shelter ratings was in Soda Gulch.

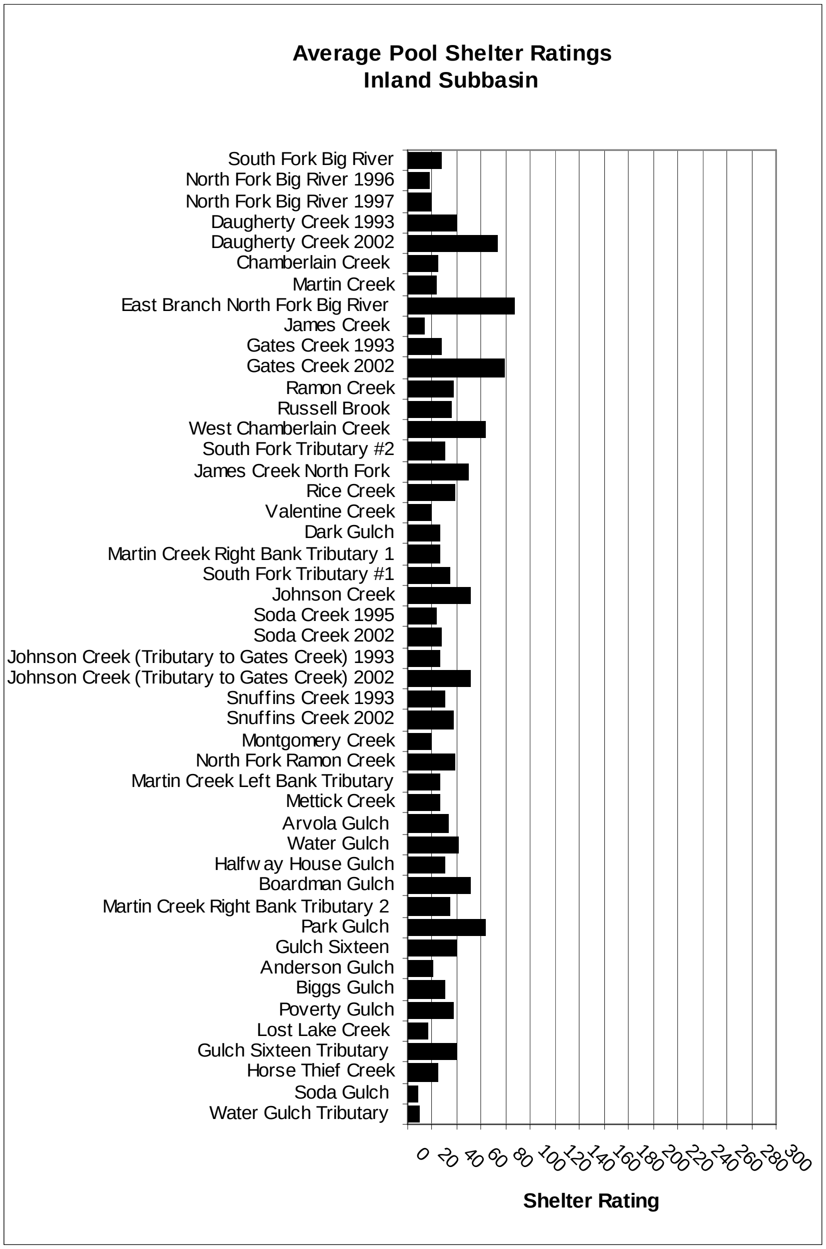


Figure 133. Average pool shelter ratings from CDFG stream surveys in the Inland Subbasin.

Streams are listed in descending order by drainage area (largest at the top).

Pool shelter is composed of those elements within a stream channel that provide salmonids protection from predation, reduce water velocities so fish can rest and conserve energy, and allow separation of territorial units to reduce density related competition. Using an overhead view, a quantitative estimate of the percentage of the habitat unit covered by nine different cover types was made during stream surveys. The mean percent of pool shelter cover in each cover type was calculated for each surveyed stream. The predominant pool cover types in most Inland Subbasin tributaries were undercut banks, woody debris, and boulders (Table 194).

Table 194. Mean percent of shelter cover types in pools for surveyed tributaries in the Inland Subbasin.

Stream	Undercut Banks	Small Woody Debris	Large Woody Debris	Root Mass	Terrestrial Vegetation	Aquatic Vegetation	Whitewater	Boulders	Bedrock Ledges
South Fork Big River	5.5	10.7	6.8	5.3	7.8	9.4	0.3	29.9	24.3
North Fork Big River 1997	8.9	9.1	13	14.8	11.4	0	0.5	23.2	19.3
North Fork Big River 1996	10	3.6	14.3	23.6	0.4	0	0.4	38.6	9.3
Daugherty Creek 1993	8	11	15	15	14	4	0	12	21
Daugherty Creek 2002	15.4	11.4	32.9	9.4	12	5.5	0.2	9.8	2.2
Chamberlain Creek	17.6	15.9	20.3	5.6	10.9	0	3.3	7.2	19
Martin Creek	8	7	15	4	2.8	0.6	0.7	31	31
East Branch North Fork Big River	22	9	26	19	2	1	3	8	10
James Creek	13	10	13	10	1	0	5	45	4
Gates Creek 1993	14	16	12	4	5	0	0	28	21
Gates Creek 2002	13.5	15.3	23.5	16.8	3.8	6.2	5.3	11.5	1.8
Ramon Creek	11.5	21.2	29.7	7.2	4.8	0.1	0.2	8.1	16.1
Russell Brook	8	16	34	11	4.7	0.7	1.3	16	9
West Chamberlain Creek	20.7	13.1	28.8	4.4	4.6	2.6	4.9	9	11.9
South Fork Tributary #2	25	10.5	9.3	34.8	8	1	0	0.5	11
James Creek North Fork	12.5	26.4	13	6.8	13	0.4	3.2	23.9	0.7
Rice Creek	13	22	34	5	9.9	3.2	1.4	10	3
Valentine Creek	7	16	4	4	4.6	0	0.6	46	17
Dark Gulch	10.9	10.9	29.3	1.3	3.4	7.1	0	27.3	9.9
Martin Creek Right Bank Tributary 1	10	19	14	7	0.9	0	4.1	35	9
South Fork Tributary #1	20.9	7.4	7.8	16.8	0	0.3	0	33.6	13.4
Johnson Creek	15.1	30.4	31.1	2.2	4.7	2.5	1.2	5.5	3.2
Soda Creek 1993	8.1	26.3	17.2	16.2	5.1	0	14.1	4	9.1
Soda Creek 2002	34.2	12.3	34.4	5.3	0	0	7	2.5	4.3
Johnson Creek (Tributary to Gates Creek) 1993	10	9	13	7	1	1	0	58	1
Johnson Creek (Tributary to Gates Creek) 2002	15.1	30.4	31.1	2.2	4.7	2.5	1.2	5.5	3.2
Snuffins Creek 1993	19	13	23	16	5	0	0	14	10
Snuffins Creek 2002	16.4	20.9	26.5	7.3	4.5	1	0	22.2	1.4
Montgomery Creek	22.2	15.9	9.7	7.8	0	2.5	1.9	35.6	4.4
North Fork Ramon Creek	9.4	21.5	28.6	14	5.4	1.3	7.3	8.1	4.4
Arvola Gulch	31.7	3.3	43.3	0.8	8.3	0	0.8	10	1.7
Martin Creek Left Bank Tributary	13	8	15	7	0.7	0.2	0.2	44	11
Mettick Creek	13.9	21.3	8.3	9.4	4.2	4.3	6.4	7.9	18.8
Water Gulch	18.3	8.3	23.3	10.6	5.8	0.6	0	31.1	0
Halfway House Gulch	6.7	17.5	42.5	3.3	0	0	9.2	5.8	15
Boardman Gulch	14.1	22.7	20.8	14.2	10.1	0.3	3.5	3.4	10.8
Martin Creek Right Bank Tributary 2	8	17	53	1	0	0	1.9	17	2
Park Gulch	26	11.3	38.2	1.8	4.7	2.7	6.1	7.1	0.5
Gulch Sixteen	29.3	47.1	23.6	0	0	0	0	0	0
Anderson Gulch	10.3	7.8	6.7	6.9	0	0	0.8	11.1	56.4
Biggs Gulch	10.3	13.8	45.6	5.9	3.2	0	4.1	4.7	12.4
Poverty Gulch	32.5	11.3	30	17.5	0	0	2.5	2.5	3.8
Lost Lake Creek	2	0	6	2	8	2	12	68	0
Gulch Sixteen Tributary	15.6	18.9	25.6	8.9	11.1	4.4	3.3	12.2	0
Horse Thief Creek	32.5	27.5	35	0	0	0	5	0	0
Soda Gulch	8.3	21.7	35	0	0	0	0	35	0
Water Gulch Tributary	42.2	25.6	22.2	0	10	0	0	0	0

Streams are listed in descending order by drainage area (largest at the top).

MRC Habitat Surveys

MRC surveyed habitat conditions across their ownership in the Big River Basin in 2000 (Table 195).

Table 195. Surveyed stream segments on MRC ownership in the Inland Subbasin (MRC 2003).

Stream Segment	Segment ID	Survey Length (feet)
East Branch North Fork Big River	BE1	929
East Branch North Fork Big River	BE2	546
Bull Team Gulch	BE8	218
Frykman Gulch	BE14	234
Big River in Rice Creek PW	BI1	810
North Fork Big River	BL1	889
North Fork Big River	BL3	916
Steam Donkey Gulch	BL7	159
Dunlap Gulch	BL12	329
South Fork Big River	BM1	934
South Fork Big River	BM3	972
South Fork Big River	BM5	932
Ramon Creek	BM25	337
Ramon Creek	BM26	511
Ramon Creek	BM27	408
North Fork Ramon Creek	BM31	495
North Fork Ramon Creek	BM32	306
Mettick Creek	BM54	371
Mettick Creek	BM55	438
Boardman Gulch	BM59	201
Halfway House Gulch	BM64	418
South Fork Big River Tributary	BM76	177
Big River in Russell Brook PW	BR1	1,105
Big River in Russell Brook PW	BR2	1,117
Big River in Russell Brook PW	BR4	806
Russell Brook	BR5	565
Russell Brook	BR6	460
Russell Brook	BR7	312
Wildhorse Gulch	BR9	400
Pig Pen Gulch	BR29	197
Daugherty Creek	BS1	874
Daugherty Creek	BS3	627
Daugherty Creek	BS5	310
Soda Creek	BS15	389
Gates Creek	BS23	542
Johnson Creek	BS24	519
Snuffins Creek	BS49	331

Canopy Closure

Canopy closure measured on stream segments across the MRC's ownership in the Inland Subbasin ranged from less than 50% on the South Fork Big River and Ramon Creek to greater than 90% on 14 surveyed stream segments (Figure 134). Low canopy density is expected on higher order streams such as the North and South forks Big River and Daugherty Creek. Canopy density on Ramon Creek appears to be very low.

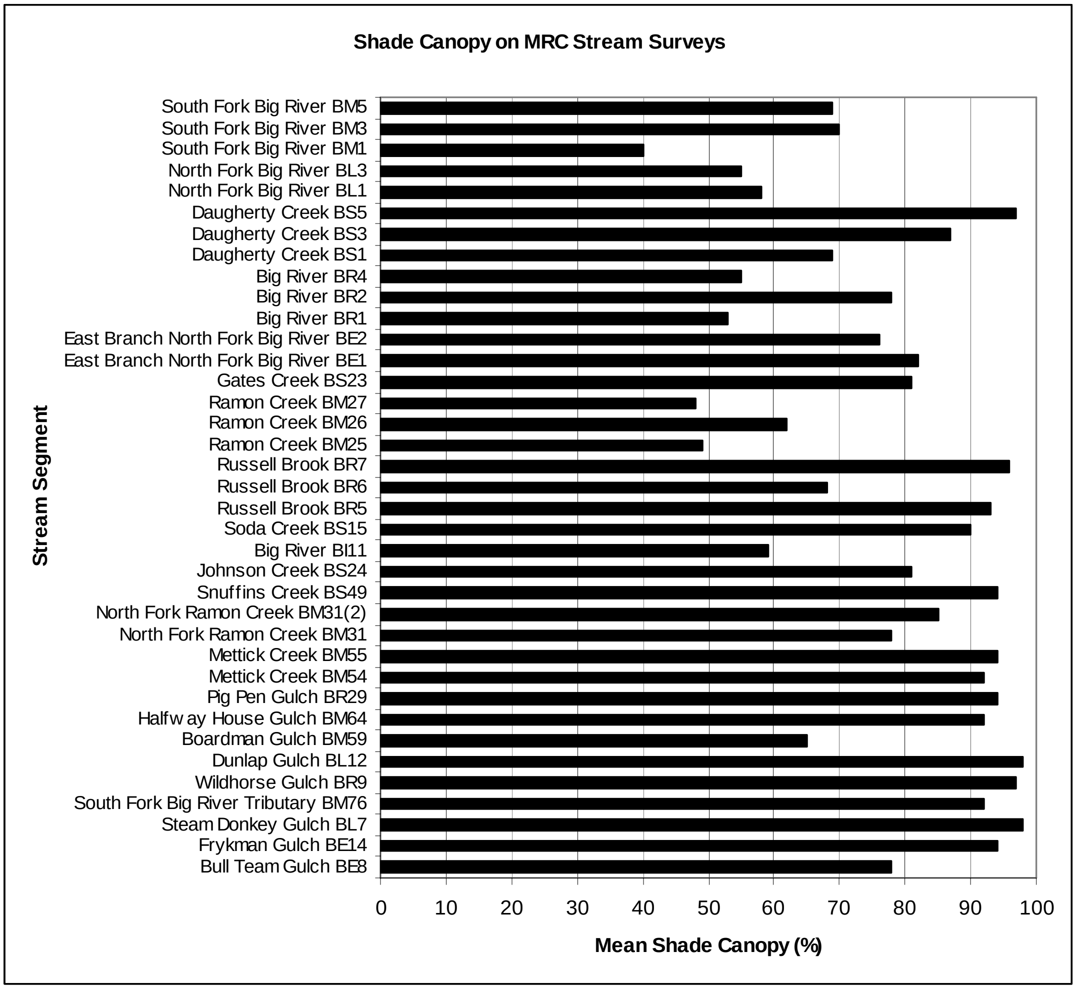


Figure 134. Stream canopy closure on stream segments in the MRC ownership of the Inland Subbasin (MRC 2003).

Pools

The number of pools measured on stream segments across the MRC's ownership in the Inland Subbasin ranged from none to 11 (Table 196). The percentage of pools with mean residual pool depths greater than 3 feet was 50% or greater in only four surveyed segments. Most pools were bank forced.

Table 196. Pool characteristics measured on stream segments in the MRC ownership of the Inland Subbasin (MRC 2003).

Stream	Segment	% Pool:Riffle: Flatwater by stream length	Total # of pools	Pool Spacing reach length/bankfull/#pools	Shelter rating	Mean residual pool depth (feet)	% of all pools with residual depth ≥3 ft.	Key LWD + rootwads / 328 ft. With Debris Jams	Pool Mechanism			
									Free	LWD forced	Boulder forced	Bank forced
MRC 'Good' Target		>50%pools	NA	≤ 2.9	>120	NA	>50%	>6.6 in streams >40 feet BFW >3.9 in streams <40 feet BFW	NA	NA	NA	NA
North Fork Big River	BL1	60:10:30	3	6.3	57	2.7	33	0	0	1	0	2
North Fork Big River	BL3	68:11:21	3	6.4	72	4.3	67	0	1	0	0	2
Steam Donkey Gulch	BL7	44:56:0	4	4.9	43	1.4	0	2.1	2	0	0	2
East Branch North Fork Big River	BE1	54:46:0	9	3.3	62	NA	7	0	1	2	3	3
East Branch North Fork Big River	BE2	56:44:0	4	6.7	83	1.4	0	2.4	0	1	0	3
Bull Team Gulch	BE8	37:63:0	6	5.4	56	0.8	0	4.5	0	4	0	2
Frykman Gulch	BE14	64:36:0	7	4.1	43	NA	0	2.8	0	1	0	6
Dunlap Gulch	BL12	40:60:0	5	6	122	0.9	0	16.9	0	3	1	1
South Fork Big River	BM1	58:32:10	4	3.7	78	2.8	20	0	2	0	0	2
South Fork Big River	BM3	78:13:9	4	4.7	64	4.0	50	0	0	0	0	4
South Fork Big River	BM5	81:19:0	4	5.1	93	2.9	50	0	0	0	0	4
Ramon Creek	BM25	55:45:0	4	2.2	63	1.4	0	1.9	0	2	0	2
Ramon Creek	BM26	50:50:0	7	3.3	58	1.6	14	2.6	0	2	1	4
Ramon Creek	BM27	61:39:0	3	8.3	59	0.9	0	0.8	0	1	0	2
North Fork Ramon Creek	BM31	44:56:0	8	4.7	71	2.1	25	0	1	0	0	7
North Fork Ramon Creek	BM32	43:39:18	3	10.1	93	1.1	0	3.2	0	2	0	1
Mettick Creek	BM54	63:37:0	6	4.3	79	1.3	0	0	1	0	0	5
Mettick Creek	BM55	40:60:0	4	7.8	48	0.9	0	0.7	1	0	0	3
Boardman Gulch	BM59	61:39:0	0	0	36	0.9	0	0	0	0	0	0
Halfway House Gulch	BM65	53:47:0	5	9.3	101	1.7	14	3.9	0	2	0	3
Unnamed 20 Mile tributary to South Fork	BM76	44:56:0	3	7.4	43	0.5	0	0	0	1	0	2

Stream	Segment	% Pool:Riffle: Flatwater by stream length	Total # of pools	Pool Spacing reach length/bankfull/#pools	Shelter rating	Mean residual pool depth (feet)	% of all pools with residual depth ≥3 ft.	Key LWD + rootwads / 328 ft. With Debris Jams	Pool Mechanism			
									Free	LWD forced	Boulder forced	Bank forced
Big River												
Daugherty Creek	BS1	56:44:0	5	4.8	70	2.6	20	0.4	1	0	0	4
Daugherty Creek	BS3	52:36:12	4	6.1	70	2.3	25	2.6	1	0	1	2
Daugherty Creek	BS5	53:47:0	6	3.6	63	1.8	0	6.3	0	4	0	2
Soda Creek	BS15	61:39:0	7	2.7	69	1.2	17	5.9	1	3	0	3
Gates Creek	BS23	45:40:15	5	3.4	67	1.3	0	2.4	0	0	0	5
Johnson Creek (tributary to Gates Creek)	BS24	59:41:0	11	2.7	68	1.1	0	5.7	2	6	0	3
Snuffins Creek	BS49	46:54:0	7	4.4	94	1.6	14	9.9	1	4	1	1
Big River	BI1	48:44:8	5	3.3	51	1.8	20	0	1	0	0	4
Big River	BR1	80:10:10	4	5.8	29	3.1	33	0.9	0	0	0	4
Big River	BR2	63:37:0	6	3.6	74	3.0	50	0.3	0	1	0	5
Big River	BR4	82:18	5	3.2	69	2.7	60	0	1	0	0	4
Russell Brook	BR5	61:23:16	8	2.6	53	1.2	0	0.6	1	0	6	1
Russell Brook	BR6	58:42:0	8	5.4	78	1.1	0	5	1	4	0	3
Russell Brook	BR7	44:56:0	8	3.7	83	1.1	0	10.5	0	2	3	3
Pigpen Gulch	BR29	52:48:0	6	3.1	43	0.9	0	3.3	1	1	2	2

Spawning Gravel

The amount of spawning gravel measured on stream segments across the MRC's ownership in the Inland Subbasin ranged from 1.5 to greater than 3% (Table 197); the target of greater than three percent was reached on 18 stream segments. MRC characterized spawning gravels as fair quality on 32 segments surveyed and good quality on four.

Table 197. Spawning gravel characteristics measured on stream segments in the MRC ownership of the Inland Subbasin (MRC 2003).

Stream	Segment	Spawning gravel quantity (%)	% Embeddedness	Sub-surface fines	Gravel Quality	% Over-wintering substrate
MRC 'Good' Target		>3%	<25%	1.0-1.6	1.0-1.6	>40% of units cobble or boulder dominated
North Fork Big River	BL3	>3	25-50	Fair	Good	0
Steam Donkey Gulch	BL7	1.5-3	>50	Poor	Fair	62
East Branch North Fork Big River	BE1	>3	>50	Fair	Fair	50
East Branch North Fork Big River	BE2	>3	25-50	Fair	Fair	0
East Branch North Fork Big River	BL1	>3	25-50	Fair	Good	16
Bull Team Gulch	BE8	1.5-3	>50	Fair	Fair	0
Frykman Gulch	BE14	>3	>50	Fair	Fair	20
Dunlap Gulch	BL12	1.5-3	>50	Poor	Fair	66
South Fork Big River	BM1	>3	25-50	Fair	Fair	0
South Fork Big River	BM3	>3	<25	Fair	Good	0
South Fork Big River	BM5	>3	25-50	Fair	Fair	11
Ramon Creek	BM25	1.5-3	>50	Fair	Fair	0
Ramon Creek	BM26	>3	>50	Poor	Fair	0
Ramon Creek	BM27	1.5-3	>50	Fair	Fair	0
North Fork Ramon Creek	BM31	1.5-3	>50	Fair	Fair	0
North Fork Ramon Creek	BM32	1.5-3	>50	Fair	Fair	0
Mettick Creek	BM54	1.5-3	25-50	Fair	Fair	18
Mettick Creek	BM55	>3	25-50	Fair	Fair	0
Boardman Gulch	BM59	1.5-3	>50	Fair	Fair	0
Halfway House Gulch?	BM65	1.5-3	25-50	Fair	Fair	38
Unnamed 20 Mile tributary to South Fork Big River	BM76	1.5-3	>50	Fair	Fair	0
Daugherty Creek	BS1	>3	>50	Fair	Fair	50
Daugherty Creek	BS3	>3	25-50	Fair	Fair	44
Daugherty Creek	BS5	>3	>50	Fair	Fair	0
Soda Creek	BS15	1.5-3	>50	Fair	Fair	50
Gates Creek	BS23	>3	25-50	Fair	Fair	50
Johnson Creek (tributary to Gates Creek)	BS24	>3	>50	Fair	Fair	0
Snuffins Creek	BS49	1.5-3	>50	Poor	Fair	0
Big River	BI1	1.5-3	25-50	Fair	Fair	0
Big River	BR1	>3	25-50	Fair	Fair	10
Big River	BR2	>3	25-50	Fair	Good	67
Big River	BR4	>3	25-50	Fair	Fair	33
Russell Brook	BR5	1.5-3	>50	Fair	Fair	50
Russell Brook	BR7	1.5-3	>50	Fair	Fair	0
Pigpen Gulch	BR29	1.5-3	>50	Fair	Fair	11
Russell Brook	BR6	1.5-3	>50	Fair	Fair	13

Large Woody Debris

MRC (2003) examined LWD loading and demand in 37 stream segments across their ownership in the Inland Subbasin (Table 198). Only seven segments on Bull Team Gulch, Dunlap Gulch, Halfway House Gulch, Russell Brook, Soda Creek, Johnson Creek, and Snuffins Creek made the MRC target value for key LWD. The target value set was 3.3 pieces of LWD per 100 meters for streams with bankfull widths greater than 45 feet; 3.9 with bankfull widths 35-45 feet; 4.9 with bankfull widths 15-35 feet; and 6.6 with bankfull widths less than 15 feet.

Table 198. MRC LWD survey results in the Inland Subbasin (MC 2003).

Stream	# of Segments Surveyed	Pieces of Functional LWD		Total Volume of LWD		Key LWD	Jams	
		Number Including Jams	Number per 328 feet (including jams)	Cubic Yards (including jams)	Cubic Yards per 328 feet (including jams)	Number Including Jams	% of LWD pieces in jams	% of volume in jams
East Branch North Fork Big River	2	45	6-12.4	39.1	7.7-9.3	4	0	0
Bull Team Gulch	1	35	52.7	22.9	34.4	6	43	8
Frykman Gulch	1	15	21.0	15.8	22.2	2	0	0
Big River in Rice Creek PW	1	7	2.8	3.3	1.3	0	0	0
North Fork Big River	2	19	21-4.8	17.7	2.2-4.2	0	0	0
Steam Donkey Gulch	1	11	22.7	4.8	9.9	1	0	0
Dunlap Gulch	1	81	80.8	142.4	141.9	27	40	68
South Fork Big River	3	22	1.4-3.4	11.5	0.4-2.0	0	0	0
Ramon Creek	3	54	6.8-19.3	37.8	8.3-10.6	10	0-52	0-50
North Fork Ramon Creek	2	49	8.6-38.6	26.6	2.3-24.9	5	0-42	0-51
Mettick Creek	2	24	6.2-12.7	7.9	1.1-5.1	1	0	0
Boardman Gulch	1	10	16.3	1.3	2.1	0	0	0
Halfway House Gulch	1	33	25.9	42.5	33.3	9	42	29
South Fork Big River Tributary	1	7	13.0	0.7	1.2	0	0	0
Big River in Russell Brook PW	3	61	2.8-10.0	134.2	1.6-24.0	6	0-47	0-80
Russell Brook	3	166	26.1-58.9	119.9	13.6-55.7	18	0	0
Wildhorse Gulch	1	21	17.2	10.2	8.4	1	0	0
Pig Pen Gulch	1	20	33.3	5.9	9.8	2	0	0
Daugherty Creek	3	40	4.9-16.9	30.2	3.6-13.6	12	0	0
Soda Creek	1	17	14.3	12.8	10.8	7	0	0
Gates Creek	1	19	11.5	10.3	6.2	4	0	0
Johnson Creek	1	43	27.2	29.2	18.4	9	0	0
Snuffins Creek	1	48	47.6	31.1	30.8	10	0	0

Although debris jams were scarce, they did contain a significant portion of the LWD present when they occurred. MRC also found that a considerable amount of the LWD observed was at least partially buried and thus could not be quantified. LWD was dominated by redwood, likely because it is more stable than hardwood species.

Nearly all surveyed segments contained LWD that was not recently recruited to the stream. It did not appear that much LWD had been contributed within the past ten years, except for a blow-down in Johnson Creek. Low recruitment in recent years could be a result of timber harvest practices.

MRC gave surveyed stream segments in the Inland Subbasin low quality LWD ratings (Figure 135, Table 199). Only Russell Brook, East Branch North Fork Big River, Ramon Creek, Halfway House Gulch, Daugherty Creek, Soda Creek, Gates Creek, and Snuffins Creek were rated marginal. Combined with the low LWD recruitment potential discussed in the Riparian Conditions section, the low quality LWD ratings across the MRC ownership show that much of the streams are badly in need of LWD. Major channels, such as the mainstem Big River, South Fork Big River, North Fork Big River, and East Branch North Fork Big River are especially in need of LWD.

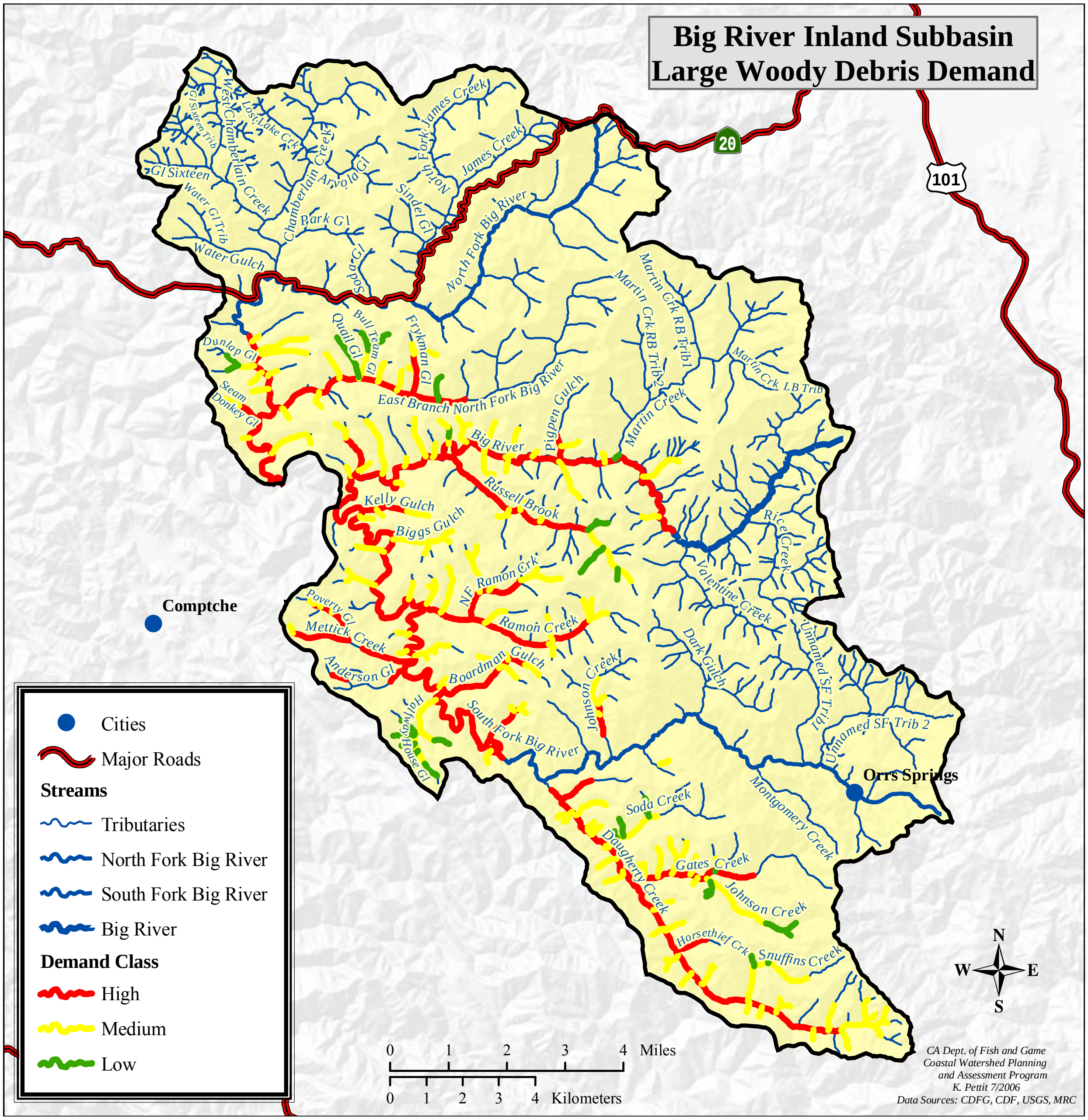


Figure 135. Map of instream LWD demand in MRC ownership in the Inland Subbasin (MRC 2003).

Table 199. Instream LWD quality ratings for major streams and sections of streams in MRC ownership in the Inland Subbasin.

Stream	Instream LWD Quality Rating
Big River in Russell Brook PW	Deficient
Big River in Rice Creek PW	Deficient
Russell Brook	Marginal
North Fork Big River in Lower North Fork Big River PW	Deficient
East Branch North Fork Big River	Marginal
South Fork Big River in Mettick Creek PW	Deficient
Ramon Creek	Marginal
Mettick Creek	Deficient
Anderson Gulch	Deficient
Boardman Gulch	Deficient
Halfway House Gulch	Marginal
Daugherty Creek	Marginal
Soda Creek	Marginal
Gates Creek	Marginal
Snuffins Creek	Marginal

MRC 2003

Fish Passage Barriers

Stream Crossings

Three stream crossings were surveyed in the Inland Subbasin as a part of the coastal Mendocino County culvert inventory and fish passage evaluation conducted by Ross Taylor and Associates (2001). Orr Springs Road has culverts on Dark Gulch, Johnson Creek, and an unnamed tributary to the South Fork of the Big River. All three culverts were found to be total salmonid barriers (Table 200). The culverts on Johnson Creek and Dark Gulch were also mentioned in surveys documented in NMFS (Jones 2000). Priority ranking of 24 culverts in coastal Mendocino County for treatment to provide unimpeded salmonid passage to spawning and rearing habitat placed the culvert on Johnson Creek at rank 5, the culvert on Dark Gulch at rank 7, and the culvert on the unnamed tributary to the South Fork of the Big River at rank 10. Criteria for priority ranking included salmonid species diversity, extent of barrier present, culvert risk of failure, current culvert condition, salmonid habitat quantity, salmonid habitat quality, and a total salmonid habitat score. The culvert on Johnson Creek and was replaced by an open bottom arch culvert in 2004, and the culvert on an unnamed tributary to South Fork Big River was modified to improve fish passage in 2003.

Table 200. Culverts surveyed for barrier status in the Inland Subbasin (Taylor 2001).

Stream Name	Road Name	Priority Rank	Barrier Status	Upstream Habitat	Treatment
Dark Gulch	Orr Springs Road	7	Total barrier. A barrier for adult coho salmon and steelhead trout and all age classes of juveniles due to excessive velocities over steep slope, lack of depth at lower migration flows, and the leap required to enter the culvert.	Approximately 1.7 miles of fair salmonid habitat.	
Johnson Creek	Orr Springs Road	5	Total barrier. A barrier for adult coho salmon and steelhead trout and all age classes of juveniles due to excessive velocities over steep slope, lack of depth at lower migration flows, and the leap required to enter the culvert.	Approximately 1.7 miles of good salmonid habitat.	Improved in 2004
Unnamed tributary to the South Fork of the Big River	Orr Springs Road	10	Total barrier. A barrier for adult coho salmon and steelhead trout and all age classes of juveniles due to excessive velocities and a lack of depth at lower migration flows within the culvert.	Approximately 0.5 miles of good salmonid habitat.	Improved in 2003

CDFG stream surveys noted culverts on four tributaries: North Fork James Creek, Gulch Sixteen Tributary, Water Gulch Tributary, and Soda Gulch (Table 201). The stream tributary report for Gulch Sixteen Tributary in 1997 recommends removal of the culvert at the confluence with Gulch Sixteen to provide fish passage. The tributary enters Gulch Sixteen through a metal pipe, three feet in diameter. Some loss of flow occurs due to holes throughout the culvert. The culvert contains no baffles and is impassible to fish.

The stream tributary report for Soda Gulch in 1997 also recommends that fish passage through the State Route 20 culvert located 114 feet from the confluence with the North Fork Big River needs to be improved. Alternatives need to be explored with the assistance of CDFG. The culvert has a five foot drop onto boulders. The culvert is 6 feet in diameter and has no baffles.

The MRC Big River Watershed Analysis identified culverts on a tributary to Ramon Creek (Donkeyhouse Gulch), Bull Team Gulch, Frykman Gulch, and Boardman Gulch. In addition, NMFS (Jones 2000) documented fish passage barriers found on surveys of Chamberlain Creek in the mid 1990s and James Creek in 1996. A pinched bedrock area under a road crossing was found to be a barrier to coho during low flow years in Chamberlain Creek. In James Creek, a barrier to coho salmon was found to occur in low flow years, such as 1996.

A complete barrier to downstream migration of salmonids was identified by CDFG in the North Fork Big River in August 1996 (Emig). It was recommended that this site be modified. The 1997 stream survey of the North Fork Big River does not mention a barrier at that location. An additional problematic stream crossing was identified on Martin Creek right bank tributary #1 where a rusty bottomed culvert created a high jump from below for salmonids (Harris, personal communication, 2006).

Table 201. Culverts described on streams inventoried by CDFG and in the MRC Watershed Analysis (2003) in the Inland Subbasin.

Stream Name	Number of Culverts	Feet of Culvert	Barrier Status*	Upstream Habitat
Ramon Creek Tributary/Donkeyhouse Gulch	2	NA	Complete barrier. Complete barrier to upstream salmonid migration.	0.5 miles coho salmon 1 mile steelhead trout
Boardman Gulch	1	NA	Partial barrier. Passable under 16% of potential flows by adult steelhead trout and completely impassable to juvenile steelhead trout.	2 miles steelhead trout
Bull Team Gulch	1	NA	Complete barrier. Complete upstream migration barrier to salmonids.	0.3 miles coho salmon 0.6 miles steelhead trout
Frykman Gulch	1	NA	Partial barrier. Barrier to upstream adult steelhead migration under 55% of the range of stream discharges, and an upstream barrier to juvenile salmonids.	0.3 miles coho salmon 0.6 miles steelhead trout
Water Gulch Tributary	1	42	NA	
Gulch Sixteen Tributary	1	60	NA	
Soda Gulch	1	95	NA	
North Fork James Creek	2	86	NA	

* NA - not assessed.

Dry Channel

A main component of CDFG Stream Inventory Surveys was habitat typing, in which the amount and location of pools, flatwater, riffles, and dry channel is recorded. Although the habitat typing survey only records the dry channel present at the point in time when the survey was conducted, this measure of dry channel can give an indication of summer passage barriers to juvenile salmonids. Dry channel conditions in the Big River Basin generally become established from late July through early September. Therefore, CDFG stream surveys conducted outside this period are less likely to encounter dry channel.

Dry channel disrupts the ability of juvenile salmonids to move freely throughout stream systems. Juvenile salmonids need well-connected streams to allow free movement to find food, escape from high water temperatures, escape from predation, and migrate out of their stream of origin.

The amount of dry channel reported in surveyed stream reaches in the Inland Subbasin is 2.9% of the total length of streams surveyed. This dry channel was found in 31 streams (Table 202 and Figure 136). Dry habitat units occurred near the mouth of nine tributaries, in the middle reaches of 20 tributaries, and at the upper limit of anadromy in 19 tributaries. Dry channel at the mouth of a tributary disconnects that tributary from the mainstem Big River, which can disrupt the ability of juvenile salmonids to access tributary thermal refugia in the summer. Dry channel in the middle reaches of a stream disrupts the ability of juvenile salmonids to forage and escape predation. Lastly, dry channel in the upper reaches of a stream indicates the end of anadromy.

Table 202. Dry channel recorded in CDFG stream surveys in the Inland Subbasin.

Stream	Survey Period	# of Dry Units	Dry Unit Length (ft)	% of Survey Dry Channel
North Fork Big River	August - September 1997	0	0	0.0
East Branch of the North Fork Big River	June 1998	2	119	0.3
Chamberlain Creek	July 1997	1	21	0.1
Water Gulch	July 1997	1	19	0.2
Water Gulch Tributary	July - August 1997	3	59	2.9
Park Gulch	June 1997	2	29	0.5
West Chamberlain Creek	June 1997	2	11	0.1
Gulch Sixteen	July 1997	7	94	2.0
Gulch Sixteen Tributary	July 1997	2	21	0.9
Arvola Gulch	July 1997	0	0	0.0
Lost Lake Creek	July 1997	3	489	10.0
Soda Gulch	September 1997	33	1,204	33.8
James Creek	October 1996	2	15	0.1
North Fork James Creek	July - August 1997	1	52	0.4
South Fork Big River (First Half)	June 2002	0	0	0.0
South Fork Big River (Second Half)	August - September 2002	8	997	2.1
Biggs Gulch	June 2002	2	116	4.1
Ramon Creek	June 2002	1	13	0.1
North Fork Ramon Creek	June 2002	0	0	0.0
Mettick Creek	June - July 2002	2	482	9.0

Stream	Survey Period	# of Dry Units	Dry Unit Length (ft)	% of Survey Dry Channel
Poverty Gulch	July 2002	0	0	0.0
Anderson Gulch	August 2002	4	98	3.9
Boardman Gulch	June 2002	0	0	0.0
Halfway House Gulch	June 2002	1	14	1.4
Daugherty Creek	July 2002	3	41	0.1
Soda Creek	May 2002	0	0	0.0
Gates Creek	May - June 2002	0	0	0.0
Johnson Creek (Gates Creek Tributary)	May 2002	0	0	0.0
Horse Thief Creek	June 2002	0	0	0.0
Snuffins Creek (2002)	July - August 2002	13	431	6.6
Johnson Creek	July - August 2002	10	338	6.8
Dark Gulch	August 2002	27	2,853	38.0
Montgomery Creek	July 2002	6	1,394	42.2
South Fork Big River Tributary #1	July 2003	16	1,037	17.7
South Fork Big River Tributary #2	July 2002	12	1,844	57.0
Russell Brook	July 2002	7	814	3.8
Martin Creek	July 2002	0	0	0.0
Martin Creek Left Bank Tributary	July 2002	3	300	10.2
Martin Creek Right Bank Tributary #1	July 2002	1	20	0.3
Martin Creek Right Bank Tributary #2	July 2002	3	31	1.0
Valentine Creek	July - August 2002	9	1,206	12.6
Rice Creek	August 2002	23	1,451	15.7

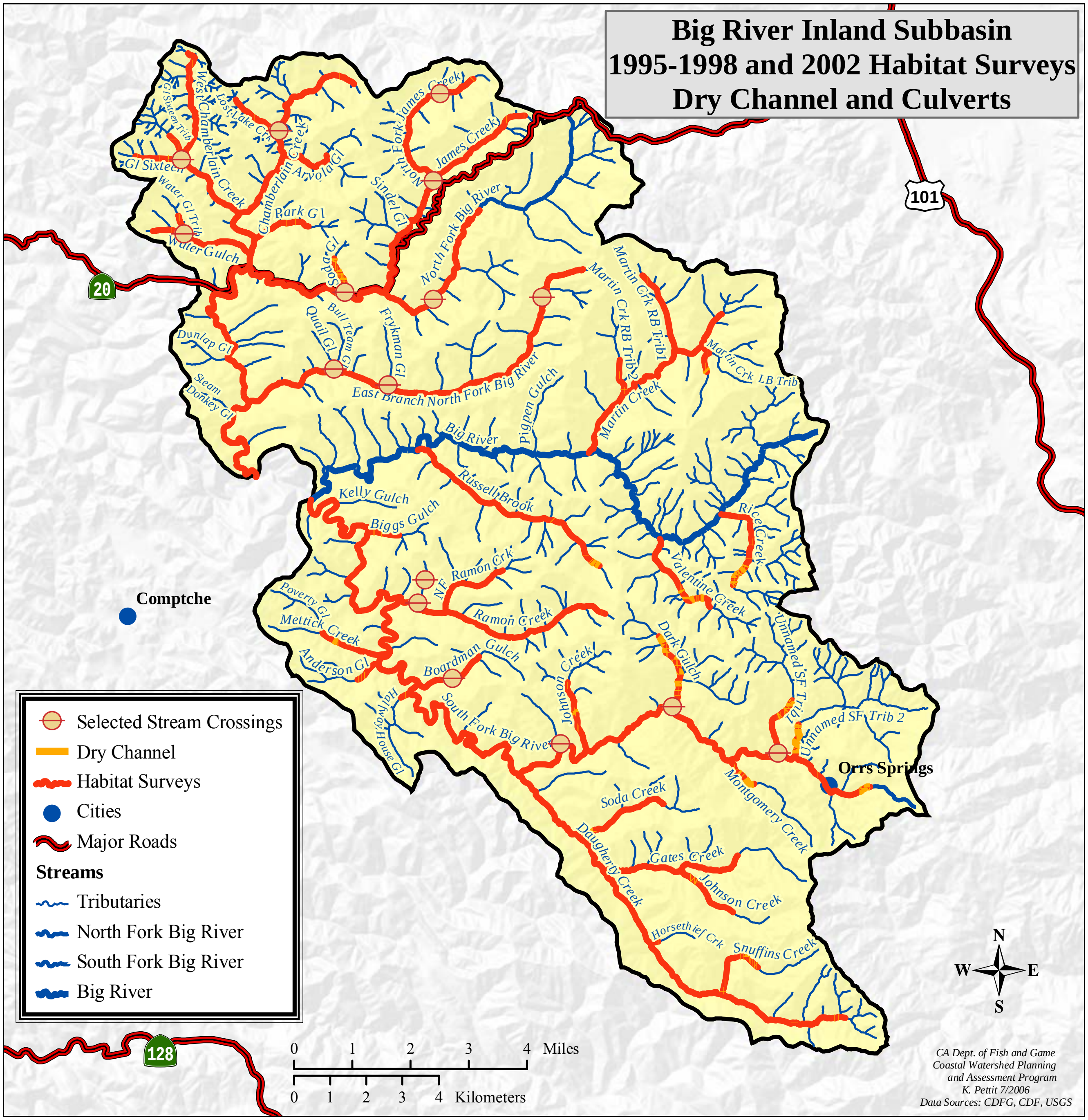


Figure 136. Dry and wetted channel and culverts reported during CDFG stream surveys, and culverts.

Reported by Ross Taylor (2001) and MRC (2004) in the Inland Subbasin

Restoration Programs

The CDFG Fisheries Restoration Grants Program has funded various projects in the Inland Subbasin (Table 203). Projects include research, education, bank stabilization, riparian planting, and fish passage barrier removal.

Restoration opportunities were identified in Mettick and Ramon creeks in 1996 under a cooperative agreement between USFWS, L-P, and the Center for Manpower Resources. Restoration work was completed in 1999 and 2000 under a cooperative agreement between USFWS, MRC, and the E Center. Additional restoration work was completed in an unnamed tributary to South Fork Big River and upper Mettick Creek in 2002.

Table 203. Restoration projects in the Inland Subbasin.

Name	Years	Project Leader	Project
North Fork Big River downstream from Steam Donkey Gulch	1986-1987	Center for Education and Manpower Resources	Stream bank stabilized, log jam removed
North Fork Big River Restoration Project	1986-1989	Center for Education and Manpower Resources	Stream bank stabilized, log jam removed
Frykman Gulch Migration Barrier Elimination and Erosion Control Project	2004	Mendocino Redwood Company, LLC	Stream bank stabilized, Rock weir installed (not below culvert), fish barrier removed, culvert replaced with bridge, culvert or other stream crossing removed and not replaced, grass planted, stream bank stabilized: riprap
South Fork Big River/Russell Brook Watershed Assessment Project	2001-2003	Trout Unlimited - California Council	Survey, study, research, watershed assessment and planning
Ramon Creek Barrier Removal	1987-1990	Northcoast Salmon Habitat Restoration Group	Pool created, fish barrier removed, large wood placement, stream bank stabilized: log revetment installed, log jam removed
Mettick Creek Barrier Removal	1987-1990	Northcoast Salmon Habitat Restoration Group	Fish barrier removed, stream bank stabilized: log revetment installed, log jam removed
Mettick Creek Stream Restoration	1996	Center for Education and Manpower Resources	Fish barrier removed, log jam removed
Anderson Gulch Barrier Removal	1987-1990	Northcoast Salmon Habitat Restoration Group	Fish barrier removed
Halfway House Gulch Barrier Removal	1987-1990	Northcoast Salmon Habitat Restoration Group	Pool created, fish barrier removed, large wood placement
Daugherty Creek Log Jam Barrier Modification	1986-1990	New Growth Forestry	Fish barrier removed, log jam removed
Daugherty Creek Enhancement	1994-1996	California Conservation Corps	Large wood placement, pool created using scour structure
Daugherty Creek Bank Stabilization	1995	Louisiana Pacific Corporation	Stream bank stabilized, stream bank stabilized: riprap (rock revetment) installed, willows planted (simple planting, not bioengineering)
Daugherty Creek Stream Enhancement Project	1997-1998	California Conservation Corps	Large wood placement, pool created using scour structure
Soda Creek Enhancement	1994-1996	California Conservation Corps	Rock weir installed (not below culvert), fish barrier removed, weir installed below culvert outlet Large wood placement, pool created using scour structure
Gates Creek Fish Passage Project	1984-1985	New Growth Forestry	Log jam removed
Johnson Creek (tributary to Gates Creek) Enhancement	1995	California Conservation Corps	Large wood placement, pool created using scour structure
Johnson Creek Log Barrier Modifications	1989-1990	Mendocino County Resource Conservation District	Fish barrier removed, large wood placement, log jam removed
Johnson Creek Jump Pool	1992-1994	Center for Education and Manpower Resources	Fish barrier removed, pool created using scour structure, culvert/bridge upgraded
Johnson Creek Instream Fish Barrier Culvert Removal	2004	Mendocino County Department of Transportation	Fish barrier removed, culvert replaced with open-bottom arch culvert
Dark Gulch Barrier Modification	1990	Center for Education and Manpower Resources	Fish barrier removed, large wood placement, pool created using scour structure
Dark Gulch: Creation of Jump Pool	1989-1991	Center for Education and Manpower Resources	Weir installed below culvert outlet
Dark Gulch Restoration Project	1993-1995	Center for Education and Manpower Resources	Fish barrier removed, culvert/bridge upgraded
Instream Barrier Removal Project on Tributary to South Fork Big River at Orr Springs Road	2003	Mendocino County Department of Transportation	Boulders placed in stream, rock weir installed (not below culvert), fish barrier removed, weir installed below culvert outlet
Russell Brook Barrier Removal	1987-1990	Northcoast Salmon Habitat Restoration Group	Fish barrier removed
Russell Brook Restoration Project	1993-1995	Center for Education and Manpower Resources	Pool created, boulders placed in stream, fish barrier removed, large wood placement
Valentine Creek Restoration Project	1986-1989	Center for Education and Manpower Resources	Stream bank stabilized, log jam removed
Rice Creek Fish Passage Project	1984-1985	New Growth Forestry	Log jam removed
Rice Creek Log Jam Barrier Modification	1986-1990	New Growth Forestry	Fish barrier removed, log jam removed

Two log cribwalls were constructed along the left bank of Mettick Creek by a bank slide that was determined to be a barrier to fish migration in 1999. In addition, the slide face was terraced and planted, and some minor small woody debris was removed to improve fish passage. Additional restoration work in upper Mettick Creek in 2002 included removal of seven culverts, streambank re-contouring, and installation of a grade control structure.

Three sites along Ramon Creek were restored in 1999. In order to close a bottleneck caused by a bank slide at one site, a log cribwall was constructed and a large woody debris accumulation was modified. Large wood was re-positioned to direct flows away from a slide at another site and the slide was planted with conifers and willows. At the third site, a large bank slide was terraced and planted, a log cribwall was constructed, and the flow corridor width was increased.

A metal culvert at the mouth of a small unnamed tributary to South Fork Big River was replaced in 2002 to prevent the old culvert from failing.

Restoration sites will be monitored annually until 2013 and thus far restoration structures on Mettick and Ramon creeks have been stable.

Changes in Habitat Conditions from 1960 to 2001

Streams surveyed in the 1950s and 1960s and habitat inventory surveyed in the 1990s or 2002 were compared to indicate changes between historic and current conditions. Data from 1960s stream surveys provide a snapshot of the conditions at the time of the survey. Terms such as excellent, good, fair, and poor are based on the judgment of the biologist or scientific aid who conducted the survey. The results of historic stream surveys are qualitative and cannot be used in comparative analyses with quantitative data provided by habitat inventory surveys with any degree of accuracy. However, the two data sets can be compared to show general trends.

Where habitat data was available from both older stream surveys and recent stream inventories it appeared that spawning habitat decreased in seven streams and remained similar elsewhere (Table 204). Pool habitat decreased in 12 streams and remained similar elsewhere. Shelter decreased in 13 streams and remained similar elsewhere.

Table 204. Comparison between historic habitat conditions with current habitat inventory surveys in the North Fork Subbasin.

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of changes from historic to current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
North Fork Big River	ND*	Suitable	Very good to excellent	Unsuitable	Very good	Unsuitable	Very Good	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
East Branch North Fork Big River	ND	Suitable	Excellent throughout lower first mile	Unsuitable	Medium sized throughout lower first mile	Unsuitable	Good	Suitable	Spawning habitat decreased
Chamberlain Creek	ND	Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Water Gulch	ND	Fully Suitable	ND	Unsuitable	ND	Unsuitable	ND	Unsuitable	ND
Water Gulch Tributary	ND	Fully Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Park Gulch	ND	Fully Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
West Chamberlain Creek	ND	Fully Suitable	ND	Unsuitable	ND	Fully Unsuitable	ND	Suitable	ND
Gulch Sixteen	ND	Fully Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Gulch Sixteen Tributary	ND	Fully Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Arvola Gulch	ND	Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Lost Lake Creek	ND	Fully Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Soda Gulch	ND	Fully Suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
James Creek	ND	Unsuitable	Poor	Unsuitable	Common to scarce	Fully unsuitable	Excellent	Fully unsuitable	Shelter decreased
North Fork James Creek	ND	Suitable	Medium to good	Unsuitable	Common, average one - two feet deep	Fully unsuitable	Excellent	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
South Fork Big River	ND*	Suitable	Good to excellent	Suitable	Excellent - large and frequent pools	Suitable	Very good	Unsuitable	Shelter decreased
Biggs Gulch	ND	Fully suitable	ND	Suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Ramon Creek	ND	Suitable	Extremely good	Unsuitable	Good	Fully unsuitable	Fair to good	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
North Fork Ramon Creek	ND	Suitable	ND	Suitable	ND	Fully unsuitable	ND	Unsuitable	ND
Mettick Creek	ND	Suitable	ND	Suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Poverty Gulch	ND	Suitable	ND	Insufficient data	ND	Fully unsuitable	ND	Unsuitable	ND
Anderson Gulch	ND	Fully suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Boardman Gulch	ND	Fully suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND	Unsuitable	ND
Halfway House Gulch	ND	Suitable	ND	Fully suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Daugherty Creek	ND	Suitable	Good to fair	Suitable	Well developed	Unsuitable	Good to fair	Suitable	Pool habitat decreased
Soda Creek	ND	Suitable	Good throughout	Suitable	Abundant	Fully unsuitable	Good	Unsuitable	Pool habitat and shelter

Stream	Canopy Cover		Spawning Conditions		Pool Depth/Frequency		Shelter/Cover		Summary of changes from historic to current
	Historic	Current	Historic	Current	Historic	Current	Historic	Current	
			middle and upper areas						decreased
Gates Creek	ND	Fully suitable	ND	Suitable	ND	Unsuitable	ND	Suitable	ND
Johnson Creek (tributary to Gates Creek)	ND	Fully suitable	Good	Unsuitable	Good	Fully unsuitable	Good	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
Horse thief Creek	ND	Fully suitable	ND	Insufficient data	ND	Fully unsuitable	ND	Fully unsuitable	ND
Snuffins Creek	ND	Suitable	Fair to poor	Unsuitable	Uncommon and poor	Fully unsuitable	Fair to good	Unsuitable	Shelter decreased
Johnson Creek	ND	Suitable	Fair	Suitable	Good	Fully unsuitable	Excellent	Unsuitable	Pool habitat and shelter decreased
Dark Gulch	ND	Suitable	ND	Suitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Montgomery Creek	ND	Suitable	ND	Unsuitable	ND	Fully unsuitable	ND	Fully unsuitable	ND
Unnamed Tributary to the South Fork Big River #1	ND	Suitable	Fair to poor	Unsuitable	Fair and poor	Fully unsuitable	Provided by logging debris and undercut banks	Unsuitable	Habitat similar between years
Unnamed Tributary to the South Fork Big River #2	ND	Suitable	Scarce, some fair	Unsuitable	Small and infrequent	Fully unsuitable	Adequate and fair	Unsuitable	Habitat similar between years
Russell Brook	ND*	Suitable	Fair to good	Unsuitable	Good	Fully Unsuitable	Excellent	Unsuitable	Spawning habitat, pool habitat, and shelter decreased
Pig Pen Gulch	ND	ND	Poor to fair	ND	Good	ND	Abundant	ND	ND
Martin Creek	ND	Suitable	Fair to good	Unsuitable	Abundant	Fully Unsuitable	Excellent	Fully Unsuitable	Spawning habitat, pool habitat, and shelter decreased
Martin Creek Left Bank Tributary	ND	Fully Suitable	Fair to poor	Unsuitable	Common	Fully Unsuitable	Good to excellent	Fully Unsuitable	Pool habitat and shelter decreased
Martin Creek Right Bank Tributary #1	ND	Suitable	ND	Unsuitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND
Martin Creek Right Bank Tributary #2	ND	Fully Suitable	ND	Fully Unsuitable	ND	Fully Unsuitable	ND	Unsuitable	ND
Valentine Creek	ND	Suitable	Poor to fair	Unsuitable	Abundant	Fully Unsuitable	Good to excellent	Fully Unsuitable	Pool habitat and shelter decreased
Rice Creek	ND	Suitable	Fair to poor	Unsuitable	Poor	Fully Unsuitable	Poor to none	Unsuitable	Habitat similar between years
East Branch Rice Creek	ND	ND	Poor	ND	Poor	ND	Poor to fair	ND	ND

*ND = No data
If more than one year of historic data were available, the oldest data were used.

Fish History and Status

Historically, the Inland Subbasin supported runs of Chinook salmon, coho salmon, and steelhead trout (Table 205). CDFG biological stream surveys were conducted for 26 tributaries in this subbasin from 1959 to 1966. The USFWS electrofished four transects in the North Fork Big River, four transects in the mainstem Big River, East Branch North Fork Big River, South Fork Big River, and Martin Creek in 1973 (Perry 1974). East Branch North Fork Big River was also surveyed by the Center for Education and Manpower Resources in 1979.

Out of the 27 streams surveyed in the 1950s, steelhead trout were found in 13 and unidentified salmonids were found in North Fork Big River, East Branch North Fork Big River, James Creek, North Fork James Creek, and Soda Creek. Coho salmon were found in the East Branch North Fork Big River, South Fork Big River, Daugherty Creek, and possibly Russell Brook. Steelhead trout success was described as satisfactory to good in most surveyed tributaries. James Creek and Water Gulch were considered to have little value to fish life after being altered from their natural states.

East Branch North Fork Big River was also surveyed in 1966 and 1979, and steelhead trout were reported in 1966 and unidentified salmonids were reported in both years. South Fork Big River, Johnson Creek (tributary to Gates Creek), and Snuffins Creek were also surveyed in 1966. Steelhead trout were observed in all three, though coho salmon were only observed in South Fork Big River.

North Fork James Creek was electrofished in October of 1966 as part of a study of salmonid carrying capacity in Northern California coastal streams (Burns 1971). No coho salmon were detected, though steelhead trout were found. North Fork Big River was electrofished a second time in 1966 in another survey and coho salmon and steelhead trout were found.

North Fork Big River, Russell Brook, Pig Pen Gulch, Martin Creek, and Rice Creek were surveyed in 1967. Coho salmon were found in North Fork Big River while steelhead trout were found in all streams except for Martin Creek.

Coho salmon eggs and fingerlings were stocked in Chamberlain Creek, South Fork Big River, and mainstem Big River at various times from 1950 to 1980. More details are provided in the Basin Profile Fish History and Status section.

CDFG, CDF, the Salmon Trollers Stream Restoration Project, and MRC studies have continued to document the presence of coho salmon and steelhead trout in the Inland Subbasin.

Surveys of six streams in 1980 and 1981 were documented in NMFS (Jones 2000). Steelhead trout and coho salmon were found in Chamberlain Creek, Arvola Gulch, Lost Lake Creek, and James Creek while unidentified salmonids were found in Water Gulch. No fish were observed in Park Gulch.

CDFG conducted electrofishing surveys in several tributaries in 1983, 1993, 1995, 1996, and 1997. In 1983, coho salmon were detected in Chamberlain Creek and steelhead trout were detected in Upper North Fork Big River, Chamberlain Creek, West Chamberlain Creek, Water Gulch, Park Gulch, Arvola Gulch, and James Creek. Steelhead trout were also detected in James Creek in 1993 and 1995, Upper North Fork Big River in 1995 and 1996, and North Fork Big River above Chamberlain Creek in 1996. CDF detected steelhead trout during a 1994 electrofishing survey of North Fork Big River near the confluence with Chamberlain Creek.

A 1987 carcass survey conducted by CDFG in Gates Creek detected 1 redd and two live coho salmon. CDFG electrofishing in Daugherty Creek in 1988 detected both steelhead trout and coho salmon. Salmon Trollers Stream Restoration Project carcass surveys of six streams in 1990 found redds in South Fork Big River and Ramon Creek. A 1995 CDFG carcass survey in Daugherty Creek found 16 redds.

CDFG stream inventory surveys across the subbasin also detected coho salmon and steelhead trout from 1993 through 1998. Coho salmon were detected in 13 of 41 surveyed tributaries: North Fork Big River, Water Gulch, Arvola Gulch, Daugherty Creek, Soda Creek, Snuffins Creek, Dark Gulch, two unnamed tributaries to South Fork Big River, Russell Brook, Martin Creek, Martin Creek Right Bank Tributary #1, and Valentine Creek. Steelhead trout were detected in 27 surveyed tributaries.

Table 205. Summary of all electrofishing, snorkel survey, and bank observation surveys conducted in the Inland Subbasin.

CDFG = Department of Fish and Game survey; CI = Department of Fish and Game Coho Inventory; CEMR = Center for Education and Manpower Resources; MRC = Mendocino Redwood Company Report; HTC = Hawthorne Timber Company; SONAR = School of Natural Resources at Mendocino High School; NMFS = National Marine Fisheries Service (Jones 2000)

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
North Fork Big River	1958	CDFG	Visual Observation			Present
	1959	CDFG	Visual Observation		Present	
	1966	NMFS	Electrofishing	Present	Present	
	1967	NMFS	Visual Observation	Present	Present	
	1973	USFWS	Electrofishing	Present	Present	
	1985	CDFG	Carcass Survey			
	1994	MRC	Snorkel Survey		Present	
		CDF	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
		NMFS	Electrofishing	Present	Present	
	1996	MRC	Snorkel Survey	Present	Present	
		CDFG	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present	Present	
	1997	CDFG	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Snorkel Survey	Present	Present	
		CDFG	Coho Inventory	Present		
	2002	MRC	Snorkel Survey	Present	Present	
Steam Donkey Gulch	1996	MRC	Electrofishing			
	2000	MRC	Snorkel Survey			
	2001	MRC	Electrofishing			
North Fork Big River-Middle	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Dunlap Gulch	1996	MRC	Electrofishing			
	2000	MRC	Snorkel Survey			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing			
North Fork Big River-Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Upper North Fork Big River	1983	CDFG	Electrofishing		Present	
	1995	CDFG	Electrofishing		Present	
	1996	CDFG	Electrofishing		Present	
East Branch North Fork Big River	1958	CDFG	Visual Observation			Present
	1959	CDFG	Visual Observation	Present	Present	
	1966	CDFG	Visual Observation	Present	Present	
	1973	USFWS	Electrofishing	Present	Present	
	1979	CEMR	Visual Observation			Present
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
	1998	CDFG	Electrofishing		Present	
	2001	CDFG	Coho Inventory	Present		
East Branch North Fork Big River-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing	Present	Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
	2002	MRC	Snorkel Survey	Present	Present	
East Branch North Fork Big River-Middle	1994	MRC	Electrofishing		Present	
Quail Gulch	1996	MRC	Electrofishing			
Bull Team Gulch	1996	NMFS	Electrofishing	Present	Present	
	1996	MRC	Electrofishing	Present	Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing	Present	Present	
East Branch North Fork Big River-Upper	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Electrofishing	Present	Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing	Present	Present	
East Branch North Fork Big River-Upper 2	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Frykman Gulch	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing		Present	
Chamberlain Creek	1979	CDFG	NA	Present	Present	
	1980	NMFS	Visual Observation	Present	Present	
	1983	CDFG	Electrofishing	Present	Present	
	1995	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing	Present	Present	
	1997	NMFS	Electrofishing	Present	Present	
		CDFG	Electrofishing		Present	
	2001	SONAR	Carcass Surveys			
Water Gulch	1959	CDFG	Visual Observation			
	1981	NMFS	Visual Observation			Present
	1983	CDFG	Electrofishing		Present	
	1995	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing	Present	Present	
	1997	NMFS	Electrofishing	Present	Present	
		CDFG	Electrofishing	Present	Present	
Water Gulch Tributary	1995	CDFG	Electrofishing		Present	
Park Gulch	1981	NMFS	Visual Observation			
	1983	CDFG	Electrofishing		Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing			
	1997	NMFS	Electrofishing		Present	
		CDFG	Electrofishing		Present	
West Chamberlain Creek	1981	NMFS	Visual Observation			
	1983	CDFG	Electrofishing		Present	
	1995	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing	Present	Present	
	1997	NMFS	Electrofishing	Present	Present	
		CDFG	Electrofishing		Present	
	2001	SONAR	Carcass Survey			
Gulch Sixteen	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
		CDFG	Electrofishing		Present	
Gulch Sixteen Tributary	1997	CDFG	Electrofishing			
Arvola Gulch	1979	CDFG	NA	Present	Present	
	1980	NMFS	Visual Observation	Present	Present	
	1983	CDFG	Electrofishing		Present	
	1995	NMFS	Electrofishing	Present	Present	
	1996	NMFS	Electrofishing	Present	Present	
	1997	NMFS	Electrofishing	Present	Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
		CDFG	Electrofishing	Present	Present	
Lost Lake Creek	1980	NMFS	Visual Observation		Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
	1997	CDFG	Electrofishing		Present	
Soda Gulch	1997	CDFG	Electrofishing			
James Creek	1958	CDFG	Visual Observation			Present
	1980	NMFS	Visual Observation	Present	Present	
	1983	CDFG	Electrofishing		Present	
	1993	CDFG	Electrofishing		Present	
	1995	CDFG	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	1996	CDFG	Electrofishing		Present	
		NMFS	Electrofishing	Present	Present	
	1997	NMFS	Electrofishing		Present	
North Fork James Creek	1958	CDFG	Visual Observation			Present
	1966	Burns 1971	Electrofishing		Present	
	1995	CDFG	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
South Fork Big River	1957/1958	CDFG	Visual Observation	Present	Present	
	1966	CDFG	Visual Observation	Present	Present	
	1973	USFWS	Electrofishing		Present	
	1983	CDFG	Electrofishing		Present	
	1990	Nielsen et al.	Carcass Survey	Present		
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing	Present	Present	
		NMFS	Electrofishing	Present		
	2001	CDFG	Coho Inventory			
	2002	CDFG	Visual Observation	Present	Present	
South Fork Big River-Lower	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Snorkel Survey		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Kelly Gulch	circa 1950	CDFG	Visual Observation			
Biggs Gulch	circa 1950	CDFG	Visual Observation			
	2002	CDFG	Visual Observation			
No Name Gulch	1995	MRC	Electrofishing			
	1996	MRC	Electrofishing			
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
Ramon Creek	1959	CDFG	Visual Observation		Present	
	1990	Nielsen et al.	Carcass Survey	Present		
	1995	NMFS	Electrofishing	Present	Present	
	2001	CDFG	Coho Inventory			
	2002	CDFG	Visual Observation	Present	Present	
	2003	SC	Visual Observation			
Ramon Creek-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
Ramon Creek-Middle	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing	Present	Present	
	1996	MRC	Electrofishing	Present	Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
North Fork Ramon Creek	1995	NFS	Electrofishing	Present	Present	
North Fork Ramon-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing	Present	Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
North Fork Ramon-Middle	2002	MRC	Snorkel Survey		Present	
North Fork Ramon-Upper	1994	MRC	Electrofishing			
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
Ramon Creek-Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
Ramon Creek-Upper2	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Mettick Creek	circa 1950	CDFG	Visual Observation			
	1990	Nielsen et al.	Carcass Survey			
	1994	NMFS	Electrofishing		Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	2002	CDFG	Visual Observation			
	2003	SC	Visual Observation			
Mettick Creek-Lower	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Mettick Creek-Upper	1994	MRC	Visual Observation		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
Poverty Gulch	2002	CDFG				
South Fork Big River-Middle	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
Anderson Gulch	circa 1950	CDFG	Visual Observation			
	1990	Nielsen et al.	Carcass Survey			
	1994	NMFS	Electrofishing		Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	2002	CDFG	Visual Observation			
Anderson Gulch-Lower	1994	MRC	Visual Observation		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey			
	2001	MRC	Electrofishing			

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
	2002	MRC	Snorkel Survey			
Boardman Gulch	circa 1950	CDFG	Visual Observation			
Boardman Gulch - Lower	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing		Present	
Boardman Gulch - Upper	1996	MRC	Electrofishing			
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing			
Halfway House Gulch	1996	NMFS	Electrofishing		Present	
		MRC	Visual Observation		Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing		Present	
South Fork Big River-Upper	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Snorkel Survey		Present	
	2002	MRC	Electrofishing	Present	Present	
Daugherty Creek	1959	CDFG	Visual Observation	Present	Present	
	1988	CDFG	Electrofishing	Present	Present	
	1988	LPP	Carcass Survey	Present	Present	
	1990	Nielsen et al.	Carcass Survey			
	1993	CDFG	Electrofishing		Present	
	1995	CDFG	Carcass Survey		Present	
	1996	NMFS	Electrofishing	Present	Present	
	2001	CDFG	Coho Inventory			
	2002	CDFG	Snorkel Survey	Present	Present	
Daugherty Creek-Lower	1994	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Daugherty Creek-Middle	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Electrofishing		Present	
Soda Creek	1959	CDFG	Visual Observation	??	??	
	1988	CDFG	Electrofishing	Present	Present	
	1993	CDFG	Electrofishing	Present	Present	
	1995	NMFS	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	1997	NMFS	Electrofishing		Present	
		NMFS	Electrofishing			
	2002	CDFG	Electrofishing	Present	Present	
Soda Creek-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Soda Creek-Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Gates Creek	1979	CDFG	NA		Present	
	1987	CDFG	Carcass Survey	Present	Present	
		CDFG	Electrofishing		Present	
	1988	CDFG	Electrofishing	Present	Present	
	1990	Nielsen et al.	Carcass Survey			
	1993	CDFG	Electrofishing		Present	
	1996	CDFG	Electrofishing	Present	Present	
		NMFS	Electrofishing		Present	
	2002	CDFG	Electrofishing	Present	Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
Gates Creek-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Gates Creek-Middle2?	2002	MRC	Snorkel Survey	Present	Present	
Gates Creek-Middle	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Gates Creek-Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Tributary to Gates Creek	2000	MRC	Electrofishing		Present	
Gates Creek-Upper2	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey			
Johnson Creek (tributary to Gates Creek)	1959	CDFG	Visual Observation		Present	
	1966	CDFG	Visual Observation		Present	
	1993	CDFG	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	2002	CDFG	Electrofishing		Present	
Johnson Creek (Tributary to Gates Creek)-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey		Present	
Johnson Creek (Tributary to Gates Creek)-Upper	1994	MRC	Electrofishing			
	1995	MRC	Electrofishing			
	1996	MRC	Electrofishing			
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
Horse thief Creek	2002	CDFG	Electrofishing			
Daugherty Creek-Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey	Present	Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Snuffins Creek	1959	CDFG	Visual Observation			
	1966	CDFG	Visual Observation		Present	
	1993	CDFG	Electrofishing		Present	
	1996	NMFS	Electrofishing		Present	
	2002	CDFG	Snorkel Survey	Present	Present	
Snuffins Creek-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing	Present	Present	
Snuffins Creek-Upper	1994	MRC	Electrofishing			
	1995	MRC	Electrofishing			
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing			
Daugherty Creek	2002	MRC	Electrofishing	Present	Present	
Daugherty Creek	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Electrofishing		Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
	2000	MRC	Electrofishing		Present	
Daugherty Creek	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing		Present	
Johnson Creek	1959	CDFG	Visual Observation		Present	
	2000	NMFS	Visual Observation			
	2001	CDFG	Coho Inventory			
	2002	CDFG	Electrofishing		Present	
Dark Gulch	1958	NMFS	Visual Observation			
	1999	NMFS	Visual Observation			
	2002	CDFG	Electrofishing	Present	Present	
Dark Gulch Tributary	2002	CDFG	Electrofishing		Present	
Montgomery Creek	2000	NMFS	Visual Observation			
	2002	CDFG	Visual Observation			
Unnamed Tributary to the South Fork Big River #1	1958	CDFG	Visual Observation		Present	
	2002	CDFG	Electrofishing	Present	Present	
Unnamed Tributary to the South Fork Big River #2	1958	CDFG	Visual Observation		Present	
	2002	CDFG	Electrofishing	Present	Present	
Mainstem Big River (confluence with South Fork Big River to Duffy Flat)	1990	Salmon trollers stream restoration project	Carcass Survey			
Big River at South Fork Camp	1973	USFWS	Electrofishing	Present		
Big River Main-Lower	1994	MRC	Snorkel Survey		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Snorkel Survey	Present	Present	
Big River at Wildhorse Opening	1973	USFWS	Electrofishing	Present	Present	
Russell Brook	1959	CDFG	Visual Observation	Present	Present	
	1967	NMFS	Visual Observation		Present	
	1996	NMFS	Electrofishing		Present	
	2002	CDFG	Visual Observation	Present	Present	
	2003	SC	Visual Observation			
Russell Brook-Lower	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Russell Brook -Middle	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Snorkel Survey		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing	Present	Present	
Russell Brook -Upper	1994	MRC	Electrofishing		Present	
	1995	MRC	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing	Present	Present	
Russell Brook -Upper 2	1996	MRC	Electrofishing		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Electrofishing		Present	
Big River-Main-Midreach	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	2000	MRC	Snorkel Survey		Present	

Stream	Year Surveyed	Data Source	Survey Method	Coho Salmon	Steelhead Trout	Unidentified Salmonids
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Big River upstream from dam site	1973	USFWS	Electrofishing	Present	Present	
Pig Pen Gulch	1959	CDFG	Visual Observation		Present	
	1967	NMFS	Visual Observation		Present	
	1994	MRC	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
		NMFS	Electrofishing		Present	
	1996	MRC	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	2000	MRC	Electrofishing			
	2001	MRC	Electrofishing			
	2002	MRC	Electrofishing			
Big River-Above Pig Pen	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Snorkel Survey		Present	
	2002	MRC	Snorkel Survey		Present	
Martin Creek	1959	CDFG	Visual Observation		Present	
	1967	NMFS	Visual Observation			
	1973	USFWS	Electrofishing		Present	
	1994	NMFS	Electrofishing		Present	
	1995	CDFG	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	1996	CDFG	Electrofishing		Present	
		NMFS	Electrofishing		Present	
	2002	CDFG	Visual Observation	Present	Present	
Martin Creek-LP Prop L	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey			
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Martin Creek Left Bank Tributary	1959	CDFG	Visual Observation		Present	
	2002	CDFG	Visual Observation		Present	
Martin Creek Right Bank Tributary #1	2002	CDFG	Visual Observation	Present	Present	
Martin Creek Right Bank Tributary #2	2002	CDFG	Visual Observation			
Big River-Upper/Site#1	1994	MRC	Electrofishing		Present	
	1995	MRC	Snorkel Survey		Present	
	1996	MRC	Snorkel Survey		Present	
	2000	MRC	Electrofishing		Present	
	2001	MRC	Electrofishing		Present	
	2002	MRC	Snorkel Survey	Present	Present	
Valentine Creek	1959	CDFG	Visual Observation		Present	
	2002	CDFG	Visual Observation	Present	Present	
Rice Creek	circa 1959	CDFG	Visual Observation			
	1967	NMFS	Visual Observation		Present	
	2002	CDFG	Visual Observation		Present	
East Branch Rice Creek	1959	CDFG	Visual Observation			

Electrofishing in 25 streams in 1994 through 1997 was documented in NMFS (Jones 2000). Steelhead trout were found in all 25 streams, and coho salmon were found in North Fork Big River, East Branch North Fork Big River, Bull Team Gulch, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, Lost Lake Creek, James Creek, South Fork Big River, Ramon Creek, and Daugherty Creek. Electrofishing in Dark Gulch in 1999 and Johnson Creek in 2000 found no fish.

The 2001 CDFG Coho Inventory detected coho salmon in North Fork Big River and East Branch North Fork Big River. The Inventory did not detect coho salmon in South Fork Big River, Ramon Creek, Daugherty Creek, or Johnson Creek.

The School of Natural Resources at Mendocino High School conducted carcass surveys in Chamberlain Creek and West Chamberlain creeks in 2001. No fish or redds were observed.

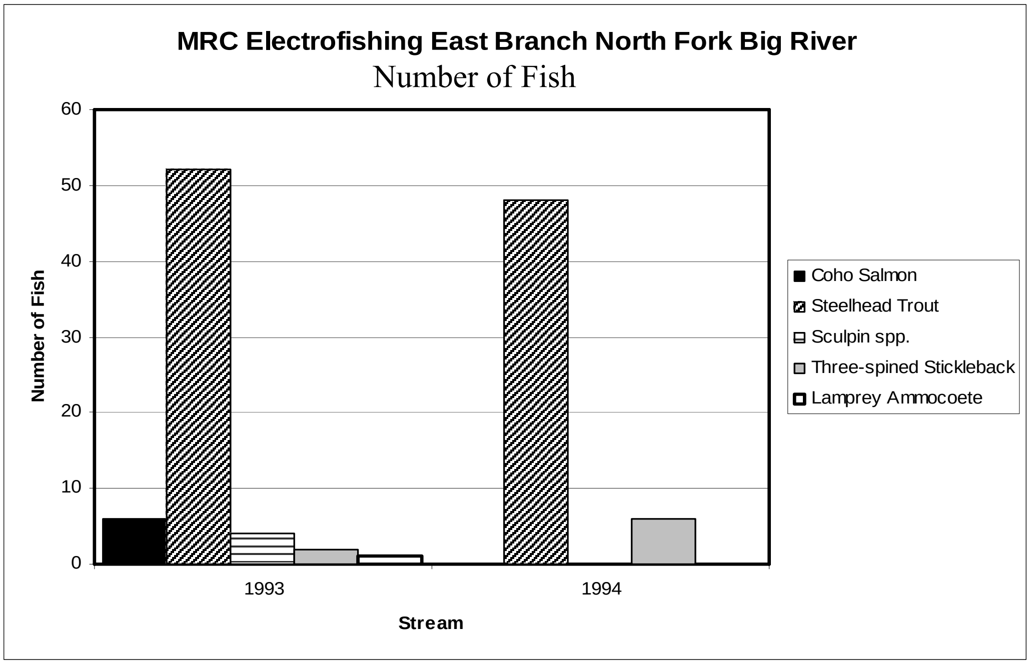
MRC has collected both quantitative and non-quantitative electrofishing data in the Inland Subbasin. Quantitative data were collected for a site in the East Branch North Fork Big River in 1993 and 1994, two sites on Gates Creek from 1990 to 1994, and a site in the mainstem Big River at Wild Horse Opening in 1993 and 1994 (Figure 137, Figure 138, Figure 139). These data can be used to investigate fish density, biomass, or changes in abundance. Coho salmon were only found in East Branch North Fork Big River in 1993. Steelhead trout were found at all four sites at all sample times. Steelhead were found at similar abundance levels in both 1993 and 1994 in East Branch North Fork Big River. Steelhead trout were more abundant in Lower Gates Creek than other sample sites.

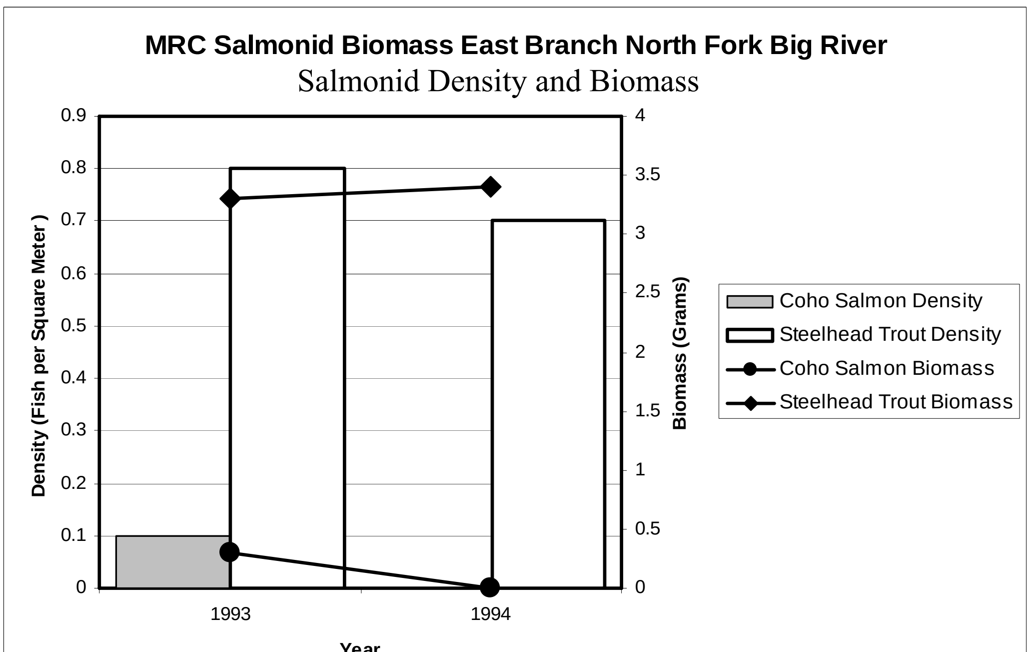
MRC also conducted single-pass electrofishing or snorkel surveys in 56 sites across the Inland Subbasin in the years 1994-1996, and 2000-2002. The sites were surveyed for the purpose of detecting the presence of fish species. These data do not enable the assessment of fish health or abundance, but do provide a look at fish community structure, and specifically the presence of coho salmon or other species.

Coho salmon were found in the mainstem Big River and 11 tributaries: North Fork Big River, East Branch North Fork Big River, Bull Team Gulch, South Fork Big River, Ramon Creek, North Fork Ramon Creek, Daugherty Creek, Gates Creek, Snuffins Creek, Russell Brook, and Martin Creek in 2002 (

Steelhead trout were found in the mainstem Big River and 20 tributaries: North Fork Big River, East Branch North Fork Big River, Bull Team Gulch, Frykeman Gulch, South Fork Big River, Ramon Creek, North Fork Ramon Creek, Mettick Creek, Anderson Gulch, Boardman Gulch, Halfway House Gulch, Daugherty Creek, Soda Creek, Gates Creek, tributary to Gates Creek, Johnson Creek (tributary to Gates Creek), Snuffins Creek, Russell Brook, Pig Pen Gulch, and Martin Creek.

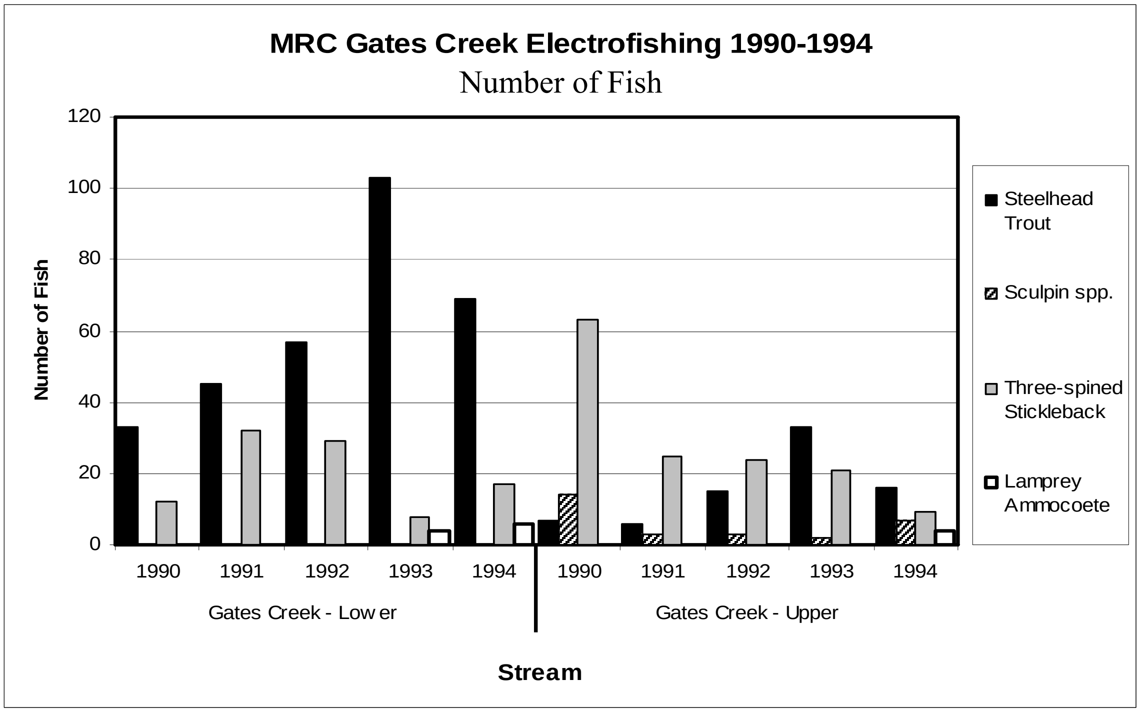
No salmonids were detected in Steam Donkey, Dunlap, Quail, and No Name gulches. More detailed summaries of stream surveys and fisheries studies in the Inland Subbasin are provided in the CDFG appendix.





Surveys by MRC

Figure 137. Electrofishing results from 1993 and 1994 for East Branch North Fork Big River.



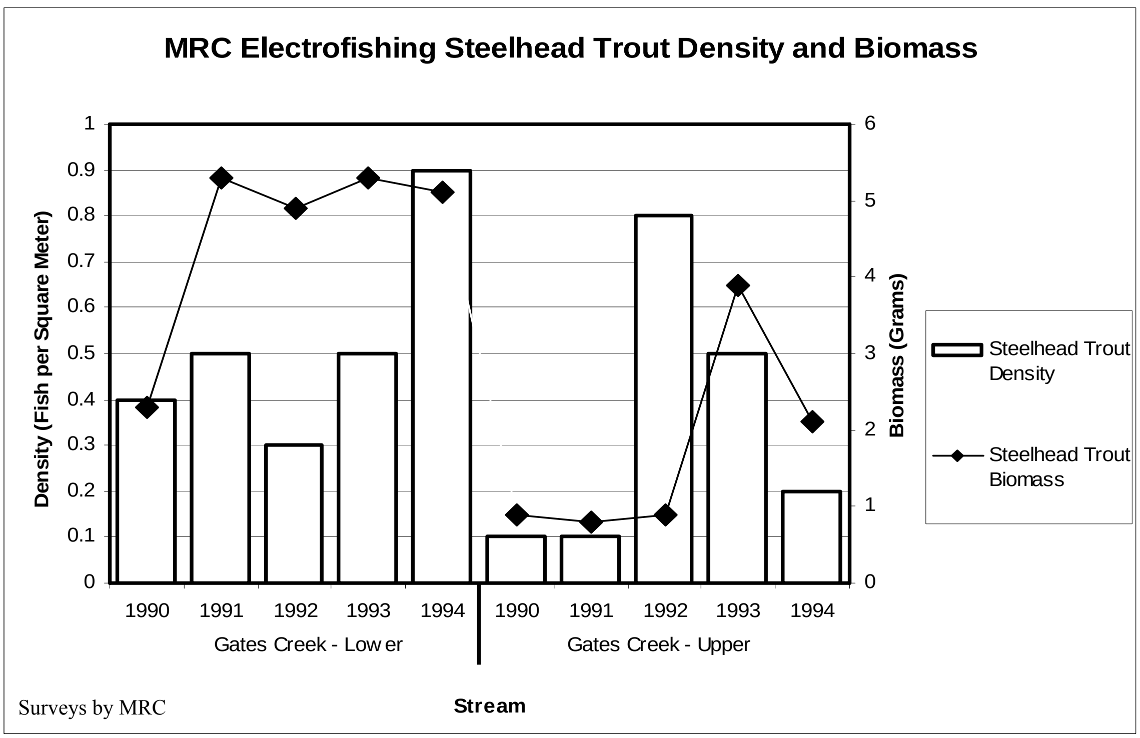
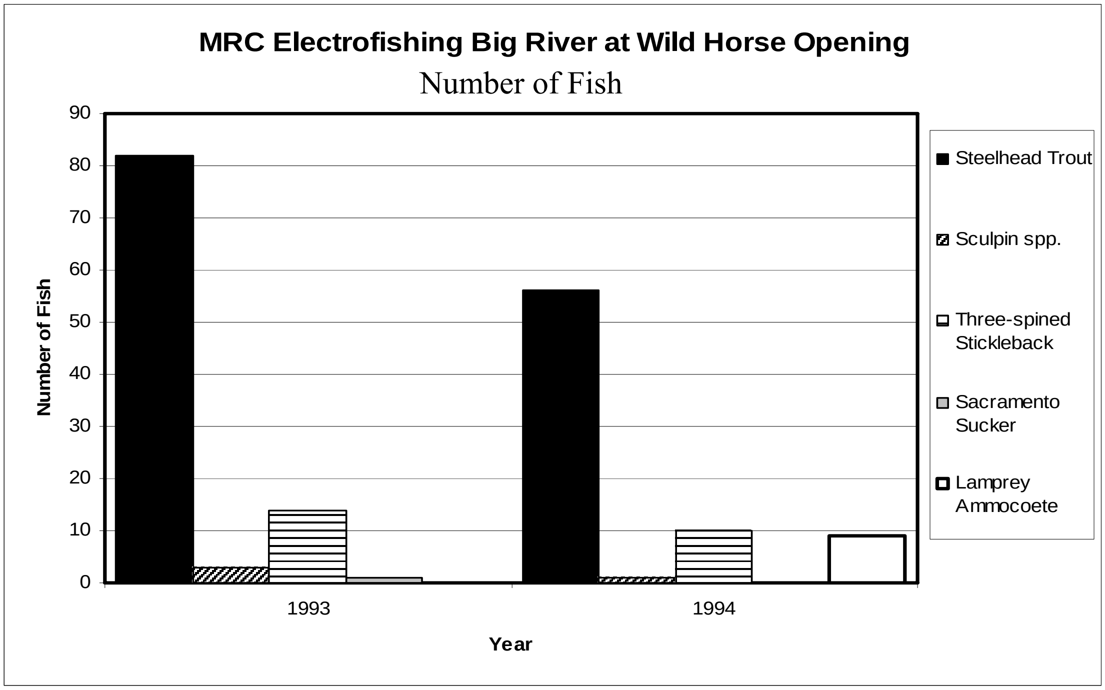


Figure 138. Electrofishing results from 1993 and 1994 for Gates Creek.



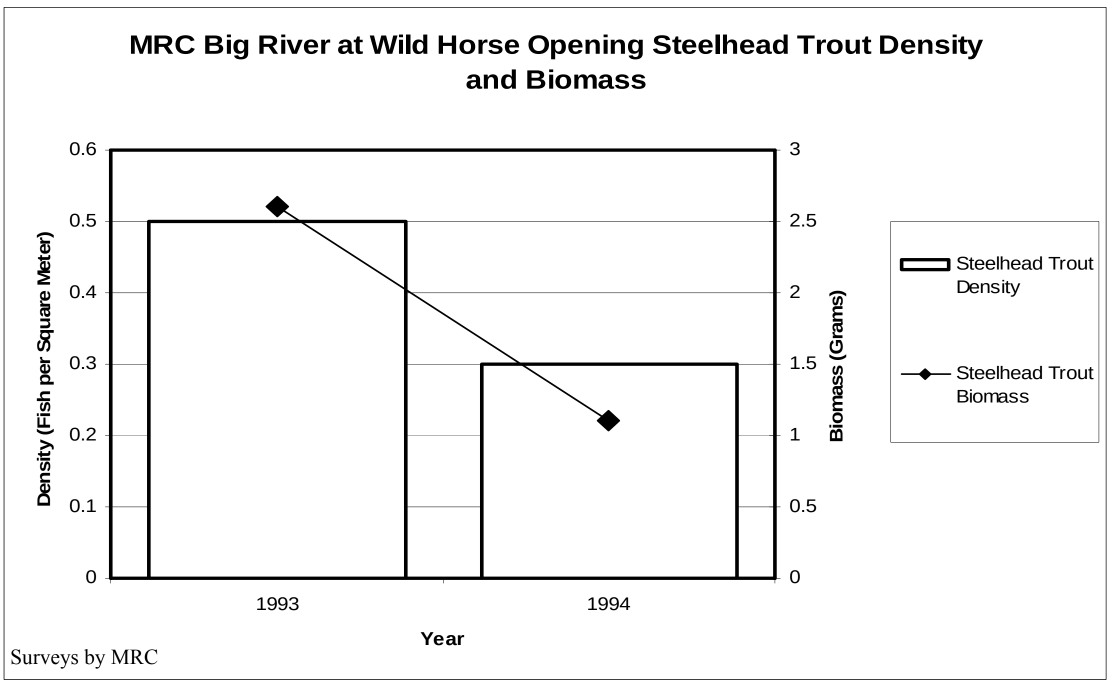


Figure 139. Electrofishing results from 1993 and 1994 for mainstem Big River at Wild Horse Opening.

Inland Subbasin Issues

From the various disciplines' assessments and constituent input, the following issues were developed for the Inland Subbasin. These must be considered in context of the Big River Basin's Franciscan mélange geology.

- Water temperatures are thought to be unsuitable for salmonids in the mainstem Big River and larger tributaries;
- There is concern that road related failures are contributing large amounts of sediments to stream channels during major storms;
- A significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek based on McNeil samples collected by GMA and MRC;
- High levels of fine material in streams are a concern.

Inland Subbasin Integrated Analysis

The following section provides a dynamic, spatial picture of watershed conditions for the freshwater lifestages of salmon and steelhead. Different watershed factors are analyzed together to examine their combined effects on stream channels. The interactions between geology, vegetation, landuse, water quality, and stream channels indicate the quantity and quality of the freshwater habitat for salmon and steelhead.

Landsliding Interactions

GMA (2001) calculated the unit volume of delivering landslides, comprised of the total of delivering landslides in unmanaged forest, brush and grasslands, roads and timber harvest areas, to be 218 tons/square mile/year for 1989-2000. In the Inland Subbasin, it was reported that 20.2% of the landslides occurred in grassland areas, none occurred in unmanaged forest, and the remaining 79.8% occurred in timber harvest areas or was related to roads (Figure 140 and Table 196). Of the delivering landslides from harvest related activities and roads, it was estimated that 23% were related to roads and 57% were related to timber harvesting (including skid trails). Results over the entire study period (1937-2000) showed that 34% of the delivering landslides were road related, 55% were related to timber harvesting (including skid trails), 11% were related to grassland areas, and the remaining <1% occurred in unmanaged forest areas.

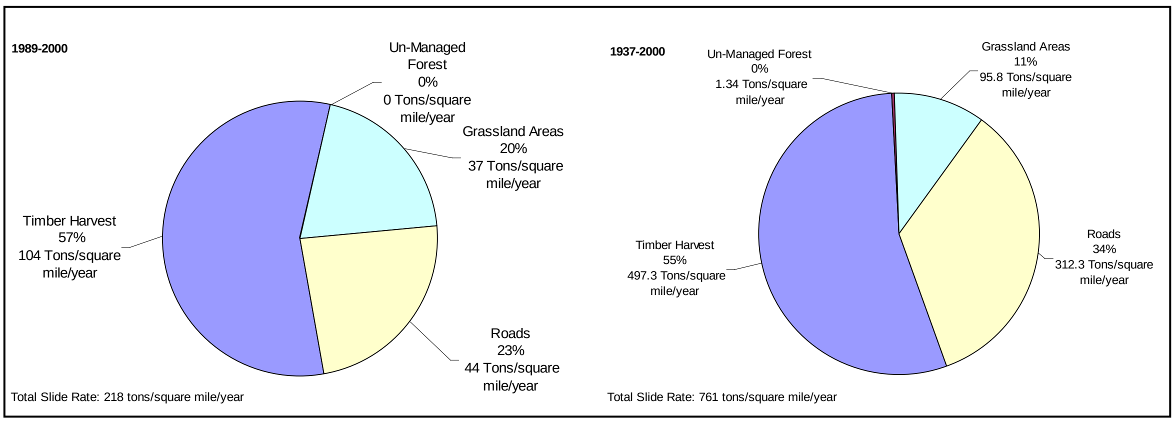


Figure 140. Delivering landslides by category, Inland Subbasin (GMA 2001a).

Thus, when comparing the 1989-2000 time period to that of the entire study period, the percentage of delivering landslides due to roads decreased while those due to timber harvesting remained similar. Timber harvest activities appear to contribute to the majority of the delivering landslides in the Inland Subbasin for the whole study period. While the relative percentages of volume from landsliding related to various land uses have stayed similar, it is important to note that the total estimated slide rate decreased from 761 to 218 tons per square mile per year, a substantial drop in sediment input by landslides.

When examining the differences throughout the Inland Subbasin, sediment volume related to roads in the North Fork drainage was much more than twice as high as the South Fork and upper headwaters drainages (Table 206). This appears to be largely due to a significant amount of road-related landslides in the Chamberlain Creek PW, which by itself contributes 30.1% of the total volume from all road-related activities. Harvest related sediment was highest in the South Fork drainage. Brush and grassland related sediment were highest in the South Fork drainage as well. Skid trail related sediment was highest in the South Fork and North Fork drainages.

The percentage of sediment volumes delivered by landslides associated with various land uses varied significantly between different PWs. Harvest related volumes varied from 23.0% to 79.96%, with the highest relative volumes in the Mettick Creek and Leonaro Lake PWs. Road-related sediment volumes ranged from 1.1% in the Leonaro Lake PW to 77.0% in the James Creek PW. Overall sediment volume delivered by landslides was highest in the Chamberlain Creek PW and lowest in the Upper North Fork Big River PW. Skid trail related landsliding was locally significant in the Dark Gulch PW at 21.3%.

Table 206. Volumes of delivering slides by land use by PW for entire study period.

PW	Forest	Brush & Grassland	Harvest-Related					Road-Related	Total
			Partial Or Clear Cut	Harvest (<20 Yrs)	Harvest (>20 Yrs)	Skid Trails	Total		
Upper North Fork Big River		4,390 3.9%		14,559 13.0%	24,395 21.8%	5,636 5.0%	44,590 39.9%	62,826 56.2%	111,806
James Creek				15,544 4.8%	13,887 4.3%	45,279 14.0%	74,710 23.0%	249,619 77.0%	324,329
Chamberlain Creek	2,650 0.2%			116,599 10.8%	286,863 26.6%	62,520 5.8%	465,982 43.3%	608,713 56.5%	1,077,345
East Branch North Fork Big		4,961 1.7%		79,331 27.2%	70,991 24.3%	2,659 0.9%	152,981 52.4%	133, 730 45.8%	291,672
Lower North Fork Big River	3,744 1.6%		48 <0.1%	38,668 16.5%	62,751 26.8%	20,773 8.9%	122,240 52.3%	107,746 46.1%	233,731
Leonaro Lake		235,897 24.7%		172,240 18.1%	535, 082 56.1%		707,322 74.1%	10,841 1.1%	954,060
Dark Gulch		118,862 27.6%	33,117 7.7%	58,189 13.5%	70,904 16.5%	91,651 21.3%	253,861 58.9%	58,114 13.5%	430,837
South Daugherty Creek	3,680 0.5%	270,130 33.0%		121,504 14.9%	88,911 10.9%	34,775 4.3%	245,190 30.0%	298,546 36.5%	817,546
Mettick Creek	996 0.2%	22,385 5.2%	853 0.2%	108,571 25.0%	226,911 52.3%	10,255 2.4%	346,590 79.9%	63,541 14.7%	433,512
Rice Creek		60,726 7.6%	18,198 2.3%	288,784 36.0%	196,445 24.5%	36,555 4.6%	539,982 67.2%	202,290 25.2%	802,998
Martin Creek		60,530 13.9%	440 0.1%	178,865 41.2%	46,630 10.7%	33,470 7.7%	259,405 59.7%	114,399 26.3%	434,334
Russell Brook		10,823 4.3%		35,665 14.0%	90,088 35.4%	3,506 1.4%	129,259 50.8%	114,147 44.9%	254,230
Inland Subbasin	11,070 0.2%	788,704 12.8%	52,656 0.9%	1,228,518 19.9%	1,713,858 27.8%	347,079 5.6%	3,342,111 54.2%	2,024,512 32.8%	6,166,397

Figures are in tons and percent of subbasin total (GMA 2001a)

Most PWs across the Inland Subbasin had a peak in sediment production in 1952, though two PWs had peaks in 1965 and one in 1988 (Table 207). The highest peak sediment production was 828, 336 tons in 1952 in the Leonaro Lake PW. Harvest-related landslides provided more volume in the peak year for the seven PWs in the South Fork and Upper drainages, while road-related sediment was greater for the other five PWs in the North Fork drainage.

In the 2000 study period, sediment production from landslides ranged from 2,535 tons in the James Creek PW to 65,068 tons in the Upper Mainstem Big PW. Harvest related landslides provided more volume in seven PWs, roads in two, and grasslands in three. All thee PWs with the most sediment related to grasslands were in the South Fork drainage.

Sediment production related to landsliding showed varying trends in different PWs from 1937 to 2000. From 1952 to 1965, most PWs showed a decrease in sediment as most PWs had shown a peak in sediment production in 1952. Half of the PWs had harvest-related landslides providing the most sediment, while four had more road-related and two had more grasslands and brush-related.

All PWs showed a decrease in sediment production from 1965 to 1978, though eight PWs showed an increase from 1978 to 1988. More landslide sediment was related to harvest in most PWs during the 1978 study period, but there was more variation between PWs in the 1988 study period. In the last study period (1988 to 2000) there was the most variation between PWs with five showing increased sediment and seven showing decreased sediment. All three PWs in the headwaters drainage showed an increase in sediment production in this time period. Eight PWs had most of the landslide sediment production related to timber harvest, while two each had more sediment production related to roads and grassland and brush.

Table 207. Volume of delivering slides by land use, PW, and year (in tons).

Year	PW	Forest	Brush & Grassland	Harvest-Related					Road-Related	Study Period Total
				Partial Or Clear Cut	Harvest (< 20 Years)	Harvest (> 20 Years)	Skid Trail	Total		
1952	Upper North Fork Big		3,249		2,590	16,298	2,427	21,314	12,530	37,093
1965			1,141		2,776	6,953		9,729	5,610	16,480
1978					67		3,160	3,227	7,679	10,906
1988					4,570	1,016	50	5,635	33,530	39,165
2000					4,557	128		4,685	3,478	8,164
TOTAL			**4,390**	**0**	**14,559**	**24,395**	**5,636**	**44,591**	**62,826**	**111,807**
1952	Lower North Fork Big	3,223			18,495	37,738		56,232	61,406	120,861
1965		522			19,384	19,654	20,773	59,812	34,331	94,664
1978						340		340	2,085	2,424
1988						432		432	8,450	8,881
2000				48	789	4,588		5,425	1,475	6,900
TOTAL		**3,744**	**0**	**48**	**38,668**	**62,751**	**20,773**	**122,240**	**107,746**	**233,731**
1952	James Creek				9,113	940		10,053	120,729	130,782
1965					3,519	6,958	13,450	23,926	92,620	116,547
1978					2,296	4,534	5,674	12,504	8,076	20,580
1988						212	25,986	26,199	27,686	53,885
2000					616	1,243	168	2,028	507	2,535
TOTAL			**0**	**0**	**15,544**	**13,887**	**45,279**	**74,709**	**249,619**	**324,328**
1952	East Branch North Fork Big		4,787		43,313	13,783	643	57,740	72,292	134,819
1965			174		15,798	35,858	996	52,652	17,336	70,162
1978					145	652	1,020	1,817	15,932	17,748
1988					1,210	16,202		17,412	26,767	44,179
2000					18,865	4,496		23,361	1,404	24,765
TOTAL			**4,961**	**0**	**79,331**	**70,991**	**2,659**	**152,981**	**133,730**	**291,673**
1952	Chamberlain Creek	2,650			99,668	236,546	2,683	338,897	462,642	804,189
1965					12,621	38,721	44,079	95,421	127,471	222,892
1978						3,111	14,404	17,515	10,883	28,398
1988						3,614	1,353	4,967	4,699	9,666
2000					4,310	4,872		9,182	3,018	12,200
TOTAL		**2,650**	**0**	**0**	**116,599**	**286,863**	**62,520**	**465,982**	**608,713**	**1,077,345**
1952	Leonaro Lake		173,112		168,393	475,990		644,384	10,841	828,336
1965			11,826		3,846	38,703		42,549		54,375
1978			8,339			6,155		6,155		14,494
1988			27,841			12,647		12,647		40,489
2000			14,779			1,587		1,587		16,365
TOTAL			**235,897**	**0**	**172,240**	**535,082**	**0**	**707,322**	**10,841**	**954,059**
1952	Dark Gulch		46,780		16,385	26,007		42,392	5,502	94,674
1965			53,929	33,003	34,487	36,085	83,639	187,213	41,785	282,927
1978			14,642	46	2,535	3,144	7,653	13,378	3,329	31,349
1988			2,215	68	4,669	1,031	205	5,973	4,438	12,626
2000			1,296		113	4,637	155	4,904	3,061	9,261
TOTAL		**0**	**118,862**	**33,117**	**58,189**	**70,904**	**91,651**	**253,861**	**58,114**	**430,836**
1952	South Daugherty Creek	3,680	144,143		104,158	22,591	4,077	130,826	80,350	359,000
1965			99,498		4,731	33,590	14,749	53,069	166,610	319,177
1978			6,988		935	2,767	1,239	4,940	7,853	19,781
1988			5,184		11,424	20,202	12,847	44,473	37,020	86,676
2000			14,317		257	9,761	1,863	11,881	6,712	32,910
TOTAL		**3,680**	**270,130**	**0**	**121,504**	**88,911**	**34,775**	**245,189**	**298,546**	**817,544**
1952	Mettick Creek	996	15,292	853	52,964	127,588		181,404	9,526	207,219
1965			7,093		16,688	55,214		71,902	24,267	103,262
1978					9,717	4,339	8,259	22,316	23,550	45,865
1988					9,965	5,819	1,996	17,780	2,551	20,331
2000					19,237	33,951		53,188	3,647	56,836
TOTAL		**996**	**22,385**	**853**	**108,571**	**226,911**	**10,255**	**346,590**	**63,541**	**433,513**
1952	Rice Creek		38,617	2,245	216,612	99,986		318,842	43,429	400,888
1965			18,283	15,953	52,680	64,780	15,575	148,988	89,330	256,601
1978					10,590	14,231	3,159	27,980	6,051	34,031
1988			3,716		8,903	13,263	5,161	27,328	15,367	46,410
2000			110			4,184	12,660	16,845	48,113	65,068
TOTAL			**60,726**	**18,198**	**288,784**	**196,445**	**36,555**	**539,982**	**202,290**	**802,998**
1952	Martin Creek		5,007	440	66,521	5,600		72,561	45,490	123,057
1965			7,165		99,517	25,168		124,685	56,867	188,716
1978			2,057		6,872	178	29,234	36,284	4,559	42,901
1988			21,867		3,980	611	4,236	8,827	1,311	32,005
2000			24,433		1,975	15,072		17,048	6,173	47,655
TOTAL			**60,530**	**440**	**178,865**	**46,630**	**33,470**	**259,405**	**114,399**	**434,334**
1952	Russell Brook		4,443		22,849	69,153		92,003	38,381	134,826
1965			3,677		3,556	14,891		18,447	15,288	37,411
1978						2,801	2,587	5,388	3,964	9,352
1988						966	919	1,885	28,197	30,082
2000			2,703		9,260	2,276		11,536	28,318	42,558
TOTAL			**10,823**	**0**	**35,665**	**90,088**	**3,506**	**129,259**	**114,147**	**254,230**

It should also be noted that background landslides, other than what was observed in unmanaged forest, has not been included in the direct comparisons discussed thus far (and shown in Figure 141). Background landslide estimates are discussed separately because they were estimated from past studies, rather than through direct observation in aerial photographs. Background landslide rates were estimated based on previous observation of natural background landslides in the South and North Fork of Caspar Creek (Matthews 2001). However, this presented a potentially significant difference in data quality and could be misleading if compared directly.

The background landslide rate for the 1989-2000 time period was estimated to be 159 tons/mi^2/yr. The background landslide rate for the 1921-2000 time period was estimated to be 175 tons/mi^2/yr. Regardless of data quality concerns, these estimates point to background landslides as a potentially significant component of sediment input. As a point of reference, all other landslides during the 1989-2000 time period contributed an estimated 218 tons/square mile/year. This would indicate that background landslides may have contributed roughly 47% of the total sediment input by all categories of landslides.

When compared to the TMDL load allocations for each category of landslide, there is no reduction needed for background landslides, as it is naturally occurring. However, each category of landslide that is related to human management has been assigned a load allocation (US EPA 2001). The overall goal of the load allocation is to limit sediment input to no more than 125% of naturally occurring background levels by reducing sediment input from the various categories accordingly. These are charted in Figure 141 for comparison to the estimated landsliding rates during the 1989-2000 time period. Note that estimated values and TMDL load allocations for timber harvest also include landslides related to skid trails. Based on these preliminary comparisons, it appears as though landsliding related to roads, timber harvesting, and grassland areas needs to be addressed to meet the TMDL load allocation goals.

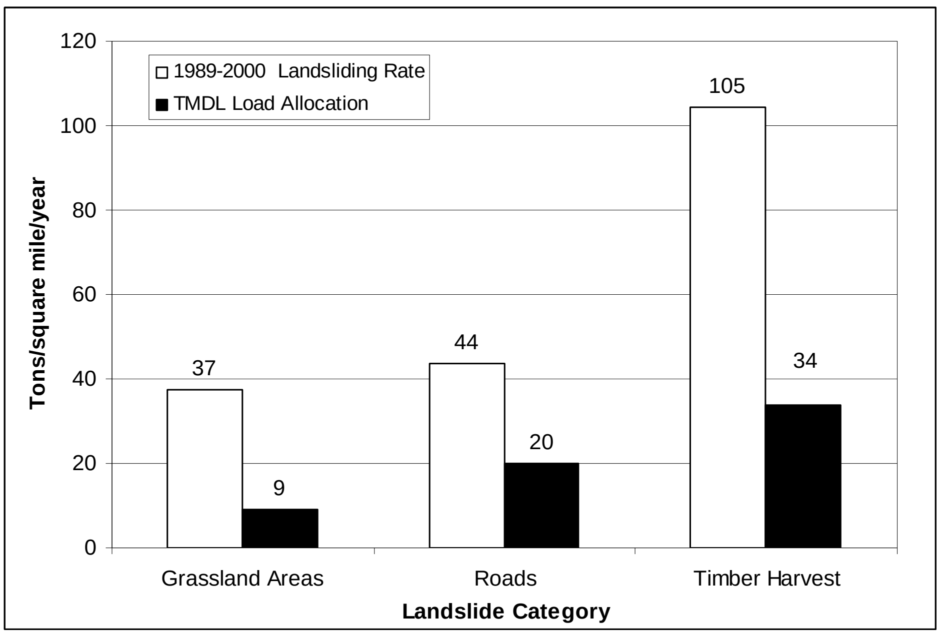


Figure 141. Landslide rate vs. TMDL load allocations, Inland Subbasin (GMA 2001a).

The MRC Watershed Analysis found that of the 884 shallow-seated landslides observed in the MRC ownership of the Inland Subbasin, 535, or 61%, were road-associated (Table 208).

Table 208. Percent of road-associated landslides by PW for lands under MRC ownership.

PW	Road Associated
East Branch North Fork Big River	31%
Rice Creek	29%
Lower North Fork Big River	29%
Mettick Creek	44%
Dark Gulch	31%
Russell Brook	47%
South Daugherty	40%
Total	61%

MRC 2003

Road associated mass wasting was found to have contributed about 408,000 tons (256 tons/square mile/year) in the study period. This is 65% of the total mass wasting sediment inputs for the MRC ownership in the Inland Subbasin. Road associated mass wasting was a major sediment source in the Mettick Creek, Russell Brook, and South Daugherty PWs (Figure 142).

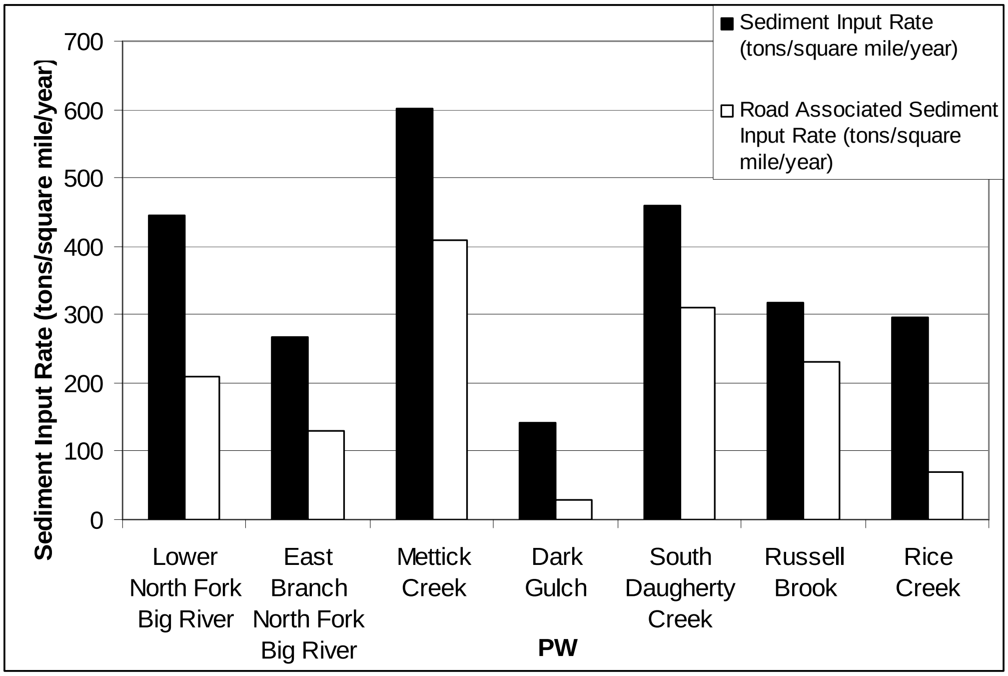


Figure 142. Sediment input rate from all shallow-seated landslides and road-associated shallow-seated landslides for the MRC ownership from 1970 to 2000.

Slope Interactions

An analysis of different types of roads on slopes of varying percent showed that most road miles are on slopes from 31 to 50% in this subbasin (Table 209). When GMA (2001) grouped slopes into categories, they found that most of the roads are mid-slope, followed by riparian, and then ridge-top (Table 210). The proportion of roads in each location is similar across PWs (Table 211).

Table 209. Length of truck roads by side slope and road surface in the Inland Subbasin.

Side Slope in Percent	Total Length in Miles				Miles per Sq Mile				Proportion of Length			
	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total	Native	Paved	Rocked	Total
0 -15	71	5	7	83	0.5	0.0	0.1	0.6	8.5	0.6	0.8	9.9
16 - 30	182	12	25	218	1.4	0.1	0.2	1.7	21.7	1.4	3.0	26.0
31 - 50	290	10	43	342	2.2	0.1	0.3	2.6	34.5	1.2	5.1	40.7
51 - 65	110	2	15	126	0.8	0.0	0.1	1.0	13.1	0.2	1.8	15.0
Greater than 65	62	1	9	71	0.5	0.0	0.1	0.5	7.4	0.1	1.1	8.5
Total	**713**	**29**	**99**	**840**	**5.5**	**0.2**	**0.8**	**6.4**	**84.9**	**3.5**	**11.8**	**100.0**

Table 210. Inland Subbasin roads by location and surface type.

	Paved	Rocked	Un-surfaced
Ridgetop			
Miles	2.7	8.2	150.3
% Total Basin Miles	<0.1	1.0	17.9
Mid-slope			
Miles	14.7	57.3	392.3
% Total Basin Miles	1.8	6.8	46.7
Riparian			
Miles	10.3	34.8	168.7
% Total Basin Miles	1.2	4.1	20.2

Total subbasin roads = 839.2 miles, 6.4 miles/square mile

Blue categories have the lowest potential for road surface erosion (2.9%). Orange categories have medium potential for surface erosion (25.9%). Magenta categories have the highest potential for surface erosion (71.0%). Road surface erosion is a source of fine sediment that can be delivered to streams, which is deleterious to fish habitat.

Table 211. Existing miles of road in different road positions by types and PW.

PW	Riparian			Mid-Slope			Ridge			Total By PW		
	Paved	Rocked	Native	Paved	Rocked	Native	Paved	Rocked	Native	Riparian	Mid-Slope	Ridge
Upper North Fork Big River		3.1	10.3	0.5	8.6	29.1	0.1	1.4	6.8	13.4	38.2	8.3
James Creek	0.7		12.7	4.7	1.1	22.6	0.4	0.6	8.8	13.4	28.4	9.8
Chamberlain Creek		1.4	25.6		0.3	24.1		0.1	12.6	26.9	24.4	12.6
East Branch North Fork Big		5.5	7.0		5.9	25.4		0.4	9.1	12.5	31.3	9.6
Lower North Fork Big River	2.5	3.0	10.7	1.4	4.7	28.5	0.0	0.1	9.4	16.2	34.6	9.6
Leonaro Lake	1.4		6.8	2.1		16.4	0.4		7.2	8.3	18.5	7.5
Dark Gulch	5.3	0.1	13.9	0.5	0.1	26.5		0.4	11.1	19.2	27.0	11.5
South Daugherty Creek	0.3	6.3	16.2	5.5	8.8	48.2	0.7	1.0	22.0	22.8	62.4	23.7
Mettick Creek	0.1	7.7	20.6		13.6	54.0	1.2	0.8	17.7	28.4	67.6	19.7
Rice Creek		0.9	19.3		1.3	42.9		0.0	20.3	20.2	44.3	20.4
Martin Creek		5.3	7.8		9.3	28.4		3.0	13.0	13.1	37.7	15.9
Russell Brook		1.6	17.9		3.6	46.3		0.5	12.4	19.6	49.9	12.8

GMA 2001a

The MRC Watershed Analysis found that about 87% of field observed shallow landslides inventoried on MRC land in the Inland Subbasin were initiated on slopes greater than or equal to 60% gradient. Almost 65% of shallow landslides initiated on slopes greater than or equal to 70% gradient. Of the field observed landslides occurring on slopes with gradients less than 70%, only four were not road related. This suggests that few landslides are occurring on slopes less than 70% gradient unless triggered by a road or skid trail.

Shallow-seated landslides were in the greatest concentration in inner gorge and steep streamside areas. Combined, these two locations accounted for just under 50% of the shallow-seated landslides; 21% inner gorge and 29% steep streamside slopes. Headwall swells accounted for 12%, and the remainder occurred in midslope areas, often as a result of roads, landings, and skid trails.

In the MRC's ownership, low slope class roads make up 55% of all the contributing road area (Table 212). The East Branch North Fork Big River PW has the highest percentage of low slope roads, and the Russell Brook PW has the lowest. Low slope class roads delivered 7,150 tons/year, compared to 6,030 tons/year for middle slope class roads and 1,350 tons/year on high slope class roads. This indicates the importance of monitoring low and mid-sloped roads.

Table 212. Contributing road area, proportion estimates, and surface and point source erosion estimates by slope class and PWs for MRC ownership in the Inland Subbasin.

PW	Low-Slope			Mid-Slope			High-Slope		
	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)	Contributing Road Area (acres)	Percent Roads	Surface and Point Source Erosion (tons/year)
East Branch North Fork	6.2	75%	930	2.0	25%	480	0.0	0%	170
Lower North Fork	4.1	48%	360	4.2	50%	540	0.1	2%	30
Mettick Creek	10.4	54%	1580	7.8	38%	1290	0.6	3%	270
Rice Creek	1.7	65%	250	0.9	35%	180	0.0	0%	10
Russell Brook	5.2	45%	1320	5.6	49%	2250	0.7	6%	480
South Daugherty	9.4	52%	2710	8.1	45%	1290	0.6	3%	390
Total	37.0	55%	7150	28.6	42%	6030	2.0	3%	1350

No data for MRC ownership in Dark Gulch. MRC 2004.

Road Interactions

GMA (2001) estimated that road surface erosion across the Inland Subbasin increased significantly from 1937 to 2000, coinciding with an increased amount of roads, (Table 213). Roads in 2000 were estimated to produce 89.3 tons of sediment per square mile per year across the subbasin, an increase over 1952 rates. Existing road surface erosion in 2000 was highest in the Lower North Fork Big River PW and lowest in the Leonaro Lake PW.

Table 213. Computed road surface erosion by study period by PW.

PW	Computed Surface Erosion From Roads By Period (Tons/Yr)					Total By PW For Entire Period	% Total Watershed Road Surface Erosion	Entire Study Period Average Unit Area Road Surface Erosion	2000 Unit Area Road Surface Erosion
	1937-1952	1953-1965	1966-1978	1979-1988	1989-2000	(Tons)	(%)	(Tons/Mi2/Yr)	
Upper North Fork Big River	167.0	481.9	646.4	691.0	911.8	35,191.3	5.3	66.0	107.8
James Creek	101.9	419.0	487.6	578.7	732.3	27,989.5	4.2	63.8	105.2
Chamberlain Creek	531.6	907.3	1,201.1	1,231.4	1,240.6	63,132.9	9.5	81.6	101.0
East Branch North Fork Big	92.8	133.8	532.2	586.9	688.3	24,271.8	3.7	47.8	85.4
Lower North Fork Big River	360.2	524.9	707.1	769.7	834.6	39,539.6	6.0	81.2	108.0
Leonaro Lake	172.0	335.5	351.7	362.5	445.7	20,658.4	3.1	39.4	53.6
Dark Gulch	294.3	642.1	731.9	754.4	905.5	40,981.0	6.2	58.2	81.1
South Daugherty Creek	336.8	700.7	951.7	1024.0	1286.2	52,543.7	7.9	50.1	77.2
Mettick Creek	86.8	397.6	1060.5	1203.3	1535.3	50,805.3	7.7	44.0	83.8
Rice Creek	196.9	666.8	737.8	904.8	1173.3	44,536.9	6.7	56.3	93.5
Martin Creek	134.6	326.0	420.9	492.5	745.5	25,735.5	3.9	44.0	80.3
Russell Brook	106.4	353.1	597.1	928.4	1177.1	37,463.9	5.7	54.3	107.5
Inland Subbasin	2,581.3 (22.1%)	5,888.5 (50.4%)	8,426.1 (72.2%)	9,527.6 (81.6%)	11,676.2 (100.0%)	462,849.8	69.8	56.2	89.3

GMA 2001a

GMA (2001) estimated that sediment production from skid roads across the subbasin was small (Table 214). The analysis suggested a peak in surface erosion at the time of high harvest rates using high-density tractor logging methods from 1953-1978. Surface erosion from 1989 to 2000 was highest in the South Daugherty Creek PW and lowest in the Chamberlain Creek PW.

Table 214. Summary of surface erosion estimates from harvest areas by study period in the Inland Subbasin.

PW	1937-1952 TOTAL (Tons)	1953-1965 TOTAL (Tons)	1966-1978 TOTAL (Tons)	1979-1988 TOTAL (Tons)	1989-2000 TOTAL (Tons)	1937-2000 TOTAL BY PW OR SW (Tons)
Inland Subbasin	**20,816.0**	**39,005.9**	**72,641.3**	**17,742.8**	**9,243.9**	**159,449.0**
Upper North Fork Big River	2,291.4	3,464.3	4,110.3	476.3	1,034.3	11,376.6
James Creek	944.5	10,795.0	5,084.7	765.9	296.3	17,886.5
Chamberlain Creek	872.2	5,393.8	17,528.7	58.9	1.0	23,854.5
East Branch North Fork Big	1,978.0	259.7	12,594.2	387.5	1,112.8	16,332.3
Lower North Fork Big River	2,306.0	1,862.5	6,874.8	1.3	453.0	11,497.6
Leonaro Lake	230.8	402.9	0.0	45.0	125.8	804.4
Dark Gulch	3,486.2	3,857.0	210.4	158.1	560.4	8,272.2
South Daugherty Creek	2,094.0	3,812.6	3,887.6	868.8	1,527.6	12,190.5
Mettick Creek	2,196.3	3,072.7	9,461.2	5,522.9	376.4	20,629.40
Rice Creek	1,213.1	2,486.0	641.7	603.6	1,396.3	6,340.7
Martin Creek	1,413.8	681.5	4,967.9	753.0	1,450.8	9,267.0
Russell Brook	1,789.5	2,917.9	7,279.8	8,101.7	909.2	20,998.1

GMA 2001a

As can be seen in Figure 143, estimates of surface erosion from roads and timber harvest areas (including skid trails) indicate that both exceed the TMDL load allocation for surface erosion. Surface erosion related to roads, in particular, appears to be a significant problem. The increase in surface erosion from roads in the 1989-2000 time period versus the entire study period (1937-2000) is likely due to continued road building through the years which has resulted in greater road surface area.

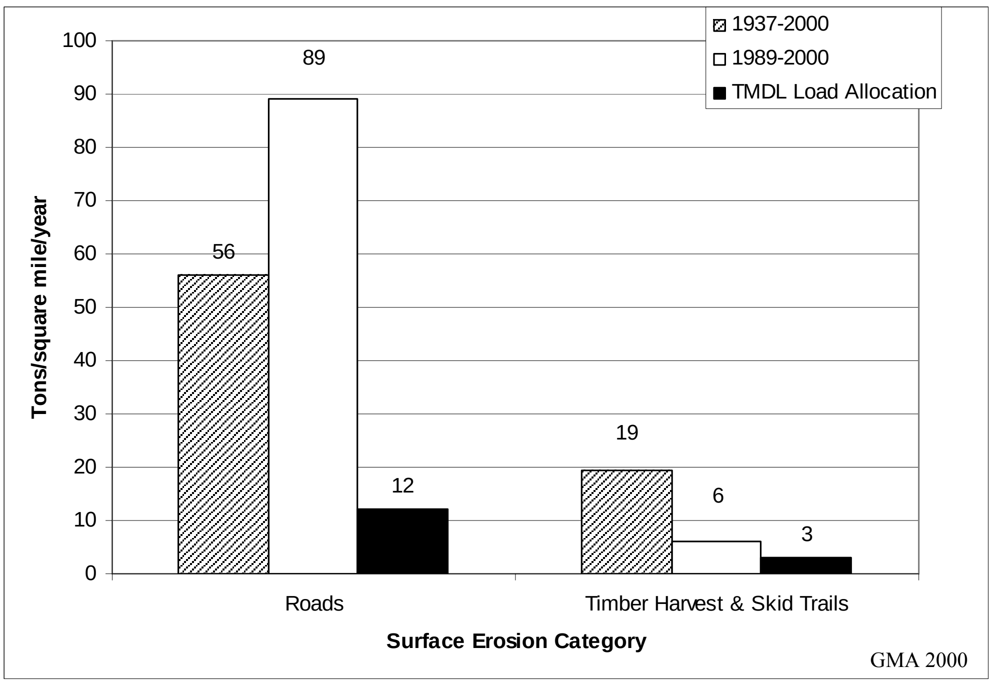


Figure 143. Surface erosion rate vs. TMDL load allocations.

Roads within MRC's ownership in the Inland Subbasin were estimated to generate 310 tons/square mile/year of sediment from road associated surface and point erosion (MRC 2003) (Table 215). The highest amounts of sediment generated are in the South Daugherty and Mettick Creek PWs. The highest sediment erosion rates are in the Russell Brook, East Branch North Fork Big River, and South Daugherty PWs. These PWs have higher road densities and a smaller amount of MRC owned land. Point source erosion was also high in these three PWs. The surface erosion rate was higher than the point source erosion rate in the Lower North Fork, Mettick Creek, and Rice Creek PWs.

Table 215. Road associated surface and point source erosion estimates by PW for MRC ownership.

PW	Total Road Associated Erosion (tons/year)	MRC owned acres	Road Associated Erosion Rate (tons/square mile/year)	Surface Erosion Rate (tons/square mile/year)	Point Source Erosion Rate (tons/square mile/year)
East Branch North Fork	1,580	2,527	400	165	235
Lower North Fork	930	2,170	270	235	35
Mettick Creek	6,140	10,294	200	130	70
Rice Creek	440	924	300	290	20
Russell Brook	4,050	5,926	440	170	270
South Daugherty	4,390	7,242	390	160	230
Total	**14,530**	**29,083**	**310**	**160**	**150**

No data for MRC ownership in Dark Gulch (MRC 2003)

MRC found that the high level of tractor based yarding used for timber harvest in the 1940s, 1950s, and 1960s on their ownership produced a high level of sediment delivery (Table 216 and Figure 144). However, the widespread geographic extent of skid trails in the 1970s and 1980s produced the most total skid trail area and the highest sediment delivery rates. There were peaks in sediment delivery rate from skid trails in the Lower North Fork and Rice Creek PWs in the 1970s, and in the East Branch North Fork Big River, Russell Brook, Mettick Creek, and South Daugherty PWs. Skid trail delivery rates diminished across the MRC ownership in the 1990s with less harvest activity and stricter regulations.

Table 216. Skid trail use in acres for MRC ownership in the Inland Subbasin (MRC 2003).

PW	1940s	1950s	1960s	1970s	1980s	1990s
Lower North Fork Big River	1,038	618	208	1,137	793	57
East Branch North Fork Big River	38	0	1,574	1,538	2,036	390
Russell Brook	94	22	1,050	2,756	3,360	317
Rice Creek	0	0	0	139	89	99
Dark Gulch	326	460	0	283	268	0
Mettick Creek	829	845	3,420	5,171	5,490	1,449
South Daugherty	991	1,500	2,120	2,203	3,968	463

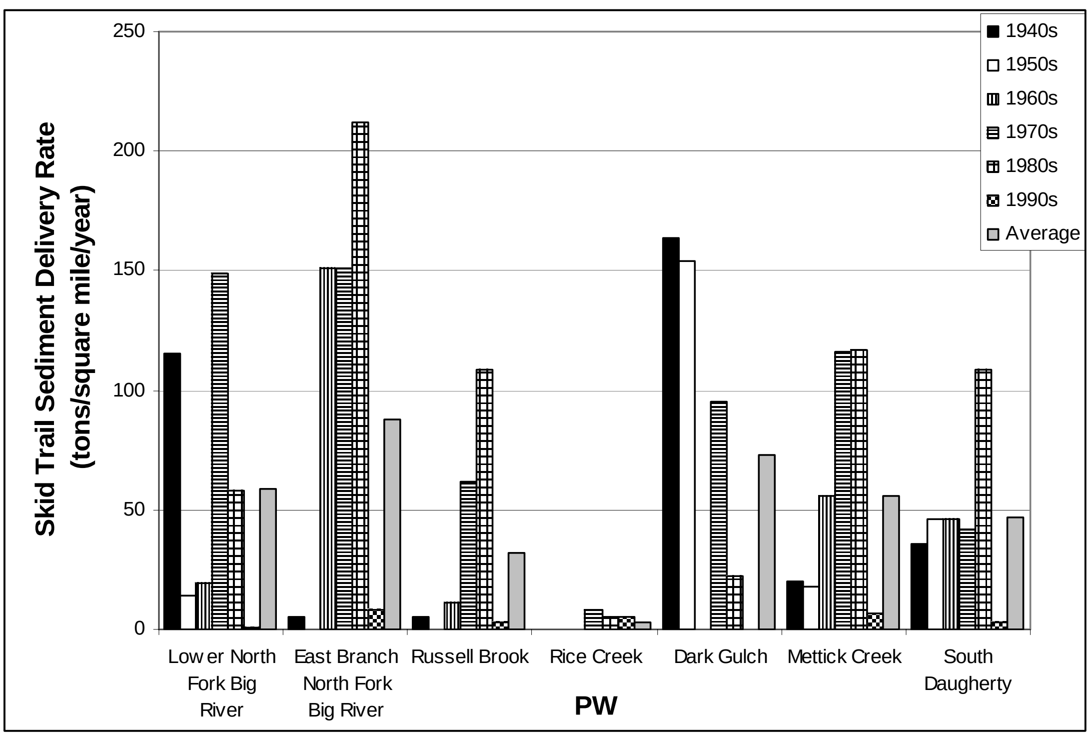


Figure 144. Skid trail sediment delivery estimates for MRC ownership in the Inland Subbasin (MRC 2003).

MRC (2003) estimated the total sediment inputs for their ownership in the Inland Subbasin. The average estimated sediment input for the past 30 years was 836 tons/square mile/year (Table 217). Road associated erosion was the dominant sediment contributing process in the MRC ownership in the Inland Subbasin, making up 67% of the sediment input. When skid trail erosion is included in road-associated erosion totals the percentage increases to 81%.

Table 217. Estimated sediment inputs by input type for the MRC ownership averaged over 30 years, 1970-2000.

PW	Road Surface Erosion	Road Point Source Erosion	Road Associated Mass wasting	Hillslope Mass wasting	Skid Trail Erosion	Total
East Branch North Fork	165	235	100	140	150	790
Rice Creek	290	20	70	230	10	620
Lower North Fork	235	35	205	240	75	790
Mettick Creek	130	70	320	190	170	880
Dark Gulch	n/a	n/a	20	110	50	180
Russell Brook	170	270	200	90	90	820
South Daugherty	160	230	270	150	90	900
Total	**158**	**157**	**243**	**159**	**118**	**836**

MRC 2003

Road Crossings

Today there are 127 miles of roads in the watercourse buffer zone (Table 218). Seventy two percent were built before 1979 (Table 219). While the data show 98 miles as native road surface, the Forest Practice Rules require that landowners that use roads for harvesting timber reduce the potential for sediment transport, so many are being surfaced with rock. There are more than 16 streams crossings per square mile in this subbasin (Table 220).

Table 218. Length of truck roads in near proximity to watercourse in miles by watercourse classification and road classification.

Watercourse Class	Total Length in Miles				Length in Miles per Sq Mile			
Inland Subbasin	**Native**	**Paved**	**Rocked**	**Total**	**Native**	**Paved**	**Rocked**	**Total**
w/in 150' of FPR Class I or USGS Perennial	57.3	6.8	15	79	0.4	0.1	0.1	0.6
w/in 75' of FPR Class II or USGS Intermittent	30.6	0.4	4.3	35.3	0.2	0.0	0.0	0.3
w/in 25' of FPR Class III	10.3	0.5	1.7	12.4	0.1	0.0	0.0	0.1
Total	**98.1**	**7.7**	**20.9**	**126.9**	**0.8**	**0.1**	**0.2**	**1.0**

Table 219. Length of truck roads in near proximity to watercourse in miles by period of construction and road classification.

Period	Total Length in Miles				Length in Miles per Sq Mile			
Inland Subbasin	**Native**	**Paved**	**Rocked**	**Total**	**Native**	**Paved**	**Rocked**	**Total**
1937 - 1952	9.5	6.4	3.4	19.4	0.1	0.0	0.0	0.1
1953 - 1965	35.1	1.3	8.7	45	0.3	0.0	0.1	0.3
1966 - 1978	22.6	0	4.6	27.2	0.2	0.0	0.0	0.2
1979 - 1988	13.2	0	2.8	15.8	0.1	0.0	0.0	0.1
1989 - 2000	12.7	0	1.2	13.9	0.1	0.0	0.0	0.1
Total	**64.2**	**6.1**	**13.1**	**83.6**	**0.5**	**0.0**	**0.1**	**0.6**

Table 220. Number of watercourse truck road crossings by watercourse and road classification.

Watercourse Class Inland Subbasin	Total Crossings				Crossings per Sq Mile			
	Native	**Paved**	**Rocked**	**Total**	**Native**	**Paved**	**Rocked**	**Total**
FPR Class I or CFF Perennial	193	10	36	239	1.5	0.1	0.3	1.8
FPR Class II or CFF Intermittent	460	16	81	557	3.5	0.1	0.6	4.3
FPR Class III	1087	52	206	1345	8.3	0.4	1.6	10.3
Total	**1740**	**78**	**323**	**2141**	**13.3**	**0.6**	**2.5**	**16.4**

Fluvial Erosion

GMA (2001a) estimates of bank erosion and small streamside mass wasting (Table 221) found little sediment from these sources.

Table 221. Bank erosion and small streamside mass wasting in the Inland Subbasin.

Planning Watershed	Bank Erosion and Small Streamside Mass Wasting		Total (Tons/Year)
	Class 1 (Tons/Year)	Class 2 (Tons/Year)	
Inland Subbasin	3,430	5,146	8,576
Upper Mainstem Big River	324	554	877
Martin Creek	168	454	623
Lower Mainstem Big River	292	445	736
Upper North Fork Big River	214	277	491
James Creek	193	273	466
Chamberlain Creek	266	785	1,051
East Branch North Fork Big	223	221	445
Lower North Fork Big River	334	184	518
Upper South Fork Big River	142	443	586
Middle South Fork Big River	277	397	674
Daugherty Creek	376	443	819
Lower South Fork Big River	620	669	1,289

GMA 2001a

Stream Interactions

The products and effects of the watershed delivery processes examined in the geologic, slope, and landsliding Integrated Analyses tables are expressed in the stream habitats encountered by the organisms of the aquatic riparian community, including salmon and steelhead. Several key aspects of salmonid habitat in the Big River Basin are presented in the Stream Interactions Integrated Analysis. Channel and stream conditions are not necessarily exclusively linked to their immediate surrounding terrain, but may in fact be both spatially and temporally distanced from the sites of the processes and disturbance events that have been blended together over time to create the channel and stream's present conditions. Instream habitat data presented here were compiled from CDFG stream inventories described in more detail in the Fish Habitat Relationships sections of this report.

Primary Pools

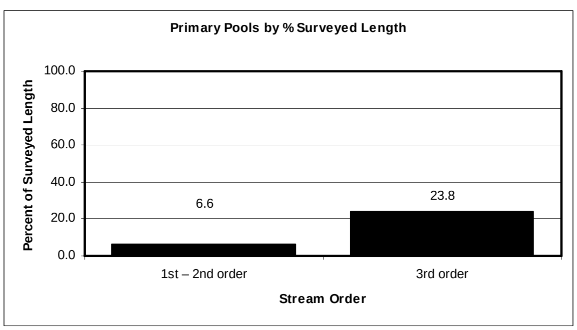


Figure 145. Primary Pools in the Inland Subbasin.

Pools greater than 2 feet deep in 1st and 2nd order streams and greater than 3 feet deep in 3rd and 4th order streams are considered primary pools.

Significance: Primary pools provide escape cover from high velocity flows, hiding areas from predators, and ambush sites for taking prey. Pools are also important juvenile rearing areas. Generally, a stream reach should have 30-55% of its length in primary pools to be suitable for salmonids. In first and second order streams, a primary pool is described as being at least two feet deep. In third and fourth order streams, a primary pool is described as being at least three feet deep.

Comments: The percent of primary pools by length in the Inland Subbasin is generally below target values for salmonids, and appears to be less suitable in lower order streams than in higher order streams.

Spawning Gravel Quality

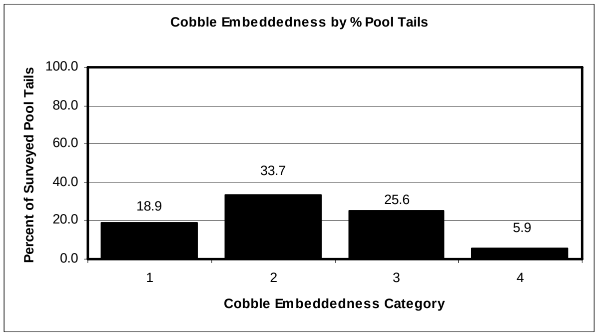


Figure 146. Cobble Embeddedness in the Inland Subbasin.

Cobble Embeddedness will not always sum to 100% because Category 5 (not suitable for spawning) is not included.

Significance: Successful salmonid egg and embryo survival diminishes when spawning occurs in streambeds with excessive silt, clay, and other fine sediment. Cobble embeddedness is the percentage of an average sized cobble at a pool tail out embedded in fine substrate. Category 1 is 0-25% embedded, category 2 is 26-50% embedded, category 3 is 51-75% embedded and category 4 is 76%-100% embedded. Cobble embeddedness categories 3 and 4 are not within the suitable range for successful use by salmonids. Category 5 describes pool tail outs with unspawnable substrate such as bedrock, log sills, or boulders.

Comments: Just over one half of the surveyed stream lengths within the Inland Subbasin have cobble embeddedness in categories 1 and 2, which meets spawning gravel target values for salmonids.

Shade Canopy

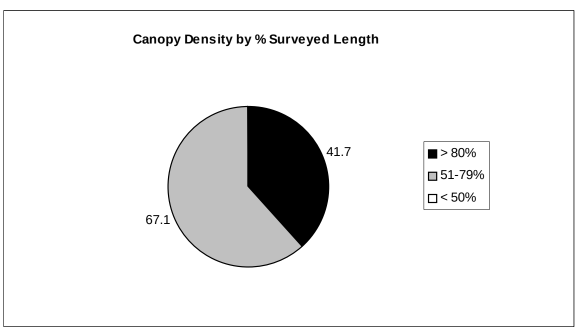


Figure 147. Canopy Density in the Inland Subbasin.

Significance: Near-stream forest density and composition contribute to microclimate conditions that help regulate air temperature, which is an important factor in determining stream water temperature. Stream water temperature can be an important limiting factor of salmonids. Generally, canopy density less than 50% by survey length is unsuitable and greater than 85% is fully suitable.

Comments: All of the surveyed stream lengths within the Inland Subbasin have canopy densities greater than 50% and over 40% of the surveyed lengths have canopy densities greater than 80%. This is above the canopy density target values for salmonids.

Fish Passage

Table 222. Salmonid habitat artificially obstructed for fish passage (N=3 Culverts).

Feature/Function		Significance	Comments
Type of Barrier	% of Estimated Historic Coho Salmon Habitat Currently Inaccessible Due to Artificial Passage Barriers	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.	The Inland Subbasin had three streams crossings where fish passage was being artificially barred. All of these barriers were total passage barriers. Two of them were modified to improve fish passage and currently only 0.9% of the estimated historic coho salmon distribution is blocked.
All Barriers	0.9		
Partial and Temporary Barriers	0.0		
Total Barriers	0.9	Partial barriers exclude certain species and lifestages from portions of a watershed and temporary barriers delay salmonid movement beyond the barrier for some period of time. Total barriers exclude all species from portions of a watershed.	

1998-2000 Ross Taylor and Associates Inventories and Fish Passage Evaluations of Culverts within the Humboldt County and the Coastal Mendocino County Road Systems

Table 223. Juvenile salmonid passage in the Inland Subbasin (1993-2002 CDFG Stream Surveys, CDFG Appendix).

Feature/Function		Significance	Comments
Juvenile Summer Passage	**Juvenile Winter Refugia**	Dry channel disrupts the ability of juvenile salmonids to move freely throughout stream systems.	Dry channel recorded in the Inland Subbasin during stream surveys has the potential to disrupt the ability of juvenile salmonids to forage and escape predation in 12 tributaries. Juvenile salmonids seek refuge from high winter flows, flood events, and cold temperatures in the winter. Intermittent side pools, back channels, and other areas of relatively still water that become flooded by high flows provide valuable winter refugia.
3.0 Miles of Surveyed Dry Channel	No Data		
2.8% of Surveyed Dry Channel			

Pool Shelter

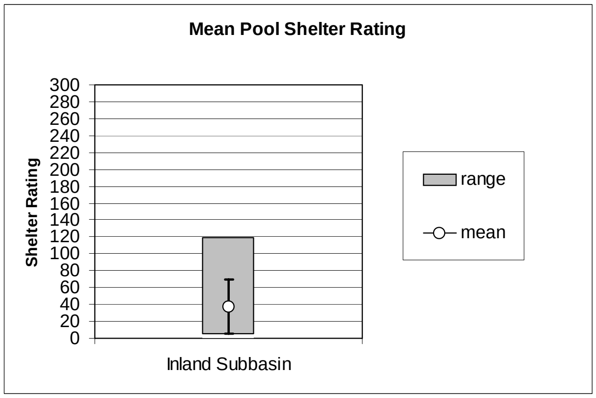


Figure 148. Pool shelter in the Inland Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described and rated in CDFG surveys.

Significance: Pool shelter provides protection from predation and rest areas from high velocity flows for salmonids. Shelter ratings of 100 or less indicate that shelter/cover enhancement should be considered.

Comments: The average mean pool shelter rating in the Inland Subbasin is 37.5. This is below the shelter target value for salmonids.

Large Woody Debris

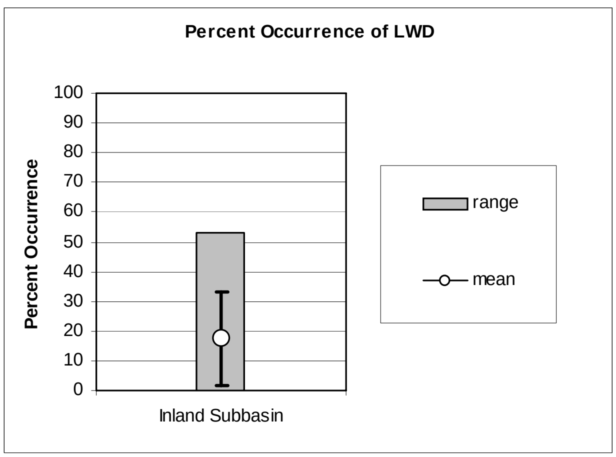


Figure 149. Large Woody Debris (LWD) in the Inland Subbasin.

Error bars represent the standard deviation. The percentage of shelter provided by various structures (i.e. undercut banks, woody debris, root masses, terrestrial vegetation, aquatic vegetation, bubble curtains, boulders, or bedrock ledges) is described in CDFG surveys. The dominant shelter type is determined and then the percentage of a stream reach in which the dominant shelter type is provided by organic debris is calculated.

Significance: Large woody debris shapes channel morphology, helps a stream retain organic matter, and provides essential cover for salmonids. There are currently no target values established for the percent occurrence of LWD.

Comments: This subbasin has the lowest average percent occurrence of large woody debris in surveyed streams of the Big River Subbasins. The dominant shelter type recorded in almost 32% of the stream reaches surveyed was boulders. LWD was the dominant shelter recorded in 19% of stream reaches surveyed.

Although instream habitat conditions for salmonids varied across the Inland Subbasin, several generalities can be made. Instream habitat conditions were generally good within this subbasin at the time of CDFG surveys. Canopy density levels were above 50% and cobble embeddedness was suitable for salmonids in over one-half of the surveyed stream lengths in the subbasin. However, the percentage of primary pools by survey length was generally below target values as found in CDFGs *California Salmonid Stream Habitat Restoration Manual* and calculated by the EMDS. Additionally, the percent occurrence of large woody debris was in the lower range of values recorded in the Big River Basin. In addition, dry channel occurred in 3.1 miles of surveyed stream (2.9% of the surveyed stream length) and the Inland Subbasin had the highest percentage of estimated historic coho habitat blocked by artificial barriers in the Big River Basin.

Stream Reach Conditions EMDS

The anadromous reach condition EMDS evaluates the conditions for salmonids in a stream reach based upon water temperature, canopy cover, stream flow, and in channel characteristics. Data used in the Reach EMDS come from CDFG Stream Inventories. Currently, data exist in the Big River Basin to evaluate overall reach, canopy, in channel, pool quality, pool depth, pool shelter, and embeddedness conditions for salmonids. More details of how the EMDS functions are in the EMDS Appendix. EMDS calculations and conclusions are pertinent only to surveyed streams and are based on conditions present at the time of individual survey.

EMDS stream reach scores were weighted by stream length to obtain overall scores for tributaries and the entire Inland Subbasin. Weighted average reach conditions on surveyed streams in the Inland Subbasin as evaluated by the EMDS are somewhat unsuitable for salmonids (Table 224, Figure 150). Suitable conditions exist for canopy across the subbasin except for James Creek; and for pool shelter in East Branch North Fork Big River, West Chamberlain Creek, Daugherty Creek, and Gates Creek. Suitable conditions exist for pool depth for North and South forks of Big River; and for embeddedness in ten creeks in the South Fork drainage. Unsuitable conditions exist for pool quality in all tributaries evaluated.

Six tributaries, North Fork Big River, Daugherty, Soda, Gates, Johnson (tributary to Gates Creek), and Snuffins creeks, had two years of data, 1993, 1995, or 1996 and 1997 or 2002. A comparison of the two years data shows an increase in the suitability of canopy and pool quality and a decline in the suitability of pool depth in North Fork Big River. The other five tributaries showed an increase in the suitability of pool quality, pool shelter, and cobble embeddedness. Suitability of canopy increased in Daugherty, Gates, and Johnson (tributary to Gates) creeks. Suitability of pool depth increased in Daugherty and Gates creeks.

Table 224. EMDS Anadromous Reach Condition Model results for the Inland Subbasin.

Stream		Reach	Water Temperature	Canopy	Stream Flow	In Channel	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Inland Subbasin		-	**U**	++	**U**	-	--	--	--	-
North Fork Big River	1996	-	**U**	-	**U**	-	-	+	--	-
	1997	-	**U**	+	**U**	-	--	--	--	-
East Branch of the North Fork Big River		-	**U**	+	**U**	-	-	---	++	--
Chamberlain Creek		-	**U**	+	**U**	-	---	---	---	-
Water Gulch		-	**U**	+++	**U**	-	--	--	-	-
Water Gulch Tributary		-	**U**	+++	**U**	-	---	---	---	-
Park Gulch		-	**U**	+++	**U**	-	--	---	-	-
West Chamberlain Creek		-	**U**	+++	**U**	-	-	---	+	--
Gulch Sixteen		-	**U**	+++	**U**	-	--	---	--	-
Gulch Sixteen Tributary		-	**U**	+++	**U**	-	--	---	--	-
Arvola Gulch		-	**U**	++	**U**	-	--	---	--	--
Lost Lake Creek		-	**U**	+++	**U**	-	---	---	---	-
Soda Gulch		-	**U**	+++	**U**	-	---	---	---	---
James Creek		-	**U**	-	**U**	-	---	---	---	-
North Fork James Creek		-	**U**	++	**U**	-	--	---	-	-
South Fork Big River		-	**U**	++	**U**	-	-	+	--	+
Biggs Gulch		-	**U**	+++	**U**	-	---	---	---	+
Ramon Creek		-	**U**	+	**U**	-	--	---	--	-
North Fork Ramon Creek		-	**U**	+	**U**	-	--	---	--	++
Mettick Creek		-	**U**	+	**U**	-	---	---	---	+
Poverty Gulch		-	**U**	+	**U**	-	--	---	--	**U**
Anderson Gulch		-	**U**	+++	**U**	-	---	---	---	--
Boardman Gulch		-	**U**	+++	**U**	-	--	---	--	---
Halfway House Gulch		-	**U**	++	**U**	-	---	---	---	+++
Daugherty Creek	1993	-	**U**	-	**U**	-	--	---	--	--
	2002	-	**U**	++	**U**	-	-	--	+	+
Soda Creek	1995	-	**U**	++	**U**	-	---	---	---	-
	2002	-	**U**	++	**U**	-	--	---	--	++
Gates Creek	1993	-	**U**	++	**U**	-	---	---	---	--
	2002	-	**U**	+++	**U**	-	-	--	++	+
Johnson Creek (Gates Creek Tributary)	1993	-	**U**	++	**U**	-	---	---	---	---
	2002	-	**U**	+++	**U**	-	--	---	--	-
Horse Thief Creek		-	**U**	+++	**U**	-	---	---	---	**U**

Stream		Reach	Water Temperature	Canopy	Stream Flow	In Channel	Pool Quality	Pool Depth	Pool Shelter	Embeddedness
Snuffins Creek (2002)	1993	-	**U**	++	**U**	-	---	---	---	---
	2002	-	**U**	++	**U**	-	--	---	--	-
Johnson Creek		-	**U**	+	**U**	-	--	---	-	++
Dark Gulch		-	**U**	++	**U**	-	---	---	---	+
Montgomery Creek		-	**U**	++	**U**	-	---	---	---	--
South Fork Big River Tributary #1		-	**U**	+	**U**	-	--	---	--	-
South Fork Big River Tributary #2		-	**U**	++	**U**	-	--	---	--	--
Russell Brook		-	**U**	++	**U**	-	--	---	--	--
Martin Creek		-	**U**	++	**U**	-	---	---	---	-
Martin Creek Left Bank Tributary		-	**U**	+++	**U**	-	---	---	---	--
Martin Creek Right Bank Tributary #1		-	**U**	++	**U**	-	---	---	---	--
Martin Creek Right Bank Tributary #2		-	**U**	+++	**U**	-	--	---	--	---
Valentine Creek		-	**U**	++	**U**	-	---	---	---	-
Rice Creek		-	**U**	++	**U**	-	--	---	--	--

Key:
+ ++ +++ Highest Suitability
U Insufficient Data or Undetermined
- -- --- Lowest Suitability

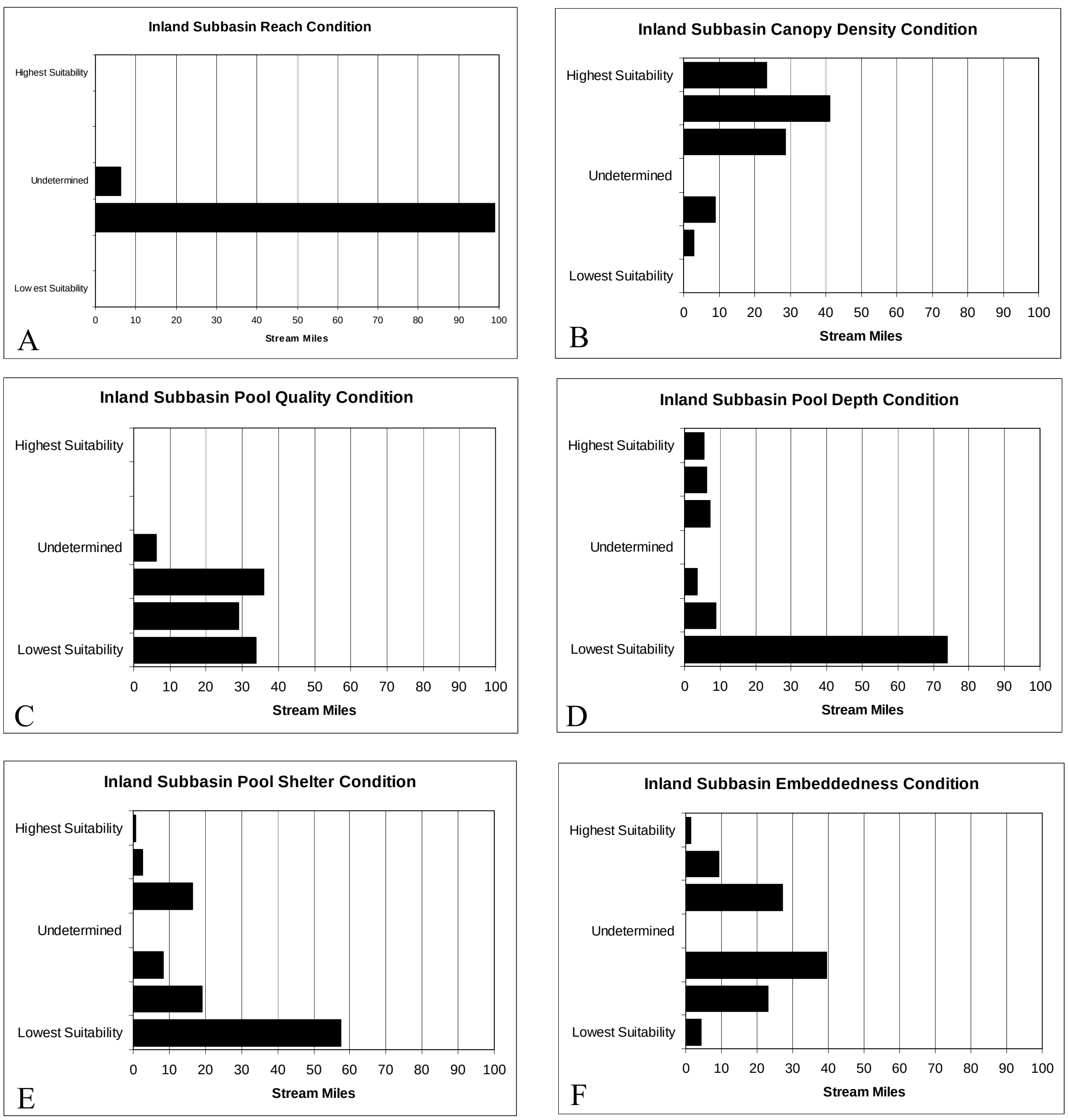


Figure 150. EMDS Reach Condition model results for the Inland Subbasin by surveyed stream miles.
In streams with multiples years of data, the most current year was used.
A. Overall reach condition. B. Canopy density. C. Pool quality. D. Pool depth. E. Pool shelter. F. Cobble embeddedness.

Analysis of Tributary Recommendations

CDFG inventoried 105.1 miles on 41 tributaries in the Inland Subbasin. A CDFG biologist selected and ranked recommendations for each of the inventoried streams (except for Poverty Gulch) based upon the results of these standard CDFG habitat inventories (Table 225). More details about the tributary recommendation process are given in the Big River Synthesis Section of the Basin Profile.

Table 225. Ranked tributary recommendations summary in the Inland Subbasin based on CDFG stream inventories.

Stream	# of Surveyed Stream Miles	Bank	Roads	Canopy	Temp	Pool	Cover	Spawning Gravel	LDA	Livestock	Fish Passage
North Fork Big River	12.0			2			1				
East Branch North Fork Big River	7.4	4	5	6	1	2	3				
Chamberlain Creek	5.1			2			1				
Water Gulch	1.9		2				1				
Water Gulch Tributary	0.4		2				1				
Park Gulch	1.0		2				1				
West Chamberlain Creek	3.5	3	4			1	2				
Gulch Sixteen	0.9		3			1	2				
Gulch Sixteen Tributary	0.4		3				2				1
Arvola Gulch	0.9	4	3		1		2		5		
Lost Lake Creek	0.9	3	4			1	2				
Soda Gulch	0.7		3				2		4		1
James Creek	4.4		2	4		3	1				
James Creek North Fork	2.4		3		1	4	2				
South Fork Big River Part 1	11.7	4	5	2	1	6	3		7		
South Fork Big River Part 2	8.8	2	3				4				1
Biggs Gulch	0.5	5				2		3	4		1
Ramon Creek	3.0	2		4		1			5		3
North Fork Ramon Creek	1.5	1	2			3			4		
Mettick Creek	1.0	1	2			3	4				
Anderson Gulch	0.5	1	2			3	4		5		
Boardman Gulch	1.3	1	2			3	4		5		6
Daugherty Creek	8.8			3		1	2				4
Soda Creek	1.7					1	2				
Gates Creek	2.7		1								
Johnson Creek (Gates Creek Tributary)	1.2	3				1	2				
Horse Thief Creek	0.1								1		
Snuffins Creek	1.3		3			1	2		4		
Johnson Creek	0.9	1		3	2	4	5		6		7
Dark Gulch	1.4		2	1	6	4			3		5
Montgomery Creek	0.7	1	2			3	4				5
South Fork Big River Tributary #1	1.1	2		1		3	4				5
South Fork Big River Tributary #2	0.6	2	3		1	4	5				
Russell Brook	4.1	1	2			4	6		3	5	
Martin Creek	3.7	1	2			4	5		3	6	7
Martin Creek Left Bank Tributary	0.6	1	2			3	4		5		
Martin Creek Right Bank Tributary #1	1.5	1				2	3		4		5
Martin Creek Right Bank Tributary #2	0.6	1				2	3		4		5
Valentine Creek	1.8	2	3		1	4	5		6		7
Rice Creek	1.8	2	3		1	4	5		6		7

Temp = summer water temperatures seem to be above optimum for salmon and steelhead; Pool = pools are below target values in quantity and/or quality; Cover = escape cover is below target values; Bank = 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 = there is evidence that stock is impacting the stream or riparian area and exclusion should be considered; Fish Passage = there are barriers to fish migration in the stream.

In order to further examine Inland Subbasin issues through the tributary recommendations given in CDFG stream surveys, the top three ranking recommendations for each tributary were collapsed into five different recommendation categories: Erosion/Sediment, Riparian/Water Temp, Instream Habitat, Gravel/Substrate, and Other (Table 226). When examining recommendation categories by number of tributaries, the most important recommendation category in the Inland Subbasin is Erosion/Sediment.

Table 226. Top three ranking recommendation categories by number of tributaries in the Inland Subbasin.

Target Issue	Related Table Categories	Count
Erosion / Sediment	Bank / Roads	44
Riparian / Water Temp	Canopy / Temp	15
Instream Habitat	Pool / Cover	41
Gravel / Substrate	Spawning Gravel / LDA	5
Other	Livestock / Barrier	5

However, comparing recommendation categories in the North Fork Subbasin by number of tributaries could be confounded by the differences in the number of stream miles surveyed on each tributary. Therefore, the number of stream miles in each subbasin assigned to the various recommendation categories was calculated (Figure 151). When examining recommendation categories by number of stream miles, the most important recommendation categories in the Inland Subbasin shift to Instream Habitat, Erosion/Sediment, and Riparian/Water Temp. These comprise the top tier of recommended improvement activity focus areas.

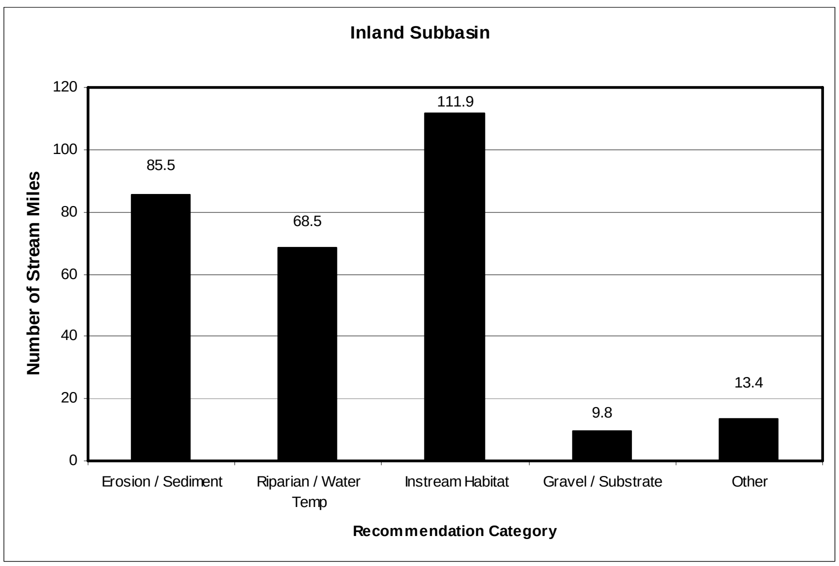


Figure 151. Recommendation categories by stream miles in the Inland Subbasin.

The high number of Instream Habitat, Erosion/Sediment, and Riparian/Water Temp recommendations across the Inland Subbasin indicates that high priority should be given to restoration projects emphasizing pools, cover, sediment reduction, and riparian replanting.

MRC Road Hazard Map

MRC classified the roads in their ownership into three erosion hazard classes (Figure 152). MRC aimed to identity current problems, consider reconstruction, and prioritize maintenance through this process. A brief summary of the erosion hazard classes is:

- High Road Erosion Hazard Class - Highest amount of recent deliverable surface erosion to watercourses and a high potential for future deliverable erosion;
- Moderate Road Erosion Hazard Class - Moderate amounts of recent deliverable surface erosion to watercourses and low potential for future deliverable erosion;
- Low Road Erosion Hazard Class - Low amounts of recent deliverable surface erosion to watercourses and low potential for future deliverable erosion.

MRC identified 23 high treatment immediacy point source erosion sites in their ownership in the Inland Subbasin (Table 227).

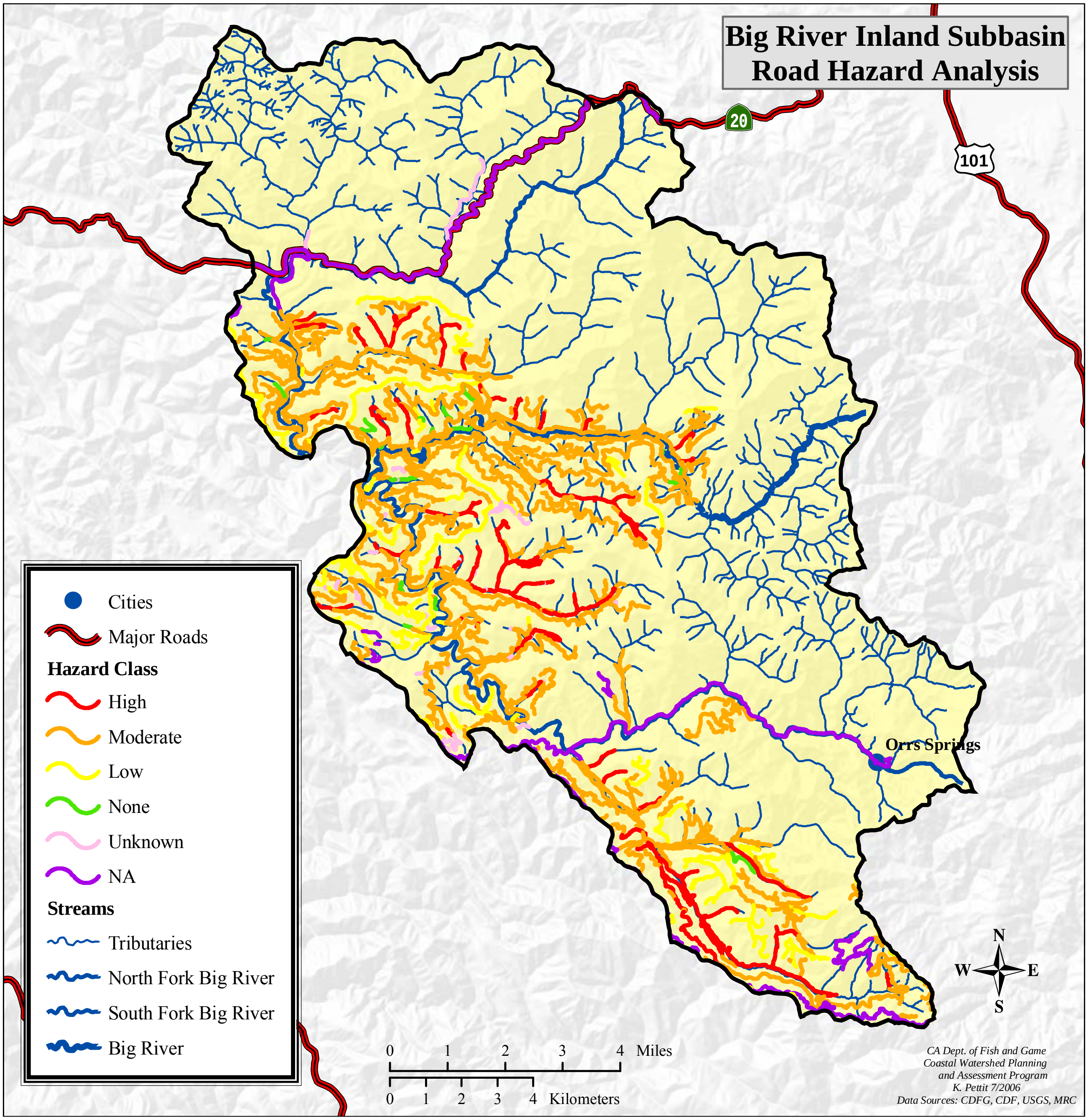


Figure 152. MRC roads erosion hazard classes in the Inland Subbasin.

Table 227. Select high treatment immediacy road sites within MRC ownership.

Site #	PW	Controllable Erosion (square yards)	Description
BL-1	Lower North Fork Big River	5	Plugged culvert
BE-1	East Branch North Fork Big River	40	Gully erosion
BE-2	East Branch North Fork Big River	21	Gully erosion
BE-3	East Branch North Fork Big River	4	Damaged culvert
BE-4	East Branch North Fork Big River	600	Diverted watercourse crossing
BE-5	East Branch North Fork Big River	28	Gully erosion
BE-6	East Branch North Fork Big River	100	Culvert failing
BE-7	East Branch North Fork Big River	138	Gully erosion
BR-1	Russell Brook	6	Gully erosion
BR-2	Russell Brook	5	Watercourse erosion
BM-1	Mettick Creek	1100	Fish barrier, failing culvert
BM-2	Mettick Creek	28	Road slide

Site #	PW	Controllable Erosion (square yards)	Description
BM-3	Mettick Creek	6	Gully erosion
BM-4	Mettick Creek	85	Plugged culvert
BM-5	Mettick Creek	18	Bridge crossing erosion
BM-6	Mettick Creek	26	Road slide
BM-7	Mettick Creek	27	Gully erosion
BM-8	Mettick Creek	32	Gully erosion
BS-1	South Daugherty	710	Road slide
BS-2	South Daugherty	65	Watercourse wash-out
BS-3	South Daugherty	85	Watercourse wash-out
BS-4	South Daugherty	105	Plugged culvert
BS-5	South Daugherty	58	Culvert starting to plug

MRC 2003

Refugia Areas

The NCWAP interdisciplinary team identified and characterized refugia habitat in the Inland Subbasin (Table 228) by using expert professional judgment and criteria developed for north coast watersheds. The criteria included measures 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. The team also used results from information processed by the NCWAPs EMDS at the stream reach scale.

The most complete data available in the Inland Subbasin were for tributaries surveyed by CDFG. However, many of these tributaries were still lacking data for some factors considered by the NCWAP team.

Salmonid habitat conditions in the Inland Subbasin on surveyed streams are generally rated as medium potential refugia. North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek, and Gates Creek provide the best salmonid habitat in this subbasin. Stream Donkey, Quail, Soda, and Poverty gulches provide low quality refugia. Additionally, the North Fork and South Forks Big River and Daugherty Creek serve as critical contributing areas. The following refugia area rating table summarizes subbasin salmonid refugia conditions.

Table 228. Tributary Salmonid Refugia Area Ratings in the North Fork Subbasin.

Stream	Refugia Categories*:				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
North Fork Big River		X				X	X
Stream Donkey Gulch				X			X
Dunlap Gulch			X				X
East Branch North Fork Big River		X					X
Quail Gulch				X			X
Bull Team Gulch		X					X
Frykman Gulch			X				X
Chamberlain Creek		X					X
Water Gulch		X					X
Water Gulch Tributary			X				X
Park Gulch				X			X
West Chamberlain Creek		X					X
Gulch Sixteen			X				X
Gulch Sixteen Tributary			X				X
Arvola Gulch		X					X
Lost Lake Creek			X				X
Soda Gulch				X			X
James Creek		X					X
James Creek North Fork			X				X
South Fork Big River		X				X	X
Biggs Gulch			X				X
Ramon Creek		X					X
North Fork Ramon Creek		X					X
Mettick Creek			X				X

Stream	Refugia Categories*:				Other Categories:		
	High Quality	High Potential	Medium Potential	Low Quality	Non-Anadromous	Critical Contributing Area/Function	Data Limited
Poverty Gulch				X			X
Anderson Gulch				X			X
Boardman Gulch			X				X
Halfway House Gulch			X				X
Daugherty Creek		X				X	X
Soda Creek		X					X
Gates Creek		X					X
Johnson Creek (Gates Creek Tributary)			X				X
Horse Thief Creek			X				X
Snuffins Creek		X					X
Johnson Creek			X				X
Dark Gulch		X					X
Montgomery Creek				X			X
South Fork Big River Tributary #1		X					X
South Fork Big River Tributary #2		X					X
Big River mainstem		X					X
Russell Brook		X					X
Pig Pen Gulch			X				X
Martin Creek		X					X
Martin Creek Left Bank Tributary			X				X
Martin Creek Right Bank Tributary #1		X					X
Martin Creek Right Bank Tributary #2			X				X
Valentine Creek		X					X
Rice Creek			X				X
Subbasin Rating			X				X

*Ratings in this table are done on a sliding scale from best to worst. See page 45 in the Program Introduction and Overview for a discussion of refugia criteria.

Responses to Assessment Questions

What are the history and trends of the sizes, range, and relative health and diversity of salmonid populations within the Inland Subbasin?

<u>Findings and Conclusions</u>

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast;
- Based on limited CDFG, USFWS, and MRC presence surveys and surveys documented by NMFS since the 1960s, the distributions of coho salmon and steelhead trout do not appear to have changed;
- More reaches surveyed by CDFG and MRC since 1990 had steelhead trout that coho salmon, and reaches with coho always had steelhead as well;
- Twenty-two tributaries and the mainstem Big River had records of coho salmon and steelhead trout since 1990. Seventeen additional tributaries also recorded only steelhead trout.

What are the current salmonid habitat conditions in this subbasin? How do these conditions compare to desired conditions?

Findings and Conclusions

Erosion/Sediment

- McNeil samples indicated that a significant amount of fine sediment may be entering the North Fork Big River either from James Creek, or between James Creek and Chamberlain Creek. This could indicate unsuitable conditions for salmonids;
- Turbidity and suspended sediment samples in ten locations across the basin showed values ranging from 1.6 NTU in James Creek to 811 NTU in South Fork Big River below the confluence with Daugherty Creek.

Riparian/Water Temperature

- Water temperatures at sites on Donkey House, Frykman, Steam Donkey, Goddard, No Name, Water, Johnston, Wildhorse, and Arvola gulches; Chamberlain, James, West Chamberlain, North Fork Ramon, Montgomery, and Martin creeks; Russell Brook; and East Branch North Fork, and North Fork Big River are suitable for salmonids;
- Water temperatures at sites on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks are unsuitable for salmonids;
- Sites that appear to have strong groundwater influences based on their thermographs include Goddard, Donkey House, No Name, Water, Frykman, Steam Donkey, Goddard Wildhorse, and Johnston gulches;
- Relatively large diurnal fluctuations in virtually all of the monitored sites throughout the South Fork drainage indicate that there is poor canopy and/or low flows. The only exceptions to this are the monitoring sites at Montgomery Woods Reserve, and the sites located in gulches that are apparently dominated by groundwater;
- Montgomery Creek was within the fully suitable range at approximately 60°F during all three years monitored. The maximum diurnal fluctuations varied between 4-5°F. This site is in an undisturbed location in the Montgomery Woods Reserve and is probably a good example of what can be achieved with adequate canopy in the warmer interior portion of the Big River Basin. It should be noted that much of the interior watershed is naturally grasslands, and could not reasonably be expected to achieve these water temperatures;
- It appears as though James Creek has a cooling effect on the North Fork Big River, Gates Creek provides some cooling effect to Daugherty Creek, Russell Brook contributes cooler water to the mainstem Big River, and Water Gulch and West Chamberlain Creek contribute some amount of cooling to Chamberlain Creek;
- Canopy cover was suitable for salmonids on all surveyed tributary reaches within this subbasin except for James Creek.

Instream Habitat

- A high incidence of shallow pools, and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in 21 out of 41 surveyed tributaries;
- Areas of dry channel found in 31 surveyed tributaries during CDFG surveys may indicate fish passage problems.

Gravel Substrate

- Cobble embeddedness values in 36 out of 41 CDFG surveyed tributaries were unsuitable for salmonid spawning success. In addition, the MRC characterized spawning gravels as fair quality on 32 segments surveyed and good quality on four;
- Permeability sampling indicated low to moderate amounts of fine material at East Branch North Fork Big River, and significant fine material at Daugherty and Ramon creeks. This could indicate unsuitable conditions for salmonids in Daugherty and Ramon creeks.

Refugia Area

- Salmonid habitat conditions in this subbasin on surveyed streams are generally rated as medium potential refugia;
- North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek provide the best salmonid refugia in this subbasin;
- The North Fork and South Forks Big River and Daugherty Creek serve as critical contributing areas.

Other

- Fish passage barriers exist on Dark Gulch, Johnson Creek, an Unnamed tributary to the South Fork of the Big River, Gulch Sixteen Tributary, and Soda Gulch;
- On February 27, 2001 a tanker truck containing approximately 7,000 gallons of used motor oil and diesel overturned on highway 20 and discharged numerous petroleum compounds into James Creek. However, this event was episodic and is in active cleanup. Because of the active cleanup and frequent verification monitoring, this spill is unlikely to have a sustained impact on fish and wildlife;
- A water quality sampling site on the South Fork Big River below the confluence with Daugherty Creek had specific conductance and total dissolved solids measurements that were relatively high compared to Basin Plan water quality objectives;
- Limited water quality data from Chamberlain Creek indicated that specific conductance was at or slightly below Basin Plan standards. Several other water quality parameters, including aluminum, copper, sodium, and zinc exceeded their respective criteria. Given the limited nature of this sampling effort and uncertainties about the method and exact location of sampling, it is suspected that this does not represent actual in-stream water quality but possibly water quality at some point in the drinking water system;
- Sodium was detected at concentrations above the water quality criteria at the North Fork Big River;
- Ammonia samples collected in the North Fork and South Forks Big River indicated that ammonia did not exceed the numeric criteria in either site;
- The two samples of boron and sodium in the South Fork Big River exceeded their numeric criteria. In the case of boron, both samples also equaled or exceeded the DHS action level (1,000 µg/l) and agricultural use criteria (700-750 µg/l).

What are the impacts of geologic, vegetative, fluvial, and other natural processes on watershed and stream conditions in this subbasin?

Findings and Conclusions

- Many of the tributaries in this subbasin are intermittent in their upper reaches and usually have summer and fall flows less than 1 cfs;
- This subbasin is mostly underlain by Franciscan Coastal Belt geology. This portion of the Franciscan complex is relatively stable compared to the mélange terrane of the Central Belt, which is found only in the upper parts of this subbasin. A small portion of Tertiary age sandstone is found in the Greenough Ridge - Montgomery Woods State Reserve area;
- This subbasin has a high percentage of area in higher slope classes;
- About 77% of the slides found across the Big River Basin and 80% of sediment delivered in the basin were in this subbasin. The South Daugherty Creek PW had the highest number of slides while the Chamberlain Creek PW had the highest volumes of sediment delivered;
- Redwood and Douglas fir forest has historically and continues to dominate this subbasin. Additional vegetation includes grass, oak, bay laurel, tan oak, madrone, and alder. Pre-European forests consisted of mostly large old-growth trees. Today, trees averaging 12-24 inches dbh cover 65% of the subbasin and trees averaging greater than 24-inch dbh cover 28%;
- The North Fork Big River was the studied major channel least impacted by stream disturbance features between 1984 and 2000. Only 8.3% of the blue-line stream length was impacted in 1984 and 7.6% in 2000;

- The South Fork Big River improved from nearly 19% of the blue-line stream length impacted in 1984 to less than 12% in 2000;
- Daugherty Creek showed the greatest improvement in channel conditions between 1984 and 2000. In 1984, nearly 24% of the length of Daugherty Creek was impacted, including parts of the headwaters channel with a gradient above 10%. This suggests recent disturbance, probably in 1983. In 2000 less than 6% of the blue-line channel was impacted, mostly in the lower half of the tributary in reaches having gradients below 4%.

How has land use affected these natural processes?

Findings and Conclusions:

- Twenty-four splash dams throughout the subbasin likely greatly accelerated erosion and widened the width of the channels in stream channels in this subbasin. Post-splash damming channels are deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD. South Fork Big River is still heavily incised from flushing logs;
- Early splash damming and barrier removal projects in the JDSF starting in the 1950s cleared many stream channels of timber-related woody debris. The lack of instream complexity seen today likely results from these past practices;
- Appropriative water right permits exist for a total of about 8.5 acre-feet per year of water from the South Fork Big River or an unnamed tributary to the South Fork;
- Construction of near stream roads throughout this subbasin and railroads along the North Fork Big River constricted stream channels and destabilized streambanks;
- Roads and timber harvesting are listed in the Total Maximum Daily Loads as major sources of human-related sediment into the fluvial system. Many of the effects from these activities are spatially and temporally removed from their upland sources;
- County culverts located on Dark Gulch, Johnson Creek, and an unnamed tributary to the South Fork of the Big River have been identified as total salmonid passage barriers by a Mendocino County roads study;
- Historic timber harvest activities reduced riparian canopy; however, canopy is currently suitable along most surveyed tributary reaches in this subbasin. Streams with canopy densities under 70% by length were Poverty Gulch, South Fork Tributary #1, James Creek, and North Fork Big River;
- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in pre-European times (66% of trees in watercourse buffer zones have dbh less than 24 inches). The small diameter of near stream trees across this subbasin limits the recruitment potential of large woody debris to streams and contributes to the lack of instream habitat complexity;
- A lack of LWD also allows sediment to move more quickly through the stream system and move downstream in greater quantities than pre-disturbance.

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

- Based on the information available for this subbasin, it appears that salmonid populations are currently being limited by reduced habitat complexity, high water temperatures, low summer stream flows, embedded spawning gravels, and artificial passage barriers.

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

Recommendations:

Flow and Water Quality Improvement Activities

- Protect instream flows in James Creek, Chamberlain Creek, East Branch North Fork Big River, Montgomery Creek, and Russell Brook for thermal refugia from the warmer North and South Forks and mainstem Big River in the summer;

- Ensure that adequate streamside protection measures are used to provide shade canopy and reduce heat inputs to the North and South Forks Big River, mainstem Big River, and Daugherty Creek.

Erosion and Sediment Delivery Reduction Activities

- Continue efforts such as road improvements, and decommissioning throughout this subbasin to reduce sediment delivery to Big River and its tributaries. CDFG stream surveys indicated Water Gulch, Water Gulch tributary, Park Gulch, Gulch Sixteen, Gulch Sixteen Tributary, Arvola Gulch, Soda Gulch, James Creek, North Fork James Creek, South Fork Big River, North Fork Ramon Creek, Mettick Creek, Anderson Gulch, Boardman Gulch, Gates Creek, Snuffins Creek, Dark Gulch, Montgomery Creek, South Fork Big River Tributary #2, Russell Brook, Martin Creek, Martin Creek Left Bank Tributary, Valentine Creek, and Rice Creek have road sediment inventory and control as a top tier tributary recommendation;
- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks in the Chamberlain Creek PW, South Fork drainage, and the headwaters drainage.

Riparian and Instream Habitat Improvement Activities

- Consider adding pool enhancement elements (e.g. LWD) to increase the number of pools or deepen existing pools and add shelter complexity to all surveyed tributaries in the North Fork drainage, Daugherty, Soda, Johnson (tributary to Gates Creek), and Snuffins creeks, and the right bank tributaries of Martin Creek;
- Consider modifying debris accumulations in Horse thief Creek, Dark Gulch, Russell Brook, and Martin Creek to facilitate fish passage;
- Ensure that this high quality habitat is protected from degradation. The highest stream reach conditions as evaluated by the stream reach EMDS and refugia analysis were found in the North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, Water Gulch, West Chamberlain Creek, Arvola Gulch, South Fork Big River, Daugherty Creek and Gates Creek.

Education, Research, and Monitoring Activities

- Continue water temperature monitoring at current locations where high temperatures have been detected on the mainstem Big River, North and South Forks Big River, James, Gates, Martin, Ramon, and Daugherty creeks;
- Conduct a stream habitat survey of the mainstem Big River upstream from the confluence with North Fork Big River.

Subbasin Conclusions

The Inland Subbasin is the largest of the Big River Subbasins. Additionally, land use impacts in this subbasin occurred later in time than the other two subbasins due to its location further inland, away from easy ocean access. Much of this subbasin is owned and managed by the JDSF and large timber companies. Salmon and steelhead habitat conditions in the Inland Subbasin are generally degraded, but support some salmonid production. Salmonid populations are currently being limited by reduced habitat complexity, high water temperatures, low summer stream flows, embedded spawning gravels, and artificial passage barriers. However, historical accounts indicate that stream conditions were favorable for salmonid populations in the past.

There are many opportunities for improvements in stream conditions in this subbasin as well as a great need to restore areas of stream refugia. Surveys by landowners, water temperature monitoring, riparian canopy restoration, improvements to channel complexity such as additional LWD are examples of such opportunities. The stability and erosiveness of terrain should be considered before project implementation and appropriate BMPs should be followed to minimize erosion and sediment delivery to streams. Conditions beneficial to salmonids may be further enhanced in this subbasin through encouraging all motivated subbasin landowners to use good land stewardship practices and enlisting the aid and support of agency technology, experience, and funding opportunities.

Big River Basin in the Regional Context

The Big River Basin is a fairly small watershed located on the Mendocino coast, far from major metropolitan areas. The 2000 Census counted just over 500 people in the basin and most of the land is owned by large timber companies or in public ownership. The predominant landuse both historically and currently is timber harvest. Much of the basin has been harvested multiple times. Prior to 1920, 27 splash dams were used across the basin and these impacted all downstream channels. However, historical accounts indicate that the coho salmon and steelhead trout in the Big River Basin appeared to begin declining in the 1950s. This could indicate that the watershed impacts from tractor logging were more related to the salmonid decline than splash damming. Current salmonid populations appear to be limited by poor quality summer rearing and overwintering habitat due to reduced habitat complexity, high water temperatures in the mainstem Big River, low summer stream flows in tributaries in the Inland Subbasin, embedded spawning gravels, and artificial passage barriers. Landowners have shown great interest in recovering the fisheries resources of the basin and restoration projects on both public and private lands hold much promise for the future.

Summary of Basin Conditions and Recommendations

Geology

- The Big River Basin is primarily comprised of Coastal Belt Franciscan Complex, which is relatively stable compared to the mélange terrane of the Central Belt found only in the upper parts of the watershed;
- The Coastal and Middle subbasins have lower relief and longer slopes while the Inland Subbasin has a high percentage of area in higher slope classes;
- Steep slopes, weathered and fractured marine sedimentary rock, tectonic activity, locally thick colluvial soils, a history of timber harvest practices, and the occurrence of high intensity rainfall events combine to make mass wasting a common occurrence in the Big River Basin;
- A study of landslides on MRC ownership within the basin, which comprises 29% of the basin, found that the vast majority of landslides occurred on slopes greater than 60%, and few landslides on lower gradient slopes were not triggered by roads or skid trails.

Land Use Impacts

- Roads, timber harvesting, and grasslands are listed in the Total Maximum Daily Loads as major sources of human-related sediment into streams;
- There has been a significant increase in road building since 1989 across the basin, especially in the Coastal and Middle subbasins. However, new roads have been built to higher standards, on ridge-tops, and are paved; thus creating less of a sediment source;
- Construction of near stream railroads in the Coastal and Middle subbasins and North Fork Big River and roads throughout the basin constricted stream channels and destabilized streambanks;
- Studies in the basin have indicated that over half of the shallow-seated landslides are associated with roads and that these landslides contributed sediment to watercourses in the study period of 1970 to 2000;
- Over 40 years of splash dam logging across the basin before 1920 led to stream channels that are deeply entrenched, cut down to bedrock in many places, lacking functional floodplains, and depleted of LWD;
- As a result of timber harvest, the current landscape is comprised of smaller diameter forest stands than in the past; this limits the recruitment potential of large woody debris to streams and contributes to a lack of instream habitat complexity.

Water Quality

- Water temperatures at monitoring sites in the mainstem of the Big River and larger tributaries in the Inland Subbasin such as the North and South forks Big River were unsuitable for salmonids. Temperatures Coastal and Middle tributaries were generally suitable for salmonids.

Salmonid Populations

- Both historic and current data are limited. Little data are available on population trends, relative health, or diversity. According to NOAA Fisheries listing investigations, the populations of salmonids have likely decreased in the Big River Basin as they have elsewhere along California and the Pacific Coast;
- Based on limited CDFG, USFWS, HTC, MRC, and SONAR presence surveys and surveys documented by NMFS since the 1960s, the distributions of coho salmon and steelhead trout do not appear to have changed;
- More reaches surveyed by CDFG and MRC since 1990 had steelhead trout that coho salmon;
- Thirty tributaries, the mainstem Big River, and the estuary had records of coho salmon and steelhead trout since 1990. Twenty additional tributary also recorded only steelhead trout.

Salmonid Habitat

- Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins;
- Several reaches where fine sediment data have been collected indicate that levels are high and conditions may be unsuitable for salmonids;
- Cobble embeddedness in spawning gravels in many surveyed tributaries across the basin indicated that conditions were unsuitable for salmonid spawning success. In addition measured permeability in spawning areas in Daugherty and Ramon creeks indicated significant amounts of fine materials;
- Canopy cover was suitable for salmonids on all surveyed reaches within the basin except for James Creek and the mainstem Big River. As a larger order stream, the mainstem Big River is expected to have lower canopy levels;
- In general, a high incidence of shallow pools, and a lack of cover and large woody debris have contributed to a simplification of instream salmonid habitat in surveyed tributary reaches and the estuary;
- Fish passage barriers have been identified in seven surveyed tributaries across the basin and small tributaries along the estuary are blocked to fish passage by perched culverts. Additionally, areas of dry channel in some tributaries in the drier summer months may indicate fish passage problems.

Limiting Factors Analysis Conclusions

Based on available information for the Big River Basin, the team believes that current negative salmonid habitat conditions include:

- Reduced habitat complexity;
- High water temperatures in the mainstem Big River;
- Low summer stream flows in tributaries in the Inland Subbasin;
- Embedded spawning gravels;
- Fish passage barriers.

Refugia Rating

Based on this assessment of watershed processes and conditions, fishery status, and current salmonid habitat, the Big River Basin has medium potential as refugia for salmon and steelhead trout. Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins.

Recommendations

Flow and Water Quality Improvement Activities

- Protect instream flows in tributaries with cooler water temperatures for thermal refugia from the warmer North and South Forks and mainstem Big River in the summer;
- To minimize and reduce the effects of water diversions, take actions to improve SWRCB coordination with other agencies to address season of diversion, off-stream reservoirs, bypass flows protective of coho

salmon and other anadromous salmonids and natural hydrograph, and avoidance of adverse impacts caused by water diversion;

- Land managers should work to reduce the temperature of water flowing into the Middle and Coastal subbasins. In order to do this, they should maintain and/or establish adequate streamside protection zones to increase shade and reduce heat inputs to Big River and its tributaries throughout the basin;
- Follow the procedures and guidelines outlined by NCRWQCB to protect water quality from ground applications of pesticides.

Erosion and Sediment Delivery Reduction Activities

- To reduce sediment delivery to Big River, land managers should continue their efforts such as road improvements, good maintenance, and decommissioning and other erosion control practices associated with landuse activities throughout the basin. Thirty-six CDFG stream surveys had road sediment inventory and control as a top tier tributary recommendation;
- Support and encourage existing and active road management programs undertaken by landowners throughout the basin;
- Sediment sources from eroding streambanks and adjacent hillslopes should be identified and treated to reduce sediment generation and delivery to creeks;
- Map unstable soils and use soil mapping to guide land-use decisions, road design, THPs, and other activities that can promote erosion;
- Limit winter use of unsurfaced roads and recreational trails by unauthorized and impacting uses to decrease fine sediment loads;
- Develop erosion control projects similar to the North Fork Ten Mile River erosion control plan (Mendocino Department of Transportation 2001).

Riparian and Habitat Improvement Activities

- Improve instream structure for juvenile ambush escape and cover, including the addition of LWD to develop habitat diversity and to increase shelter complexity, where appropriate/feasible. Thirty-one CDFG stream surveys and the mainstem Big River have increase escape cover as a top tier tributary recommendation. In addition, there is a need to leave large wood on stream banks and in estuarine channels for potential recruitment into stream channels and the estuary;
- Maintain and improve existing riparian cover where needed;
- Ensure that any land management activities include protection and preservation of stream and riparian habitats and maintain or improve ecological integrity within the basin;
- Consider modifying debris accumulations to facilitate fish passage where necessary;
- Adequately fund prioritization and upgrading of culverts to provide coho salmon passage within the range of coho salmon and to pass 100-year flows and the expected debris loads;
- Ensure that high quality habitat is protected from degradation. Salmonid habitat conditions in the Big River Basin are generally best in the Coastal Subbasin, and mixed in the Middle and Inland subbasins;
- Consider the use of management strategies such as conservation easements to maximize potential benefits to aquatic habitats from near-stream forest protection.

Education, Research, and Monitoring Activities

- State Parks, DFG, MRC, and HTC should continue and expand existing monitoring of anadromous salmonid populations to include some winter and spring fish sampling;
- Support stream gage installations and maintenance to establish a long term record of Big River hydrologic conditions;
- Additional investigations of the physical characteristics of Big River are needed to re-evaluate the Sediment Source Analysis. A regional curve of bankfull dimensions vs. drainage area should be developed for Mendocino County and used to validate CGS (2004) bankfull discharge estimates for Big River;

- Hillslope and in-stream monitoring proposed by the MRC in their Watershed Analysis (2003) should be carried out and additional monitoring programs throughout the basin should planned with respect to be comparable to MRC techniques;
- A study examining how sediment plugs moved downstream from historic splash dam locations over time on air photos is recommended;
- Continue water temperature monitoring at current locations and expand these efforts where appropriate;
- Further study of timberland herbicide use is recommended.

Propensity for Improvement

Advantages

The Big River Basin has several advantages for planning and implementing successful salmonid habitat improvement activities that include:

- An expanding group of cooperative landowners that includes both public and private landowners from all thee subbasins in the Big River that are interested in improving watershed and fishery conditions. The effect of this is the ability to choose locations for projects where the best result can be achieved in the shortest time period;
- The recent purchase of a large portion of the estuary and transfer to the State of California for management as a park also will likely improve temperature and sediment conditions in that area of the Big River Basin;
- Much Of the basin is in the ownership of a few large landowners, making the creation and implementation of a coordinated basin-wide watershed program simpler;
- This assessment provides focus on watershed conditions and processes from the basin scale, through the subbasin scale, and down to the level of specific tributaries. This helps focus project design efforts so that local landowners can pursue the development of site specific improvement projects on an adaptive basis;
- Like most river systems, Big River coho salmon and steelhead trout meta-populations have evolved and adapted to the basin's unique conditions. Although these meta-populations are likely below historic levels, there remain local stocks that can take advantage of improved conditions.

Challenges

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

- Not all landowners are interested in salmonid habitat improvement efforts. Without a watershed wide cooperative land-base, treatment options are limited. In some cases this can remove some key areas from consideration of project development;
- Current levels of coho salmon and steelhead meta-populations could limit the amount of needed straying to rapidly colonize fish into improved or expanded habitat conditions.

Conclusion

The likelihood that any North Coast basin will react in a responsive manner to management improvements and restoration efforts is a function of existing watershed conditions. In addition, the status of processes influencing watershed condition will affect the success of watershed improvement activities. A good knowledge base of these current watershed conditions and processes is essential for successful watershed improvement.

Acquiring this knowledge requires property access. Access is a requirement to design, implement, monitor, and evaluate suitable improvement projects. Thus, systematic improvement project development is dependent upon the cooperative attitude of resource agencies, watershed groups and individuals, and landowners and managers.

The Big River assessment has considered a great deal of available information regarding watershed conditions and processes in the basin. This long assessment process has identified problems and made recommendations to address them while considering the advantages and challenges of conducting watershed improvement programs in the Big River Basin.

After considering these problems, recommendations, advantages and challenges, the Big River Basin appears to be an excellent candidate for a successful long-term, programmatic watershed improvement effort. According to the current refugia analysis, the Big River has medium potential to become a basin with high quality fishery refugia. Reaching that goal is dependent upon the formation of a well organized and thoughtful improvement program founded on broad based community support for the effort.

Limitations of this Assessment

This watershed assessment provides useful and valuable information and represents a considerable effort of the involved agencies, contractors, and public. It was limited in duration, scope, detail, and analysis level due to constraints in budget, time, access, and overall resources. Specific limitations are presented below to put the assessment in context.

- This assessment only addresses habitat conditions in the Big River Basin. Ocean habitat conditions are not addressed;
- Data collected from individual stream reaches or point locations within them were described in relation to their streams or subbasins. As descriptions and inferences are extrapolated from those data to larger regional and basin scales, the certainty associated with those conclusions and inferences is reduced;
- CGS produced GIS data and maps. Preliminary interpretations based on geologic and geomorphic data are presented herein;
- CDFGs habitat inventory surveys provided instream condition data to the EMDS Stream Reach Model, the Limiting Factors Analysis, and the Restoration Recommendations and Priorities. However, not all subbasin streams were surveyed. Basin wide 34.1% of the stream length was surveyed;
- A lack of information on the suitability and/or use of the estuarine habitat for rearing and over-wintering by juvenile salmonids;
- CDFs land use analysis used aerial photos exclusively;
- Monitoring of two water temperature sites on James Creek in 1994 was conducted by JSF. Although the raw data are not available, summary data such as MWAT and maximum temperature was reported (Valentine 1994). Neither of these sites appeared in the FSP data;
- Many of the water temperature data loggers were set to collect data at 120 or 144 minutes. Previous research (Lewis et al. 2000) suggests that monitoring intervals greater than 96 minutes may result in missing the instantaneous peak temperatures. Therefore, it is possible that the MWMT and overall maximum temperatures may be slightly understate these values;
- It is presumed that all of the monitoring locations, except the MWA sites, are representative of the conditions in their respective stream reaches. For example, for water temperature monitoring sites, it was assumed that the data loggers were placed in a location that was representative of the average summer water temperatures in their respective thermal reach. MWAs stated goal was to monitor thermal refugia for salmonids. Therefore, these temperature monitors were generally placed in deep pools and other areas where you would expect water temperatures to be lower than the average for the thermal reach;
- In many sites throughout the Big River Basin, jumps in water temperatures in excess of 4°F were observed in consecutive measurements. In no case was it determined that a data set should be excluded because of this temperature variation. In absence of any other abnormal data characteristics, it was hypothesized that the observed temperature jump was likely the result of sudden direct exposure to sunlight in the thermal reach. If this were the case, it would be naturally occurring and representative of stream conditions. However, study of these cyclical temperature increases should be undertaken to verify the cause;
- Only surface water quality was assessed. In the instances where the streams are “gaining” (receiving groundwater input), the surface water will be a combination of surface run-off and groundwater. Therefore, surface water quality was assessed under the assumption that any influence from groundwater

would appear in the overall surface water quality. Groundwater water quality data, if it exists, was not incorporated separately into this assessment;

- As mentioned previously, the bulk sediment sampling for both MRC and GMA were collected using a gravimetric technique, which can lead to significantly different results from the volumetric technique that the Big River TMDL target is based on. Furthermore, MRC reported the gravimetric fractions of the entire bulk sediment samples, while GMA only reported the subsurface fractions of the samples. Therefore, even through data from MRC and GMA was reportedly collected in a similar manner, the data may be skewed relative to each other;
- During the review of the raw water temperature data plots, it was noted that there were, in some cases, unusual diurnal fluctuations. Typically, these types of issues were resolved by comparing the periods of unusual fluctuations with the same period of record at other sites in the subbasin. By close inspection of other nearby sites, it was often discovered that while they do not exhibit such dampened diurnal fluctuations, they do show a similar pattern in the fluctuations. Data loggers that exhibited unusual diurnal fluctuations that appeared to be unresponsive to temperature changes in their respective subbasin would be indicative of equipment or battery failure. In the Big River Basin, only one data set was not used for this type of problem. This was the single season recorded at Lower Quail Gulch (MRC 75-20), which did not appear to respond to basin-wide temperature variations and may have malfunctioned. Additional years of data are needed at this site to determine if it is characteristic of the site or if it was indeed a malfunctioning unit. Any file that did not cover the period of June 21 to August 15 or by visual inspection appeared to miss the peak temperatures were flagged. In the Big River Basin, six such temperature files were not used because it was determined that the recorded period likely missed the peak temperatures;
- The EMDS model used is preliminary; not all components of the model are currently in use due to data and modeling issues (i.e., stream temperature, fish passage, stream flow); not all data layers used in the model were fully subjected to quality control review.

Appendices

Glossary

AGGRADATION: The geologic process in which streambeds, 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 stages 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 lay 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. For example, aircraft equipped with cameras capture images of the earth in air photos.

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: see watershed.

BED SUBSTRATE: The materials composing the bottom of a stream.

BENTHIC: The collection of organisms 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 streamside vegetation.

CANOPY COVER: The vegetation that projects over the stream.

CANOPY DENSITY: The percentage of the sky above the stream screened 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.

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: 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: Logjam. Accumulation of logs and other organic 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 in which stream beds and floodplains are lowered in elevation by the removal of material. It is the opposite of aggradation.

DEMOGRAPHY: The study of the characteristics of populations, such as size, growth, density, distribution, and vital statistics.

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 (m^3/sec), or cubic feet per second (cfs).

DISSOLVED OXYGEN (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 and temperature.

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 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: 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 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 water passage where the tide meets a river current.

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 or run habitat.

FLOOD: Any flow that exceeds the bankfull capacity of a stream or channel and flows out of 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 substances 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.

GENETIC DRIFT: The random change of the occurrence of a particular gene in a population.

GEOGRAPHIC INFORMATION SYSTEM (GIS): A collection of computer hardware, software, and geographic data used for capturing, managing, analyzing, and displaying all forms of geographically referenced information on the Earth's surface. Typically, a GIS is used to produce graphics (maps) on the screen or on paper to convey the results of analyses.

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.

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: 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.

HETEROZYGOSITY: The presence of different alleles at one or more loci on homologous chromosomes.

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.

INBREEDING: The breeding of related individuals within an isolated or a closed group of organisms.

INBREEDING DEPRESSION: The exposure of individuals in a population to the effects of deleterious recessive genes through matings between close relatives.

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.

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: A genus of the family salmonidae (salmons and trouts). 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: Photogrammetry is the technique of measuring objects (2D or 3D) from photographs or other digital imagery. May also be referred to as Remote Sensing.

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 size, 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.

RUBBLE: Stream substrate particles between 2.5 and 10 inches (64 and 256 millimeters) in diameter.

SALMONID: Fish of the family *Salmonidae*, including salmon, trout, chars, whitefish, ciscoes, and graylings.

SCOUR: The localized removal of material from the streambed 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.

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.

STREAM: (includes creeks and rivers): 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, spring, and 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: 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 streambed.

THREATENED SPECIES: 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.

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.

V*: Measures of percent sediment filling of a stream pool with deposits such as silt, sand, and gravel compared to the total volume.

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.

WETLAND: An area subjected to periodic inundation, usually with soil and vegetative characteristics that separate it from adjoining non-inundated areas.

List of Abbreviations

CalEPA	California Environmental Protection Agency
CCWPAP	California Coastal Watershed Planning and Assessment Program
CDF	California Department of Forestry and Fire Protection
CEMPR	Center for Manpower Resources
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFS	Cubic Feet per Second
CDFG	California Department of Fish and Game
DOC/CGS	California Department of Conservation-California Geological Survey
DPR	California Department of Parks and Recreation
DWR	California Department of Water Resources
EMDS	Ecological Management Decision Support
EPA	Environmental Protection Agency
ESA	Federal Endangered Species Act
ESU	Evolutionarily Significant Units
FRGP	Fishery Restoration Grants Program
FISRWG	Federal Interagency Stream Restoration Working Group
FPA	Z'Berg-Nejedly Forest Practice Act
GIS	Geographic Information System
GMA	Graham Mathews and Associates
HA	Hydrologic Area
HCP	Habitat Conservation Plan
HR	North Coast Hydrologic Region
HAS	Hydrologic Sub-area
HTC	Hawthorne Timber Company
HU	Hydrologic Unit
IA	Integrated Analysis
JDSF	Jackson State Demonstration Forest
LFA	Limiting Factor Analysis
LP	Louisiana Pacific Lumber Company
LWD	Large Woody Debris
MOU	Memorandum of Understanding
MRC	Mendocino Redwood Company, LLC
MWAT	Maximum Weekly 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
PW	Planning Watershed
RM	River Mile
SONAR	Mendocino High School of Natural Resources
SRP	Scientific Review Panel
SWRCB	California State Water Resources Control Board
TMDL	Total Maximum Daily Load
TPZ	Timber Production Zone
USFS	United States Forest Service
USGS	United States Geologic Survey
WMA	Watershed Management Area
WQO	Water Quality Objectives
WRIMS	State Water Resources Control Board Water Right Information System

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Spatial Data Availability, Catalog, Standards and Analyses

Data Availability

For GIS data associated with this report please contact the individual agencies listed below:

CaSIL – California Spatial Information Library (formerly Teale – Stephen P. Teale data center, State of California): http://gis.ca.gov/

CDF – California Department of Forestry and Fire Protection: www.fire.ca.gov

CGS – Department of Conservation, California Geological Survey: www.consrv.ca.gov/CGS

CWMC – California Watershed Mapping Committee: http://www.ca.nrcs.usda.gov/features/calwater

CWPAP – Coastal Watershed Planning and Assessment Program: http://www.coastalwatersheds.ca.gov

CDFG – California Department of Fish and Game: http://www.dfg.ca.gov

DOD – Department of Defense: http://www.defenselink.mil/

DWR – California Department of Water Resources: http://www.water.ca.gov/

FRAP – Forest Resource Assessment Program: http://frap.cdf.ca.gov/

NCRWQCB – North Coast Regional Water Quality Control Board: http://www.swrcb.ca.gov/rwqcb1/

RNSP – Redwood National and State Parks: http://www.nps.gov/redw

SSRRCD – Sotoyome-Santa Rosa Resource Conservation District: http://sotoyomercd.org/

USDA – United States Department of Agriculture: http://www.usda.gov/wps/portal/usdahome

USGS – United States Geological Survey: http://www.usgs.gov/

Spatial and Geographic Information Systems (GIS) Data Standards and Analyses

Data records were collected 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 that could be easily used 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 and base information disseminated to the public through the program would be in the following format (See data catalog 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. 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 (see http://support.esri.com/index.cfm?fa=knowledgebase.whitepapers.viewPaper&PID=43&MetaID=294 for more information). 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 form the USGS for the entire assessment 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 the integrated analyses section.