**California Regional Water Quality Control Board**
**North Coast Region**

# Assessment of Aquatic Conditions in the Mendocino Coast Hydrologic Unit

**September 7, 2001**

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# Chapter 1
# Introduction

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## 1.1 PURPOSE

The Assessment of Aquatic Conditions in the Mendocino Coast Hydrologic Unit provides an analysis of existing instream data in the Ten Mile River, Big River, Albion River and Gualala River watersheds. The Assessment is intended for use in the development of Total Maximum Daily Loads ("TMDLs") for these watersheds, specifically the problem statements and numeric targets. It is intended also to inform the implementation of the TMDLs once they are approved. Similar analyses have already been conducted in the Garcia River, Noyo River and Navarro River watersheds. An assessment of the aquatic conditions in these watersheds can be found in the *Garcia River Watershed Water Quality Attainment Strategy for Sediment* (Mangelsdorf and Lundborg 1997), the *Noyo River Watershed Total Maximum Daily Load for Sediment* (CWQCB 1999), and the *Navarro River Watershed Technical Support Document for Sediment and Technical Support Document for Temperature* (CWQCB 2000).

## 1.2 TOTAL MAXIMUM DAILY LOADS

Section 303(d) of the federal Clean Water Act[1] requires the development of TMDLs for pollutants impairing navigable waters throughout the nation. A TMDL is a calculation of the loading of a given pollutant that a waterbody can receive and still support the beneficial uses of the water. The U.S. Environmental Protection Agency ("U.S. EPA") has responsibility for identifying impaired waters and calculating the TMDL that will protect water quality and support beneficial uses. State agencies, such as the State Water Resources Control Board ("SWRCB") and the associated regional boards,[2] have responsibility for implementing water quality control programs that protect water quality and support beneficial uses. Historically, the SWRCB and the regional boards have proposed waters for listing as impaired (i.e., listing on the 303(d) list) to the U.S. EPA and have developed the TMDLs necessary to protect those impaired waters. The role of the U.S. EPA has been to review and approve the State proposals. As a result of legal action[3] the U.S. EPA entered into a consent decree that imposes a strict schedule for developing and approving TMDLs for several North Coast watersheds.

The North Coast Regional Water Quality Control Board ("Regional Water Board") staff developed a TMDL for the Garcia River watershed in 1998; but, the Regional Water

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[1] 33 U.S.C. §1251 et seq.

[2] There are nine Regional Water Quality Control Boards, including Region 1-- the North Coast Regional Water Quality Control Board -- in which the Mendocino Coast watersheds are located.

[3] Pacific Coast Federation of Fishermen's Associations v. Marcus, U.S. District Court for the Northern District of California, No. C-95-4474 MHP.

Board had not approved the TMDL prior to the March 1999 consent decree due date. As a result, the Regional Water Board workplan was modified and the U.S. EPA developed a TMDL for the Garcia River watershed that was promulgated to meet the deadline. Based on this experience, Regional Water Board staff and U. S. EPA developed a workplan that divides the technical development of TMDLs between the two agencies. U. S. EPA will take responsibility for finalizing and approving TMDLs for each of the watersheds included in the consent decree. Staff at the Regional Water Board will develop the technical basis for the Noyo River, Navarro River, and Gualala River TMDLs. U. S. EPA staff will develop the technical bases for TMDLs for the Ten Mile River, Big River and Albion River watersheds. Table 1.1 lists all the watersheds in the Mendocino Coast Hydrologic Unit that are currently listed as impaired waterbodies and the agency responsible for TMDL development.

**TABLE 1.1**
**TMDL SCHEDULE FOR MENDOCINO COAST WATERSHEDS**

| Watershed | Responsible Agency | Pollutant(s) | Due Date |
|---|---|---|---|
| Albion River | U. S. EPA | Sediment | 2001 |
| Big River | U. S. EPA | Sediment | 2001 |
| Garcia River[1] | Regional Water Board | Sediment | 1998 |
| Gualala River | Regional Water Board | Sediment | 2001 |
| Navarro River | Regional Water Board | Sediment and Temperature | 2000 |
| Noyo River[1] | Regional Water Board | Sediment | 1999 |
| Ten Mile River | U. S. EPA | Sediment | 2000 |

[1] NOTE: TMDLs for the Garcia River and Noyo River watersheds have been developed and approved.

## 1.3 MENDOCINO COAST HYDROLOGIC UNIT

The Mendocino Coast Hydrologic Unit is defined as that region of coastal streams in Mendocino and northern Sonoma Counties that drain to the Pacific Ocean from the Usal Creek drainage in the north to the Russian Gulch drainage to the south. It includes the following hydrologic areas:

- Rockport (including Ten Mile River)
- Noyo River
- Big River
- Albion River
- Navarro River
- Point Arena
- Garcia River
- Gualala River
- Russian Gulch

Each hydrologic area is further divided into watersheds and is named after the predominant watershed in the hydrologic area. The location of the Mendocino Coast Hydraulic Unit and its watersheds is shown in Map 1.1 (all maps are located at the end of this document).

## 1.4 ASSESSMENT OF AQUATIC CONDITIONS

TMDLs are required for watersheds in all but the Point Arena and Russian Gulch hydrologic areas in the Mendocino Coast hydrologic unit. TMDLs have already been developed and approved for the Garcia River and Noyo River watersheds. A TMDL for the Navarro River watershed was approved by the U.S. EPA in December 2000. The remaining 303(d) listed watersheds in the Mendocino Coast hydrologic unit (i.e., Ten Mile River, Big River, Albion River, and Gualala River watersheds) have been combined for simultaneous analysis to streamline data collection and analysis. Regional Water Board staff have collected and assessed instream data for the Ten Mile River, Big River, Albion River, and Gualala River watersheds. This report is the result of that assessment. U.S. EPA has responsibility for collecting and assessing the associated sediment source data for each of these watersheds (except the Gualala River watershed). Regional Water Board staff will conduct the source analysis for the Gualala River, in addition to the assessment for the Ten Mile River, Big River, Albion River, and Gualala River watersheds. This assessment and the source analyses for each of the watersheds will provide the technical basis for the development of TMDLs for the Ten Mile River, Big River, Albion River, and Gualala River watersheds.

# Chapter 2
# Overview of the Pacific Salmon Life Cycle and Habitat Requirements

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## 2.1 INTRODUCTION

Pacific salmonids are fish species in the family *Salmonidae*, including salmon, trout and char (Meehan 1991). There are both anadromous and nonanadromous (resident) salmonids. Anadromous fish are those that mature in the ocean but spawn in freshwater. Salmonids in the Mendocino Coast Hydrologic Unit include: chinook salmon (*Oncorhynchus tshawytscha* – also called king salmon), coho salmon (*O. kisutch* – sometimes called silver salmon), and steelhead trout (*O. mykiss* – formerly classified as *Salmo gairdneri*). Nonanadromous fish are those that mature and spawn in freshwater, such as rainbow trout, the nonanadromous version of steelhead trout.

The typical life cycle of anadromous salmonids includes the following stages, as described by Meehan (1991):

- Adults migrate to freshwater spawning grounds. The timing of migration depends on the species and race.
- The female builds several redds (gravel nests) and lays eggs over which the male ejects sperm.
- The fertilized eggs (embryos) hatch from the eggs as alevins in one to three months. The alevins emerge with yolk sacs and reside in the interstices of the gravel until they are ready to feed on macroinvertebrates in the water column.
- The alevins emerge from the gravel as fry in one to five months, generally in the spring or summer.

- The juvenile fish remain in freshwater from a few days to four years, depending on the species and locality.
- The juvenile fish move into the estuary, undergo "smoltification" then migrate to the ocean as smolts, generally in the spring or early summer. "Smoltification" is a process of physical change that allows a freshwater fish to survive in a saline environment.
- The smolt resides and grows in the ocean for one to four years before returning to it's natal stream for spawning.
- Steelhead trout do not invariably die after spawning, though Pacific salmon do.

Salmon populations regionally and statewide have significantly declined throughout the twentieth century (Brown et al. 1994, U.S. EPA 1999). NMFS listed coho salmon in the Southern Oregon/Northern California Coasts Evolutionary Significant Unit ("ESU") as threatened in 1997, under the federal Endangered Species Act ("ESA"). Chinook salmon in Northern California were listed as threatened by NMFS in the California Coastal ESU in 1999, and steelhead trout were listed as threatened in the Northern California Coast ESU in June 2000.[4]

The numbers of salmonids in the North Coast watersheds have been greatly reduced from historic levels. Brown et al. (1994) concluded that the reasons for the decline of coho salmon in California include: 1) stream alterations, brought about by land-use practices and by the effects of periodic floods and drought, 2) the breakdown of genetic integrity of native stocks, 3) introduced diseases, 4) over-harvest, and 5) climatic change. Of the factors that have contributed to the decline in salmonid populations, the most relevant to the beneficial uses in the basin are watershed changes and land management that results in impacts to freshwater habitat.

## 2.2 STATUS OF CALIFORNIA SALMNOIDS

### 2.2.1 CHINOOK SALMON

In February 1998, NMFS published a *Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California* (Myers et al. 1998). The following information is summarized from that report.

Chinook salmon are the largest of the Pacific salmon. The species distribution in North America historically ranged from the Ventura River in California to Point Hope, Alaska. Chinook salmon have a complex life history in which several different life history patterns are possible. For example, there are spring-, summer- and fall-run chinook salmon. Historically, fall-run chinook salmon were predominant in most coastal river systems south to the Ventura River. However, their current distribution in coastal streams only extends to the Russian River. There have also been spawning fall-run chinook salmon reported in small rivers draining into San Francisco Bay (Myers et al. 1998).

Chinook salmon populations south of Cape Blanco (Oregon) all exhibit an ocean-type life history. The majority of fish migrate to the ocean as subyearlings although the

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[4] The Federal Register listing decisions can be found at 61 FR 56138, 65 FR 36074 and 65 FR 42422.

proportion of fish which smolted as subyearlings vs. yearlings varies from year to year. This fluctuation in age at smoltification is more characteristic of an ocean-type life history. Furthermore, the low flows, high temperatures, and barrier bars that develop in smaller coastal rivers during the summer months would favor an ocean-type (subyearling smolt) life history (Myers et al. 1998).

### 2.2.2 COHO SALMON

In September 1995, NMFS published a report entitled *Status Review of Coho Salmon from Washington, Oregon, and California* (Weitkamp et al. 1995). The following information is summarized from that report.

The vast majority of adult coho salmon returning to freshwater spawn are three year-olds, having spent half of their lives in fresh water and half in the ocean. The primary exception to this pattern are “jacks” which are sexually mature males that return to freshwater to spawn after only five to seven months in the ocean. The production of jacks in a population is related to genetics and to environmental factors. Weitkamp et al. (1995) suggest that there is a latitudinal distribution in the proportion of jacks in a coho population, with the southern populations having more jacks than those in the north.

Most coho from the west coast return from the ocean to rivers in October and spawn from November to December and sometimes into January. Coho in the Mendocino Coast Hydrologic Unit generally enter rivers in late December or January, and spawn immediately afterwards. This short time in rivers as adults is probably in response to later peak river flows of limited duration. Consequently, Mendocino coastal fish spend little time between river entry and spawning, while northern stocks may spend one or two months in fresh water before spawning (Weitkamp et al. 1995).

Higgins et al. (1992) evaluated coho salmon population trends and characterized the coho runs in many watersheds in the Mendocino Coast Hydrologic Unit as at high or moderate risk of extinction or as a stock of concern (see the note in Table 2.1 for a definition of these terms). Higgins concluded that the coho runs in Pudding Creek, the Garcia River and the Gualala River have a high risk of extinction.

**TABLE 2.1**
**ASSESSMENT OF COHO SALMON STATUS (Higgins et al. 1992)**

| Watershed | Coho Salmon Status |
|---|---|
| Albion River | Stock of concern |
| Big River | Stock of concern |
| Garcia River | High risk of extinction |
| Gualala River | High risk of extinction |
| Navarro River | Stock of concern |
| Noyo River | Stock of concern |
| Pudding Creek | High risk of extinction |
| Ten Mile River | Stock of concern |

- Higgins used the categories and criteria described by Nehlsen et al. (1991).
- Stocks at high risk of extinction are those where spawning escapements are declining and stocks with fewer than 200 spawners.
- Stocks described as a stock of concern have low and unstable numbers, but there may be insufficient information on the actual population numbers, or the population may have higher spawner escapements but some specific threat is known that could cause severe population decline or loss.

Statewide in California, coho spawning escapement ranged between 200,000 and 500,000 adults per year in the 1940s (Brown et al. 1994). By the mid-1960s, statewide spawning escapement was estimated to have fallen to about 100,000 fish per year, followed by a further decline to about 30,000 fish in the mid-1980s (Weitkamp et al. 1995). This is a decline from the 1940s to the 1960s of 50 to 80% and from the 1960s to 1980s of 70%, for a total decline from the 1940s to the 1980s of 85 to 94%. From 1987 to 1991, spawning escapement averaged about 31,000, with hatchery populations comprising 57% of this total (Brown et al. 1994).

Specifically addressing the population abundance in the ESU that encompasses the Mendocino Coast watersheds, Weitkamp reported that the west coast Biological Review Team unanimously agreed that "…natural populations of coho salmon in this ESU are presently in danger of extinction. The chief reasons for this assessment were extremely low current abundance, especially compared to historical abundance, widespread local extinctions, clear downward trends in abundance, extensive habitat degradation and associated decreased carrying capacity, and a long history of artificial propagation with the use of non-native stocks. In addition, recent droughts and current ocean conditions may have further reduced run sizes."[5]

### 2.2.3 STEELHEAD TROUT

In August 1996, NMFS published a report entitled *Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California* (Busby et al. 1996). The following information is taken from that report.

Steelhead trout are ecologically complex. The steelhead status review (Busby et al. 1996) stated:[6]

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[5] Weitkamp et al. 1995, page vi.

[6] Busby et al. 1996, page 8.

> *Oncorhynchus mykiss* is considered by many to have the greatest diversity of life history patterns of any Pacific salmonid species (Shapovalov and Taft 1954, Barnhart 1986), including varying degrees of anadromy, differences in reproductive biology, and plasticity of life history between generations.

Steelhead are divided into two reproductive types, based on the state of sexual maturity at the time of river entry and on the duration of spawning migration (Busby et al. 1996). One type enters the stream in a sexually immature condition. These steelhead mature in freshwater and then spawn after several months. In northern California, this type is known as summer steelhead. The ocean-maturing steelhead (known as winter steelhead) are sexually mature when they enter freshwater and spawn shortly after entering freshwater. It appears that the summer steelhead occur where habitat is not fully utilized by winter steelhead; summer steelhead usually spawn farther upstream than winter steelhead (Busby et al. 1996). Coastal streams are dominated by winter steelhead.

In the 1960s, a total of 65,000 steelhead trout are estimated to have existed in the Mendocino Coast Hydrologic Unit (e.g., 9,000 from the Ten Mile, 8,000 from the Noyo, 12,000 from the Big, 16,000 from the Navarro, 4000 from the Garcia and 16,000 from the Gualala. Busby et al. (1996) give no current estimates.

## 2.3 SALMONID LIFE CYCLE REQUIREMENTS

This section draws heavily on two references that reviewed materials from many sources: Spence et al. 1996, *An Ecosystem Approach to Salmonid Conservation*, and Bjornn and Reiser 1991, *Habitat Requirements of Salmonids*. For more detailed information, the primary sources that are reviewed by these references should be examined.

The life cycle of salmonids can be broken into distinct life cycle stages, each with its own specific environmental requirements. The life cycle requirements are well understood for some life cycle stages and not as well understood for others. Much of what is known about some life cycle stages (e.g., spawning, incubation, and emergence) is gathered from laboratory tests. Other knowledge (e.g., rearing, outmigration, etc.) is gathered from field studies and observations. Specific habitat requirements may vary with the different salmonid species, different life stages, season, and ESU. Different species and different life cycle stages within a species may occur at different times of the year and different locations in a watershed. There are suitable habitat requirements associated with each life stage, and those requirements vary temporally and spatially. The temperature requirements, for example, of spawning coho (4.4 to 9.9 °C) are cooler than those that are preferred for juvenile rearing (11.8 to 14.6 °C), but those life stages take place at different times in different locations in stream.

The following discussion of habitat conditions is arranged into discrete chemical and physical requirements for each life stage. Such an arrangement could create an artificially simple view of the salmonid ecosystem when, in reality, the aquatic habitat requirements are connected, and form part of a complex riparian ecosystem that must be understood. As Spence et al. (1996) explain:[7]

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[7] Spence et al. 1996, page 1.

> Aquatic habitats critical to salmonids are the product of processes acting throughout watersheds and particularly within riparian areas along streams and rivers. This document depends on the premise that salmonid conservation can be achieved only by maintaining and restoring these processes and their natural rates.

McCullough (1999) also describes the importance of understanding the requirements of salmonids on a watershed level:[8]

> In the management of coldwater fish species, the greatest degree of expression of life history variation by species is achieved by restoration of the thermal regime on a stream system-wide basis, along with other pre-management conditions of channel morphology and the watershed. Moving the summer maximum temperature threshold upstream constricts the available spawning or rearing area of all coldwater fish species. Fish zonation from headwaters to downstream reaches in the Pacific Northwest can be characterized roughly as proceeding from bull trout/cutthroat trout to steelhead, to spring chinook/coho, to summer chinook, to fall chinook, to chum (Li et al. 1987). With the exception of bull trout, the other species do not vary substantially in their response to summer maximum temperature. However, they do vary in their preference for size of spawning and rearing stream, size of spawning gravel, and stream gradient tolerated. Increase in summer maximum temperature in headwater stream zones cannot occur without causing increase to downstream reaches. Constraining species more and more to compete in high gradient streams that may provide suitable water temperatures would severely limit production and impair survival in the majority of the historic habitat of each species, but further, it is not feasible energetically for large-stream species to occupy smaller, high gradient streams."

The habitat features that determine the suitability of a stream for salmonids include (Spence et al. 1996):

1. Flow regime – depth and velocity of water, total available habitat, sediment distribution, gravel flushing and movement, vegetation dispersal
2. Water quality – cool temperatures, high dissolved oxygen, natural nutrient concentrations, low levels of pollutants
3. Habitat structure – pools, riffles, substrate cover, depth, channel complexity
4. Food sources – maintain natural inputs of food and the habitat structures needed to retain food
5. Biotic interactions – competition, predator-prey, and disease-parasite interactions

In general, salmonids require cold water with low turbidity. Since salmonids are poikilothermic, water temperature has a fundamental effect on all of their life processes. Water temperature is a trigger for some changes in salmonid life stages. "Variation in temperature is required to trigger spawning, support growth, initiate smoltification, and enable other parts of the salmonid life cycle."[9] Water temperatures outside of the preferred ranges can cause lethal and sublethal effects. "Two important elements of temperature affect the growth and survival of fish: 1) the relationship between temperature, metabolism, and food conversion efficiency over long periods, and 2) the

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[8] McCullough 1999, Page 193.

[9] Spence et al. 1996, page 4.

thermal tolerance of fish to lethal temperatures over relatively short periods."[10] Some of the salmonid life cycle processes affected by temperature include: metabolism; food requirements (appetite and digestion); growth rates; development of embryos and alevin; timing of life history events (such as adult migration, fry emergence, smoltification); competitor and predator-prey interactions; disease-host and parasite-host interactions; and, the development of aquatic invertebrate food sources (Spence et al. 1996, McCullough 1999, Sullivan et al. 2000). McCullough (1999) explains that even within the range of tolerance, water temperatures may affect salmonid behavior and survival.

> Within temperature boundaries defined by the tolerance zone, swimming, metabolism, growth, food conversion efficiency, reproductive capacity, embryonic development, and aggregation of fishes (Brett 1970, Alderdice 1972; both as cited by Griffiths and Alderdice 1972) may all have different response fields and may each have an influence on survival and fitness.[11]

For cold water fish, such as salmonids, on the North Coast the critical temperature regime is associated with summer rearing because water temperatures during summer have been recorded routinely above the preferred range. The range of temperature requirements for coho salmon are shown in Table 2.2 and are discussed as they relate to individual life stages further in this chapter.

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[10] Sullivan et al. 2000, page 2-2.

[11] McCullough 1999, page 168.

**TABLE 2.2**
**TEMPERATURE REQUIREMENTS FOR COHO (Bjornn and Reiser 1991, Spence et al. 1996, McCullough 1999, Sullivan 2000)**

| Temperature (°C) | Adult Migration | Spawning | Egg & Alevin Incubation | Preferred Juvenile Rearing | Smoltification & Outmigration | Lethal Limits |
|---|---|---|---|---|---|---|
| 25 | | | | | | **Upper Lethal** |
| 24 | | | | | | |
| 23 | | | | | | **Cease Growth** |
| 22 | | | | | | |
| 21 | | | | | | |
| 20 | | | | | | |
| 19 | | | | | | |
| 18 | | | | | | |
| 17 | | | | | | |
| 16 | | | | | | |
| 15 | **15.6** | | | | | |
| 14 | ▨ | | | **14.6** | | |
| 13 | ▨ | | **13.3** | ▨ | | |
| 12 | ▨ | | ▨ | ▨ | **12** | |
| 11 | ▨ | | ▨ | **11.8** | ▨ | |
| 10 | ▨ | | ▨ | | ▨ | |
| 9 | ▨ | **9.4** | ▨ | | ▨ | |
| 8 | ▨ | ▨ | ▨ | | ▨ | |
| 7 | **7.2** | ▨ | ▨ | | ▨ | |
| 6 | | ▨ | ▨ | | ▨ | |
| 5 | | ▨ | ▨ | | ▨ | |
| 4 | | **4.4** | **4.4** | | **4.5** | |
| 3 | | | | | | |
| 2 | | | | | | |
| 1 | | | | | | **Lower Lethal** |
| 0 | | | | | | |

**The shaded areas refer to the upper and lower temperature range limits.**

Stream temperature also determines the amount of dissolved oxygen ("D.O.") that can be carried by a stream, with higher temperatures resulting in lower dissolved oxygen concentrations. Salmonids require well-oxygenated water. Spence et al. (1996) report that greater than 6 mg/l D.O. is a general requirement and that levels below saturation can be harmful.

Excess sediment in streams can affect salmonids at every life stage. Spawning and incubation are most directly affected by deposited sediments -- decreasing flow of water through the gravel interstices, thereby reducing the dissolved oxygen, raising the temperature, and physically blocking emergence of fry from the redd (Spence et al. 1996). Rhodes (1994) states, "The negative correlation of salmonid survival and production to fine sediment has been mainly attributed to reduced survival-to-emergence

(STE) and the loss of interstitial rearing habitat in channel substrate."[12] Bjornn and Reiser (1991) relate embeddedness to a reduction in salmonid biomass directly by interfering with the carrying capacity of the stream for fish and indirectly by reducing the aquatic invertebrates that are used for food. Suspended sediment can interfere with visual feeding and with predator interactions. Rhodes also discusses the indirect impacts of sediment on salmonids, "…the changes in channel conditions caused by changes in sediment delivery not only have multiple effects on salmon at several lifestages, but also affect the food web, and water quality conditions, such as water temperature and dissolved oxygen. … shifts in sediment loads set off a complex of channel responses including changes in channel gradient, sinuosity, pool volumes, pool frequency, channel width, channel cross-sections, channel network geometry, particle size distribution in stream substrate, bedload transport, and suspended sediment loads."[13]

Different metrics has been used to describe fine sediment impacts on salmonids – a measure of the percent of sediment less than a specified size is often used. Fines that impact embryo development are generally defined as particles that pass through a 0.85 mm sieve. The 0.85 mm size is an arbitrarily established value based on the available sieve sizes at the time of the initial studies in this area.

In a broad survey of literature reporting percent fines in unmanaged streams (streams without a history of land management activities), Peterson et al. (1992) found fines (<0.85 mm) ranging from 4% in the Queen Charlotte Islands to 28% on the Oregon Coast, with a median value for all the data of about 11%. Peterson et al. (1992) recommend the use of 11% fines (< 0.85 mm) as a target for Washington streams because the study sites in unmanaged streams in Washington congregated around that figure. None of the data summarized by Peterson et al. (1992) were from California.

Burns (1970) conducted three years of study in Northern California streams, including three streams he classified as unmanaged: Godwood and South Fork Yager creeks in Humboldt County and North Fork Caspar Creek in Mendocino County. He found a range of values for fines (< 0.8 mm) in each of these streams: 17 to 18% in Godwood Creek, 16 to 22% in South Fork Yager Creek, and 18 to 23% in Caspar Creek. Data collection for this study began a few years following big storms in 1964 that many conclude caused extensive hillside erosion and instream aggradation, the results of which are still observed today.

Some researchers have proposed the geometric mean particle size diameter as a metric by which to describe the substrate composition (Platts et al. 1979, Shirazi et al. 1981). When emergence from the gravel is plotted against the geometric mean of the particle size diameter [$d_g=(d_{16}d_{84})½$] the two are found to be related. Others have argued that the geometric mean can be similar for very different gravel mixtures because, for example, a large $d_{84}$ can offset a small $d_{16}$ (Tappel et al. 1983).

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[12] Rhodes 1994, page 6.

[13] Rhodes 1994, page 78.

The fredle index, developed by Lotspeich and Everest (1981) incorporates elements that integrate gravel permeability and pore size. It is calculated as $f_i=d_g/S_o$ where $S_o=(d_{75}/d_{25})^{½}$. Lotspeich and Everest (1981) relate the fredle index to survival-to-emergence of coho salmon and steelhead placed in laboratory mixes of gravels. Chapman (1988) used Tappel and Bjornn's (1983) data and also found a significant regression of survival on $f_i$ between $f_i$=1.0 and $f_i$=4.0.

Table 2.3 identifies the seven life cycle stages common to each of the salmonid species of concern. It also identifies potential impacts to salmonids at each life cycle stage and some of the potential sources of the impacts named.

**TABLE 2.3**
**SALMONID LIFE CYCLE STAGES AND POTENTIAL IMPACTS (from Bjornn and Reiser 1991 and Spence et al. 1996)**

| Life Cycle Stage | Potential Impacts | Potential Sources of Impact |
|---|---|---|
| **Adult Migration**<br>During migration from the ocean to natal streams adults require resting sites such as pools, suitable flows, minimum water depths and passage, and good water quality. | • Barriers that stop or impede access of adult fish to spawning grounds<br>• Water flow insufficient to allow adult migration and resting<br>• Physical harm<br>• Poor water quality | • Low flow conditions<br>• Sediment deltas or bars<br>• Log or debris jams<br>• Water supply dams<br>• Poorly engineered or maintained road crossings<br>• Over-fishing<br>• Predation<br>• Habitat changes that adversely affect water quality |
| **Spawning**<br>Spawning adults select spawning sites based on substrate quality, cover, water quality and water quantity. | • Absence of, or reduction in, appropriate substrate sizes<br>• Substrate embedded by fine sediment | • Mass wasting, including debris flows and stream bank failures<br>• Gully erosion<br>• Sheet and rill erosion<br>• Drought<br>• Loss or substantial loss of sediment storage capacity (e.g., removal or reduction in the availability of large woody debris)<br>• Habitat changes that adversely affect water quality |
| **Incubation and Emergence**<br>Successful incubation and emergence of fry from the gravel requires gravel substrate with good permeability and porosity, suitable dissolved oxygen and water temperature, and protection from scour and fill. | • Scouring or movement of redds<br>• Suffocation or substantial entombment of redds<br>• Substrate embedded or substantially embedded by fine sediment<br>• Poor water quality – low intragravel D.O., high water temperature | • Spring freshets<br>• Elevated peak flows<br>• Physical disturbance<br>• Fine sediment delivery and/or remobilization<br>• Habitat changes that adversely affect water quality |

**TABLE 2.3**
**SALMONID LIFE CYCLE STAGES AND POTENTIAL IMPACTS (from Bjornn and Reiser 1991 and Spence et al. 1996)**

| Life Cycle Stage | Potential Impacts | Potential Sources of Impact |
|---|---|---|
| **Summer Rearing**<br>After emergence from gravels, the fry of many salmonids occupy shallow waters along the margins of streams. As they grow in size, they move into deeper, faster water. Juvenile coho prefer pool habitats in the summer, whereas steelhead juveniles prefer riffle habitats in the summer. Juvenile chinook use faster waters (such as riffle and glide habitats) than juvenile coho. Backwaters and side channels are important salmonid rearing habitat. Juveniles require suitable flows and good water quality (including appropriate water temperatures and dissolved oxygen). | • Elevated stream temperatures<br>• Absence of or decline in the volume of rearing space (e.g., pools)<br>• Absence of or decline in the amount of shelter<br>• Absence of or decline in the amount of food<br>• Disease<br>• Poor water quality – low D.O., high water temperature | • Loss of or reduction in riparian vegetation, vegetation vigor, or complexity of community structure<br>• Loss of or reduction in deep water habitat<br>• Loss of or reduction in summer groundwater inflow<br>• Loss of or reduction in summer intragravel flow<br>• Delivery and/or remobilization of sediment to pools<br>• Loss of or substantial reduction in instream structural elements (e.g., large woody debris)<br>• Delivery and/or remobilization of fine sediment over aquatic macroinvertebrate habitat (e.g., gravels)<br>• Increase in the types or ferocity of diseases (e.g., via release of hatchery-raised fish)<br>• Habitat changes that adversely affect water quality |
| **Winter Rearing**<br>Juvenile coho prefer side channels and other off-channel habitat in the winter. Juvenile steelhead may move to pool habitat for the winter. Backwaters and side channels are important salmonid rearing habitat. Some salmonid species seek shelter from low water temperatures in substrate interstices. Juveniles require protection from high flows and good water quality (including appropriate water temperatures). | • Absent or limited off-channel habitat<br>• Absent or limited instream shelter (e.g., large woody debris)<br>• Elevated peak flows<br>• Increased stream flow velocities<br>• Poor water quality | • Disconnection of stream channel from floodplain<br>• Removal or reduction of large woody debris and other structural elements in the stream channel<br>• Modification of upslope hydrology (e.g., compacted soils, expanded surface drainage system, reduction in vegetation transpiration rate)<br>• Habitat changes that adversely affect water quality |
| **Juvenile Migration**<br>During migration from natal streams to the ocean, juveniles require "unobstructed (either physically or chemically) access to upstream and downstream reaches for migration or dispersal to feeding grounds." (Spence et al. 1996, page 102) Smolt migration is believed to be triggered by factors such as water temperature, photoperiod and changes in stream flow. Spence et al. (1996, page 104) report that "…alteration of thermal regimes | • Stop or impede access of fry to adequate shelter and food<br>• Stop or impede access of juveniles to the estuary and/or ocean<br>• Physical harm<br>• Poor water quality – unsuitable water temperatures | • Low flow conditions<br>• Sediment deltas or bars<br>• Log or debris jams<br>• Water supply dams<br>• Poorly engineered or maintained road crossings<br>• Over-fishing<br>• Predation |

**TABLE 2.3**
**SALMONID LIFE CYCLE STAGES AND POTENTIAL IMPACTS (from Bjornn and Reiser 1991 and Spence et al. 1996)**

| Life Cycle Stage | Potential Impacts | Potential Sources of Impact |
|---|---|---|
| through land use practices and dam operations can influence the timing of migration." | | |
| **Ocean Rearing**<br>Ocean rearing is not discussed in the text of this document. | • Physical harm<br>• Absence of or decline in food supplies<br>• Alteration of water temperatures | • Harvest<br>• Predation<br>• Disease<br>• Pollution<br>• Climatic changes (e.g., greenhouse warming) |

## 2.3.1 UPSTREAM MIGRATION

Native salmonids usually have sufficient extra time in their maturation, migration, and spawning schedules to accommodate delays caused by normally occurring low flows, high turbidities, or unsuitable temperatures. The flexibility in maturation and migration schedules observed in many stocks of native salmonids is not unlimited, however; and has evolved for the specific environment of each stock. Significant natural or anthropogenic changes in the environment can, therefore, prevent fish from completing their maturation or migration to spawning areas.

### 2.3.1.1 Temperature

Delays in upstream migration due to elevated natal stream temperatures have been observed for chinook salmon and steelhead (Bjornn and Reiser 1991). Bell (1986) reported upstream migration within the temperature ranges shown for the following salmonid species: fall chinook salmon (10.6 to 19.4°C) and coho salmon (7.2 to 15.6°C).

### 2.3.1.2 Dissolved Oxygen

Bjornn and Reiser (1991) recommend a minimum dissolved oxygen concentration for spawning fish of 5.0 mg/L of at least 80% saturation. Spence et al. (1996) report that greater than 6 mg/l D.O. is a general requirement and that levels below saturation can be harmful.

### 2.3.1.3 Turbidity

Migrating salmonids avoid waters with high silt loads, or cease migration when such loads are unavoidable (Bjornn and Reiser 1991). Bell (1986) reported a study in which salmonids did not move in streams where the suspended sediment concentration exceeded 4,000 mg/L (as a result of a landslide). High turbidity in rivers may delay migration, but turbidity alone generally does not seem to significantly affect the homing of salmonids (Bjornn and Reiser 1991)

#### 2.3.1.4 Barriers

Bjornn and Reiser (1991) report on salmon jumping over obstacles two to three meters in height. They cite sources that state that the abilities of salmon and trout to pass over barriers depended on the swimming velocity of the fish, the horizontal and vertical distances to be jumped, and the angle to the top of the barrier. These sources, as reported by Bjornn and Reiser (1991), computed maximum jumping heights of salmonids on the basis of darting speeds:

| | |
|---|---|
| Chinook | 2.4 meters |
| Coho | 2.2 meters |
| Steelhead | 3.4 meters |

#### 2.3.1.5 Streamflow

Bell (1986) reports the following minimum depths and maximum velocities for successful upstream migration:

| | |
|---|---|
| Fall chinook | 0.24 m, 2.44 m/s |
| Coho | 0.18 m, 2.44 m/s |
| Steelhead | 0.18 m, 2.44 m/s |

### 2.3.2 SPAWNING

The amount of suitable stream substrate for spawning varies with the size of the stream and the species of salmonid using it (Bjornn and Reiser 1991). Bjornn and Reiser (1991) report that nonanadromous salmonids may use second-order (streams resulting from the junction of two or more headwater streams) and third-order (streams resulting from the junction of two or more first-order streams) streams. The large anadromous steelhead, coho salmon and chinook salmon spawned in a few third-order streams; but most were found in fourth- and fifth-order streams. As stream order increased, gradient decreased but stream, length, width and depth increased. The amount of spawning gravel per kilometer of stream was greatest in fourth-order coastal watersheds.

#### 2.3.2.1 Streamflow

Streamflow regulates the amount of spawning area available in any stream by regulating the area covered by water and the velocities and depths of water over the gravel beds (Bjornn and Reiser 1991).

#### 2.3.2.2 Temperature

Bell (1986) reports the following temperature ranges suitable for spawning:

| | |
|---|---|
| Fall chinook | 5.6 to 13.9 °C |
| Coho | 4.4 to 9.4 °C |
| Steelhead | 3.9 to 9.4 °C |

#### 2.3.2.3 Space

The number of redds that can be built in a stream depends on the amount of suitable spawning habitat and the area required per spawning pair of fish (Bjornn and Reiser 1991). Many salmonids prefer to spawn in the transitional area between pools and riffles because the downwelling provides flow through the redd. Bjornn and Reiser (1991) report from various sources that the average area of a fall chinook salmon redd is 5.1 $m^2$;

a coho salmon redd averages 2.8 $m^2$; and a steelhead trout redd ranges from 4.4 to 5.4 $m^2$. Bjornn and Reiser (1991) also cite sources that state that 20.1 $m^2$ and 11.7 $m^2$ of spawning habitat is needed per spawning pair of fall chinook salmon and coho salmon, respectively.

#### 2.3.2.4 Water Depth/Velocity and Substrate

Spence et al. (1996) state, "Salmonids typically deposit eggs within a range of depths and velocities that minimize the risk of desiccation as water level recedes and that ensure the exchange of water between surface and substrate interstices is adequate to maintain high oxygen levels and remove metabolic wastes from the redd." Suitable spawning gravel size is generally proportional to adult size – the larger species use larger gravels. Table 2.4 shows the depths and velocities preferred for spawning.

**Table 2.4**
**Water Depths and Velocity Used by Anadromous Salmonids for Spawning (from Bjornn and Reiser 1991 and Spence et al. 1996)**

| Species | Depth (cm) | Velocity (cm/s) | Substrate size (cm) | Source |
|---|---|---|---|---|
| Fall Chinook | ≥24 | 25 to 115 | 1.3 to 10.2 | Bjornn and Reiser 1991<br>Spence et al. 1996 |
| Coho | ≥18 | 25 to 91 | 1.3 to 10.2 | |
| Steelhead | ≥24 | 40 to 91 | 0.6 to 10.2 | |

Flosi et al. (1998) describe a technique for measuring the mean percentage of a surface cobble particle that is buried in fine sediment. Measurements are collected at pool tail-outs where spawning is likely to occur. At least five cobble particles are collected and removed from the substrate. The line between the cobble "shiny" and "dull" surfaces marks the degree to which the cobble was buried by fines. The amount of the "shiny" surface (i.e., the amount embedded by fines) is estimated as <25%, 26 to 50%, 51 to 75%, or >75% embedded. The average of all measured particles is the pool tail embeddedness rating for that reach. The Department of Fish and Game ("CDFG") concluded that cobble embeddedness of less than 25% is best suited for salmonid spawning (Flosi et al. 1998). Spence et al. (1996) reviewed literature regarding salmonid habitat requirements and reported that fines in excess of 13% less than 0.85 mm resulted in intragravel mortality for coho and steelhead embryos due to oxygen stress.

#### 2.3.2.5 Cover

Some anadromous fish—chinook salmon and steelhead trout, for example—enter freshwater streams and arrive at the spawning grounds weeks or even months before they spawn. During the time that adults remain in freshwater, cover is a required habitat element. Nearness of cover to spawning areas may be a factor in the selection of spawning sites by some species.

### 2.3.3 INCUBATION

Successful incubation of embryos and emergence of fry requires gravel substrate with good permeability and porosity, suitable water temperature and dissolved oxygen, and protection from scour and fill. Other factors that affect incubation include:

- Biochemical oxygen demand of material carried in the water and deposited in the redd
- Substrate size (including the amount of fine sediment)
- Channel gradient
- Channel configuration
- Water depth above the redd
- Surface water discharge and velocity
- Velocity of water through the redd

#### 2.3.3.1 Substrate

The redd construction process reduces the amount of fine sediments and organic matter in the pockets where eggs are deposited (Bjornn and Reiser 1991) at least temporarily. If fine sediments are being transported in a stream either as bedload or in suspension, some of them may be deposited in the redd (Bjornn and Reiser 1991). Bjornn and Reiser (1991) report on sources that relate percent embryo survival to percentage of fines <6.35 mm. Chinook salmon survival decreases to 75% when the percentage of fines <6.35 mm reaches about 35%. It decreases to 50% when the percentage of fines <6.35 mm reaches about 40%. Steelhead trout survival decreases to 75% when the percentage of fines <6.35 mm reaches about 30%. It decreases to 50% when the percentage of fines <6.35 mm reaches about 40%. No relationship was reported for coho salmon.

Identifying a specific percentage of fines that can comprise the bulk core sample and still ensure adequate embryo survival is not clearly established in the literature. Cederholm et al. (1981) found about 30% coho salmon survival in a Washington stream when trough mixes of fines (<0.85 mm) were 10% fines and fines (<0.85 mm) in natural redds were 15% of the bulk sample. Koski (1966), on the other hand, found that coho survival was about 45% on an Oregon stream when fines (<0.85 mm) were measured at 20% of the bulk sample. This differs from the Washington and Idaho work of Tappel and Bjornn (1983), which found a range of survival from 20 to 80% when fines (< 0.85 mm) were 10% of the bulk sample and gravel (<9.5 mm) varied from 25 to 60%. For example, Tappel and Bjornn (1983) predicted that a 70% steelhead embryo survival rate required that the substrate contain no more than 11% fines (< 0.85 mm) and 23% gravels (< 9.50 mm). McNeil and Ahnell (1964) in their early work in Alaska found substrates with no more than 12% fines (<0.85 mm) in moderately to highly productive pink salmon streams.

#### 2.3.3.2 Dissolved Oxygen

Salmonid embryos and alevins need high levels of dissolved oxygen to survive (Spence et al. 1996). Low levels of D.O. can have lethal consequences along with sublethal effects on the rate of development, the time to hatching, and the size of alevin and emerging fry (Spence et al. 1996). Bjornn and Reiser (1991) report on sources that conclude that newly hatched steelhead and chinook salmon alevins were smaller and weaker when they had been incubated as embryos at low and intermediate D.O. concentrations than when they were incubated at higher concentrations. In field studies, survival of steelhead embryos and coho salmon embryos (Bjornn and Reiser 1991) were positively correlated with intragravel D.O. levels in redds. Spence et al. (1996) cite sources that concluded that intragravel D.O. concentrations must average greater than 8 mg/L for embryos and alevins to survive.

#### 2.3.3.3 Temperature

Salmonid eggs develop in the gravel redd and alevins remain in the intragravel interstices for a period of time after hatching. The temperature needed for survival and emergence from the gravels has been studied for different salmonid species.[14]

> Murray and McPhail (1988) studied embryo and alevin survival at incubation temperatures of 2, 5, 8, 11, and 14°C for coho, sockeye, chum, pink, and chinook salmon. For coho, embryo survival from fertilization to hatching was high at 5, 8, and 11°C, but was markedly less at 2°C and 14°C. Coho alevin survival at 14°C was lower than at the other incubation temperatures.

Alevins seem less sensitive to temperature than embryos (Spence et al. 1996). The amount of time required for embryos to hatch and for alevins to emerge from redds is related to temperature (Bjornn and Reiser 1991). For example, time to 50% hatch for Pacific salmon species ranges from 115 to 150 days at 4°C and from 35 to 60 days at 12°C; coho salmon require the least time (Bjornn and Reiser 1991). Steelhead trout require about 85 days at 4°C and 26 days at 12°C to reach 50% hatch. According to Bell (1986), incubation of fall chinook salmon embryos is best between 5.0 and 14.4 °C, and for coho salmon embryos between 4.4 and 13.3 °C. McCullough (1999) reports that there is variation among salmonid species in development when incubated at different temperatures. Coho were found to have a reduction in alevin and fry size when incubated at 14 °C.

### 2.3.4 SUMMER FRESHWATER REARING

The abundance of juvenile salmonids in streams is a function of many factors, including the numbers of new fry, habitat quantity and quality, quantity and quality of food sources, and interactions with other species, including prey, predators and competitors (Bjornn and Reiser 1991). Changes in the abundance of spawners and the relative success of incubation and emergence influence the number of young fish entering a stream (Bjornn and Reiser 1991). The number of juveniles that can rear in a stream is controlled by factors that are related to density (such as predation and competition) and those that are independent of density (such as the amount of suitable habitat, quality of cover, productivity of the stream) (Bjornn and Reiser 1991).

Temperature, productivity, suitable space, and water quality (turbidity, D.O., etc.) are examples of variables that regulate the general distribution and abundance of fish within a stream or drainage (Bjornn and Reiser 1991). Each life stage has different optimal habitat conditions and salmonids will distribute among different microhabitats within a stream reach to find the optimal conditions for that species and life stage (Spence et al. 1996). All of the general factors must be within suitable ranges for salmonids during the time they use a stream segment; otherwise the population will be depressed (Bjornn and Reiser 1991).

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[14] McCullough 1999, page 28

#### 2.3.4.1 Dissolved Oxygen

Spence et al. note that, “Salmonids are strong, active swimmers and require highly oxygenated waters. Maximum sustained swimming performance dropped off for coho and chinook salmon when D.O. concentrations decreased much below air saturation levels”[15]

Salmonids may be able to survive when D.O. concentrations are relatively low (<5 mg/L), but growth, food conversion efficiency, and swimming performance will be adversely affected (Bjornn and Reiser 1991). High water temperature, which reduces oxygen solubility, can compound the stress on fish caused by marginal D.O. concentrations (Bjornn and Reiser 1991).

#### 2.3.4.2 Temperature

The temperature tolerances of juvenile salmonids are variable; however, most species are at risk when temperatures exceed 23 to 25 °C (Bjornn and Reiser 1991). The upper and lower lethal temperatures and the preferred temperature ranges are shown in Table 2.5. Temperature tolerance of individual salmonids can vary. Spence et al. (1996) state, “These temperatures provide a general range of tolerable temperatures, however, the ability of fish to tolerate temperature extremes depends on their recent thermal history. Fish acclimated to low temperatures, for example, have lower temperature thresholds than those acclimated to warmer temperatures.”[16] Fish can tolerate temperatures higher than the upper lethal temperature for short periods, especially if thermal refugia are available.

**TABLE 2.5**
**TEMPERATURE REQUIREMENTS OF REARING SALMONIDS (from Bjornn and Reiser 1991)**

| Species | Lower Lethal Temperature (°C) | Upper Lethal Temperature (°C) | Preferred Temperature (°C) | Source |
|---|---|---|---|---|
| Chinook | 0.8 | 26.2 | 12 to 14 | Bjornn and Reiser 1991 |
| Coho | 1.7 | 26.0 | 12 to 14 | Bjornn and Reiser 1991 |
|  | 1.7 | 28.8 | 12 to 14 | Bjornn and Reiser 1991 |
| Steelhead | 0.0 | 23.9 | 10 to 13 | Bell 1986 |

High water temperature can affect smoltification and prematurely trigger the migratory response in juveniles. McCullough (1999) cites a source that recommends water temperatures at or below 12°C for coho smoltification:

> Some physiological processes in smoltification of salmonids are greatly retarded by water temperatures >13°C and in some Pacific salmonids smolt stage cannot be attained at temperatures reaching 16°C (see references as cited by Johnston and Saunders 1981). It is recommended for chinook and coho that a maximum temperature of approximately 12°C exist to maintain the migratory response and seawater adaptation in juveniles (Wedemeyer et al. 1980, CDWR 1988, p. 4 ). Temperatures must be maintained at <12°C to prevent premature smolting (Zaugg and McLain 1976, as cited by Hoar 1988; Wedemeyer et al. 1980).[17]

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[15] Spence et al. 1996, page 102.
[16] Spence et al. 1996, page 101.
[17] McCullough 1999, page 69.

#### 2.3.4.3 Turbidity

Larger juvenile and adult salmon and trout do not appear to be affected by transitory high concentrations of suspended sediments that occur during storms and episodes of snowmelt (Bjornn and Reiser 1991). Bisson and Bilby (1982) report, however, that juvenile coho salmon avoid water with turbidities that exceed 70 NTU (nephelometric turbidity units). Bjornn and Reiser (1991) report that feeding and territorial behavior of juvenile coho salmon are disrupted by short-term exposures (2.5 to 4.5 days) to turbid water up to 60 NTU. High turbidity may interfere with juvenile foraging behavior by reducing the distance from which they can locate drifting prey (Spence et al. 1996). Turbidities in the 25 to 50 NTU range reduce growth and cause more newly emerged salmonids to emigrate from laboratory streams than does clear water (Bjornn and Reiser 1991).

#### 2.3.4.4 Productivity of Streams

Streams vary in productivity due largely to the nutrients and energy available (Bjornn and Reiser 1991). If the findings for sockeye salmon (Bjornn and Reiser 1991) are similar for other salmonids, a yearling salmonid in a stream with daily mean temperature of 10°C would need a daily food supply equivalent to 6 to 7% of its body weight to attain maximum growth. Production of aquatic invertebrates that juvenile salmonids eat depends on the amount of organic material available in streams (Bjornn and Reiser 1991).

#### 2.3.4.5 Space

Fish densities in streams provide a measure of the spatial requirements of juvenile salmonids; but, the wide variation in observed densities illustrates the diversity of habitat quantity and quality and other factors that regulate fish abundance (Bjornn and Reiser 1991). The summer space requirements of juvenile salmonids during their first year in streams probably ranges from 0.25 to 10 $m^2$ of stream per fish (Bjornn and Reiser 1991). Density requirements depend on factors such as the species and age composition of fish present, stream productivity, and quality of the space. Bjornn and Reiser (1991) cite earlier work that demonstrated that by reducing pool volume by half and surface area of water deeper than 0.3 meters by two-thirds, fish numbers decline by two-thirds. Knopp (1993) demonstrates that pools in relatively undisturbed watersheds on the California north coast have a mean V* of no more than 0.21.[18] Flosi et al. (1998) report that in the better coho streams in northern California at least 40% of their habitat length is composed of primary pools. In first and second order streams a primary pool has a maximum depth of at least two feet, occupies at least half the width of the low-flow channel, and is as long as the low-flow channel width (Flosi et al. 1998). In third and fourth order streams the criteria is the same, except maximum depth must be at least three feet (Flosi et al. 1998).

#### 2.3.4.6 Streamflow

Bjornn and Reiser (1991) discussed a correlation between the commercial catch of coho salmon and annual runoff, summer flow, and lowest monthly flow in 21 western Washington drainages. In the last two decades, hatchery production of coho salmon

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[18] V* is a unitless measurement of the percent of a pool's total volume that is filled with fine sediment.

smolts has increased markedly and made such comparisons more difficult. The implication of the available studies is that the abundance of adult coho salmon is a function of the number of smolts produced, which is in turn related to streamflow and the other factors that regulate the production of smolts.

#### 2.3.4.7 Velocity

Given flow in a stream, velocity is probably the next most important factor in determining the amount of suitable space for rearing salmonids (Bjornn and Reiser 1991). Newly emerged salmon and trout fry (20 to 35 mm long) require velocities of less than 10 cm/s, based on studies of sites selected by the fish in streams (Bjornn and Reiser 1991). Larger fish (4 to 18 cm long) usually occupy sites with velocities up to about 40 cm/s (Bjornn and Reiser 1991).

#### 2.3.4.8 Depth

Young trout and salmon have been seen in water barely deep enough to cover them and in water more than a meter deep (Bjornn and Reiser 1991). Densities (expressed as fish/$m^2$) of some salmonids are often higher in pools than in other habitat types; but, that may reflect the space available rather than a preference for deep water, especially for smaller fish (<15 cm long) (Bjornn and Reiser 1991). Bjornn and Reiser (1991) cite significant correlation between size of fish and total water depth at sites occupied by juvenile chinook salmon and steelhead. Most fish, regardless of size, were near the bottom.

#### 2.3.4.9 Cover

Some of the features that may provide cover and increase the carrying capacity of streams for fish are water depth, water turbulence, large-particle substrates, overhanging or undercut banks, overhanging riparian vegetation, woody debris (brush and logs), and aquatic vegetation (Bjornn and Reiser 1991). Coho salmon production declined when woody debris was removed from second-order streams in southeast Alaska (Bjornn and Reiser 1991). More large woody debris and juvenile coho salmon were found in streams surrounded by mature, mixed-conifer forest than in streams lined by red alder that had grown in a 20-year-old clear-cut (Bjornn and Reiser 1991). When woody debris was removed from a stream, the surface area, number and size of pools decreased, water velocity increased, and the biomass of the char, dolly varden, decreased (Bjornn and Reiser 1991). In another stream, young steelhead were more abundant in clear-cut than in wooded areas in summer, but moved to areas with pools and forest canopy in winter (Bjornn and Reiser 1991).

Newly emerged fry can occupy the voids of substrate made up of 2 to 5 cm diameter rocks, but larger fish need cobble and boulder-size (>7.5 cm diameter) substrates (Bjornn and Reiser 1991). The summer or winter capacity of the stream for fish declines when fine sediments fill the interstitial spaces of the substrate (Bjornn and Reiser 1991). Bjornn and Reiser (1991) discuss a laboratory stream experiment in which the production of juvenile coho salmon was related to the amount of fine sediments in the substrate. Bjornn and Reiser (1991) cite a source showing that the density of juvenile steelhead and chinook salmon in summer and winter was reduced by more than half when enough sand was added to fully embed the large cobble substrate. The addition of fine sediments to stream substrates as a result of watershed disturbances and erosion may reduce the abundance of aquatic invertebrates, as well.

### 2.3.5 WINTER FRESHWATER REARING

Bjornn and Reiser (1991) describe streamflow and velocity as two of the most critical factors influencing salmonid abundance. Streamflows and velocities are highest in coastal streams in northern California during winter months due to seasonal rainfall. As a result, overwintering salmonids must find shelter that is not subject to high winter stream velocities. For example, Bjornn and Reiser (1991) discuss work showing higher densities of steelhead (0.66 smolts/$m^2$ and 9.94 g/$m^2$) and coho salmon (0.85 smolts/$m^2$ and 12.8 g/$m^2$) in side-channel pools than are commonly found in the main channels of Pacific coastal streams. Coho salmon have been reported moving into side-channel pools for the winter; salmonids will hide in the interstitial spaces in stream substrates, particularly in winter when voids are accessible (Bjornn and Reiser 1991). Juvenile steelhead and chinook salmon responded to various types and amounts of cover in winter by either staying in or leaving outdoor laboratory streams (Bjornn and Steward, unpublished data, as cited by Bjornn and Reiser 1991).

# Chapter 3
# Reference Watershed: Summary of Caspar Creek Studies

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## 3.1 INTRODUCTION

The Caspar Creek watershed is approximately 3.4 acres or 8.4 $mi^2$. Caspar Creek enters the Pacific Ocean approximately nine miles south of the City of Fort Bragg. The watershed is divided into the North Fork, Middle Fork and South Fork. The North Fork and South Fork were designated as experimental watersheds in 1962. The North Fork is 1.8 $mi^2$ and the South Fork is 1.6 $mi^2$.

Like much of the Mendocino Coast Hydrologic Unit, the entire Caspar Creek watershed was subject to old growth logging from 1864 to 1900. The entire South Fork watershed was logged of its second growth wood from 1971 to 1973 using selective cut logging and tractor yarding. From 1985 to 1991, about 43% of the North Fork watershed was clearcut in blocks of nine to 60 hectares and then yarded with skyline cable.

The overall goal of the experiments in the Caspar Creek drainage is to understand the varying impacts to a coastal watershed resulting from pre- and post-Forest Practices Act logging requirements.[19] Various parameters were compared between the North and South Forks. Various experiments also tried to identify impacts that were the result of old-growth logging at the turn-of-the-century and that continue today (Henry 1998). Experiments of interest address the following topics:

- Salmonid population
- Quality and quantity of salmonid habitat
- Variation in rates and effects of sediment loading
- Variation in rates and effects of large woody debris loading

Because of the old-growth logging at the turn-of-the-century, data collected in Caspar Creek since the 1960s can not provide insight into pre-management natural conditions. However, Caspar Creek data could potentially provide a reference for “background” conditions where “background” is understood to be the result of natural conditions and conditions resulting from historic landuse practices. In addition, Caspar Creek data could potentially provide some insight into the rate at which various impacts have been accelerated above “background” conditions, as a result of both pre- and post-Forest Practices Act logging activities.

## 3.2 GENERAL SETTING

### 3.2.1 PHYSIOGRAPHY

The Caspar Creek watershed covers 8.4 $mi^2$ with a range in elevation from 121 to1,050 feet (Henry 1998). The stream channels are generally incised within steep inner gorges (Henry 1998). The hillslope typically becomes more gentle near the broad and rounded ridgetops about 328 to 1,148 feet from the channel (Henry 1998).

### 3.2.2 GEOLOGY

Both the North and South Forks of Caspar Creek are underlain by the Coastal Belt of the Franciscan Complex (Cafferata and Spittler 1998). The dominant rock types include well-consolidated marine sedimentary sandstone with intergranular clay and silt

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[19] Public Resources Code §4511 et seq.

(graywacke) and feldspatic sandstone, with lesser amounts of siltstone, mudstone and conglomerate (Cafferata and Spittler 1998). Both forks of Caspar Creek also contain alluvium of Holocene age. The upper portion of the North Fork watershed, in particular, contains a significant accumulation of this material that was deposited behind an ancient landslide dam (Cafferata and Spittler 1998).

The channels of the both the North and South Forks of Caspar Creek flow in relatively narrow, bedrock-controlled stream channels (Cafferata and Spittler 1998). Artificial floods associated with log drives and the removal of riparian vegetation and in-channel large woody debris have had a profound and lasting impact on channel geometry, stream bank stability, and sediment discharge (Napolitano 1996).

### 3.2.3 CLIMATE

Temperatures are mild with muted annual extremes and narrow diurnal fluctuations due to the moderating effect of the Pacific Ocean (Henry 1998). The mean annual precipitation from 1963 through 1997 was 1,132 mm (45 inches) with a range from 305 to 2,008 mm (12 to 79 inches).[20] The frequent occurrence of summer coastal fog makes a small, but unmeasured, contribution to the total precipitation in the form of fog drip. Snowfall is rare at the low elevations in this region (Henry 1998).

Two weirs have been operating in the Caspar Creek watershed since 1960. One is located in the North Fork and the other in the South Fork. Additional weirs have been installed since then in some of the tributaries of North Fork Caspar Creek. Rainfall data has been collected at rain gauge SFC620 just above the South Fork weir since 1963 and at NFC408 just above the North Fork weir since 1986. The rainfall pattern in Caspar Creek is typical of the Mendocino coast with the majority of rain falling between October and May, peaking in December/January. The December/January peak is approximately 235% of the average monthly rainfall.

If one looks at the 1986 to 1997 data only it appears that there is a second peak in March that is approximately 185% of the average monthly rainfall. This second peak does not appear in the 1963 to 1985 dataset. And, given the timing of this second peak, there may be an increased risk to coho redds from scouring as a result of this increase in March rainfall. The runoff threshold in Caspar Creek above which redds are likely to scour is unknown. As such, it is difficult to determine the degree to which this risk is real.

Cafferata and Spittler (1998) analyzed the precipitation records for Caspar Creek to identify trends in rainfall with respect to large landslide events (>100 $yd^3$). They developed precipitation criteria (exceeding a 1-day, 3-day, or 10-day rainfall threshold or an antecedent precipitation index) above which significant landsliding was likely. The identified 1-day, 3-day and 10-day precipitation thresholds are 4.88 cm (1.92 in), 11.94 cm (4.70 in), and 20.09 cm (7.91 in), respectively. Forty-one days and 34 unique storm sequences met the screening criteria.

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[20] The climate data were obtained from www.rsl.psw.fs.fed.us.

### 3.2.4 STREAMFLOW

Streamflow has been measured at both the South Fork and North Fork weirs since the 1963 hydrologic year (with the exception of 1977, which was a dry year and is missing from the record). Flood events with 5-year or greater return frequencies occurred before and after logging for the South Fork phase, as well as before and after logging in the North Fork phase (Cafferata and Spittler 1998) are shown in Table 3.1.

**TABLE 3.1**
**PEAK STREAM FLOWS IN CASPAR CREEK (Cafferata and Spittler 1998)**

| DATE | DISCHARGE (cfs) | RETURN INTERVAL (yr) |
|---|---|---|
| 12/21/64 | 257.5 | 10 |
| 01/04/66 | 304.9 | 21 |
| 01/16/74 | 304.3 | 21 |
| 03/29/74 | 263.8 | 12 |
| 12/21/82 | 209.6 | 6 |
| 01/20/93 | 241.6 | 8 |
| 03/14/95 | 191.5 | 5 |
| 12/09/97 | 198.0 | 5 |

Though the stream gauging records for Caspar Creek are available since 1963, other regional records indicate that the only other two floods of the century probably occurred in Caspar Creek in December 1955 (10-year return interval) and 1937 (Cafferata and Spittler 1998).

Rice et al. (1979) report that about 80% of suspended sediment measured during the South Fork phase was transported by flows exceeding 1.13 cms (40cfs). Discharges of this magnitude occur about 1% of the time in both the North and South forks of Caspar Creek (Cafferata and Spittler 1998).

The return frequencies for rainfall events and runoff differ due to complexities related to the differences in antecedent moisture conditions, storm intensities, and storm durations (Cafferata and Spittler 1998).

### 3.2.5 VEGETATION

**3.3** The Caspar Creek area supports dense stands of second-growth Douglas-fir (*Pseudotsuga menzieee*), coast redwood (*Sequoia sempervirens*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*) as well as minor amounts of various hardwoods (Henry 1998). The timber stands average 700 $m^3$/hectare of stem wood (Henry 1998). The second growth forest is between 90 and 130 years old and consists of natural regeneration of the original species (Reid and Hilton 1998). About 55% of the stems greater than 15 cm in diameter are redwood, 26% Douglas fir, 10% tanoak and 5% grand fir (Reid and Hilton 1998). About 61% of the stems are less than 0.5 m in diameter and 7% are greater than 1m (Reid and Hilton 1998).

## 3.3 LOGGING HISTORY

### 3.3.1 OLD GROWTH LOGGING

Most of the Caspar Creek watershed was purchased by the Caspar Logging Company in 1860 (Henry 1998). The company erected a lumber mill at the mouth of the creek and produced 25,000 board feet of lumber per day at its peak (Henry 1998). Jacob Green Jackson (after whom the Jackson Demonstration State Forest is named), bought the mill in 1864 and built three log crib dams on Caspar Creek to aid in winter log drives (Henry 1998).

In this early era of logging, clearcut logging was employed as was broadcast burning to remove obstructions to yarding (Henry 1998). The inner gorge slope areas of the Caspar Creek watershed were significantly altered during the process by which logs were jack screwed into the creek to be floated downstream (Henry 1998). By the late 1890s, most of the Caspar Creek watershed had been logged (Henry 1998). By 1906, logging in Caspar Creek reached a quiet period as the Caspar Lumber Company looked to other watersheds (Henry 1998).

### 3.3.2 PRE-FOREST PRACTICES ACT SECOND GROWTH LOGGING

Timber harvest in the Caspar Creek watershed did not begin again until 1967 when logging roads were built in the South Fork Caspar Creek as part of the Caspar Creek Watershed study (Henry 1998). The Caspar Creek Watershed study was conceived of and conducted by a joint group of federal and state agencies including: the California Department of Forestry and Fire Protection, Jackson Demonstration State Forest, the Pacific Forest and Range Experiment Station, Redwood Sciences Laboratory, Humboldt State University, the California Department of Fish and Game, and the University of California at Berkeley (Henry 1998). The South Fork Caspar Creek phase (Phase 1) began with data collection in 1963 and has continued to the present through the pre-logging (second growth) period, early road-building period (1967), timber harvesting period (1971 to 1973), and post-harvest period (1974 to present) (Henry 1998).

Simultaneously, data were collected in the North Fork Caspar Creek watershed, which was identified as a control watershed (Henry 1998). Data collected included: precipitation, streamflow, suspended sediment, debris basin, and fisheries (Henry 1998). Over time, various other parameters have been added, including: solar radiation, air temperature, water temperature, landslide/soil erosion, aquatic invertebrates, and nutrients (Henry 1998).

The logging conducted in the South Fork Caspar Creek watershed under Phase 1 of the study included single tree and small group selection silviculture from three sale units (Henry 1998). The first sale unit involved the removal of about 60% of the timber volume from 101 hectares (Henry 1998). The second sale unit involved the removal of about 70% of the timber volume from 128 hectares (Henry 1998). The third sale unit involved the removal of about 65% of the timber volume from 176 hectares (Henry 1998). The South Fork Caspar Creek watershed has an area of 424 hectares. As such, approximately 65% of the timber volume was removed from about 95% of the watershed area (Henry 1998).

To accommodate the logging conducted during Phase 1, about 6.8 km of logging roads were constructed, primarily along the stream corridor, in the South Fork Caspar Creek watershed (Henry 1998). About 2.3 km of road directly impinged on the stream channel while about 6 km were within 61 m of the stream (Henry 1998). Ground-lead tractor log yarding was employed with most of the landings located near the canyon bottom (Henry 1998). More than 15 percent of the watershed was compacted from skid trail, landing and road construction; skid trail construction accounted for more than half of that compaction, and road construction accounted for more than one-third (Henry 1998).

### 3.3.3 POST-FOREST PRACTICES ACT SECOND GROWTH LOGGING

By the late 1970s, the study designers began to consider expanding the experiment to include a comparison between early second growth logging techniques (as employed in the South Fork Caspar Creek) and more modern techniques required under the new Forest Practices Act (Henry 1998). To conduct such a comparison, the roles of the South and north forks of Caspar Creek were reversed: North Fork Caspar Creek became the experimental watershed while South Fork Caspar Creek became the control (Henry 1998). Phase 2 work in the North Fork Caspar Creek began in 1985 (Henry 1998).

**Table 3.2**
**LOGGING HISTORY OF CASPAR CREEK (Henry 1998)**

| | SOUTH FORK CASPAR CREEK | NORTH FORK CASPAR CREEK |
|---|---|---|
| Watershed area (ha) | 424 | 473 |
| Period of old-growth logging | < 1906 | < 1906 |
| Type of old-growth logging | Clearcut | Clearcut |
| Type weed control | Broadcast burning | Broadcast burning |
| Percentage of watershed logged | ~100% | ~100% |
| Period of second-growth logging | 1967 to 1973 | 1985 to 1991 |
| Type of second-growth logging | Single tree and small-group selection | Clearcut |
| Type of yarding | 100% ground-based yarding | 78% skyline cable, 22% ground-based yarding |
| Type of weed control | Undocumented | Burning and herbicide application |
| Percentage of watershed logged | 95% | 50% |
| Percentage of watershed compacted by roads, landings, and skid trails | 15% | 3% |
| Location of roads | Primarily along the stream corridor, 34% impinging on the stream itself | Primarily above mid-slope |
| Water Course and Lake Protection | None | 8% of harvest area protected as WLPZ; 34% of WLPZ harvested |

Under Phase 2 of the study, approximately 50% of the North Fork basin was harvested in clearcut blocks from 22 to 148 acres (Henry 1998). Approximately 78% of the area harvested was yarded using skyline cables while the remaining area (22%) was harvested by ground-based tractors (Henry 1998). Approximately 34% of the Watercourse and Lake Protection Zone was harvested (Henry 1998). Approximately 3% of the North Fork Caspar Creek watershed was compacted with new roads, new landings, and new skid trails (Henry 1998). The North Fork Caspar Creek was divided into 13 nested subwatersheds ranging in size from 10 to 384 ha (Henry 1998). Eleven of these subwatersheds were clearcut from 1985 to 1991 (about 10% of the harvest occurred as selective cutting in the WLPZ) (Henry 1998). Six of the subwatersheds were burned (1990 to 1991) and sprayed with herbicide (1993 to 1996) to control weed species (Henry 1998).

## 3.4 SALMONID POPULATIONS

Data on the salmonid population in Caspar Creek was obtained from Graves and Burns (1970), Burns (1971), Nakamoto (1998), Harvey and Nakamoto (1996), and unpublished CDFG studies. Although the studies discussed in this section are of interest to understanding watershed processes in the other watersheds of the Mendocino Coast, care must be taken in extrapolating population abundance trends across scales, such as from the small Caspar Creek watershed to much larger watersheds.

### 3.4.1 GRAVES AND BURNS (1970)

Graves and Burns (1970) installed modified cranberry traps located downstream from the streamflow gauging weir on the South Fork Caspar Creek to collect downstream migrants from March 13 to July 1 in 1964 and 1968. All emigrants were counted, measured and separated into one of two classes (fry or smolts) using a length-frequency method. Graves and Burns counted 79 steelhead smolts, 581 coho smolts and 32 coho fry in 1964, prior to road construction. This is a total of 79 steelhead trout and 613 coho salmon. Coho made up 89% of the total. The steelhead smolts averaged 114 mm in length while the coho smolts averaged 84 mm and the coho fry averaged 48 mm.

By comparison, in 1968 they measured 187 steelhead smolts, 488 steelhead fry, 341 coho smolts and 1,429 coho fry. This is a total of 675 steelhead trout and 1,770 coho salmon. Coho made up 72% of the total. With respect to fork length, steelhead smolts averaged 102 mm, steelhead fry averaged 41 mm, coho smolts averaged 94 mm, and coho fry averaged 40 mm.

These data indicate a 138% increase in the number of steelhead smolts from 1964 to 1968 with a corresponding 11% decrease in smolt fork length. In total, there was a 754% increase in the number of steelhead trout, overall. Steelhead smolts went from being 100% of the steelhead trout counted in 1964 to only 30% of those counted in 1968.

**Table 3.3**
**SUMMARY OF STEELHEAD TROUT AND COHO SALMON POPULATION DATA (from Graves and Burns 1970)**

| SPECIES | SMOLTS | | | | FRY | | | | TOTAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1964 | | 1968 | | 1964 | | 1968 | | 1964 | | 1968 | |
| | No. | Fork length (mm) | No. | Fork length (mm) | No. | Fork length (mm) | No. | Fork length (mm) | No. | Fork length (mm) | No. | Fork length (mm) |
| Steelhead | 79 | 114 | 187 | 102 | 0 | 0 | 488 | 41 | 79 | | 675 | |
| Coho | 581 | 84 | 341 | 94 | 32 | 48 | 1,429 | 40 | 613 | | 1,770 | |
| **TOTAL** | 660 | | 528 | | 32 | | 1,917 | | 692 | | 2,445 | |

These data also indicate a 41% decrease in the number of coho smolts from 1964 to 1968 with an increase in the number of coho fry in this time period of more than 4,000%. In total, there was a 253% increase in the number of coho, overall. Coho smolt fork length increased by 12% while fry length decreased by 17%. Coho smolts went from being 95% of the coho salmon counted in 1964 to only 20% of those counted in 1968.

Graves and Burns (1970) hypothesize that the increased emigration in 1968 was the result of premature emigration caused by a decrease in favorable living space upstream. This is supported by the large increase in the number of emigrating fry in 1968, altering the overall percentage of emigrating salmonids that were smolts from 95% in 1964 to 122% in 1968. They further hypothesize that the fewer, but larger, coho smolts in 1968 are the result of better competition among those surviving a higher mortality rate. The smaller fry they presume to be the result of poor intergravel conditions arising from road construction.

### 3.4.2 BURNS (1972)

Burns (1972) captured fish using a back-pack electroshocker and estimated populations by the Petersen single-census, mark-and-recovery method or by the two-catch, removal method. Fish were monitored for three years in the South Fork Caspar Creek, in June and again in October. The June 1967 measurements represent pre-road building while the other measurements occurred after road building during the summer of 1967.

The data indicate a decrease in the number, density, and biomass of salmonids from June to October. The only exception is in 1968 when the density of young-of-the-year (“YOY”) steelhead trout increased by 22% during this period. Given this general trend, however, it is clear that the rate of decrease was it’s most dramatic immediately after road building in the summer of 1967. The number of steelhead trout (YOY and older) decreased by 86% from June 1967 to October 1967 while the number of coho salmon decreased by 83% during that time. In 1968, on the other hand, the number of steelhead decreased by 64% during the summer period and the number of coho decreased by 49%. Again, in 1969, the number of steelhead decreased by 66% during the summer period while coho salmon decreased by 63%.

**Table 3.4**
**SUMMARY OF STEELHEAD TROUT AND COHO SALMON DATA (from Burns 1972)**

| DATE | STEELHEAD TROUT | | | | | | COHO SALMON | | |
|---|---|---|---|---|---|---|---|---|---|
| | Young-of-the-year | | | Yearling and older | | | | | |
| | No./m$^2$ (kg/ha) | Mean Fork Length (mm) | No. | No./m$^2$ (kg/ha) | Mean Fork Length (mm) | No. | No./m$^2$ (kg/ha) | Mean Fork Length (mm) | No. |
| 6/67 | 1.69<br>(11.81) | 37<br>(36-38) | 10,183 | 0.11<br>(10.26) | 86<br>(78-93) | 673 | 1.00<br>(15.90) | 47<br>(45-48) | 6,001 |
| 10/67 | 0.29<br>(4.94) | 50<br>(48-52) | 1,436 | 0.02<br>(4.53) | 124<br>(112-135) | 106 | 0.21<br>(5.45) | 58<br>(56-60) | 1,038 |
| 6/68 | 1.32<br>(10.51) | 43<br>(42-44) | 6,580 | 0.04<br>(3.65) | 95<br>(92-99) | 176 | 0.50<br>(7.42) | 49<br>(48-50) | 2,510 |
| 10/68 | 0.58<br>(12.77) | 58<br>(57-59) | 2,363 | 0.01<br>(2.13) | 115<br>(108-122) | 51 | 0.32<br>(5.78) | 54<br>(53-55) | 1,283 |
| 6/69 | 1.45<br>(17.38) | 47<br>(46-48) | 9,512 | 0.06<br>(5.70) | 92<br>(89-94) | 407 | 0.77<br>(11.62) | 51<br>(50-52) | 5,036 |
| 10/69 | 0.81<br>(17.07) | 57<br>(56-58) | 3,224 | 0.04<br>(5.23) | 111<br>(107-113) | 141 | 0.48<br>(8.08) | 54<br>(53-55) | 1,885 |

The total salmonid biomass was 37.97 kg/ha in June of 1967 and then dropped by 61% to 14.92 kg/ha by that October. By June of 1969 the salmonid biomass had returned to 91% of the pre-road building level. However, coho had comprised 42% of the salmonid biomass in June 1967, but by October 1969 it made up only 27%.

The mean fork lengths of salmonids generally increased from 1967 to 1969. YOY steelhead fork length increased from 37 mm in June 1967 to 47 mm in June of 1969. Older steelhead fork length increased from 86 mm in June 1967 to 92 mm in June 1969. And, coho fork length increased from 47 mm in June 1967 to 54 mm in June 1969.

Burns (1972) hypothesized that road construction may have reduced the total yield of coho salmon and steelhead trout smolts in 1968 and 1969 because of high mortality of both species and premature emigration of yearling and older steelhead trout in 1968. This in turn may have led to more successful competition among those who remained.

### 3.4.3 NAKAMOTO (1998)

Nakamoto (1998) captured aquatic vertebrates in both the North and South Forks of Caspar Creek during August 1986 and June and July of 1987 through1995. He used block nets across the upstream and downstream boundaries of each habitat unit of interest. Fish were sampled using a backpack electrofisher, speciated, measured for fork length, and (between 1990 and 1995) weighed.

Nakamoto (1998) determined that YOY steelhead densities and biomass are generally slightly higher in the North Fork Caspar Creek than in South Fork Caspar Creek while the fork lengths are smaller in the North Fork. However, logging in the North Fork Caspar Creek from 1989 to 1991 served to decrease the density and biomass in the North Fork. The differences in YOY steelhead density between creeks were not significant between survey periods (p=0.38) and high interannual variation characterized the mean biomass in both creeks (Nakamoto 1998).

Yearling steelhead densities and biomass also were generally higher in the North Fork than in the South Fork though these were depressed by logging in the North Fork Caspar Creek. The differences were not significant between periods (p=0.54) (Nakamoto 1998).

Coho density and biomass was generally higher in the South Fork than in the North Fork Caspar Creek. In both creeks, the density and biomass decreased during the period of North Fork logging (Nakamoto 1998).

Nakamoto (1998) concluded that the abundance of coho in both creeks was variable until 1990 after which coho virtually disappeared. The extremely low population levels in both creeks combined with the low statistical power of the comparison resulted in a low probability of detecting logging-associated changes in the coho population. However, current increases in LWD and pool availability in the North Fork should benefit coho although competition between juvenile coho and steelhead in Caspar Creek may slow the recovery of coho (Nakamoto 1998).

### 3.4.4 HARVEY AND NAKAMOTO (1996)

Harvey and Nakamoto (1996) used a cross-classified experimental design to measure the effect of juvenile steelhead on age-0 coho salmon growth and survival within fenced stream sections in the North and South Forks of Caspar Creek over six weeks, from July 19 to August 31, 1993. They studied both the North and South Forks because of the consistent differences in fish densities over the previous five years (Nakamoto 1998). In the North Fork Caspar Creek, all the treatments included 0.3 coho/$m^2$ (age-0) and three different densities of age-0 steelhead (0, 1.5 fish/$m^2$ and 3.0 fish/$m^2$). The natural density of age-0 coho in the North Fork Caspar Creek was measured as 0.2 fish/$m^2$ while that of age-0 steelhead was measured as 1.5 fish/$m^2$.

Harvey and Nakamoto (1996) report a high coho survival rate during the experiment (87% overall). Coho survival was not related to steelhead density. Coho growth, however, did vary based on steelhead density. For example, in the North Fork Caspar Creek experiment, coho gained weight in the zero-density steelhead treatment. They did not change weight in the presence of the natural density of age-0 steelhead (1.5 fish/$m^2$). Coho lost weight in the presence of twice the natural density of age-0 steelhead. Coho growth was lower in the South Fork Caspar Creek than in the North Fork, but also indicated a negative relationship to steelhead density.

Harvey and Nakamoto (1996) hypothesize that reduced growth is likely to have population level consequences for coho salmon because juvenile size is related to the probability of survival and reproduction in salmonids. Further, they opine that the differences between coho response in the north versus south forks may reflect natural differences in resource availability. For example, salmonid biomass averaged about 40% more in the North Fork than in the South Fork from 1989 to 1993 (Nakamoto 1998). Thus, the fact that weight change was imperceptible in the North Fork with densities approximating natural levels, suggests a strong link between natural density and available resources. Relatively low resource availability in the South Fork may explain the particularly low survival of steelhead in the higher density South Fork treatment (Harvey and Nakamoto 1996). Finally, both habitat and diet partitioning between coho and steelhead have been observed in other systems, as well as in Caspar Creek.

The result of habitat simplification in Caspar Creek is that with very shallow riffles, steelhead dominate pool habitat (the coho preferred habitat) rather than spread more widely as is their nature (Harvey and Nakamoto 1996). Further, the fact that pools are neither very deep or frequent in Caspar Creek concentrates coho and steelhead into limited habitat. Finally, the downstream position coho generally maintain, relative to steelhead, may be responsible for their more limited access to drifting food and resulting lower weight gains (Harvey and Nakamoto 1996).

### 3.4.5 CALIFORNIA DEPARTMENT OF FISH AND GAME (unpublished data)

The California Department of Fish and Game ("CDFG") has been collected salmonid density and biomass data at two locations on the mainstem of Caspar Creek since 1986. CDFG staff prepared a series of field notes regarding salmon carcass surveys in the Caspar Creek watershed from 1986 through 1994 (CDFG unpublished data 'a'). Additional CDFG unpublished data are reported in two separate sources. An anonymous staff report, filed with the CDFG on November 12, 1991, presented coho and steelhead electroshocking data from 1984 to 1991 at two stations on Caspar Creek (CDFG unpublished data b). The other CDFG source is an unpublished database developed by Scott Harris of the CDFG that includes aquatic vertebrate electroshocking data collected at two stations on Caspar Creek from 1990 to 1998 (CDFG unpublished data 'c'). The electroshocking database includes information on both salmonid density (fish/m$^2$) and biomass (kg/ha) data.

The CDFG anonymous staff report (CDFG unpublished data 'b') presented results of electroshocking surveys for coho and steelhead at two stations (the Upper Station and Lower Station) in Caspar Creek in October of each year from 1984 through 1991. The Upper Station is located in the SE quarter of Section 9, T17N, R17W on the mainstem of Caspar Creek in the Jackson Demonstration State Forest. Salmonid biomass appears to have remained relatively stable from 1986 through 1993 with an average of 26.50 kg/ha and a range of 23.00 to 30.13 kg/ha. In 1994, however, the biomass increased 64% from the previous average to 43.33 kg/ha. In 1995 it fell dramatically by 60% to 17.76 kg/ha and continued to decrease to a low in 1997 of 3.80 kg/ha. In 1998, the salmonid biomass was measured at 10.72 kg/ha. Looking at the record as a whole, salmonid biomass has fallen by 91% from a high of 43.33 kg/ha in 1994 to a low of 3.8 kg/ha in 1997. It has averaged 22.88 kg/ha over this period.

The biomass of steelhead trout was less stable then that of all salmonids from 1986 through 1993 (it ranged from 11.70 to 22.09 kg/ha). It too jumped dramatically in 1994 (up 81% from the previous year) and then fell by 64% in 1995 to 13.16 kg/ha. Steelhead biomass continued to decrease to a low of 1.81 kg/ha in 1997. In 1998, it was measured at 5.42 kg/ha. Looking at the record as a whole, steelhead trout biomass has fallen by

95% from a high of 36.30 kg/ha in 1994 to a low of 1.81 kg/ha in 1997. It has averaged 15.2 kg/ha over this period. Coho biomass ranged from 1.99 kg/ha in 1997 to 11.74 kg/ha in 1987 and averaged 7.68 kg/ha. Coho have composed an average of 33% of the salmonid biomass in this period.

Salmonid density at this site has ranged in the period of 1986 to 1998 from 0.09 to 0.56 fish/m$^2$. The greatest density of salmonids was seen in 1991 while the lowest was in 1997. These are the same years of the highest and lowest densities of steelhead trout, respectively. Coho salmon, on the other hand, experienced their greatest density in 1988 (0.38 fish/m2) and their lowest in 1997 (0.06 fish/m2).

The Lower Station is located in the NW quarter of Section 9, T17N, R17W on the mainstem of Caspar Creek in the Jackson Demonstration State Forest. Salmonid biomass has ranged widely from 15.45 kg/ha in 1987 to 42.31 kg/ha in 1994. No particular pattern of change is apparent. Steelhead biomass also ranged widely from 4.56 kg/ha in 1988 to 37.15 kg/ha in 1994. Coho biomass ranged from 1.89 kg/ha in 1997 to 17.45 kg/ha in 1989. The average biomass for steelhead, coho, and all salmonids during this period was 21.44 kg/ha, 8.27 kg/ha, and 29.71 kg/ha, respectively. Coho have composed an average of 28% of all salmonids.

Salmonid density at this site has ranged in the period of 1986 to1998 from 0.14 to 0.95 fish/m$^2$ from 1986 to 1998. The greatest density of salmonids was seen in 1989 while the lowest was in 1998. For steelhead trout, the greatest density of fish was seen in 1991 (0.68 fish/m$^2$) while the lowest was seen in 1998 (0.07 fish/m$^2$). For coho salmon, the greatest density of fish was seen in 1988 (0.79 fish/m$^2$) while the lowest was seen in 1991 (0.04 fish/m$^2$).

### 3.4.6 SUMMARY OF POPULATION STUDIES

Aggregating the population data, it appears that prior to any second growth logging or road building in the South Fork Caspar Creek, the number of salmonids was approximately 2.8 fish/m$^2$ or 37.97 kg/ha with 42% of the biomass represented by coho salmon. The data collected by Weldon Jones and others at the CDFG suggest that large storm events may depress salmonid populations. For example, biomass significantly decreased from 1994 to 1995 in the aftermath of large storms. As such, the figures recorded in 1967 may also reflect negatively altered conditions resulting from the 1966 winter storms which were much larger than the 1994 and 1995 storms.

The total number of fish declined immediately following road-building in the South Fork drainage, as did the salmonid biomass. In addition, the percentage of salmonids represented by coho dropped. By the 1990s, the salmonid biomass averaged only about 20.67 kg/ha, a decline of 54% from the 1967 figures. Coho salmon represented only about 13% of the total salmonid biomass in the 1990 to 1995 period, as well. If the 1967 figures were indeed depressed as a result of the 1966 storms, then the decline in populations is more extreme than reported here.

A similar record for the North Fork Caspar Creek does not exist. However, it appears that the average salmonid biomass from 1990 to 1995 was about 24.17 kg/ha, approximately 17% higher than that in the South Fork for the same period. Coho salmon, however, represented less than 3% of that total.

During the early 1990s, total salmonid biomass was actually rising in the Caspar Creek mainstem, but it declined sharply after a peak in 1994. Applying Graves and Burns (1970) conclusions, one might surmise that the logging and burning that occurred in the North Fork Caspar Creek from 1989 to 1991 may have resulted in higher than normal emigration from the North Fork to the mainstem with the loss of good quality habitat resulting from sedimentation in the North Fork Caspar Creek. Alterations to habitat due to the storms of 1995 may also have played a role in population decreases.

These population studies highlight a few ecological effects worth considering when assessing biological data in other watersheds. For example:

- Fluctuation in the number and/or biomass of outmigrants may indicate changes in upstream habitat availability which has forced premature emigration.
- Fluctuation in the fork length of outmigrants may indicate changes in the competitive advantage of one species over another or one year class over another.
- Fluctuation in the percentage of salmonid biomass attributable to coho salmon may indicate changes in the competitive advantage of steelhead trout over coho due to changes in the availability of the more specific coho habitat needs.

## 3.5 SALMONID HABITAT AND FOOD STUDIES

### 3.5.1 BURNS (1970 and 1972)

Burns (1970) measured the particle size distribution of substrate in the North Fork Caspar Creek as well as South Fork Caspar Creek in June and October of 1967 to 1969. Road building and logging began in the South Fork Caspar Creek during the summer of 1967. The North Fork Caspar Creek was measured as a control.

Pre-road building sampling was conducted in June 1967 followed immediately by road building and post-road building sampling in October 1967. The percentage of particles <0.8 mm declined between June and October in the North Fork by 5% while it increased in the South Fork by 66%. The percentage of particles <0.8 mm in the South Fork recovered to its pre-road building level by the following year. However, it increased again (by 38%) in 1969. There was a 26% increase in the percentage of particles <0.8 mm in the North Fork from June 1967 to August 1969. The percentage of particles <0.8 mm prior to road building or second growth logging in the North or South Fork Caspar Creek ranged from 16.0 to 23.4% in June 1967 with a combined average of 19.5%. The percentage of particles <3.3 mm in June 1967 ranged from 28.8 to 40.6% with a combined average of 34.2%. The percentage of particles <26.7 mm in June 1967 ranged from 67.4 to 77.9% with a combined average of 72.7% (Burns 1970).

**Table 3.5**
**SUBSTRATE COMPOSITION DATA (from Burns 1970)**

| DATE | NORTH FORK CASPAR CREEK Mean percentage of total sample volume | | | SOUTH FORK CASPAR CREEK Mean percentage of total sample volume | | |
|---|---|---|---|---|---|---|
| | < 0.8 mm | <3.3 mm | <26.7 mm | <0.8 mm | <3.3 mm | <26.7 mm |
| June 1967 | 18.4<br>(16.0-20.7) | 32.0<br>(28.8-35.1) | 72.0<br>(67.4-76.6) | 20.6<br>(17.8-23.4) | 36.4<br>(32.3-40.6) | 73.3<br>(68.6-77.9) |
| Oct. 1967 | 17.5<br>(14.4-20.6) | 33.5<br>(28.5-38.6) | 79.5<br>(75.5-83.4) | 34.2<br>(25.6-42.8) | 47.8<br>(38.6-57.1) | 77.8<br>(71.5-84.2) |
| June 1968 | 18.2<br>(14.5-21.9) | 34.6<br>(30.4-38.8) | 78.0<br>(73.7-82.3) | 17.9<br>(10.9-24.9) | 37.2<br>(29.6-44.9) | 84.4<br>(79.4-89.5) |
| Oct. 1968 | 18.0<br>(15.6-20.4) | 35.5<br>(32.4-38.7) | 75.7<br>(72.8-78.6) | 19.0<br>(14.8-23.2) | 37.1<br>(31.8-42.5) | 74.8<br>(68.2-81.4) |
| Aug. 1969 | 23.2<br>(20.1-26.2) | 40.5<br>(35.5-45.5) | 80.4<br>(73.6-87.2) | 28.5<br>(24.6-32.3) | 44.2<br>(39.8-48.5) | 75.0<br>(69.8-80.2) |
| Sept. 1969 | NR | NR | NR | 27.1<br>(23.7-30.5) | 40.8<br>(35.7-45.8) | 75.7<br>(71.0-80.5) |

Burns (1972) measured the area of each study site in the South Fork Caspar Creek that was in pools and in riffles. The ratio of riffles to pools changed from 1.0 in June 1967 to 1.6 in October 1967 and then fluctuated between 0.7 and 0.9 through October 1969. That is, the proportion of habitat in pools immediately decreased, perhaps as a result of logging; but, it later increased above the pre-logging proportion and remained elevated two years later.

Burns (1972) reports that road construction and right-of-way logging were immediately detrimental to most aquatic invertebrates in South Fork Caspar Creek. There was an overall increase in benthos. However, the increase was related to two invertebrate orders, only (*diptera* and *plecoptera*). All other orders declined markedly (Burns et al. no date, as cited by Burns 1972). The increase in benthos in the South Fork Caspar Creek was accompanied by an equivalent increase in benthos in the North Fork Caspar Creek (120%). Thus, the increase in the South Fork can not be attributed to road construction and fertilization, alone (Burns 1972). Within two years, however, the South Fork benthos was 370% above pre-road conditions while the North Fork's benthos was only 64% greater for the same period (Burns et al. undated, as cited by Burns 1972). The weight of insects dropping into the South Fork doubled over the pre-road construction values but, aquatic organisms were more important in the diets of steelhead trout and coho salmon than were terrestrial organisms (Burns 1972).

### 3.5.2 LISLE (1989)

Lisle (1989) measured infiltration of fine sediment (<2 mm in diameter) into clean gravel beds, bed material size distributions, scour-fill depths, and sediment transport during ten storm flow events in three streams of north coastal California, including the North Fork Caspar Creek, Jacoby Creek, and Prairie Creek. He reported that within the size interval of <32 mm, the median particle diameter ranged from 8.0 (Jacoby Creek) to 9.0 mm (Prairie Creek). Percent of bed material finer than 2 mm ranged from 22.8% (North Fork Caspar Creek) to 25.0% (Prairie Creek). Grain size distributions were unimodal. There was remarkably little variation in the percentage of particles finer than 2 mm at various depths in North Fork Caspar Creek (Lisle 1989). The ratio of the median size of surface material to bed load was 3.2 in North Fork Caspar Creek

Lisle (1989) observed that appreciable transport of sand over a stable gravel bed during moderately high discharges did not occur in the monitored streams. The most likely cause for the absence of selective transport of sand was a lack of supply of sand in these streambeds, manifested in part by the unimodality of size distributions of surface and subsurface material. In addition, deposits of unarmored sand in pools, for example, were small. In North Fork Caspar Creek, however, maximum bed load particle size was less (finer than 2 mm) during rising stages than falling stages. Active bed thickness (defined as the difference between the highest bed elevation surveyed between storms and the lowest level of scour (measured by scour chains) was more than twice as great in Jacoby (mean value 0.32 m) and Prairie Creeks (0.39 m) than in North Caspar Creek (0.11 m).

Lisle (1989) concluded that the potential survivability of ova appears to be greatest in North Caspar Creek, the smallest stream of the three. The scour-fill depths were least. Flows capable of transporting enough bedload to cause deleterious amount of deposition of fines in cleaned gravel beds had a recurrence interval of over two years, compared with less than one year for the other two streams. Because of geology, sedimentology, and suspended sediment transport curves were similar to those for Jacoby Creek, the more favorable spawning habitat in North Caspar Creek is most likely due to its being higher in drainage. Thus, there appears to be an advantage for fish to migrate as far upstream as possible before spawning.

The main component of sediment infiltrating the bed was fine bed load, not suspended sediment, because of its frequent contact with the bed and ability to fit into framework interstices. Deposition was necessarily most concentrated near the bed surface and sealed off underlying depths to more infiltrating sediment. The seal decreased the rate of infiltration as bed load transport progressed, but not before enough fine sediment was deposited to endanger egg survival. Small streams apparently offer the least risk to spawning because of low rates of unit bed load transport (Lisle 1989).

Lisle (1989) predicted the following process based on the findings in North Fork Caspar Creek, Jacoby Creek, and Prairie Creek:

1. Fish excavate a pit, deposit eggs, and cover them with a mound of bed material that has reduced amounts of fine sediment.
2. During rising stages of a subsequent storm flow, increasing amounts of suspended sediment and fine bed load are transported over the bed. Some enters the bed, and because of its small size, deposits at all depths down to the level that eggs were laid.
3. As the entrainment threshold of the bed surface is exceeded, the topography of the redd is obliterated, and a surface seal of sand forms. The seal inhibits further infiltration of fine sediment, despite the increase of suspended sediment concentration in the surface flow.

4. As bed load transport fluctuates during peak flow, the bed scours, eroding and forming seals at successively lower levels. Scour may be deep enough to excavate and wash away the eggs.
5. Alternatively, bed load is deposited over the bed and forms a thick seal in combination with ingressing sand deposited below the original bed surface. Bed load deposited at riffle crests may be coarser than that in transport because of local sorting. Other scenarios are possible with different sequences of scour and fill.
6. Little change in bed material occurs after scour and fill cease during waning stages of the hydrograph.

### 3.5.3 KNOPP (1993)

V* (pronounced Vee-star) provides a unitless measurement of the fraction of a pool volume that is filled with fine sediment. This is a measure of the in-channel supply of mobile bedload sediment. It is affected by sediment inputs and is related to the quality of fish habitat (Lisle and Hilton 1992; Hilton and Lisle 1993). Hilton and Lisle (1993) suggest that care should be taken in interpreting V* and $V^*_w$ (the weighted mean of V* for a reach):[21]

> Knowledge of variations if V* between streams with different geologies and stream types is needed to interpret variations in V* with respect to sediment supply. For example, a value of $V^*_w$ of 0.15 would be expected to represent high sediment supply in basins underlain by competent metamorphic rocks, but would be considered low for basins in weathered granite. V* values can be expected to be associated with substrate conditions important to aquatic organisms, such as embeddedness or infiltration, but specific responses will depend on the community present, which will in turn depend on the natural range and variability of substrate conditions in the channel.

Knopp (1993) measured V* in watersheds throughout the North Coast Region. Stream reaches were categorized as highly disturbed, moderately disturbed, or as an index reach, based on historical accounts and a sediment budget for the stream. Index reaches were further divided into those without any historical landuse activity and those with some landuse activity (Knopp 1993). V* measurements showed a significant difference between disturbed watersheds and index watersheds (Knopp 1993). The region-wide mean V* value for index reaches was 0.21 or 21% of the pool volume filled with fine sediment (Knopp 1993). The mean value for undisturbed reaches was 0.17 or 17% of the pool volume filled with fine sediment (Knopp 1993).

Two of the streams measured were North Fork Caspar Creek and South Fork Caspar Creek. Two reaches in each fork were measured: three were identified as moderately disturbed and one was identified as undisturbed. The stations located below the weirs on each stream showed significantly lower V* values than those above. Apparently the weirs act to meter sediment to the lower reaches of the respective watersheds. The undisturbed reach identified below the weir in the North Fork Caspar Creek showed a higher mean V* than that below the weir of the South Fork Caspar Creek. The V* measurement collected below the North Fork Caspar Creek weir is the highest value measured for any undisturbed reach throughout the North Coast Region. All of the

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[21] Hilton and Lisle 1993.

sampling reaches showed V* values greater than the mean index value of 0.21. Further, the moderately disturbed reaches sampled above the weirs showed V* values exceeding the region-wide mean for moderately disturbed watersheds of 0.37.

**Table 3.6**
**V* DATA FOR NORTH FORK AND SOUTH FORK CASPAR CREEK (from Knopp 1993)**

| STREAM | DISTURBANCE CATEGORY | V* |
|---|---|---|
| South Fork Caspar Creek (above weir) | Moderate | 0.55 |
| South Fork Caspar Creek (below weir) | Moderate | 0.22 |
| North Fork Caspar Creek (above weir) | Moderate | 0.40 |
| North Fork Caspar Creek (below weir) | Undisturbed | 0.27 |

### 3.5.4 NAKAMOTO (1998)

Nakamoto (1998) conducted habitat inventories in both the North Fork Caspar Creek and South Fork Caspar Creek in May or June of 1986, 1990, 1993, and 1995. Logging began in North Fork Caspar Creek in the summer of 1986. South Fork Caspar Creek was used as a control. He reports habitat types as either “fast” (riffles, cascades, runs and glides) or “slow” (pools). In addition, he specifically identified pools with large woody debris.

Nakamoto’s (1998) data indicate that the ratio of fast to slow moving habitat types in 1986 was 2.7 in the North Fork and 2.4 in the South Fork. In 1990 this ratio was 1.4 in the North Fork and 0.92 in the South Fork, a change of 48% and 62%, respectively. In 1993 this ratio was 1.5 in the North Fork and 1.2 in the South Fork a change from 1986 of 67% and 50%, respectively. In 1995 this ratio was 1.3 in the North Fork and 1.9 in the South Fork, a change from 1986 of 52% and 21%, respectively. These data indicate a shift in habitat types due to both natural conditions (e.g., climatic events) and management activities.

Nakamoto’s (1998) data indicate that the proportion of pools with large woody debris in North Fork Caspar Creek was significantly higher than that in the South Fork Caspar Creek, as measured in 1986 prior to logging in the North Fork (70% versus 46%). It decreased in North Fork Caspar Creek by 27% from 1986 to 1990. There after the proportion remained relatively stable (an average of 53%). The proportion of pools with large woody debris in South Fork Caspar Creek decreased by only 7% from 1986 to 1990. It too remained relatively stable there after (an average of 42%). The road building and logging conducted in South Fork Caspar Creek from 1967 to1973 may have decreased the amount of large woody debris in the stream channel relative to the North Fork. In turn, the logging conducted in North Fork Caspar Creek from 1989 to1991 may have decreased the amount of large woody debris in the stream channel relative to pre-logging amounts. In 1995, the last year of the study, the proportion of pools with large woody debris in North Fork Caspar Creek was slightly higher than that in South Fork Caspar Creek suggesting that South Fork Caspar Creek continues to manifest the effects of second and perhaps old growth logging.

### 3.5.5 CALIFORNIA DEPARTMENT OF FISH AND GAME

In 1995, CDFG inventoried the habitat in North Fork Caspar Creek, Middle Fork Caspar Creek, South Fork Caspar Creek, and the mainstem (see CDFG 1995a, 1995b, 1995c, and

1995d, respectively). To inventory the habitat, staff walked over 58,000 feet of stream, identifying and measuring the length of every habitat unit and making other relevant measurements in approximately 10% of the identified habitat units.

The South Fork Caspar Creek, North Fork Caspar Creek and mainstem are all identified as F-type channels, using the Rosgen stream classification system.[22] F-type channels are entrenched, meandering, riffle/pool channels on low gradients with high width/depth ratios. The Middle Fork Caspar Creek is identified as a B-type channel. B-type channels are moderately entrenched, riffle-dominated channels with moderate gradients and infrequently spaced pools. B-type channels have a very stable plan form and profile, as well as stable banks.

Based on length, the pools identified in South Fork Caspar Creek and North Fork Caspar Creek made up 46% and 39% of the inventoried stream, respectively. Only 3% of the pools in both tributaries were deeper than three feet. Only 19% were deeper than two feet. With respect to embeddedness, shelter, and large woody debris the North Fork appeared more suited for salmonids than the South Fork. For example, only 13% of all cobble were less than 25% embedded in South Fork Caspar Creek while 30% were less than 25% embedded in North Fork Caspar Creek. North Fork Caspar Creek pools had an average shelter rating[23] of 37 (out of a possible rating of 300) while South Fork Caspar Creek pools had an average shelter rating of 22. (CDFG recommends stream restoration at sites with shelter ratings less than 100). The North Fork Caspar Creek had an average of 4.6 pieces of large woody debris (including live trees) in the bankfull channel per 100 feet of stream. South Fork Caspar Creek had an average of 1.4 pieces of large woody debris (including live trees) in the bankfull channel per 100 feet of stream. Thus, though the differences are not large, North Fork Caspar Creek appears to have somewhat better spawning substrate, rearing shelter, and stream channel structure.

### 3.5.6 SUMMARY OF HABITAT AND FOOD STUDIES

The second growth forests of the North Fork Caspar Creek and South Fork Caspar Creek were unlogged as of June 1967 when James Burns began his study in the watershed. At

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[22] For a discussion of the Rosgen stream channel classification system, see: Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

[23] A shelter rating is assigned by estimating the percent of a habitat unit area that offers some form of shelter and multiplying it by a shelter quality rating of zero to three. The maximum shelter rating is 300. A shelter quality rating is assigned as follows: If the shelter in a habitat unit consists of one to five boulders, bare undercut bank, bare bedrock ledge or a single piece of large wood, then the unit is given a shelter quality rating of one. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of one or two pieces of large woody associated with any amount of small wood, six of more boulders per 50 feet, a stable undercut bank with root mass, a single root wad lacking complexity, etc., then the unit is given a shelter quality rating of 2. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of combinations of large woody debris, boulders and root wads, three or more pieces of large woody debris combined with small woody debris, three or more boulders combined with large woody debris/small woody debris, etc., then the unit is given a shelter quality rating of 3. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). Flosi et al. (1998) recommend improving shelter availability through habitat restoration efforts where the shelter rating is less than 80.

that time, the percentage of particles <0.8 mm in the North and South Forks averaged 18.4% and 20.6%, respectively. In North Fork Caspar Creek (the control), the percentage of particles <8 mm averaged 19.1% from 1967 to 1969. It ranged from 14.4 to 26.2% during that time. These data indicate that particle size distribution in the Caspar Creek watershed was somewhat elevated in the late 1960s above the levels necessary for salmonid success: 14% fines <0.85 mm (wet volume) (Mangelsdorf and Lundborg 1997). Whether this fact is related to natural conditions, such as an unusually wet decade, or lingering effects of old growth logging is unclear. While particle size distribution data for later years is unavailable for comparison, Lisle (1989) reported that North Fork Caspar Creek experienced flows capable of transporting enough bedload to cause deleterious amounts of deposition of fines in cleaned gravel beds less than every two years. This is better than the recurrence interval for either Prairie or Jacoby Creeks. And, it is infrequent enough to ensure ova success in multiple coho year classes.

Lisle (1989) also reported that the scour-fill depths in North Fork Caspar Creek are the smallest of the three streams he studied, implying that redds are less likely to be washed away there than in either Prairie or Jacoby Creeks.

The California Department of Fish and Game (1995a, 1995c) reported that cobbles are significantly embedded in both the North and South Forks of Caspar Creek though North Fork Caspar Creek is somewhat better than South Fork Caspar Creek. As such, salmonids may have difficulty preparing redds. And further, eggs that are laid may have a difficult time emerging as fry should a sediment seal form.

Based on Nakamoto (1998) and the CDFG stream inventories (1995a, 1995b, 1995c, 1995d), it appears that the Caspar Creek watershed has fewer pools than other habitat types. Both Burns (1972) and Nakamoto (1998) showed an overall increase in the proportion of habitat in pools through the 1990s. Burns (1972) showed a decrease in the proportion of habitat in pools immediately after road-building activities, a condition that was corrected by the following year. Nakamoto (1998) also showed a decrease in the proportion of pools associated with large woody debris, perhaps a result of logging. Pool depths in both the North and South Forks are too shallow, as of 1995, to provide adequate salmonid refuge. Further, the shelter in pools is inadequate to protect young salmonids from predation. Knopp (1993) showed elevated V* values above and below the weirs in both the North Fork Caspar Creek and South Fork Caspar Creek.

In short, neither the North Fork Caspar Creek nor South Fork Caspar Creek currently offer ideal or even adequate salmonid habitat, though the size of the watershed appears to favor the success of salmonid ova inasmuch as streamflow is not often great enough to scour redds. Prior to second growth logging in the late 1960s, the proportion of habitat in pools may have been adequate (50%). But, only one data point exists. Neither pool depths nor large woody debris loading in the 1960s are available as corroborative evidence of rearing habitat quality at that time. Even in 1967, it appears that the substrate was too rich in fines to ensure adequate incubation success. This may have been a short-lived condition, however, resulting from the storms of 1964 and 1966. In addition to indicating current poor habitat conditions, the data do indicate that second growth logging activities may have altered the proportion of habitat in pools and the amount of large woody debris (including live trees) on the stream bank and in the stream, for the worse. The type of food available to salmonids may be altered by logging activities (e.g., species composition is altered and richness declines). However, the abundance of food does not appear to be negatively impacted by logging activities in this watershed.

## 3.6 ANALYSIS OF SEDIMENT SOURCES

Elements of a sediment source analysis have been conducted in the Caspar Creek watershed by a variety of researchers. Rice et al. (1979), Rice (1996), Cafferata and Spittler (1998), Keppler (1992), and Rice and Lewis (1991) have studied the effects of land management on hillslope erosion in the Caspar Creek watershed. The results of their studies are discussed below. Rice et al. (1979) and Rice (1996) have studied the delivery of sediment, which also is discussed in this section. Lewis (1998) has studied sediment yield in the North Fork and South Fork Caspar Creek, which is discussed in this section.

### 3.6.1 HILLSLOPE EROSION

Land management activities can alter the natural rate of erosion by modifying natural hydrology, compacting the soil, modifying evapotranspiration rates, and/or reducing slope stability through loss of root strength or other means. Several researchers have attempted to quantify the degree to which land management activities increase the rate of hillslope erosion in the Caspar Creek watershed.

#### 3.6.1.1 Rice et al. (1979) and Rice (1996)

Rice (1996) collected erosion data from harvest plots, road plots, and other large landslide features throughout the North Fork Caspar Creek in 1995 (Rice 1996). This was four years after the completion of logging activities and after large storms in 1993 and 1995 that produced annual runoff 252% and 312% above the annual mean (as measured from 1964 to 1997), respectively. Large erosional features were tracked by walking the stream channel and following all landslide features. If the landslide features were greater than 10 yd$^3$, they were inventoried, as were some as small as 2 yd$^3$, by mistake. These features are ones that should not otherwise show up in the harvest plot or road plot data sets as only two of the random plots were located in the Water Course and Lake Protection Zone (Rice 1996). In addition to the large erosional features inventory associated with this study, Rice (1996) also collected hillslope erosion data from three control subwatersheds. These subwatersheds contained very minor amounts of logging and road-building and totaled 187 acres (0.3 mi$^2$).

Rice et al. (1979) measured 963 yd$^3$/mi$^2$ of road-related hillslope erosion in the South Fork Caspar Creek in 1976. The surveyors measured 26,222 yd$^3$/mi$^2$ of harvest-related hillslope erosion in that same time period. The total amount of logging-related erosion measured in 1975 was 27,185 yd$^3$/mi$^2$. These measurements were made after a significant storm year (i.e., 1974) so as to capture the bulk of the failures expected as a result of logging and road-building from 1967 to 1973. Only three percent of the total erosion was rill erosion; the remainder occurred as landslides or large gullies (Rice et al.

1979). Sheet erosion was not included in the erosion estimate (Cafferata and Spittler 1998).

Rice (1996) measured a median of 3,155 $yd^3/mi^2$ road-related hillslope erosion in the North Fork Caspar Creek in 1995.[24] The North Fork road-related erosion is 328% of that resulting from South Fork Caspar Creek road-building in the 1960s. Rice (1996) measured a median of 14,067 $yd^3/mi^2$ harvest-related hillslope erosion in the North Fork Caspar Creek in 1995. This figure includes sheet erosion measurements. Sheet erosion from harvest plots was not measured in the earlier South Fork study. Harvest-related hillslope erosion excluding sheet erosion, then, is 8,742 $yd^3/mi^2$. The North Fork harvest-related erosion is 33% of that resulting from South Fork Caspar Creek logging in the 1960s and early 1970s. In total, Rice (1996) measured a median of 11,667 $yd^3/mi^2$ logging-related hillslope erosion. (This figure is calculated by adding harvest plot erosion to road plot erosion, and subtracting harvest-related sheet erosion). The North Fork logging-related erosion is thus 43% of that measured in the South Fork Caspar Creek in 1976.

The control subwatersheds generated a median of 1,619 $yd^3/mi^2$ (including harvest-related sheet erosion and large stream-side features). The study subwatersheds generated a median of 20,531 $yd^3/mi^2$ of erosion. A comparison of these figures indicates that the background rate of erosion accounted for only 8% of the total erosion in logged subwatersheds.

#### 3.6.1.2 Cafferata and Spittler (1998)

Cafferata and Spittler (1998) mapped landslides from field investigations (in the upper North Fork Caspar Creek) and aerial photos in both the South Fork Caspar Creek and North Fork Caspar Creek. Landslides were categorized based on their likely age and association with land management features. Landslides were divided into two size categories: smaller than 0.2 hectares and larger than 0.2 hectares. Cafferata and Spittler (1998) also re-evaluated data collected by Rice et al. (1979) and Rice (1996), updating some of the data.

Cafferata and Spittler's (1998) interpretation of 1975 aerial photos indicate the following distribution of landslide features resulting from road-building and harvest activities in the South Fork Caspar Creek from 1967 to 1973:

- 35 debris slides and debris flows associated with roads (53%),
- 12 associated with landings (18%),
- 16 with skid trails (24%), and
- 3 not associated with ground disturbance or within the logged area (5%).

This is a total of 66 debris slides and debris flows. Of these, 17 were larger than 0.2 hectares (0.5 acres). The largest percentage of large landslides were associated with landings (41%). Roads were the next largest source of these big features (35%). By comparison, only ten landslides were mapped in the North Fork Caspar Creek from 1985

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[24] Rice stated that because the data are skewed, the median is a better indicator of central tendency than the mean

to 1991. Six of these were associated with logged units while four were in unlogged portions of the watershed. Only one of the landslides exceeded 0.2 hectares (0.5 acres) in size (Cafferata and Spittler 1998).

#### 3.6.1.3 Keppler (1992)

Elizabeth Keppeler at the U.S. Forest Service Pacific Southwest Research Station has been keeping an inventory of large failures (>10 $yd^3$) in the North Fork Caspar Creek since the 1986. Field surveys are conducted after every major storm (>0.4 return interval) or at least once per year. Surveys are conducted in the South Fork Caspar Creek, as well -- but only since 1995.

Keppeler's data are coded to identify whether an erosional feature was due to windthrow, associated with a road, or associated with a harvest treatment. Not all features were coded with respect to harvest treatment. As such, the distribution of features based on cause is uncertain and will not be overstated here.

What is clear from these data is that the North Fork Caspar Creek is currently (1986 to 1998) producing only about 35% of the erosion that is being produced in the South Fork Caspar Creek (1995 to 1998). This is ten years after logging in the North Fork Caspar Creek has ceased and 28 years after logging in the South Fork Caspar Creek has ceased. This is similar to the relationship seen when comparing the data collected by Rice (1996) in the North Fork Caspar Creek to that collected by Rice et al. (1979) in the South Fork Caspar Creek.

**Table 3.7**
**TOTAL EROSION, ONSITE SOIL AND DELIVERED SEDIMENT (from Keppler 1992)**

| EROSION SOURCE | TOTAL EROSION (tons/$mi^2$/yr) | | ONSITE SOIL (tons/$mi^2$/yr) | | DELIVERED SEDIMENT (tons/$mi^2$/yr) | |
|---|---|---|---|---|---|---|
| | NFCC | SFCC | NFCC | SFCC | NFCC | SFCC |
| Road-related erosion | 117 | 645 | 27 | 248 | 90 | 397 |
| Harvest-related erosion | 23 | 13 | 12 | 11 | 11 | 2 |
| Natural erosion | 39 | 0 | 23 | 0 | 16 | 0 |
| Unknown source of erosion | 379 | 916 | 221 | 496 | 159 | 420 |
| **TOTAL** | 558 | 1574 | 283 | 755 | 275 | 818 |
| % of total whose source is unknown | 68 | 58 | 78 | 66 | 58 | 51 |

Other observations are based on the assignment of landslide causes. As such, they should not be given significant weight. However, it appears that windthrow accounts for about 20% of the erosion that occurs in the North Fork Caspar Creek but only 1% of that which occurs in the South Fork. This may be due to the use of evenage timber management in the North Fork Caspar Creek. In addition, 21% of the erosion in the North Fork Caspar Creek is associated with roads, while 41% of that in the South Fork Caspar Creek is associated with roads. This may be due to the age and quality of the roads in the South Fork as compared to those in the North Fork Caspar Creek. Further, 24% of the road-related erosion in the North Fork Caspar Creek remains on-site while 38% of it remains on-site in the South Fork Caspar Creek. This may be due to the differing location of the roads: North Fork roads are generally on steeper mid-slope areas, whereas South Fork roads are generally in the valley bottom.

#### 3.6.1.4 Rice and Lewis (1991)

Rice and Lewis (1991) conducted an analysis to identify critical erosion sites associated with logging and forest roads. From a literature review, they concluded that most of the erosion from logging operations occurred from a small percentage of the area. That is, mass movement was the most significant process by which erosion occurred. For example, on the North Coast, Rice and Lewis (1991) found that the average road produces 106 $yd^3$/acre of erosion whereas critical road sites produce 3,581 $yd^3$/acre, or more than 33 times more. Similarly, the average harvest area in 1978 to 79 produced 6 $yd^3$/acre of erosion whereas critical harvest areas produced 393 $yd^3$/acre or greater than 65 times more. Non-critical road sites produced 26 $yd^3$/acre whereas non-critical harvest areas produced only 3 $yd^3$/acre.

### 3.6.2. SEDIMENT DELIVERY

Rice et al. (1979) reported that a total of 27,185 $yd^3/mi^2$ excess erosion was produced due to logging activities in the South Fork Caspar Creek from 1971to1976. In this same period, Rice et al. (1979) calculates an excess rate of sedimentation of 6,091 $yd^3/mi^2$. As such, a sediment delivery ratio of 0.224 is calculated for logging-related erosion in the South Fork Caspar Creek.

By comparison, Rice (1996) reported a delivery ratio of 0.113 at the North Fork weir based on all of his North Fork data, except the sheet erosion data. This is exactly half of that calculated for the South Fork Caspar Creek. It may be that the institution of Water Course and Lake Protection Zone protections in the North Fork phase of the study (but not the South Fork phase) is responsible for the improved rate of soil capture in the North Fork Caspar Creek as compared to the South Fork Caspar Creek. It may also be that the loss of sediment from an old splash dam in the South Fork skews the South Fork Caspar Creek sedimentation. Or, it may be that instream tractor use during the South Fork phase of the study served to eliminate much of the South Fork Caspar Creek instream sediment storage capacity sending most of the sediment delivered from the hillslope directly to the South Fork weir. The delivery ratios calculated for individual subwatersheds in the North Fork Caspar Creek ranged from 0.0104 to 0.8968 with a mean of 0.1637 and a median of 0.0629. The highest two delivery ratios were calculated for two of the control watersheds: 0.8968 and 0.5273, respectively.

### 3.6.3 SEDIMENT YIELD

Suspended and bedload sediment measurements have been made in both the North Fork Caspar Creek and South Fork Caspar Creek since 1963, prior to the second growth logging of either tributary. The mean sediment yields in the North Fork and South Fork from 1963 to1999 (including all measured sediment yields before and after second growth logging in the basin) are 475 tons/$mi^2$/yr and 568 tons/$mi^2$/yr, respectively.[25] These figures represent 23 years of pre-logging measurements, seven years of

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[25] These yields were derived from the Pacific Southwest Forest Service web site at www.rsl.psw.fs.fed.us.

measurements during logging, and nine years of post-logging measurements in the North Fork. They represent five years of pre-logging measurements, seven years of measurements during logging, and 27 years of post-logging measurements in the South Fork. Anywhere from 15 to 30% of this is bedload and 70 to 85% is suspended load (Napolitano 1998 and Cafferata and Spittler 1998). Cafferata and Spittler (1998) concluded that the ratio of bedload to suspended load is most likely approximately 30:70.

Lewis (1998) has developed linear regressions between the logarithms of the annual suspended sediment loads at each of the weirs in the North Fork and South Fork to characterize the relationship of the North Fork to the South Fork before the 1971-1973 logging in the South Fork. From these, Lewis is able to predict background suspended sediment and total sediment yield for each watershed and calculate the percent difference between the predicted and actual yields. His analysis indicates that in the South Fork, suspended sediment loads were 212% and total sediment yields were 184% above background yields in the six years during and after logging from 1972 to1978. That is, under background conditions, the sediment yield would have been 429 tons/mi$^2$/yr in this period. But, due to road building and second growth logging, the sediment yield was 1,218 tons/mi$^2$/yr, instead.

Lewis (1998) also compared untreated subwatersheds within the North Fork watershed with treated subwatersheds. This analysis indicates an 89% increase in suspended sediment yields over background after logging began in the North Fork Caspar Creek. (The analysis is not adjusted to account for a large landslide in an uncut basin in the North Fork watershed that produced more sediment than any of the post-disturbance years documented during the life of the study through water year 1995). From this, it appears that increases in suspended sediment yield were at least 2.4 times greater as a result of the South Fork logging than as a result of the North Fork logging. Lewis (1998) does not report changes in total sediment yield in the North Fork as a result of logging.

Lewis assisted Regional Water Board staff in estimating total sediment yield in the North Fork Caspar Creek in the absence of logging effects. Lewis provided Regional Water Board staff with a predicted suspended sediment yield (i.e., sediment yield in the absence of logging effects) at the North Fork weir for every major storm from 1986 through 1998 (Lewis, personal communication). His predicted suspended sediment yields are derived from a regression of storm-related suspended sediment loads measured at the North Fork weir versus the mean of the storm-related suspended sediment loads from the control watersheds H and I. The regression equation is based on 14 pre-logging storms from which there are good estimates in the period of 1986 to 1989.

Lewis recommended that the storm-related predicted suspended sediment measurements be converted to annual suspended sediment loads by summing the predicted storm-related suspended sediment loads and adjusting them based on the proportion of measured total suspended sediment load that was attributable to the measured storms. Similarly, the proportion of the measured total annual sediment load that is attributable to suspended sediment is used to adjust the predicted suspended load to a predicted total load. The result is that an average of 171 tons/mi$^2$/yr of sediment would have been produced by the

North Fork from 1986 to 1998, in the absence of second growth logging. However, the North Fork produced 242 tons/mi$^2$/yr of sediment in that period. Thus, it appears that post-Forest Practices Act logging resulted in an increase in sediment above background of 42%. This compares to the increase predicted during and immediately after pre-Forest Practices Act logging in the South Fork (i.e., from 1972-1978) of 184%.

Summing the annual sediment yields in the North Fork from 1963 to 1985 (i.e. prior to second growth logging) and the predicted annual sediment yields in the North Fork from 1986 to 1998 (i.e., in the theoretical absence of second growth logging), the predicted sediment yield for the period of 1963 to 1998 for the North Fork Caspar Creek is 451 tons/mi$^2$/yr. This represents the total annual sediment yield from 1963 to 1998 predicted for a small coastal watershed logged of its old growth at the turn of the century; but unimpacted by second growth logging. The predicted figure includes periods of significant rainfall as well as significant drought.

This prediction compares to actual measurements in the North Fork for this period of 477 tons/mi$^2$/yr and in the South Fork of 563 tons/mi$^2$/yr. In the pre-logging period, sediment yield in the South Fork was 88% of that in the North Fork. Thus, these comparisons suggest that:

- Areas logged using pre-Forest Practices Act practices (e.g., 95% of the watershed harvested using selection logging; 100% of the harvest area yarded with tractors; 15% of the watershed compacted with roads, landings and skid trails; etc) require 27 years of rest after logging to achieve sediment yields no more than 42% above background (e.g. [563-(0.88)(451)]/563). To achieve sediment yields no more than 10% above background may require more than 40 years of rest.
- Areas logged using very conservatively applied Forest Practices Act practices (e.g., 50% of the watershed harvested using clearcut logging in 22 to148 acre blocks; 78% of the harvest area yarded with skyline cables; 3% of watershed compacted with roads, landings and skid trails; etc.) require nine years of rest after logging to achieve sediment yields no more than 6% above background.
- Areas logged using more commonly applied Forest Practices Act practices may take anywhere from 10 to 40 or more years of rest after harvesting to achieve a sediment yield within 10% of background.

### 3.6.4 SUMMARY OF SEDIMENT ANALYSES

All of the sediment-related data suggest that the pre-Forest Practices Act logging conducted in the South Fork Caspar Creek from 1967 to 1974 produced significantly more erosion and delivered significantly more sediment than the post-Forest Practices Act logging conducted in the North Fork Caspar Creek from 1985 to 1991. The number of landslides produced in the North Fork as a result of logging was only 15% of that which was produced in the South Fork. The total management-related erosion in the North Fork was 43% of that in the South Fork. The sediment delivery ratio for management-related erosion in the North Fork was half of that in the South Fork. And, the sediment yield above background was four times greater as a result of South Fork logging than North Fork logging. Only with respect to roads did the North Fork logging produce greater erosion than the South Fork logging.

The logging conducted in the North Fork Caspar Creek subwatershed was conservative compared to that commonly applied elsewhere in the Mendocino Coast Hydrologic Unit. Fifty-percent of the subwatershed was logged in 22 to 148 acre blocks. This compares to other locations where a subwatershed may be logged in its entirety two or three times over the course of 30 years. Cable yarding was used as the predominant yarding method. This compares to other locations where tractor yarding is still the predominant yarding method. And, only 3% of the watershed was compacted with roads, landings, or skid trails. This compares to other locations where 6 to 20% of the watershed is compacted with roads, landings, or skid trails.

Nonetheless, even with conservatively applied Forest Practices Act logging practices, management activities accounted for 92% of the total erosion measured in the North Fork Caspar Creek subwatershed. Further, sediment yields in the North Fork exceeded background yields by 42% as a result of logging. This suggests that as applied elsewhere, the Forest Practices Act may not adequately prevent management-related hillslope erosion nor prevent sediment delivery to watercourses.

## 3.7 LARGE WOODY DEBRIS

Napolitano (1998) studied the loading of large woody debris in North Fork Caspar Creek and concluded that the loading to and stability of large woody debris in the sub-basin has been significantly altered by historic old growth logging and the resulting second growth forest cover. Large woody debris jams in old growth streams provide:

(a) A stepped channel profile,
(b) Stable channel roughness elements and long-term sediment storage, and
(c) Stable channel structure that creates a diverse assemblage of channel morphologies and flow conditions such as that often associated with high quality fish habitat (Keller and Tally 1979, as cited by Napolitano 1998).

Evidence in the North Fork Caspar Creek suggests that the existing large woody debris jams are dynamic, short-lived features (Napolitano 1996) with significantly less sediment storage capacity and existing sediment storage behind jams then is found in other old growth streams (Napolitano 1998).

Napolitano (1998) researched the conditions of 19th century logging and channel alterations in the North Fork Caspar Creek. He conducted a field survey to look for current evidence of 19th century log drives, large woody debris removal, and other elements of the identified history. He then compared the results of large woody debris surveys conducted by Keller and others (1981, as cited by Napolitano 1998) from upper Little Lost Man Creek in Humboldt County (an old growth stream) to the North Fork Caspar Creek (a second growth stream). He also compared channel attributes above a historic splash dam in North Fork Caspar Creek to those below it. He was able to identify the changes in large woody debris loading and channel structure that likely occurred as a result of historic logging and have not yet recovered despite little activity in the sub-basin up through the 1980s.

Evidence of log drives exists in the form of old splash dam structures and in-place old growth stumps on valley fills. Nineteenth-century loggers generally cut old growth redwoods well above the root swell since they were paid by a log's smallest diameter. As such, old growth stumps are generally several meters above ground surface (Napolitano 1998). Stumps along the mainstem of North Fork Caspar Creek, however, are cut flush with the ground surface, presumably to avoid snagging the logs that floated by during log drives (Napolitano 1998). Removal of large woody debris from the channel is surmised by the absence of old growth logs in the stream. The largest logs in the channel today are 0.5 meters in diameter, approximately the same diameter as the largest second growth trees in the basin (Napolitano 1998). Based on USDA Forest Service maps identifying debris jams storing ≥ 25 $m^3$ of sediment, the volume of sediment stored behind large woody debris jams in the North Fork Caspar Creek is 530 $m^3$/2405 m of stream (0.22 $m^3$/m).

Napolitano (1998) hypothesized that the North Fork Caspar Creek historically resembled upper Little Lost Man Creek because both are steep, second-order, gravel-bedded streams with narrow valleys, similar drainage area, channel width, and slope. Table 3.8 summarizes the quantitative differences between characteristics of North Fork Caspar Creek and upper Little Lost Man Creek.

**Table 3.8**
**A COMPARISON OF WATERSHED CHARACTERISTICS OF THE NORTH FORK CASPAR CREEK AND LITTLE LOST MAN CREEK (from data presented in Napolitano 1998)**

| WATERSHED CHARACTERISTICS | NORTH FORK CASPAR CREEK | | LITTLE LOST MAN CREEK | |
|---|---|---|---|---|
| | **Upper** | **Lower** | **Upper** | **Lower** |
| Basin area ($km^2$) | 1.6 | 3.9 | 3.5 | 9.1 |
| Stream order | 2 | 2 | 2 | 2 |
| Slope | 0.016 | 0.013 | 0.033 | 0.048 |
| Channel sinuosity (m/m) | 1.1 | | 1.1 | NA |
| Channel width (m) | 5.3 | | 6.4 | NA |
| Channel margins | Hillslopes and/or narrow valley flat | | Hillslopes and/or narrow valley flat | NA |
| Debris loading ($kg/m^2$) | 21 | 24 | 142 | 49 |
| Pool to pool spacing (by channel widths) | 3.5 | 3.8 | 1.9 | 1.8 |
| Pool morphology influenced by debris (%) | 82 | 43 | 100 | 90 |
| Sediment storage ($tons/km^2$) | 340 | | 1795 | NA |
| Available storage ($tons/km^2$) | <50 | | 1010 | NA |

NA = Not Available

These data indicate that upper Little Lost Man Creek contains two to seven times more large wood than North Fork Caspar Creek. Similarly, log jams in Little Lost Man Creek store about five times as much sediment, and have approximately 20 times as much unfilled storage capacity, as in North Fork Caspar Creek (Napolitano 1998). Napolitano (1998) cited findings that woody debris jams in old growth streams are generally quite stable, often more than 100 years old. The presence of many collapsed or partially collapsed jams and the lack of mature trees growing through the debris pieces suggest that the debris jams found in North Fork Caspar Creek are dynamic, short-lived features (Napolitano 1996).

Napolitano (1998) concluded that 19th century logging practices resulted in the significant alteration of the stream channel form and structure in the North Fork Caspar Creek. In particular, he observed (or surmised) that 19th century logging resulted in:

(a) The erosion of sediment stored in debris jam backwaters;
(b) The incision and confinement of the stream channel;
(c) The loss of high flow channels auxiliary to the mainstem;
(d) The conversion of valley fills from large-volume, long-term sediment sinks (floodplains) to substantial sediment sources (terraces); and
(e) An increase in the mobilization of large woody debris.

Napolitano (1998) concluded that it is unlikely that North Fork Caspar Creek will recover its former morphology until the former relationship between the size of woody debris and flow magnitude is reestablished. Reestablishing such a relationship requires the availability and high recruitment potential of large trees similar in size to those in an old growth forest.

## 3.8 CONCLUSIONS

The Caspar Creek watershed is a small coastal watershed. It is significantly smaller than the Ten Mile River, Big River, Albion River and Gualala River watersheds. Yet its general characteristics are sufficiently similar to these study watersheds to offer reasonable points of comparison, particularly for some of the smaller coastal tributary basins within the large study watersheds.

Old growth and pre-Forest Practices Act second growth logging in the Caspar Creek watershed is similar in intensity and style to that conducted in other coastal watersheds throughout the Mendocino Coast Hydrologic Unit, though the second growth logging was very short-lived compared to other watersheds along the coast. The post-Forest Practices Act second growth logging conducted in the North Fork Caspar Creek, however, is significantly different than second growth logging conducted after 1972 elsewhere on the North Coast. Less area of the watershed was logged than elsewhere. Less of the yarding was conducted using ground-based tractors than elsewhere. Less of the Water Course and Lake Protection Zone was harvested than elsewhere. And, less of the watershed was compacted with roads, landings and skid trails than elsewhere.

There is a clear indication of population decline in Caspar Creek from 1967 to 1995. Further, there has been a clear shift in salmonid population structure towards a greater percentage of steelhead trout than coho. Thus, in other watersheds where population data are scarce, the Caspar Creek population data could be used to depict the kind of trends that are seen in coastal watersheds of a similar scale.

The Caspar Creek studies are generally inadequate to depict trends in aquatic habitat quality and quantity. Perhaps one exception is the understanding of changes in large woody debris over time. Researchers demonstrated that old growth logging, pre-Forest

Practices Act logging and post-Forest Practices Act logging have all served to reduce the volume of large woody debris in the stream channel. The loss of large woody debris appears to have a major influence over channel form, flow dynamics, pool formation and sediment storage. Napolitano (1998) concluded that until the former relationship between the size of woody debris and flow magnitude is reestablished, it is unlikely that the North Fork Caspar Creek will recover its former morphology. Reestablishing this former relationship requires the availability and high recruitment potential of large trees similar in size to those in an old growth forest. Where the logging history is at least as intense as in the Caspar Creek watershed, one might assume that the loss of large woody debris is similarly problematic.

Neither the North Fork Caspar Creek not South Fork Caspar Creek demonstrate particularly good coho habitat. But, with respect to common indicators, the North Fork Caspar Creek is somewhat better than the South Fork Caspar Creek thereby suggesting that with similar old growth logging history, second growth logging practices can have an effect on aquatic habitat quality. Generally speaking, however, the values for habitat indicators in the Caspar Creek watershed do not make good target values for other watersheds.

The sediment data collected in Caspar Creek is useful for comparison to other watersheds. The Caspar Creek data provide an estimate of background sediment yields where background is understood to be the combination of natural sediment sources and sources resulting from 19th century logging. It also allows an assessment of the sediment yield resulting from pre-Forest Practices Act logging as compared to conservatively implemented post-Forest Practices Act logging. Further, it allows an assessment of the sediment yield resulting from conservatively implemented post-Forest Practices Act logging in the North Fork Caspar Creek to more liberally implemented post-Forest Practices Act logging in tributaries of the study watersheds.

Other general statements excerpted from studies in Caspar Creek may be useful in application to the study watersheds, as well:

- Activities that increase peak flows or decrease the stability of the armor layer may elevate the risk of poor ova survival (Lisle 1989).
- Cable yarding substantially reduces the risk of immediate landsliding as well as post-harvest landsliding (Cafferata and Spittler 1998).
- Suspended sediment loads increase after road building and logging but return to normal levels after seven years of rest (Lewis 1998).
- There is a statistically significant, positive relationship between ground disturbance and suspended sediment (Lewis 1998; Lewis, personal communication).
- Post-Forest Practices Act-related excess sediment loads are mostly related to increases in storm flow volumes. Reductions may be achieved by reducing or preventing disturbance to small drainage channels (Lewis 1998).
- Peak flows, except those during very large storms, and annual runoff increase as a result of logging. Clear-cutting causes greater such increases than selective harvest. These effects subside within 15 years of rest as the trees re-grow (Ziemer 1998).

- Deep pools are important to salmonid success in small, low-gradient streams where water depth and habitat complexity are otherwise reduced (Harvey and Nakamoto 1996).
- The presence of juvenile steelhead has a negative effect on the growth of juvenile coho salmon and such affects may have population-level ramifications. When the two species are found together, coho occupy the middle of pools whereas steelhead are more widely distributed. The availability of large pools, then, is important to coho successful competition (Harvey and Nakamoto 1996).
- The most common sources of large woody debris to streams are from windthrow and bank erosion (O'Connor and Ziemer 1989).

# Chapter 4
# Ten Mile River Watershed

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## 4.0 BRIEF CONCLUSIONS

The Ten Mile River watershed harbors the last native coho salmon in Mendocino County (Weitkamp 1995). As such, protection of the fish and restoration of their habitat in the Ten Mile River watershed is of special interest. The existing data indicate that coho salmon continue to spawn and rear with some regularity in the Little North Fork Ten Mile River, Clark Fork Ten Mile River, Bear Haven Creek, South Fork Ten Mile River, Smith Creek, Campbell Creek, and Churchman Creek. For the most part, these streams have at least some habitat characteristics that favor salmonids – some C-type channel, good scour pool frequency, LWD-formed habitat, and suitable summer stream temperatures. Coho salmon habitat in the Ten Mile River watershed could be significantly improved with reductions in sediment delivery, protection and improvement in riparian functions, increases in large woody debris for sediment metering and habitat, and modification of stream channel type.

The steelhead trout population data and substrate composition data are two of the strongest data sets available for the Ten Mile River watershed. The coho salmon population data allows for an assessment of presence and absence, only; it does not provide unequivocal population numbers for the species.

- Little North Fork Ten Mile River is one of the watershed's strongest coho streams. If sediment delivery rates are reduced, habitat conditions could be significantly improved.
- Bear Haven Creek is another of the strongest coho streams in the watershed. With the exception of limited backwater pools, the primary issue of concern in Bear Haven Creek appears to be aggradation.
- Smith Creek and Campbell Creek are two other strong coho streams in the Ten Mile River watershed. Habitat conditions could potentially be improved by reducing fine

sediment loading. Temperatures in Campbell Creek could potentially be improved by increasing the streamside canopy.

## 4.1 GENERAL BACKGROUND

### 4.1.1 BASIN PLAN – BENEFICIAL USES

The primary beneficial use of concern in the Ten Mile River watershed, as described in the *Water Quality Control Plan, North Coast Region* ("the Basin Plan," California North Coast Regional Water Quality Control Board 1994), is the cold freshwater fishery which supports coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), and chinook salmon (*Oncorhynchus tshawytscha*). The Ten Mile River watershed also supports other native and introduced fish and aquatic species including: three-spined stickleback, coast range sculpin, prickly sculpin, several species of lamprey, pacific giant salamander, several species of newt, yellow-legged frog, and tailed frog. The beneficial uses of water related to rare, threatened or endangered species has been proposed for this basin. As with many of the north coast watersheds, the cold water fishery appears to be the most sensitive of the beneficial uses in the watershed because of the sensitivity of salmonid species to habitat changes and water quality degradation. Accordingly, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by impaired water quality.

The Basin Plan identifies the following additional beneficial uses related to the Ten Mile River watershed's cold water fishery:

- Commercial and sport fishing (COMM)
- Cold freshwater habitat (COLD)
- Migration of aquatic organisms (MIGR)
- Spawning, reproduction, and early development (SPWN); and
- Estuarine habitat (EST)

### 4.1.2 LOCATION

The Ten Mile River watershed drains an area of approximately 31,000 hectares or 120 $mi^2$ (Ambrose et al. 1996). It is located north of the City of Fort Bragg by eight miles, sharing ridges with Pudding Creek and the North Fork of the Noyo River to the south and Wages Creek and the South Fork of the Eel River to the north. Elevations range between sea level and 977 meters (3,205 feet, Ambrose et al. 1996).

### 4.1.3 CLIMATE

The Ten Mile River watershed experiences a Mediterranean-type climate typified by abundant rainfall and cool temperatures during the winter and dry, hot summers punctuated with cool breezes and fog along the coast. Precipitation occurs primarily as rain with 40 inches in the western portion and 50 inches in the eastern portion of the watershed (WRCC 2000a). Approximately 90% of the annual precipitation occurs between October and April.

### 4.1.4 VEGETATION

The Ten Mile River watershed has a dominant overstory consisting of Redwood (*Sequoia sempervirens*) and Douglas fir (*Pseudotsuga menziesii*) (Ambrose et al. 1996). Redwood is the dominant constituent of coastal forest stands while Douglas fir dominates the more inland sites. Minor conifer components in the area include Grand Fir (*Abies grandis*) and Western Hemlock (*Tsuga heterophylla*) (Ambrose et al. 1996).

Hardwood species such as Tanoak (*Lithocarpus densiflorus*) and Pacific Madrone (*Arbutus menziesii*) are other common components of conifer stands, though only on xeric sites (Ambrose et al. 1996). Generally, Tanoak and Pacific Madrone constitute a higher percentage of the stands in the inland portions of the watershed (Ambrose et al. 1996). Interior Live Oak (*Quercus wislizenii*) is a minor component at most xeric sites on inland ridges (Ambrose et al. 1996).

Further inland, near the headwaters of the North Fork and Clark Fork, open grassland dominates with an overstory of California Black Oak (*Quercus kelloggii*) and Oregon White Oak (*Quercus garryana*) punctuated with Douglas-fir/Redwood/Tan Oak stands (Ambrose et al. 1996).

## 4.2 SALMONID DISTRIBUTION AND ABUNDANCE

Population abundance trends are an indicator of risk in salmonid populations. Trends may be quantified if data such as spawner surveys, dam or weir counts, stream surveys and catchment are available. If quantitative data are not available, general trends in population abundance may be estimated by comparing historical and current estimates.

### 4.2.1 HISTORIC SALMONID ABUNDANCE

As described in Chapter 2, salmonid abundance has declined dramatically throughout the Mendocino Coast Hydrologic Unit. Coho and chinook salmon have declined sharply in the Ten Mile River watershed as described below. Steelhead trout, however, may be now surpassing the population numbers identified in the 1960s.

#### 4.2.1.1 Coho Salmon

In the early 1960s the Ten Mile River was estimated to have a coho run of 6,000 fish according to the California Wildlife Plan, published by the Fish and Game Commission in 1965. The California Wildlife Plan described the fishery habitat conditions in the Ten Mile River to be severely degraded by logging activity. The decline in water quality conditions is related to an over-abundance of sediment.

The California Department of Fish and Game (“CDFG”) unpublished records indicate that coho were planted in the Ten Mile River dating back as far as 1955. The effort to restore this run by artificial propagation appears to have been unsuccessful. The Oregon coho stocks may have been inappropriate to this watershed and habitat problems and the limitations that exist may have contributed as well (Maahs and Gilleard 1994).

The more recent coho run estimates range from 32 to 52 fish in 1989 to 90, 14 to 42 fish in 1991 to 92, and 78 to 351 fish in 1995 to 96. Weitkamp et al. (1995) estimates using data from Brown et al. (1994) that the average coho salmon spawner abundance in Mendocino County includes 160 native coho salmon in the Ten Mile River. Higgins et al. (1992) characterizes the coho salmon run in the Ten Mile River watershed as one of “special concern.”

#### 4.2.1.2 Steelhead Trout

In the 1960s, the Ten Mile River was estimated to have a total steelhead trout population of 9,000 fish (California Fish and Game Commission 1965; Busby et al. 1996). More recent data, including electrofishing, outmigrant, and spawning surveys indicate fairly stable populations of steelhead distributed throughout the Ten Mile River watershed. As discussed later in this chapter, the electrofishing data collected by Georgia-Pacific ("G-P"), in particular, seems to indicate that the abundance of steelhead may have increased since the 1960s.

According to CDFG (unpublished data 'f'), very few steelhead trout have been planted in the Ten Mile River.

#### 4.2.1.3 Chinook (King) Salmon

Maahs and Gilleard (1994) state that chinook salmon are not considered to be native to the Ten Mile River, although they acknowledge that chinook have been reported caught in the River "several decades ago."[26] Maahs and Gilleard (1994) also report that chinook have been introduced to the Ten Mile River in the 1980s, with the last and largest release in 1987 (9,000 fingerlings released). They also report that chinook carcasses found in the watershed are composed of various age groups and may indicate a rare successful introduction. Shapovalov (1948) reports findings that chinook spawned in the Noyo and Big Rivers "and somewhat more in the Ten Mile."

The U.S. Fish and Wildlife Service (1960) estimated the total sport catch of king salmon in northwestern California during 1956 at over 44,000 fish. Maahs (1996) concludes that low numbers of chinook introduced into the Ten Mile River watershed, while occasionally productive, may have experienced river conditions unfavorable to continued natural production. This conclusion is based on the estimates of more recent runs, which range from 34 to 54 fish in 1989-90, 51 to 154 fish in 1991-92 and less than ten fish in 1995-96. Though few, chinook are found widely scattered throughout the Ten Mile River watershed, including: Little North Fork Ten Mile River, North Fork Ten Mile River, Clark Fork Ten Mile River, and South Fork Ten Mile River (Maahs and Gilleard 1994). Unfortunately, very limited data regarding chinook salmon has been collected over the years. As such, this assessment focuses on coho salmon and steelhead trout.

### 4.2.2 SOURCES OF CURRENT SALMONID DISTRIBUTION AND ABUNDANCE DATA

There are several good sources of current salmonid distribution and abundance data in the Ten Mile River watershed. The watershed is predominantly owned by Hawthorne Timber Company and is managed by Campbell Timberland Management, Inc. The company was formerly owned by Georgia-Pacific West, Inc. As G-P, the company produced numerous documents reporting the results of their surveys and research in the Ten Mile River watershed. G-P established a monitoring network throughout the watershed including 47 stations: one station in the lower Ten Mile River subwatershed, 15 stations in the North Fork Ten Mile River subwatershed, 14 in the Clark Fork Ten

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[26] Maahs and Gilleard 1994, page 52.

Mile River subwatershed, and 17 in the South Fork Ten Mile River subwatershed (see Table 4.1and Maps 4.5, 4.6 and 4.7 at the end of this document). Aquatic vertebrate data are available from 26 of the 47 stations from 1993 to 1999.

**TABLE 4.1**
**G-P MONITORING STATIONS LOCATED IN THE TEN MILE RIVER WATERSHED**

| STATION ID | STATION LOCATION | STREAM TEMPERATURE | AQUATIC VERTEBRATES | SUBSTRATE COMPOSITION |
|---|---|---|---|---|
| **LOWER TEN MILE RIVER** | | | | |
| TEN1 | Mill Creek | X | X | X |
| North Fork Ten Mile River Subwatershed | | | | |
| NFT1 | NFT @ Patsy Creek | X | X | X |
| NFT2 | Bald Hill Creek | X | X | X |
| NFT3 | NFT @ O'Connor Gulch | X | | |
| NFT4 | NFT @ Camp 3 | X | X | |
| NFT5 | NFT @ Camp 5 | X | X | X |
| NFT6 | Lower Little North Fork Ten Mile River | X | X | X |
| NFT7 | Buckhorn Creek | X | X | X |
| NFT8 | Upper Little North Fork Ten Mile River | X | X | |
| NFT9 | NFT @ Gulch 9 | X | X | X |
| NFT10 | Patsy Creek | | X | X |
| NFT11 | NFT @ property line | X | | |
| NFT12 | Bald Hill Creek (riffle) | X | | |
| NFT13 | NFT @ Patsy Creek (riffle) | X | | |
| NFT14 | NFT @ Camp 5 (riffle) | X | | |
| NFT15 | NFT/CFT confluence | X | | |
| **CLARK FORK TEN MILE RIVER SUBWATERSHED** | | | | |
| CFT1 | CFT @ Reynolds' Gulch | X | X | X |
| CFT2 | CFT @ Little Bear Haven Creek | X | | X |
| CFT3 | Lower Bear Haven Creek | X | X | X |
| CFT4 | Lower CFT | X | | X |
| CFT5 | Booth Gulch | X | X | X |
| CFT6 | Little Bear Haven Creek | X | X | X |
| CFT7 | Upper Bear Haven Creek | X | X | |
| CFT8 | CFT @ Ford Gulch | X | X | |
| CFT9 | Lower CFT (riffle) | X | | |
| CFT10 | Booth Gulch (riffle) | X | | |
| CFT11 | CFT @ Bensi Crossing | X | | |
| CFT12 | CFT @ Gulch 18 | X | | |
| CFT13 | CFT @ Gulch 18 (riffle) | X | | |
| CFT19 | Gulch 16 | X | | |
| **SOUTH FORK TEN MILE RIVER SUBWATERSHED** | | | | |
| SFT1 | Smith Creek | X | X | X |
| SFT2 | Campbell Creek | X | X | X |
| SFT3 | SFT @ Brower's Gulch | X | X | X |
| SFT4 | Churchman Creek | X | X | X |
| SFT5 | SFT @ Buck Mathew's Gulch | X | X | X |
| SFT6 | SFT @ Camp 28 | X | X | X |
| SFT7 | Lower Redwood Creek | X | X | |
| SFT8 | Upper Redwood Creek | X | X | X |
| SFT9 | Upper SFT | X | X | X |
| SFT11 | Gulch 11 | X | | |
| SFT12 | SFT above Gulch 11 | X | | |

**TABLE 4.1**
**G-P MONITORING STATIONS LOCATED IN THE TEN MILE RIVER WATERSHED**

| STATION ID | STATION LOCATION | STREAM TEMPERATURE | AQUATIC VERTEBRATES | SUBSTRATE COMPOSITION |
|---|---|---|---|---|
| SFT13 | SFT @ Churchman Creek | | | X |
| SFT15 | SFT @ Camp 28 | X | | |
| SFT16 | Lower SFT | X | X | |
| SFT17 | SFT @ Brower's Gulch (riffle) | X | | |
| SFT18 | SFT @ Buck Mathew's Gulch (riffle) | X | | |
| SFT19 | Lower SFT (riffle) | X | | |

Several other organizations also have studied the basin and reported their findings. Sources of information include:

- G-P and CDFG presence/absence surveys
- Ten Mile River Hatchery and CDFG salmonid release data
- CDFG stream surveys
- Outmigrant studies performed by Salmon Troller's Marketing Association
- Spawning surveys performed by the Salmon Troller's Marketing Association

### 4.2.3 CURRENT DISTRIBUTION AND ABUNDANCE OF SPAWNING SALMONIDS

Spawning surveys have been conducted 1) to determine which species are present and their relative abundance, 2) to determine if adults are returning to and spawning within a stream reach or basin area, and 3) to determine the relative abundance of a run. Generally speaking, targeted stream reaches were surveyed on a weekly basis if flow and other factors indicated that spawning activity was likely or reasonable to expect. A surveyor recorded all live salmonids, carcasses, and redds encountered. Species of live fish and carcasses were recorded, if identifiable. Coho spawning generally occurs in December and January, while steelhead usually spawn between February an April. Therefore, redds observed after February first were assumed to be those of spawning steelhead trout. Redds observed prior to February were assumed to be salmon.

Four separate spawning surveys were conducted in the Ten Mile River watershed:
a) 1989-90,
b) 1990-91,
c) 1995-96, and
d) 1996-97.

The survey conducted in 1989 to 1990 was the most extensive, covering 409 miles. But, the data were tallied from November through February. It is therefore difficult to ascertain whether counted redds belong to salmon or steelhead trout. It appears that the survey reaches were chosen based on information indicating the presence of salmonids, taking into consideration limited access (weekends only) in most areas of the watershed.

Only sporadic surveys were conducted in 1990 to 1991. Surveyors did not go out on a weekly basis, but only as time allowed. In 1995 to 1996, 43 miles of stream were surveyed. In 1996 to 1997, the survey included 27 miles in Smith Creek and Campbell Creeks, only. The 1996 to 1997 survey was specifically designed to augment the outmigrant data collected in these same streams.

Table 4.2 summarizes the results of redd counts, live fish, and coho carcasses in 1989 to 1990 and 1995 to 1996, the two years in which spawning surveys were most extensive. The data are inadequate to compute total number of spawners for individual years or to compare total spawners across years. But, comparisons in individual tributaries is appropriate, where the data exist.

**TABLE 4.2**
**SUMMARY OF SALMONID SPAWNING SURVEY RESULTS -- NUMBER OF REDDS FOUND PER MILE OF STREAM SURVEYED (Maahs 1995, 1996, 1997a)**

| **Stream** | **November 1989-February 1990** | | | **December 1995-January 1996** | | | **February – April 1996** | | |
|---|---|---|---|---|---|---|---|---|---|
| | Redds/ mile | Live fish/mile | Coho carcasses | Redds/ mile | Live fish/mile | Coho carcasses | Redds/ mile | Live fish/mile | Coho carcasses |
| **Lower Ten Mile River Subwatershed** | | | | | | | | | |
| Lower Ten Mile River | 0.78 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| Mill Creek | 0.1 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| **North Fork Ten Mile River Subwatershed** | 0.58 | 0.38 | 0 | NS | NS | NS | NS | NS | NS |
| Vallejo Gulch | NS | NS | NS | 0 | 2.5 | 0 | 0 | 2.5 | 0 |
| **North Fork Ten Mile River Subwatershed** | | | | | | | | | |
| Little North Fork | 2.88 | 0.26 | 0 | 7.6 | 1.4 | 10 | 6.4 | 0.1 | 1 |
| Buckhorn Creek | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 0 | 0 |
| Cavanaugh Gulch | 0 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| Bald Hills Creek | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Patsy Creek | 0.48 | 0.12 | 0 | NS | NS | NS | NS | NS | NS |
| Stanley Creek | 0 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| **Clark Fork Ten Mile River Subwatershed** | | | | | | | | | |
| Mainstem Confluence to Bear Haven Creek | 0.48 | 0.16 | 4 | 1.2 | 1.1 | 1 | 2.6 | 0.07 | 0 |
| Bear Haven Creek to Little Bear Haven Creek | 0.48 | 0.16 | 4 | 1.6 | 0.8 | 1 | 1.9 | 0.2 | 0 |
| Little Bear Haven Creek to Booth Gulch | 0.48 | 0.16 | 4 | 1.9 | 0.3 | 0 | 3.2 | 0.1 | 0 |
| Booth Gulch to headwaters | 0.48 | 0.16 | 4 | 0 | 0 | 0 | 4.4 | 0 | 0 |
| Bear Haven Creek | 2.4 | 0.16 | 0 | 5.9 | 0.7 | 4 | 9.0 | 0.1 | 1 |
| SF Bear Haven | NS | NS | NS | 2.5 | 0.9 | 0 | 15.0 | 0 | 0 |
| Little Bear Haven Creek | 3.3 | 0 | 0 | 0 | 0 | 0 | 3.8 | 0 | 0 |

| Stream | November 1989-February 1990 | | | December 1995-January 1996 | | | February – April 1996 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Redds/ mile | Live fish/mile | Coho carcasses | Redds/ mile | Live fish/mile | Coho carcasses | Redds/ mile | Live fish/mile | Coho carcasses |
| **South Fork Ten Mile River Subwatershed** | | | | | | | | | |
| Campbell Creek to Churchman Creek- | 0.96 | 0.33 | 2 | 1.4 | 0.6 | 5 | 0.9 | 0 | 1 |
| Churchman to Camp 28 | 0.96 | 0.33 | 2 | 3.9 | 0.8 | 1 | 1.1 | 0.3 | 0 |
| Redwood Creek to headwaters | 0.96 | 0.33 | 2 | 0 | 0 | 0 | 5.3 | 1.6 | 0 |
| Campbell Creek | 2.32 | 0.06 | 0 | 1.4 | 0.7 | 7 | 7.1 | 1.0 | 0 |
| Churchman Creek | 0.2 | 0.30 | 0 | 2.3 | 0 | 2 | 1.5 | 0 | 0 |
| Gulch 11 | 0 | 0 | 0 | 0 | 0 | 0 | 6.9 | 0 | 0 |
| Redwood Creek | 0.41 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| North Fork Redwood Creek | 0 | 0 | 0 | NS | NS | NS | NS | NS | NS |
| Smith Creek | 0.80 | 0.09 | 0 | 4.6 | 1.2 | 4 | 3.9 | 0.5 | 0 |
| Redds present between December and January are more likely to be coho or chinook redds. The redds present February through April are more likely to be steelhead. | | | | | | | | | |

### 4.2.3.1 1989-90 Survey

The 1989 to 1990 spawning survey was conducted from November through February. All of the data collected was tallied and reported together. Thus, it is impossible to know if tallied redds were made by salmon or steelhead trout. Redds were observed in:

- Mainstem Ten Mile River,
- Mill Creek,
- Mainstem Little North Fork,
- Patsy Creek,
- Clark Fork Ten Mile River,
- Bear Haven Creek,
- Little Bear Haven Creek,
- South Fork Ten Mile River,
- Campbell Creek,
- Churchman Creek,
- Redwood Creek, and
- Smith Creek.

Coho carcasses were found in the Clark Fork Ten Mile River and South Fork Ten Mile River. Steelhead carcasses were seen throughout the survey area. There was no evidence of spawning in Buckhorn Creek, Cavanaugh Creek, Bald Hill Creek, Stanley Creek, Gulch 11, or North Fork Redwood Creek and no live fish were observed in these reaches. In addition, most live fish were observed in the mainstem reaches, Bear Haven, and Redwood Creek. The greatest number of redds were observed in the Little North Fork, Bear Haven Creek, Little Bear Haven Creek, and Campbell Creek. This does not necessarily correlate with the number of live fish observed.

#### 4.2.3.2 1990-91 Survey

The 1990 to 1991 spawning survey was conducted from December through April. The data were tallied and reported in two time periods: December through January and February through April. Redds counted in December through January are presumed to be those of salmon while those seen after January are presumed to be made by steelhead trout. The survey was conducted sporadically, as time allowed. The numbers do not represent total spawners during the spawning season and can not be compared to other years. The 1990 to 1991 data are best used to identify the presence and absence of spawners. These data are not included in Table 4.2.

There were at total of 98 redds counted in December and January, presumably those of salmon. Coho were observed in:

- Little North Fork Ten Mile River,
- Lower North Fork Ten Mile River,
- Lower and Middle Clark Fork Ten Mile River,
- Bear Haven Creek,
- Campbell Creek, and
- Much of the South Fork Ten Mile River.

One redd was found in Bald Hill Creek in late January; but no live fish or carcasses were seen from which to surmise the species of the spawning pair. Chinook were seen in the Clark Fork above Bear Haven Creek, the South Fork Ten Mile River, and Little North Fork Ten Mile River. Steelhead were seen in each surveyed stream except Smith Creek, where no evidence of spawning whatsoever was observed.

#### 4.2.3.3 1995-96 Survey

The 1995 to 1996 spawning survey was conducted from December through April. The data were tallied and reported in two time periods: December through January and February through April. Salmon are presumed to be responsible for the redds counted in December and January. Steelhead trout are presumed to be responsible for those counted after January.

Presumed salmon redds were observed in:

- Little North Fork,
- Lower and Middle Clark Fork Ten Mile River up to Booth Gulch,
- Bear Haven Creek,
- South Fork Bear Haven Creek,
- South Fork Ten Mile River up to Redwood Creek,
- Campbell Creek,
- Churchman Creek, and
- Smith Creek.

There was no evidence of salmon spawning in Vallejo Gulch, Buckhorn Creek, Bald Hill Creek, Gulch 11, upper Clark Fork Ten Mile River, or upper South Fork Ten Mile River from Booth Gulch up to the headwaters. However, redds were observed in each of the tributaries except Vallejo Gulch and Bald Hills Creek during the February to April surveys, indicating steelhead spawning. Stanley Creek and North Fork Redwood Creek were not surveyed in 1995 to 1996.

Surveyors found an average of 1.8 redds/mile and 0.7 live fish/mile in the main forks, and 3.3 redds/mile and 0.9 live fish /mile in the tributaries from December through January. Based on these data, it appears that salmon are nearly twice as likely to spawn in the tributaries than in the main forks of the Ten Mile River watershed. The reaches of main fork streams that exceeded the average redds/mile and/or live fish/mile were the Clark Fork Ten Mile River from the confluence to Booth Gulch and the South Fork Ten Mile River from Church Creek to Camp 28. The tributaries that exceeded the average redds-per-mile and/or live-fish-per-mile are Vallejo Gulch, Little North Fork Ten Mile River, Bear Haven Creek, South Fork Bear Haven Creek, and Smith Creek. Bald Hills Creek is the only stream surveyed in which there was no evidence of steelhead spawning. During February through April surveys, all other streams showed either redds, live fish, or carcasses.

#### 4.2.3.4 1996-97 Survey

The 1996 to 1997 spawning survey was conducted only in Smith Creek and Campbell Creek. It was designed specifically to augment outmigration data also collected from these tributaries. The 1996 to 1997 data are reported in two time periods: December through January and February through April to distinguish salmon spawners from steelhead trout spawners.

The 1996 to 1997 survey data indicate that there is spawning in Smith and Campbell Creeks. Though, as compared to the basin wide average in 1995 to 1996, neither creek demonstrated unusually high numbers of redds or live fish in the December to January period. In the period of December through January, there were 2.8 redds/mile, 0.3 live fish/mile and one coho carcass found in Smith Creek. There were 2.9 redds/mile and no live or dead chinook or coho found in Campbell Creek. From February to April, there were 15.0 redds/mile, 0.2 live fish/mile and two steelhead carcasses found in Smith Creek. There were 8.1 redds/mile, one live fish/mile and no steelhead carcasses found in Campbell Creek. There were two unidentified carcasses found in Campbell Creek sometime between December and April.

#### 4.2.3.5 Estimate of Coho Spawners

In his 1996 and 1997 reports, Maahs used the various data collected during the spawning surveys to estimate the size of the spawning coho populations in the streams in which data were collected. Maahs and Gilleard (1994) demonstrated that both live fish- and carcass-based methods of population estimation underestimate the spawning populations while methods using redd counts produced wide-ranging estimates. The 1995 to 1996 and 1996 to 1997 data are inadequate to further validate any particular method of population estimation. Thus, a range of possible spawning population sizes is given. Table 4.3 summarizes the estimates of spawning populations from the 1995 to 1996 and 1996 to 1997 data as derived from each of the data sources. A discussion of the actual models used to estimate population size is given in Nielsen et al. (1990).

From these data we can assess the relative importance of various tributaries for coho spawning. Of the streams surveyed in 1995 to 1996, the South Fork Ten Mile River and the Little North Fork Ten Mile River appear to draw the greatest number of coho spawners with somewhere between one and 83 and 21 to 101 fish, respectively. If tributary streams are nearly twice as likely as the main forks to support salmon spawning, then the South Fork Ten Mile River must draw the greatest number of coho spawners primarily because of the size of the stream. Churchman Creek draws the fewest coho spawners with two to nine fish.

Smith Creek and Campbell Creek are the only two creeks with reliable spawning data for two separate years. The population models estimate in Smith Creek a population of spawning coho between ten and 40 fish in 1995 to 1996 and one to 16 fish in 1996 to 1997. These ranges overlap and cannot show whether spawning escapement improved or worsened from 1995/1996 to 1996/1997. In Campbell Creek, the population of spawning coho is estimated between six and 26 fish in 1995 to 1996 and zero and 12 fish in 1996 to 1997. In this case, too, the ranges overlap.

**TABLE 4.3**
**ESTIMATED COHO RUN SIZE BY FOUR DIFFERENT POPULATION ESTIMATION PROCEDURES**

| **STREAM** | **CARCASS RETENTION** (Est. # of spawning coho) | | **LIVE FISH** (Est. # of spawning coho) | | **REDD AREA** (Est. # of spawning coho) | | **REDD #** (Est. # of spawning coho) | |
|---|---|---|---|---|---|---|---|---|
| | **1995-96** | **1996-97** | **1995-96** | **1996-97** | **1995-96** | **1996-97** | **1995-96** | **1996-97** |
| **NORTH FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | | |
| Little N. Fork | 31 | NR | 21 | NR | 47 | NR | 25-101 | NR |
| **CLARK FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | | |
| Clark Fork | 5 | NR | 19 | NR | 22 | NR | 9-37 | NR |
| Bear Haven | 9 | NR | 7 | NR | 35 | NR | 14-55 | NR |
| **SOUTH FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | | |
| South Fork | 12 | NR | 27 | NR | 52 | NR | 21-83 | NR |
| Churchman | 13 | NR | 0 | NR | 7 | NR | 2-9 | NR |
| Smith | 11 | 1 | 12 | 3 | 14 | 6 | 10-40 | 4-16 |
| Campbell | 25 | 0 | 18 | 0 | 13 | 6 | 6-26 | 3-12 |
| **Total** | 106 | 1 | 104 | 3 | 190 | 12 | 78-351 | NR |

NR = Not reported

## 4.2.4 CURRENT DISTRIBUTION AND ABUNDANCE OF REARING SALMONIDS

CDFG files include a series of historical stream surveys in which field staff walked portions of streams noting their observations. These surveys indicate that steelhead and coho were present in Little North Fork, South Fork, Smith Creek and Campbell Creek in 1961. No coho or steelhead were seen in Booth Gulch in 1961 due to an impassable barrier at the mouth. In 1969, coho and steelhead were seen in Mill Creek. Steelhead were observed in Little Bear Haven Creek in 1961 and again in 1983. No mention of coho salmon was made in this tributary. These data are consistent with the results of more recent spawning surveys; however, it is impossible to derive information on population size from these data.

CDFG has conducted electrofishing surveys in the Ten Mile River watershed since their stream surveys of the 1960s. Their data represent a snap shot in time and does not allow for estimates of population size or trends in abundance or distribution. G-P, on the other hand, has conducted electrofishing surveys at 25 locations in the Ten Mile River from 1993 through 1999. These data are more robust and allow for greater spatial and temporal comparisons. One note of caution, however, is that the locations were chosen in 1993 before much habitat data had been collected. Ambrose and Hines (1997) noted that, as a result, the locations may not be truly representative of the watershed as a whole. This should be considered when reviewing the fish density data (Table 4.4) and the estimated basin-wide populations (Ambrose and Hines 1997) presented in Table 4.5. G-P, and the current owner, Campbell Timber Management, Inc., chose to continue monitoring these sites in favor of consistency.

**Table 4.4**
**Fish Density Data for Sampling Locations Throughout the Ten Mile River Watershed [as reported by CDFG (unpublished data), Ambrose et al. 1996, Ambrose and Hines 1997 & 1998, and Hines 2000]**

| Site ID | Stream | Coho Salmon Density (fish/m$^2$) | | | | | Steelhead Trout Density (fish/m$^2$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1995 | 1996 | 1997 | 1998 | 1999 | 1983* | 1991* | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| **Lower Ten Mile River Subwatershed** | | | | | | | | | | | | | | | |
| TEN1 | Mill Creek | 0 | 0 | 0 | 0.01 | 0 | NS | NS | 0.32 | 0.32 | 0.38 | 0.35 | 0.37 | 0.60 | 0.49 |
| **North Fork Ten Mile River Subwatershed** | | | | | | | | | | | | | | | |
| NFT1 | NFT below Patsy Creek | 0 | 0 | 0 | 0 | 0.004 | NS | NS | 0.45 | 0.47 | 0.58 | 0.61 | 1.05 | 0.46 | 0.76 |
| NFT2 | Bald Hill Creek | 0 | 0.01 | 0 | 0 | 0 | 0.20 | 0.40 | 0.48 | 0.47 | 0.53 | 0.42 | 0.41 | 0.23 | 0.37 |
| NFT4 | NFT @ Camp 3 | 0 | 0.05 | 0 | 0 | 0.005 | NS | NS | 0.36 | 0.99 | 0.12 | 0.12 | 0.07 | 0.11 | 0.08 |
| NFT5 | NFT @ Camp 5 | 0 | 0 | 0 | | 0 | NS | NS | 0.39 | 0.60 | 0.04 | 0.21 | 0.23 | 0.09 | 0.27 |
| NFT6 | Lower Little North Fork Ten Mile River* | 0 | 0.18 | 0.01 | 0.004 | 0.02 | 0.60 | NS | NS | 1.50 | 0.57 | 0.62 | 0.77 | 0.92 | 0.02 |
| NFT7 | Buckhorn Creek | 0 | 0.22 | 0 | 0 | 0 | 0.30 | 0.22 | 0.50 | 0.72 | 0.75 | 0.49 | 0.26 | 0.36 | 0.26 |
| NFT8 | Upper Little North Fork Ten Mile River | 0 | 0.15 | 0.01 | 0 | 0 | NS | NS | 0.38 | 0 | 0.85 | 0.75 | 0.16 | 0.20 | 0.59 |
| NFT9 | NFT @ Gulch 9 | 0 | 0 | 0 | 0 | 0 | NS | NS | 0.32 | 0.64 | 1.63 | 0.29 | 0.50 | NS | 0.47 |
| **Clark Fork Ten Mile River Subwatershed** | | | | | | | | | | | | | | | |
| CFT1 | CFT @ Reynold’s Gulch | 0 | 0.02 | 0 | 0 | 0 | NS | NS | 0.74 | 0.44 | 0.78 | 0.61 | 0.57 | 0.46 | 1.02 |
| CFT3 | Lower Bear Haven Creek | 0 | 0.01 | 0.03 | 0 | 0 | 2.37 | 0.62 | 0.83 | 1.20 | 0.61 | 0.52 | 0.56 | 0.41 | 0.28 |
| CFT5 | Booth Gulch | 0 | 0 | 0 | 0 | 0 | 0.93 | NS | 0.45 | 0.13 | 0.74 | 1.00 | 0.41 | 0.20 | 0.74 |
| CFT6 | Little Bear Haven Creek | 0 | 0 | 0 | 0 | 0 | 0.45 | 0.32 | 0.28 | 0.40 | 0.36 | 0.44 | 0.42 | 0.25 | 0.32 |
| CFT7 | Upper Bear Haven Creek | 0 | 0.01 | 0.14 | 0 | 0.005 | NS | NS | 0.48 | 0.58 | 0.71 | 0.61 | 0.64 | 0.45 | 0.31 |
| CFT8 | CFT @ Ford Gulch | 0 | 0 | 0 | NS | NS | NS | NS | 0.20 | 0.15 | 0.28 | 0.11 | 0.18 | NS | NS |

|  |  | **1995** | **1996** | **1997** | **1998** | **1999** | **1983*** | **1991*** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **South Fork Ten Mile River Subwatershed** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| SFT1 | Smith Creek | 0.01 | 0.15 | 0.04 | 0 | 0 | NS | NS | 0.53 | 0.67 | 0.36 | 0.50 | 0.32 | 0.23 | 0.17 |
| SFT2 | Campbell Creek | 0.02 | 0.35 | 0.01 | 0 | 0.01 | NS | 0.13 | 0.30 | 0.61 | 0.74 | 0.85 | 0.56 | 0.53 | 0.42 |
| SFT3 | SFT @ Brower's Gulch | 0 | 0.004 | 0 | 0 | 0.004 | NS | NS | 0.08 | 0.66 | 0.19 | 0.33 | 0.33 | 0.25 | 0.71 |
| SFT4 | Churchman Creek | 0 | 0.05 | 0.10 | 0.004 | 0.02 | NS | NS | 0.42 | 1.20 | 0.37 | 0.34 | 0.48 | 0.30 | 0.21 |
| SFT5 | SFT @ Buck Mathews Gulch | 0 | 0.02 | 0 | 0 | 0.01 | NS | NS | 0.23 | 0.83 | 0.57 | 0.30 | 0.52 | 0.27 | 0.32 |
| SFT7 | Lower Redwood Creek | 0 | 0 | 0 | 0 | 0 | NS | 0.34 | NS | 0.89 | 0.77 | 0.57 | 0.77 | 0.55 | 0.97 |
| SFT8 | Upper Redwood Creek | 0 | 0 | 0 | 0 | 0 | NS | NS | 0.25 | 0.70 | 0.25 | 0.33 | 0.42 | 0.66 | 0.34 |
| SFT9 | Upper SFT | 0 | 0 | 0 | 0 | 0 | NS | 0.21 | 0.17 | 0.35 | 0.34 | 0.07 | 0.03 | 0.66 | 0.07 |
| SFT15 | SFT @ Camp 28 | 0 | 0 | 0 | NS | NS | NS | NS | 0.85 | 2.30 | 1.74 | 1.33 | 1.35 | 0.91 | 1.14 |

* The California Department of Fish and Game collected data at a locations in the Ten Mile River watershed in 1983, 1986, 1991, and 1994. In 1983, CDFG only recorded coho salmon in Little North Fork Ten Mile River in a density of 5.89 fish/$m^2$. In 1991, coho were reported only at Bear Haven Creek at a density of 0.08 fish/$m^2$ & at Bald Hill Creek 0.008 fish/$m^2$. The steelhead data collected in 1983 and 1991 is reported above. In 1986, the CDFG found 0.38 steelhead/$m^2$. In 1994, they found 0.88 steelhead/$m^2$, a figure in perfect agreement with that reported by G-P for the same year and place.

The sample sites were selected by G-P to provide uniform coverage of the watershed and an equal distribution of sample locations on the mainstems and tributaries. G-P used a performance curve (described in Brower et al. 1989, as referenced by Ambrose et al. 1996) to determine if the number of monitoring sites was adequate to represent populations trends in the watershed. The results of this analysis indicated that the sample size was adequate for estimating steelhead populations, but not adequate for the less abundant coho due to the variation in their density from year to year (Ambrose and Hines 1997). G-P noted that coho populations have been sparse and erratic in distribution throughout their sampling and that steelhead appear to be ubiquitous and far more stable in the Ten Mile River than coho**.** As such, the density data are useful for estimating steelhead population size; but, the data are only useful for identifying where in the watershed coho salmon are present or absent.

Ambrose and Hines (1997), nonetheless, has estimated population size for both coho salmon and steelhead trout in each year that electrofishing was conducted, as shown in Table 4.5. Basin-wide fish densities for each species were estimated to look at population trends over a four-year period (1993 to 1996). To accomplish this, the Ten Mile River watershed was broken into segments and the surface area calculated. Fish densities for each species were applied to those stream segments surrounding or adjacent to each sampling location. Tributary and mainstem segments were derived separately to avoid applying estimates to widely differing stream types. All segments were then combined to establish the basin wide estimate (Ambrose and Hines 1997).

**TABLE 4.5**
**ANNUAL BASIN-WIDE ESTIMATES OF SALMONID SPECIES IN THE 10-MILE WATERSHED (data from Ambrose and Hines 1997)**

| **YEAR** | **COHO SALMON** | | **STEELHEAD TROUT** | |
|---|---|---|---|---|
| | **NO. OF FISH** (% of total) | **DENSITY** (fish/m$^2$) | **NO. OF FISH** | **DENSITY** (fish/m$^2$) |
| 1993 | 10,063<br>(1.3%) | 0.006 | 781,810 | 0.439 |
| 1994 | 5,149<br>(0.4%) | 0.003 | 1,192,519 | 0.670 |
| 1995 | 1,165<br>(0.1%) | 0.001 | 907,195 | 0.510 |
| 1996 | 56,356<br>(6.5%) | 0.032 | 816,672 | 0.459 |

#### 4.2.4.1 Coho Salmon

Coho density data are only available for 1995 to 1999. CDFG also sampled several stations in the watershed in 1983, 1986, 1991 and 1994. The largest recorded density of coho salmon was in the Little North Fork Ten Mile River in 1983 at 5.8 fish/m$^2$. This is twice the density of coho found in the South Fork Caspar Creek, an insignificant coho stream, in the 1960s prior to any second growth logging. It is also 155 times the coho density of Little North Fork Ten Mile River at 0.037 fish/m$^2$.

The data collected by G-P and the CDFG is summarized above in Table 4.4. Coho salmon have been observed in 14 of the 25 sampling locations throughout the Ten Mile River watershed (see Map 4.5 at the end of this document). During that time period, the coho run of 1995 to 1996 was the strongest of the three runs, as indicated by higher summer fish densities in 1996 and greater distribution of juveniles throughout the watershed. Their progeny produced far fewer fry in 1999, however.

Coho densities are estimated to range between 0.004 and 0.35 fish/m$^2$ from 1995 through 1999. The basin-wide average is 0.016 fish/m$^2$.

As explained above, the estimates of coho salmon population size are uncertain due to annual variation in the data. Nevertheless, if these estimates are used**,** coho salmon may currently comprise only about 2% of the salmonid population in the Ten Mile River watershed.

#### 4.2.4.2 Steelhead Trout

CDFG electrofished several streams in the Ten Mile River watershed in 1983, 1986, 1991 and 1994. G-P also collected fish density data for steelhead from 1993 to 1999. Steelhead trout were found at every station in every year in which they were sampled. The density of steelhead trout ranges from 0.03 to 2.37 fish/mi$^2$. The basin-wide average is 0.51 fish/mi$^2$. An estimated 905,169 steelhead trout have occupied the basin from 1993 to 1997. This is 100 times greater than the 9,000 steelhead trout estimated to occupy the basin in the 1960s.

The 1993 to 1999 density data suggests that the summer populations of steelhead trout are relatively stable. Basin-wide density figures vary by no more than 32% around the mean. However, individual sample locations show a varied picture (see Table 4.5). Some streams appear to support a relatively stable population of summer fish while the population of others has fluctuated widely. The cause(s) of variation, is unknown. The variation may indicate ocean, climate, or other changes as mentioned earlier. It is likely, however, that instream changes, are continually occurring (see Section 4.4, Synthesis).

### 4.2.5 CURRENT DISTRIBUTION AND ABUNDANCE OF OUTMIGRATING SALMONIDS

Michael Maahs of the Salmon Troller's Marketing Association conducted outmigrant studies in the Ten Mile River watershed in the 1995 to 1996, 1996 to 1997, and 1997 to 1998. These studies were conducted in the South Fork Ten Mile River, Smith Creek and Campbell Creek (tributaries to the South Fork). Traps were set to capture salmonids migrating downstream during the peak migration season for both coho salmon and steelhead trout (March to June) to determine the number of outmigrants. Other vertebrate species were also captured.

The traps were specifically set to capture outmigrants, not fish migrating upstream. To accommodate migrating adult fish, side channels were kept open during high flow periods. To prevent trap-related mortalities, traps were designed to allow fish to escape. They were also removed occasionally during high flow periods. To estimate the efficiency of the traps, juvenile steelhead were marked with a caudal fin clip and released upstream for recapture and counting (Maahs 1995, 1996, 1997b). Due to their threatened status, coho were not marked to determine their recovery rates. The average recovery rate for steelhead smolts was utilized to estimate coho smolt trapping efficiency. Combined smolt and parr recovery was used to estimate juvenile steelhead trapping efficiency. The recovery rate for steelhead smolts was much higher in both the Smith and Campbell Creeks, than for steelhead parr. The reverse situation was found in the South Fork (Maahs 1997b).

In June of 1995 and 1996, the traps captured a large portion of the total numbers of outmigrants. The traps operated in May 1997, but did not operate in June 1997. Thus, to estimate the number of fish that would have migrated in June of 1997, the average number of steelhead trapped per day in 1996 was compared between the months of May and June. The ratio of the rate of May to June captures in 1996 was applied to the rate of capture in May of 1997 to estimate the rate of capture in June 1997 (Maahs 1997b).

Table 4.6 shows the results of the outmigrant studies for 1996 and 1997. In 1995, the outmigrant traps were only set in the South Fork Ten Mile River. They were not set in either Campbell Creek or Smith Creek. The data collected in 1995 does not distinguish between coho and steelhead young-of-the-year. The 1995 results indicate that 5,466 salmonid young-of-year ("YOY") were captured in the South Fork Ten Mile River as were 221 one year old or older ("Y+") fish. Further, the 1995 data indicates that there were ten coho Y+ fish captured along with 211 steelhead Y+ fish. Numerous problems with the trap in high flows make developing an accurate estimate of salmonid outmigrants in 1995 impossible.

**TABLE 4.6**
**NUMBER OF DOWNSTREAM MIGRATING YOY AND PARR TRAPPED IN SOUTH FORK TEN MILE RIVER, CAMPBELL CREEK AND SMITH CREEK (Maahs 1996, 1997b)**

| | | SOUTH FORK TEN MILE RIVER | | CAMPBELL CREEK | | SMITH CREEK | |
|---|---|---|---|---|---|---|---|
| | | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 |
| COHO | YOY | 42<br>**1,685** | 2<br>**2** | 4,493<br>**5,493** | 205<br>**206** | 2,479<br>**4,410** | 208<br>**210** |
| | Y+ | 29<br>**493** | 411<br>**1,726** | 9<br>**34** | 230<br>**512** | 40<br>**89** | 350<br>**729** |
| STEELHEAD | YOY | 5,526<br>**35,039** | 4,313<br>**6,089** | 22,441<br>**27,189** | 19,931<br>**25,546** | 32,812<br>**41,387** | 17,621<br>**24,058** |
| | Y+ | 1,728<br>**15,795** | 601<br>**3,172** | 947<br>**2,379** | 864<br>**2,367** | 1,216<br>**3,954** | 667<br>**1,700** |
| TOTAL | YOY | 5,568<br>**36,724** | 4,315<br>**6,091** | 26,934<br>**32,682** | 20,136<br>**25,752** | 35,291<br>**45,797** | 17,829<br>**24,268** |
| | Y+ | 1,757<br>**16,288** | 1,012<br>**4,898** | 956<br>**2,413** | 1,094<br>**2,879** | 1,256<br>**4,043** | 1,017<br>**2,429** |
| | **Total** | 7,325<br>**53,012** | 5,327<br>**10,989** | 27,890<br>**35,095** | 21,230<br>**28,631** | 36,547<br>**49,840** | 18,846<br>**26,697** |

The numbers in **bold** represent the estimated population of outmigrants based on an expansion from a full week of trapping (where necessary) and including the calculated trap efficiency rates.

The total number of outmigrants declined from 1996 to 1997 in each of the study locations (South Fork Ten Mile River, Campbell Creek, and Smith Creek). The decline was most dramatic in the South Fork Ten Mile River from which 53,012 outmigrating salmonids were estimated in 1996 and 10,989 were estimated in 1997. This is a decline of 79%, largely related to a steep decline in the estimated numbers of outmigrating steelhead trout at this location. The decline from 1996 to 1997 in Campbell Creek is 18% and in Smith Creek is 46%.

The estimated total number of Y+ salmonids outmigrating from Campbell Creek actually increased from 1996 to 1997 by 19%. This is the only trap location from which an increase in the total number of outmigrating Y+ salmonids was measured though each location showed an increase in the estimated number of coho Y+ fish from 1996 to 1997. The percent increase in coho Y+ fish from 1996 to 1997 was dramatic, but the actual number of fish was modest and did not strongly influence the total number of outmigrating salmonids.

Coho salmon outmigrants account for 4% of the total outmigrating salmonid population in the South Fork in 1996 and 16% in 1997. They account for 16% of the outmigrating salmonid population in Campbell Creek in 1996 and 3% in 1997. They account for 9% of the outmigrating salmonid population in Smith Creek in 1996 and 4% in 1997. The changes to the proportion of coho represented in the outmigrant population is related to reductions in coho YOY and steelhead trout from 1996 to 1997.

Coho generally smolt as yearlings. As such, the yearlings trapped in outmigrant traps are likely fish returning to the estuary for smoltification and eventual migration to the ocean. Their increase in number from 1996 to 1997 suggests that 1996 to 1997 was a more successful spawning season than was 1995 to 1996. The explanation for YOY trapped in outmigrant traps, however, is less clear. Perhaps a reduction in upstream habitat or food forced the movement of YOY downstream. Or, perhaps competition with steelhead trout forced the downstream movement of coho YOY. Maahs (1996) suggests that the thousands of coho YOY that were outmigrating from Campbell Creek in 1996 indicate that the habitat was fully seeded and unable to support the outmigrating YOY. The same, perhaps, could be said for coho in Smith Creek and steelhead in all three studied streams. Whatever the case, the decrease in YOY downstream migrants suggests that the cause of population redistribution in 1996 was less significant in 1997.

### 4.2.6 HATCHERY RELEASES

The Salmon Restoration Association ("SRA") of California, a non-profit organization comprised of commercial fisherman and other individuals concerned with the declining salmon and steelhead populations in California, at one time operated a fish hatchery on the Ten Mile River. The hatchery, located nine miles north of Fort at the mouth of Vallejo Gulch, began propagating fish in 1975 (Ambrose and Hines 1997). The goal of the SRA is to restore salmon and steelhead populations in the Ten Mile River basin. Initially, the target species was chinook salmon. However, sport-caught steelhead were spawned, the eggs hatched and reared to yearlings for release into the Ten Mile River watershed. The first documented release of coho salmon from the facility was in 1987 (Nielsen et al. 1990). The facility was renovated in 1989 to 1990 when a new hatchery and rearing facility, consisting of two rearing-ponds and two rearing tanks (10-foot circular), were constructed. Trapping stations on the South Fork Ten Mile River, Clark Fork Ten Mile River, and Bear Haven Creek operated from 1993 to 1996. These locations were the source of all coho in the hatchery. Operations at the facility ceased in December of 1996, due to the listing of coho as a federal Endangered Species Act threatened species by the National Marine Fisheries Service.

In addition to the releases from the Ten Mile River hatchery, CDFG records indicate releases of coho, chinook, and steelhead dating from 1955 to 1987 (CDFG, unpublished data 'f'). Unfortunately, the specific locations of CDFG and SRA releases were not well documented. In most cases, releases to the main stem or to the Ten Mile River in general, were reported. Without data indicating the specific location of releases, it is impossible to make any conclusions regarding the effect of fish plants on the salmonid population in specific tributaries.

CDFG unpublished records indicate that coho were planted in the Ten Mile River dating back as far as 1955. During the 1960s and 1970s, approximately 270,000 and 400,000 coho were planted in the river, respectively. The records indicate that coho were not planted in the river during the 1980s and between 1994 and 1996, approximately 9,000 coho were planted in the Ten Mile River (see Table 4.7). The effort to restore the coho run by artificial propagation appears to have been unsuccessful. The Oregon coho stocks may have been inappropriate to this watershed and habitat problems and the limitations that exist may have contributed as well (Maahs and Gilleard 1994).

**TABLE 4.7**
**TEN MILE RIVER FISH SUPPLEMENTATION (CDFG unpublished data ‘f’)**

| YEAR | COHO SALMON (A) | STEELHEAD TROUT (B) | CHINOOK SALMON (C) | APPROXIMATE NUMBER OF FISH PLANTED | PLANTING LOCATION | ENTITY RESPONSIBLE FOR PLANTING |
|---|---|---|---|---|---|---|
| 1955 | A | B | | A) 1,475; B)1,168 | TMR | CDFG |
| 1956 | | B | | B) 68,702 | TMR | CDFG |
| 1957 | | B | | B) 20,576 | TMR | CDFG |
| 1958 | | B | | B) 1,485 | TMR | CDFG |
| 1959 | A | B | | A) 72; B) 168 | TMR | CDFG |
| 1964 | A | | | A) 70,000 | TMR | CDFG |
| 1965 | A | | | A) 60,240 | TMR | CDFG |
| 1966 | A | | | A) 60,006 | TMR | CDFG |
| 1967 | A | | | A) 80,034 | TMR | CDFG |
| 1971 | A | | | A) 20,004 | TMR | CDFG |
| 1972 | A | | | A) 222,206 | TMR | CDFG |
| 1973 | A | | | A) 20,002 | TMR | CDFG |
| 1974 | A | | | A) 121,114 | TMR | CDFG |
| 1975 | A | | | A) 10,007 | TMR | CDFG |
| 1976 | A | | | A) 10,013 | TMR | CDFG |
| 1979 | A | | C | A) 9,988; C) 350,000 | TMR | A) CDFG; B) SRA |
| 1980 | | | C | C) 199,000 | TMR (main) | SRA |
| 1981 | | | C | C) 20,000 | TMR (main) | SRA |
| 1982 | | | C | C) 95,000 | TMR (main) | SRA |
| 1983 | | | C | C) 75,000 | TMR | CDFG |
| 1985 | | | C | C) 1,845 | TMR | CDFG |
| 1986 | | | C | C) 5,000 | TMR (main) | SRA |
| 1987 | | | C | C) | | |
| 1987 | A | | C | A) 6,000; C) 7,134 ; C) 9,000 | TMR | CDFG, SRA |
| 1991 | | B | | B) 10,000 | TMR (main) | SRA |
| 1994 | A | B | | A) 503; B) 13,396 | A) CFT; B) CFT & NFT | SRA |
| 1995 | A | B | | A) 5,389; B) 14,850 | TMR (main) | SRA |
| 1996 | A | B | | A) 3,510; B) 22,500 | A) SFT, Big Bear Creek (CFT); B) TMR (main) | SRA |

According to CDFG hatchery records (unpublished data ‘f’), very few steelhead trout have been planted in the Ten Mile River, historically. Beginning in 1955 and continuing through 1959, approximately 90,000 steelhead were planted in the river. Records indicate that between 1960 and 1990, steelhead were not planted in the river. From 1991 to 1996, approximately 60,000 steelhead were planted in the Ten Mile River.

Chinook salmon were planted in the Ten Mile River, between 1979 and 1997, in an quantity totaling approximately 750,000 fish.

### 4.2.7 SUMMARY OF SALMONID DISTRIBUTION AND ABUNDANCE DATA

This assessment looks at existing data regarding the distribution and abundance of three life stages of salmonids in the Ten Mile River watershed as provided by spawning surveys, summer electroshocking (summer rearing) estimates, outmigrant studies, and estimates of hatchery releases. Each of these data sources has the potential to provide useful information on relative population structure and abundance.

For example, spawner escapement may predict the number of young-of-the-year, assuming adequate aquatic conditions. Similarly, the number of downstream migrants represent successfully reared fish and may predict the number of returning adults, assuming adequate ocean conditions and spawning escapement. Logic follows that with higher rates of survival to smolt and a constant ocean mortality (assumed for sake of discussion), that a larger escapement would result. At some point the spawning and rearing habitat of the stream become limiting and the population is “stable,” fluctuating in response to instream and ocean mortality.

Unfortunately, the picture offered by the limited existing data in the Ten Mile River watershed is not that clear. However, the following are general observations made from the summary of salmonid distribution and abundance data presented in Table 4.8.

**TABLE 4.8**
**SUMMARY OF SALMONID DISTRIBUTION AND ABUNDANCE FINDINGS**

| STREAM | SPAWNING SURVEYS | SUMMER ELECTROSHOCKING SURVEY | OUTMIGRANTS | FISH PLANTS |
|---|---|---|---|---|
| **Ten Mile River Watershed—General Observations** | | | | |
| Ten Mile River Watershed | a. 6,000 spawning coho est. in early 1960s<br>b. 9,000 spawning steelhead estimated in early 1960s<br>c. Habitat described as "severely damaged" in early 1960s.<br>d. 1995 spawning coho estimated at 78-351 fish.<br>e. 1996 spawning coho estimated at 1-28 fish. | a. 1994 and 1995 greatest steelhead summer population of record (1993-99)<br>b. 1996 greater coho year of record (1995-97)<br>c. Steelhead population estimated as average of 905,169 from 1993-97 | None | a. Coho released to Ten Mile River watershed in 1955, 1959, 1964-67, 1971-76 and 1979<br>b. Chinook released in 1979-1987<br>c. Steelhead released 1955-59 |
| **Lower Ten Mile River Subwatershed** | | | | |
| Mill Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 no survey<br>d. 1996-96 no survey | a. 1969 coho and steelhead<br>b. 1993-99 steelhead<br>c. 1995-97 no coho | No data | No data |
| Vallejo Gulch | a. 1989-90 no survey<br>b. 1990-91 no survey<br>c. 1995-96 coho and steelhead<br>d. no surveys | No data | No data | No data |
| Ten Mile River | a. 1989-90 salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 no survey<br>d. 1996-97 no survey | No data | No data | a. 1980-82 and 1986 chinook<br>b. 1991, 1995-96 steelhead<br>c. 1995 coho |
| **North Fork Ten Mile River Subwatershed** | | | | |
| North Fork Ten Mile River | a. 1989-90 no survey<br>b. 1990-91 coho and steelhead<br>c. 1995-96 no survey<br>d. 1996-97 no survey | a. 1996 coho<br>b. 1993-99 steelhead. Greater than avg. in upper watershed | No data | a. 1994 steelhead |

| STREAM | SPAWNING SURVEYS | SUMMER ELECTROSHOCKING SURVEY | OUTMIGRANTS | FISH PLANTS |
|---|---|---|---|---|
| Little North Fork Ten Mile River | a. 1989-90 salmonid spawners<br>b. 1990-91 coho, steelhead and chinook<br>c. 1995-96 coho and steelhead (21-101 coho spawners est.)<br>d. 1996-97 no survey | a. 1961 coho and steelhead<br>b. 1983 coho and steelhead (5.89 fish/$m^2$)<br>c. 1996-97 coho: 0.17 fish/$m^2$ (1996); 0.01 fish/$m^2$ (1997)<br>d. 1993-99 steelhead. Greater than avg. in lower watershed | No data | No data |
| Buckhorn Creek | a. 1989-90 no salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 no coho; steelhead present<br>d. 1996-97 no survey | a. 1996 coho<br>b. 1983, 1991, 1993-99 steelhead | No data | No data |
| Cavanough Gulch | a. 1989-90 no salmonid spawners<br>b. no other surveys | No data | No data | No data |
| Bald Hill Creek | a. 1989-90 no salmonid spawners<br>b. 1990-91 salmonid spawners<br>c. 1995-96 no salmonid spawners<br>d. 1996-97 no survey | a. 1996 coho<br>b. 1983, 1991, 1993-99 steelhead | No data | No data |
| Gulch 11 | a. 1989-90 no salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 no coho; steelhead present<br>d. 1996-97 no survey | No data | No data | No data |
| Stanley Creek | a. 1989-90 no salmonid spawning<br>b. no other surveys | No data | No data | No data |
| Patsy Creek | a. 1989-90 salmonid spawners<br>b. No other surveys | No data | No data | No data |

| STREAM | SPAWNING SURVEYS | SUMMER ELECTROSHOCKING SURVEY | OUTMIGRANTS | FISH PLANTS |
|---|---|---|---|---|
| **Clark Fork Ten Mile River Subwatershed** | | | | |
| Clark Fork Ten Mile River | a. 1989-90 coho and others<br>b. 1990-91 coho, steelhead and chinook<br>c. 1995-96 coho and steelhead (5-37 coho spawners est.)<br>d. 1996-97 no survey | a. 1996 coho<br>b. 1993-99 steelhead. Greater than avg at Reynold's Gulch | No data | a. 1994 coho and steelhead |
| Bear Haven Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 coho and steelhead<br>c. 1995-96 coho and steelhead (7-55 coho spawners est.)<br>d. 1996-97 no survey | a. 1996-97 coho<br>b. 1983, 1991, 1993-99 steelhead. Greater than avg. in lower watershed | No data | No data |
| Little Bear Haven Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 no salmonid spawners<br>d. 1996-97 no survey | a. 1961 and 1983 steelhead. No coho mentioned<br>b. 1983, 1991, 1993-99 steelhead | No data | No data |
| Booth Gulch | a. 1961 impassable barrier at mouth<br>b. no surveys | a. 1983, 1993-99 steelhead | No data | No data |
| **South Fork Ten Mile River Subwatershed** | | | | |
| South Fork Ten Mile River | a. 1989-90 coho and others<br>b. 1990-91 coho, steelhead and chinook<br>c. 1995-96 coho and steelhead. (12-83 coho spawners est.; 0.9-5.3 redds/mi; 0-1.6 live fish/mi; 1 coho carcass). NO coho in headwaters<br>d. 1996-97 no survey | a. 1961 coho and steelhead<br>b. 1996 coho (0.01 fish/$m^2$)<br>c. 1993-99 steelhead: 0.67 fish/$m^2$ (1995); 0.48 fish/$m^2$ (1996). Greater than avg. at Camp 28. | a. 1996 coho: 1,985 YOY and 493 Y+<br>b. 1996 steelhead: 35,039 YOY and 15,795 Y+<br>c. 1997 coho: 2 YOY and 1,726 Y+<br>d. 1997 steelhead: 6,089 YOY and 3,172 Y+ | a. 1996 coho (3,510 est.) |
| Smith Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 no salmonid spawners<br>c. 1995-96 coho and steelhead (10-40 coho spawners est; 3.9 redds/mi; 0.5 live fish/mi; 0 carcasses)<br>d. 1996-97 coho and steelhead | a. 1961 coho and steelhead<br>b. 1995-97 coho: 0.01 fish/$m^2$ (1995), 0.15 fish/$m^2$ (1996)<br>c. 1993-99 steelhead; 0.36 fish/$m^2$ (1995); 0.50 fish/$m^s$ (1996) | a. 1996 coho: 4,410 YOY and 89 Y+<br>b. 1996 steelhead: 41,387 YOY and 3,954 Y+<br>c. 1997 coho: 210 YOY and 729 Y+<br>d. 1997 steelhead: 24,058 YOY and 1,700 Y+ | No data |

| STREAM | SPAWNING SURVEYS | SUMMER ELECTROSHOCKING SURVEY | OUTMIGRANTS | FISH PLANTS |
|---|---|---|---|---|
| Campbell Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 coho<br>c. 1995-96 coho and steelhead (6-26 coho spawners est.; 7.1 redds/mi; 1.0 live fish/mi; 0 carcasses0<br>d. 1996-97 coho and steelhead | a. 1995-97 coho: 0.02 fish/m$^2$ (1995); 0.35 fish/m$^2$ (1996)<br>b. 1991, 1993-99 steelhead: 0.61 fish/m$^2$ (1995); 0.74 fish/m$^2$ (1996) | a. 1996 oho: 5,493 YOY and 34 Y+<br>b. 1996 steelhead: 27,189 YOY and 2,379 Y+<br>c. 1997 oho: 206 YOY and 512 Y+<br>d. 1997 steelhead: 25,546 YOY and 2,367 Y+ | No data |
| Churchman Creek | a. 1989-90 salmonid spawners<br>b. 1990-91 no survey<br>c. 1995-96 coho and steelhead (0-13 coho spawners est.)<br>d. 1996-97 no survey | a. 1996-97 coho<br>b. 1993-99 steelhead | No data | No data |
| Redwood Creek | a. 1989-90 salmonid spawners. No spawners in North Fork.<br>b. No other surveys | a. 1991, 1993-99 steelhead. Greater than avg. in lower watershed | No data | No data |

#### **4.2.7.1 Steelhead**

Steelhead have been found spawning throughout the watershed, except in Cavanough Creek, Bald Hills Creek, Stanley Creek and North Fork Redwood Creek. The data collected during steelhead spawning season (Maahs 1996 and 1997) indicate that the mainstem Ten Mile River, the Little North Fork, the North Fork at Patsy Creek, the Clark Fork including Little Bear Haven Creek and Bear Haven Creek, and the South Fork including Campbell and Churchman Creeks may be the preferred locations for steelhead spawning.

The electrofishing (summer rearing) data that indicate the highest populations of steelhead are located on the South Fork at Camp 28 (Ambrose and Hines 1998). Other locations where steelhead populations are also consistently higher than others, include the Lower Little North Fork (prior to 1999), Clark Fork at Reynold's Gulch, Upper Bear Haven Creek, and Lower Redwood Creek in the South Fork subwatershed.

Steelhead outmigrants in the South Fork Ten Mile River, Campbell Creek and Smith Creek were significantly higher in 1996 than in 1997. The decrease in steelhead outmigrants was particularly significant in the South Fork Ten Mile River. Neither differences between spawning and/or rearing success between the two years explains the decline in outmigrants since both young-of-year and Y+ fish left the South Fork Ten Mile River in large numbers in 1996 but not in 1997. Premature emigration may have been caused by a decrease in favorable living space upstream (see discussion of Graves and Burns 1970 in Chapter 3), for example, as a result of logging activities in 1995.

#### **4.2.7.2 Coho**

The Ten Mile River watershed may be the last refuge for native coho on the Mendocino coast with an estimated population of 160 fish (Weitkamp, et al. 1995).

Coho salmon have been found spawning in the Little North Fork Ten Mile River, Clark Fork Ten Mile River, Bear Haven Creek, South Fork Ten Mile River, Smith Creek, Campbell Creek, and Churchman Creek. The spawning survey data indicate that the Little North Fork, Bear Haven Creek and South Fork Ten Mile River are the best locations for spawning coho. Data collected in Campbell Creek and Smith Creek in both 1995 to 1996 and 1996 to 1997 indicate that the number of spawners was much greater in the 1995 to 1996 season. Maahs (1997a) noted that even at very low numbers, the coho smolts appear to survive at a high enough rate to continue a South Fork run of coho.

The density of rearing coho was much greater in 1996 than in any other year between 1993 and 1999. This is consistent with the impression given by the spawning data that 1995/1996 was a big spawning year. This conclusion is also consistent with other observations throughout the North Coast Region (Ambrose and Hines 1997).

Brown, et al. (1994) and Weitkamp et al. (1995) note some variables affecting populations, which include ocean conditions, stream conditions and climate. In addition, coho salmon have a three-year life cycle, in which abundance or absence does not relate directly to the next, but to every third year. As noted by Ambrose and Hines (1997), all of these factors act to obscure cause and effect relative to coho declines.

The outmigrant data in South Fork Ten Mile River, Campbell Creek and Smith Creek indicate that young-of-year coho migrated in significantly larger numbers in 1996 than in 1997. The opposite is true of Y+ fish which left in large numbers in 1997. The large migration of coho in 1997 corresponds with the large spawning season in 1995/1996 and large rearing season in 1996. The large number of YOY coho outmigrants in 1996 suggests, as with steelhead trout, that upstream habitat conditions may have forced a premature migration.

## 4.3 AQUATIC HABITAT

As described in Chapter 2, salmonids are anadromous fish that live part of their lives in the ocean and part in freshwater. The intent of this section is to evaluate the condition of the freshwater habitat available to salmonids migrating to the Ten Mile River watershed for spawning, rearing, and outmigration to the ocean. While conditions outside of the Ten Mile River watershed certainly have an effect on the success of the salmonid populations that return there to spawn, it is the condition of the freshwater environment that is the focus of this assessment.

### 4.3.1 SOURCES OF AQUATIC HABITAT DATA

There are several sources of aquatic habitat data in the Ten Mile River watershed. The watershed is predominantly owned by Hawthorn Timber Company and managed by Campbell Timberland Management, Inc. It was formerly owned by G-P. As G-P, the company produced numerous documents reporting the results of their surveys and research in the Ten Mile River watershed. Campbell Timberland Management, Inc. has been willing to share previous released data and information produced by G-P. But, it has been hesitant to release any new data or information or electronic data. As an important salmonid fishery on the Mendocino coast, several other organizations also have studied the basin and reported their findings. Sources of information include:

- Substrate composition data collected by G-P
- Stream temperature data collected by G-P
- Habitat inventories conducted by G-P
- Habitat inventories conducted by Salmonid Restoration Association, Inc.
- Miscellaneous letters and memorandums from Mendocino County Water Agency, CDFG, and Regional Water Quality Control Board files

### 4.3.2 GRAVEL MINING

A letter from the County of Mendocino Department of Planning and Building Services to U.S. EPA dated February 16, 2000 and the files of the Mendocino County Water Agency, indicate that there are two permits for gravel mining currently in effect in the Ten Mile River watershed. These are Use Permit and Reclamation Plan #U 27-91 and Vested Right #VR 1-94. Permit #U 27-91 is issued to Watkins Sand & Gravel for the removal of up to 2,500 cubic yards of gravel per year from several sites in the South Fork of the Ten Mile River channel and up to 10,000 cubic yards from a hillside quarry. Permit #VR 1-94 is issued to Baxman Gravel Company for the removal of up to 50,000 cubic yards of rock per year from a hillside quarry. There have been other gravel mining operations in the Ten Mile River watershed prior to those associated with these two permits. However, previous operations were unpermitted. As such, the Mendocino County Department of Planning and Building Services has no record of their location, size or impact.

### 4.3.3 SEDIMENT DATA

Since 1993, G-P has sampled substrate composition of streambed gravels at the pool/riffle juncture of locations throughout the Ten Mile River watershed using a McNeil sampler and following the protocol recommended by Valentine (Ambrose et al. 1996). G-P established 23 instream substrate sampling stations (see Map 4.6 at the end of this document). Sampling was conducted during low flow conditions of late summer or early fall. Samples were not always extracted from known salmonid redds though some may have been. Data are reported as wet volume. Weighted averages are calculated by dividing sample locations into categories based on channel type and then averaging the percent fines values based on the proportion of subwatershed and nine in the South Fork Ten Mile River subwatershed each channel type within the subwatershed. The intent of the weighted average is to give each sample site more accurate representation when aggregating the data so that, for example, a sample taken on the mainstem is given greater weight than one taken on a headwater tributary (Hines 2000). These data are presented in Table 4.9.

**TABLE 4.9**
**SUMMARY OF SUBSTRATE COMPOSITION DATA (% FINES <0.85 mm) AVERAGED FOR EACH SUBWATERSHED (Hines 2000)**

| YEAR | CLARK FORK | | NORTH FORK | | SOUTH FORK | |
|---|---|---|---|---|---|---|
| | Avg | Wt'd avg | Avg | Wt'd avg | Avg | Wt'd avg |
| 1993 | 16.7 | 15.6 | 19.8 | 19.1 | 17.0 | 17.4 |
| 1994 | 18.3 | 18.4 | 20.5 | 20.6 | 16.5 | 16.5 |
| 1995 | 19.1 | 18.4 | 22.3 | 21.3 | 17.0 | 17.0 |
| 1996 | 17.4 | 16.8 | 19.1 | 17.5 | 17.3 | 17.7 |
| 1997 | 17.6 | 16.2 | 18.3 | 17.7 | 16.5 | 17.0 |
| 1998 | 16.8 | 16.6 | 18.7 | 17.9 | 17.6 | 18.2 |
| 1999 | 18.5 | 18.0 | 16.8 | 15.8 | 14.6 | 14.9 |
| **Avg. 1993-99** | 17.8 | 17.1 | 19.4 | 18.6 | 16.6 | 17.0 |

For comparison purposes, a range of 14 to 20% fines (<0.85 mm) is used to evaluate sediment composition in the Ten Mile River watershed. An assessment of studies in locations throughout the Pacific Northwest indicate that substrate composed of no more than 14% fines (<0.85 mm) adequately supports successful spawning, incubation and emergence (CWQCB 1997). Waters (1995) concluded that substrate containing more than 20% fine sediment (<0.85 mm) inadequately supports successful spawning, incubation and emergence. Locations with fine sediment (< 0.85 mm) falling within the range of 14 to 20% are therefore judged to be less than ideal with respect to sediment composition; but, they may nonetheless allow for at least minimal salmonid spawning, incubation and emergence success.

Using these criteria, it appears that each of the three main forks of the Ten Mile River watershed, on average, only minimally support salmonid spawning, incubation, and emergence success. The subwatersheds of the Clark and South Forks of the Ten Mile River are essentially identical in the percentage of substrate that is composed of fine sediment (<0.85 mm). The North Fork Ten Mile River subwatershed appears slightly more rich in fine sediment (<0.85 mm) than the other two. Hines (2000) observed that fines in the North Fork Ten Mile River subwatershed are decreasing while those in the South Fork Ten Mile River subwatershed and Clark Fork Ten Mile subwatershed appeared relatively stable from 1993 to 1999. Hines (2000) hypothesized that since old-growth trees were harvested more recently in the North Fork than elsewhere in the basin, then current sediment data may be reflecting a recovery trend from this activity. Sediment data in the other subwatersheds may have missed the downward trend and simply be measuring post-disturbance stabilization (Hines 2000).

Table 4.10 contains the fine sediment data for individual sampling locations for individual years from 1995 through 1999. Hines (2000) reports trends in the data using data collected from 1993 through 1999. However, individual data were not provided to Regional Water Board staff for 1993 and 1994.

**TABLE 4.10**
**SUBSTRATE COMPOSITION DATA (Ambrose et al. 1996, Ambrose and Hines 1997, 1998)**

| **LOCATION** | | **PERCENT FINES less than 0.85 mm** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **1995** | **1996** | **1997** | **1998** | **1999** | **5-Year Average** |
| **LOWER TEN MILE RIVER** | | | | | | | |
| TEN1 | Mill Creek | 22.6 | 23.7 | 17.4 | 19.1 | 20.7 | 20.7 |
| **NORTH FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | |
| NFT1 | NFT at Patsy Creek | 20.7 | 18.4 | 14.7 | 23.3 | 14.4 | 18.3 |
| NFT2 | Bald Hill Creek | 16.2 | 13.7 | 14.2 | 12.6 | 10.7 | 13.5 |
| NFT5 | NFT at Camp 5 | 20.8 | 15.5 | 16.5 | 16.3 | 16.6 | 17.1 |
| NFT6 | Lower Little North Fork Ten Mile River | 18.9 | 17.3 | 17.1 | 17.6 | 11.2 | 16.4 |
| NFT7 | Buckhorn Creek | 23.7 | 16.2 | 20.8 | 22.5 | 19.9 | 20.6 |
| NFT9 | NFT at Gulch 9 | 26.5 | 20.7 | 23.9 | 19.1 | 19.2 | 21.9 |
| NFT10 | Patsy Creek | 28.8 | 27.1 | 21.7 | 19.3 | 21.8 | 23.7 |
| **CLARK FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | |
| CFT1 | CFT at Reynold’s Gulch | 17.0 | 15.1 | 20.0 | 19.8 | 21.1 | 18.6 |
| CFT2 | CFT at Little Bear Haven Creek | 16.5 | 19.7 | 14.2 | 8.8 | 14.4 | 14.7 |
| CFT3 | Lower Bear Haven Creek | 18.6 | 12.9 | 11.4 | 23.2 | 18.1 | 16.8 |
| CFT4 | Lower CFT | 20.9 | 16.9 | 17.2 | 15.6 | 18.5 | 17.8 |
| CFT5 | Booth Gulch | 22.2 | 22.5 | 26.7 | 20.6 | 22.9 | 23.0 |
| CFT6 | Little Bear Haven Creek | 19.6 | 17.4 | 16.2 | 12.5 | 16.1 | 16.4 |
| **SOUTH FORK TEN MILE RIVER SUBWATERSHED** | | | | | | | |
| SFT1 | Smith Creek | 14.7 | 17.2 | 16.6 | 21.1 | 19.1 | 17.7 |
| SFT2 | Campbell Creek | 23.1 | 22.8 | 22.0 | 18.7 | 22.5 | 21.8 |
| SFT3 | SFT at Brower’s Gulch | 16.5 | 21.8 | 18.4 | 16.1 | 13.5 | 17.3 |
| SFT4 | Churchman Creek | 15.8 | 19.2 | 12.4 | 13.6 | 16.4 | 15.5 |
| SFT5 | SFT at Buck Mathew’s Gulch | 16.6 | 16.9 | 12.9 | 28.2 | 16.1 | 18.1 |
| SFT6 | SFT at Camp 28 | 18.4 | 16.2 | 15.4 | 20.3 | 16.9 | 17.4 |
| SFT8 | Upper Redwood Creek | 19.5 | 16.0 | 22.7 | 17.1 | 15.2 | 18.1 |
| SFT9 | Upper SFT | 14.0 | 13.2 | 13.6 | 12.0 | 9.9 | 12.5 |
| SFT13 | SFT at Churchman Creek | 14.2 | 12.4 | 14.5 | 11.2 | 9.2 | 12.3 |

At 13% of the sample locations, the average percent fines (<0.85 mm) over five years is less than 14%. These locations are NFT2, SFT9, and SFT13. There are no such locations in the Clark Fork Ten Mile River subwatershed. At 61% of the sample locations, the average percent fines (<0.85 mm) over a five year period was between 14% to 20%. These are the majority of the sampling locations. They are identified in Table 4.10 and are located throughout the watershed. At 26% of the sample locations, the average percent fines (<0.85 mm) over a five year period is greater than 20%. These locations are NFT7, NFT9, NFT10, CFT5, and SFT2. These are located throughout the watershed but concentrated in the North Fork Ten Mile River subwatershed.

G-P conducted a trend analysis and found trends at ten of the 23 sampling locations (NFT2, NFT5, NFT6, NFT9, NFT10, CFT4, CFT6, SFT1, SFT2, and SFT13). All of these locations are stable or decreasing in percent fines (<0.85 mm), except SFT1, which is increasing. Regression lines for the additional 13 sampling locations are useful in providing a subjective assessment of trends but are not conclusive (Hines 2000). Locations where regression lines suggest an increase in the percent fines (<0.85 mm) include CFT1, CFT3, CFT5, and SFT6 (Hines 2000). There are no stations in the North Fork Ten Mile River subwatershed where an increase in the percent fines (<0.85 mm) is indicated. Locations where regression lines suggest a decrease in the percent fines (<0.85 mm) include NFT7, SFT3, and SFT4 (Hines 2000). No trends are evident at six sampling locations, including TEN1, NFT1, CFT2, SFT5, SFt8, and SFT9.

In 1994, G-P studies gross aggradation/degradation in the South Fork Ten Mile River. The results of this study indicate that the South Fork Ten Mile River is a dynamic system with large local changes in streambed elevation. A change in mean streambed elevation could not be computed due to the loss of numerous benchmarks during the 1994/95 storms (Ambrose et al. 1996).

#### 4.3.4 TEMPERATURE DATA

G-P installed temperature data loggers in numerous pools and a few riffles throughout the Ten Mile River watershed beginning in 1993. Temperature data loggers record stream temperature at regular intervals, numerous times a day for several weeks at a time. From these data, daily temperature statistics can be calculated (e.g., mean, maximum and minimum), as well as weekly or monthly temperature statistics (e.g., maximum weekly average temperature). G-P reported temperature data for the Ten Mile River watershed for the summers of 1995, 1996 and 1997, in a slightly different way in each year. In 1995, the continuous temperature data are reported in the form of a line graph for each sample site. From this presentation, one can identify the maximum and minimum instantaneous temperatures. One can also estimate the degree to which daily temperatures are within a given range. In addition, the weekly average temperature is reported in the form of a bar graph for each sample site. The weekly average temperature was computed for each calendar week in which there were seven measurements. From this presentation, one can identify the weeks in which the weekly average temperature exceeded some threshold. In 1996, the average, minimum and maximum daily values are reported in the form of a line graph for each sample site. In addition, a 7-day moving average is reported in the form of a line graph for each sample site. In 1997, only the 7-day moving average is reported for each sample site. As such, only a weekly average temperature statistic is available for comparison amongst each of the three years.

Bjornn and Reiser (1991) define a short-term maximum summer temperature for rearing coho to be 22 °C. None of the continuous temperature data indicates exceedances of this value. Bjornn and Reiser (1991) also define a range of preferred summer temperatures for rearing coho to be 11.8 to 14.6 °C. The continuous temperature data reported by G-P (i.e., 1995 and 1996) indicate that at a few of the monitoring locations the summer temperatures fall within this range. These stations are:

- Mill Creek (TEN1)
- Buckhorn Creek (NFT7)
- Upper Little North Fork Ten Mile River (NFT8)
- Bear Haven Creek (CFT3)
- Little Bear Haven Creek (CFT6)
- Upper Bear Haven Creek (CFT7)
- Upper Clark Fork Ten Mile River at Ford Gulch (CFT8)

None of these stations are in the South Fork Ten Mile River subwatershed. All of the other monitoring stations exhibit summer temperatures that fall outside of this range some to most of the time.

A weekly average temperature is a moving average of continuous temperature data over seven days. When graphed, one can compare the weekly average temperature to a maximum or target. For the purpose of evaluating the G-P temperature data, a maximum weekly average temperature (“MWAT”) of 16.8°C is chosen. This target is chosen based on the work conducted by David Hines and Jonathan Ambrose for G-P comparing the presence and absence of coho in streams to the weekly average temperatures found there over time. They conclude that a maximum weekly average temperature (calculated as the mean of daily maximums) of 16.8°C predicts whether or not coho will be present in a stream (Ambrose and Hines 1998). Using a hard copy of the temperature graphs provided by Ambrose and Hines (1996, 1997, 1998), Regional Water Board staff drew in a target line at 16.8°C and measured the amount of time from June1 to August 31 that the reported weekly average temperature exceeded this target. Table 4.11 summarizes these measurements (to the closest 5%).

**TABLE 4.11**
**SUMMARY OF 1995-1997 TEMPERATURE DATA IN THE TEN MILE CREEK WATERSHED (interpreted from data presented in Ambrose and Hines 1996, 1997, 1998)**

| Site ID | | Estimated % of time (to closest 5%) from June through August that weekly average maximum temperature exceeded 16.8°C° | | |
|---|---|---|---|---|
| | | 1995 | 1996 | 1997 |
| **Lower Ten Mile River** | | | | |
| TEN1 | Mill Creek | 0 | 0 | 0 |
| **North Fork Ten Mile River Subwatershed** | | | | |
| NFT1 | NFT @ Patsy Creek | 50 | NR | 85 |
| NFT2 | Bald Hill Creek | 0 | 0 | 15 |
| NFT3 | NFT @ O’Connor Gulch | 15 | 75 | 80 |
| NFT4 | NFT @ Camp 3 | 15 | 70 | 90 |
| NFT5 | NFT @ Camp 5 | 40 | 75 | 90 |
| NFT6 | Lower Little North Fork Ten Mile River | 0 | NR | 0 |
| NFT7 | Buckhorn Creek | 0 | 0 | 0 |
| NFT8 | Upper Little North Fork Ten Mile River | 0 | 0 | 0 |
| NFT9 | NFT @ Gulch 9 | 15 | NR | 80 |
| NFT11 | NFT at property line | NS | 45 | 100 |
| NFT12 | Bald Hill Creek (riffle) | 0 | NR | NR |

**TABLE 4.11**
**SUMMARY OF 1995-1997 TEMPERATURE DATA IN THE TEN MILE CREEK WATERSHED (interpreted from data presented in Ambrose and Hines 1996, 1997, 1998)**

| Site ID | | Estimated % of time (to closest 5%) from June through August that weekly average maximum temperature exceeded 16.8°C$^{\circ}$ | | |
|---|---|---|---|---|
| | | 1995 | 1996 | 1997 |
| NFT13 | NFT @ Patsy Creek (riffle) | NS | 85 | NS |
| NFT14 | NFT @ Camp 5 (riffle) | NS | 100 | NS |
| NFT15 | NFT/CFT confluence | NS | 100 | 95 |
| **Clark Fork Ten Mile River Subwatershed** | | | | |
| CFT1 | CFT @ Reynold's Gulch | 0 | 35 | 45 |
| CFT2 | CFT @ Little Bear Haven Creek | 25 | NR | 80 |
| CFT3 | Lower Bear Haven Creek | 0 | 0 | 0 |
| CFT4 | Lower CFT | 0 | 35 | 85 |
| CFT5 | Booth Gulch | 0 | 0 | 0 |
| CFT6 | Little Bear Haven Creek | 0 | 0 | 0 |
| CFT7 | Upper Bear Haven Creek | 0 | 0 | 0 |
| CFT8 | CFT @ Ford Gulch | 0 | 0 | 0 |
| CFT9 | Lower CFT (riffle) | 15 | 75 | NS |
| CFT10 | Booth Gulch (riffle) | 0 | 0 | NS |
| CFT11 | CFT @ Bensi Crossing | NS | 45 | 60 |
| CFT12 | CFT @ Gulch 18 | NS | 75 | NR |
| CFT13 | CFT @ Gulch 18 (riffle) | NS | 80 | NS |
| CFT19 | Gulch 16 | NS | NS | 0 |
| **South Fork Ten Mile River Subwatershed** | | | | |
| SFT1 | Smith Creek | 0 | 0 | 0 |
| SFT2 | Campbell Creek | 0 | 30 | 50 |
| SFT3 | SFT @ Brower's Gulch | 15 | 75 | 45 |
| SFT4 | Churchman Creek | NS | 0 | 0 |
| SFT5 | SFT @ Buck Matthews Gulch | 50 | 90 | 90 |
| SFT6 | SFT @ Camp 28 | 15 | 75 | 85 |
| SFT7 | Lower Redwood Creek | 0 | 55 | 40 |
| SFT8 | Upper Redwood Creek | 0 | 0 | 10 |
| SFT9 | Upper SFT | 0 | NR | 0 |
| SFT11 | Gulch 11 | NS | 0 | 0 |
| SFT12 | SFT above Gulch 11 | 0 | 40 | 0 |
| SFT15 | SFT @ Camp 28 | 15 | 65 | NS |
| SFT16/19 | Lower SFT | NS | 0 | 0 |
| SFT17 | SFT @ Brower's Gulch (riffle) | NS | 65 | NS |
| SFT18 | SFT @ Buck Matthew's Gulch (riffle) | NS | 100 | NS |

NR = Not reported. Ambrose and Hines provide a table in the monitoring report for each year that lists the stations from which data were collected. If a station was listed as a monitoring location for a given year but the data were not presented, then it was listed here as NR.

NS = Not Sampled.

Ambrose and Hines collected temperature data from 36 pools. Temperature data are available for an additional nine riffles. Regarding the pool data, 31% of the pools sampled in the North Fork Ten Mile River subwatershed exhibit weekly average summer temperatures regularly below a 16.8°C MWAT. Approximately 45% of the pools sampled in the Clark Fork Ten Mile River subwatershed exhibit suitable weekly average summer temperatures. And, 27% of the pools sampled in the South Fork Ten Mile River subwatershed exhibit suitable weekly average summer temperatures. In total, 36% of the pools sampled in the Ten Mile River watershed exhibit suitable weekly average summer temperatures.

With respect to temperature, then, G-P data indicate that:

1. Neither the North Fork Ten Mile River, Clark Fork Ten Mile River, nor South Fork Ten Mile River exhibit summer temperature conditions that are lethal to coho salmon (e.g., daily temperatures do not exceed 22 °C at any of the locations).
2. The Little North Fork Ten Mile River subwatershed exhibits continuous daily temperatures and weekly average temperatures that are ideal for coho summer rearing (e.g., daily temperatures at NFT7 and NFT8 are between 11.8 and 14.6°C and weekly average temperatures are below 16.8°C).
3. The Middle Clark Fork Ten Mile River subwatershed and the upper reaches of the Upper Clark Fork Ten Mile River subwatershed exhibit continuous daily temperatures and weekly average temperatures that are ideal for coho summer rearing.
4. The continuous daily temperatures in Little Bear Haven Creek and Booth Creek periodically exceed the upper limit of temperatures preferred by rearing coho. However, the weekly average temperatures are adequate to support coho summer rearing.
5. The continuous daily temperatures in the South Fork Ten Mile River subwatershed either periodically or regularly exceed the upper limit of temperatures preferred by rearing coho. However, the weekly average temperatures regularly exhibited in Smith Creek, Churchman Creek, Redwood Creek, and the upper reaches of the Upper South Fork Ten Mile River subwatershed are adequate to support coho summer rearing.
6. Mill Creek exhibits continuous daily temperatures and weekly average temperatures that are ideal for coho summer rearing.
7. All other sampling locations exhibit temperatures that are inadequate to support coho summer rearing.

### 4.3.5 HABITAT INVENTORIES

The California Department of Fish and Game developed a protocol for inventorying the type and quality of habitat available in a given stream reach. The protocol is described in Flosi et al. 1998. CDFG uses the results of its habitat inventories to identify and prioritize habitat restoration opportunities. The data also provide snapshot of the overall habitat availability in a watershed.

Two habitat inventories have been conducted in the Ten Mile River watershed. One, conducted in 1991, was a cursory assessment looking at selected reaches of individual streams. The other, conducted in 1994 and 1995, was a more extensive assessment looking at the full length of individual streams accessible to anadromous fish. The number of streams selected for the inventory in 1994/95 was more extensive than those selected in 1991. The difference in the number and extent of inventoried streams in the 1991 and 1994/95 assessments prohibits a direct comparison of the findings. As above, CDFG recommends against such a comparison, in any case. Reported below is a summary of the data results of the 1994/95 inventory as reported by Ambrose et al. (1995).

In 1994 and 1995 G-P surveyed anadromous fish-bearing streams throughout its ownership in the Ten Mile River watershed. A total of 573,711 feet (109 miles) of stream were surveyed and the following measurements collected:

- Flow (Marsh-McBirney Flo-Mate™ Model 2000)
- Channel type (Rosgen 1985 revised in 1996)
- Habitat type (Flosi and Reynolds 1994)
- Embeddedness (ocular estimate of the percent of cobble samples embedded under fine sediment)
- Shelter Rating (quantitative measure of overhead cover multiplied by a qualitative rating of shelter value)
- Substrate composition (ocular estimate of dominant and sub-dominant substrate size classes)
- Canopy (hand-held spherical densiometer readings with ocular estimate of distribution of coniferous and deciduous cover)
- Bank composition and vegetation (ocular estimate of dominant bank substrate type, vegetation type, and percent of bank covered by vegetation)

Regional Water Board staff evaluated the data as follows:

- Calculate the miles of stream that based on existing channel type are capable of providing suitable salmonid habitat. A comparison of the population data with the channel type data indicate coho are only present in Ten Mile River watershed streams that have at least some amount of C-type channel. (See Table 4.12 at the end of this section)
- Identify stream reaches that are potentially limiting various salmonid life stages based on existing habitat type. Lateral scour pools are the most widely used salmonid habitat, followed by backwater pools, mid-channel pools, and pocket water. Edgewater habitat, high gradient riffles, and runs are also important to various salmonid life cycle stages (Flosi et al. 1998). (See Tables 4.13 and 4.14 at the end of this section)
- Identify those stream reaches with a frequency and mean depth of pool that are too little to provide adequate summer rearing habitat for coho salmon. Flosi et al. (1998) report that the better coho streams have 40% of their habitat length in primary pools (e.g., in third- and fourth-order streams, primary pools have a maximum depth of at least three feet, are at least half as wide as the low flow channel, and are at least as long as the low flow channel is wide. (See Tables 4.13 and 4.14 at the end of this section).
- Identify those stream reaches with a mean shelter rating that is too low to provide adequate protection against predators.[27] (See Table 4.14 at the end of this section)

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[27] A shelter rating is assigned by estimating the percent of a habitat unit area that offers some form of shelter and multiplying it by a shelter quality rating of zero to three. The maximum shelter rating is 300. A shelter quality rating is assigned as follows: If the shelter in a habitat unit consists of one to five boulders, bare undercut bank, bare bedrock ledge or a single piece of large wood, then the unit is given a shelter quality rating of one. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of one or two pieces of large woody associated with any amount of small wood, six of more boulders per 50 feet, a stable undercut bank with root mass, a single root wad lacking complexity, etc., then the unit is given a shelter quality rating of 2. This is multiplied by the percentage of the unit area that is providing

- Identify those stream reaches with gravels that are too few or too heavily embedded to provide adequate spawning habitat. Flosi et al. (1998) indicate that gravels that are less than 25% are preferred for spawning. (See Table 4.15 at the end of this section)
- Identify those stream reaches with canopy cover too little to provide adequate summer shade or too dominated by deciduous species to provide adequate large woody debris. Flosi et al. (1998) indicate that stream canopy should be 80% or more to maintain suitable water temperatures. (See Table 4.16 at the end of this section).

#### 4.3.5.1 Lower Ten Mile River Subwatershed

Within the Lower Ten Mile River subwatershed, G-P assessed habitat conditions in Mill Creek, only. As reported by Ambrose et al. (1996), the elevation of Mill Creek ranges from 24 m (40 feet) at the mouth to 488 m (2,200 feet) in the headwaters. A total of 9,606 feet (1.8 miles) of Class I stream were surveyed in Mill Creek from July 14 through June 15, 1994. Table 4.15 at the end of this section summarizes the lengths of channel surveyed in Mill Creek, as well as the distribution of Rosgen channel types identified. F-type channels predominate (64%) followed by B-type channels (36%).[28]

Mill Creek is dominated by flatwater units (55% by length). The majority of the flatwater units are step runs, a habitat type used only by YOY steelhead. Runs, used by Y+ steelhead, make up only 6% of the habitat types while pocket water and edgewater are completely absent. Pools make up only 10% of the habitat units, by length (see Table 4.13 at the end of this section). Mid-channel pools account for 2% while scour pools account for the remaining 8%. Backwater pools are completely absent. In addition, the average pool depth in Mill Creek is 0.7 feet. The mid-channel pools, channel confluence pools, corner pools, and plunge pools have an average depth of two feet (see Table 4.14 at the end of this section). Based on these observations, it appears that Mill Creek may be limited as a salmonid stream by an inadequate quantity and quality of rearing and overwintering habitat.

The mean shelter rating for pools in Mill Creek is 44. Shelter in cascades and log-enhanced lateral scour pools exceed a mean rating of 100. But, the shelter in all of the other habitat types is rated at far less than 80 (see Table 4.14 at the end of this section). Based on this information, it appears that Mill Creek does not offer adequate cover to successfully protect young salmonids from predators.

Coho salmon, chinook salmon and steelhead trout build their redds in the gravels found in low gradient riffles such as those seen at the pool tail-outs of mid-channel pools and scour pools, as well as in pocket water (Flosi et al. 1998). Gravel-sized particles dominate the substrate of low

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the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of combinations of large woody debris, boulders and root wads, three or more pieces of large woody debris combined with small woody debris, three or more boulders combined with large woody debris/small woody debris, etc., then the unit is given a shelter quality rating of 3. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). Flosi et al. (1998) recommend improving shelter availability through habitat restoration efforts where the shelter rating is less than 80.

[28] For a discussion of Rosgen channel typing, see Rosgen 1996. B-type channels are moderately entrenched, riffle-dominated channels with moderate gradient and infrequently spaced pools. They have a very stable plan and profile as well as stable banks. F-type channels are entrenched, meandering channels with riffle/pool sequences on low gradients with high width/depth ratios.

gradient riffles found in Mill Creek. However, there is no pocket water habitat in the stream and little mid-channel or scour pool habitat. In addition, substrate particles in Mill Creek are on average more than 50% embedded (see Table 4.15 at the end of this section). As such, the spawning habitat in Mill Creek may be limited.

Finally, the banks of Mill Creek are well vegetated and provide an average of 97% canopy throughout the riparian zone, except in dry stream reaches which are open. Vegetation is primarily deciduous, however, and will not provide long-lasting woody debris to the stream (see Table 4.16 at the end of this section).

#### 4.3.5.2 North Fork Ten Mile River Subwatershed

As reported by Ambrose et al. (1996), the elevation of North Fork Ten Mile River subwatershed ranges from 12 m (40 feet) at the mouth to 671 m (2,200 feet) in the headwater areas. It drains approximately 24,967 acres (39 $mi^2$) and includes the following tributaries:

- Little North Fork Ten Mile River
- Cavanough Gulch
- O'Connor Gulch
- Bald Hill Creek
- Gulch 8
- Gulch 11
- Gulch 19
- Patsy Creek
- Gulch 23

A total of 205,212 feet (38.9 miles) of Class I stream were surveyed in the North Fork Ten Mile River subwatershed from July 27 through November 2, 1995. Table 4.12 at the end of this section summarizes the length of channel surveyed in the mainstem and each tributary, as well as the distribution of Rosgen channel types identified. A total of 183,947 feet of main channel plus 2,957 feet of side channel were surveyed in the North Fork Ten Mile River subwatershed. Within the North Fork Ten Mile River subwatershed, B-type channels predominate (67%) followed by F-type channels (24%). A small proportion of the main channels surveyed were C-type channels (8%) while an even smaller proportion were D-type channels (1%).[29]

The mainstem North Fork Ten Mile River is predominated by pools (47%). The same is true of the Little North Fork Ten Mile River. The tributaries, on the other hand, are generally predominated by flatwater units. Two notable exceptions are Barlow Gulch and Cavanough Gulch which are predominated by dry units (38% and 54%, respectively). Gulch 19 and Gulch 23 are predominated by riffle units (42% and 38%, respectively). Only in the mainstem North Fork Ten Mile River do the majority (>50%) of pools have maximum depths that exceed three

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[29] B-type channels are moderately entrenched, riffle-dominated channels with moderate gradient and infrequently spaced pools. They have a very stable plan and profile as well as stable banks. C-type channels are low gradient, meandering alluvial channels with point-bars, riffle/pool sequences, and broad, well-defined floodplains. D-type channels are braided with longitudinal and transverse bars. They are very wide with eroding banks. F-type channels are entrenched, meandering channels with riffle/pool sequences on low gradients with high width/depth ratios.

feet. In all the other tributaries the majority of pools have maximum depths no greater than two feet (see Tables 4.13 and 4.14 at the end of this section). Large, deep pools are necessary as rearing habitat for coho salmon. Flosi et al. (1998) found that primary pools make up more than 40% of the habitat units found in good coho streams. As such, only the mainstem North Fork Ten Mile River is potentially well-suited for coho salmon rearing. The Little North Fork Ten Mile River contains an adequate ratio of pools to riffles/flatwater. But, the pools are shallow. Barlow Gulch and Cavanough Gulch offer poor rearing habitat due to numerous dry reaches that may strand young fish. And the rest of the North Fork Ten Mile River subwatershed is lacking in both an adequate number of pools and pools of adequate depth.

Scour pools make up the largest percentage of the pools in both the mainstem North Fork Ten Mile River and the Little North Fork Ten Mile River followed by main channel pools and very few backwater pools. Five of the tributary watersheds are also predominated by scour pools, including Cavanough Gulch, O’Connor Gulch, Bald Hill Creek, Gulch 11, and Gulch 19. The others are predominated by main channel pools, including Blair Gulch, Barlow Gulch, Buckhorn Gulch, McGuire Creek, Gulch 8, Patsy Creek and Gulch 23. Only Cavanough Gulch and Gulch 19 have notable numbers of backwater pools —10% and 8%, respectively (see Table 4.14 at the end of this section). A predominance of scour pools may describe a stream in which there is optimum sediment storage capacity, sediment sorting, and diverse forms of shelter (e.g., large woody debris, undercut banks, white water, etc.). However, a specific relationship between the predominance of scour pools and channel functioning and/or habitat availability is currently unknown. Backwater pools, on the other hand, are commonly thought to be associated with the successful overwintering of young salmonids which would otherwise be washed downstream in the absence of shelter from high, mainstem, winter flows (see Table 4.14 at the end of this section). As such, Cavanough Gulch and Gulch 19 may offer potential overwintering habitat in which young salmonids can successfully find refuge from high winter flows.

In none of the surveyed streams do the mean shelter ratings in pools exceed 80 -- a target used by CDFG when considering habitat restoration. In a majority of the surveyed streams, the mean shelter ratings are no greater than 50 (see Table 4.14 at the end of this section). Based on this information, one can surmise that the North Fork Ten Mile River subwatershed does not generally offer adequate cover to successfully protect young salmonids from predators.

In nearly all of the surveyed streams, gravel is the dominant substrate size class found in low gradient riffles. Coho salmon and steelhead trout build redds in the gravels found in low gradient riffles, such as those seen at pool tail-outs. Most of the surveyed streams in the North Fork Ten Mile River subwatershed appear to provide potential spawning habitat for these salmonid species. Gulch 11 and Gulch 23 are the exceptions. The low gradient riffles in these tributaries are dominated by boulder size particles. These tributaries probably do not offer substantial spawning habitat for coho salmon or steelhead trout. Unfortunately, despite the predominance of gravel-sized particles in low gradient riffles, particles appear to be substantially embedded. Particles less than 25% embedded are generally ideal for successful redd-building and incubation/emergence. None of the surveyed streams possess spawning substrates where a majority of the substrate is less than 25% embedded. Indeed, more than half of the potential spawning habitat in all of the surveyed streams is more than 50% embedded. In five out of 14 surveyed streams, more than 80% of the potential spawning habitat is more than 75% embedded—or essentially fully embedded. (See Table 4.15 at the end of this section)

Finally, the banks of North Fork Ten Mile River subwatershed are dominated by deciduous vegetation. Only in Buckhorn Gulch, McGuire Creek, Gulch 11 and Gulch 19 does coniferous vegetation dominate the stream banks. More than 10% of the stream banks are open in the mainstem North Fork Ten Mile River, Bald Hills Creek, Gulch 8, Gulch 11, and Gulch 19. While the distribution of vegetation and open conditions along a stream bank do not directly relate to woody debris production, it does speak to the general capacity of a reach of stream to produce long lasting (e.g., rot resistant) woody debris around which habitat can be formed and sediment stored and sorted. (See Table 4.16 at the end of this section)

#### 4.3.5.3 Clark Fork Ten Mile River Subwatershed

As reported by Ambrose et al. (1996), the elevation of the Clark Fork Ten Mile River subwatershed ranges from 140 feet at the mouth to 3,000 feet in the headwater areas. It drains approximately 21,400 acres (33 mi$^2$) and includes the following tributaries:

- Bear Haven Creek
- Little Bear Haven Creek
- Booth Gulch
- Gulch 27

A total of 154,857 feet (29.3 miles) of Class I stream were surveyed in the Clark Fork Ten Mile River subwatershed from August 17, 1994 through July 18, 1995. Table 4.12 at the end of this section summarizes the lengths of channel surveyed in the mainstem and each tributary, as well as the distribution of Rosgen channel types identified. Within the Clark Fork Ten Mile River subwatershed, B-type channels predominate (65%) followed by C-type channels (23%). A small proportion of the mainstem channels surveyed were F-type channels (12%) while an even smaller proportion were A-type channels (<1%).[30]

The mainstem Clark Fork Ten Mile River is predominated by pools (44%). Flatwater units, on the other hand, dominate the tributaries. Only in the mainstem Clark Fork Ten Mile River do the majority (>50%) of pools have maximum depths that exceed three feet. In all the other tributaries, the majority of pools have maximum depths no greater than two feet. Large, deep pools are necessary are rearing habitat for coho salmon. Flosi et al. (1998) have found that primary pools make up more than 40% of the habitat units found in good coho streams. As such the mainstem Clark Fork Ten Mile River is potentially well-suited for coho salmon rearing. But, the tributaries may offer only marginal rearing habitat. (See Tables 4.13 and 4.14 at the end of this section)

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[30] A-type channels are generally found within valley types that due to their inherent channel steepness, exhibit a high sediment transport potential and a relatively low in-channel sediment storage capacity. The influx of large woody debris can play a major role in determining the bedform and overall channel stability of A-type channels. A-type channels are generally steep, entrenched, cascading step/pool streams and are very stable if bedrock or boulder dominated. A description of the other channel types is given in the discussion of the North Fork Ten Mile River subwatershed habitat data, above.

Scour pools make up the largest percentage of the pools in both the mainstem Clark Fork Ten Mile River and Bear Haven Creek. The other tributaries are predominated by main channel pools. A predominance of scour pools may describe a stream in which there is optimum sediment storage capacity, sediment sorting, and diverse forms of shelter (e.g., large woody debris, undercut banks, white water, etc.). However, a specific relationship between the predominance of scour pools and channel functioning and/or habitat availability is currently unknown. Backwater pools, on the other hand, are commonly thought to be associated with successful overwintering of young salmonids which would otherwise be washed downstream in the absence of shelter from high, mainstem, winter flows. None of the streams within the Clark Fork Ten Mile River subwatershed offer significant backwater pool habitat. (See Table 4.14 at the end of this section)

In none of the surveyed streams do the mean shelter ratings in pools exceed 80 — a target used by CDFG when considering habitat restoration. In a majority of surveyed streams, the mean shelter ratings are no greater than 50. Based on this information, one can surmise that the Clark Fork Ten Mile River subwatershed does not generally offer adequate cover to successfully protect young salmonids from predators. (See Table 4.14 at the end of this section)

In all but Gulch 27, gravel is the dominant substrate size class found in low gradient riffles. Coho salmon and steelhead trout build redds in the gravels found in low gradient riffles such as those seen at pool tail-outs. As such, most of the surveyed streams in the Clark Fork Ten Mile River subwatershed appear to provide potential spawning habitat for these salmonid species. Gulch 27 is an exception since low gradient riffles are dominated by small cobble in this stream. (See Table 4.15 at the end of this section)

Unfortunately, despite the predominance of gravel-sized particles, the particles appear to be substantially embedded. Particles less than 25% embedded are generally ideal for successful redd-building and incubation/emergence. None of the surveyed streams exhibit spawning substrates where a majority of the substrate is less than 25% embedded. Indeed, more than half of the potential spawning habitat in all of the surveyed streams is more than 75% embedded. In two out of five surveyed streams, more than 80% of the potential spawning habitat is more than 75% embedded — essentially fully embedded. (See Table 4.15 at the end of this section)

Finally, the banks of the Clark Fork Ten Mile River subwatershed are dominated by deciduous vegetation. Only in Bear Haven Creek and Booth Gulch do coniferous vegetation dominant the stream banks. Indeed, more than 15% of the stream banks are open throughout the subwatershed. While the distribution of vegetation and open conditions along a stream bank do not directly relate to woody debris production, it does speak to the general capacity of a reach of stream to produce long lasting (e.g., rot resistant) woody debris around which habitat can be formed and sediment stored and sorted. (See Table 4.16 at the end of this section)

#### 4.3.5.4 South Fork Ten Mile River Subwatershed

As reported by Ambrose et al. (1996), the elevation of the South Fork Ten Mile River subwatershed ranges from 20 feet at the mouth to 3,000 feet in the headwater areas. It drains approximately 19,630 acres (31 mi$^2$) and includes the following tributaries:

- Smith Creek
- Campbell Creek

- Churchman Creek
- Redwood Creek

A total of 213,642 feet (40.5 miles) of Class I stream were surveyed in the South Fork Ten Mile River subwatershed from June 15, 1994 through August 16, 1994. Table 4.12 at the end of this section summarizes the lengths of channel surveyed in the mainstem and each tributary, as well as the distribution of Rosgen channel types identified. Within the South Fork Ten Mile River subwatershed, B-type channels predominate (74%) followed by C-type channels (25%). A small proportion of the mainstem channels surveyed were F-type channels (1%). A description of the channel types is given in the discussion of the North Fork Ten Mile River subwatershed habitat data, above.

The mainstem South Fork Ten Mile River and each of the surveyed tributaries are predominated by flatwater units. In addition, no where in the South Fork Ten Mile River do the majority (>50%) of pools have maximum depths that exceed three feet. In the mainstem South Fork Ten Mile River and all the surveyed tributaries the majority of pools have maximum depths no greater than two feet. Large, deep pools are necessary are rearing habitat for coho salmon. Flosi et al. (1998) found that primary pools make up more than 40% of the habitat units found in good coho streams. As such the South Fork Ten Mile River subwatershed may offer only a marginal coho rearing habitat. (See Tables 4.13 and 4.14at the end of this section)

Where pools do exist, scour pools make up the largest percentage of those pools in the mainstem South Fork Ten Mile River and each of the surveyed tributaries. A predominance of scour pools may describe a stream in which there is optimum sediment storage capacity, sediment sorting, and diverse forms of shelter (e.g., large woody debris, undercut banks, white water, etc.). However, a specific relationship between the predominance of scour pools and channel functioning and/or habitat availability is currently unknown. Backwater pools, on the other hand, are commonly thought to be associated with successful overwintering of young salmonids which would otherwise be washed downstream in the absence of shelter from high, mainstem, winter flows. None of the streams within the South Fork Ten Mile River subwatershed offer significant backwater pool habitat. As such, overwintering habitat in the South Fork Ten Mile River subwatershed is sorely lacking. (See Table 4.14 at the end of this section)

In none of the surveyed streams do the mean shelter ratings in pools exceed 80 — a target used by CDFG when considering habitat restoration. In a majority of the surveyed streams, the mean shelter ratings are no greater than 40. Based on this information, one can surmise that the South Fork Ten Mile River subwatershed does not generally offer adequate cover to successfully protect young salmonids from predators. (See Table 4.14 at the end of this section)

Gravel is the dominant substrate size class found in low gradient riffles throughout the South Fork Ten Mile River subwatershed. Coho salmon and steelhead trout build redds in the gravels found in low gradient riffles such as those seen at pool tail-outs. As such, most of the surveyed streams in the South Fork Ten Mile River subwatershed appears to provide potential spawning habitat for these salmonid species. (See Table 4.15 at the end of this section)

Unfortunately, despite the predominance of gravel-sized particles, the particles appear to be substantially embedded. Particles less than 25% embedded are generally ideal for successful redd-building and incubation/emergence. None of the surveyed streams possess spawning substrates where a majority of the substrate is less than 25% embedded. Indeed, more than half of the potential spawning habitat in all of the surveyed streams is more than 75% embedded. In four out of five surveyed streams, more than 80% of the potential spawning habitat is more than 75% embedded, essentially fully embedded. (See Table 4.15 at the end of this section)

Finally, the banks of the South Fork Ten Mile River subwatershed are dominated by deciduous vegetation. Only in Redwood Creek does coniferous vegetation dominant the stream banks. Indeed, more than 15% of the stream banks are open throughout the subwatershed. While the distribution of vegetation and open conditions along a stream bank do not directly relate to woody debris production, it does speak to the general capacity of a reach of stream to produce long lasting (e.g., rot resistant) woody debris around which habitat can be formed and sediment stored and sorted. (See Table 4.16 at the end of this section)

#### 4.3.5.5 Riparian Habitat Conclusions

Flosi et al. (1998) identified the habitat types most beneficial to steelhead trout and coho salmon in each of their freshwater life stages. For example, YOY steelhead trout make use of all habitat types in the summer and fall. The Y+ fish, however, prefer pocket water, later scour pools and high gradient riffles. Juvenile coho salmon use all pool types in the summer and fall months. Mid-channel pools, backwater pools and scour pools provide the predominant spawning habitat for both steelhead trout and coho salmon in the winter and spring (Flosi et al. 1998). The habitat typing data available for the Ten Mile River watershed was collected in the summer and fall months. As such, the data are not particularly well-suited for evaluating winter and spring spawning habitat. But, assuming that the proportion of habitat types, if measured in the winter or spring, would be similar to that found in the summer and fall, then some conclusions can be drawn about the proportion of habitat types with respect to spawning habitat.

- **Stream Channel Type**

Stream channels are identified by type during a habitat survey so that instream restoration can be designed which is appropriate for the channel type in question. Flosi et al. (1998) did not specifically address the question of whether salmonids prefer one channel type over another or if some habitat types are more common to one channel type than another. But, as will be discussed further in Section 4.4, it generally appears that the streams with C-type channel are the same as those with coho salmon present. Streams with C-type channel include: Little North Fork Ten Mile River, Bear Haven Creek, Little Bear Haven Creek, mainstem of the South Fork Ten Mile River, Smith Creek and Campbell Creek. Two exceptions to this observed relationship are Little Bear Haven Creek which has C-type channel but no coho and Churchman Creek which has coho but not C-type channel. As such, the presence of C-type channel may be a reasonable screening tool for identifying streams with potential for supporting coho salmon.

- **Specific Habitat Types Important to Salmonids**

Flosi et al. (1998) described lateral scour pools as the most widely used salmonid habitat. Pools, in general, make up more than 40% of the habitat by length in only three surveyed reaches: mainstem North Fork Ten Mile River, Little North Fork Ten Mile River, and mainstem Clark

Fork Ten Mile River. What little pool habitat that does exist throughout the rest of the watershed is dominated by lateral scour pools in the following streams:

- Mill Creek (82% of pools are lateral scour pools)
- Mainstem North Fork Ten Mile River (60%)
- Little North Fork Ten Mile River (61%)
- Cavanough Gulch (51%)
- O'Connor Gulch (63%)
- Bald Hill Creek (53%)
- Gulch 11 (70%)
- Gulch 19 (51%)
- Mainstem Clark Fork Ten Mile River (58%)
- Bear Haven Creek (63%)
- Mainstem South Fork Ten Mile River (71%)
- Smith Creek (78%)
- Campbell Creek (73%)
- Churchman Creek (72%)
- Redwood Creek (58%)

Another important habitat type is backwater pools, which are used by salmonids as overwintering habitat (Flosi et al. 1998). Backwater pools are not prevalent anywhere in the basin. But, they exist in 15 of the 25 surveyed streams and make up greater than 5% of pools in the following streams:

- Little North Fork Ten Mile River (4%)
- Cavanough Gulch (10%)
- Gulch 19 (8%)
- Little Bear Haven Creek (5%)

- **<u>Frequency of Primary Pools</u>**

Ambrose et al. (1996) concluded that the North Fork Ten Mile River subwatershed has less than 50% of its length in primary pools. Primary pools are at least two feet deep in first- and second-order streams and at least three feet deep in third- and fourth-order streams. The South Fork Ten Mile River subwatershed and Clark Fork Ten Mile River subwatershed, however, each have more than 50% of their lengths in primary pools indicating favorable depths for salmonids. These conclusions are contrary to our own. Based on our reading of the data presented in Ambrose et al. (1996), it appears that only the North Fork Ten Mile River, Little North Fork Ten Mile River, and Clark Fork Ten Mile River have pool frequencies indicating a suitable quantity of rearing habitat for successful coho rearing (e.g., ≥40%). Neither the North Fork, Little North Fork or Clark Fork Ten Mile Rivers, however, have adequate pool depths: the average of none of them exceeds 1.6 feet.

Ambrose et al. (1996) further concluded that the South Fork Ten Mile River subwatershed has the highest percentage of pools formed by large woody debris (42%) followed by the Clark Fork Ten Mile River subwatershed (19%) and the North Fork Ten Mile River subwatershed (18%). A possible association was also found between coho sites and the occurrence of pools formed by LWD: the only coho found were in creeks where there was a large percentage of LWD. This suggests that a low percentage of LWD-formed pools could adversely affect juvenile coho populations. The four creeks were coho were found had over 30% of their pools formed by LWD. The association of coho with habitat formed by large woody debris is further discussed in Section 4.4.

- **Shelter**

Flosi et al. (1998) recommend consideration of instream restoration for stream reaches with a shelter rating of less than 80 (out of a possible rating of 300). The mean shelter rating is below 80 for pools, riffles, and flatwater units in every stream surveyed within the Ten Mile River watershed. As such, shelter in the Ten Mile River watershed can be considered a factor potentially limiting the success of salmonids in the basin.

- **Substrate**

Regarding substrate, Ambrose et al. (1996) concluded that there is ample gravel available for spawning throughout the watershed. However, they also conclude that the high embeddedness values could hinder the survival of the eggs deposited in the redds. We concur with these conclusions.

- **Canopy**

Flosi et al. (1998) recommend consideration of stream restoration when streamside canopy is less than 80%. Ambrose et al. (1996) conclude that the canopy offered in each subwatershed is, on average, greater than 80%. Looking more specifically, however, one can see that the mainstems of the North Fork Ten Mile River, Clark Fork Ten Mile River, and South Fork Ten Mile River have less than 80% canopy cover (e.g., 70%, 76%, and 77%, respectively). All the other streams have an average canopy cover exceeding 80%. Ambrose et al. (1996) observed that in the North Fork Ten Mile subwatershed, deciduous trees occupy a slightly larger portion of the canopy cover than coniferous trees. The canopy found in both the Clark and South Fork Ten Mile River subwatersheds is equally divided between coniferous and deciduous trees (Ambrose et al. 1996). Looking more specifically, one can see that seven of the 25 streams surveyed are dominated by coniferous streamside canopy. These include:

- Buckhorn Gulch (52% of the streamside canopy is coniferous)
- McGuire Creek (47%)
- Gulch 11 (51%)
- Gulch 19(49%)
- Bear Haven Creek (57%)
- Booth Gulch (54%)
- Redwood Creek (56%)

Ambrose et al. (1996) concluded that wood from alder and other deciduous species deteriorates rapidly potentially leaving less LWD in the stream available for fish cover and LWD formed pools. Further, coniferous streamside canopy left to reach late seral stage would provide significantly better, longer lasting LWD than small, young conifers.

**TABLE 4.12**
**LENGTH OF CHANNEL SURVEYED & ROSGEN CHANNEL-TYPE FOR EACH REACH THROUGHOUT THE TEN MILE RIVER WATERSHED (Ambrose et al. 1996)**

| **Stream** | **A-type channel** feet (%) | **B-type channel** feet (%) | **C-type channel** feet (%) | **D-type channel** feet (%) | **F-type channel** feet (%) | **Total main channel** feet | **Total side channel** feet (side/main) |
|---|---|---|---|---|---|---|---|
| **Lower Ten Mile River Subwatershed** | | | | | | | |
| Mill Creek | | 3,479<br>(36) | 0 | 0 | 6,127<br>(64) | 9,606 | 0 |
| **North Fork Ten Mile River Subwatershed** | | | | | | | |
| Mainstem North Fork Ten Mile River | 0 | 82,612<br>(100) | 0 | 0 | 0 | 82,612 | 1,299<br>(0.02) |
| Little North Fork Ten Mile River | 0 | 3,990<br>(19) | 14,578<br>(68) | 0 | 2,854<br>(13) | 21,422 | 62<br>(0.00) |
| Blair Gulch | 0 | 0 | 0 | 0 | 5,236<br>(100) | 5,236 | 0<br>(0.00) |
| Barlow Gulch | 0 | 0 | 0 | 0 | 3,633<br>(100) | 3,633 | 0<br>(0.00) |
| Buckhorn Gulch | 0 | 269<br>(2) | 0 | 0 | 11,121<br>(98) | 11,390 | 1,403<br>(0.12) |
| McGuire Creek | 0 | 8,248<br>(84) | 0 | 1,622<br>(16) | 0 | 9,870 | 19<br>(0.00) |
| Cavanough Gulch | 0 | 5,691<br>(100) | 0 | 0 | 0 | 5,691 | 0<br>(0.00) |
| O’Connor Gulch | 0 | 3,488<br>(100) | 0 | 0 | 0 | 3,488 | 0<br>(0.00) |
| Bald Hill Creek | 0 | 6,656<br>(47) | 0 | 0 | 7,555<br>(53) | 14,211 | 174<br>(0.01) |
| Gulch 8 | 0 | 5,455<br>(100) | 0 | 0 | 0 | 5,455 | 0<br>(0.00) |
| Gulch 11 | 0 | 5,021<br>(100) | 0 | 0 | 0 | 5,021 | 0<br>(0.00) |
| Gulch 19 | 0 | 0 | 0 | 0 | 5,455<br>(100) | 5,455 | 0<br>(0.00) |
| Patsy Creek | 0 | 0 | 0 | 0 | 8,009<br>(100) | 8,009 | 0<br>(0.00) |
| Gulch 23 | 0 | 2,454<br>(100) | 0 | 0 | 0 | 2,454 | 0<br>(0.00) |
| North Fork Ten Mile River Subwatershed | 0 | 123,884<br>(67) | 14,578<br>(8) | 1,622<br>(1) | 43,863<br>(24) | 183,947 | 2,957<br>(0.02) |
| **Clark Fork Ten Mile Rive Subwatershed** | | | | | | | |
| Mainstem Clark Fork Ten Mile River | 0 | 81,325<br>(91) | 0 | 0 | 7,957<br>(9) | 89,282 | 1,131<br>(0.01) |
| Bear Haven Creek | 0 | 5,847<br>(17) | 29,533<br>(83) | 0 | 0 | 35,380 | 409<br>(0.01) |
| Little Bear Haven Creek | 121<br>(1) | 5,879<br>(48) | 6,286<br>(51) | 0 | 0 | 12,286 | 0 |
| Booth Gulch | 0 | 1,869<br>(18) | 0 | 0 | 8,669<br>(82) | 10,538 | 0 |
| Gulch 27 | 79<br>(1) | 4,380<br>(75) | 0 | 0 | 1,372<br>(24) | 5,831 | 0 |

**TABLE 4.12**
**LENGTH OF CHANNEL SURVEYED & ROSGEN CHANNEL-TYPE FOR EACH REACH THROUGHOUT THE TEN MILE RIVER WATERSHED (Ambrose et al. 1996)**

| **Stream** | **A-type channel** feet (%) | **B-type channel** feet (%) | **C-type channel** feet (%) | **D-type channel** feet (%) | **F-type channel** feet (%) | **Total main channel** feet | **Total side channel** feet (side/main) |
|---|---|---|---|---|---|---|---|
| **Stream** | **A-type channel** feet (%) | **B-type channel** feet (%) | **C-type channel** feet (%) | **D-type channel** feet (%) | **F-type channel** feet (%) | **Total main channel** feet | **Total side channel** feet (side/main) |
| Clark Fork Ten Mile River Subwatershed | 200<br>(0) | 99,300<br>(65) | 35,819<br>(23) | 0 | 17,998<br>(12) | 153,317 | 1,540<br>(0.01) |
| **South Fork Ten Mile River Subwatershed** | | | | | | | |
| Mainstem South Fork Ten Mile River | 0 | 76,748<br>(82) | 16,030<br>(17) | 0 | 1,216<br>(1) | 93,994[1] | 2,101<br>(0.02) |
| Smith Creek | 0 | 6,802<br>(21) | 26,044<br>(79) | 0 | 0 | 32,846[2] | 0 |
| Campbell Creek | 0 | 11,623<br>(61) | 7,408<br>(39) | 0 | 0 | 19,031 | 162<br>(0.01) |
| Churchman Creek | 0 | 23,050<br>(100) | 0 | 0 | 0 | 23,050 | 0 |
| Redwood Creek | 0 | 26,402<br>(100) | 0 | 0 | 0 | 26,402 | 276<br>(0.01) |
| Total South Fork Ten Mile River | 0 | 144,625<br>(74) | 49,482<br>(25) | 0 | 1,21<br>(1) | 195,323 | 2,539<br>(0.01) |

[1] Ambrose et al. (1996) report a total of 111,369 feet of surveyed stream. However, they only report a channel type for 93,994 feet of stream.

[2] Ambrose et al. (1996) report a total of 33,352 feet of surveyed stream. However, they only report a channel type for 32,846 feet of stream.

Rosgen (1994) Channel Types:
A-type channels are steep, entrenched, cascading, step/pool streams. They have high energy and debris transport capacity and area associated with depositional soils. They are very stable if the channel is bedrock or boulder dominated.
B-type channels are moderately entrenched, riffle-dominated channels with moderate gradient and infrequently spaced pools. They have a very stable plan and profile as well as stable banks.
C-type channels are low gradient, meandering alluvial channels with point-bars, riffle/pool sequences, and broad, well-defined floodplains.
D-type channels are braided with longitudinal and transverse bars. They are very wide with eroding banks.
F-type channels are entrenched, meandering channels with riffle/pool sequences on low gradients with high width/depth ratios.

**TABLE 4.13**
**MEAN LENGTH AND DISTRIBUTION OF HABITAT UNITS IN EACH SURVEYED STREAM (as reported by Ambrose et al. 1996)**

| Stream Name | Riffle Units | | Flatwater Units | | Pool Units | | Dry Units | |
|---|---|---|---|---|---|---|---|---|
| | Mean length (ft) | % of total | Mean length (ft) | % of total | Mean length (ft) | % of total | Mean length (ft) | % of total |
| **Lower Ten Mile River Subwatershed** | | | | | | | | |
| Mill Creek | 51 | 28 | 95 | 55 | 20 | 10 | 328 | 7 |
| **North Fork Ten Mile River Subwatershed** | | | | | | | | |
| Mainstem North Fork Ten Mile River | 53 | 16 | 86 | 37 | 79 | 47 | 92 | 0 |
| Little North Fork Ten Mile River | 28 | 15 | 54 | 41 | 32 | 44 | 0 | 0 |
| Blair Gulch | 18 | 15 | 42 | 59 | 14 | 19 | 56 | 7 |
| Barlow Gulch | 20 | 17 | 47 | 34 | 13 | 11 | 171 | 38 |
| Buckhorn Gulch | 35 | 25 | 65 | 49 | 16 | 11 | 238 | 15 |
| McGuire Creek | 23 | 15 | 72 | 56 | 15 | 16 | 101 | 13 |
| Cavanough Gulch | 33 | 12 | 61 | 28 | 12 | 7 | 305 | 54 |
| O’Connor Gulch | 36 | 28 | 86 | 59 | 14 | 12 | 17 | 1 |
| Bald Hill Creek | 29 | 22 | 62 | 47 | 23 | 26 | 100 | 5 |
| Gulch 8 | 30 | 27 | 69 | 48 | 20 | 23 | 103 | 2 |
| Gulch 11 | 33 | 36 | 71 | 56 | 12 | 8 | 0 | 0 |
| Gulch 19 | 30 | 42 | 36 | 39 | 15 | 18 | 80 | 1 |
| Patsy Creek | 33 | 33 | 46 | 45 | 22 | 19 | 85 | 2 |
| Gulch 23 | 32 | 38 | 48 | 23 | 15 | 9 | 244 | 30 |
| **Clark Fork Ten Mile River Subwatershed** | | | | | | | | |
| Mainstem Clark Fork Ten Mile River | 51 | 16 | 112 | 40 | 85 | 44 | 179 | 0 |
| Bear Haven Creek | 35 | 16 | 73 | 45 | 35 | 33 | 90 | 6 |
| Little Bear Haven Creek | 21 | 13 | 70 | 55 | 26 | 33 | 0 | 0 |
| Booth Gulch | 31 | 22 | 60 | 49 | 18 | 13 | 578 | 16 |
| Gulch 27 | 39 | 32 | 68 | 47 | 28 | 22 | 0 | 0 |
| **South Fork Ten Mile River** | | | | | | | | |
| Mainstem South Fork Ten Mile River | 54 | 14 | 143 | 55 | 61 | 31 | 68 | 1 |
| Smith Creek | 42 | 21 | 101 | 53 | 29 | 21 | 72 | 5 |
| Campbell Creek | 38 | 19 | 94 | 53 | 33 | 25 | 99 | 3 |
| Churchman Creek | 42 | 11 | 141 | 62 | 21 | 8 | 226 | 20 |
| Redwood Creek | 50 | 13 | 154 | 66 | 36 | 19 | 64 | 2 |

**TABLE 4.14**
**MAXIMUM POOL DEPTHS AND MEAN SHELTER RATINGS IN POOLS (as reported by Ambrose et al. 1996)**

| Stream Name | Distribution of Pool Types as Percent of Total Length | | | Maximum Pool Depth as Percent of all Pools | | Mean Shelter Rating in Pools |
|---|---|---|---|---|---|---|
| | Main Channel Pools | Scour Pools | Backwater Pools | <2 feet | ≥3 feet | |
| **Lower Ten Mile River Subwatershed** | | | | | | |
| Mill Creek | 18 | 82 | 0 | 80 | 0 | 44 |
| **North Fork Ten Mile River Subwatershed** | | | | | | |
| Mainstem North Fork Ten Mile River | 40 | 60 | 1 | 16 | 53 | 36 |
| Little North Fork Ten Mile River | 35 | 61 | 4 | 55 | 13 | 44 |
| Blair Gulch | 72 | 27 | 1 | 66 | 3 | 42 |
| Barlow Gulch | 73 | 27 | 0 | 97 | 0 | 22 |
| Buckhorn Gulch | 73 | 27 | 1 | 77 | 3 | 48 |
| McGuire Creek | 57 | 41 | 2 | 77 | 5 | 42 |
| Cavanough Gulch | 39 | 51 | 10 | 79 | 3 | 65 |
| O’Connor Gulch | 37 | 63 | 0 | 66 | 0 | 75 |
| Bald Hill Creek | 46 | 53 | 1 | 58 | 11 | 68 |
| Gulch 8 | 76 | 22 | 2 | 61 | 10 | 63 |
| Gulch 11 | 30 | 70 | 0 | 70 | 6 | 40 |
| Gulch 19 | 41 | 51 | 8 | 71 | 8 | 58 |
| Patsy Creek | 66 | 34 | 0 | 69 | 7 | 73 |
| Gulch 23 | 70 | 30 | 0 | 87 | 0 | 40 |
| **Clark Fork Ten Mile River Subwatershed** | | | | | | |
| Mainstem Clark Fork Ten Mile River | 41 | 58 | 1 | 10 | 52 | 43 |
| Bear Haven Creek | 36 | 63 | 1 | 59 | 11 | 31 |
| Little Bear Haven Creek | 53 | 42 | 5 | 60 | 10 | 42 |
| Booth Gulch | 58 | 41 | 1 | 54 | 13 | 35 |
| Gulch 27 | 64 | 36 | 0 | 27 | 24 | 51 |
| **South Fork Ten Mile River Subwatershed** | | | | | | |
| Mainstem South Fork Ten Mile River | 29 | 71 | 0 | 23 | 37 | 41 |
| Smith Creek | 22 | 78 | 0 | 56 | 4 | 31 |
| Campbell Creek | 27 | 73 | 0 | 65 | 7 | 29 |
| Churchman Creek | 27 | 72 | 2 | 75 | 2 | 39 |
| Redwood Creek | 40 | 58 | 2 | 44 | 17 | 31 |

**TABLE 4.15**
**COBBLE EMBEDDEDNESS IN POOL TAIL-OUTS AND SUBSTRATE COMPOSITION OF LOW GRADIENT RIFFLES (as reported by Ambrose et al. 1996)**

| Stream Name | Mean % of each Cobble Particle that is Embedded by Fine Sediment | | | | Substrate Composition of Low Gradient Riffles (% of all class sizes) | |
|---|---|---|---|---|---|---|
| | 0-25% | 26-50% | 51-75% | 76-100% | Dominant | Sub-Dominant |
| **Lower Ten Mile River Subwatershed** | | | | | | |
| Mill Creek | 0 | 0 | 70 | 30 | Gravel (100%) | None |
| **North Fork Ten Mile River Subwatershed** | | | | | | |
| Mainstem North Fork Ten Mile River | 2 | 9 | 16 | 72 | Gravel (53%) | Sm. cobble (19%) |
| Little North Fork Ten Mile River | 0 | 0 | 12 | 88 | Gravel (100%) | None |
| Blair Gulch | 0 | 0 | 0 | 100 | Gravel (100%) | None |
| Barlow Gulch | 0 | 0 | 0 | 100 | Gravel (100%) | None |
| Buckhorn Gulch | 0 | 0 | 7 | 93 | Gravel (100%) | None |
| McGuire Creek | 0 | 0 | 15 | 85 | Gravel (100%) | None |
| Cavanough Gulch | 4 | 4 | 54 | 39 | Sm. Cobble (75%) | Gravel (25%) |
| O'Connor Gulch | 0 | 10 | 17 | 72 | Gravel (67%) | Boulder (33%) |
| Bald Hill Creek | 12 | 35 | 34 | 19 | Gravel (75%) | Lg. Cobble (17%) |
| Gulch 8 | 3 | 31 | 29 | 36 | Gravel (33%)<br>Sm. Cobble (33%)<br>Boulder (33%) | None |
| Gulch 11 | 0 | 24 | 45 | 30 | Boulder (75%) | Gravel (25%) |
| Gulch 19 | 5 | 8 | 23 | 64 | Gravel (50%) | Boulder (33%) |
| Patsy Creek | 11 | 24 | 11 | 54 | Gravel (33%)<br>Boulder (33%) | Sm. Cobble (17%)<br>Lg. Cobble (17%) |
| Gulch 23 | 0 | 7 | 20 | 73 | Boulder (100%) | None |
| **Clark Fork Ten Mile River Subwatershed** | | | | | | |
| Mainstem Clark Fork Ten Mile River | 2 | 12 | 31 | 55 | Gravel (38%) | Sm. Cobble (29%)<br>Boulder (29%) |
| Bear Haven Creek | 0 | 1 | 17 | 82 | Gravel (86%) | Sand (5%)<br>Lg. Cobble (5%)<br>Boulder (5%) |
| Little Bear Haven Creek | 0 | 0 | 5 | 95 | Gravel (75%) | Sand (25%) |
| Booth Gulch | 0 | 4 | 24 | 72 | Gravel (75%) | Sm. Cobble (25%) |
| Gulch 27 | 0 | 13 | 19 | 68 | Sm. Cobble (75%) | Boulder (25%) |
| **South Fork Ten Mile River** | | | | | | |
| Mainstem South Fork Ten Mile River | 0 | 0 | 26 | 74 | Gravel (88%) | Sm. Cobble (10%) |
| Smith Creek | 0 | 0 | 16 | 84 | Gravel (99%) | Sm. Cobble (1%) |
| Campbell Creek | 0 | 0 | 13 | 87 | Gravel (98%) | Sand (1%)<br>Sm. Cobble (1%) |
| Churchman Creek | 0 | 0 | 2 | 98 | Gravel (96%) | Sm. Cobble (2%) |
| Redwood Creek | 0 | 0 | 12 | 88 | Gravel (89%) | Sm. Cobble (10%) |

**TABLE 4.16**
**STREAM BANK VEGETATION -- CONIFEROUS, DECIDUOUS, OPEN (as reported by Ambrose et al. 1996)**

| Stream Name | Percent of Stream Banks Covered by Vegetation | | |
|---|---|---|---|
| | **Coniferous** | **Deciduous** | **Open** |
| **Lower Ten Mile River Subwatershed** | | | |
| Mill Creek | 10 | 87 | 3 |
| **North Fork Ten Mile River Subwatershed** | | | |
| Mainstem North Fork Ten Mile River | 15 | 55 | 30 |
| Little North Fork Ten Mile River | 44 | 49 | 7 |
| Blair Gulch | 46 | 54 | 0 |
| Barlow Gulch | 48 | 51 | 1 |
| Buckhorn Gulch | 52 | 41 | 7 |
| McGuire Creek | 47 | 43 | 10 |
| Cavanough Gulch | 23 | 75 | 2 |
| O'Connor Gulch | 23 | 76 | 1 |
| Bald Hill Creek | 37 | 50 | 13 |
| Gulch 8 | 35 | 51 | 14 |
| Gulch 11 | 51 | 30 | 19 |
| Gulch 19 | 49 | 38 | 13 |
| Patsy Creek | 38 | 53 | 9 |
| Gulch 23 | 35 | 55 | 10 |
| **Clark Fork Ten Mile River Subwatershed** | | | |
| Mainstem Clark Fork Ten Mile River | 25 | 51 | 24 |
| Bear Haven Creek | 57 | 34 | 9 |
| Little Bear Haven Creek | 45 | 46 | 9 |
| Booth Gulch | 54 | 37 | 9 |
| Gulch 27 | 19 | 66 | 15 |
| **South Fork Ten Mile River Subwatershed** | | | |
| Mainstem South Fork Ten Mile River | 36 | 41 | 23 |
| Smith Creek | 36 | 47 | 17 |
| Campbell Creek | 31 | 52 | 17 |
| Churchman Creek | 36 | 54 | 10 |
| Redwood Creek | 56 | 28 | 16 |

### 4.3.6 STREAM ALTERATION ACTIVITIES

It is generally purported that the removal of migration barriers by the CDFG in the 1960s through 1980s resulted in the loss of substantial volumes of large woody debris habitat in north coast streams. Quantified evidence of this has been collected by Mendocino Redwood Company for the Noyo River watershed (CWQCB 1999). However, no such evidence exists for the Ten Mile River watershed.

From 1991 to 1992, the Center for Education and Manpower Resources, Inc. (1993a, 1993b, 1993c) conducted stream restoration work in the North Fork, Clark Fork, South Fork, Redwood Creek, and North Fork Redwood Creek in the Ten Mile River watershed. They installed 126 habitat structures (e.g., scour logs and cover logs) -- 36 in the North Fork, 37 in the Clark Fork and 53 in the South Fork. They also removed five barriers from the South Fork Ten Mile River and modified eight barriers in the Redwood Creek drainage. G-P, which funded the Center for Education and Manpower Resources, Inc. in the Redwood Creek drainage, estimated that 6.83 km (4.24 mi) of stream were made accessible to salmonids, as a result of these barrier modifications (Ambrose, et al. 1996).

G-P also conducted a variety of stream restoration and upslope corrections to reduce sediment delivery and improve salmonid habitat (Ambrose et al. 1996, Ambrose and Hines 1997). G-P used a substrate composition target of 20% fines (<0.85 mm) as the basis for identifying locations requiring sediment-related corrective action. The North Fork Ten Mile River subwatershed was targeted for corrective action due to the number of sites in which fines exceeded this target. Enhancements throughout the watershed, included:

- Approximately 117 km (73 miles) of road were rocked from 1993 to 1997
- Waterbars were installed at greater frequency than required. Whole mulching and silt barriers were placed, as appropriate.
- On the Ten Mile River, an old failing bridge just below the confluence of the North Fork and the Clark Fork was replaced with a new railcar bridge.
- Sixty-two new and upgraded culverts installed on existing roads in North Fork Ten Mile River drainage. A number of culverts were upgraded elsewhere in the basin.
- Barriers on O’Connor Gulch, Gulch 2 and Gulch 19 in North Fork Ten Mile River drainage were identified. A culvert on O’Connor Gulch was replaced with bridge. Gulch 2 is currently downcutting as a result of newly installed upgraded culvert. A jump pool was installed in Gulch 19.
- In the North Fork Ten Mile River subwatershed, three dirt stringer bridges were replaced with railcar bridges; in the Little North Fork Ten Mile River, on North Fork Ten Mile River main haul road in the vicinity of Camp 6 ½ Gulch and on the main haul road elsewhere in the North Fork Ten Mile River subwatershed
- Rip-rap was placed at the toes of three stream bank erosion sites in the North Fork Ten Mile River (i.e., at the 10.5 mile, 14.5 mile, and 17.5 mile markers on the main haul road)
- Vegetation was planted along the stream banks of newly constructed bridges and crossings throughout the North Fork Ten Mile River subwatershed
- Enhancements were made in Patsy Creek, including:

    - Restoration of old water bars and ditching and/or installation of new water bars, ditches and rolling dips
    - Five culverts were upgraded with larger pipe and/or downspouts
    - A potential landslide area was de-watered with 200’of 10’ deep trench
    - The drainage of five existing channels were re-routed into four channels which were identified as “original channels”
    - Springs were de-watered by installing culverts and/or waterbars
    - Three stream bank slumps were removed and the associated roadside drainage restored
    - A stream bank site was rip rapped and a small washout and recent slump were rocked
    - A drainage swale was constructed to the east of the bridge over the North Fork Ten Mile River
    - As a result of its habitat typing, G-P concluded that the lower reaches of the South Fork Ten Mile River were substantially aggraded and lacking in habitat complexity. They created 14 scour log sites within a three-mile reach of the South Fork Ten Mile River from Camp 22 to Blind Gulch.
    - G-P also started a conifer release effort in Mill Creek to encourage the growth of suppressed redwoods along the stream for future large woody debris recruitment.
- In the Clark Fork Ten Mile River subwatershed, three dirt stringer bridges were replaced with railcar bridges.

G-P, The Timber Company and/or Campbell Timberland Management, Inc. may have conducted additional instream restoration or upslope corrections since 1997. However, they have not been reported to Regional Water Board staff.

## 4.4 SYNTHESIS

The goal of this section is to identify the factors potentially limiting the success of salmonids in the Ten Mile River watershed. First, the steelhead population data are compared to the sediment data to determine if there is a specific pattern of relationship between the two. Then, the coho salmon presence and absence data are compared to the habitat data to identify those habitat characteristics that may be most critical to coho in the Ten Mile River watershed. Finally, the population and habitat data for each stream is assessed individually to identify the factors that may be limiting the success of salmonids there.

### 4.4.1 STEELHEAD POPULATION VS. PERCENT FINES (<0.85 mm)

The steelhead trout population data and substrate composition data are two of the strongest data sets available for the Ten Mile River watershed. The coho salmon population data allows for an assessment of presence and absence, only; it does not provide unequivocal population numbers for the species. The temperature data set is presumably robust, but, the data were not presented to Regional Water Board staff in a manner (e.g., electronic) supportive of more detailed analysis. A comparison of steelhead trout population data to substrate composition data was conducted. It showed no consistent or statistically significant relationship, indicating that factors in addition to or instead of variation in substrate composition affect the population of steelhead trout in individual tributaries from year to year.

### 4.4.2 HABITAT CHARACTERISTICS CRITICAL TO COHO SALMON

As described in Section 4.2, coho salmon are currently present in the following streams:

- Little North Fork Ten Mile River
- Clark Fork Ten Mile River
- Bear Haven Creek
- Smith Creek
- Campbell Creek
- South Fork Ten Mile River
- Churchman Creek

In reviewing the stream channel characteristics of each of the surveyed stream in the Ten Mile River watershed, it is apparent that the above streams constitute all but one of the streams in the basin with C-type stream channel characteristics. Little Bear Haven Creek is the only other stream in the basin with C-type stream channel. (Clark Fork Ten Mile River and Churchman Creek do not have any C-type stream channel; but, coho salmon are present there, nonetheless). This suggests that C-type channel characteristics allow for the creation of habitat most suitable to coho salmon in the Ten Mile River watershed and are in fact preferred by the species. As such, the streams with C-type channel — or channel types that can be modified to increase the amount of C-type channel — may be potentially restorable coho streams.

The streams where coho salmon are present have other habitat parameters in common. For example, if one calculates the mean value associated with a variety of habitat parameters, then those that show a significant difference for coho streams versus non-coho streams can be viewed as potentially critical habitat parameters for the species. These habitat parameters can then be used to predict whether coho salmon are present in streams where population data are unavailable. The habitat parameters that appear to be critical include: percent of pools by area, percent of scour pools by length and area and the percent of large woody debris-formed habitat by length and area. Table 4.17 identifies the values, derived from the ranges of habitat values seen in the data set, that appear to indicate coho presence or absence. Applying the values for the percent of habitat in pools by length correctly predicts coho presence 80% of the time and coho absence 67% of the time. Applying the values for the percent of habitat in scour pools by length and area correctly predicts coho presence 80% of the time and coho absence 100% of the time. Applying the values for the percent of habitat formed by large woody debris by length and area correctly predicts coho presence 80% of the time and coho absence 100% of the time. As such, the percent of habitat in any given stream that is composed of scour pools and habitat formed by large woody debris appear to be the best indicators of coho presence and absence.

**TABLE 4.17**
**PERCENT VALUES FOR HABITAT CHARACTERISTICS THAT MAY BE GOOD INDICATORS OF COHO PRESENCE AND ABSENCE**

| Habitat Characteristics | Coho Streams | Non-Coho Streams |
|---|---|---|
| % of habitat in pools (length) | ≥21 | ≤19 |
| % of habitat in scour pools (length) | ≥17 | ≤14 |
| % of habitat in scour pools (area) | ≥23 | ≤19 |
| % of habitat formed by large woody debris (length) | ≥11 | ≤5 |
| % of habitat formed by large woody debris (area) | ≥16 | ≤8 |

Hines and Ambrose (1998) have conducted a similar analysis, comparing combinations of habitat characteristics in search of a good predictor of coho presence and absence. They found that stream temperature is one of the leading predictive characteristics. Indeed, they determined that a maximum weekly average temperature of 16.8 °C is a biologically-relevant cut-off between streams that appear to support coho and those that do not.

Table 4.18 lists the value for each of these "critical" habitat characteristics (e.g., % C-type channel, % scour pools, % LWD-formed habitat, and % summer MWAT exceeding 16.8 °C) in measured Ten Mile River watershed streams. Values that meet the criteria discussed above are highlighted. It is important to note that channel type, scour pool, large woody debris-formed habitat, and temperature data assist in identifying those locations where coho are or are likely to be present. But, the criteria identified above are not adequate to determine where habitat characteristics are sufficient to support sustainable populations of coho salmon.

The data suggest that the main forks of the Ten Mile River watershed have a sufficient percentage of their habitat in scour pools; they have an insufficient percentage of their habitat formed by large woody debris; and, the instream temperatures are generally too warm for salmonids. Coho were observed spawning in the lower North Fork Ten Mile River in 1990 to 1991; but, they were not observed any other time. Coho were found rearing at Camp 3 in the North Fork Ten Mile River during 1996 (e.g., 0.05 fish/$m^2$). Spawning surveys in the Clark Fork and South Fork Ten Mile Rivers indicate wide spread coho spawning throughout these forks. Coho were found rearing in the Clark Fork only at Reynold's Gulch during 1996 (e.g., 0.02 fish/$m^2$). By comparison, coho were found rearing in the South Fork at three locations during 1996 [e.g., Brower's Gulch (0.004 fish/$m^2$), Buck Mathew's Gulch (0.02 fish/$m^2$), and Big Cat Crossing (0.01 fish/$m^2$)]. The South Fork Ten Mile River has only slightly more large woody debris-formed habitat than the other two forks and its instream summer temperatures are comparable to those of the Clark Fork Ten Mile River. But, unlike the other two mainstem channel, the South Fork Ten Mile River has C-type channel.

The Little North Fork Ten Mile River, Bear Haven Creek, and Smith Creek have C-type channel; enough scour pools, large woody debris-formed habitat; and cool enough instream temperatures for coho salmon to be present. Coho salmon have been found spawning in each of these tributaries. Indeed, the Little North Fork Ten Mile River had the largest number of salmon redds in 1995 to 1996 while Bear Haven Creek and Smith Creek had the second and third largest numbers, respectively. Coho were found rearing in the Little North Fork Ten Mile River and Bear Haven Creek in two out of three years and in Smith Creek three out of three years.

**TABLE 4.18**
**SELECTED HABITAT CHARACTERISTICS IN TEN MILE RIVER WATERSHED STREAMS**

| STREAM | % C-TYPE CHANNEL (LENGTH) | % SCOUR POOLS (LENGTH) | % SCOUR POOLS (AREA) | % LWD-FORMED HABITAT (LENGTH) | % LWD-FORMED HABITAT (AREA) | % OF SUMMER MWAT >16.8 °C |
|---|---|---|---|---|---|---|
| Mill Creek | 0 | 8 | 10 | 4 | 3 | 0 |
| North Fork Ten Mile River | 0 | 28 | 39 | 8 | 9 | 65 |
| Little North Fork Ten Mile River | 68 | 27 | 32 | 18 | 19 | 0 |
| Blair Gulch | 0 | 5 | 12 | 1 | 2 | NS |
| Barlow Gulch | 0 | 3 | 5 | 1 | 2 | NS |
| Buckhorn Creek | 0 | 3 | 6 | 0 | 0 | 0 |
| McGuire Creek | 0 | 6 | 19 | 2 | 3 | NS |
| Cavanough Gulch | 0 | 4 | 7 | 1 | 2 | NS |
| O’Connor Gulch | 0 | 8 | 7 | 0 | 0 | NS |
| Bald Hill Creek | 0 | 14 | 19 | 5 | 7 | 5 |
| Gulch 8 | 0 | 5 | 1 | 1 | 1 | NS |
| Gulch 11 | 0 | 6 | 7 | 0 | 0 | NS |
| Gulch 19 | 0 | 9 | 15 | 0 | 0 | NS |
| Patsy Creek | 0 | 7 | 9 | 2 | 3 | NS |
| Gulch 23 | 0 | 3 | 9 | 0 | 0 | NS |
| Clark Fork Ten Mile River | 0 | 26 | 26 | 7 | 9 | 35 |
| Bear Haven Creek | 83 | 21 | 32 | 12 | 19 | 0 |
| Little Bear Haven Creek | 51 | 14 | 12 | 2 | 2 | 0 |
| Booth Gulch | 0 | 5 | 10 | 0 | 0 | 0 |
| Gulch 27 | 0 | 8 | 9 | 3 | 4 | NS |
| South Fork Ten Mile River | 17 | 22 | 23 | 9 | 10 | 35 |
| Smith Creek | 79 | 17 | 23 | 11 | 16 | 0 |
| Campbell Creek | 39 | 19 | 25 | 12 | 16 | 25 |
| Churchman Creek | 0 | 6 | 12 | 4 | 9 | 0 |
| Redwood Creek | 0 | 11 | 17 | 5 | 8 | 20 |

Shaded figures are those for which habitat indicators are equal or greater in value than those in coho streams.

Campbell Creek is the only tributary surveyed that has C-type channel, appears to contain enough scour pools and large woody debris-formed habitat, but, whose instream temperatures are slightly warmer than necessary. The number of coho salmon redds in Campbell Creek is lower than the basin wide average (for the year measured). But, rearing fish were observed there in three out of the three years of sampling. These data suggest that if habitat characteristics are sufficient, instream temperatures can exceed an MWAT of 16.8°C up to 25% of the time and still allow for coho to be present in the stream.

Several tributaries, including Mill Creek, Buckhorn Creek, Little Bear Haven Creek, Booth Gulch, and Churchman Creek have cool summer instream temperatures, but there are not enough scour pools or large woody debris-formed habitat for coho to be present.

Little Bear Haven Creek also has C-type channel. Of these streams, coho are actually present in Churchman Creek, despite pool habitat characteristics. Coho were also observed once in Buckhorn Creek since 1995. But, they are not present in any of the other listed streams, including Little Bear Haven Creek. The data for Churchman Creek are difficult to interpret.

Coho are not predicted to be present in any of the other tributaries due to a lack of C-type channel, insufficient length and area of habitat in scour pools and large woody debris-formed habitat units, as well as elevated summer temperatures. Coho have been observed once in Bald Hills Creek and Redwood Creek since 1995. But, because of their infrequent visits, coho are nonetheless considered to be absent from these tributaries.

### 4.4.3 POTENTIAL LIMITING FACTORS

Limiting factors are those factors that are potentially limiting the success of salmonids within a given stream or watershed. They include such things as fine sediment in gravel limiting the growth or survival-to-emergence of salmonid embryos or elevated summer temperatures limiting the growth or survival of juveniles. For the purposes of this report, potentially limiting factors are identified based on the following data:

- Spawning (dominant substrate, embeddedness)
- Survival to emergence (% fine sediment, embeddedness)
- Summer rearing (temperature, % scour pools, % large woody debris-formed habitat, % pools ≥3 feet, % dry units, % canopy)
- Overwintering (% large woody debris-formed habitat, % backwater pools)
- Channel stability (% scour pools, % large woody debris-formed habitat)

None of the available data shed light on the condition of migration corridors from the ocean to potential spawning grounds. Potentially there are barriers to migration that should be considered a limitation to salmonid success. Their locations, however, are unknown to staff at the Regional Water Board.

#### 4.4.2.1 Mill Creek

Mill Creek is a tributary to the Ten Mile River. There has been evidence of spawning in Mill Creek, as well as juvenile steelhead found. Coho were observed rearing in the stream in 1969, as were steelhead. Since that time only steelhead have been found. Spawners were observed in 1989 to 1990, but the species were not identified.

Mill Creek has both F-type (64%) and B-type (36%) channel characteristics with gravel (100%) dominated low gradient riffles and a pool frequency of 10%. The substrate contains an average of 20.7% fines (<0.85 mm) and is highly embedded (e.g., 100% of cobble is >50% embedded). Hines (2000) found no trend from 1995 to 1999 in the percent fines (<0.85 mm) data. The scour pools and LWD-formed habitat make up only 8% and 4% of the habitat by length, respectively. There are no backwater pools. None of the pools are greater than three feet deep. Seven percent of the habitat is dry. Weekly average stream temperatures never exceed an MWAT of 16.8 °C and there is a 97% shade canopy over the stream.

Mill Creek is potentially limited in its ability to support coho salmon as a result of its deep entrenchment, high stream bank erosion rates (e.g., F-type channel), elevated fine sediment, high embeddedness, poor pool frequency, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, and poor pool depths. Excellent stream temperatures and shade canopy may provide refuge from elevated mainstem temperatures.

#### 4.4.2.2 North Fork Ten Mile River

The North Fork Ten Mile River is a tributary to the Ten Mile River. There is evidence of coho spawning in the lower reaches of the North Fork Ten Mile River. Juvenile coho have been observed once in the lower reaches, as well. Steelhead trout are regularly seen throughout the North Fork Ten Mile River.

The North Fork Ten Mile River is predominantly a B-type channel (100%) with gravel (53%) and small cobble (19%) dominated low gradient riffles and a pool frequency of 47%. The substrate contains an average of 19.1% fines (<0.85 mm) and is highly embedded (e.g., 72% of cobble is >75% embedded). Hines (2000) found no trend in the percent fines (<0.85 mm) data high in the subwatershed; but, he determined that sediment conditions have been fairly stable from 1995 to 1999 at points midway and low in the subwatershed. The scour pools and LWD-formed habitat make up 28% and 8% of the habitat by length, respectively. One percent of the pools are backwater pools. Fifty-three percent of the pools are greater than three feet deep. None of the stream channel is dry in the summer. Weekly average stream temperatures exceed an MWAT of 16.8 °C 65% of the summer and there is a 70% shade canopy over the stream.

North Fork Ten Mile River is potentially limited in its ability to support coho salmon as a result of its elevated fine sediment, high embeddedness, poor LWD-formed habitat frequency, poor backwater pool frequency, elevated summer temperatures, and poor shade canopy. Good scour pool frequency and pool depths could potentially provide summer rearing habitat if stream temperatures were lower. Coho have been found up to Camp 3 in the North Fork Ten Mile River (just above the confluence with Clark Fork Ten Mile River and below Little North Fork Ten Mile River). Prime habitat indicators suggest that LWD-formed habitat and stream temperatures are critical limiting factors.

#### 4.4.2.3 Little North Fork Ten Mile River

The Little North Fork Ten Mile River is a tributary to the North Fork Ten Mile River. There is evidence of both coho and steelhead spawning in the Little North Fork Ten Mile River. In addition, there is evidence of juvenile rearing of both species going back to 1961.

The Little North Fork Ten Mile River has C-type (68%), B-type (19%), and F-type(13%) channel characteristics with gravel (100%) dominated low gradient riffles and a pool frequency of 44%. The substrate contains an average of 16.4% fines (<0.85 mm) and is highly embedded (e.g., 88% of cobble is >75% embedded). Hines (2000) found a decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 27% and 18% of the habitat by length, respectively. Four percent of the pools are backwater pools. Thirteen percent of the pools are greater than three feet deep. None of the stream channel is dry in the summer. Weekly average stream temperatures never exceed an MWAT of 16.8°C and there is a 93% shade canopy covering the stream.

Little North Fork Ten Mile River is potentially limited in its ability to support coho salmon as a result of elevated fines (<0.85 mm), high embeddedness, and poor pool depth. The Little North Fork channel form with its low gradient, meandering point-bar, riffle/pool complex and broad, well-defined floodplain may provide some the greatest possibility for coho salmon habitat restoration in the basin. Its pool frequency, scour pool frequency, LWD-formed habitat frequency, backwater pool frequency, and stream temperatures explain why the Little North Fork Ten Mile River currently supports the greatest density of coho spawners in the basin and an above-average density of summer juveniles.

#### 4.4.2.4 Blair Gulch, Barlow Gulch, and Buckhorn Gulch

Blair Gulch, Barlow Gulch and Buckhorn Gulch are tributaries to the Little North Fork Ten Mile River. There are no data regarding salmonid presence for Blair and Barlow Gulches. Data collected from Buckhorn Gulch shows little evidence of steelhead spawning and no evidence of coho spawning. Juvenile steelhead are regularly found in Buckhorn Gulch while coho juveniles have been found only once.

All are F-type channel with gravel (100%) dominated low gradient riffles and pool frequencies ranging from 11 to 19%. There are no substrate composition measurements in Blair or Barlow Gulches. But, substrate in Buckhorn Gulch contains an average of 20.6% fines (<0.85 mm). Hines (2000) could not confirm an apparent decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. Cobble in all three streams are completely embedded (e.g., 93 to 100% of cobble >75% embedded). The scour pools and LWD-formed habitat make up between 3 to 5% and 0 to 1% of the habitat length, respectively. Zero to one percent of the pools are backwater pools. Zero to three percent of the pools are greater than three feet deep. Blair Gulch is 7% dry, while Barlow Gulch and Buckhorn Gulch are 38% and 15% dry, respectively. There are no stream temperature data for Blair Gulch or Barlow Gulch, but Buckhorn Creek never exceeds an MWAT of 16.8 °C. Shade canopy ranges from 93 to 100%.

Blair Gulch, Barlow Gulch, and Buckhorn Creek are potentially limited in their ability to support coho salmon as a result of their deep entrenchment, stream bank erosion rate (e.g., F-type channel), poor pool frequency, elevated fine sediment, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, and poor pool depth. Without substrate composition measurements and/or hillslope erosion rate estimates for Blair and Barlow Gulches, it is difficult to assess the degree to which sediment conditions in those streams impact the Little North Fork Ten Mile River. With little LWD for sediment metering and high cobble embeddedness, there may be significant sediment delivery downstream. Similarly, the elevated fine sediment in Buckhorn Gulch is likely impacting conditions downstream. It is unlikely that Blair Gulch, Barlow Gulch or Buckhorn Gulch are impacting the stream temperatures of Little North Fork Ten Mile River due to their excellent shade canopy.

#### 4.4.2.5 McGuire Creek

McGuire Creek is a tributary to the Little North Fork Ten Mile River. There are not data regarding the presence or absence of salmonids in McGuire Creek. Prime habitat indicators suggest the absence of coho from McGuire Creek.

McGuire Creek has both B-type (84%) and D-type (16%) channel characteristics with gravel (100%) dominated low gradient riffles and a pool frequency of 16%. There are no substrate composition measurements, but cobble is highly embedded (e.g., the majority is greater than 75% embedded). The scour pools and LWD-formed habitat make up 6% and 2% of the habitat length, respectively. Two percent of the pools are backwater pools. Five percent of the pools are greater than three feet deep. Thirteen percent of the stream channel is dry in the summer. There are no summer temperature measurements, but there is a 90% shade canopy covering the stream.

McGuire Creek is potentially limited in its ability to support coho salmon as a result of its poor pool frequency, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, poor pool depth and dry summer reaches. Without sediment composition data it is difficult to determine the degree to which sediment delivery from McGuire Creek may be impacting the Little North Fork Ten Mile River. With little LWD, moderate gradients, and high embeddedness, there may be a significant delivery of fines downstream. Good shade canopy suggests that stream temperatures are likely good. A B-type channel has a moderate gradient and is predominated by rapids and scour pools. The poor scour pool frequency and dry area suggest that the stream may be aggraded. Upslope assessment may identify excessive soil movement and delivery.

#### 4.4.2.6 Cavanough Gulch

Cavanough Gulch is a tributary to the North Fork Ten Mile River. Cavanough Gulch is a B-type channel (100%) with small cobble dominated low gradient riffles, and a pool frequency of 7%. There are no substrate composition measurements for Cavanough Gulch, but cobble is substantially embedded (e.g., majority of cobble greater than 50% embedded). The scour pools and LWD-formed habitat make up 4% and 1% of the habitat by length, respectively. Ten percent of the pools are backwater pools. Three percent of the pools are greater than three feet deep. Fifty-four percent of the stream channel is dry in the summer. There are no stream temperature measurements, but there is a 98% shade canopy over the stream.

Cavanough Gulch is potentially limited in its ability to support coho salmon as a result of it’s large substrate size, poor pool frequency, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor pool depth, and large dry area. Though there are no substrate composition measurements, the lack of LWD for sediment metering and the high embeddedness suggest that fines may be high. Though there are no stream temperature measurements, the excellent shade canopy suggests that temperatures are probably fine. A B-type channel has a moderate gradient and is dominated by rapids and scour pools. The poor scour pool frequency and large dry area suggest that the stream is substantially aggraded. Upslope assessment may identify excessive soil movement and delivery. There is no evidence of coho in Cavanough Gulch and the prime indicators suggest they are not present.

#### 4.4.2.7 O'Connor Gulch

O'Connor Gulch is a tributary to the North Fork Ten Mile River. O'Connor Gulch is B-type channel (100%) with gravel-dominated low gradient riffles and a pool frequency of 12%. There are no substrate composition measurements for O'Connor Gulch; but, cobble is substantially embedded (e.g., majority of cobble is >75% embedded). The scour pools and LWD-formed habitat make up 8% and 0% of the habitat by length, respectively. None of the pools are backwater pools. None of the pools are greater than three feet deep. One percent of the stream channel is dry in the summer. There are no stream temperature measurements, but there is a 99% shade canopy covering the stream.

O'Connor Gulch is potentially limited in its ability to support coho salmon as a result of poor pool frequency, high embeddedness, poor scour pools frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, and poor pool depth. Though there are no substrate composition measurements, the lack of LWD for sediment metering and high embeddedness suggest that there may be elevated fine sediment. Though there are no stream temperature measurements, the excellent shade canopy suggests that stream temperatures are likely acceptable. A B-type channel has a moderate gradient and is predominated by rapids and scour pools. The poor scour pool frequency and pool depth suggest that the stream may be aggraded. Upslope assessment may identify excessive soil movement and delivery. There is no evidence of coho in O'Connor Gulch and prime indicators suggest they are not present.

#### 4.4.2.8 Bald Hills Creek

Bald Hills Creek is a tributary to the North Fork Ten Mile River. About half of Bald Hills Creek is a B-type channel while the remaining half is an F-type channel. It has gravel-dominated low gradient riffles and a pool frequency of 26%. The substrate contains an average of 13.5% fines (<0.85 mm) but is moderately to highly embedded (e.g., half the cobble is <50% embedded while the remaining is > 50% embedded). Hines (2000) found a decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 14% and 5% of the habitat length, respectively. One percent of the pools are backwater pools. Eleven percent of the pools are greater than three feet deep. Five percent of the stream channel is dry in the summer. Weekly average temperatures exceed an MWAT of 16.8 °C only 5% of the summer and there is 87% shade canopy covering the stream.

Bald Hills Creek is potentially limited in its ability to support coho salmon as a result of its deep entrenchment and high stream bank erosion rates in the F-type channel reaches, moderate pool frequency, moderate embeddedness, moderate scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, and moderate pool depth. Its substrate composition and stream temperature are excellent, however. Coho were seen rearing in Bald Hills Creek one summer. One pair may have been observed spawning one year, as well; but, the species was not identified. Prime habitat indicators suggest that coho are not currently present. However, improvements to LWD loading could potentially improve scour pool formation and pool depth to a degree acceptable to coho.

#### 4.4.2.9 Gulch 8, Gulch 11, and Gulch 23

Gulch 8, Gulch 11, and Gulch 23 are tributaries to the North Fork Ten Mile River. Gulch 8, Gulch 11 and Gulch 23 are B-type channels (100%). Gulch 8 has an equal mixture of gravel, cobble and boulder composing its low gradient riffles while Gulch 11 and Gulch 23 are dominated by boulder. Gulch 8 has a pool frequency of 23% while Gulch 11 and Gulch 23 have a pool frequency of 8% and 9%, respectively. There are no substrate composition measurements for these Gulches, but cobble are highly embedded (e.g., majority of cobble are >50% embedded). The scour pools and LWD-formed habitat make up between 3 to 6% and 0 to 1% of the habitat length, respectively. Zero to two percent of the pools are backwater pools. Zero to ten percent of the pools are greater than three feet deep. Between 0 to 2% of Gulch 8 and Gulch 11 are dry during the summer which 30% of Gulch 23 is dry. There are no stream temperature measurements for these Gulches. There is a 90% shade canopy over Gulch 23. But, Gulch 8 and Gulch 11 have 86% and 81% shade canopy, respectively.

Gulch 8, Gulch 11 and Gulch 23 are potentially limited in their ability to support coho salmon as a result of their large substrate size, high embeddedness, pool scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, and poor pool depths. In addition, a comparison of stream temperature and shade canopy data basin wide indicates that a shade canopy greater than 90% may be necessary to protect stream temperatures. As such, Gulch 8 and Gulch 11 may be limited by moderate stream temperatures. The poor pool frequencies in Gulch 11 and Gulch 23 as well as the extensive dry reaches in Gulch 23 may also be limiting. A B-type channel has a moderate gradient and is predominated by rapids and scour pools. The poor scour pool frequency, poor pool depths and large dry area (in Gulch 23) suggest that these streams may be aggraded. Upslope assessment may identify excessive soil movement and delivery. There is no data indicating the presence or absence of coho in these streams. Prime habitat indicators, however, suggest that they are absent.

#### 4.4.2.10 Gulch 19 and Patsy Creek

Gulch 19 and Patsy Creek are tributaries to the North Fork Ten Mile River. Gulch 19 and Patsy Creek are F-type channels. Gulch 19 has gravel-dominated low gradient riffles (50%) though boulder are subdominant (33%). The low gradient riffles in Patsy Creek are evenly composed of gravel, boulder and cobble. Pool frequencies range from 18 to 19%. There are no substrate composition measurements for Gulch 19. But, the substrate of Patsy Creek contains an average of 23.7% fines (<0.85 mm) -- the highest measured in the basin. Hines (2000) found a decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. Cobble is highly embedded (e.g., majority of cobble are greater than 50% embedded). The scour pools and LWD-formed habitat make up between 7 to 9% and 0 to 2%, respectively. Eight percent of the pools Gulch 19 are backwater pools while none of the pools in Patsy Creek are. Between 7 to 8% of the pools are greater than three feet deep. Between 1 to 2% of the stream channels are dry in the summer. There are no stream temperature measurements in either stream, but shade canopy is 87% in Gulch 19 and 92% in Patsy Creek.

Gulch 19 and Patsy Creek are potentially limited in their ability to support coho salmon as a result of their deep entrenchment, high stream bank erosion rate, moderate availability of gravel, moderate pool frequency, elevated fine sediment, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, and poor pool depth. In addition, Patsy Creek may be limited by poor backwater pool frequency and moderate stream temperatures. The potential value of these streams for coho appears minimal. There is no evidence of coho spawning or rearing in these streams. Indeed, prime habitat indicators suggest that they are absent. Their potential contribution of sediment to the North Fork Ten Mile River, however, appears substantial.

#### 4.4.2.11 Clark Fork Ten Mile River

The Clark Fork Ten Mile River is a tributary to the Ten Mile River. The Clark Fork Ten Mile River is predominantly a B-type channel (91%) with equal proportions of gravel, cobble and boulder in low gradient riffles, and a pool frequency of 44%. The substrate contains an average of 18.6% fines (<0.85 mm) and is highly embedded (e.g., majority of cobble is greater than 75% embedded). Hines (2000) found a stable trend in percent fines (<0.85 mm) from 1995 to 1999 at a point low in the subwatershed. He found no trend at a point midway up the subwatershed and was unable to confirm an apparent increasing trend at a point high in the subwatershed. The scour pools and LWD-formed habitat make up 26% and 7% of the habitat length, respectively. One percent of the pools are backwater pools. Fifty-two percent of the pools are greater than three feet deep. None of the stream channel is dry in the summer. Weekly average stream temperatures exceed an MWAT of 16.8 °C 35% of the summer and there is 76% shade canopy covering the stream.

The Clark Fork Ten Mile River is potentially limited in its ability to support coho salmon as a result of its moderate availability of gravel, moderately elevated fine sediment, high embeddedness, poor LWD-formed habitat frequency, poor backwater pool frequency, and elevated summer stream temperatures. Good scour pool frequency and pool depths could potentially provide summer rearing habitat if stream temperatures were lower. Coho salmon have been observed both spawning and rearing in the Clark Fork Ten Mile River. Prime habitat indicators suggest that LWD-formed habitat and stream temperatures are critical limiting factors.

#### 4.4.2.12 Bear Haven Creek

Bear Haven Creek is a tributary to the Clark Fork of the Ten Mile River. Bear Haven Creek is predominantly a C-type channel (83%) with gravel dominated low gradient riffles and a pool frequency of 33%. The substrate contains an average of 16.8% fines (<0.85 mm) and is highly embedded (e.g., majority of cobble is greater than 75% embedded). Hines (2000) was unable to confirm an apparent increasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up

21% and 12% of the habitat length, respectively. One percent of the pools are backwater pools. Eleven percent of the pools are greater than three feet deep. Six percent of the stream channel is dry in the summer. Weekly average stream temperatures never exceed an MWAT of 16.8 °C during the summer and there is a shade canopy of 91%.

Bear Haven Creek is potentially limited in its ability to support coho salmon as a result of its moderately elevated fine sediment, high embeddedness, poor backwater pool frequency, moderate pool depth, and moderate length of dry stream. Coho have been observed both spawning and rearing in Bear Haven Creek. Indeed, the prime habitat indicators suggest their presence in the stream.

#### 4.4.2.13 Little Bear Haven Creek

Little Bear Haven Creek is a tributary to the Clark Fork Ten Mile River. There is evidence of steelhead spawning in Little Bear haven Creek, but not that of coho salmon. Juvenile steelhead are also found throughout the stream, while coho salmon are not. Habitat indicators suggest that coho are absent from the stream.

About half of Little Bear Haven Creek is a C-type channel while the remaining is a B-type channel. Little Bear haven Creek is predominated by gravel in its low gradient riffles (75%) with sand making up the remaining proportion. It has a pool frequency of 33%. The substrate contains 16.4% fines (<0.85 mm) on average and is entirely embedded (e.g., 95% of cobble is greater than 75% embedded). Hines (2000) found a decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 14% and 2% of the habitat length, respectively. Five percent of the pools are backwater pools. Ten percent of the pools are greater than three feet deep. None of the stream channel is dry in the summer. Weekly average stream temperatures never exceed an MWAT of 16.8 °C in the summer and there is 91% shade canopy over the stream.

Little Bear Haven Creek is potentially limited in its ability to support coho salmon as a result of its moderate fines sediment levels, high embeddedness, moderate scour pool frequency, poor LWD-formed habitat frequency, and poor pool depths. The availability of C-type channel, the pool frequency, backwater pool frequency, and lack of dry reaches, indicates that Little Bear Haven Creek has the potential to support coho were fine sediment reduced and large woody debris volumes increased.

#### 4.4.2.14 Booth Gulch

Booth Gulch is a tributary to the Clark Fork Ten Mile River. There is little evidence of coho spawning in Booth Gulch though juvenile coho have never been reported. Juvenile steelhead, on the other hand, have been seen in Booth Gulch regularly. Habitat indicators suggest that coho salmon are absent from Booth Gulch.

Booth Gulch is predominantly and F-type channel (82%) through a small portion is classified as B-type channel. Gravel (75%) and cobble (25%) are found in the low gradient riffles and the pool frequency is 13%. The substrate contains 23.0% fines (<0.85 mm) on average and is highly embedded (e.g., 72% of cobble are greater than

75% embedded). Hines (2000) was unable to confirm an apparent increasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 5% and 0% of the habitat length, respectively. One percent of the pools are backwater pools. Thirteen percent of the pools are greater than three feet in depth. Sixteen percent of the stream channel is dry in the summer. Weekly average stream temperatures never exceed an MWAT of 16.8 °C in the summer and there is 91% shade canopy over the stream.

Booth Gulch is potentially limited in its ability to support coho salmon as a result of its high stream bank erosion rates, poor pool frequency, elevated fine sediment, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, poor pool depth, and dry stream reaches. The availability of cool water temperatures and good shade canopy may offer cold water refuge from elevated stream temperatures in the Clark Fork Ten Mile River.

#### 4.4.2.15 Gulch 27

Gulch 27 is a tributary to the Clark Fork Ten Mile River. There are no data regarding the presence or absence of coho in Gulch 27. Habitat indicators, however, suggest that coho are absent.

Gulch 27 is predominantly a B-type channel (75%) but contains F-type channel (24%) and A-type channel (1%), as well. Gulch 27 is dominated by small cobble (75%) and boulder (25%) in its low gradient riffles and has a pool frequency of 22%. The proportion of fine sediment in Gulch 27 has not been measured. But, embeddedness is high (e.g., 68% of cobble are greater than 75% embedded). The scour pools and LWD-formed habitat make up 8% and 3% of the habitat length, respectively. None of the pools are backwater pools. Twenty-four percent of the pools are greater than three feet deep. None of the stream channel is dry in the summer. Stream temperatures have not been measured in Gulch 27, but there is 85% shade canopy covering the stream.

Gulch 27 is potentially limited in its ability to support coho salmon as a result of its moderate stream bank erosion rate, large substrate size, poor pool frequency, high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, moderate pool depth, and moderate shade canopy. The value Gulch 27 as coho stream appears minimal.

#### 4.4.2.16 South Fork Ten Mile River

The South Fork Ten Mile River is a tributary to the Ten Mile River. There is evidence of both coho and steelhead spawning in the South Fork Ten Mile River. In addition, there is evidence of both species at that location going back to 1961. The South Fork Ten Mile River is predominantly a B-type channel (82%) with some C-type channel (17%) and F-type channel (1%) also represented. Its low gradient riffles are dominated by gravel (88%) and small cobble (10%) and its pool frequency is 31%. The substrate contains 15.5% fines (<0.85 mm) on average. The range, however, is from 9.2% to 28.2%. Hines (2000) found a decreasing trend in percent fines (<0.85 mm) from 1995 to 1999 at a point midway up the subwatershed. He found no trend at a point just immediately upstream.

Nor did Hines find a trend at a point in the upper subwatershed. Hines (2000) was unable to confirm an apparent increasing trend in percent fines (<0.85 mm) at a point high in the subwatershed or an apparent decreasing trend at a point in the lower subwatershed. Cobble are highly embedded (e.g., 74% of cobble are greater than 75% embedded). The scour pools and LWD-formed habitat make up 22% and 9% of the habitat length, respectively. None of the pools are backwater pools. Thirty-seven percent of the pools are greater than three feet deep. One percent of the stream channel is dry in the summer. Weekly average temperatures exceed a MWAT of 16.8 °C an average of 35% of the summer and there is shade canopy of 77%.

The South Fork Ten Mile River is potentially limited in its ability to support coho salmon as a result of its moderate level of fine sediment, high embeddedness, poor LWD-formed habitat frequency, poor backwater pool frequency, elevated stream temperatures, and poor shade canopy. The availability of C-type channel, gravel substrate, good scour pool frequency, moderately good pool depths, and absence of significant dry reaches suggest that the stream offer significant potential benefits to coho salmon.

#### **4.4.2.17 Smith Creek and Campbell Creek**

Smith and Campbell Creeks are tributaries to the South Fork Ten Mile River. There is evidence of both coho and steelhead spawning in the stream. In addition, there is evidence of juveniles of both species rearing in the both streams. The evidence for Smith Creek goes back to 1961.

Smith and Campbell Creeks have both B-type and C-type channel reaches, through in different proportion: Smith Creek ha 21% B-type channel and 79% C-type channel, while Campbell Creek has 61% B-type channel and 39% C-type channel. The low gradient riffles of Smith and Campbell Creeks are dominated by gravel (99% and 98%, respectively). Their pool frequencies are 21% and 25%, respectively. The substrate contains 17.7% and 21.8% fines (<0.85 mm), respectively and is entirely embedded (e.g., 84% and 87% of the cobble, respectively, is greater than 75% embedded). Hines (2000) found a stable trend in percent fines (<0.85 mm) from 1995 to 1999 in Campbell Creek, but an increasing trend in Smith Creek. The scour pools make up 17% and 19% of the habitat length, respectively. The LWD-formed habitat makes up 11% and 12% of the habitat length, respectively. None of the pools in either stream are backwater pools. Seven percent and two percent of the pools in Smith Creek and Campbell Creek are greater than three feet deep, respectively. Five percent and three percent of the stream channel is dry in the summer, respectively. Weekly average stream temperatures in Smith Creek never exceed an MWAT of 16.8 °C while they exceed the MWAT in Campbell Creek 25% of the time. The shade canopy in both creeks is 83%.

Smith and Campbell Creeks are potentially limited in their ability to support coho salmon as a result of their poor pool frequency, moderately to highly elevated fine sediment, high embeddedness, poor backwater pool frequencies, poor pool depths, moderate dry reaches, and moderate shade canopy. Campbell Creek may be further limited by its moderate summer stream temperatures. Coho are present in these streams which may be due to the availability of C-type channel, scour pools, and LWD-formed habitat. In addition, there are cool temperatures in Smith Creek. Habitat conditions could potentially be improved by reducing fine sediment loading and improving the sediment metering and scouring functions of the stream channels with an increase in LWD volume.

### 4.4.2.18 Churchman Creek

Churchman Creek is a tributary to the South Fork Ten Mile River. There is evidence of both coho salmon and steelhead trout spawning and rearing in this stream.

Churchman Creek is a B-type channel (100%) with gravel-dominated low gradient riffles (96%) and a pool frequency of 8%. The substrate contains 15.5% fines (<0.85 mm), on average, and its entirely embedded (e.g., 98% of the cobble is greater than 75% embedded). Hines (2000) could not confirm an apparent decreasing trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 6% and 4% of the habitat length, respectively. Two percent of the pools are backwater pools. Two percent of the pools are greater than three feet deep. Twenty percent of the stream channel is dry in the summer. Weekly average temperatures never exceed an MWAT of 16.8 °C and there is 90% shade canopy over the stream.

Churchman Creek is potentially limited in its ability to support coho salmon as a result of its poor pool frequency, moderate level of fine sediment, high embeddedness, poor scour pools frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, poor pool depths, and large area of dry stream channel in the summer. Indeed, it is unclear why coho salmon are found in this stream. What coho are able to spawn here may stay in Churchman Creek simply because of the stream temperatures. Coho may also be populating Churchman Creek as an alternative to Smith or Campbell Creek when those two stream are fully seeded. Improving sediment metering and scouring ability of the stream would potentially improve habitat conditions for salmonids.

### 4.4.2.19 Redwood Creek

Redwood Creek is a tributary to the South Fork Ten Mile River. There is evidence of spawning in Redwood Creek, but the species is unknown. There is no evidence of coho rearing, but juvenile steelhead are regularly seen in Redwood Creek.

Redwood Creek is a B-type channel with gravel (89%) and small cobble (10%) dominated low gradient riffles and a pool frequency of 19%. The substrate contains 18.1% fines (<0.85 mm) on average and is entirely embedded (e.g., 88% of cobble is greater than 75% embedded). Hines (2000) found no trend in percent fines (<0.85 mm) from 1995 to 1999. The scour pools and LWD-formed habitat make up 11% and 5% of the habitat length, respectively. Two percent of the pools are backwater pools. Seventeen percent of the pools are greater than three feet deep. Two percent of the stream channel is dry in the summer. Weekly average temperatures exceed an MWAT of 16.8 °C 20% of the summer and there is 84% shade canopy over the stream.

Redwood Creek is potentially limited in its ability to support coho as a result of its poor pool frequency, moderate level of fines (<0.85 mm), high embeddedness, poor scour pool frequency, poor LWD-formed habitat frequency, poor backwater pool frequency, poor pool depth, elevated stream temperatures, and moderate stream canopy. Redwood Creek is limited in its ability to support coho as result of its location in the headwaters of the South Fork Ten Mile subwatershed. Reductions in sediment delivery and improvements in sediment metering could potentially improve deliver of fine sediment to downstream reaches.

## 4.5 CONCLUSIONS AND RECOMMENDATIONS

According to Weitkamp (1995), the Ten Mile River watershed harbors the last native coho salmon in Mendocino County. As such, protection of the fish and restoration of their habitat in the Ten Mile River watershed is of special interest.

### 4.5.1 POPULATION AND HABITAT CONCLUSIONS

The existing data indicate that coho salmon continue to spawn and rear with some regularity in the Little North Fork Ten Mile River, Clark Fork Ten Mile River, Bear Haven Creek, South Fork Ten Mile River, Smith Creek, Campbell Creek, and Churchman Creek. For the most part, these streams have at least some C-type channel; scour pool frequency of at least 17% (by length), LWD-formed habitat frequency of at least 11% (by length), and weekly average summer stream temperatures no more than 16.8 °C. Campbell Creek has all of these habitat characteristics except good stream temperatures. The South Fork Ten Mile River is lacking large woody debris-formed habitat. The Clark Fork Ten Mile River has sufficient scour pools only. And, Churchman Creek has cool stream temperatures only. Coho salmon have been observed once in the North Fork Ten Mile River, Bald Hill Creek, Buckhorn Creek, and Redwood Creek, as well.

The level of fine sediment (<0.85 mm) in substrate is elevated in reaches throughout the watershed. Fines (<0.85 mm) are particularly elevated (e.g., >20%) in Mill Creek, Buckhorn Creek, the North Fork Ten Mile River at Gulch 9, Patsy Creek, Booth Gulch, and Campbell Creek. They are generally decreasing, however, in the North Fork Ten Mile River subwatershed and holding steady in the Clark Fork and South Fork Ten Mile River subwatersheds. Hines (2000) suggested that the decrease in fine sediment (<0.85 mm) in the North Fork Ten Mile River subwatershed may reflect the fact that old growth logging was completed there far later than in the Clark and South forks. As such, the level of fines (<0.85 mm) in substrate may soon reach a plateau as the subwatershed recovers from the old growth logging.

Other conclusions:

- Shelter is extremely poor throughout the watershed, including large woody debris.
- Stream temperatures are elevated in the three main forks. Temperatures are also elevated in Campbell Creek and Redwood Creek. At these locations, more than 16% of the stream side canopy is open.
- The percentage of habitat in scour pools is extremely poor in all but the main forks and Little North Fork Ten Mile River, Bear Haven Creek, Smith Creek and Campbell Creek.

- The percentage of habitat formed by large woody debris is extremely poor in all but Little North Fork Ten Mile River, Bear Haven Creek, Smith Creek and Campbell Creek.
- The availability of C-type channel is limited to Little North Fork Ten Mile River, Bear Haven Creek, Little Bear Haven Creek, South Fork Ten Mile River, Smith Creek, and Campbell Creek.

### 4.5.2 POTENTIAL WATERSHED IMPROVEMENTS

Coho salmon habitat in the Ten Mile River watershed could be significantly improved with reductions in sediment delivery, protection and improvement in riparian functions, increases in large woody debris for sediment metering and habitat, and modification of stream channel type.

Potential watershed improvements are identified for each of the tributaries of the Ten Mile River watershed, divided by priority. High priority streams are refuge streams or streams tributary to refuge streams. Moderate priority streams are non-coho streams with habitat characteristics that could be improved for coho salmon or streams that are tributary to restorable coho streams. The main forks are low priority streams since improvements in upstream sediment delivery, sediment metering, and stream temperature are necessary before significant instream changes can be expected.

#### 4.5.2.1 High Priority Streams

- Little North Fork Ten Mile River is one of the watershed's strongest coho streams. If sediment delivery rates are reduced, habitat conditions could be significantly improved: lower percentage of fines (<0.85 mm) in the substrate, lower embeddedness, and deeper pools. The tributaries to Little North Fork Ten Mile River may be significant sediment contributors.
- Blair Gulch, Barlow Gulch, and Buckhorn Gulch. Only the streamside canopy and stream temperatures of these tributaries favor the presence of coho. None of the other reported habitat characteristics are favorable. These tributaries may be significant sources of sediment to Little North Fork Ten Mile River. As such, they should be a high priority for sediment delivery reduction. A major conversion of channel type from F-type channel to C-type channel might provide greater salmonid habitat. But, the significance of the effort would make this a low restoration priority. Coho salmon have been observed in Buckhorn Creek once before. As such, instream restoration work in Buckhorn Creek may take precedence over the others.
- McGuire Creek does not appear to offer significant potential coho habitat. It does, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the Little North Fork Ten Mile River. As such, McGuire Creek should be a high priority for sediment delivery reduction.
- Bear Haven Creek is another of the strongest coho streams in the watershed. With the exception of limited backwater pools, the primary issue of concern in Bear Haven Creek appears to be aggradation. Sediment delivery reductions in the Bear Haven Creek basin should be a high priority. Improvements to LWD volumes may also improve sediment metering and backwater pool formation.

- Smith Creek and Campbell Creek are two other strong coho streams in the Ten Mile River watershed. Habitat conditions could potentially be improved by reducing fine sediment loading and improving the sediment metering and scouring functions of the stream channels with an increase in LWD volume. Temperatures in Campbell Creek could potentially be improved by increasing the streamside canopy.
- Churchman Creek. Habitat conditions in Churchman Creek could potentially be improved by reducing fine sediment loading and improving sediment metering and scouring functions of the stream channel with an increase in LWD volume.

#### 4.5.2.2 Moderate Priority Streams

- Cavanough Gulch does not appear to offer significant potential coho habitat. It does, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the North Fork Ten Mile River.
- O'Connor Gulch does not appear to offer significant potential coho habitat. It does, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the North Fork Ten Mile River.
- Bald Hill Creek is similar in many respects to the Little North Fork Ten Mile River basin, one of the watershed's best coho streams. One significant difference, however, is the absence of C-type channel in the Bald Hill Creek basin. It may be possible to convert some of the F-type channel found in Bald Hill Creek to C-type channel. But, the C-type channel will not regain access to its former floodplain, which is now defined as terrace. Most significantly, Bald Hill Creek could benefit from LWD placement for improved scouring. Sediment delivery reduction does not appear to be a high priority here. Coho salmon have been observed here once before.
- Gulch 8, Gulch 11, and Gulch 23 do not appear to offer significant potential coho habitat. They do, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the North Fork Ten Mile River.
- Gulch 19 and Patsy Creek do not appear to offer significant potential coho habitat. They do, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the North Fork Ten Mile River.
- Habitat conditions in Little Bear Haven Creek potentially could be improved by reducing sediment delivery and improving sediment metering and channel scouring abilities with an increase in LWD volume. Little Bear Haven Creek has C-type channel and thus may have potential as a coho stream.
- Booth Gulch does not appear to offer significant potential coho habitat. It does, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the Clark Fork Ten Mile River.
- Gulch 27 does not appear to offer significant potential coho habitat. It does, however, appear to be substantially aggraded and may be contributing to elevated sediment downstream in the Clark Fork Ten Mile River.
- Habitat conditions in Redwood Creek could potentially be improved by reducing sediment delivery and improving sediment metering and channel scouring abilities with an increase in LWD volume. Improvements to streamside canopy may improve instream temperatures, as well. Coho salmon have been observed here once before.

Bald Hill Creek, Little Bear Haven Creek and Redwood Creek are streams in which coho currently appear to be absent but in which coho may have spawned and reared in the recent past. As such, the restoration of these streams as coho streams is an important endeavor.

### 4.5.3 ADDITIONAL DATA NEEDS

The habitat inventories available for the Ten Mile River watershed provide useful information about habitat conditions. The population data, temperature data, and substrate composition data are especially useful for understanding conditions and trends in the basin. The availability of each of these data sets in electronic form for each of the years in which they were collected would vastly improve the ability of Regional Water Board staff to analyze it. Some additional parameters that would help better understand changes in sedimentation in the basin, include:

- Longitudinal profiles
- Cross-sections
- V*
- LWD volume and distribution

Some locations where substrate data could confirm suspected aggradation include:

- Blair Gulch
- Barlow Gulch
- McGuire Creek
- Cavanough Gulch
- O’Connor Gulch
- Gulch 8
- Gulch 11
- Gulch 19
- Gulch 23
- Gulch 27

Continued and improved spawning, rearing, and outmigrant salmonid population studies are necessary to keep close track of the success of the few remaining native coho salmon.

# Chapter 5
# Big River Watershed

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## 5.0 BRIEF CONCLUSIONS

The Big River watershed provides degraded conditions for salmonids because of poor quality summer rearing and overwintering habitat, which is limited by high sedimentation, low LWD, a low number of pools, the shallow depth of pools, and a lack of connection to off-channel habitat. Spawning gravels generally are present, but their quality is low due to embeddedness of the gravels and fine sediment in the substrate. Low canopy cover and high water temperatures in some of the subwatersheds also serve to diminish the value of the habitat to salmonids. Populations of coho and steelhead are severely depressed compared to historic levels, although steelhead populations are relatively more robust than coho.

Upper Big River: Data for the Upper Big River watershed are limited. Available data indicate degraded habitat and depressed salmonid populations in this subwatershed.

North Fork Big River and Two Log Creek: The North Fork Big River and the Two Log Creek subwatersheds are particularly sensitive to disturbances because of the relatively high abundance of non-confined, low-gradient channels that are valuable habitat. These subwatersheds have high sedimentation and erosion potential, however, which diminishes and further threatens the habitat value.

South Fork Big River: Throughout the South Fork Big River subwatershed, canopy cover is low and water temperatures are above the preferred range for coho. Generally the pools in the subwatershed are shallow. Spawning gravels are present but are embedded with fine sediment.

Chamberlain Creek: Stream channels in the Chamberlain Creek subwatershed are degraded with channel entrenchment and low LWD. As in the overall watershed, pool depth is shallow and gravel embeddedness is high. This subwatershed has a high sediment input and low canopy cover.

Little North Fork Big River: The Little North Fork Big River subwatershed contains valuable wetlands, leading to a relatively high habitat complexity. The subwatershed has relatively high amounts of LWD and canopy cover. Unfortunately, like the rest of the Big River watershed, this subwatershed is adversely affected by high sediment input, substrate embeddedness, and low pool volume.

Lower Big River: The Lower Big River subwatershed includes valuable estuarine habitat whose value is diminished by sediment deposition and channel confinement. Natural and anthropogenic levee formation is fragmenting habitat -- cutting off the lower river from the floodplain, and reducing biological productivity. Tidal flux through the lower river has been reduced. Decreased access to adjacent off-channel habitat reduces the sheltering, rearing, and feeding areas for salmonids.

There is little systematic information about the entire Big River watershed. What information is available is difficult to assess because it was developed for individual portions of the watershed. Additionally, evaluation of the available data was made difficult because the methodologies often were poorly documented, the selection of sampling points was not described, and a systematic investigation over time was not conducted. Overall, additional data are needed, especially population information and habitat data developed from a systematic watershed analysis or limiting factors analysis.

## 5.1 GENERAL BACKGROUND

### 5.1.1 BASIN PLAN – BENEFICIAL USES

The primary beneficial use of concern in the Big River watershed, as described in the *Water Quality Control Plan, North Coast Region* ("the Basin Plan," California North Coast Regional Water Quality Control Board 1994), is the cold freshwater fishery which supports coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*), both listed as threatened under the federal Endangered Species Act.[31] The Basin Plan identifies municipal, industrial, agricultural, and recreational uses of the Big River watershed. The beneficial uses of water related to rare, threatened or endangered species has been proposed for this basin. As with many of the north coast watersheds, the cold water fishery appears to be the most sensitive of the beneficial uses in the watershed because of the sensitivity of salmonid species to habitat changes and water quality degradation. Accordingly, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation.

The Basin Plan identifies the following beneficial uses related to the Big River watershed's cold water fishery:

- Commercial and sport fishing;
- Cold freshwater habitat;
- Migration of aquatic organisms;
- Spawning, reproduction, and early development; and,

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[31] 61 FR 56138 and 65 FR 36074.

- Estuarine habitat.

### 5.1.2 LOCATION

The Big River watershed drains an area of approximately 116,000 acres, or about 181 square miles. The Big River estuary is located immediately south of the town of Mendocino and approximately ten miles south of Fort Bragg. Map 5.1 shows the location of the Big River watershed, and Map 5.2 shows the subwatersheds within the Big River watershed. The watershed drains from the east to the west, sharing ridges with the Noyo River watershed to the north, the Eel River watershed to the east, and the Albion and Navarro River watersheds to the south. The location of stream channels may be locally controlled by weak rock in fault shear zones, including erodible bedrock, synclines, or joint systems (CDF 1999). Map 5.3 shows the geology of the Big River watershed. The Big River is controlled to a lesser extent by the northwest trend (structural grain) of the Coast Range and flows in broad floodplains across this structural grain in some mainstem reaches (CDF 1999). Stream channels exhibit a trellis drainage pattern, in which tributaries typically join larger streams at roughly right angles. Analysis of California Division of Mines and Geology maps and field observations suggests that many low-order tributary streams may be naturally disconnected from high-order streams by the presence of alluvial depositional features such as alluvial fans and valley fills (CDF 1999).

The Big River watershed is divided into 16 Planning Watersheds ("PW"), as designated by the CalWater California Watershed Map (Interagency California Watershed Mapping Committee 1999).[32] These are shown in Table 5.1. The PWs range in size from 3,246 acres to 11,732 acres and are generally based on subwatershed boundaries.

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[32] The California Watershed Map (CalWater, version 2.2) is a set of standardized watershed boundaries meeting standardized delineation criteria. A number of state and federal agencies are involved with CalWater, through a Memorandum of Understanding. Watershed boundaries were digitized on a 1:24,000-scale base. Information about CalWater can be found on the CDFG website at http://maphost.dfg.ca.gov/cau/ibis/mcalwat.htm.

**TABLE 5.1**
**PLANNING WATERSHEDS WITHIN THE BIG RIVER WATERSHED (Interagency California Watershed Mapping Committee 1999)**

| Planning Watershed Number | Planning Watershed Name | Planning Watershed Size | |
|---|---|---|---|
| | | acres | miles$^2$ |
| 1113.300101 | Dark Gulch | 7,156 | 11.2 |
| 1113.300102 | South Daugherty Creek | 10,667 | 16.7 |
| 1113.300103 | Mettick Creek | 11,732 | 18.3 |
| 1113.300104 | Leonaro Lake | 5,329 | 8.3 |
| 1113.300201 | Martin Creek | 5,945 | 9.3 |
| 1113.300202 | Russell Brook | 7,016 | 11.0 |
| 1113.300203 | Rice Creek | 8,039 | 12.6 |
| 1113.300301 | James Creek | 4,459 | 7.0 |
| 1113.300302 | Chamberlain Creek | 7,868 | 12.3 |
| 1113.300303 | East Branch North Fork Big River | 5,160 | 8.1 |
| 1113.300304 | Lower North Fork Big River | 4,953 | 7.7 |
| 1113.300305 | Upper North Fork Big River | 5,420 | 8.5 |
| 1113.300401 | Laguna Creek | 3,246 | 5.1 |
| 1113.300402 | Berry Gulch | 7,999 | 12.5 |
| 1113.300403 | Mouth of Big River | 9,548 | 14.9 |
| 1113.300406 | Two Log Creek | 11,432 | 17.9 |
| **TOTAL** | **Big River Watershed** | **115,969** | **181.4** |

### 5.1.3 CLIMATE

The Big River watershed has a Mediterranean climate, characterized by a pattern of low-intensity rainfall in the winter and cool, dry summers with coastal fog. Mean annual precipitation is 40 inches at Fort Bragg near the western margin of the watershed and 51 inches at Willits [Western Regional Climate Center (“WRCC”) 2000a] to the east. About 90% of the precipitation in this area falls between October and April with the highest average precipitation in January (WRCC 2000a). Snowfall is very rare and hydrologically insignificant (WRCC 2000a). Map 5.4 shows the rainfall pattern across the watershed.

### 5.1.4 VEGETATION

The Big River, like the other coastal watersheds in Mendocino County, “lies in the Oregonian Biotic Province (Munz 1959), which includes the moist, cool strip from Vancouver, Canada south to San Francisco Bay.”[33] Vegetation in the Big River basin is predominantly coniferous with redwoods near the coast and in the stream bottoms and Douglas fir in the interior and along the ridges (USFWS 1974). Broadleaf trees typical of the area include tan oak, live oak, alder, bay and madrone. They are interspersed throughout the conifer stands (USFWS 1974). On the drier slopes in the headwaters there is considerable oak-grassland and brush. California black oak, Oregon oak, ceanothus, currant, raspberry, and manzanita comprise woody species dominant in these

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[33] Seacat et al. 1981, page 106.

areas (USFWS 1974). Herbaceous species consist of oat grasses, bromes, fescues, and filagree (USFWS 1974). Map 5.5 shows vegetation types in the Big River watershed.

Of particular note in the Big River watershed are the brackish and freshwater bogs, the extensive estuary, and the freshwater marshes. Seacat et al. (1981) noted eight freshwater marshes within the first seven miles of the estuary valley. Salt water extends up the Big River estuary approximately 8.3 miles in the summer and three miles during the winter (Warrick and Wilcox 1981). Plants common in the brackish and freshwater bogs include: sedge, yellow skunk cabbage, common spike rush, bulrush, water hemlock, willow herb, brooklime, and cattail. The estuary contains eelgrass, pondweed, water plantain, sedge, low club rush, and brass buttons. The marshes include sedge, cattail, yellow pond lily, water hemlock, yellow cress, pondweed, azolia, duckweed, and bladderwort.

## 5.2 SALMONID DISTRIBUTION AND ABUNDANCE

Population abundance trends are an indicator of risk in salmonid populations. Trends may be quantified if data such as spawner surveys, dam or weir counts, stream surveys and catchment are available. If quantitative data are not available, general trends in population abundance may be estimated by comparing historical and current estimates.

### 5.2.1 Summary -- Salmonid Distribution and Abundance

Unfortunately, there are limited quantitative data to assess population numbers in the Big River watershed, although the numbers are extremely low compared to historical levels. Available data also are inadequate to assess population trends of coho and steelhead in relation to forest practices, hillslope sediment delivery, channel morphology, and fish abundance (CDF 1999). However, increases in hillslope sediment delivery to streams and changes in channel morphology have likely resulted in substantial habitat degradation in Big River watershed streams (CDF 1999). In large part, this is a legacy of historical practices and historical and current removal of large woody debris ("LWD"). Post-Forest-Practices-Act logging activities, as well as the drought-storm cycles of the 1970s, 1980s, and 1990s have almost certainly contributed to habitat degradation and loss.

Salmonid population data collected since the 1970s have shown coho presence in the following streams:

- Upper Big River
- Chamberlain Creek
- Bull Pen Gulch
- Middle Big River
- Ramon Creek
- Daugherty Creek
- Little North Fork Big River
- Water Gulch
- Arvola Gulch
- North Fork Big River
- East Branch North Fork Big River
- Two Log Creek
- South Fork Big River
- North Fork Ramon Creek
- Berry Gulch
- Lower Big River (estuary)
- Park Gulch
- James Creek

In the early 1970s, the Department of Fish and Game ("CDFG") released 20,000 coho per year to the Big River, perhaps skewing the population findings in the early 1970s. Hatchery releases of coho ceased in 1976 while releases of steelhead trout began in 1979.

Compared to coho, currently steelhead are reported to be relatively more abundant and more widespread in the Big River watershed, but the actual population numbers are low for both species, especially as compared to historic levels.

Regional data suggest that coho and steelhead have declined substantially this century throughout the Mendocino Coast. For example, counts of coho and steelhead conducted by CDFG at Benbow Dam on the South Fork Eel River (approximately 50 miles north of JDSF) show a decline of approximately 85% in the numbers of both species between 1938 and 1972 (CDF 1999). Historically, coho and steelhead are thought to have occurred throughout the Big River watershed. All of the planning watersheds in the Big River watershed have accessible streams presumed to have been suitable for sustaining populations of salmonids under pre-management (reference) conditions.

### 5.2.2 SALMONID ABUNDANCE AND DISTRIBUTION BEFORE THE 1990S

Fish population data for the pre-logging period are not known to exist for streams in or near the Big River watershed. NMFS (Weitkamp et al. 1995) described the current coho run size as a severe decline from the historic levels. NMFS stated that the runs were reduced to a small fraction of the historic levels and that continued declines are anticipated. In 1965, CDFG (1965) estimated that there were 6,000 coho spawners and 12,000 steelhead spawners and no chinook in the Big River. Similarly, Brown et al. (1994) estimated there were 6,000 coho spawners in the Big River watershed in 1973.

As described in Chapter 2, salmonid abundance has declined dramatically throughout the Mendocino Coast Hydrologic Unit. Brown et al. (1994) report data from NMFS regarding commercial landings of coho and chinook from 1976 to 1993. Coho landings fell from a high of 3.6 million pounds in 1976 in California to a low of 11,000 pounds in 1992.

The California Department of Forestry and Fire Protection ("CDF") assumed that coho salmon and steelhead trout historically were found in all of the planning watersheds in the Jackson Demonstration State Forest ("JDSF") assessment area. This conclusion can be applied to the Big River watershed because of the suitability of the physical habitat (especially in the pre-management conditions), similarity in species present, and because the JDSF includes some of the planning watersheds of the Big River watershed. The conclusion is echoed by NMFS, in that the critical habitat designation for coho includes all waterways in the area below impassable barriers.[34]

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[34] 64 Federal Register 24049, May 5, 1999.

#### 5.2.2.1 1978-79 Salmonid Distribution in Estuary-- Britschgi and Marcus

As part of an investigation into the "natural history" of the Big River estuary, Britschgi and Marcus conducted an aquatic survey in the fall of 1978 and the spring of 1979 to determine how different fish species use the estuary (Britschgi and Marcus 1981). They identified 22 fish species, including coho and steelhead in the estuary. Pacific herring was the most abundant species observed. Three adult coho, ten adult steelhead and 14 juvenile salmonids were observed. The juveniles exhibited parr marks, showing that they likely would remain in the river and estuary for another year. Britschgi and Marcus observed that "Solitary individuals and small schools of fry – 10 to 15 fish – were seen in freshwater pools and shallow brackish-water areas of Big River." [35]

#### 5.2.2.2 1970s Salmonid Abundance & Distribution -- U.S. Fish and Wildlife Service

In 1973, the U.S. Fish and Wildlife Service ("USFWS") conducted a field investigation associated with a Fisheries Improvement Study of the Big River. Among other things, the USFWS (1974) reported the number of juvenile coho salmon and steelhead trout observed[36] using electroshock techniques at ten sampling locations in July and October, including:

- Four locations on the Big River
  - S-11 on the upper Big River just above Valentine Creek,
  - S-19 just above South Fork Big River,
  - S-16 just below North Fork Big River, and
  - S-18 in the Lower Big River just above the Little North Fork Big River;
- One location on the South Fork Big River
  - S-14 below Daugherty Creek;
- One location, S-5, on the East Branch North Fork Big River;
- Three locations on the North Fork Big River
  - S-20 above James Creek,
  - S-4 just below Chamberlain Creek, and
  - S-6 below East Branch North Fork Big River; and,
- One location, S-9, on Martin Creek, a tributary to the Upper Big River.

The USFWS data indicated the presence of steelhead trout at all locations sampled. Coho were found at six of the ten locations. Coho were found on the mainstem (at S-11, S-18 and S-19), in the North Fork Big River (at S-4), in the East Branch North Fork Big River (at S-5), and in the South Fork Big River (at S-14). The highest number of coho was observed in the South Fork Big River at S-14. The highest number of steelhead also was observed at site S-14.

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[35] Britschgi and Marcus 1981, page 90.

[36] Biomass was reported only irregularly and was not separated between coho and steelhead, so is not reported here.

### 5.2.2.3 1980s Salmonid Abundance & Distribution -- California Department of Forestry

CDF used electrofishing techniques to determine the composition of fish populations in Mendocino County streams, including some in the Big River watershed, from 1983 to 1989 during the late summer and early fall (CDF 1989). CDF sampled at the 12 locations shown in Table 5.2.

CDF reported coho at four locations:

- Berry Gulch,
- East Branch Little North Fork Big River,
- Chamberlain Creek, and
- Two Log Creek.

Coho density ranged from 0.01 fish/m$^2$ in Chamberlain Creek to 0.32 fish/m$^2$ in Berry Gulch. The coho biomass ranged from 0.48 kg/ha in Chamberlain Creek to 16.04 kg/ha in Berry Gulch.

Steelhead were reported at all locations sampled by CDF. Steelhead density ranged from 0.03 fish/m$^2$ in East Branch Little North Fork Big River to 2.23 fish/m$^2$ in West Fork Chamberlain Creek. Steelhead biomass ranged from 1.64 kg/ha in East Branch Little North Fork Big River to 92.63 kg/ha in Chamberlain Creek. The CDF salmonid population data are shown in Table 5.2.

**TABLE 5.2**
**CDF SURVEYS -- SALMONID POPULATION DATA FROM THE BIG RIVER WATERSHED 1983 TO 1987 (CDF 1989)**

| Location | Year Sampled | Coho Density (fish/m$^2$) | Coho Biomass (kg/ha) | Steelhead Density (fish/m$^2$) | Steelhead Biomass (kg/ha) |
|---|---|---|---|---|---|
| Berry Gulch | 1986 | 0.32 | 16.04 | 0.19 | 8.08 |
| East Branch Little North Fork Big River | 1986 | 0.06 | 1.39 | 0.03 | 1.64 |
| North Fork Big River | 1983 | 0 | 0 | 0.50 | 58.11 |
| James Creek | 1983 | 0 | 0 | 0.21 | 11.89 |
| Chamberlain Creek | 1983 | 0.01 | 0.48 | 2.04 | 92.63 |
| Arvola Creek | 1983 | 0 | 0 | 0.20 | 9.68 |
| Park Gulch | 1983 | 0 | 0 | 0.22 | 8.99 |
| Water Gulch | 1983 | 0 | 0 | 0.70 | 16.09 |
| West Fork Chamberlain Creek | 1983 | 0 | 0 | 2.23 | 37.31 |
| Gates Creek (u/s station) | 1987 | 0 | 0 | 0.30 | 13.71 |
| Gates Creek (d/s station) | 1987 | 0 | 0 | 0.29 | 9.69 |
| Two Log Creek | 1983 | 0.17 | 7.68 | 0.23 | 10.58 |

#### 5.2.2.4 1980s Salmonid Abundance & Distribution -- California Department of Fish and Game

The California Department of Fish and Game also surveyed reaches of the Big River watershed, using an electrofishing technique to stun and count aquatic vertebrates. From 1983 to 1996, CDFG conducted 20 such surveys (CDFG, unpublished 'h'). The 1980s data are discussed in this section. The 1990s data are discussed in Section 5.2.3.1. Data from both decades, however, are shown in Table 5.3.

During the surveys in the 1980s, coho salmon were found on only three occasions: in Berry Gulch, Chamberlain Creek, and Two Log Creek. All of the coho salmon found were young-of-the-year ("YOY") fish. Coho salmon densities ranged from 0.02 fish/m$^2$ in Chamberlain Creek to 0.31 fish/m$^2$ in Berry Gulch. Coho salmon biomass ranged from 0.48 kg/ha in Chamberlain Creek to 15.43 kg/ha in Berry Gulch.

Steelhead were relatively more abundant and represented YOY and year-old age classes; two-year steelhead were not observed in the surveys in the 1980s. Steelhead trout were found at every location surveyed, except for Lower Gates Creek where only sculpin and stickleback were found. Steelhead trout densities ranged from 0.18 fish/m$^2$ in Berry Gulch to 2.25 fish/m$^2$ in West Chamberlain Creek. Steelhead trout biomass ranged from 7.62 kg/ha in Berry Gulch to 70.86 kg/ha in Chamberlain Creek.

The CDFG aquatic vertebrate inventory data from the 1980s and the 1990s for the Big River watershed are shown in Table 5.3. Since the steelhead represented a mixed age class, the density of fish may be low for a relatively high biomass.

**TABLE 5.3**
**CDFG STEELHEAD TROUT AND COHO SALMON POPULATION DATA (CDFG, unpublished 'h')**

| Stream Reach | Date | Steelhead Density (fish/$m^2$) | Steelhead Biomass (kg/ha) | Coho Density (fish/$m^2$) | Coho Biomass (kg/ha) |
|---|---|---|---|---|---|
| Arvola Gulch | 9/16/83 | 0.19 | 9.68 | 0 | 0 |
| Berry Gulch | 6/18/86 | 0.18 | 7.62 | 0.31 | 15.43 |
| Berry Gulch | 10/26/95 | 0.11 | 4.76 | 0.19 | 6.07 |
| Chamberlain Creek | 9/14/83 | 2.20 | 70.86 | 0.02 | 0.48 |
| Chamberlain Creek | 9/15/83 | 2.23 | 37.31 | 0 | 0 |
| Chamberlain Creek (West) | 9/15/83 | 2.25 | 37.30 | 0 | 0 |
| Gates Creek (lower) | 11/17/87 | 0 | 0 | 0 | 0 |
| Gates Creek (middle) | 11/17/87 | 0.28 | 9.69 | 0 | 0 |
| Gates Creek (upper) | 11/17/87 | 0.30 | 13.71 | 0 | 0 |
| James Creek | 6/30/93 | 0.33 | 23.05 | 0 | 0 |
| James Creek | 10/25/95 | 0.33 | 15.94 | 0 | 0 |
| Martin Creek | 10/31/95 | 0.39 | 15.25 | 0 | 0 |
| Martin Creek | 10/22/96 | 0.26 | 11.49 | 0 | 0 |
| North Fork Big River | 10/25/96 | 0.52 | 40.48 | 0 | 0 |
| Park Gulch | 9/15/83 | 0.23 | 9.01 | 0 | 0 |
| South Fork Big River | 9/26/83 | 0.60 | 18.84 | 0 | 0 |
| Two Log Creek | 10/4/83 | 0.23 | 10.58 | 0.17 | 7.68 |
| Upper North Fork Big River | 9/14/83 | 0.22 | 26.02 | 0 | 0 |
| Upper North Fork Big River | 10/22/96 | 0.53 | 13.95 | 0 | 0 |
| Water Gulch | 9/15/83 | 0.74 | 17.04 | 0 | 0 |

#### 5.2.2.5 1989-90 Salmonid Abundance & Distribution -- Nielsen et al.

Nielsen et al. (1990) reported on a survey of 82 streams and tributaries in Mendocino County during the 1989-1990 spawning season. The South Fork Big River and seven tributaries (Ramon Creek, Mettick Creek, Anderson Creek, Daugherty Creek, Soda Creek, Gates Creek and one unnamed tributary) were included in the survey. During the entire survey period, the survey team observed only four live coho and 13 redds in Ramon Creek. Six redds were observed on Daugherty Creek. Nielsen et al. (1990) stated that the low numbers of salmonids was due more to ongoing drought conditions than to available spawning habitat.

#### 5.2.2.6 Historic Salmonid Distribution -- Jones

Jones (2000) prepared a draft "Current Stream Habitat Distribution Table" for California coastal salmon and steelhead that cites sources indicating the historic presence or absence of salmonids in the Big River watershed. Jones reports on the presence of coho and steelhead. Chinook were reported only as strays, "…only straggler king salmon enter and spawn in both Big River…" Jones reported the presence of:

- Coho and steelhead throughout the mainstem between 1958 and 1997;
- Juvenile coho and steelhead in East Branch Little North Fork Big River to river mile 1.8 in 1967;
- Juvenile steelhead in Two Log Creek to river mile 3.3 in 1966;
- Coho and steelhead in Two Log Creek to river mile 3.3 in 1983;
- Juvenile coho and steelhead in North Fork Big River to river mile 8.8 and 13.2, respectively, in 1966, 1967 and 1974;

- Coho and steelhead in East Branch North Fork Big River to river mile 5 in 1966;
- Juvenile coho and steelhead in Chamberlain Creek at river mile 3.5 and 4.6, respectively, in 1980 and 1983;
- Coho and steelhead in Water Gulch to river mile 2 in 1981;
- Juvenile steelhead in Park Gulch to river mile 0.7 in 1981;
- Coho and steelhead in Arvola Gulch to river mile 1 in 1980;
- Coho and juvenile steelhead to river mile 4 in James Creek in 1980;
- Juvenile coho and steelhead in South Fork Big River to river mile 17.5 in 1966;
- Steelhead in Ramon Creek to river mile 3.7 in 1979;
- Steelhead in Russell Brook Creek to river mile 3.5 in 1979;
- Steelhead in Martin Creek to river mile 1.7 in 1979; and,
- Steelhead in Valentine Creek to river mile 2.4 in 1979.

### 5.2.3 Current Salmonid Distribution and Abundance [37]

Information regarding the current distribution and abundance of salmonids within the Big River watershed is limited. Several sources, however, provide some information. The data are organized below based on author and include:

- Data from a Department of Fish and Game aquatic vertebrate inventory (CDFG unpublished ‘h’)
- Data from the Georgia-Pacific Corporation Sustained Yield Plan (G-P 1997)
- Department of Forestry and Fire Protection -- Draft Habitat Conservation Plan/Sustained Yield Plan for Jackson Demonstration State Forest (CDF 1999)
- Department of Forestry and Fire Protection Fish Counts (CDF 1994a)
- Mendocino Redwood Company and Louisiana-Pacific Fish Distribution Data (MRC 2000a)

#### 5.2.3.1 Aquatic Vertebrate Survey -- Department of Fish and Game

As described in Section 5.2.2.4, CDFG surveyed reaches of the Big River watershed using an electrofishing technique to stun and count aquatic vertebrates. From 1983 to 1996, CDFG conducted 20 such surveys (CDFG, unpublished ‘h’).

During the surveys in the 1990s, coho salmon were found on only one occasion -- in Berry Gulch (October 1995). The coho salmon found were YOY fish. The coho density at the site was calculated to be 0.19 fish/m$^2$ and the biomass was calculated to be 6.07 kg/ha.

Steelhead were relatively more abundant and represented all age classes, although two-year steelhead were observed only twice (James Creek in June 1993 and the North Fork Big River in October 1996). Steelhead were found at every location surveyed in the 1990s.[38] Steelhead densities ranged from 0.11 fish/m$^2$ in Berry Gulch (in 1995) to 0.53 fish/m$^2$ in the upper North Fork Big River (in 1996). Steelhead biomass ranged from 4.76 kg/ha in Berry Gulch (in 1995) to 40.48 kg/ha in North Fork Big River (in 1996).

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[37] In this section, “current” refers to fish populations beginning in 1990.

[38] In the 1980s CDFG surveys, steelhead were not found at lower Gates Creek, which was not re-surveyed by CDFG in the 1990s.

Unfortunately, the CDFG data are not sufficiently robust for a reliable quantitative analysis. There was no information about the choice of sampling locations.

#### 5.2.3.2 Sustained Yield Plan -- Georgia-Pacific Corporation

Georgia-Pacific Corporation ("G-P") collected salmonid population data at two locations in the Big River watershed from 1993 to 1996 as reported in the G-P Sustained Yield Plan (G-P 1997). These locations were in the Lower Little North Fork Big River and Lower Two Log Creek. The G-P data are shown in Table 5.4. Unfortunately, the G-P data are not sufficiently robust for a reliable quantitative analysis. There was no information about the choice of sampling locations.

**TABLE 5.4**
**COHO SALMON AND STEELHEAD TROUT POPULATION DATA (Georgia-Pacific Corporation 1997)**

| | Lower Little North Fork Big River Density (fish/m$^2$) | | Lower Two Log Creek Density (fish/m$^2$) | |
|---|---|---|---|---|
| Year | Coho | Steelhead | Coho | Steelhead |
| 1993 | 0.46 | 0.50 | 0.02 | 0.09 |
| 1994 | 0.07 | 0.42 | 0 | 0.26 |
| 1995 | 0.35 | 0.23 | 0.07 | 0.08 |
| 1996 | 0.27 | 0.25 | 0.30 | 0.22 |

#### 5.2.3.3 Draft Habitat Conservation Plan and Sustained Yield Plan for the Jackson Demonstration State Forest -- California Department of Forestry and Fire Protection

The California Department of Forestry and Fire Protection ("CDF") reported on the Jackson Demonstration State Forest ("JDSF") assessment area which includes eight planning watersheds in the Big River watershed, as well as seven planning watersheds in the Noyo River, Hare Creek, Mitchell Creek, Caspar Creek, and Russian Gulch watersheds. Map 5.6 shows the location of the JDSF in relation to the Big River watershed. CDF (1999) reported fisheries-related findings for the assessment area overall. The findings relevant to the Big River watershed alone are not reported separately. As such, a summary of findings for all of the 15 planning watersheds within Jackson Demonstration State Forest are given here, where they appear specifically relevant to the Big River watershed.

CDF (1999) estimated the miles of Class I (fish-bearing) stream likely to support coho salmon and steelhead trout in the whole assessment area based on stream gradient (e.g., ≤4% for coho and <8% for steelhead). Coho were expected to be distributed in 123 miles of Class I stream while steelhead were expected in 192 miles of Class I (CDF 1999). Field surveys confirmed the presence of coho salmon in 92 miles of Class I stream (75% of the predicted distribution based on gradient) and steelhead trout in 123 miles of Class I stream (64% of the predicted distribution based on gradient). In addition, coho were found in two miles of Class I stream in which they were not expected, including upstream segments of the East Branch Little North Fork Big River and James Creek, as well as other streams in the assessment area.

CDF (1999) further estimated the amount of change one might expect in the coho and steelhead smolt production if habitat conditions improved. Using a population model based on Beverton-Holt stock-production relationships, CDF predicted that smolt production could be increased by 11.9% for coho salmon and 23.5% for steelhead trout, if current habitat conditions were improved to match the best habitat conditions observed in the assessment area. CDF (1999) describes the "best observed habitat conditions" to include the following:

- Usable pool area ranging from 23-39% for channel types with gradients <2%, and
- Usable pool area ranging from 23-28% for channel types with gradients from 2-8%.

These conditions should not be confused with those described as "desirable conditions" or "target conditions." They are simply the best currently available in the Jackson Demonstration State Forest and may be improved even further through additional controls and mitigation. CDF does not describe what would constitute the best possible conditions in this area, nor do they describe targets or indicators of the best possible habitat in the area.

#### 5.2.3.4 Fish Counts -- California Department of Forestry and Fire Protection

CDF (1994) performed electroshock fish counts at two sites on the Big River in November 1994. The two sites sampled were on Chamberlain Creek near the confluence with the North Fork Big River. The survey observed 39 steelhead in the two sites. There is no information about the choice of sampling locations.

#### 5.2.3.5 Fish Distribution Data -- Mendocino Redwood Company and Louisiana-Pacific

Mendocino Redwood Company ("MRC" 2000a) reported fish population data, using electrofishing and snorkeling techniques, for sampling locations in the Big River watershed from 1994-1996. The surveys were conducted over a three-year period to correspond with the life cycle of coho. MRC states that the fish were counted and placed into distribution categories and that, "The abundance categories have no correlation to actual numbers or fish populations. The fish distribution surveys were not designed to estimate fish populations, rather to simply ascertain the presence of species within our ownership."[39] Rather than reporting the actual number of fish counted, MRC (2000a) reported a relative abundance category for the fish count (e.g., <10, 10-40, 40-399, >400) and the age class of observed fish. Biomass data were not reported. As such, the data can not be compared to the data collected by CDFG and G-P. It is used here only to indicate presence, age class, and relative abundance of salmonids in streams where MRC conducted sampling.

MRC (2000a) has an extensive series of fish sampling locations spread throughout the Big River watershed, including a total of 58 sites, which are listed below. The sampling locations where coho were reported are shown in bold type. Coho were reported in 13 of the 58 sites (22%).

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[39] MRC 2000a, unnumbered page titled "Important Information."

- <u>Upper Big River</u> (74-1, **74-6**, 74-8, 74-10)
- Russell Brook Creek (74-2, 74-3, 74-4, 74-5)
- Pig Pen Gulch (74-7)
- Martin Creek (74-9)
- <u>North Fork Big River</u> (**75-1, 75-3, 75-5**)
    - Steam Donkey Gulch (75-2)
    - Dunlap Gulch (75-4)
- <u>East Branch North Fork Big River</u> (75-6, 75-7, **75-10**, 75-11)
    - Quail Gulch (75-8)
    - Bull Pen Gulch (**75-9**)
- <u>Two Log Creek</u> (**76-1**, 76-2)
    - Middle Big River (**76-4**)
    - Beaver Pond Gulch (76-3)
    - Tramway Gulch (76-5, 76-6)
- <u>South Fork Big River -- North</u> (**79-1**, 79-11, 79-15)
    - No Name Gulch (79-2)
    - Ramon Creek (79-3, **79-4**, 79-7, 79-8)
    - North Fork Ramon Creek (**79-5**, 79-6)
    - Mettick Creek (79-9, 79-10)
    - Anderson Gulch (79-12)
    - Boardman Gulch (79-13)
    - Halfway House Gulch (79-14)
    - Daugherty Creek (79-16, **79-17**)
    - Soda Creek (79-18, 79-19)
    - Gates Creek (79-20, 79-21, 79-22, 79-23)
- <u>South Fork Big River -- South</u>
    - Johnson Creek (79-24, 79-25)
    - Daugherty Creek (**79-26**, 79-29, 79-30)
    - Snuffins Creek (79-27, 79-28)

Coho salmon yearlings were seen only once, in 1996 in Daugherty Creek. All other observed coho salmon were YOY fish. And, with the exception of the North Fork Big River (at site 75-1 in 1996) and Daugherty Creek (at site 79-26 in 1996), no more than nine coho were ever counted at a single sampling station. At the North Fork Big River and Daugherty Creek sites in 1996, between ten and 40 fish were counted on one occasion at each site.

Compared to coho, steelhead presence was more widespread and steelhead were relatively more abundant in the Big River watershed. Steelhead[40] were observed in 50 of the 58 sampling locations listed above. Of the 58 sites surveyed, steelhead were <u>not</u> reported in Steam Donkey Gulch (75-2), Dunlap Gulch (75-4), Quail Gulch (75-8),

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[40] MRC stated, “Some of the survey sites may have had resident rainbow trout present, but they were identified as steelhead trout due to the difficulties in distinguishing resident and anadromous forms of rainbow trout.” (MRC 2000a, Section 3, page 2)

Tramway Gulch (76-6), Beaver Pond Gulch (76-3), No Name Gulch (79-2), Boardman Gulch (79-13), Johnson Creek (79-25). In 145 sampling events in the Big River watershed, as conducted by MRC or its predecessor Louisiana-Pacific Corporation ("L-P"), steelhead trout were observed in all but 15 sampling events (90%). YOY steelhead trout were observed in all but 29 of the 145 sampling events from 1994 to 1996 (80%). Yearling steelhead trout were observed in 108 of the 145 sampling events (75%) while two-year old fish were observed in 101 of the 145 sampling events (70%). Population numbers are reportedly fairly sparse (<40). There were no sampling stations in which more than 400 individuals were counted and only 19 sampling events in which more than 40 individuals were counted, including observations at the following locations:

- Upper Big River (74-6, 74-8, 74-10)
- Middle Big River (76-4)
- East Branch North Fork Big River (75-10)
- South Fork Big River (79-1, 79-11, 79-15)
  - Ramon Creek (79-3)
  - Daugherty Creek (79-17, 79-26)
  - Gates Creek (79-20, 79-21)

### 5.2.4 HATCHERY SUPPLEMENTATION

The primary source of information about hatchery supplementation is the CDFG, but there is some mention of hatchery releases by other observers, including Britschgi and Marcus (1981) and Nielsen et al. (1990).

Britschgi and Marcus (1981) conducted an aquatic survey of the Big River estuary in the fall of 1978 and the spring of 1979. They observed three adult coho, ten adult steelhead and 14 juvenile salmonids in the estuary. Britschgi and Marcus stated, "Solitary individuals and small schools of fry – 10 to 15 fish – were seen in freshwater pools and shallow brackish-water areas of Big River. CDFG, through its anadromous fisheries program, planted many thousands of salmon fingerlings in the upper south fork of Big River during 1978, at the onset of this survey. Many of these fry probably migrated out to sea, but some remained in Big River estuary. Most salmon and steelhead netted in the estuary were in pre-smolt condition" [41]

Nielsen et al. (1990) mentioned coho supplementation in their report of anadromous salmonids in the Mendocino Coast watersheds. They stated, "Johnson Creek, a tributary of the S.F. Big River had a coho enhancement project in place from 1981-1987. About 2,500 fry were reared and released from this site in 1987."[42] There is no further information provided about the coho releases.

CDFG reports that hatchery-raised salmonids were released to the Big River watershed from 1959 to 1983 (CDFG, unpublished 'i'). A total of 599,188 coho were released to the Big River watershed from 1959 to 1976. A total of 75,363 steelhead trout were

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[41] Britschgi and Marcus 1981, page 90.

[42] Nielsen et al. 1990, page 53.

released to the Big River from 1979 to 1983.[43] On average, the coho salmon released by CDFG to the Big River watershed were 0.05 lb/fish. Steelhead trout released to the Big River watershed by CDFG were 0.15 lb/fish, on average. There is no indication in the CDFG record of where in the watershed the fish were released, although Britschgi and Marcus (1981) state that salmonids were planted by CDFG in the South Fork Big River, and Nielsen et al. state that coho were released into Johnson Creek, a tributary of the South Fork Big River. Table 5.5 provides the hatchery releases on the Big River reported by CDFG.

**TABLE 5.5**
**COHO SALMON AND STEELHEAD TROUT HATCHERY RELEASES TO THE BIG RIVER WATERSHED (CDFG, unpublished 'i')**

| Year | Coho Salmon Released (no. of fish) | Steelhead Trout Released (no. of fish) |
|---|---|---|
| 1959 | 40,000 | 0 |
| 1963 | 72,613 | 0 |
| 1964 | 36,247 | 0 |
| 1965 | 38,025 | 0 |
| 1970 | 30,004 | 0 |
| 1971 | 20,010 | 0 |
| 1972 | 20,007 | 0 |
| 1973 | 20,007 | 0 |
| 1974 | 111,101 | 0 |
| 1975 | 111,197 | 0 |
| 1976 | 99,977 | 0 |
| 1979 | 0 | 21,993 |
| 1981 | 0 | 15,990 |
| 1982 | 0 | 12,180 |
| 1983 | 0 | 25,200 |
| **TOTAL** | **599,188** | **75,363** |

The CDFG release of coho salmon to the Big River watershed reportedly ended in 1976 and, therefore, probably had minimal impact on the number of coho seen in the CDFG 1983 to 1996 population surveys beginning in 1983. The 1987 releases of coho mentioned by Nielsen et al. however, overlapped with this period and the impact of hatchery releases on the population numbers seen in the survey is not known. The CDFG release of steelhead trout continued up to 1983 when the CDFG population surveys began. The largest steelhead densities and biomass were recorded in 1983, particularly in Chamberlain Creek and West Chamberlain Creek, and may partially reflect the release of steelhead that year. Population surveys were not repeated in Chamberlain Creek or West Chamberlain Creek in succeeding years, so it is difficult to determine if there is a relationship between the CDFG steelhead releases and the population size.

A memorandum describing a meeting held by CDFG on July 19, 1955 indicated that king salmon (chinook) were released to the Big River for four years from 1949 to 1952 (CDFG 1955). It is unclear whether CDFG or another entity was responsible for the releases. A total of 615,000 chinook fingerlings were reportedly released during this

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[43] The CDFG data do not report the 1978 salmonid releases mentioned by Britschgi and Marcus or the 1987 coho releases mentioned by Nielsen et al.

period. Of the 135,000 fingerlings that were marked, however, only 14 were later recovered. CDFG estimated that a total of 72 of the marked fish might have returned from the ocean. The meeting participants generally agreed that the Big River watershed was primarily a coho salmon stream and that chinook supplementation efforts ought to be directed elsewhere (CDFG 1955).

## 5.3 HABITAT

There are several sources of information regarding aquatic habitat in the Big River watershed. Data and information regarding the Big River estuary and marshes are collected from the following sources:

- Warrick and Wilcox (1981)
- Marcus and Reneau (undated)
- Reneau (1981a and b)
- CDF (1999)

Data and information regarding riverine aquatic habitat conditions are collected from the following sources:

- CDF (1994, 1999)
- CDFG stream habitat data (CDFG 1998a)
- Louisiana-Pacific Corporation (1997)
- Mendocino Redwood Company (2000b)
- Georgia-Pacific Corporation (1997)

### 5.3.1 SUMMARY OF HABITAT CONDITIONS

The habitat conditions in the Big River watershed do not provide properly functioning conditions for salmonids, particularly overwintering and summer rearing habitat. The in-stream sedimentation from hillslope sources has embedded spawning gravels and reduced the volume of pools. The sediment also is causing levee formation in the lower river, fragmenting the habitat and cutting the main channel off from valuable off-channel habitat areas. In some areas, the lack of canopy cover has caused an increase in water temperatures above the preferred range for salmonids. Low LWD recruitment, along with increased sediment, has reduced the number and depth of pools.

### 5.3.2 ESTUARY AND MARSHES

Estuaries are important for juvenile salmonids – estuaries are productive areas that provide feeding habitat and a place to acclimatize to a saline environment. A report describing the factors for decline of west coast steelhead[44] expresses concern that the loss of wetland, estuarine, and lagoonal habitat will limit food resources for juvenile salmonids, increasing the tendency to migrate into open water at an earlier age and more susceptible size than would occur naturally. The report states that ocean survival is increased in salmonids that spend more time rearing in an estuary.

Estuaries along the Mendocino coast are generally lagoonal or semi-enclosed, isolated by sand spits or bars (Warrick and Wilcox 1981). "In contrast, Big River Estuary is long

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[44] NMFS 1996.

and narrow. A sand bar at the mouth partially constricts water flow in the estuary. Tidal water intrudes into the channel as far as 13.3 kilometers (8.3 mi.) during highest spring tides, making the Big River Estuary the longest estuary in northern California."[45] In addition to the estuarine characteristics unique to the Big River, there are numerous freshwater marshes within the Big River watershed. Relevant information regarding the Big River estuary is summarized here to provide a brief description of the estuarine habitat found in the Big River and its consequence to salmonid survival.

The Big River estuary occupies a narrow, steep-sided valley below the level of marine terraces (Reneau 1981a). In the lower valley less than a half-mile separates the marine terraces on each side of the valley. The estuary is 400 to 500 feet below the terraces in the lower valley. Floodplains adjacent to the Big River estuary exhibit relatively low relief.

Reneau describes the Lower Big River valley as a classic example of a drowned river valley, eroded by a terrestrial river, and later flooded by a rise in the sea level (Reneau 1981a). The original estuary may have extended much farther up the valley than it does today. This is partially shown by the three tributaries to Big River above tide water that have extensive flat, marshy bottoms.

In the JDSF assessment area, riverine and/or estuarine marshes or wetlands primarily occur on the floodplains of the Big River near Dry Dock Gulch and Laguna Creek, Laguna Creek, and Little North Fork Big River near Cookhouse Gulch (CDF 1999). These wetlands formed in valley fill along mainstem reaches that likely were formerly dammed either by large Holocene deep-seated landslides or by tributary debris flows that drained out onto the higher-order valley floors and delivered large volumes of soil and organic debris and formed alluvial fans (CDF 1999). For example, downcutting of the Big River across the northwest-trending ridges likely triggered deep-seated landslides that caused deposition of valley fill in which marshes developed (CDF 1999). Analysis of California Division of Mines and Geology geomorphic maps suggests that marshes are located near debris-slide amphitheaters (first-order basins) or are associated with tributary basins dominated by large deep-seated landslides and mass wasting (CDF 1999).

Reneau states that estuaries are areas of natural active sedimentation resulting from erosion in upstream drainages. When sediment-laden water reach the relative quiescence of the estuary, sediment is deposited. Build-up of sediment in the estuary has resulted in substantial decreases in the width of the estuary, the filling of tidal sloughs, and the rapid colonization of mudflats by salt marsh vegetation.

One of the features of the floodplains adjacent to the Big River estuary is the crescent-shaped Oxbow Marsh approximately five miles above the river's mouth on the south side of the channel (Reneau 1981a). The formation of the marsh may have resulted from the gradual filling of the estuary by river deposits. Reneau (1981a) states that the Oxbow Marsh receives water only in the rainy season and slowly loses water during the rest of

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[45] Warrick and Wilcox 1981, page 3.

the year. “Across the estuary from Oxbow Marsh lie two freshwater marshes occupying the submerged lower ends of tributary drainages: Dry Dock Gulch and Chapman Gulch. Prior to the development of levees here they may have had salt water influx, existing as relatively short arms of the estuary.”[46] Another geomorphic feature of interest is Apple Slough. The mouth of Apple Slough is located four miles upstream from the ocean. At high tide, Apple Slough is an estuary about 20 feet wide; at low tide, Apple Slough has the most extensive mudflats above the lowermost estuary. (Reneau 1981a)

The sediment of the floodplains adjacent to Big River estuary consists of alternating layers of sand and sandy silt (Reneau 1981a). The sand layers are up to one foot thick and were deposited by high-energy floods. Reneau stated:[47]

> The floods of modern times are probably more efficient at transporting material through the Big River estuary and out to sea than were the floods of the previous several thousand years. The percentage of sediment carried out to sea have probably increased over time, the relative energy of the floodwaters at the mouth increasing as the river deposit (delta) system has progressed down the estuary. Although considerable sediment may still be deposited within the valley by each flood, much is also carried to the ocean.

Since the early 1900s, levees were constructed adjacent to the main channel along two miles of the lower estuary. Levees formed a separation between the salt marshes/mudflats and the floodplains along much of the lower estuary and, thus, have affected the distribution of vegetation in this area. (Reneau 1981a).

The Big River and its tributaries were used to transport logs during the early logging of the watershed (Reneau 1981a). Waterways were dammed and their floodgates were opened every winter to float the accumulated logs to the sawmill. Booms were constructed in the estuary to keep the logs from being swept out to sea. Logs were taken to the mill in rafts that were floated with the tide.

Railroads in the lower Big River watershed along Laguna Creek, Railroad Gulch, and the Little North Fork Big River were constructed in 1901 to transport logs (Reneau 1981a). Logs were transported by rail to a log dump, where they were dropped into the estuary. Pilings from a dock and log dump and the remains of two bridges that crossed the estuary can still be seen. Reneau (1981b) examined old aerial photographs in an effort to understand the natural and anthropogenic levee creation. He stated that the railroad pilings originally “…stood well out from the bank, and the edge of the channel sloped gently into a salt marsh. No levee was present at the time.”[48] Aerial photos taken in 1952 show a levee near the log dump. Reneau stated, “Within a 25-year period prior to 1952, the character of the Big River estuary at the log dump had changed from a channel sloping gently into salt marshes to a channel sharply confined within levees.”[49]

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[46] Reneau 1981a, page 24.

[47] Reneau 1981a, page 30.

[48] Reneau 1981b, page 256.

[49] Reneau 1981b, page 256.

The development of levees along the estuary created a transitional zone -- a two-mile stretch distinct from the rest of the estuary in both geomorphic characteristics and vegetation distribution (Reneau 1981b). On the transitional flats, salt-water inflow is now limited. As a response to this, an ecological succession is occurring. Alders, willows, and coastal scrub vegetation, which have little salt tolerance, are colonizing the levees and inner margins of the tidal flats. Marcus and Reneau (undated) believe that the direct replacement of rushes by alder and coastal scrub is unusual. While coastal scrub species are occasionally distributed around the periphery of salt marshes, wetland areas are not normally replaced by this community (Marcus and Reneau undated). The direct colonization of newly deposited levees by alder and coastal scrub acts to produce riparian woodlands over former wetlands (Marcus and Reneau undated). A comparison of aerial photographs from 1952, 1963, and 1978 demonstrate that this colonization is extremely rapid in places (Reneau 1981b).

The results of significant sedimentation can be seen also at the tidal float opposite the sawmill site (Reneau 1981b). At present, approximately half of the tidal flat is covered by salt marsh vegetation. A pre-1936 photograph, however, shows the area to be composed entirely of tidal mudflats. Vegetation colonized a broad strip adjacent to the main channel between the time of the photograph and Reneau's observations. Another example of sedimentation cited by Reneau is the remains of three barges about 1.7 miles above the mouth. One barge is completely surrounded by vegetation. Reneau suggested that this is the result of "…either a major shrinking of the slough or, if the barge was grounded on a bordering mudflat, extensive salt marsh growth following sedimentation."[50]

Reneau (1981a) explained that the Big River estuary has experienced major geomorphic changes since the advent of logging in the watershed in 1852 and that the progression of river deposits down the estuary has apparently been greatly accelerated in the last 130 years. Primary indicators of this acceleration are the levees bordering the main channel, which today extend at least two miles farther down the estuary than they did 80 years ago (Reneau 1981a). Accompanying the rapid development of levees has been a major decrease in the width of the estuary, the filling of tidal sloughs, and rapid colonization of the remaining mudflats by salt marsh vegetation (Reneau 1981a).

Salt marshes are important to supporting viable salmonid populations because they are the primary nutrient producers for estuaries. Tidal flux through salt marshes is vital to transport organic detritus from the marshes to the estuary where it serves as the food source for filter-feeding invertebrates. Elimination of tidal flux between the Big River estuary and the adjacent salt marshes by sedimentation will result in the reduction of biological activity up the food chain, affecting the Big River salmonid population.

### 5.3.3 AQUATIC HABITAT

Of concern to land managers is the quality of aquatic habitat now available to salmonid species and the identification of management activities that can limit or contribute to

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[50] Reneau 1981b, page 256.

habitat improvements. The causes of the decline in coho and steelhead populations are numerous. For example, climatic changes leading to sea level changes, elevated ocean temperatures, extreme drought-flood cycles, and harvest have had adverse effects on salmonid populations. These natural environmental conditions, however, have been coupled with a long history of logging, road building, stream channel modification, and other management activities that adversely affect riparian habitat conditions. The precarious condition of salmonid populations requires actions to re-establish properly functioning conditions in order to improve the survival of coho and steelhead in the Big River watershed. As such, the following section focuses on riparian habitat conditions to provide a basis from which to consider management techniques to improve aquatic habitat.

#### 5.3.3.1 Jackson Demonstration State Forest -- California Department of Forestry and Fire Protection

CDF manages the Jackson Demonstration State Forest in Mendocino County. The JDSF includes property in the Noyo River, Caspar Creek, and Big River watersheds, as well as a few small coastal streams. Stillwater Sciences, under contract to CDF, produced a draft Habitat Conservation Plan ("HCP")/Sustained Yield Plan ("SYP") in June 1999 (CDF 1999). Regional Water Board staff believe this is the last version of the report produced. The report was not finalized.[51] Though the report was produced as an agency review draft and not intended for public release, CDF agreed to allow Regional Water Board staff to use the information in assessing aquatic conditions in the Big River watershed (Cafferata, CDF, pers. comm. 2000). The JDSF watershed assessment included eight planning watersheds that are within the Big River watershed. The eight Big River planning watersheds are incorporated into two Watershed and Wildlife Assessment Areas ("WWAA"). Table 5.6 shows the Big River planning watersheds and WWAAs in the JDSF.

**TABLE 5.6**
**BIG RIVER PLANNING WATERSHEDS IN THE JACKSON DEMONSTRATION STATE FOREST (CDF 1999)**

| WWAA Name | Planning Watershed ID No. | Planning Watershed Name |
|---|---|---|
| Southern WWAA | 1113.300406 | Two Log Creek |
| | 1113.300403 | Lower Big River |
| | 1113.300402 | Berry Gulch |
| | | |
| Eastern WWAA | 1113.300305 | Upper North Fork Big River |
| | 1113.300304 | Lower North Fork Big River |
| | 1113.300303 | East Branch North Fork Big River |
| | 1113.300302 | Chamberlain Creek |
| | 1113.300301 | James Creek |

According to CDF (1999), most of the eight planning watersheds are managed for timber, either by CDF, industrial timber companies, or non-industrial operations. Only in the

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[51] A December 20, 1999 CDF news release stated that work was stopped on the JDSF HCP and that relevant information would be incorporated into the preparation of a draft management plan. Regional Water Board staff believes that small portions of the JDSF report were incorporated into a draft management plan, but that the majority of the HCP/SYP was never finalized.

Upper North Fork Big River planning watershed (#1113.300305) is there any appreciable range land management (13% of the planning watershed) (CDF 1999).

- **Stream Channel Impacts from Pre-Logging to Present**

Channel surveys in JDSF in 1997 and a review of the literature that is available for other redwood-forested watersheds in coastal northern California (CDF 1999) suggest that the following generalizations can be made about channel conditions in the prior to logging and other land management activities:

- Pools were larger, deeper, and more frequent, with most mid-order channels exhibiting forced pool-riffle and step-pool morphology;
- LWD loading was 3-5 times higher, and LWD formed many of the pools and stored large amounts of sediment;
- Most higher-order channels (reaches with gradients <3%) had smaller cross-sectional areas, and floodplain-channel connectivity was greater;
- The average bed substrate particle size in high-order channels may have been finer than at present, due to lower sediment transport capacity;
- Denser vegetation, including mature redwoods, occurred in most areas along the lower gradient streams throughout what is now JDSF; and,
- Stream shading would have been much higher than what typically occurs today in managed watersheds with second-growth forests.

Since logging began in the JDSF assessment area in the early 1860s, streams have experienced two major periods of sediment input associated with logging activities: the late 1800s to early 1900s and the 1950s to mid-1970s (CDF 1999). The initial harvesting of old-growth forests in the late 1800s and early 1900s likely resulted in substantial increases in hillslope erosion, particularly surface erosion from skid trails and yarder roads, and the use of fire. Large inputs of fine sediment likely resulted in filling of pools, siltation of spawning gravels, and filling of substrate interstices used for cover by many aquatic organisms. Abundance and diversity of aquatic invertebrates likely were also reduced. Changes to channel geometry, especially through aggradation and widening, caused large-scale losses of high-quality salmonid rearing habitat such as pools and large substrates. Removal of riparian vegetation for timber or to facilitate timber harvesting had negative impacts on stream shading, inputs of organic matter to the stream, and LWD recruitment (CDF 1999).

Splash-dam logging resulted in large-scale destruction or alteration of habitat for aquatic organisms downstream of the dams by causing severe bed and bank erosion. Clearing of LWD and other channel bed and bank obstructions downstream of splash dams to facilitate log transport resulted in reduced channel roughness and habitat complexity (Bauer and Ralph 1999). The subsequent scouring of channels, sometimes to bedrock, eliminated pools, spawning gravel, and much of the fish and other aquatic life (CDF 1999). Entrenchment and reductions in LWD and other roughness elements continue to affect channels where splash damming occurred. As a result, habitat suitability for aquatic organisms, particularly summer rearing and overwintering habitat for juvenile salmonids, has been reduced compared to reference conditions in these channels (CDF 1999).

Entrenchment of stream channels has reduced the interaction between channels and their floodplains and reduced the availability of off-channel habitat, which is important to juvenile salmonids. Access to spawning areas may have been impeded during and after old-growth logging by obstacles such as dams associated with stream log transport, railroad landings constructed in the stream channels, debris jams, and a lack of surface flow caused by aggradation of the channel bed (CDF 1999).

The expansion of tractor logging and road construction following World War II led to removal of riparian vegetation along many streams and significantly increased the road-related mass wasting and surface erosion, resulting in a second pulse of sediment input to channels throughout the assessment area (CDF 1999). Beginning in the 1950s and 1960s, basin-wide removal of in-stream LWD, the majority of which occurred in 0-4% gradient channels, reduced the amount of LWD-stored sediment, reduced pool frequency and depth, and caused a conversion from bar-pool to plane-bed channel topography in some reaches (CDF 1999). Increases in sediment transport capacity due to LWD removal and large floods may have caused a relative coarsening of the bed substrates in the larger, lower-gradient channels, potentially reducing spawning gravel availability and shifting macroinvertebrate community structures (CDF 1999). These changes suggest that in the decades following World War II, aquatic and riparian habitats were substantially altered by timber operations, with increased water temperatures, losses of pool and off-channel habitat, and increased fine sediment in bed substrates (CDF 1999).

Crucial habitat for anadromous salmonids is susceptible to increased sediment loading, increased water temperatures, and loss of habitat complexity (CDF 1999). The most prevalent causes of these conditions in the JDSF assessment area are sediment delivery from hillslope sources, reductions in riparian canopy shading, and removal of LWD from stream channels (CDF 1999).

- **Potential Limiting Factors**

Although some portions of JDSF streams currently have relatively high amounts of LWD (e.g., Little North Fork Big River), LWD loading in most assessment area streams is low compared to undisturbed streams. For example, according to CDF (1999) current LWD frequency in JDSF streams is, on average, more than three times lower than the values in old-growth watersheds tributary to Redwood Creek in coastal Humboldt County, California. CDF (1999) recorded the removal of LWD as fish barriers from streams throughout JDSF in the 1950s, 1980s, and 1990s, including the following streams in the Big River watershed:

- Tramway Gulch;
- Two Log Creek;
- Berry Gulch;
- East Branch Little North Fork Big River;
- Big River Laguna;
- James Creek;
- Chamberlain Creek;
- Water Gulch;

- East Branch North Fork Big River; and,
- North Fork Big River.

A limiting factors analysis in the JDSF assessment area concludes that overwintering and summer rearing habitat limits the populations of coho and steelhead. This conclusion is consistent with the effects of channel entrenchment and LWD removal. Throughout the JDSF assessment area, connection of streams to floodplains and off-channel areas is uncommon; 97% of all stream channels in JDSF are confined (CDF 1999). Surveys show that channels in the Eastern WWAA (North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, and James Creek) are especially degraded, with channel entrenchment and LWD depletion (CDF 1999). CDF believes that recovery will require LWD recruitment, controlling sediment sources, and increasing sediment transport capacity. CDF notes that entrenched channels can take centuries to recover (CDF 1999).

Stream shading is low to moderate in the Southern WWAA -- Two Log Creek, Lower Big River, and Berry Gulch (CDF 1999). Water temperature monitoring by CDF has been conducted throughout JDSF since 1993. CDF stated:[52]

> Maximum weekly average temperatures (MWAT) in summer 1996 exceeded the upper preferred threshold of 62°F (16.8 °C) for juvenile coho salmon (NMFS and USFWS 1997) on at least one occasion at eight temperature monitoring locations, seven of which are located on the North Fork Big River in the Eastern WWAA.

Stream channels that are not confined and that have gradients averaging less than 2% are assumed to provide the most valuable aquatic habitat for salmonids, but only 3% of the Class I channel length in the JDSF assessment area meets these criteria (CDF 1999). CDF expressed concerns that “The high habitat value and high vulnerability to disturbance of this channel type, in conjunction with its relative scarcity, increases the relative importance of this channel type to fish and other aquatic organisms in the assessment area.”[53]

- **<u>Factors Related to Aquatic Resource Sensitivity</u>**

CDF rated each channel type with respect to its relative need for protection and its expected response to disturbance. CDF gave high sensitivity ratings (and, therefore, highest need for protection) to channel types that were especially valuable to fish and were vulnerable to increased sediment input. CDF (1999) reported the findings of an aquatic resource sensitivity analysis. CDF described watershed sensitivity as an indication of how vulnerable a watershed is to the adverse consequences of disturbances. A highly sensitive watershed might require a higher level of protection to prevent or minimize adverse impacts. The numeric results of the sensitivity analysis are included in Table 5.7. The analysis includes the following elements:

- Stream drainage density;
- Channel sensitivity;

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[52] CDF 1999, page I-25. Note that Chapter 2 refers to a preferred water temperature range for coho of 12° to 14°C. This is more restrictive than the 16.8°C for juvenile coho cited by CDF.

[53] CDF 1999, page I-98.

- Percent response channels;
- Percent low or moderate streamside shade; and,
- Percent documented LWD removal.

CDF explained aquatic resource sensitivity:[54]

> Each channel type was evaluated in terms of its relative need for protection based on its expected response to disturbance. Channel types that are both valuable to fisheries and vulnerable to increases in sediment input were given the highest sensitivity ratings, as illustrated in Table 2.2.3-3 (also see Appendix B-5, Table B-5.3). Channel types with high habitat value and high vulnerability thus require the greatest protection; conversely, channel types with low habitat value and low vulnerability require the least protection. Channels with other combinations of habitat value and vulnerability are assumed to have intermediate sensitivity values.

**TABLE 5.7**
**CHANNEL SENSITIVITY RATING FACTORS FOR JDSF WATERSHEDS LOCATED IN THE BIG RIVER WATERSHED (reported by CDF 1999)**

| Planning Watershed Number | Planning Watershed Name | Stream Drainage Density (mi/mi$^2$) a | Channel Sensitivity Score b | Percent Response Channels c | Percent Low or Moderate Streamside Shade d | Percent Documented LWD Removal e |
|---|---:|---:|---:|---:|---:|---:|
| 113.30040 | Two Log Creek | 6.1 | 12.4 | 20.3 | 29.0 | 17.4 |
| 113.30042 | Berry Gulch | 6.7 | 11.1 | 18.6 | 3.0 | 17.8 |
| 113.30043 | Lower Big River | 6.6 | 15.1 | 24.3 | 31.9 | 1.7 |
| 113.30030 | Upper North Fork Big River | 5.7 | 6.5 | 10.4 | 0.0 | 21.4 |
| 113.30031 | James Creek | 5.5 | 7.2 | 12.9 | 7.7 | 85.7 |
| 113.30032 | Chamberlain Creek | 5.5 | 7.1 | 10.2 | 4.8 | 62.4 |
| 113.30033 | East Branch North Fork Big River | 5.4 | 8.1 | 10.8 | 14.3 | 42.7 |
| 113.30034 | Lower North Fork Big River | 5.3 | 15.9 | 23.3 | 23.5 | 42.0 |

**NOTES**:
**a** is the miles of modeled stream length per square mile of watershed drainage area.
**b** is based on potential fishery habitat value and the vulnerability of the habitat to increases sediment supply. The score was reported by CDF (1999) but the derivation of this score was not available to Regional Water Board staff.
**c** are channels with average gradients less than 3%, and are predicted to show significant impacts from increases in upstream sediment supply.
**d** is the percent of stream length that had low (0-40%) or moderate (40-70%) levels of streamside shading.
**e** is the percent of Class I channel length in which documented removal occurred.

The relative sensitivity of aquatic habitat is determined, in part, by the physical characteristics of the stream channel network (CDF 1999). The extent of the channel network in a watershed, measured as drainage density, provides an indication of how efficiently hillslope inputs such as sediment are transported throughout the drainage systems (CDF 1999). A watershed with a high drainage density has high potential for

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[54] CDF 1999, page I-98.

hillslope impacts to be manifested in downstream reaches, where the most valuable aquatic habitat is often located. The Lower North Fork Big River planning watershed has the smallest drainage density within the JDSF assessment area -- 5.3 miles of stream per square mile of drainage area. The highest drainage density in the Big River portion of the JDSF is 6.7 mi/mi$^2$ in Berry Gulch.

CDF (1999) scored stream channel sensitivity using a rating system based on channel confinement and stream gradient. The rating system is described in a watershed analysis methods manual, which was not provided to Regional Water Board staff and therefore not reviewed. Nonetheless, CDF (1999) reported the following findings:

- Channel sensitivity scores are highest in Lower North Fork Big River planning watershed, indicating high habitat value and high vulnerability.
- High channel sensitivity scores also are found in Two Log Creek, Berry Gulch, and the Lower Big River. The channels in these planning watersheds are particularly sensitive because of the relatively high abundance of low-gradient channels that are not confined (CDF 1999). These channels typically provide valuable habitat for spawning and rearing coho salmon and steelhead, but are among the most vulnerable to increased sediment loading.
- Channel sensitivity scores in Upper North Fork Big River, James Creek, Chamberlain Creek, and East Branch North Fork Big River planning watersheds are moderate, indicating either less habitat value or less vulnerability to threats, in comparison to those throughout the JDSF assessment area.

The relative proportion of “response channels” in a watershed gives an indication of how much of the channel network may be affected by increased sediment delivery from channels upstream and the magnitude of the resultant impacts on the aquatic habitat. The percentage of response channels ranges from a low of 10.2% in the Chamberlain Creek planning watershed to a high of 39.7% in the Mitchell Creek planning watershed (CDF 1999). Response channels in the Two Log Creek, Lower Big River, and Lower North Fork Big River planning watersheds exceed 20%, whereas those in the Berry Gulch, Upper North Fork Big River, James Creek, Chamberlain Creek, and East Branch North Fork Big River planning watersheds are all less than 20%.

CDF (1999) used a variety of factors to assign a fish habitat/channel sensitivity score on a scale of 1-100 to each planning watershed within the JDSF assessment area. The method for assigning a rank is given in a separate manual that was not provided to Regional Water Board staff and, therefore, was not reviewed; however, CDF drew the following conclusions.

- Two Log Creek, Berry Gulch, Lower Big River and East Branch North Fork Big River planning watersheds have a channel sensitivity rank greater than the 50th percentile, indicating that these areas are especially sensitive to disturbances.
- Upper North Fork Big River, James Creek, and Chamberlain Creek planning watersheds have a channel sensitivity rank less than the 50th percentile, indicating less sensitivity to disturbance or less habitat value.

- **Streamside Shade**

CDF (1999) measured the streamside shading in Class I and Class II streams visible in aerial photographs. Channels with low or moderate streamside shade are those in which the stream surface is at least partially visible in the aerial photographs, corresponding to an estimated shade level of 70% or less (CDF 1999). The planning watersheds with the least streamside shade in the Big River portion of the JDSF assessment area are the Lower Big River and Two Log Creek.

- **Habitat Complexity – LWD Removal**

The suitability of aquatic habitat for rearing coho salmon and steelhead, as well as for amphibians and other aquatic organisms, can be adversely impacted by the reduction of habitat complexity and low-velocity refugia (CDF 1999). LWD is one of the most important elements of stream habitat complexity, and removal of LWD leads to stream channels that are less complex and less stable than needed for properly functioning conditions. Documented LWD removal is highest in the James Creek planning watershed, with 85.7% of its Class I stream having been subject to LWD removal. LWD removal is lowest in the Lower Big River planning watershed with only 1.7% of its stream length having been so altered. Chamberlain Creek planning watershed also had high levels of documented LWD removal (>50%).

#### 5.3.3.2 Temperature -- California Department of Forestry and Fire Protection

CDF monitored water temperature at three locations in the Big River headwaters portion of the JDSF in the summer of 1994 (July 7 to September 7 -- Valentine 1994). The monitoring sites and results are:

- Upper James Creek (tributary to North Fork Big River)

  At the upper James Creek station, where the groundwater influx was highest, the maximum, minimum and average temperatures recorded were 16.5°C, 9.8°C, and less than 15°C, respectively. The temperatures at this site were fairly constant.
- Middle James Creek

  At the mid-James Creek station, the maximum, minimum and average temperatures recorded were 20.5°C, 10.9°C and less than 18°C, respectively.[55] At this location daily water temperatures varied as much as 6.2°C.
- North Fork Big River downstream of Chamberlain Creek (referred to as the Big River station).

  At the Big River station, the maximum, minimum and average temperatures recorded were 19.3°C, 12.6°C, and less than 18°C, respectively.

Mean canopy shade was not measured in this study. Valentine stated, "…peak water temperatures approached the 20°C level for much of July, and did not consistently stay below 18° until after mid-August at the Big River station…"[56] Temperatures in the coho-

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[55] Unfortunately, the data as presented do not allow a more precise reading of the temperatures. CDF reported temperatures as "less than 18° C."

[56] Valentine 1994, page 4.

preferred range (12 - 14°C) "…are continuous at the upper James Creek location, infrequent at the mid-James station until early August, and were not observed on Big River until the end of August."[57] Valentine expressed concern that the water temperatures are so high especially given that the monitoring locations were in the upper watershed.

#### 5.3.3.3 Stream Surveys -- California Department of Fish and Game

CDFG conducted stream surveys in the Big River watershed in 1995 and 1996, identifying habitat characteristics[58] using the methodology described in Flosi and Reynolds (1994). CDFG field crews surveyed 62 miles of main channel and almost one mile of side channels in the Big River watershed.[59] The streams surveyed included those indicated in Table 5.8. The streams have been organized into subwatersheds for the purpose of discussing these data.

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[57] Valentine 1994, page 4.

[58] CDFG used the Rosgen channel classification system (see Rosgen 1996). Briefly, the Rosgen classification system describes channels as morphological types with the following characteristics:

<u>A-type</u> channels are stable, steep and entrenched step/pool channels.

<u>B-type</u> channels are described as stable, moderate gradient, moderately entrenched channels dominated by riffles with few pools.

<u>C-type</u> stream channels are described as meandering, low gradient, point-bar, riffle/pool alluvial channels with broad well-defined floodplains.

<u>D-type</u> channels are wide, eroding braided channels with long transverse bars.

<u>E-type</u> channels are described as stable, low gradient, meandering, pool/riffle stream channels. Unlike the C-type channel, E-type channels have very low width/depth ratios.

<u>F-type</u> channels are entrenched, low gradient, meandering, pool/riffle channels. Unlike either the C- or E-type channels, the F-type channel is fairly entrenched, resulting in high rates of bank erosion and sediment deposition.

<u>G-type</u> channels are moderate gradient, entrenched, step/pool "gullies" with a low width/depth ratio. G-type channels tend to be unstable and have high bank erosion rates.

[59] These figures exclude the 1996 survey of the North Fork Big River, which was repeated in 1997.

**TABLE 5.8**

**STREAMS SURVEYED IN THE BIG RIVER WATERSHED BY THE CALIFORNIA DEPARTMENT OF FISH AND GAME (CDFG unpublished ‘j’)**

| Stream Name | Length of Main Channel Surveyed (feet) | Length of Surveyed Side Channel (feet) |
|---|---|---|
| **SOUTH FORK BIG RIVER SUBWATERSHED** | | |
| Daugherty Creek | 41,242 | 612 |
| Gates Creek | 12,798 | 349 |
| Johnson Creek | 6,164 | 23 |
| Snuffins Creek | 1,823 | 0 |
| Soda Creek | 3,080 | 23 |
| **NORTH FORK BIG RIVER SUBWATERSHED** | | |
| East Branch North Fork Big | 39,034 | 488 |
| North Fork Big (1997) | 63,204 | 1,181 |
| Soda Gulch | 3,563 | 0 |
| James Creek | 23,326 | 561 |
| North Fork James Creek | 12,718 | 144 |
| **CHAMBERLAIN CREEK SUBWATERSHED** | | |
| Lost Creek | 4,868 | 17 |
| Water Gulch | 9,713 | 113 |
| Tributary to Water Gulch | 2,037 | 0 |
| West Chamberlain Creek | 18,320 | 89 |
| Chamberlain Creek | 26,246 | 319 |
| Gulch 16 | 4,653 | 217 |
| Tributary to Gulch 16 | 2,356 | 20 |
| **Little North Fork Big River Subwatershed** | | |
| Berry Gulch | 12,918 | 293 |
| Tributary to Berry Gulch | 5,844 | 79 |
| Little North Fork Big | 19,441 | 210 |
| Manly Gulch | 3,563 | 0 |
| Rocky Gulch | 1,098 | 0 |
| **Other Subwatersheds** | | |
| Railroad Gulch | 5,671 | 12 |
| Two Log Creek | 2,413 | 0 |
| **TOTAL LENGTH OF SURVEYED STREAM** | **326,093** | **4,750** |

- **South Fork Big River Subwatershed**

The South Fork Big River subwatershed includes surveys in: Daugherty Creek, Gates Creek, Johnson Creek, Snuffins Creek, and Soda Creek, covering a total of 12.33 stream miles. The data are reported in Table 5.9.

**TABLE 5.9**
**STREAM SURVEY DATA[60] COLLECTED BY CDFG IN 1996 AND 1997 IN THE SOUTH FORK BIG RIVER SUBWATERSHED (CDFG 1998a)**

| | **Daugherty Creek** | | **Gates Creek** | | **Johnson Creek** | | **Snuffins Creek** | | **Soda Creek** | | **Sub-Watershed** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % |
| Riffles | 14,008 | 34 | 4,732 | 37 | 3,019 | 49 | 576 | 32 | 2,054 | 67 | 24,389 | 38 |
| Cascades | 7 | 0 | 38 | 0 | 0 | 0 | 0 | 0 | 107 | 3 | 152 | 0 |
| Flatwater | 16,768 | 41 | 5,671 | 44 | 1,834 | 30 | 903 | 50 | 526 | 17 | 25,702 | 39 |
| Main Channel Pools | 3,885 | 9 | 678 | 5 | 191 | 3 | 149 | 8 | 267 | 9 | 5,170 | 8 |
| Scour Pools | 6,430 | 16 | 1,670 | 13 | 217 | 4 | 153 | 8 | 97 | 3 | 8,567 | 13 |
| Backwater Pools | 144 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 29 | 1 | 182 | 0 |
| Dry Channels | 0 | 0 | 0 | 0 | 903 | 15 | 42 | 2 | 0 | 0 | 945 | 2 |
| Culvert | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Not Surveyed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 41,242 | 100 | 12,798 | 99 | 6,164 | 101 | 1,823 | 100 | 3,080 | 100 | 65,107 | 100 |

The data collected by CDFG (1998a) indicate that the majority of streams in the South Fork Big River subwatershed are composed of riffles (38%) and flatwater (39%). Pools make up no more than 21% of the stream channels in this subwatershed while 2% are dry (96% of the dry channel was found in Johnson Creek). Throughout the South Fork Big River subwatershed, the mean pool depth was less than two feet. Mean pool depths in individual streams (e.g., Johnson Creek, Snuffins Creek, and Soda Creek) were less than one foot. Mean pool depth was deepest in Daugherty Creek. Nowhere in the South Fork Big River subwatershed did the mean shelter rating[61] exceed 60 and canopy cover was less than 80% in Daugherty Creek (68%), Gates Creek (77%), and Snuffins Creek (78%). Only in Soda Creek (93%) did the canopy cover measure greater than 90%, though less than 50% of the canopy cover was attributable to conifers (CDFG unpublished ‘j’).

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[60] For a description of the habitat types, please see page III-29 in Flosi et al. (1998).

[61] A shelter rating is assigned by estimating the percent of a habitat unit area that offers some form of shelter and multiplying it by a shelter quality rating of zero to three. The maximum shelter rating is 300. A shelter quality rating is assigned as follows: If the shelter in a habitat unit consists of one to five boulders, bare undercut bank, bare bedrock ledge or a single piece of large wood, then the unit is given a shelter quality rating of one. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of one or two pieces of large woody associated with any amount of small wood, six of more boulders per 50 feet, a stable undercut bank with root mass, a single root wad lacking complexity, etc., then the unit is given a shelter quality rating of 2. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of combinations of large woody debris, boulders and root wads, three or more pieces of large woody debris combined with small woody debris, three or more boulders combined with large woody debris/small woody debris, etc., then the unit is given a shelter quality rating of 3. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). Flosi et al. (1998) recommend improving shelter availability through habitat restoration efforts where the shelter rating is less than 80.

The majority of stream channels surveyed in the Daugherty Creek subwatershed were identified as B-type channels (e.g., 56,491 feet in Daugherty Creek, Gates Creek, Johnson Creek, and Snuffins Creek). Other channel types observed include A-type channels (e.g., 5,588 feet in Daugherty Creek and Johnson Creek) and G-type channel (e.g., 3,080 feet in Soda Creek).

### North Fork Big River Subwatershed

The North Fork Big River subwatershed includes Soda Gulch, James Creek, North Fork James Creek, East Branch of the North Fork Big River and the North Fork Big River, covering a total of 26.86 stream miles. The North Fork Big River was surveyed by CDFG in 1996 and 1997. The 1997 survey was more extensive and is described here. The data from this survey are reported in Table 5.10.

**TABLE 5.10**
**STREAM SURVEY DATA COLLECTED BY CDFG IN 1996 AND 1997 IN THE NORTH FORK BIG RIVER SUBWATERSHED (CDFG 1998a)**

| | **East Branch North Fork** | | **North Fork Big River** | | **Soda Gulch** | | **James Creek** | | **North Fork James Creek** | | **Sub-Watershed** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % |
| Riffles | 10,677 | 27 | 13,489 | 21 | 193 | 5 | 6,501 | 28 | 1,373 | 11 | 32,233 | 23 |
| Cascades | 16 | 0 | 0 | 0 | 49 | 1 | 15 | 0 | 17 | 0 | 97 | 0 |
| Flatwater | 20,880 | 53 | 23,965 | 38 | 1,425 | 40 | 10,286 | 44 | 6,922 | 54 | 63,478 | 45 |
| Main channel pools | 4,099 | 11 | 12,633 | 20 | 370 | 10 | 4,162 | 18 | 2,719 | 21 | 23,983 | 17 |
| Scour pools | 3,223 | 8 | 12,678 | 20 | 227 | 6 | 2,263 | 10 | 1,481 | 12 | 19,872 | 14 |
| Backwater pools | 10 | 0 | 383 | 1 | 0 | 0 | 84 | 0 | 68 | 1 | 545 | 0 |
| Dry channels | 119 | 0 | 0 | 0 | 1,204 | 34 | 15 | 0 | 52 | 0 | 1,390 | 1 |
| Culvert | 10 | 0 | 56 | 0 | 95 | 3 | 0 | 0 | 86 | 1 | 247 | 0 |
| Not surveyed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 39,034 | 99 | 63,204 | 100 | 3,563 | 99 | 23,326 | 100 | 12,718 | 100 | 141,845 | 100 |

Data collected by CDFG (1998a) indicate that the majority of the stream channel in the North Fork Big River subwatershed is composed of flatwater (45%) and 31% of the stream channel is made up of pool habitat. The mean pool depth in the North Fork Big River subwatershed is less than two feet throughout. The mean pool depth is less than 0.8 feet in Soda Gulch and North Fork James Creek. Only in the North Fork James Creek does the mean pool shelter rating exceed 25. Here, main channel pools have a mean shelter rating of 58. Shelter ratings were not recorded in the East Branch of the North Fork Big River. Mean canopy cover in the subwatershed ranges from 60-95%. Mean canopy cover is 70% for the overall subwatershed. Except in James Creek, conifers provide the majority of the canopy cover. Soda Gulch has better canopy cover than the rest of the subwatershed -- mean canopy here is 95% with conifers providing 93% of the cover (CDFG unpublished ‘j’).

A majority of the stream channels surveyed in this subwatershed were identified as F-type channels (e.g., 77,789 feet in the North Fork Big River and North Fork James Creek). Other channel types observed were A-type (e.g., 4,242 feet in the East Branch), B-type (e.g., 34,792 feet in the East Branch), and G-type (e.g., 3,563 feet in Soda Gulch).

- **Chamberlain Creek Subwatershed**

The Chamberlain Creek subwatershed includes Lost Creek, Water Gulch and its tributary, West Chamberlain Creek, Chamberlain Creek, and Gulch 16 and its tributary, covering a total of 12.92 stream miles. The data from this subwatershed are reported in Table 5.11.

## TABLE 5.11
## STREAM SURVEY DATA COLLECTED BY CDFG IN 1996 AND 1997 IN THE CHAMBERLAIN CREEK SUBWATERSHED (CDFG 1998a)

| | **Lost Creek** | | **Water Gulch** | | **Trib. to Water Gulch** | | **West Chamberlain Creek** | | **Chamberlain Creek** | | **Gulch 16** | | **Trib. to Gulch 16** | | **Sub-Watershed** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % |
| Riffles | 1,528 | 31 | 791 | 8 | 309 | 15 | 2,992 | 16 | 7,332 | 28 | 1,075 | 23 | 450 | 19 | 14,477 | 21 |
| Cascades | 65 | 1 | 40 | 0.4 | 13 | 1 | 27 | 0 | 77 | 0 | 8 | 0 | 0 | 0 | 230 | 0 |
| Flatwater | 1,540 | 31 | 5,041 | 52 | 1,123 | 55 | 9,895 | 54 | 11,488 | 44 | 2,447 | 53 | 1,248 | 53 | 32,782 | 48 |
| Main Channel Pools | 349 | 7 | 2,852 | 29 | 298 | 15 | 3,534 | 19 | 4,328 | 16 | 726 | 16 | 410 | 17 | 12,467 | 18 |
| Scour Pools | 180 | 4 | 339 | 3 | 193 | 9 | 1,748 | 10 | 2,668 | 10 | 286 | 6 | 167 | 7 | 5,581 | 8 |
| Backwater Pools | 1,200 | 25 | 631 | 7 | 0 | 0 | 113 | 1 | 251 | 1 | 17 | 0 | 0 | 0 | 2,212 | 3 |
| Dry Channels | 36 | 1 | 19 | 0.2 | 59 | 3 | 11 | 0 | 21 | 0 | 94 | 2 | 21 | 1 | 261 | 0 |
| Culvert | 0 | 0 | 0 | 0 | 42 | 2 | 0 | 0 | 81 | 0 | 0 | 0 | 60 | 3 | 183 | 0 |
| Not Surveyed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TOTAL** | 4,898 | 100 | 9,713 | 99.6 | 2,037 | 100 | 18,320 | 100 | 26,246 | 99 | 4,653 | 100 | 2,356 | 100 | 68,193 | 98 |

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CDFG (1998a) surveys indicate that the majority of the stream channel in the Chamberlain Creek subwatershed is composed of flatwater (48%) and 27% of the stream channel is made up of pool habitat. The mean pool depth in the Chamberlain Creek subwatershed is less than 1.25 feet throughout. The mean pool depth is less than one foot in Lost Creek, Water Gulch, Tributary to Water Gulch, and Gulch 16. The mean pool shelter rating ranges from ten in the Tributary to Water Gulch to 70 in scour pools in West Chamberlain Creek. With the exception of West Chamberlain Creek (87%) and Chamberlain Creek (73%) the mean canopy cover is greater than 90%. In every stream, except West Chamberlain Creek, 90% or more of the canopy cover is composed of conifers. In West Chamberlain Creek, 82% of the canopy cover is composed of conifers (CDFG unpublished 'j').

A majority of the stream channels surveyed in this subwatershed were identified as F-type channels (e.g., 50,718 feet in the West Chamberlain Creek, Chamberlain Creek, Gulch 16, and the Tributary to Gulch 16). Other channel types observed were A-type (e.g., 1,433 feet in West Chamberlain Creek and Gulch 16), B-type (e.g., 7,240 feet in Water Gulch and the Tributary to Water Gulch), E-type (e.g., 4,510 feet in Water Gulch) and G-type (e.g., 4,898 feet in Lost Creek).

- **Little North Fork Big River Subwatershed**

The Little North Fork Big River subwatershed includes some stream channel in Berry Gulch, a tributary to Berry Gulch, Little North Fork Big River, Manly Gulch, and Rocky Gulch, covering a total of 8.12 stream miles. The data from this subwatershed are reported in Table 5.12.

**TABLE 5.12**
**STREAM SURVEY DATA COLLECTED BY CDFG IN THE LITTLE NORTH FORK BIG RIVER SUBWATERSHED (CDFG 1998a)**

| | **Berry Gulch** | | **Trib. to Berry Gulch** | | **Little North Fork Big River** | | **Manly Gulch** | | **Rocky Gulch** | | **Sub-Watershed** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | feet | % | feet | % | feet | % | feet | % | feet | % | feet | % |
| Riffles | 1,974 | 15 | 1,391 | 24 | 1,543 | 8 | 175 | 5 | 314 | 29 | 5,397 | 13 |
| Cascades | 73 | 1 | 118 | 2 | 45 | 0 | 0 | 0 | 43 | 4 | 279 | 1 |
| Flatwater | 5,800 | 45 | 2,414 | 41 | 6,449 | 33 | 1,969 | 55 | 332 | 30 | 16,964 | 40 |
| Main Channel Pools | 2,561 | 20 | 1,074 | 18 | 8,891 | 46 | 508 | 14 | 27 | 2 | 13,061 | 30 |
| Scour Pools | 966 | 7 | 423 | 7 | 1,182 | 6 | 182 | 5 | 70 | 6 | 2,823 | 7 |
| Backwater Pools | 0 | 0 | 359 | 6 | 106 | 1 | 0 | 0 | 0 | 0 | 465 | 1 |
| Dry Channels | 82 | 0 | 0 | 0 | 1,121 | 6 | 729 | 20 | 312 | 28 | 2,244 | 5 |
| Culvert | 94 | 1 | 65 | 1 | 104 | 1 | 0 | 0 | 0 | 0 | 263 | 1 |
| Not Surveyed | 1,368 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,368 | 3 |
| **TOTAL** | 12,918 | 100 | 5,844 | 99 | 19,441 | 101 | 3,563 | 99 | 1,098 | 99 | 42,864 | 101 |

The data collected by CDFG (1998a) indicate that the majority of the stream channel in this subwatershed is composed of flatwater (40%) and 38% of the stream channel is composed of pools. The mean pool depth in the Little North Fork Big River subwatershed is less than 1.45 feet throughout, except in the tributary to Berry Creek where the mean depth of backwater pools is 2.28 feet. The mean pool shelter rating ranges from 3 in the main channel pools of Little North Fork Big River to 60 in the scour pools of Berry Gulch. Shelter ratings were not reported for Rocky Gulch. Mean canopy cover is greater than 90% except in Rocky Gulch where the mean canopy cover is 88%. In every stream, except the tributary to Berry Gulch, 90% or more of the canopy cover is composed of conifers. In the tributary to Berry Gulch, 88% of the canopy cover is composed of conifers (CDFG unpublished ‘j’).

The predominant channel types in the Little North Fork Big River subwatershed are G-type (e.g., 23,004 feet in Little North Fork Big River and Manly Gulch) and F-type (e.g., 17,711 feet in Berry Gulch and the tributary to Berry Gulch). Other channel types observed include B-type (e.g., 1,051 feet in Berry Gulch) and E-type (e.g., 1,098 feet in Rocky Gulch).

- **Two Log Creek and Railroad Gulch**

Two Log Creek (1.07 stream miles surveyed) and Railroad Gulch (0.46 stream miles surveyed) are two small subwatersheds in the middle and lower Big River watershed. The data from these subwatersheds are reported in Table 5.13.

**TABLE 5.13**
**STREAM SURVEY DATA COLLECTED BY CDFG IN TWO LOG CREEK AND RAILROAD GULCH OF THE BIG RIVER WATERSHED (CDFG 1998a)**

| | **Two Log Creek** | | **Railroad Gulch** | |
|---|---|---|---|---|
| | feet | % | feet | % |
| Riffles | 99 | 4 | 524 | 9 |
| Cascades | 0 | 0 | 21 | 0 |
| Flatwater | 341 | 14 | 2,933 | 52 |
| Main Channel Pools | 125 | 5 | 1,605 | 28 |
| Scour Pools | 57 | 2 | 249 | 4 |
| Backwater Pools | 0 | 0 | 196 | 3 |
| Dry Channels | 1,791 | 74 | 57 | 1 |
| Culvert | 0 | 0 | 86 | 2 |
| Not Surveyed | 0 | 0 | 0 | 0 |
| **TOTAL** | 2,413 | 99 | 5,671 | 99 |

CDFG (1998a) indicates that Two Log Creek is primarily composed of dry channel (74%) while Railroad Gulch is primarily composed of flatwater (52%). Only 7% of the Two Log Creek stream channel is composed of pools, whereas 35% of the Railroad Gulch stream channel is composed of pools. The mean pool depth in Two Log Creek is less than 0.63 feet throughout. In Railroad Gulch, the mean depth of main channel pools and scour pools is less than 0.80 feet; but the mean depth of backwater pools is two feet. The mean pool shelter rating is less than 30 throughout both of these streams. Mean canopy cover is 94% in Two Log Creek and 93% in Railroad Gulch. Nearly all canopy cover in Two Log Creek is provided by conifers (98%), whereas only 64% of the canopy in Railroad Gulch is attributable to conifers (CDFG unpublished ‘j’).

Two Log Creek is a B-type channel throughout its surveyed length while Railroad Gulch is an F-type channel throughout its surveyed length.

#### 5.3.3.4 Sustained Yield Plan -- Louisiana-Pacific Corporation

Louisiana-Pacific Corporation (L-P 1997a) produced a Sustained Yield Plan for its holdings in coastal Mendocino County in 1997, including the upper Big River, North Fork Big River, and Two Log Creek Watershed and Wildlife Assessment Areas. In Volume 1 of the Sustained Yield

Plan, L-P indicated that the following habitat parameters have been assessed in the Big River Planning Watersheds in which they own property:

- Availability of spawning gravels;
- Substrate embeddedness;
- Amount of subsurface fines;
- Availability of pools;
- Pool depth;
- In-stream cover;
- Channel confinement;
- Number of key pieces of LWD; and,
- Abundance of coarse substrate.

None of the actual data for these parameters, however, is reported in Volume 1. Instead, L-P uses a relative rating system, filtering the data through linear models for spawning, summer rearing and overwintering habitat to determine if conditions are "poor," "fair," or "good" with respect to life stage habitat requirements. Regional Water Board staff assume that the models used here are the same as those described in the Albion River Watershed Assessment and described in Chapter 6 of this report. There is no documentation to support an assessment of these models. Without the data and a description of the methodology, it is impossible to evaluate the L-P assessment.

L-P concluded that the upper Big River (WWAA 74, including two survey sites on the Big River, and one site on Russell Brook) "…has a low potential for the production of coho, primarily because of the low levels of quality summer rearing habitat. LWD levels were low in the reaches visited and contributed to the small size of the available pools … In addition, spawning gravels were relatively low in availability and quality. Although embeddedness was generally good, moderate to high levels of sand and fines were observed beneath the surface layer of gravels…"[62]

L-P evaluated the spawning habitat as good, but summer rearing and overwintering habitat as poor in the North Fork Big River (WWAA 75, including two survey sites on the East Branch North Fork Big River, two sites on North Fork Big River, one site in Bull Team, and one site in Dunlap Gulch). L-P concluded, "…it is likely that some streams in WWAA 75 under current conditions have fair potential for production of coho and steelhead."[63]

In the Two Log Creek subwatershed (WWAA 76, including a survey site on the Big River, Two Log Creek, and Tramway Gulch), L-P concluded that the potential for coho production is low, and that summer rearing habitat may be limiting.

L-P concluded that the South Fork Big River subwatershed (WWAA 79, including one survey site each on Gates Creek, Daugherty Creek, South Fork Big River and Ramon Creek) has poor habitat for coho. The assessed sites had poor summer rearing habitat in all surveyed sites because of limited cover, a lack of pools and low LWD.

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[62] L-P 1997a, page 8 in WWAA 74.

[63] L-P 1997a, page 8 in WWAA 75.

Habitat conditions in Big River planning watersheds, as assessed by L-P (1997a), are reported in Table 5.14. L-P (1997a) concluded that 56% of the 16 monitored sites in the Big River watershed offer poor spawning conditions, 88% offer poor summer rearing conditions, and 38% offer poor overwintering conditions. “Good” ratings were given to only four of the 16 sites, and only for spawning conditions. Summer rearing and overwintering habitat is rated as fair or poor.

**TABLE 5.14**
**ANADROMOUS FISHERY FRESHWATER HABITAT CONDITIONS (as assessed by L-P 1997a)**

| Stream Names | Sampling Site no. | Spawning Conditions | Summer Rearing Conditions | Overwintering Conditions |
|---|---|---|---|---|
| Russell Brook | 74-1 | poor | poor | fair |
| Upper Big River | 74-2 | fair | poor | fair |
| Upper Big River | 74-3 | poor | poor | fair |
| East Branch North Fork Big River | 75-1 | good | poor | fair |
| North Fork Big River | 75-2 | good | fair | poor |
| Dunlap Gulch | 75-3 | poor | poor | poor |
| North Fork Big River | 75-3b | fair | poor | fair |
| Bull Team | 75-4 | poor | fair | poor |
| East Branch North Fork Big River | 75-4b | good | poor | poor |
| Tramway Gulch | 76-1 | poor | poor | poor |
| Two Log Creek | 76-2 | fair | poor | fair |
| Big River | 76-3 | poor | poor | fair |
| Gates Creek | 79-1 | poor | poor | fair |
| Daugherty Creek | 79-2 | poor | poor | fair |
| South Fork Big River | 79-3 | good | poor | fair |
| Ramon Creek | 79-4 | poor | poor | poor |
| | | | | |
| **% poor** | NA | 56% | 88% | 38% |
| **% fair** | NA | 19% | 12% | 62% |
| **% good** | NA | 25% | 0% | 0% |

**NOTE: The terms “poor,” “fair” and “good” were those used in the L-P assessment. Assessment criteria and data were not available for review.**

### 5.3.3.5 Temperature -- Mendocino Redwood Company

MRC reported on stream temperature monitoring on MRC timberlands for 1997, 1999 and 2000 (MRC 2000b). Stream temperatures were recorded continuously using remote electronic temperature recorders placed in shallow pools just downstream of riffles from June to September each year. MRC reported maximum, maximum weekly average temperature (“MWAT”), and maximum weekly maximum temperature (“MWMT”) for 13 sites. The maximum, MWAT values reported by MRC exceeded the preferred range of 12-14°C (54-57°F) for coho salmon for all locations during each reporting year. Only three locations fell below the upper temperature of 16.8°C used by CDF (1999) for juvenile coho:

1. Data for Russell Brook were only reported for the year 2000. The Russell Brook site exceeded the CDF (1999) preferred threshold for the maximum value (with a value of 18.1°C) and the MWMT (with a value of 17.3°C) but had a reported MWAT value of 16.0°C.

2. Data for Two Log Creek were only reported for the year 2000. The Two Log Creek site exceeded the CDF (1999) preferred threshold for the maximum value (17.8°C) and the MWMT (17.3°C) but had a reported MWAT value of 15.8°C.
3. Data for North Fork Ramon Creek were only reported for the year 2000. The North Fork Ramon Creek site exceeded the CDF (1999) preferred threshold for the maximum value (with a value of 17.2°C) but had a reported MWAT of 15.1 and a reported MWMT value of 16.4°C.

MRC provided the calculated values instead of raw data and graphs that are useful for understanding the trends but not sufficient to discern actual readings. Table 5.15 shows the values reported by MRC.

**TABLE 5.15**
**MAXIMUM, MWAT & MWMT TEMPERATURES FOR MRC SITES IN THE BIG RIVER WATERSHED (MRC 2000b)**

| Stream | MRC Site Id No. | Year | Temperature (C°) | | |
|---|---|---|---|---|---|
| | | | Maximum | MWAT | MWMT |
| Big River | 74-1 | 2000 | 22.9 | 19.3 | 21.8 |
| Russell Brook | 74-3 | 2000 | 18.1 | 16.0 | 17.3 |
| Big River | 74-2 | 1999 | 22.1 | 18.8 | 21.1 |
| East Branch NF Big River | 75-1 | 1997 | 21.4 | 17.9 | 20.7 |
| East Branch NF Big River | 75-1 | 1999 | 20.1 | 17.1 | 19.2 |
| East Branch NF Big River | 75-1 | 2000 | 19.5 | 17.1 | 18.8 |
| East Branch NF Big River | 75-3 | 1997 | 20.5 | 17.9 | 20.1 |
| Big River | 76-1 | 1999 | 22.7 | 19.4 | 21.8 |
| Two Log Creek | 76-2 | 2000 | 17.8 | 15.8 | 17.3 |
| South Fork Big River | 79-1 | 1997 | 23.0 | 20.5 | 22.4 |
| South Fork Big River | 79-1 | 1999 | 22.8 | 20.0 | 21.8 |
| South Fork Big River | 79-1 | 2000 | 23.2 | 20.4 | 22.4 |
| Ramon Creek | 79-2 | 1997 | 21.7 | 18.4 | 21.2 |
| Ramon Creek | 79-2 | 1999 | 22.0 | 18.7 | 20.7 |
| Daugherty Creek | 79-4 | 1997 | 21.9 | 18.4 | 20.9 |
| Daugherty Creek | 79-4 | 1999 | 21.6 | 18.2 | 20.4 |
| Daugherty Creek | 79-4 | 2000 | 21.8 | 19.0 | 20.7 |
| Daugherty Creek | 79-5 | 1997 | 20.9 | 18.7 | 20.6 |
| North Fork Ramon Creek | 79-8 | 2000 | 17.2 | 15.1 | 16.4 |
| Gates Creek | 79-9 | 1997 | 21.6 | 18.2 | 20.2 |

**Note: MRC provided calculated values instead of raw data. This table shows the values calculated by MRC.**

### 5.3.3.6 Sustained Yield Plan -- Georgia-Pacific Corporation

In 1997, Jones and Stokes produced a Sustained Yield Plan for Georgia-Pacific Corporation's ("G-P") Fort Bragg timberlands based on a three-year data gathering effort that began in 1994. Included in the Sustained Yield Plan is a watershed assessment. G-P stated that the fieldwork was performed in summer and early fall using the Flosi and Reynolds (1994) protocols. To assess watershed conditions the following habitat data[64] was collected:

- Channel type
  - Water slope gradient

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[64] The habitat elements are described in Flosi and Reynolds 1994.

  - Entrenchment
  - Width/depth ratio
  - Dominant substrate
  - Sinuosity
- <u>Stream discharge at low flow</u>
- <u>Habitat type</u>
  - Riffles
  - Flatwater
  - Pools
  - Dry channel
- Ten percent of the habitat units and most pools were additionally described by measuring:
  - Mean channel width
  - Mean depth
  - Maximum depth
  - Embeddedness
  - Cover
  - Substrate
  - Canopy
  - Residual pool depth
  - Bank composition and vegetation
  - Habitat complexity
  - Cover area
  - LWD cover area
  - Canopy area
  - Sediment

None of the individual data for these parameters was included in the Sustained Yield Plan. Instead, the data were used to assess the quality of stream habitat and the sensitivity of the stream channel to change. Each stream segment was rated for 11 variables using a three-level scoring system that was not available for review.

The stream channel analysis evaluates the response of streams to disturbances. G-P analyzed stream channel sensitivity in four different categories:

(1) Fine sediment deposition;
(2) Channel scour;
(3) Bank erosion; and,
(4) Pool formation.

Hillslope conditions were rated based on three hazards:

(1) Erosion and mass wasting,
(2) Streamside landslides, and
(3) Roads.

Stream habitat quality was analyzed in four categories:

(1) Habitat complexity;
(2) Fine sediment;
(3) Coarse sediment; and,
(4) Stream shade.

Documentation that would allow the rating system to be evaluated was not provided. As such, it is difficult to assess the validity of the results. Nonetheless, the results of the G-P stream channel sensitivity analysis is reported in Table 5.16 and the G-P stream habitat quality analysis is reported in Table 5.17. The G-P analysis concludes that sediment deposition and channel scour are likely responses to watershed disturbances. Bank erosion and pool formation are less likely channel responses. The information also shows that G-P assessed habitat complexity and shade as high or medium.

**TABLE 5.16**
**RESULTS OF BIG RIVER WATERSHED CHANNEL RESPONSE ANALYSIS (as reported by G-P 1997)**

| | Sensitivity Level | Little North Fork Big River (% of stream) | Lower Big River (% of stream) | Lower Middle Big River (% of stream) | Laguna Creek (% of stream) |
|---|---|---|---|---|---|
| **Sediment Deposition** | low | 0 | 0 | 4 | 0 |
| | moderate | 51 | 12 | 15 | 50 |
| | high | 49 | 88 | 81 | 50 |
| **Channel Scour** | low | 0 | 0 | 0 | 0 |
| | moderate | 100 | 29 | 18 | 50 |
| | high | 0 | 71 | 82 | 50 |
| **Bank Erosion** | low | 28 | 29 | 18 | 50 |
| | moderate | 0 | 42 | 28 | 50 |
| | high | 72 | 29 | 54 | 0 |
| **Pool Formation** | low | 57 | 100 | 40 | 50 |
| | moderate | 43 | 0 | 60 | 50 |
| | high | 0 | 0 | 0 | 0 |

- **A low sensitivity level for sediment deposition indicates that the segment is likely to transport high sediment loads to downstream reaches. A high sensitivity level for sediment deposition indicates that the segment is likely to retain sediment loads through aggradation and pool filling.**
- **Segments rated highly sensitive to bank erosion means that bank erosion is likely to occur, resulting in wider channels and more sediment loading.**
- **A high sensitivity level to pool formation means that the segment is expected to have fewer pools if wood recruitment is reduced. A low sensitivity to pool formation means that pools are less likely to form.**

**NOTE: These results are as reported by G-P; data and criteria were not available for evaluation**.

**TABLE 5.17**
**RESULTS OF STREAM HABITAT ANALYSIS IN THE BIG RIVER WATERSHED (as reported by G-P 1997)**

| | Quality Level | Little North Fork Big River (% of stream) | Lower Big River (% of stream) | Lower Middle Big River (% of stream) | Laguna Creek (% of stream) |
|---|---|---|---|---|---|
| **Habitat Complexity** | high | 100 | 59 | 5 | 50 |
| | medium | 0 | 41 | 95 | 50 |
| | low | 0 | 0 | 0 | 0 |
| **Fine Sediment** | high | 0 | 0 | 0 | 0 |
| | medium | 52 | 0 | 42 | 0 |
| | low | 48 | 100 | 58 | 100 |
| **Coarse Sediment** | high | 52 | 100 | 96 | 50 |
| | medium | 48 | 0 | 4 | 50 |
| | low | 0 | 0 | 0 | 0 |
| **Shade** | high | 48 | 42 | 23 | 100 |
| | medium | 52 | 29 | 77 | 0 |
| | low | 0 | 29 | 0 | 0 |

**NOTE: These results are as reported by G-P; data and criteria were not available for evaluation.**

With regard to stream habitat, G-P (1997) concluded that, " Streams are largely rated as high quality for habitat complexity and coarse sediment in this basin, with no streams rated as low quality for these variables … Most streams appear to be well shaded, with 41% (13 miles) rated as high quality and only 9% (3 miles) rated as low quality … Many streams (74% or 24 miles) are rated low quality for fine sediment…"[65] Without being able to evaluate the data used by G-P, it is impossible to verify the conclusions.

### 5.3.4 SEDIMENT

Most of the efforts to assess the habitat conditions in the Big River watershed, including those conducted by G-P (1997), L-P (1997a), and CDF (1999), did not specifically reported on sediment conditions in the basin. Instead, sediment data are used in a series of rating systems by which relative habitat quality is determined. As such, there is little data regarding actual amounts of sediment within the Big River watershed, except for a series of CDF stream surveys, which do not present a great deal of information. Also, in the estuarine area, Warrick and Wilcox (1981) performed a sediment analysis as part of a larger effort to describe estuarine conditions in the late 1970s. As described in Chapter 2, excess sediment can affect salmonids at every life stage, though spawning and incubation are most directly affected (Spence et al. 1996). Bjornn and Reiser (1991) relate embeddedness to a reduction in salmonid biomass directly by

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[65] G-P 1997, page 3-87.

interfering with the carrying capacity of the stream for fish and indirectly by reducing the aquatic invertebrates that are used for food.

### 5.3.4.1 Embeddedness & Substrate -- California Department of Fish and Game

CDFG conducted stream surveys throughout the Big River watershed from 1983 to 1998. The depth of embeddedness of cobbles in pool tail-outs was estimated as the percent of cobble that was surrounded or buried by fine sediment. An embeddedness level of less than 25% was considered best for salmonid habitat.

Substrate composition in low-gradient riffles or pool tail-outs was estimated. A dominant substrate composition of gravel or small cobble is best for salmonid spawning.

The results of the surveys as related to substrate and embeddedness is shown in Table 5.18. The results show that the dominant substrate was gravel, which generally is good for salmon if not embedded with fine sediment. The embeddedness levels, however, were generally very high. High embeddedness levels indicate probable clogged interstitial spaces and a habitat that is not providing properly functioning conditions for salmonids.

**Table 5.18**
**Embeddedness and Dominant Substrate Composition (from CDFG Stream Inventory Reports)**

| Stream | | Embeddedness | | | Dominant Substrate | | Ref. |
|---|---|---|---|---|---|---|---|
| **South Fork Big River** | Gates Creek | 84 pool tail-outs measured | 5 ≤ 25% embedded | 49 > 50% embedded | 105 low gradient riffles measured | 84 – gravel or small cobble | CDFG 1993b |
| | Daugherty Creek | 311 pool tail-outs measured | 40 ≤ 25% embedded | 177 > 50% embedded | 357 low gradient riffles measured | 326 – gravel or small cobble | CDFG 1993a |
| | Snuffins Creek | 15 pool tail-outs measured | 0 ≤ 25% embedded | 12 > 50% embedded | 22 low gradient riffles measured | 21 – gravel or small cobble | CDFG 1993c |
| | Soda Creek | 95 pool tail-outs measured | 8 ≤ 25% embedded | 34 > 50% embedded | 15 low gradient riffles measured | 13 – gravel or small cobble | CDFG 1995f |

**TABLE 5.18**
**EMBEDDEDNESS AND DOMINANT SUBSTRATE COMPOSITION (from CDFG Stream Inventory Reports)**

| Stream | | Embeddedness | | | Dominant Substrate | | Ref. |
|---|---|---|---|---|---|---|---|
| **North Fork Big River** | North Fork Big River | 324 pool tail-outs measured | 50 ≤ 25% embedded | 97 > 50% embedded | 324 pool tail-outs measured | 286 – gravel or small cobble | CDFG 1997c |
| | Chamberlain Creek | 210 pool tail-outs measured | 48 ≤ 25% embedded | 35 > 50% embedded | 210 pool tail-outs measured | 191 – gravel or small cobble | CDFG 1997b |
| | East Branch North Fork Big River | 218 pool tail-outs measured | 12 ≤ 25% embedded | 101 > 50% embedded | 218 pool tail-outs measured | 214 – gravel or small cobble | CDFG 1998b |
| | James Creek | 250 pool tail-outs measured | 46 ≤ 25% embedded | 147 > 50% embedded | 26 low gradient riffles measured | 24 – gravel or small cobble | CDFG 1998b |
| | North Fork James Creek | 160 pool tail-outs measured | 17 ≤ 25% embedded | 48 > 50% embedded | 160 pool tail-outs measured | 160 – gravel or small cobble | CDFG 1997d |
| | Soda Gulch | 560 pool tail-outs measured | 0 ≤ 25% embedded | 35 > 50% embedded | 56 pool tail-outs measured | 44 – gravel or small cobble | CDFG 1997f |
| | Water Gulch | 126 pool tail-outs measured | 15 ≤ 25% embedded | 92 > 50% embedded | 10 low gradient riffles measured | 8 – gravel or small cobble | CDFG 1997h |
| | West Chamberlain Creek | 238 pool tail-outs measured | 15 ≤ 25% embedded | 928 > 50% embedded | 238 pool tail-outs measured | 200 – gravel or small cobble | CDFG 1997i |
| **Little North Fork Big River** | Little North Fork Big River | 199 pool tail-outs measured | 15 ≤ 25% embedded | 155 > 50% embedded | 10 low gradient riffles measured | 8 – gravel or small cobble | CDFG 1995e |
| | Berry Gulch | 151 pool tail-outs measured | 0 ≤ 25% embedded | 80 > 50% embedded | 151 pool tail-outs measured | 125 – gravel or small cobble | CDFG 1997a |
| | Rocky Gulch | 7 pool tail-outs measured | 2 ≤ 25% embedded | 0 > 50% embedded | 7 pool tail-outs measured | 5 – gravel or small cobble | CDFG 1997e |
| | Thompson Gulch | 107 pool tail-outs measured | 7 ≤ 25% embedded | 56 > 50% embedded | 107 pool tail-outs measured | 95 – gravel or small cobble | CDFG 1997g |
| | Railroad Gulch | 75 pool tail-outs measured | 4 ≤ 25% embedded | 47 > 50% embedded | 4 low gradient riffles measured | 3 – gravel or small cobble | CDFG 1996b |

**TABLE 5.18**
**EMBEDDEDNESS AND DOMINANT SUBSTRATE COMPOSITION (from CDFG Stream Inventory Reports)**

| Stream | Embeddedness | | | Dominant Substrate | | Ref. |
|---|---|---|---|---|---|---|
| Two Log Creek | 184 pool tail-outs measured | 2 ≤ 25% embedded | 96 > 50% embedded | 183 pool tail-outs measured | 140 – gravel or small cobble | CDFG 1998c |

### 5.3.4.2 Sediment Sources in JDSF -- California Department of Forestry and Fire Protection

CDF did not report any of the aquatic data collected as part of its watershed assessment in the Big River. Instead, CDF (1999) developed a relative risk index, using various watershed parameters to assess fish habitat and channel sensitivity. It appears that some $d_{50}$ and cobble embeddedness data may have been collected as part of this exercise.[66] Those data were not reported in the watershed assessment.

As part of the Jackson Demonstration State Forest HCP/SYP, CDF discussed sediment sources and impacts. CDF conducted a rapid sediment budget to assess different erosional processes between 1957 and 1997 and the degree to which logging and road construction may have increased sediment yield in the JDSF. CDF concluded:[67]

> This analysis suggests that from 1958 to 1997, the estimated average sediment yield has been approximately 856 t/mi$^2$/yr (300 t/km$^2$/yr), an approximately 2.5-fold increase over sediment yields during this period in the absence of logging and road construction. This increase has largely been caused by road-related erosion, including shallow landsliding and surface erosion. Improved forest practices and drier climate conditions since the mid-1970s have contributed to a 50% reduction in shallow landsliding rates, largely due to a decline in road-related failures, and reduced overall sediment yields. Despite this decline, the rapid sediment budget developed for this analysis indicates that hillslope erosion and sediment yield remain substantially higher than background rates.

CDF believed that shallow landsliding is the major mass wasting process in the JDSF assessment area, and that roads caused more than half of all shallow landslides. The planning watersheds in the Eastern WWAA[68] have the largest percentage of land predicted to be unstable due to high gradient slopes and a large percentage of area comprised of inner gorges, which CDF believed to be among the most susceptible landforms in the assessment area to mass wasting. CDF (1999) also found that road surface erosion potential is generally highest in planning watershed in the Eastern WWAA. Chamberlain Creek and lower North Fork Big River have high densities of riparian roads. James Creek was reported to have the highest density of all riparian and non-riparian roads in the JDSF assessment area. James Creek and Chamberlain Creek were found to have the greatest number of Class I stream crossings. CDF observed that estimated sediment production and delivery from JDSF riparian roads is highest in the Lower Big River, Chamberlain Creek, and Lower North Fork Big River planning watersheds.

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[66] The term $d_{50}$ is used as an indicator of watershed disturbance. It denotes the median particle size measured in a pebble count.

[67] CDF 1999, page I-23.

[68] North Fork Big River, East Branch North Fork Big River, Chamberlain Creek, and James Creek.

Stream channel sensitivity varies considerably throughout the JDSF assessment area, but several of the planning watersheds that are tributary to the Big River are rated by CDF (1999) as among the most sensitive to disturbances related to sediment.

#### 5.3.4.3 Spawning Habitat -- Louisiana-Pacific Corporation

L-P did not report any of the actual data collected as part of its watershed assessment in the Big River. Instead, L-P (1997a) combined the data in a series of equations in order to evaluate whether spawning, summer rearing, and overwintering habitat was poor, fair or good. The quality of spawning habitat is based primarily on sediment-related parameters, such as availability of spawning gravels, substrate embeddedness, and amount of subsurface fines. The methodology for rating habitat quality is poorly described , however, the results of the L-P 1997 watershed assessment are reported in Table 5.14 and are discussed in Section 5.3.2.4.

#### 5.3.4.4 Sediment Deposition -- Georgia-Pacific Corporation

G-P did not report any of the actual data collected as part of its watershed assessment in the Big River. Instead, G-P (1997) developed a rating system by which it evaluated all the sediment-related data. The rating system is poorly documented and, therefore, difficult to assess.

Regarding hillslope conditions in the Big River planning watershed, G-P concluded:[69]

> …56% (18 miles) of the streams received a high rating for road hazards with 24% (8 miles) receiving a low rating … Erosion and mass wasting ratings are low for 50% (16 miles) of the streams … Streamside landslide ratings are low for 41% (13 miles) of the streams … Most (13 miles) of the streams with high road hazard are in the Lower Middle Big River planning watershed.

Regarding channel response in the Big River planning watershed, G-P concluded:[70]

> Overall, sediment deposition is expected to be the most widespread response, with 76% (25 miles) of the streams rated as having high sensitivity for sediment deposition … Channel scour is also expected, with 64% (21%) [sic] of streams rated as having high sensitivity for scour … Bank erosion may be a less widespread response: 26% (8.5 miles) of the streams are rated having low sensitivity and 43% (14 miles) of streams rated as having high sensitivity …

G-P's 1997 watershed assessment interpretations are reported in Tables 5.16 and 5.17 and are discussed in Section 5.3.2.6.

#### 5.3.4.5 Estuarine Sediment Analysis -- Warrick and Wilcox

Warrick and Wilcox (1981) performed a sediment analysis in the Big River estuary as part of a much larger effort to describe estuarine conditions in the late 1970s.[71] The following is taken from Warrick and Wilcox (1981) and describes the findings related to the channel sediment:[72]

> The channel sediment in the Big River Estuary is dominated by medium-grained sand, usually constituting over 50 percent of each sample (Table 14). The coarsest sediment is found in the upper estuary, reflecting the influence of Big River and its sediment

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[69] G-P 1997, page 3-86.

[70] G-P 1997, page 3-86 and 3-87.

[71] A description of the methodology used in the estuarine sediment analysis is found in Appendix A of Warrick and Wilcox (1981).

[72] Warrick and Wilcox 1981, pages 224-225.

> transport. Gravel is very common in the river bed down to at least 9.9 kilometers (6.2 mi) above Mendocino Bay. Although not enough samples were collected to define the trend more clearly, a general decrease in coarse sand is displayed down the estuary.
>
> Below 5.6 kilometers (3.5 mi) above the mouth, a sharp increase in silt- and clay-sized particles is apparent in the channel. The silt and clay is 1 percent or less of the entire sample above this point, and 4.5 percent or greater below it. This probably reflects efficient winnowing of the fine material from the channel in the upper estuary, and less efficiency in the lower estuary.

The lower reaches of the estuary, strongly influenced by tidal action, showed more sediment distribution variability than elsewhere in the estuary. Medium and fine sand constituted 97 to 99% of the samples at the north side of the mouth of the estuary. On the south side where tidal currents were weaker, significantly higher concentrations of silt and clay were found.

## 5.4 SUMMARY AND SYNTHESIS

### 5.4.1 UPPER BIG RIVER

The Upper Big River subwatershed includes Martin Creek, Valentine Creek, Russell Brook, and Pig Pen Gulch.

Coho have been observed in the Upper Big River and in Martin Creek. Steelhead have been observed in the Upper Big River, Martin Creek, Russell Brook Creek, Pig Pen Gulch, and Valentine Creek. The Upper Big River is one of only seven sites in the Big River watershed where more than 40 individual steelhead were observed.

The water temperature data found for the subwatershed includes only the Upper Big River and Russell Brook Creek. The Upper Big River and Russell Brook Creek had maximum and MWAT temperatures above the preferred coho range. Russell Brook Creek, though still above the preferred temperature range for coho, was cooler – the maximum temperature was reported to be 18.1°C and the MWAT was reported to be 16.0°C.

L-P concluded that the Upper Big River and Russell Brook Creek have a low potential for coho production because of poor quality summer rearing habitat due to low LWD levels and a low number of pools. Overwintering conditions were described as fair.
Spawning gravels were low in quantity and poor in quality. Moderate to high levels of fine sediment were observed in the gravels. Martin Creek also was reported to have substantial quantities of fine sediment in the substrate.

There is not a lot of information specific to the Upper Big River watershed. Available data, though, indicate that the salmonid population, especially the coho population, is depressed. The low frequency and reduction in pool volume by sediment, lack of LWD, and poor quality of spawning gravels lead to a degraded habitat for salmonids.

### 5.4.2 NORTH FORK BIG RIVER

The North Fork Big River subwatershed includes Soda Gulch, James Creek, North Fork James Creek, East Branch North Fork Big River and the North Fork Big River, covering a total of 26.86 stream miles. Only in the Upper North Fork Big River planning watershed is there any significant rangeland management (13% of the planning watershed) in addition to timberland management.

Coho and steelhead are present, though not in great numbers, in the subwatershed. In surveys in the mid-1990s, steelhead of all age classes were represented – the only place in the Big River watershed where two-year steelhead were observed. The East Branch North Fork Big River was one of seven locations where more than 40 steelhead were found.
In a Big River population survey that took place in the early 1970s salmonid biomass was the greatest in the North Fork Big River and lowest in the East Branch North Fork Big River. In more recent MRC surveys, coho were found in the East Branch North Fork Big River, the North Fork Big River, and Bull Pen Gulch. At the North Fork Big River sampling location, between ten and 40 coho were counted – higher than elsewhere in the watershed (except for Daugherty Creek).

Forty-five percent of the North Fork Big River subwatershed stream channel is flatwater, 31% is comprised of pools, and 23% in riffles. The mean pool depth throughout the subwatershed is less than two feet. The mean pool depth is less than 0.8 feet in Soda Gulch and North Fork James Creek. The Lower North Fork Big River planning watershed has the lowest drainage density in the JDSF assessment area (5.3 miles of stream per square mile of drainage area). The dominant substrate in pool tail-outs and low-gradient riffles was gravel and small cobbles, but the embeddedness of the substrate was generally high.

Some of the highest channel sensitivity scores in the JDSF assessment area are reported in the Lower North Fork Big River planning watersheds. This means that the channels are both valuable as habitat and vulnerable to the adverse effects of sedimentation from erosion in the subwatershed. The channels in this stream are particularly valuable as habitat because of the relatively high abundance of low-gradient channels that are not confined. Channel sensitivity scores in Upper North Fork Big River, James Creek, Chamberlain Creek, and East Branch North Fork Big River planning watersheds are moderate in comparison to those throughout the JDSF assessment area.

The North Fork Big River, East Branch North Fork Big River and James Creek are predicted to be unstable due to high gradient slopes and a large area of inner gorges. Additionally, this area has high potential for road surface erosion.

Of the subwatersheds in the JDSF assessment area, documented LWD removal is highest in the James Creek planning watershed, with 85.7% of its Class I stream having been subject to LWD removal. Mean canopy cover in the subwatershed is 70% overall, with only Soda Gulch having above 80% canopy cover. Canopy cover in North Fork Big River is especially low – only 60%. James Creek has a mean canopy cover of only 63% and conifers provide only 46% of the cover.

At the upper James Creek the maximum water temperature recorded was 16.5°C and the minimum was 9.8°C, the average was less than 15°C; these are above the 12-14°C coho preferred range cited in Chapter 2. The temperature at this site was fairly constant. At mid-James Creek, the maximum temperature was recorded at 20.5°C, the minimum was 10.9°C and the average was less than 18°C; these temperatures are above the coho preferred range. MRC reported temperature ranges on the East Branch North Fork Big River between 1997 and 2000. Maximum temperatures averaged 20.4°C, and MWATs ranged between 17.1°C and 17.9°C -- above the coho preferred range.

In a 1997 sustained yield plan, L-P concluded that spawning habitat was good but overwintering and summer rearing habitat were poor on the East Branch North Fork Big River and the North Fork Big River. Although L-P's data could not be verified, the conclusion is supported by other reports.

Available data indicate that the salmonid population, especially the coho population, is depressed in the North Fork Big River subwatershed. The low gradient channels of the Lower North Fork could be important habitat for coho, which makes the high erosion potential upstream in the subwatershed particularly unfortunate. The shallow pools, lack of LWD, embeddedness, and low canopy cover lead to a degraded habitat for salmonids.

### 5.4.3 TWO LOG CREEK

The Two Log Creek subwatershed includes Tramway Gulch, Beaver Pond Gulch and the middle portion of the Big River.

Coho and steelhead have been reported in Two Log Creek and the middle portion of the Big River, though the population numbers were not large. Coho have not been reported in Tramway Gulch or Beaver Pond Gulch. The survey location on the middle Big River is one of seven locations in the Big River watershed where more than 40 steelhead were reported.

Seventy-four percent of Two Log Creek is comprised of dry channel, 14% is flatwater and 7% is comprised of pools. The mean pool depth in is less than 0.63 feet. The mean pool shelter rating is less than 20%. The canopy cover in Two Log Creek is high – 94% with 98% of that provided by conifers. The Two Log Creek planning watershed contains a great amount of stream length of high relative sensitivity due to the high proportion of low-gradient, non-confined streams. The dominant substrate in pool tail-outs of Two Log Creek was gravel and small cobbles, but the embeddedness of the substrate was generally high.

Temperature data for the subwatershed are limited. Two Log Creek data indicate maximum water temperatures above the preferred coho range – a maximum of 17.8°C was reported. The MWAT value was reported to be 15.8°C, cooler but still above the range cited in Chapter 2. The water temperature data for the middle Big River sampling site was even less conducive to salmonids – the maximum was 22.7°C and the MWAT was 19.4°C.

G-P evaluated channel responsiveness in the Big River watershed and concluded that the lower middle Big River was highly responsive to sediment deposition, channel scour, and bank erosion but not highly responsive to pool formation. G-P also assessed stream habitat and concluded that the lower middle Big River has medium habitat complexity, low fine sediment, very high coarse sediment, and medium shade.

In a 1997 sustained yield plan, L-P concluded that the potential for coho production in Two Log Creek, Tramway Gulch and the middle Big River was poor. Spawning conditions and overwintering conditions were poor or fair, and summer rearing conditions were limiting.

Available data indicate that the salmonid population, especially the coho population, is depressed in the Two Log Creek subwatershed, even though the subwatershed has a large amount of low gradient, unconfined stream channel -- important habitat for salmonids. The low frequency and low pool volume and poor spawning gravels leads to poor rearing and overwintering conditions for salmonids.

### 5.4.4 SOUTH FORK BIG RIVER

The South Fork Big River subwatershed includes South Fork Big River, Daugherty Creek, Gates Creek, Johnson Creek, Snuffins Creek, Ramon Creek and Soda Creek, covering a total of 12.33 stream miles.

Coho and steelhead have been observed in the South Fork Big River, North Fork Ramon Creek, Ramon Creek, and Daugherty Creek. Coho redds were observed in Ramon Creek and Daugherty Creek. Coho have not been observed elsewhere in the subwatershed. Steelhead have been observed throughout the subwatershed except for Johnson Creek. The South Fork Big River, Ramon Creek, Daugherty Creek and Gates Creek were four of seven locations in the Big River watershed where more than 40 steelhead have been counted.

Thirty-eight percent of the South Fork Big River subwatershed is comprised of riffles, 39% is flatwater, and 21% is comprised of pools. Johnson Creek is 15% dry channel. Throughout the subwatershed, mean pool depth is less than two feet. Mean pool depths in Johnson Creek, Snuffins Creek, and Soda Creek were less than one foot. Mean pool depth was deepest in Daugherty Creek. (The South Fork Big River itself was not surveyed in this assessment.) Except for Soda Creek, mean canopy cover did not exceed 80%. Mean canopy cover in Soda Creek was 93%, but only 49% was comprised of conifers. The dominant substrate in pool tail-outs and low-gradient riffles was gravel and small cobbles, but the embeddedness of the substrate was generally high.

Water temperature data for the South Fork Big River are limited to MRC data for 1997 to 2000. The temperature data for the South Fork Big River, Ramon Creek, Daugherty Creek, and Gates Creek show temperatures well above the preferred range for coho. Data for the North Fork Ramon Creek, though still above the preferred range for coho, show lower temperatures -- a maximum temperature of 17.2°C and an MWAT of 15.1°C.

L-P concluded that the South Fork Big River, Gates Creek, Daugherty Creek and Ramon Creek provide poor habitat for coho due to poor summer rearing habitat – limited cover, lack of pools and low LWD. Only the South Fork itself was rated good for spawning, but it was rated poor for summer rearing and fair for overwintering.

Available data indicate that the salmonid population, especially the coho population, is depressed in the South Fork Big River subwatershed. In this subwatershed, Daugherty Creek and Ramon Creek appear to have the best salmonid populations, even though those populations are still very small. The low number of pools, low pool volume, low canopy cover, low LWD, high embeddedness, and high water temperatures leads to poor salmonid habitat.

### 5.4.5 CHAMBERLAIN CREEK

The Chamberlain Creek subwatershed includes Chamberlain Creek, Lost Creek, Water Gulch, West Chamberlain Creek, and Gulch 16, covering 13 miles of stream.

Coho have been reported in Chamberlain Creek and Water Gulch. Steelhead have been reported in Chamberlain Creek, Park Gulch, Water Gulch, and West Fork Chamberlain Creek.

Stream channel surveys show that Chamberlain Creek is especially degraded with channel entrenchment and LWD depletion. Channel sensitivity scores, however, show that Chamberlain Creek is moderate compared to other areas of the JDSF. Forty-eight percent of the streams in the subwatershed are comprised of flatwater, 29% pools and 21% riffles. The mean pool depth is less than 1.25 feet. In Lost Creek, Water Gulch, and Gulch 16, the mean pool depth is less than one foot. The dominant substrate in pool tail-outs in Chamberlain Creek and West Chamberlain Creek was gravel and small cobbles, but the embeddedness of the substrate was generally high.

Canopy cover is generally greater than 90%, most of which is provided by conifers; West Chamberlain Creek and Chamberlain Creek have lower levels of canopy cover. The Chamberlain Creek subwatershed has a large percentage of land predicted to be unstable due to high gradients and inner gorges. Chamberlain Creek is estimated to have a high amount of sediment delivery from riparian roads.

Available data indicate that the salmonid population, especially the coho population, is depressed in the Chamberlain Creek subwatershed. The channel entrenchment, LWD depletion, low number of pools, low pool volume, high sediment input, high embeddedness, and low canopy cover in two streams creates to poor rearing and overwintering habitat.

### 5.4.6 LITTLE NORTH FORK BIG RIVER

The Little North Fork Big River subwatershed includes the Little North Fork Big River, Berry Gulch, Manly Gulch and Rocky Gulch, covering a total of 8.12 stream miles.

Coho have been reported in lower Little North Fork Big River, Berry Gulch and the East Branch Little North Fork Big River. In three different surveys, coho density was highest in Berry Gulch than elsewhere in the Big River watershed. Steelhead have been reported in lower Little North Fork Big River, Berry Gulch and the East Branch Little North Fork Big River.

Wetlands are an important feature of the Little North Fork Big River. Log transport railroads were constructed along the Little North Fork Big River at the turn of the last century. While the Little North Fork Big River has relatively high amounts of LWD, removal of LWD has been reported in Berry Gulch and the East Branch Little North Fork Big River. Stream shading is low in Berry Gulch. Some of the highest channel sensitivity scores in the JDSF were found in Berry

Gulch, reflecting the low gradient, unconfined channel. Forty percent of the stream channels in the Little North Fork Big River subwatershed are comprised of flatwater, 38% pools, and 13% riffles. The mean pool depth is less than 1.5 feet, except for a tributary to Berry Gulch where the mean depth of a backwater pool is 2.28 feet. Mean canopy cover is near or above 90%, with almost all the canopy provided by conifers. The Little North Fork Big River has moderate to high sediment deposition, moderate channel scour, high bank erosion, and low to moderate pool formation. The Little North Fork Big River has high habitat complexity, and more coarse sediment than fine sediment. The dominant substrate in pool tail-outs and low-gradient riffles was gravel and small cobbles, but the embeddedness of the substrate was generally high, indicating a system that is highly impacted by sediment.

Available data indicate that the salmonid population, especially the coho population, is depressed in the Little North Fork Big River subwatershed. Berry Gulch seems to have a higher population of coho then elsewhere in the watershed, but even so the numbers are small. The subwatershed has low gradient, unconfined channels, which can be valuable, complex habitat but are vulnerable to sedimentation. Generally, there is low pool volume and frequency throughout the subwatershed. Canopy cover is good, but other habitat parameters are outside of properly functioning conditions, including LWD removal, low number of pools, low pool volume, high embeddedness, and high sediment input.

### 5.4.7 LOWER BIG RIVER, RAILROAD GULCH, LAGUNA CREEK

The Lower Big River has the longest estuary in northern California. Coho and steelhead have been observed in the Lower Big River and the estuary.

Stream shading is low in the Lower Big River. The Lower Big River has a high standardized channel sensitivity score, indicating low gradient channels that are vulnerable to sedimentation. The Lower Big River has high sediment deposition, high channel scour, moderate bank erosion, and low pool formation. The Lower Big River has medium to high habitat complexity. The sediment production from riparian roads is estimated to be high in the Lower Big River. The channel sediment in this reach is dominated by medium grained sand; the banks in this reach seem to be the main deposition for finer silt and clay particles. The deposition and distribution of sediment in the lowest reaches is largely influenced by tidal flux. The Lower Big River has average bed substrate particle size too small to provide suitable habitat for spawning or rearing coho salmon or steelhead.

Laguna Creek has moderate to high sediment deposition and channel scour, and low to moderate bank erosion and pool formation. Laguna Creek has medium to high habitat complexity, low fine sediment, and high shade. LWD has been removed from Laguna Creek.

Fifty-two percent of the stream channel in Railroad Gulch is comprised of flatwater and 35% is pools. The mean depth of main channel and scour pools in Railroad Gulch is less than 0.80 feet but the backwater pool surveyed was 2.00 feet deep. Canopy cover in Railroad Gulch is 93 percent, with only 64% of the cover provided by conifers. In Railroad Gulch, the dominant substrate in low-gradient riffles was gravel and small cobbles, but the embeddedness of the substrate was generally high.

Estuaries are areas of natural sedimentation; however, excessive sedimentation leading to levee formation is cutting the Lower Big River off from the adjacent floodplains. In addition to natural levee formation, levees were constructed for log transport railroads along the Lower Big River, Laguna Creek and Railroad Gulch. The separation of the river from the floodplains reduces tidal flux through the salt marshes which is important for primary production.

Available data indicate that the salmonid population, especially the coho population, is depressed in the Lower Big River, Laguna Creek, Railroad Gulch and estuary. These areas have low gradient, unconfined channels, which can be valuable, complex habitat but are vulnerable to sedimentation. Pool volume is low, also reducing sheltering habitat. The estuary is being cut off from the off channel habitat by sediment-induced levee formation; this will not only reduce off channel sheltering but will reduce the biological productivity of the entire watershed. The low gradient channels in these areas shows the effects of upstream sediment input, further reducing salmonid habitat conditions.

## 5.5 CONCLUSIONS AND RECOMMENTATIONS

Available data are inadequate to quantify population trends of coho and steelhead in Big River watershed streams, however, regional data suggest that coho and steelhead have declined substantially this century. Historically, coho and steelhead are thought to have occurred throughout the Big River watershed in streams that are accessible to salmonids. Coho are present in some areas in the watershed, but the numbers and distribution is low. Steelhead are relatively more distributed and abundant, but, even so, the population is low compared to historic levels.

Overall, the Big River watershed has poor quality summer rearing and overwintering habitat due to low LWD levels, a low number of pools, reduced pool volume, and limited cover. Spawning gravels are impacted by embeddedness, fine sediment and scouring. In some areas, channel entrenchment is a problem. In many areas, habitat is adversely impacted by lack of hydrologic connectivity with off-channel habitat.

CDF concluded that the salmonid habitat of the JDSF was limited by overwintering and summer rearing habitat, consistent with channel entrenchment, sediment loading and LWD removal. These conclusions seem to apply to the entire Big River watershed. Recovery, CDF concluded, will require recruitment of LWD, controlling sediment sources, and increasing sediment transport capacity. CDF notes that entrenched channels can take centuries to recover and re-establish functional links to the floodplains and off-channel habitat (CDF 1999).

Sedimentation is a cause of habitat degradation in the Big River watershed. Wilcox expressed concerns about sedimentation on the estuarine processes in the Big River. She stated, “Timber harvesting within the valley has apparently increased erosion on the slopes above Big River. Subsequently, the sediment load of the river has increased, as most of the material eroded within the entire 429 square kilometers (165 sq mi) watershed is eventually transported to the river.”[73] Wilcox explained that estuaries are subject to natural sedimentation with the coarser particles settling out upriver and the finer particles settling out in the estuary and floodplains along the lower reaches of the estuary. She believes, however, that sedimentation greatly accelerated after

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[73] Wilcox 1981, page 216.

logging began resulting in a major decrease in width and rapid sediment build-up along the banks in the lower river. The narrowing channel caused an increase in water velocity and increased deposition of fine sediment on the floodplains in the tidal areas. Wilcox argues that "Levees built up at the edges of wetland flats where they adjoin the main channel are primary indicators of this rapid sediment accretion. These levees now [1981] extend at least 3 kilometers (2 mi) further down the estuary than they did 80 years ago."[74] Wilcox expressed concern about the effect of excessive sedimentation in the estuary on vegetation, because sediment-driven levee formation has cut off tidewater intrusion in and around the estuarine sloughs. Wilcox finds this to be an alarming trend because the productivity of the estuary relies heavily on the production of salt marshes. Reneau (1981b) agreed with Wilcox. Reneau noted that sedimentation in the Big River estuary has reduced the area of salt marshes and has reduced tidal flux in large areas, resulting in a great decrease in the biological productivity of the estuary. Reneau states, "Conditions in an estuary are intimately linked to conditions in the adjoining watershed; it is essential that excessive erosion from logging and other human activities be controlled if estuaries are to be maintained as viable, productive ecosystems."[75]

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[74] Wilcox 1981, page 217.

[75] Reneau 1981b, page 259.

# Chapter 6
# Albion River Watershed

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## 6.0 BRIEF CONCLUSIONS

In general, the most sensitive beneficial use in the Albion River watershed – protection of salmonid species – is limited by poor habitat conditions that include excess sediment, lack of complex, deep pools, poor spawning gravels and poor shelter. Excess sediment is adversely impacting the number and volume of pools – a limiting factor for salmonids in the watershed. Sediment is also causing a moderate to high embeddedness of substrate and spawning gravels in the basin. Shelter is poor throughout the basin. Coho salmon and steelhead spawn and rear in the watershed, however, both species are present in very low numbers compared to historic levels and are continuing to decline. Although greatly reduced from historical levels, low numbers of coho and steelhead are found distributed throughout the basin. Steelhead are relatively more abundant and have more age classes represented than do coho.

Lower Albion River: The habitat quality of the Lower Albion has been assessed as fair – limited by low shelter complexity. Compared to the rest of the watershed, only in the Lower Albion do pools of at least three feet deep comprise a sizeable portion of the reach. The canopy closure is fair to good. Reported stream temperature data indicate that Railroad Gulch in the Lower Albion planning watershed generally has lower temperatures than the rest of the Albion River Watershed. Low dissolved oxygen concentrations in the estuary may be a limiting factor for salmonid use of the estuary.

Middle Albion River: The Middle Albion River spawning habitat was assessed as fair with moderate to low levels of embeddedness and fair to good gravel quality. East Railroad Gulch has relatively unembedded spawning gravels. The overall rating for spawning habitat in the Middle Albion was negatively affected by the amount of fine sediment in the watercourses. Rearing habitat was negatively affected by the low percentage of deep pools. Overall, the Middle Albion subwatershed is judged to have sparse large woody debris (“LWD”).

South Albion River: The South Fork planning watershed has, by far, the highest sediment input to watercourses in the Albion River watershed, with most of its sediment coming from roads. The habitat quality is adversely affected by the amount of embeddedness of spawning gravels and the abundant deposition of fine sediment. The condition of spawning gravels on the South Fork Albion River is lower quality than the mainstem and other areas in the watershed. Although there are deep pools and ample LWD, rearing habitat was judged to be only fair due to the high levels of embeddedness and lack of shelter complexity. Stream temperature data for much of the South Fork Albion River planning watershed are at, or above, the preferred range for steelhead and coho. In various population surveys, the numbers of observed coho was highest or second highest in the streams of the South Fork planning watershed. The middle portion of the South Fork Albion River contained a high proportion of deep pools to shallow pools, but the total number of pools in the reach was small. In spite of the low total number of pools, the availability of deeper pools in the South Fork Albion River may partially explain the greater density of coho salmon in the South Fork Albion River as compared to other tributaries in the Albion River watershed.

Upper Albion River: There is little information on stream conditions and salmonid population in the Upper Albion River planning watershed. Limited surveys found relatively good spawning habitat with moderate to unembedded gravels. The rearing habitat is rated as fair, due to shallow pools and low shelter complexity. The overwintering habitat is good with LWD and frequent pools. Compared to the rest of the Albion River watershed, the North Fork planning watershed has lower stream temperatures, although the summer temperatures are at the higher end of the preferred range.

## 6.1 GENERAL BACKGROUND

### 6.1.1 BASIN PLAN – BENEFICIAL USES

The primary beneficial use of concern in the Albion River watershed, as described in the *Water Quality Control Plan, North Coast Region* ("the Basin Plan," California North Coast Regional Water Quality Control Board 1994), is the cold freshwater fishery which supports coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*), both listed as threatened under the federal Endangered Species Act.[76]

The Basin Plan also identifies municipal, industrial, agricultural, and recreational uses of the Albion River watershed. The beneficial uses of water related to rare, threatened or endangered species has been proposed for this basin. As with many of the north coast watersheds, the cold water fishery appears to be the most sensitive of the beneficial uses in the watershed. Accordingly, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation.

The Basin Plan identifies the following additional beneficial uses related to the Albion River watershed's cold water fishery:

- Commercial and sport fishing;
- Cold freshwater habitat;
- Migration of aquatic organisms;
- Spawning, reproduction, and early development; and,
- Estuarine habitat.

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[76] 61 FR 56138 and 65 FR 36074.

### 6.1.2 LOCATION

The Albion River watershed drains an area of approximately 27,500 acres, about 43 square miles. The Albion River estuary is located near the town of Albion and is approximately 16 miles south of the city of Fort Bragg. It primarily drains from the east to the west, sharing ridges with the Big River watershed to the north and northeast and the Navarro River watershed to the southeast and south. Elevations range from sea level to 1,566 feet. A map showing the location of the watershed within the Mendocino Coast Hydraulic Unit is attached (Map 1.1).

The Albion River watershed is divided into four Planning Watersheds (“PW”), as designated under the CalWater California Watershed Map (Interagency California Watershed Mapping Committee 1999). These are described in Table 6.1. The PWs range in size from 4,878 acres to 8,739 acres and are generally divisions of the Albion River mainstem and its associated tributaries. The main tributaries of the Albion River include: Railroad Gulch, Pleasant Valley Creek, Duck Pond Gulch, South Fork Albion River, Tom Bell Creek, North Fork Albion River, and Marsh Creek. A map showing the Albion River watersheds and its tributaries, along with the Little River watershed to the north and the Salmon Creek watershed to the south is attached (Map 6.1). The Mendocino Redwood Company (“MRC”), an industrial forestry company, owns approximately 54% of the land contained in the Albion River watershed. MRC property is concentrated in the Lower Albion River, Middle Albion River, and South Fork Albion River planning watersheds (113.40001, 113.40002, and 113.40003, respectively).

**TABLE 6.1**
**PLANNING WATERSHEDS WITHIN THE ALBION RIVER WATERSHED (from Interagency California Watershed Mapping Committee 1999)**

| PLANNING WATERSHED NUMBER | PLANNING WATERSHED NAME | PLANNING WATERSHED SIZE | |
|---|---|---|---|
| | | acres | square miles |
| 1113.400001 | Middle Albion River | 4,878 | 7.62 |
| 1113.400002 | South Fork Albion River | 5,837 | 9.12 |
| 1113.400003 | Lower Albion River | 8,076 | 12.62 |
| 1113.400006 | Upper Albion River | 8,739 | 13.65 |
| **TOTAL** | Albion River Watershed | 27,530 | 43.01 |

The geology of the Albion River watersheds, along with the Little River watershed to the north and the Salmon Creek watershed to the south, is shown in Map 6.2. Most of the watershed is the Coastal Belt Franciscan Complex (shown as TKfs on map 6.2). A large part of the geology of the Upper Albion River watershed is Coastal Belt Franciscan Complex – greenstone formation (TKfs-gs). Terrace deposits (Qt) are found in the upper Albion River watershed around Comptche and around the North Fork Albion above Soda Spring Creek. Marine Terrace deposits (Qmts) are in the south part of the lower Albion River watershed stretching into the Salmon Creek watershed. On the north end of the lower Albion River watershed, stretching into the Little River watershed, Marine Terrace – upper Caspar Orchard (Qmts-u) deposits are found. In a narrow strip along the lower mainstem and along Tom Bell Creek, undivided Quaternary sedimentary rocks (Q) are found. Two small areas of alluvial fan/colluvium (Qac) are found at the upper part of the South Fork Albion watershed.

### 6.1.3 CLIMATE

The Mediterranean climate in the watershed is characterized by a pattern of low-intensity rainfall in the winter and cool, dry summers with coastal fog. Mean annual precipitation is 41 inches at Fort Bragg near the western margin of the watershed and 51 inches at Willits to the east (Western Regional Climate Center [WRCC] 2000a). About 90% of the precipitation in this area falls between October and April, with the highest average precipitation in January (WRCC 2000a). Snowfall in this watershed is very rare and hydrologically insignificant (WRCC 2000a).

The Albion River watershed has a Mediterranean climate, characterized by a pattern of low-intensity rainfall in the winter and cool, dry summers with coastal fog. Mean annual precipitation is 40 inches at Fort Bragg near the western margin of the watershed and 51 inches at Willits to the east (WRCC 2000a). About 90% of the precipitation in this area falls between October and April with the highest average precipitation in January (WRCC 2000a). Snowfall in this area is very rare and hydrologically insignificant (WRCC 2000a). A map showing precipitation patterns in the Albion River watershed, along with the Little River watershed to the north and the Salmon Creek watershed to the south is attached (Map 6.3).

### 6.1.4 VEGETATION

The Albion River, like the other coastal watersheds in Mendocino County, lies in the Oregonian Biotic Province (Warrick and Wilcox 1981). As with these other watersheds, redwood and Douglas Fir forest dominate the Albion River watershed (Dolphin 1996). White (1984) reported on a 1949 vegetation survey of the Pleasant Valley, a small valley opening into the Albion River approximately one-half mile upstream of the mouth. The survey identified the following assemblages: redwood and fir forest, laurel and poison oak, chaparral, salt marsh, sedge, coast hemlock, cypress, red alder, velvet grass, blackberry, bull thistle, and tangled underbrush. A map showing the vegetation coverage in the Albion River watershed, along with the Little River watershed to the north and the Salmon Creek watershed to the south is attached (Map 6.4).

The Albion River has a large estuary with tidal intrusion extending as much as five miles (Maahs and Cannata 1998). It contains over two miles of eel grass beds, as well as algae, sea-lettuce, rock weed, and red laver (White 1984; Dolphin 1996).

## 6.2 SALMONID DISTRIBUTION AND ABUNDANCE

Population abundance trends are an indicator of risk in salmonid populations. Trends may be quantified if data such as spawner surveys, dam or weir counts, stream surveys and catchment are available. If quantitative data are not available, general trends in population abundance may be estimated by comparing historical and current estimates.

Historic data regarding salmonid abundance and distribution in the Albion River watershed are limited. Many of the reports providing historic data can be used merely for indicating presence or absence of fish and not for quantitative analysis. While it is clear that information gathered from different sources using different methodologies cannot be directly compared, the information can be used to indicate presence and, possibly, the scale of the population size.

Trends in salmonid population size in Mendocino County and the State of California are given by Brown et al. (1994), Weitkamp et al. (1995), and others. The current distribution and abundance of coho and steelhead is indicated by surveys conducted by Mendocino Redwood Company and by its predecessor, Louisiana-Pacific Corporation ("L-P"), and spawner surveys conducted under a grant from the Coastal Land Trust. The California Department of Fish and Game ("CDFG") also reported fish population data for the Albion watershed in various stream and habitat surveys.

### 6.2.1 SUMMARY –SALMONID ABUNDANCE AND DISTRIBUTION

There are no quantitative data from which to estimate the historic population size of coho and steelhead in the Albion River watershed although there is general agreement that the populations of both have decreased substantially and continue to decline. Although greatly reduced from historic levels, low numbers of coho and steelhead are found distributed throughout the basin.

It is believed that native California coho populations have declined by 80 to 90% from their numbers in the 1940s (Brown et al. 1994; Weitkamp et al. 1995; Hassler et al. 1991). Steelhead populations also are in decline. NMFS status review of west coast steelhead concluded that steelhead stocks in the northern California ESU[77] are very low, "Population abundances are very low relative to historical estimates, and recent trends are downward in stocks for which we have data…"[78]

### 6.2.2 SALMONID ABUNDANCE AND DISTRIBUTION BEFORE THE 1990S

There are no known quantitative analyses of historic salmonid abundance and distribution in the Albion River watershed. As described in Chapter 2, salmonid abundance has declined dramatically throughout the Mendocino Coast Hydrologic Unit. The coho population is estimated at 4,950 fish in Mendocino County (Brown et al. 1994; Weitkamp et al. 1995).

Brown et al. (1994) cited sources stating that there were approximately 200,000 to 500,000 coho spawning in California in the 1940s. They estimated that the statewide population had declined to about 100,000 fish in the 1960s and about 30,000 in 1984-1985. In discussing the difficulty with ascertaining the historical abundance, Brown et al. (1994) stated, "Unfortunately, there is no way to test the reliability of the earlier estimates, and they are best regarded as accurate only within an order of magnitude."[79] Brown et al. (1994) reported data from NMFS regarding commercial landings of coho and chinook from 1976 to 1993. Coho landings fell from a high in 1976 of 3.6 million pounds in California, to a low in 1992 of 11,000 pounds, a decline of 99%. Hassler et al. (1991) reported that coho salmon run sizes in California have decreased by 80% to 90% of the 1940s levels. Weitkamp et al. (1995) discuss reports indicating that wild coho in California do not exceed 1300 individuals, and that 46% of the streams that historically supported wild coho no longer support these runs. Adams et al. (1999) reported that coho are found in 51% of the streams in which they were historically present in California, and 64% of the streams in Mendocino County in which they were historically present.

CDFG performed stream surveys in the Albion River watershed in the 1960s and 70s, which can be used to indicate stream conditions and salmonid presence. In a survey conducted on mainstem Albion River in October 1961 (CDFG 1961c), about two to three coho per pool were

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[77] The northern California ESU for steelhead includes river basins from Redwood Creek in Humboldt County to the Gualala River (inclusive).

[78] Busby et al. 1996, page 8.

[79] Brown et al. 1994, page 238.

found from the lagoon to a point above the confluence with McDonald Gulch (almost the entire length of the Albion River). Flow was low and coho fingerlings were observed stranded in drying pools. In a supplementary survey conducted on the mainstem in July 1966 (CDFG 1966a), surveyors caught and released 126 coho fingerlings that were under "some stress" and 153 steelhead that were stressed and undersized. The surveyors noted that the coho and steelhead populations could be much larger if the spawning gravels were more available to adults and if nursery grounds were more available to parr. The mainstem Albion River was also surveyed in January and February of 1979 (CDFG 1979). This survey noted that 22 salmon were counted in thirty minutes at a riffle just above the estuary.

In CDFG surveys of the South Fork Albion (CDFG 1961a and CDFG 1966b), steelhead and coho were observed in very low numbers. In October 1961, coho were observed only in a lower pool near the mainstem. Very few steelhead were seen, "…only about 1 per 3 or 4 pools…"[80] The surveyors attributed the low numbers to damage from logging and post-logging fires. In a July 1966 supplementary survey of the South Fork Albion (CDFG 1966b), coho and steelhead were noted at increased numbers compared to the 1961 surveys. Surveyors netted and released 182 coho and 99 steelhead parr. The surveyors commented that "The South Fork of the Albion River below its tributary Little North Fork provides excellent spawning grounds and fair nursery grounds."[81] The South Fork Albion above where the Little North Fork enters, however, was deemed to have "no value" to fish.

Other CDFG surveys of the Albion River watershed include:

- An October 1961 survey of the North Fork Albion (CDFG 1961b) found coho and steelhead, but surveyors noted that the North Fork "…appears to be a poor spawning and nursery area throughout most of its length."[82]
- An October 1961 survey of Railroad Gulch (CDFG 1961d) observed no fish and only small, stagnant ponds.
- An October 1961 survey of Morrison Gulch (CDFG 1961e) observed no fish. The surveyors noted that the tributary received extensive damage from past logging and fire.
- An October 1962 survey of Kaisen Gulch (CDFG 1962) observed steelhead and coho in the lower 0.1 mile. These fish were deemed to be in good condition.

Jones (2000) prepared a draft "Current Stream Habitat Distribution Table" for California coastal salmon and steelhead citing sources indicating the historic presence or absence of salmonids in the Albion River watershed. Jones reported on the presence of coho and steelhead, but not of chinook. In this reference, the presence of juvenile coho and steelhead was reported at the:

- Albion mainstem at river mile 14 in 1961;
- Albion mainstem at river mile 16 in 1983;
- North Fork Albion at river mile 4 in 1961; and,
- North Fork Albion, river mile unknown, in 1966.

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[80] CDFG 1961(a), page 2.

[81] CDFG 1966(b), page 3.

[82] CDFG 1961(b), page 3.

### 6.2.3 COHO – CURRENT ABUNDANCE AND DISTRIBUTION [83]

Wehren (1996) estimated the Albion River mainstem and North Fork Albion River coho spawning population in the winter of 1995-96 to be between four and 43 coho. This estimate is based on three assessment procedures, including a spawner survey conducted that winter in 2.4 miles of stream in the Albion River watershed. The estimate is presumed to be low due to the late start of sampling, the poor surveying weather, and the limited extent of stream surveyed.[84] Wehren (1996) stated that the coho found in the Albion are likely native since there is no record of hatchery coho plantings in this watershed.[85] Unpublished CDFG data discussed in Section 6.2.5, however, indicates two releases of hatchery coho in the Albion River in 1969 and 1970. The data collected in the Wehren 1995-96 survey are shown in Table 6.2.

**TABLE 6.2**
**WINTER 1995-1996 SURVEY: COHO AND STEELHEAD (Wehren 1996)**

| | **NUMBER OF CARCASSES** | | | **NUMBER OF LIVE FISH** | | | **NUMBER OF SKELETONS** | | | **NUMBER OF REDDS** |
|---|---|---|---|---|---|---|---|---|---|---|
| **SAMPLING LOCATION** | **Coho** | **Steelhead** | **Unknown** | **Coho** | **Steelhead** | **Unknown** | **Coho** | **Steelhead** | **Unknown** | |
| Mainstem Albion | 12 | 2 | 0 | 2 | 0 | 0 | 4 | 0 | 0 | 9 |
| North Fork Albion | 6 | 0 | 4 | 0 | 0 | 6 | 0 | 0 | 0 | 7 |

The author expressed concerns about potential undercounts in this survey,[86] however, the author concluded that the native run of coho is “severely depleted.”

#### 6.2.3.1 FISH DISTRIBUTION DATA –LOUISIANA-PACIFIC AND MENDOCINO REDWOOD COMPANY

Louisiana-Pacific Corporation and its successor, Mendocino Redwood Company, sampled the Albion River watershed for the presence of rearing salmonids, including coho salmon and steelhead by using electrofishing techniques.

MRC (Daugherty 1996) reports on the presence of juvenile coho at six sampling stations – three on the Albion River and three on the South Fork Albion River. These stations were grouped together in the report so that the three mainstem stations are reported as one, as are the three

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[83] For the purposes of this discussion, data gathered during and after the 1990s are considered current.

[84] Out of an estimated 45 miles of Class I stream in the Albion River watershed (Sanborn 2000) only 2.4 miles were sampled. One reason for the limited sampling was that the surveyors focused on lands not owned by industrial forestry corporations, knowing that the forestry corporations already were conducting surveys on their lands (Wehren 1996).

[85] Wehren 1996, page 3.

[86] Wehren explained: “A series of storms in January and February kept the water high and visibility low for an extended period of time. Only three to four surveys were possible in much of the study area during January and February, and the interval between surveys was longer than the optimum 8-10 days. A longer interval allows some fish to go uncounted, and the high water may disguise the redds before they are located and counted. In addition, the survey started late, missing the first big storm in December, with it’s accompanying run of coho. Anecdotal reports indicate that 25-30 spawners may have run before the survey was initiated.” (Wehren 1996, page 4)

stations on the South Fork Albion. The results of the surveys for juvenile coho during sampling in August of 1993, 1994, and 1995 are reported in Table 6.3.

**Table 6.3**
**Summary of Results for Juvenile Coho at Six Electrofishing Stations on the mainstem and South Fork Albion (from Daugherty 1996)**

| Stream | Survey Date | No. Juvenile Coho | Length Range (mm) |
|---|---|---|---|
| Albion | Aug 18-19, 1993 | 100 coho | 50-86 mm |
| | Aug 15-16, 1994 | 7 coho | 65-93 mm |
| | Aug 21-23, 1995 | 66 coho | 47-85 mm |
| So. Fork Albion | August 30, 1993 | 154 coho | 40-97 mm |
| | August 17, 1994 | 66 coho | 40-96 mm |
| | August 21-23, 1995 | 54 coho | 48-112 mm |

Note: The three sampling stations on the mainstem Albion were grouped together for reporting, as were the three stations on the South Fork Albion.

MRC also consolidated data and reported on fish surveys from 1994 to 1996 at 33 sampling locations[87] in the Albion River watershed (MRC 2000a). Fish population numbers are reported in relative abundance ranges (e.g., <10 fish, 10-40 fish, and 41-400 fish), rather than as absolute numbers. This type of reporting makes it impossible to determine the exact number of fish that were observed at any given station and in any given year. Using the lower and upper ends of the reported range, the Regional Water Board staff estimated the minimum and maximum number of fish that may have been observed at each station in each year.

Coho were reported at 20 of the 33 stations sampled (61%). The streams and sampling stations (identified by the MRC survey site number) are shown below; the stations where coho were found are shown in bold type.

- Lower Albion River (**78-12**,**78-13, 78-14**)
    - Deadman Gulch (78-2)
    - Railroad Gulch (**78-3**, **78-5, 78-6**)
    - Unnamed tributary to Railroad Gulch (**78-4**, 78-7)
    - Pleasant Valley Creek (**78-8**, 78-9)
    - Slaughterhouse Gulch (**78-10**)
    - Duckpond Gulch (**78-11**)
- Middle Albion River (**78-24**, **78-31**)
    - Kaisen Gulch (78-25)
    - East Railroad Gulch (**78-26, 78-27**)
    - Tom Bell Creek (**78-28**, 78-29, 78-30)
- South Fork Albion River (**78-15**, **78-16**, **78-19**, 78-21)
    - Unnamed tributary to South Fork Albion River (78-18)
    - Little North Fork (**78-17**)
    - Bull Team Gulch (78-20)
    - Winery Gulch (78-22, 78-23)
- North Fork Albion (**78-32**)
- Upper Albion River (78-33, 78-34)

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[87] Not all locations were surveyed every year.

Yearling coho fish were found in four streams: Railroad Gulch, Albion River (lower and middle), South Fork Albion River, and North Fork Albion River. All other coho observed were young-of-the-year ("YOY") fish.

In 1994, 14 stations were sampled. Coho were observed at seven of the 14 stations – 50% of the stations sampled. The total number of observed coho was between 16 and 94 fish. Coho were observed in the lower and middle Albion River, the South Fork Albion River and the lower North Fork Albion River. The greatest numbers of coho were observed in the South Fork Albion River.

In 1995, 18 stations were sampled. Coho were observed at 12 of the 18 stations – 67% of the stations sampled. The total number of observed coho was between 208 and 1,796 fish. Coho were observed in Railroad Gulch, Pleasant Valley Creek, the lower and middle Albion River, the lower and middle South Fork Albion River, Tom Bell Creek (near the confluence with the mainstem), and the North Fork Albion River. The greatest numbers of coho was observed in the middle Albion River and the South Fork Albion River.

In 1996, 32 stations were sampled. Coho were observed at 19 of the 32 stations – 59% of the stations sampled. The total number of observed coho was between 309 and 2,436 fish. Coho were observed in Railroad Gulch, Slaughterhouse Gulch, Duckpond Gulch, the lower and middle Albion River, the middle and lower South Fork Albion River, the Little North Fork Albion River, the East Railroad Gulch, Tom Bell Creek, and the North Fork Albion River. The greatest number of coho were observed in the middle Albion River followed by the South Fork Albion River.

#### 6.2.3.2 Fish Counts – California Department of Fish and Game

The California Department of Fish and Game (CDFG, unpublished data 'k') surveyed reaches of the Albion River and Big Salmon Creek watersheds in 1983 and 1996 using electrofishing techniques to stun and count aquatic vertebrates. CDFG sampled two locations in the Albion River watershed – one on the mainstem (sampled in October 1983 and September 1996) and one on the North Fork Albion River (sampled in September 1996). Although the data are sparse, they can be used to indicate presence of salmonid species. The CDFG observed coho in each sampling event. In the 1983 sampling on the mainstem, the only coho found were two YOY coho and no yearlings. In the 1996 sampling on the mainstem, 19 YOY coho and no yearlings were found. In the single sampling on the North Fork Albion in 1996, 21 YOY coho and no yearlings were found. Data from these surveys are summarized in Table 6.4.

**TABLE 6.4**
**COHO SALMON POPULATION DATA COLLECTED BY THE DEPARTMENT OF FISH AND GAME REPORTED IN CDFG BIOSAMPLE DATABASE (CDFG unpublished data 'k')**

| STREAM | DATE | NUMBER OF COHO | | COHO DENSITY (FISH/M$^2$) | COHO BIOMASS (KG/HA) |
|---|---|---|---|---|---|
| | | YOY | YEARLING | | |
| Albion River | 10/12/83 | 2 | 0 | 0.0195 | 0.6823 |
| Albion River | 09/25/96 | 19 | 0 | 0.85 | 22.15 |
| No. Fork Albion River | 09/25/96 | 21 | 0 | 0.31 | 5.48 |

## 6.2.4 STEELHEAD –CURRENT ABUNDANCE AND DISTRIBUTION

### 6.2.4.1 Fish Distribution Data –Louisiana-Pacific Corporation and Mendocino Redwood Company

As discussed in Section 6.2.3.1, Louisiana-Pacific Corporation and its successor, Mendocino Redwood Company, sampled the Albion River watershed for the presence of rearing salmonids, including steelhead, by using electrofishing. MRC (Daugherty 1996) reported on the presence of juvenile steelhead at six index sampling stations – three on the Albion River and three on the South Fork Albion River. As described previously, the three stations on the mainstem were grouped together for reporting, as were the three stations on the South Fork Albion. Steelhead were observed during each survey. The results of the surveys for juvenile steelhead during sampling in August of 1993, 1994 and 1995 are reported in Table 6.5.

**TABLE 6.5**
**SUMMARY OF RESULTS FOR JUVENILE STEELHEAD AT SIX ELECTROFISHING STATIONS**
**(from Daugherty 1996)**

| STREAM | SURVEY DATE | NO. JUVENILE STEELHEAD | LENGTH RANGE (mm) |
|---|---|---|---|
| Albion | Aug 18-19, 1993 | 211 steelhead | 37-133 mm |
| | Aug 15-16, 1994 | 166 steelhead | 32-153 mm |
| | Aug 21-23, 1995 | 187 steelhead | 33-200 mm |
| So. Fork Albion | August 30, 1993 | 52 steelhead | 37– 25 mm |
| | August 17, 1994 | 81 steelhead | 36-119 mm |
| | August 21-23, 1995 | 77 steelhead | 32-123 mm |

NOTE: The three sampling stations on the mainstem Albion were grouped together for reporting, as were the three stations on the So. Fork Albion.

Also as discussed in Section 6.2.3.1, MRC reported on fish surveys from 1994 to 1996 at 33 sampling locations[88] in the Albion River watershed as well (MRC 2000a). Fish population numbers were reported in relative abundance ranges (e.g., <10 fish, 10-40 fish, and 41-400 fish), rather than as absolute numbers. This type of reporting makes it impossible to determine the exact number of fish that were observed at any given station and in any given year. Using the lower and upper ends of the reported range, the Regional Water Board staff estimated the minimum and maximum number of fish that may have been observed at each station in each year.

During the three-year period (1994 – 1996), steelhead were reported in all but one location – Deadman Gulch (near the confluence with the lower Albion River). YOY, yearling and two year fish were distributed throughout the watershed, as summarized below:

- In 1994, 14 stations were sampled. Steelhead were observed at all of the 14 stations. The total number of steelhead observed in 1994 was between 99 and 672 fish.
- In 1995, 18 stations were sampled. Steelhead were observed at 17 of the 18 stations – steelhead were not observed in the Little North Fork Albion River although the fish were found at the location in 1994 and 1996. The total number of steelhead observed in 1995 was between 128 and 783 fish.
- In 1996, 32 stations were sampled. Steelhead were not observed at six of the 32 stations – Deadman Gulch, two locations on a tributary to Railroad Gulch, Duckpond Gulch, East

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[88] Not all locations were surveyed every year.

Railroad Gulch (not sampled at this location in the previous years), and Tom Bell Creek (steelhead observed here in 1995). The total number of steelhead observed was between 154 and 966 fish.

#### 6.2.4.2 Fish Counts – California Department of Fish and Game

As reported in Section 6.2.3.2, CDFG surveyed reaches of the Albion River and Big Salmon Creek watersheds in 1983 and 1996 using electrofishing techniques. CDFG sampled two locations in the Albion River watershed, one on the mainstem (sampled in October 1983 and September 1996) and one on the North Fork Albion River (sampled in September 1996). Although the data are sparse and were not part of a systematic collection effort, they can be used to indicate presence of steelhead. CDFG reported steelhead in each sampling event. In the 1983 sampling on the mainstem, six YOY steelhead were found along with two yearlings. In the 1996 sampling on the mainstem, 16 YOY steelhead, seven yearling steelhead and one two-year steelhead were found. In the single sampling on the North Fork Albion in 1996, only two YOY steelhead were found. Data from these samplings are summarized in Table 6.6.

**TABLE 6.6**
**STEELHEAD TROUT POPULATION DATA COLLECTED BY THE CALIFORNIA DEPARTMENT OF FISH AND GAME**
**REPORTED IN THE CDFG BIOSAMPLE DATABASE (unpublished data 'k')**

| STREAM REACH | DATE | NUMBER OF STEELHEAD | | | STEELHEAD DENSITY (fish/m$^2$) | STEELHEAD BIOMASS (kg/ha) |
|---|---|---|---|---|---|---|
| | | YOY | ONE-YEAR | TWO-YEAR | | |
| Albion River | 10/12/83 | 6 | 2 | 0 | 0.0877 | 4.6053 |
| Albion River | 09/25/96 | 16 | 7 | 1 | 0.26 | 26.40 |
| No. Fork Albion River | 09/25/96 | 2 | 0 | 0 | 0.03 | 1.45 |

### 6.2.5 HATCHERY SUPPLEMENTATION

There is little data on hatchery supplementation in the Albion River watershed. Unpublished CDFG data (CDFG, unpublished data 'l') shows that coho were released to the Albion River (location not documented) in 1969 and 1970. About 60,000 coho were released in those two years. The same CDFG unpublished data show that steelhead were released to Marsh Creek (location not documented), a tributary to the upper Albion River, in 1979, 1980, 1981, 1983 and 1985. A total of 6,142 steelhead were released during those five years. The CDFG hatchery supplementation information is shown in Table 6.7. Unfortunately, the CDFG data are not well documented and without more information it is difficult to evaluate the data.

**TABLE 6.7**
**CDFG HATCHERY SUPPLEMENTATION ON THE ALBION RIVER (CDFG, unpublished data 'l')**

| DATE OF RELEASE | SPECIES | RELEASE LOCATION | HATCHERY | NUMBER OF FISH |
|---|---|---|---|---|
| 2/27/69 | Coho | Albion River - Location Not Documented | not documented | 30,000 |
| 3/17/70 | Coho | | Darrah | 30,004 |
| 4/8/79 | Steelhead | Marsh Creek - Location Not Documented | Mad River | 1,200 |
| 4/17/80 | Steelhead | | Mad River | 1,248 |
| 3/19/81 | Steelhead | | Talmadge | 1,196 |
| 3/9/83 | Steelhead | | Mad River | 1,295 |
| 3/20/85 | Steelhead | | Pt. Arena Ponds | 1,203 |

## 6.3 AQUATIC HABITAT

### 6.3.1 Sources of Information about the Aquatic Habitat

The following sources of information about the Albion River watershed were consulted:

1. Maahs and Cannata (1998) studied conditions in the Albion River estuary. Their work is discussed in Section 6.3.2.
2. MRC (1999a) conducted a watershed analysis for their property in the watershed. This work incorporated earlier L-P efforts, in addition to field observations and aerial photo interpretation. Their work is discussed in Section 6.3.3 (riparian function) and 6.3.4 (stream channel condition) and 6.3.5.1 (habitat assessment). L-P conducted a habitat inventory of the entire mainstem Albion River, North Fork Albion River, South Fork Albion River, Railroad Gulch, and Pleasant Valley Creek in 1994 (Daugherty 1994). This work was largely included in the MRC 1999 watershed analysis and, so, is not discussed separately.
3. CDFG conducted a habitat inventory of 7.4 miles of stream in the 1990s. This included surveys in Bull Team Gulch, Little North Fork Albion River, and South Fork Albion River. This work is discussed in Section 6.3.5.2. The CDFG stream surveys previously discussed in Section 6.2.2 included habitat information about the streams that is relevant. This material also is presented in Section 6.3.5.2.
4. The Coastal Land Trust performed a habitat survey of 2.4 miles of stream in the Albion River in 1996 (Dolphin 1996) including surveys on the North Fork Albion River and Soda Spring Creek, as well as the mainstem Albion River around Comptche. This work is discussed in Section 6.3.5.3.

### 6.3.2 Estuary – Maahs and Cannata

Maahs and Cannata (1998) studied the quality and quantity of estuarine habitat in the Albion River watershed and its use by coho salmon, steelhead trout, and other species from May through December in 1997. They describe the Albion River estuary as an example of a drowned river valley resulting from a rise in sea level. Tidewater influence extends 4.5 to 5 miles upstream. The mouth of the river is defined by a narrow opening along the south side of the bay protected by rock headlands. This embayment reduces long ocean swell and sea height, which reach the mouth of the river. It also minimizes wave-induced longshore sediment transport, which causes the mouths of many California rivers to close during low flow periods due to sand bar formation. The mouth has aligned itself such that it discharges at the point of lowest wave energy, which allows the stream to remain open to the sea year around. The estuary is used as a commercial and sport fishing harbor and contains a small boat basin.

Maahs and Cannata (1988) describe the changes that the Albion River estuary has undergone since the logging era that began in the early 1850s. In the early period the estuary was used as a mill pond and transportation corridor to get logs to the mill. A series of dams was also used to transport logs downstream. At least five dam sites that were used in a synchronized fashion to transport logs downstream have been identified (Maahs and Cannata 1998). The first railroad to transport logs was built up one of the lower Albion tributaries in 1881. In the mid-1880s a railroad to transport logs to the upper estuary was built along the Albion River from Tidewater Gulch upstream several miles. The railroad was improved and extended into the Navarro River watershed in the early 1900s. The Albion Mill eventually closed in 1928 and the railroad discontinued service in 1930.

The estuary channel was described as being from 30 to 50 feet wide and 20 to 25 feet deep in the 1940s, well after the modifications resulting from erection of mills, the railroad, mill ponds and dams (White 1984). In 1961, CDFG estimated the average depth to be five feet with a maximum depth of 20 feet (CDFG 1961c). In 1966, CDFG estimated the average depth to be eight feet (CDFG 1996a). The substrate within the estuary is predominantly mud or silt with some areas of small gravel along banks or at the confluence of small tributaries (Maahs and Cannata 1998). Wherever there was significant shade in the estuary, pickleweed and other ground cover that stabilize the banks was diminished, leaving erodible banks unprotected. The banks of the estuary are comprised of soft mud and sand.

Maahs and Cannata also conducted 25 fish surveys during the study period to determine salmonid estuary use during outmigration. Coho may benefit from LWD found in the Albion River estuary. The upper Albion River estuary has a “considerable amount of LWD” and was often associated with coho presence when surveyed. The authors captured 48 juvenile coho – 26 in late May, four in early June with the numbers remaining low thereafter and no juvenile coho caught after late August. Juvenile coho were also observed in snorkel surveys in early June, but the numbers dropped off later in the month. Maahs and Cannata believed that most of the coho outmigrants had left the estuary by early June. This estuary study could not document the amount of time that coho remained in the estuary or how much growth was obtained while there. There may be some particularly weak year classes where YOY smolts entering the ocean significantly outnumber yearling smolts. Where a year class is missing due to a prior drought or other condition, YOY outmigrants could provide a mechanism to supply two-year-old spawners since an accelerated growth pattern that would increase the proportion of age-two spawners could occur (Maahs and Cannata 1998). The estuary-rearing phase for these fish is likely essential to provide the growth needed to survive the period that immediately follows ocean entry.

Unlike juvenile coho, juvenile steelhead were not found in the lower and middle estuary during the entire study period. Only five juvenile steelhead were captured during the survey and these were in the upper estuary. The authors conclude that the five steelhead were likely rearing in the upper estuary and not migrating. Steelhead outmigrants spend little time in the Albion River estuary, which may deprive them of the excellent growth opportunity that estuaries can provide. Daugherty (1994, as cited by Maahs and Cannata 1998) reported that few steelhead in upstream areas of the Albion River watershed exceeded 125 mm in length in the month of August, whereas Cannata (1998 cited by Maahs and Cannata 1998) found Navarro River estuary steelhead that averaged 170 mm during the same month. Although Maahs and Cannata did not assess the non-estuarine habitat for this study, they postulate that the Albion non-estuarine habitat may not provide proper conditions to produce a sizable population of large steelhead smolts (perhaps due to a limited number of large, deep, complex pools). The small population size in the watershed overall would lead to a smaller than expected number of smolts available to use the estuary. The authors state, "Likely the greatest opportunity for salmonid enhancement is reduced levels of erosion which could lead to larger and deeper pool habitat in its freshwater environment and improved substrate conditions in the upper estuary."[89] It is likely that between the Navarro River and Albion River estuaries there are marked differences in the type and availability of food organisms and that these differences result from the physical processes affecting each estuary. Food availability may limit salmonid production, especially for steelhead trout in the Albion River estuary. Based on scale pattern studies (with an admittedly small sample), the authors believe that there may be some mixing of juvenile steelhead between the Albion and Navarro estuaries.[90]

Maahs and Cannata (1998) hypothesize that use of the estuary by salmonids for some rearing provides greater growth opportunities than does rearing exclusively in freshwater. The greater growth potential is a result of the greater nutrients generally found in the estuarine environment. Larger out-migrating fish are more likely to survive their ocean dwelling and return to their natal streams as healthy spawners. The NMFS Limiting Factors Report on west coast steelhead cites researchers that have reached similar conclusions:[91]

> Wetlands, estuaries, and lagoons provide critical habitat for all juvenile salmonids migrating to the ocean and are essential to all anadromous salmonids. These critical habitats play an important role as a feeding area for juvenile salmonids and also in the acclimatization to higher salinities (Cooper and Johnson 1992). Loss of these habitats may limit food resources for juvenile salmonids. Therefore, juveniles may tend to migrate to open water at a smaller size and thus be more susceptible to predation (Thom 1991). The ocean survival for juvenile salmonids is greatly increased if rearing fish are able to attain larger size for an extended period in the estuary (Simenstad et al. 1982).

Maahs and Cannata measured D.O. throughout the estuary and concluded "The Albion's DO concentrations indicate that dissolved oxygen may be limiting for salmonids in these upper portions of the estuary late in the season,"[92] a condition that may be exacerbated in low flow years. Low D.O. may inhibit salmonid use in upper portions of the estuary directly, and secondarily by impacting invertebrate populations. Either an increase in freshwater discharge or increase in tidal action could improve D.O. concentrations. A decrease in water temperatures might also improve dissolved oxygen concentrations.

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[89] Maahs and Cannata 1998, page 43.

[90] Maahs and Cannata 1998, page 26.

[91] NMFS 1996, page 20.

[92] Maahs and Cannata 1998, page 17.

## 6.3.3 Riparian Function –Vegetation, Large Woody Debris, Canopy Closure (Summary of MRC 1999a, Section D)

In 1999, MRC conducted a watershed analysis for their property in the Albion River watershed using the Standard Methodology for Conducting Watershed Analysis (Version 3.0) as developed by the Washington Forest Practices Board (MRC 1999a). MRC owns approximately 54% of the land contained in the Albion River watershed. MRC property is concentrated in the Lower Albion River, Middle Albion River, and South Fork Albion River planning watersheds (113.40001, 113.40002, and 113.40003). Though the analysis relies on a qualitative rating system for identifying "poor," "fair," and "good" coho habitat, it nonetheless reports a wealth of information regarding mass wasting, surface erosion, hydrology, riparian function, channel conditions, and historic and current fish habitat. The MRC watershed analysis discussed in this section and in Section 6.3.4 (stream channel condition).

MRC conducted assessments of the potential of the riparian stands to recruit LWD to the stream channel, as well as the existing availability of LWD. Further, MRC conducted assessments of canopy closure and stream temperatures within the Albion River watershed. They describe the combination of these assessments as an analysis of "Riparian Function."

### 6.3.3.1 Large Woody Debris

For the assessment of LWD recruitment, MRC (1999a) classified the riparian vegetation using aerial photos and field observations for a distance of one tree height on either side of the channel. Vegetation was classified by vegetation type, size, and density. Vegetation type was classified as:

- Redwood,
- Mixed redwood and Douglas-fir,
- Mixed hardwood,
- Mixed hardwood and conifer, or
- Brush.

Vegetation size was classified as:

- < 8" diameter at breast height ("dbh"),
- 8-15.9" dbh,
- 16-23.9" dbh,
- 24-31.9" dbh, or
- >32" dbh.

Vegetation density was classified as:

- 5-20% canopy cover,
- 20-40% canopy cover,
- 40-60% canopy cover,
- 60-80% canopy cover, or
- >80% canopy cover.

The best riparian vegetation for LWD recruitment to the watercourse was assumed to come from large conifer trees (MRC 1999a). Nonetheless, MRC judges there to be a "high potential for LWD" recruitment in areas where "large" trees are actually quite small:

1. Redwood stands with more than 40% canopy cover and at least 50% of the trees greater than 16"dbh.

2. Redwood stands of any density with at least 50% of the trees greater than 24” dbh.
3. Mixed redwood/Douglas-fir stands with the same characteristics as #1 and #2 above.
4. Mixed hardwood/conifer stands with the same characteristics as #2 above.

In the MRC watershed analysis (MRC 1999a) the term “high recruitment potential” (e.g., estimated rate of recruitment) is not quantified, nor does MRC provide supporting evidence that stands with the characteristics described above will result in the stream habitat and function that is necessary to support salmonids. It is likely that “high recruitment potential” is defined in relation to other areas – e.g., better than other areas of MRC ownership – rather than to an objective standard. Further, the MRC data are presented in such a way that it can not be reanalyzed using different criteria.

In the watershed analysis, MRC (1999a) did not report the length of stream bank in each recruitment category, instead presenting the information on a map with each recruitment category shaded on either side of the stream. Using the MRC maps, Regional Water Board staff estimated the length of stream bank in each recruitment category in each sampling reach. These derived numbers are approximations due to the inherent inaccuracies of the exercise. But, the <u>proportion</u> of each recruitment category in the sampling reaches is useful and is shown in Table 6.8.

**TABLE 6.8**
**LWD RECRUITMENT POTENTIAL IN STREAMS ASSESSED BY MRC (1999a)**

| SAMPLE REACH # | STREAM NAME | % OF STREAM BANK WITH A HIGH LWD RECRUITMENT POTENTIAL | % OF STREAM BANK WITH A MEDIUM LWD RECRUITMENT POTENTIAL | % OF STREAM BANK WITH A LOW LWD RECRUITMENT POTENTIAL |
|---|---|---|---|---|
| 3 | Lower Albion | 36 | 43 | 21 |
| 4 | Railroad Gulch | 0 | 63 | 37 |
| 5 | Railroad Gulch | 0 | 100 | 0 |
| 6 | Railroad Gulch | 50 | 50 | 0 |
| 15 | Pleasant Valley Creek | 73 | 0 | 27 |
| 20 | Duck Pond Gulch | 26 | 57 | 17 |
| 21 | Duck Pond Gulch | 49 | 28 | 22 |
| 43 | Mid Albion | 81 | 19 | 0 |
| 44 | Mid Albion | 97 | 3 | 0 |
| 45 | East Railroad Gulch | 77 | 23 | 0 |
| 50 | Tom Bell Creek | 68 | 32 | 0 |
| 76 | South Fork Albion | 23 | 61 | 15 |
| 77 | South Fork Albion | 85 | 8 | 8 |
| 78 | South Fork Albion | 21 | 53 | 26 |
| 79 | South Fork Albion | 15 | 71 | 15 |
| 80 | South Fork Albion | 45 | 47 | 8 |
| 91 | Little North Fork Albion | 41 | 59 | 0 |
| 114 | North Fork Albion | 100 | 0 | 0 |
| **TOTAL MRC Ownership** | | 52 | 38 | 10 |

**Note: The terms “ high,” “medium” and “low” are not defined and may be relative to each other, not to a defined standard.**

In general, one can conclude that the riparian zone of the upper portion of MRC's ownership, with the exception of the South Fork Albion River, has a greater potential to recruit large woody debris than does the riparian zone in the lower portion of their ownership. This fact likely reflects differences in native vegetation from the upper to lower portions of the watershed, as well as differences in the rate and timing of logging activities. Those sample reaches with more than a quarter of the stream banks categorized with a low potential for LWD recruitment include: Railroad Gulch, Pleasant Valley Creek, and the South Fork Albion. Those with the highest percentage of the stream banks categorized with a high potential for LWD recruitment include: North Fork Albion and the middle Albion.

MRC (1999a) also inventoried watercourses for "functional" LWD and "key" LWD in the active channel and bankfull channel for each sampled stream segment. These data are reported in Table 6.9. "Functional" LWD was defined as LWD that provides habitat or morphologic function in the stream channel (i.e., pool formation, scour, debris dam, bank stabilization, or gravel storage). No minimum length or diameter characteristics were used to define "functional" LWD. A "key" piece of LWD was defined using minimum length and diameter characteristics as associated with bankfull width, as follows:[93]

| Size Requirements for "Key" LWD – Taken from MRC 1999a | | |
|---|---|---|
| Bankfull width (ft) | Diameter (in.) | Length (ft.) |
| 0-20 | 12 | 20 |
| 20-30 | 18 | 30 |
| 30-40 | 22 | 40 |
| 40-60 | 24 | 60 |

The MRC (1999a) information on "key" and "functional" LWD along with a qualitative assessment by MRC of the relative abundance of LWD (sparse, common, or abundant) is shown in Table 6.9.

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[93] MRC 1999a, page D-3.

## TABLE 6.9
## LARGE WOODY DEBRIS IN STREAMS IN THE ALBION RIVER WATERSHED (from MRC 1999a)

| STREAM | MRC ID# | ACTIVE CHANNEL |  |  | BANKFULL CHANNEL |  |  | MRC Assessment of LWD Abundance |
|---|---|---|---|---|---|---|---|---|
|  |  | Functional LWD (#/100m) | Key LWD (#/100m) | % of functional LWD that are key pieces | Functional LWD (#/100m) | Key LWD (#/100m) | % of functional LWD that are key pieces |  |
| Albion | 3.1 | 23.1 | 0.3 | 1 | 24.9 | 0.3 | 1 | abundant |
| Albion | 3.2 | 12.5 | 1.9 | 15 | 2.2 | 2.2 | 100 | common |
| Railroad Gulch | 4 | 9.1 | 0 | 0 | 13.9 | 2.1 | 15 | common |
| Railroad Gulch | 5 | 22.8 | 3.6 | 16 | 24.9 | 3.6 | 14 | common |
| Railroad Gulch | 6 | 13.4 | 4.7 | 35 | 22.9 | 5.5 | 24 | common |
| Pleasant Valley Creek | 15 | 40.0 | 7.1 | 18 | 43.9 | 7.1 | 16 | common |
| Duck Pond Gulch | 20 | 24.5 | 1.7 | 7 | 24.5 | 1.7 | 7 | common |
| Duck Pond Gulch | 21 | 29.8 | 2.1 | 7 | 31.9 | 2.1 | 7 | common |
| Albion | 43.1 | 1.8 | 0 | 0 | 3.4 | 0 | 0 | sparse |
| Albion | 43.2 | 4.0 | 0.3 | 8 | 5.1 | 0.3 | 6 | sparse |
| Albion | 44 | 7.3 | 1.0 | 14 | 9.3 | 1.3 | 14 | common |
| East Railroad Gulch | 45 | 18.8 | 3.7 | 20 | 19.7 | 3.7 | 19 | common |
| Tom Bell Creek | 50 | 4.6 | 1.8 | 39 | 6.4 | 1.8 | 28 | sparse |
| South Fork Albion | 76 | 4.4 | 0 | 0 | 4.4 | 0 | 0 | sparse |
| South Fork Albion | 77 | 3.6 | 1.6 | 44 | 4.1 | 1.6 | 39 | sparse |
| South Fork Albion | 78 | 77.3 | 3.9 | 5 | 78.9 | 3.9 | 5 | abundant |
| South Fork Albion | 79 | 12.0 | 0.8 | 7 | 17.6 | 0.8 | 5 | sparse |
| South Fork Albion | 80 | 20.1 | 1.6 | 8 | 20.9 | 1.6 | 8 | common |
| Little North Fork Albion | 91 | 31.9 | 2.2 | 7 | 44.2 | 5.1 | 12 | common |
| North Fork Albion | 114 | 2.8 | 0.8 | 29 | 6.4 | 2 | 31 | sparse |
| **WATERSHED AVERAGE** | NA | 18.2 | 2.0 | 11 | 20.5 | 2.3 | 11 | NA |

MRC (1999a) reported large woody debris per stream segment as sparse, common, or abundant, based on a field crew qualitative assessment. These qualitative judgements, however, do not correlate with the quantitative measurements of LWD pieces per 100m of stream. Without well-described criteria for determining the quality of LWD functioning in the streams surveyed, only the following can be concluded from the report:

- On average in the Albion River watershed:
  - 18.1 pieces of LWD are found per 100m of active channel.
  - 2 of these pieces are key LWD in the active channel.
  - Key pieces account for 11% of the LWD in the active channel.

  - 20.5 pieces of LWD are found per 100m of bankfull channel.
  - 2.3 of these pieces are key LWD in the bankfull channel.
  - Key pieces account for 11% of the LWD in the bankfull channel.

- Railroad Gulch, East Railroad Gulch, Pleasant Valley Creek, Tom Bell Creek, North Fork Albion River, reaches of the Albion River and reaches of South Fork Albion River each contain densities of wood and “key” pieces of LWD that exceed the basin wide averages. The MRC data do not indicate whether the existing density of LWD in these streams is sufficient to provide the stream habitat and function that is necessary to support salmonids.

- Duck Pond Gulch, reaches of the lower Albion River, and reaches of South Fork Albion River contain LWD that exceed the basin wide average but these reaches do not contain greater-than-average densities of “key” pieces of LWD.

- East Railroad Gulch contains a density of “key” pieces of LWD that exceeds the basin wide average. In spite of the high density of “key” LWD pieces, Railroad Gulch does not contain a greater-than-average density of total LWD in the bankfull channel. In the active channel, East Railroad Gulch contains a density of “key” pieces of LWD that exceeds the basin wide average and contains a greater-than-average density of LWD.

- In the bankfull channel, only the lower Albion River (Site #3.2) and South Fork Albion (Site #77) contain a relatively high proportion of LWD made up of “key” pieces (i.e., 100% and 39%, respectively). At these sites, the relatively high proportion of large LWD results only from the comparatively small overall quantity of wood present. At all other sites, the vast majority of LWD are small pieces, not qualifying as “key” pieces of LWD.

#### 6.3.3.2 Canopy Closure

In 1998, MRC took field measurements and collected multiple spherical densiometer readings in several stream segments and averaged the readings for each stream or stream reach. MRC used field measurements to update earlier canopy assessment by L-P’s which was based on aerial photo analysis[94]. The MRC field observations for stream shading in the Albion River watershed assessment are shown in Table 6.10.

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[94] L-P had previously classified Class I and Class II streams in the Albion River watershed into three canopy closure categories (0-40% canopy closure, 40-70% canopy closure, and >70% canopy closure) based on aerial photographs for use in a Sustained Yield Plan (L-P 1997a).

**Table 6.10**
**Mean Shade Canopy in Streams throughout the Albion River Watershed (from MRC 1999a)**
**Note: Streams are organized from the lowest to highest points in the watershed.**

| **Stream** | **MRC ID#** | **Mean Shade Canopy (%)** | **Stream** | **MRC ID#** | **Mean Shade Canopy (%)** |
|---|---:|---:|---|---:|---:|
| Albion | 3.1 | 71 | Albion | 44 | 67 |
| Albion | 3.2 | 73 | East Railroad Gulch | 45 | 85 |
| Railroad Gulch | 4 | 77 | Tom Bell Creek | 50 | 88 |
| Railroad Gulch | 5 | 81 | South Fork Albion | 76 | 86 |
| Railroad Gulch | 6 | 82 | South Fork Albion | 77 | 87 |
| Pleasant Valley Creek | 15 | 88 | South Fork Albion | 78 | 87 |
| Duck Pond Gulch | 20 | 88 | South Fork Albion | 79 | 85 |
| Duck Pond Gulch | 21 | 86 | South Fork Albion | 80 | 86 |
| Albion | 43.1 | 75 | Little North Fork Albion | 91 | 88 |
| Albion | 43.2 | 84 | North Fork Albion | 114 | 84 |

MRC concluded that, “Canopy closure over watercourses was observed to be high. Most stream segments in the Albion WAU had greater than 80% canopy closure.”[95] Canopy closure on the mainstem was less than other segments, which was attributed to the width of the stream channel and a streamside road that ran along part of the stream. MRC used a criterion of >70% canopy closure to define those areas with “high canopy closure.”[96] Other authorities do not consider >70% closure to be “high.” CDFG recommends consideration of streamside restoration treatments where canopy closure is less than 80% (Flosi et al. 1998). In addition, canopy closure data and stream temperature data in the Ten Mile River watershed suggest that even greater than 80% canopy closure may not protect stream temperatures in all streams (see Chapter 4). Measured canopy closure over the mainstem Albion River ranges from 67% to 84% with an average of 74% (uncorrected for variation in stream segment lengths). All other measured stream segments (with the exception of Railroad Gulch, Segment 4) exceed a mean canopy closure of 80%, although these do not reach a 90% closure. Pleasant Valley Gulch, Duck Pond Gulch, Little North Fork Albion, and Tom Bell Gulch have the greatest mean canopy closure measurements at 88%.

In addition to forest harvest activities, some of the limited canopy in the lower Albion may be explained by the extensive wetlands of this region and some of the limited canopy in the upper Albion may be explained by the presence of grassland vegetation and soils.

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[95] MRC 1999a, page D-12.

[96] MRC 1999a, Map D-2.

### 6.3.4 STREAM CHANNEL CONDITION – CHANNEL TYPE AND POOL FORMATION (Summary of MRC 1999a, Section E)

MRC (1999a) reported on several stream channel characteristics for sample reaches throughout their land in the Albion River watershed. MRC divided the watershed into six geomorphic unit types based on existing stream channel characteristics[97] and described the coarse sediment, fine sediment, and large woody debris in each geomorphic unit. The six geomorphic units and the identified characteristics of each unit are listed in Table 6.11.

**TABLE 6.11**
**SIX GEOMORPHIC UNITS AND THEIR CHARACTERISTICS IN THE ALBION RIVER WATERSHED AS DESCRIBED BY MRC (1999a, descriptions starting at page E-13)**

| GEOMORPHIC UNIT NUMBER | UNIT CHARACTERISTICS |
|---|---|
| 1 | This unit is described as "…open, unconfined canyon bottom in the lower section of the Albion River near the ocean." The Rosgen channel type is E6 with some E5. There are wetlands and connection to the floodplains, providing rearing and overwintering habitat. Silt/clay substrate is dominant. There is fine sediment deposition on floodplain. LWD is sparse. |
| 2 | This unit type is described as flowing through confined canyon bottoms, often confined between a steep slope and fill terrace. Even though the channels are low gradient, sediment transport capacity is high due to confinement. There is no floodplain or channel migration. Gravel and cobble are substrate with occasional boulders and bedrock. The Rosgen channel type is F4, F3 and F1 with some C4. Rearing and overwintering habitat is available in free-formed pools. Gravels scoured during high flows. Coarse sediment accumulates in gravel bars. There is some past aggradation. There is little fine sediment accumulation. LWD is sparse. |
| 3 | This unit type has low gradient with unconfined access to floodplains and channel migration across terraces at high flow. Side channels often go subsurface during low-water years. The channel substrate is predominantly fine silt and clay. The Rosgen channel type is E4 and E6 with areas of C4 and F4. There is an abundance of LWD and wood-formed pools. This unit often lacks bedrock, large cobble and boulder for overwintering. Coarse sediment accumulates on gravel bars, though bars are few to common. There is evidence of past and current aggradation. There is moderate to high accumulations of fine sediment. |

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[97] MRC used the Rosgen channel classification system (see Rosgen 1996). Briefly, the Rosgen classification system describes channels as morphological types with the following characteristics:

A-type channels are stable, steep and entrenched step/pool channels.

B-type channels are described as stable, moderate gradient, moderately entrenched channels dominated by riffles with few pools.

C-type stream channels are described as meandering, low gradient, point-bar, riffle/pool alluvial channels with broad well-defined floodplains.

D-type channels are wide, eroding braided channels with long transverse bars.

E-type channels are described as stable, low gradient, meandering, pool/riffle stream channels. Unlike the C-type channel, E-type channels have very low width/depth ratios.

F-type channels are entrenched, low gradient, meandering, pool/riffle channels. Unlike either the C- or E-type channels, the F-type channel is fairly entrenched, resulting in high rates of bank erosion and sediment deposition.

G-type channels are moderate gradient, entrenched, step/pool "gullies" with a low width/depth ratio. G-type channels tend to be unstable and have high bank erosion rates.

**TABLE 6.11**
**SIX GEOMORPHIC UNITS AND THEIR CHARACTERISTICS IN THE ALBION RIVER WATERSHED AS DESCRIBED BY MRC (1999a, descriptions starting at page E-13)**

| GEOMORPHIC | UNIT CHARACTERISTICS |
|---|---|
| 4 | This unit type is confined to moderately confined within steep canyon side slopes. Sediment transport capacity is moderate to high due to confinement. Sediment transport capacity is moderate to high. Channel substrate is typically gravel to cobble sized particles with some bedrock. Channels can go subsurface during summer providing poor summer rearing habitat. The Rosgen channel type is C4, G3, G4, and F3 with areas of F1. Spawning habitat limited, but gravel quality is good where present. LWD is common and provides some overwintering protection. Some coarse sediment accumulates on gravel bars, though bars are few to common. There is evidence of past aggradation and some current degradation. In spite of the high sediment transport capacity, there are moderate accumulations of fine sediment on bars, along channel margins, and in pools. |
| 5 | This unit type has moderate gradient and confined or moderately confined within canyons. There is some terrace formation and channel meandering. The substrate varies from gravel to boulder. Stream segments easily downcut through terrace deposits. Channels go subsurface in summer. Rosgen channel type is A4, A2, A3 with areas of G1, G2, and G3. Spawning habitat is infrequent. Rearing and overwintering habitat is available in boulder-formed step pools. There is coarse sediment accumulation in gravel bars. Many channels show evidence of downcutting, though there is also evidence of past aggradation. Although this is a moderate transport reach, high levels of fine sediment in transport has lead to accumulation of fine sediment in gravel bars and isolated pools. LWD often recruited to terraces not to channels. Where LWD exists, it forces storage of coarse sediment. |
| 6 | This unit type has high gradient transport reaches, often in steep-sided, V-shaped canyons. There are areas of scour during high flows and debris flows. Substrate is typically cobble to large boulders. There is no water in summer. The Rosgen channel type is A2, A3, AA2, and AA3. Salmonid spawning and rearing are unlikely, due to high gradient. There are few areas of coarse or fine sediment storage, except behind a few LWD and boulders. LWD is sparse to abundant. |

The low gradient reaches suitable for coho salmon tend to flow either through tidally influenced, open floodplains, or channels confined by steep side slopes or high terraces. Only Geomorphic Unit type 3 offers the kind of channel conditions typically considered ideal for coho: unconfined, pool/riffle channels with point bars, large woody debris and access to the floodplain. Streams with segments that were found to exhibit geomorphic unit type 3 include Railroad Gulch, Pleasant Valley Creek, Duck Pond Gulch, Tom Bell Creek, and South Fork Albion. These stream segments, however, have been aggraded in the past and show evidence of moderate to high accumulations of fine sediment today. Both the Albion River mainstem (except that which is tidally influenced) and tributaries (except reaches with slopes >8%) show evidence of aggradation. Coarse sediment continues to accumulate on bars and behind LWD and boulders and fine sediment accumulates on bars and in pools.

In the watershed analysis, MRC (1999a) provided a description of stream channel measurements, categorized stream channel reaches using the Rosgen channel classification system, and the geomorphic typing (described in Table 6.11). The MRC-categorized stream reaches are reported in Table 6.12.

**TABLE 6.12**
**STREAM CHANNEL MEASUREMENTS FOR STATIONS IN THE ALBION RIVER WATERSHED (MRC 1999a)**

| STREAM NAME | MRC ID# | Geomorphic unit | Channel confinement | Survey length (ft) | Observed slope (%) | Width/depth ratio | Entrenchment ratio (Valley width/bankfull width) |
|---|---|---|---|---|---|---|---|
| Albion | 3.1 | 2 | MC | 1052 | 1.1 | 9.3 | 3.1 |
| Albion | 3.2 | 2 | C | 1025 | 0.8 | 12.5 | 2.2 |
| Railroad Gulch | 4 | 3 | UC | 471 | 1.1 | 7.3 | 6.8 |
| Railroad Gulch | 5 | 3 | UC | 461 | 1.3 | 4.3 | 12.5 |
| Railroad Gulch | 6 | 4 | MC | 415 | 1.2 | 4.8 | 4.3 |
| Pleasant Valley Creek | 15 | 3 | UC | 418 | 1.3 | 4.6 | 14.6 |
| Duck Pond Gulch | 20 | 3 | UC | 375 | 1.2 | 2.9 | 8 |
| Duck Pond Gulch | 21 | 4 | MC | 319 | 2.4 | 2.6 | 5.6 |
| Albion | 43.1 | 2 | C | 1265 | 0.7 | 7.7 | 2.4 |
| Albion | 43.2 | 2 | C | 1219 | 1.2 | 7.3 | 1.6 |
| Albion | 44 | 2 | C | 992 | 1.2 | 5.5 | 1.7 |
| East Railroad Gulch | 45 | 4 | MC | 415 | 1.2 | 4.8 | 4.3 |
| Tom Bell Creek | 50 | 3 | UC | 360 | 1.9 | 4.5 | NR |
| South Fork Albion | 76 | 2 | C | 813 | 1.0 | 6.9 | 2.2 |
| South Fork Albion | 77 | 2 | C | 809 | 1.4 | 6.8 | 1.7 |
| South Fork Albion | 78 | 3 | UC | 590 | 0.8 | 15.8 | 4.9 |
| South Fork Albion | 79 | 3 | UC | 410 | 0.7 | 5.7 | 8.8 |
| South Fork Albion | 80 | 4 | C | 800 | 1.1 | 3.5 | 10.7 |
| Little North Fork Albion | 91 | 4 | C | 453 | 0.8 | 7.5 | 2.0 |
| North Fork Albion | 114 | 2 | C | 817 | 1.2 | 5.2 | 3.0 |
| KEY | C = confined MC = moderately confined UC = unconfined NR = not reported | | | | | | |

MRC's observations in the Ten Mile River watershed suggest that coho salmon are most likely found in stream reaches containing at least some C-type channel. Coho salmon also can be expected to be found in E-type channels. Based on the MRC characterization of streams with C- or E-type channel segments, the following stream reaches of the Albion River watershed have the potential to provide coho habitat:

- Lower and mid Albion River
- Railroad Gulch
- Lower Duck Pond Gulch
- Pleasant Valley Creek
- Lower South Fork Albion River
- Upper South Fork Albion River
- Little North Fork Albion

The MRC watershed analysis (1999a) also reported the mechanisms by which observed pools are formed in the Albion River watershed. Coho salmon are typically associated with accumulations of LWD both because of the shelter afforded as well as the pool/riffle sequence that is created by LWD. Those stream reaches with a majority of their pools formed by LWD are similar to the C-type and E-type channels listed above and include the following:

- Lower Albion River
- Mid Albion River
- Railroad Gulch
- Pleasant Valley Creek
- Duck Pond Gulch
- South Fork Albion River
- East Railroad Gulch
- Little North Fork Albion River

### 6.3.5 FISH HABITAT ASSESSMENT

#### 6.3.5.1 L-P and MRC Habitat Assessment

In 1994, L-P conducted a habitat assessment of the streams on its land in the Albion River watershed (Daugherty 1994). A total of 18 miles of stream suitable for anadromous fish habitat was assessed. L-P considered channel type, base flow, water temperature, habitat type, stream substrate embeddedness, shelter ratings,[98] stream substrate composition, canopy density, bank composition and large organic debris. Much of the data collected in this assessment was incorporated into the 1999 MRC watershed analysis, and is discussed in more detail below.

MRC (1999b) developed a rating system to divide the Albion River watershed into reaches that are poor, fair or good with respect to spawning, rearing, and overwintering habitat quality for salmonids. MRC (1999b) evaluated habitat categories for each sample reach, including:

1. Percent pools,
2. Pool spacing,
3. Shelter rating,
4. Percent pools greater than or equal to three feet deep,
5. Spawning gravel quantity,
6. Percent embeddedness,
7. Subsurface fines quality,
8. Gravel quality,
9. Abundance of key LWD and rootwads, and

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[98] A shelter rating is assigned by estimating the percent of a habitat unit area that offers some form of shelter and multiplying it by a shelter quality rating of zero to three. The maximum shelter rating is 300. A shelter quality rating is assigned as follows: If the shelter in a habitat unit consists of one to five boulders, bare undercut bank, bare bedrock ledge or a single piece of large wood, then the unit is given a shelter quality rating of one. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of one or two pieces of large woody associated with any amount of small wood, six of more boulders per 50 feet, a stable undercut bank with root mass, a single root wad lacking complexity, etc., then the unit is given a shelter quality rating of 2. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). If the shelter in a habitat unit consists of combinations of large woody debris, boulders and root wads, three or more pieces of large woody debris combined with small woody debris, three or more boulders combined with large woody debris/small woody debris, etc., then the unit is given a shelter quality rating of 3. This is multiplied by the percentage of the unit area that is providing the shelter (e.g., 1 to 100%). Flosi et al. (1998) recommend improving shelter availability through habitat restoration efforts where the shelter rating is less than 80.

10. Overwintering substrate.

Each of these factors is rated as poor (1), fair (2), or good (3) based on criteria that were not described in the report. In addition, some of the factors are themselves qualitative in nature and therefore difficult to define. For example, the means by which "spawning gravel quantity," "subsurface fines quality," "gravel quality," and "overwintering substrate" were measured or estimated is not explained. MRC then added these factors together using various weighting values to assess spawning habitat, summer rearing habitat, and overwintering habitat quality. For example, spawning habitat quality is represented by a linear equation including four equally weighted variables: spawning gravel quantity, percent embeddedness, subsurface fines quality, and gravel quality. Summer rearing habitat quality is represented by a linear equation including six variables of uneven weight: percent pools, pool spacing, shelter, percent pools at least three feet deep, percent embeddedness, and abundance of key LWD and rootwads. Overwintering habitat quality is represented by a linear equation including all of the variables in the summer rearing equation except percent embeddedness, which is replaced by an assessment of overwintering substrate quality. The habitat quality scale is divided into thirds. Results that fall in the lowest third of the scale are reported to represent "poor" habitat quality, while those within the highest third of the scale are reported to represent "good" habitat quality. This is, in effect, a relative rating system and does not necessarily indicate objective standards for "good" or "poor" habitat quality.

Based on these calculations, MRC (1999b) reported that a majority of the sampling sites on MRC property in the Albion River have "fair" spawning habitat (55% of sites) while the vast majority of sites have "fair" summer rearing habitat (95% of sites) and overwintering habitat (95% sites). Only the South Fork Albion River shows poor spawning habitat, while none of the sampling sites show poor summer rearing or overwintering habitat. The mid Albion River shows nearly ideal spawning habitat (score of 2.75 out of a top score of 3.00), according to the model.

#### 6.3.5.2 Habitat Inventory and Stream Surveys – California Department of Fish and Game

The CDFG conducted habitat inventories in Bull Team Gulch, Little North Fork Albion River and South Fork Albion River (all South Fork tributaries) in the 1990s (CDFG 1998). The data are reported in Table 6.13. The CDFG data indicate that in each of the three streams surveyed, canopy cover is adequate (i.e., >90%). In the South Fork Albion River, the percentage of bank that had conifer-related canopy cover was only 68%, while conifer-related canopy cover was greater than 80% in the two other streams. The CDFG habitat inventory includes a tabulation of each of the habitat unit types represented in the stream. Table 6.13 indicates the percentage of each stream surveyed that is represented by each of the nine Level III habitat types, as described in Flosi et al. (1998).

**TABLE 6.13**
**RESULTS OF STREAM INVENTORIES CONDUCTED BY DEPARTMENT OF FISH AND GAME IN THE SOUTH FORK ALBION RIVER SUBWATERSHED (CDFG 1998)**

| LEVEL III HABITAT TYPE [99] | BULL TEAM GULCH 1,185 FEET SURVEYED (% OF TOTAL LENGTH) | LITTLE NORTH FORK ALBION RIVER 609 FEET SURVEYED (% OF TOTAL LENGTH) | SOUTH FORK ALBION RIVER 37,414 FEET SURVEYED (% OF TOTAL LENGTH) |
|---|---|---|---|
| 1- Riffle | 10 | 15 | 10 |
| 2- Cascade | 0 | 0 | 1 |
| 3- Flatwater | 51 | 54 | 39 |
| % total riffles | 61 | 69 | 50 |
| 4- Main channel pool | 20 | 10 | 36 |
| 5- Scour pool | 3 | 0 | 7 |
| 6- Backwater pool | 0 | 0 | 0 |
| % total pools | 23 | 10 | 43 |
| % LWD-formed pools | 2 | 0 | 4 |
| 7- Dry | 15 | 17 | 0 |
| 8-Culvert | 0 | 4 | 0 |
| 9-Not surveyed | 0 | 0 | 6 |
| % other | 15 | 21 | 6 |

Scour pools in the South Fork Albion River were on average 3.5 feet deep, which is adequate for coho in California (Flosi et al. 1998). All other pool types and streams had an average pool depth less than two feet. Although the number of pools in the South Fork Albion is low, the availability of deeper pools in the South Fork Albion River may partially explain the relatively greater density of coho salmon in the South Fork Albion River as compared to other tributaries in the Albion River watershed.

The main channel pools in the Little North Fork Albion River had an average shelter rating of 128. All the other pool types and streams had an average shelter rating less than 50. A shelter rating is calculated by multiplying the percentage by area of the habitat unit providing shelter by a shelter complexity rating ranging from 0-3. One piece of large woody debris is given a complexity rating of 1 while a diverse array of shelter types (e.g., bubble curtain, large woody debris, rootwad, etc.) is given a complexity rating of 3. The shelter rating ranges from 0-300. CDFG recommends improvements to shelter in locations where the rating is less than 80 (Flosi et al. 1998).

The stream channel in the three stream reaches surveyed in the Albion River watershed are predominantly Rosgen F-type channels, as reported in Table 6.14. F-type channels are low gradient, entrenched, meandering riffle/pool channels with high width-to-depth ratios. They generally have a high rate of bank erosion. E-type channels are also low gradient, meandering, riffle/pool streams, but have a low width-to-depth ratio and little deposition. E-type channels are very efficient at moving sediment and are relatively stable and are connected to the floodplain. These channels and usually well-vegetated. The availability of low depositional, low gradient, well vegetated, stable channels in the South Fork Albion River may contribute to the relatively

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[99] For a description of the habitat types, please see page III-29 in Flossi et al. 1998.

greater density of coho salmon in the South Fork Albion River, as compared to other tributaries in the Albion River watershed.

**TABLE 6.14**
**ROSGEN CHANNEL TYPES IN THE ALBION RIVER WATERSHED AS DETERMINED BY THE DEPARTMENT OF FISH AND GAME (CDFG 1998)**

| CHANNEL TYPE | BULL TEAM GULCH | | LITTLE NORTH FORK ALBION RIVER | | SOUTH FORK ALBION RIVER | |
|---|---|---|---|---|---|---|
| | LENGTH (FT) | % | LENGTH (FT) | % | LENGTH (FT) | % |
| Aa+ | NR | NA | 0 | 0 | 0 | 0 |
| A | NR | NA | 0 | 0 | 0 | 0 |
| B | NR | NA | 0 | 0 | 0 | 0 |
| C | NR | NA | 0 | 0 | 0 | 0 |
| D | NR | NA | 0 | 0 | 0 | 0 |
| E | NR | NA | 0 | 0 | 12,299 | 33 |
| F | NR | NA | 609 | 100 | 25,115 | 67 |
| G | NR | NA | 0 | 0 | 0 | 0 |

NR = not recorded; NA = not available

The CDFG stream surveys of the 1960s and 70s included observations about habitat conditions. The relevant information from these surveys is summarized below:

- Albion Mainstem: The mainstem was surveyed in October 1961 (CDFG 1961c), July 1966 (CDFG 1966a) and in January/February 1979 (CDFG 1979). In October 1961, the river width above the estuary was recorded as ranging from one to 20 feet (averaging five feet wide). The lagoon width ranged from ten feet to 40 feet, with an average of 25 to 35 feet. The depth of the river above the lagoon ranged from one inch to seven feet, while the lagoon ranged from an estimated one foot to 20 feet in depth. Flow was recorded at 5 gps (approximately 0.7 cfs) in the headwaters and 0.2 cfs in the lagoon. Flow was described as very poor throughout the drainage. Recorded water temperatures ranged from 51° to 55°F. Pools were long and shallow, averaging only about one foot deep and 50 feet long. The surveyors concluded that the mainstem Albion River was fair to poor for spawning and rearing, due to low flows and limited gravel.

  A supplementary survey in July 1966 found flows about the same (0.5 cfs from the mouth to the South Fork and 0.2 cfs at Comptche), higher water temperatures (68°F), and continuing poor gravels throughout most of the river. In the January and February 1979 survey, the water depth above the estuary ranged from six inches to six feet. The bottom was heavily silted both in the estuary and above the estuary.

- South Fork Albion: In an October 1961 survey (CDFG 1961a) the South Fork Albion River was described as ranging from one foot in width at the headwaters to over 100 feet in width in the middle and lower stream section. The stream ranged from one to eight inches in depth at the headwaters to very dry, with little range in depth in the middle and lower sections. Where flowing, a flow of up to 0.2 cfs was measured. The upper reaches contained very little gravel compared to the lower reach, which was described as having good gravel and "rubble." Pool development was observed to be poor throughout.[100] Pools that were present were formed by LWD and undercut banks. The low flow was described as a limiting factor and was attributed to low rainfall. Surveyors noted a great quantity of slash and debris on the banks.

Slightly more water was present in the South Fork Albion by the July 1966 supplementary survey (CDFG 1966b). At the mouth, flow was measured at 0.3 cfs. Water temperature was recorded at 58°F. Spawning gravel was described as good. At and around the mouth of the Little North Fork, the stream was largely underground. Parr were seen stranded in small pools.

The January and February 1979 survey on the mainstem Albion also covered portions of the South Fork Albion (CDFG 1979). CDFG observed that there was extremely heavy siltation on the South Fork; slides on the road next to the river were causing silt to enter the stream. In the upper South Fork (presumably above the slide areas), spawning areas were described as being in good condition.

- North Fork Albion River: In a survey conducted in October 1961 (CDFG 1961b), the flow was depicted as sluggish. Water temperature was reported as 52°F. The stream bottom was described as primarily bedrock with a large amount of gravel, sand and silt in the headwater reach and isolated gravel in the middle and lower reaches. Spawning areas were very poor in the middle and lower stream. Pools in the middle and lower reaches were long and wide, averaging 50 feet long and ten feet wide, but only one foot in depth. The North Fork was described as poor for spawning and rearing, in large part because the middle and upper reaches dried out during low summer flows.

  The January and February 1979 survey on the mainstem Albion also covered portions of the North Fork Albion (CDFG 1979). CDFG observed that the North Fork had areas of good spawning gravel. Salmon were observed spawning, but a large amount of silt was seen where a salmon was observed preparing a redd.

#### 6.3.5.3 Coastal Land Trust Habitat Inventory

The Coastal Land Trust ("CLT") conducted a habitat inventory in the summer of 1996 based on the method described by Flosi and Reynolds (1994) in the second edition of the *California Salmonid Stream Habitat Restoration Manual* (Dolphin 1996). Three reaches in the upper Albion River watershed were surveyed:[101]

(1) Upper Albion River mainstem from the L-P property boundary upstream just past Marsh Creek;
(2) A portion of the North Fork Albion River; and
(3) A portion of Soda Spring Creek.

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[100] In the CDFG habitat surveys in the 1990s, the depth of scour pools in the South Fork subwatershed was described as adequate for coho. All other pool types were less than two feet in depth. The 1961 CDFG survey of this subwatershed describes poor pool development – it is not clear if this relates to the number of pools, the depth of pools, or other factors that may have changed between the 1960s and the 1990s.

[101] The CLT survey was designed to cover areas that are not owned by industrial forest owners since those owners were performing similar surveys on their lands (Dolphin 1996).

The habitat survey work performed by the CLT augments that performed by MRC since it covers the upper watershed where no other reports of watershed analysis have been found.

- **Upper Albion River**

CLT (Dolphin 1996) describes the upper mainstem Albion River that was surveyed as a third order stream with an F4 channel (low gradient, well-entrenched, meandering streams). The pools in this reach are abundant, comprising 58% of the total length of stream. However, only 23% of the stream contains pools with depths greater than three feet. The mean shelter rating for pools is also low -- only 36. Shelter in pools is thus far less complex than generally recommended for coho salmon and other salmonids in a third order stream. The low gradient riffles are dominated by gravel-sized particles, which indicates that there is suitable spawning substrate available in this reach. However, the majority of the substrate (56%) is 25-50% embedded. Very little of the substrate (6%) is embedded at greater than 50%. This indicates that, though imperfect, there is spawning substrate in the upper Albion River adequate for salmonids to build redds.

The stream banks of the upper Albion River are dominated by grass and brush. There are very few trees. One would expect LWD to be rare, under these circumstances. Yet, 25% of the habitat units identified in this reach are formed by LWD or rootwads. The banks are composed primarily of silt and clay, with some cobble and gravel. Bank erosion is likely to be high in this region due to the F4 channel type and silty soils.

- **North Fork Albion**

Dolphin (1996) describes the upper North Fork Albion River that was surveyed as a second order stream with an F1 channel (low gradient, well-entrenched, meandering streams with bedrock dominated substrate). Pools in this reach comprise 36% of the stream by length. Forty-two percent of the pools are deeper than two feet deep as recommended for coho rearing in second order streams. The mean shelter rating in pools is very low at 18. Thus, shelter in pools is far less complex than is generally recommended for coho salmon and other salmonids.

Gravel substrate is not abundant in this reach as the reach is dominated by bedrock. The majority (59%) of the gravel that exists is 25-50% embedded, though 27% of the gravel is less than 25% embedded.

The stream banks of the North Fork Albion River are dominated by brush (55%) and coniferous trees (30%). The banks are almost exclusively (97%) composed of silt and clay. Bank erosion is likely to be high in this region due to the F1 channel type and silty soils. Although one would expect stream bank failures to deliver conifers to the stream as LWD, creating LWD-formed habitat units (such as log-enhanced scour pools, rootwad-enhanced scour pools, rootwad-formed backwater pools and log-formed backwater pools), only one log-enhanced scour pool was observed in the entire survey reach.

- **Soda Spring Creek**

Dolphin (1996) describes Soda Spring Creek as a first order stream with an F1 channel (low gradient, well-entrenched, meandering streams with bedrock dominated substrate). Pools in this reach are abundant, comprising 51% of the surveyed stream length. Sixty-one percent of the pools had depths greater than two feet. Flosi et al. (1998) observes that good coho streams the size of Soda Spring Creek generally have at least 40% of their length in pools at least two feet deep. The mean shelter rating in pools is very low at 18. Thus, shelter in pools is far less complex than is generally recommended for coho salmon and other salmonids. There are few low gradient riffles and bedrock is the dominant substrate throughout the stream reach. Forty-six percent of the gravel in pool tail-outs in this reach is 25-50% embedded, though a fair amount (23%) is less than 25% embedded. Nonetheless, spawning habitat is relatively unavailable in this stream reach.

The stream banks of Soda Springs are dominated (64%) by coniferous trees. There are few deciduous trees on the stream banks. The banks are predominantly composed of silt and clay. Bank erosion is likely to be high in this region due to the channel type (F1) and silty soils. One would expect stream bank failures to deliver conifers to the stream as LWD, creating LWD-formed habitat units (such as log-enhanced scour pools, rootwad-enhanced scour pools, rootwad-formed backwater pools and log-formed backwater pools), and about seven log-enhanced scour pools and three rootwad-enhanced scour pools were observed in this survey reach, accounting for approximately 10% of the habitat units observed.

#### 6.3.5.4 Stream Temperature Data

The effect of temperature on the salmonid life cycle is complex and is discussed briefly in Chapter 2 and in greater detail in other references such as Spence et al. (1996) and Meehan (1991). Briefly, the salmonid life cycle processes affected by temperature include: metabolism; food requirements (appetite and digestion); growth rates; development of embryos and alevin; timing of life history events (such as adult migration, fry emergence, smoltification); competitor and predator-prey interactions; disease-host and parasite-host interactions; and, the development of aquatic invertebrate food sources (Spence et al. 1996). Stream temperature also determines the amount of dissolved oxygen that can be carried by a stream, with higher temperatures resulting in lower dissolved oxygen concentrations.

Stream temperature data were collected in the Albion River watershed by several investigators, often as a secondary consideration to other data collection needs. Often the sources do not report the details of data collection that would allow further analysis. In streams, temperature is not uniform in space or time. For example, deep pools and cooler tributaries can provide thermal refugia in water that is otherwise above the optimal temperature range. In a discussion of stream temperature effects on salmonids, Spence et al. (1996) state that " …coldwater pockets in stratified pools ranged from 4.1 to 8.2°C cooler than ambient stream temperatures."[102] This observation demonstrates one of the values of deep pools for salmonids. In addition, diurnal temperature variations can be large at specific locations. Temperature tolerance ranges, lethal temperatures, and preferred temperatures for the different life stages of steelhead and coho are provided in Chapter 2. The preferred temperature range for coho is 12-14°C (54-57°F).

Daugherty (1994) reported on stream temperature data gathered by L-P for the mainstem Albion, South Fork Albion and Railroad Gulch. Each stream had two monitoring stations and stream temperature was monitored continuously for the summers of 1993 and 1994 using data loggers located in pools downstream of riffles. The water temperature range per month is shown in Table 6.15. In the summer of 1995, L-P also sampled the mainstem Albion near Duck Pond Gulch for water temperature. Again, remote data loggers were used, placed in a shallow pool

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[102] Spence et al. 1996, page 94.

where the water was well mixed. L-P issued a report on the stream temperatures for watersheds in their coastal Mendocino Management Unit from 1989 through 1993. Five locations in the Albion River watershed were sampled in the summer of 1992 and 1993 (the 1993 data were previously reported in Daugherty 1994) using remote data loggers placed in well-mixed pools downstream of riffles. The 1992 data were reported for the mainstem Albion at the confluence with the South Fork Albion and for the upper South Fork Albion. The collected L-P temperature data show that the temperatures throughout much of the Albion River watershed are at or above the preferred range for coho and steelhead. These data are shown in Table 6.15.

Dolphin (1996) sampled water temperature as part of a stream survey of a reach of the mainstem in the Upper Albion River planning watershed in the summer of 1996 (areas outside of the L-P/MRC lands). Water temperatures ranged from 56°F to 64°F. Dolphin also sampled a reach of the North Fork Albion around the Soda Spring Creek confluence. Water temperatures were reported to range from 55°F to 59°F. Water temperature of a small portion of Soda Spring Creek was also measured and was found to range from 55°F to 56°F. These results are shown in Table 6.15.

As discussed in Section 6.3.5.2, the CDFG conducted habitat inventories in Bull Team Gulch, Little North Fork Albion River and South Fork Albion River in the 1990s (CDFG 1998). As part of the inventories, CDFG measured water temperature data. The temperature range for six reaches of the South Fork, monitored from June 23, 1998 to July 15, 1998, was 56°F to 62°F. The temperature range for Bull Team Gulch, a tributary to the South Fork Albion, on July 16, 1998 was 58°F to 61°F. The temperature range that was reported for the Little North Fork, also a tributary to the South Fork Albion, measured on June 23, July 14 and 15, 1998 was 58° to 63°F. These results are at or above the upper preferred range for both steelhead and coho, and are shown in Table 6.15.

As discussed in Section 6.2.3, in the winter of 1995/96, Wehren conducted a coho spawner survey in which stream temperature data were recorded (Wehren 1996). In the Albion River watershed, the sampling took place on the mainstem near Comptche, and on the North Fork Albion around the confluence with Soda Springs Creek. The report presents the temperature results as a single value for each sampling date. It is not clear if the results presented are mean values or maximum values. The temperatures reported by Wehren (1996) are within the preferred range for steelhead and coho.

**TABLE 6.15**
**TEMPERATURE DATA REPORTED FOR ALBION RIVER WATERSHED STREAMS**

| STREAM | SAMPLING LOCATION | REFERENCE | WHEN SAMPLED | RESULTS |
|---|---|---|---|---|
| **ALBION RIVER** | Albion River – just upstream from the confluence with the South Fork | L-P 1997b | summer 1992 | Maximum Daily Temperature<br>Jun 1992 63°F (17.2°C)<br>Jul 1992 64°F (17.8°C)<br>Aug 1992 64°F (17.8°C)<br>Sept 1992 60°F (15.5°C) |
| | Albion River – just upstream from the | Daugherty 1994 | summer 1993 | Jun 1993 55 to 61°F (12.8-16.1°C)<br>Jul 1993 57 to 61°F (13.9-16.1°C)<br>Aug 1993 58 to 63°F (14.4-17.2°C) |

**TABLE 6.15**
**TEMPERATURE DATA REPORTED FOR ALBION RIVER WATERSHED STREAMS**

| STREAM | SAMPLING LOCATION | REFERENCE | WHEN SAMPLED | RESULTS |
|---|---|---|---|---|
|  | confluence with the South Fork |  |  | Sept 1993 52 to 59°F (11.1-15.0°C) |
|  | Albion River – just upstream from the confluence with the South Fork | Daugherty 1994 | summer 1994 | Jun 1994 55 to 59°F (12.8-15.0°C)<br>Jul 1994 56 to 59°F (13.3-15.0°C)<br>Aug 1994 57 to 61°F (13.9-16.1°C)<br>Sept 1994 56 to 59°F (13.3-15.0°C) |
|  | Albion River – between Morrison Gulch and the North Fork | Daugherty 1994 | summer 1993 | Jun 1993 56 to 59°F (13.3-15.0°C)<br>Jul 1993 56 to 60°F (13.3-15.5°C)<br>Aug 1993 56 to 62°F (13.3-16.7°C)<br>Sept 1993 51 to 58°F (10.5-14.4°C) |
|  | Albion River – between Morrison Gulch and the North Fork | Daugherty 1994 | summer 1994 | Jun 1994 53 to 58°F (11.7-14.4°C)<br>Jul 1994 54 to 58°F (12.2-14.4°C)<br>Aug 1994 55 to 60°F (12.8-15.5°C)<br>Sept 1994 56 to 59°F (13.3-15.0°C) |
|  | Albion River – near Duck Pond Gulch | Daugherty 1996 | summer 1995 | Jul 1995 59 to 63°F (15.0-17.2°C)<br>Aug 1995 57 to 63°F (13.9-17.2°C)<br>Sept 1995 56 to 60°F (13.3-15.5°C) |
|  | Albion River – near Comptche | Wehren 1996 | winter 1995/6 | 1/13/96 47°F (8.3°C)<br>2/2/96 49°F (9.4°C)<br>2/14/96 50°F (10.0°C)<br>3/30/96 48°F (8.9°C)<br>4/26/96 51°F (10.5°C) |
|  | Albion River – upper watershed | Dolphin 1996 | summer 1996 | 56 to 64°F (13.3-17.8°C) |
|  |  |  |  |  |
| **NORTH FORK ALBION RIVER** | North Fork near Soda Springs Creek | Wehren 1996 | winter 1995/6 | 2/2/96 50°F (10.0°C)<br>2/9/96 (upper) 52.7°F (11.5°C)<br>2/9/96 (lower) 53.6°F (12°C)<br>3/25/96 49°F (9.4°C)<br>4/27/96 53°F (11.7°C) |
|  | North Fork near Soda Springs Creek | Dolphin 1996 | summer 1996 | 55 to 59°F (12.8-15.0°C) |
|  | Soda Springs Creek | Dolphin 1996 | summer 1996 | 55 to 56°F (12.8-13.3°C) |
|  |  |  |  |  |
| **SOUTH FORK ALBION RIVER** | South Fork Albion River – above confluence with the mainstem | Daugherty 1994 | summer 1993 | Jun 1993 54 to 60°F (12.2-15.5°C)<br>Jul 1993 56 to 61°F (13.3-16.1°C)<br>Aug 1993 56 to 61°F (13.3-16.1°C)<br>Sept 1993 51 to 58°F (10.5-14.4°C) |
|  | South Fork | Daugherty | summer | Jun 1994 55 to 60°F (12.8-15.0°C) |

| | | | | |
|---|---|---|---|---|
| | Albion River – above confluence with the mainstem | 1994 | 1994 | Jul 1994 56 to 58°F (13.3-14.4°C)<br>Aug 1994 55 to 60°F (12.8-15.5°C)<br>Sept 1994 54 to 57°F (12.2-13.9°C) |
| | South Fork Albion River – above Larmer Gulch | L-P 1997b | summer 1992 | Maximum Daily Temperature<br>Jun 1992 60°F (15.0°C)<br>Jul 1992 61°F (16.1°C)<br>Aug 1992 62°F (16.7°C)<br>Sept 1992 60°F (15.6°C) |
| | South Fork Albion River – above Larmer Gulch | Daugherty 1994 | summer 1993 | Jun 1993 54 to 58°F (12.2-14.4°C)<br>Jul 1993 55 to 59°F (12.8-15.0°C)<br>Aug 1993 54 to 61°F (12.2-16.1°C)<br>Sept 1993 51 to 58°F (10.5-14.4°C) |
| | South Fork Albion River – above Larmer Gulch | Daugherty 1994 | summer 1994 | Jun 1994 53 to 57°F (11.7-13.9°C)<br>Jul 1994 54 to 57°F (12.2-13.9°C)<br>Aug 1994 55 to 58°F (12.8-14.4°C)<br>Sept 1994 54 to 56°F (12.2-13.3°C) |
| | South Fork Albion River | CDFG 1998 | 6/23/98 – 7/15/98 | 56 to 62°F (13.3-16.7°C) |
| | Bull Team Gulch | CDFG 1998 | 7/16/98 | 58 to 61°F (14.4-16.1°C) |
| | Little North Fork | CDFG 1998 | 6/23/98 – 7/15/98 | 58 to 63°F (14.4-17.2°C) |
| | | | | |
| **RAILROAD GULCH** | Railroad Gulch – middle reach | Daugherty 1994 | summer 1993 | Jul 1993 55 to 58°F (12.8-14.4°C)<br>Aug 1993 56 to 58°F (13.3-14.4°C)<br>Sept 1993 52 to 58°F (11.1-14.4°C) |
| | Railroad Gulch – middle reach | Daugherty 1994 | summer 1994 | Jun 1994 54 to 55°F (12.2-12.8°C)<br>Jul 1994 54 to 55°F (12.2-12.8°C)<br>Aug 1994 54 to 55°F (12.2-12.8°C)<br>Sept 1994 55 to 56°F (12.8-13.3°C) |
| | Railroad Gulch – upper reach | Daugherty 1994 | summer 1994 | Jun 1994 55 to 55°F (12.2-12.8°C)<br>Jul 1994 54 to 56°F (12.2-13.3°C)<br>Aug 1994 55 to 57°F (12.2-13.9°C)<br>Sept 1994 54 to 55°F (12.2-12.8°C) |

### 6.3.5.5 Stream Sediment Data

The effect of excess sediment on the salmonid life cycle and habitat is complex and is discussed in Chapter 2 and, in greater detail, in other references such as Spence et al. (1996) and Meehan (1991). For successful spawning and incubation, salmonids require gravel that has low concentrations of fine sediments. Briefly, the problems associated with excess sediment loads include:

1. Delaying upstream migration of adults;
2. Reducing embryo survival by decreasing intragravel flows and reducing the dissolved oxygen in the redds;
3. Clogging substrate interstices and diminishing intragravel flows;
4. Providing a physical barrier to fry emergence;
5. Depositing organic fines that exert an oxygen demand in the gravel;

6. Disrupting the feeding behavior, including interfering with foraging behavior by reducing the distance from which they can locate drifting prey;
7. Physical damage to fishes by scouring and abrasion;
8. Reducing the diversity of aquatic invertebrates by clogging substrate interstices;
9. Covering the intragravel crevices used for shelter; and,
10. Filling pools by displacing water.

Spence et al. (1996) distinguishes between the effects of suspended and deposited sediments: "In general, deposited sediments have a greater impact on fish than do suspended sediments: spawning and incubation habitats are most directly affected."[103] While the impacts of excess sediment can be adverse, as discussed in Chapter 2 and other references, juveniles and adults reportedly are not greatly affected by transitory events, though newly emerged fry may be more susceptible than older fish.

As discussed in Chapter 2, different metrics are used to describe the sediment in streams – as channel deposits, suspended sediment, turbidity, etc. One of the measurements of turbidity is nephelometric turbidity units ("NTU").[104] Meehan (1991) reports that a turbidity of 25 to 50 NTU reduced growth and caused more young coho and steelhead to emigrate than did clear waters. Coho have been reported to avoid water exceeding 70 NTU.[105] In discussing the effect of turbidity on juvenile migration, Spence et al. state:[106]

> Turbid waters have been mentioned as affecting migration but little documentation is available in the literature. … There is also some evidence that diel migrations of salmonids is influenced by turbidity. Many salmonids tend to migrate during the evening hours (Burgner 1991), presumably to avoid predation. However, in streams with higher turbidity, migrations may be evenly dispersed during both the day and night.

In the MRC (1999a) watershed analysis of its property in the Albion River watershed, sediment was investigated.[107] This analysis was the only identified source of quantitative information on sediment in the Albion River; little of the Upper Albion Planning Watershed is included in the MRC investigation. Quantitative information about background sediment yield in the watershed was not found.[108] MRC prepared an estimation of sediment inputs, rather than a full sediment budget. The sediment sources investigated by MRC in the Albion include hillslope mass wasting, road-associated mass wasting, road surface erosion and skid trail erosion. Graham Matthews Associates is currently conducting a sediment analysis of the Mendocino Coast watersheds for the U.S. EPA, which should provide additional valuable information.

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[103] Spence et al. 1996, page 86.

[104] Nephelometric turbidity unit (or NTU) is unit of measure for the turbidity of water as measured by a nephelometer. This descriptor is based on the amount of light that is reflected off particles in the water.

[105] Meehan 1991, page 119.

[106] Spence et al. 1996, page 104.

[107] See MRC 1999a Section A for Mass Wasting, Section B for Surface Erosion, and Section G for a Summary of Sediment inputs.

[108] MRC (1999a) could not find background sediment yield information for the Albion River watershed. They found information from the nearby Caspar Creek watershed in the Jackson Demonstration State Forest, however, MRC offered several reasons why this information had limited usefulness for understanding the sediment yield in the Albion River watershed. See MRC 1999a page G-3 for a discussion of this issue.

The sediment analysis method used by MRC (1999a) relied on a combination of field investigation, aerial photography, use of topographic maps and a Shallow-Seated Landslide Slope Stability map, predictive equations, and extrapolation. MRC attempted to delineate physical features that were associated with landslides and to identify the probable triggering mechanisms. Roads or skid trails were assumed to be the trigger for adjacent landslides. The volume of material deposited in watercourses was checked by some field verification. Overall, MRC found that 73% of mapped landslides in the watershed deposit sediment directly into a watercourse.

MRC (1999a) estimated that the average Albion River watershed sediment input is 633 tons/mile$^2$/year from 1978 to 1998,[109] for a total of 236,705 tons over the entire 20-year period. Overall, MRC attributes 80% of the sediment to mass wasting, 17% to road surface erosion and about 3% to skid trail erosion. The South Fork Albion Planning Watershed was found to have the highest sediment input (estimated at 102,502 tons for the 20-year period), with most of its sediment coming from roads, not hillslope processes. While the South Fork Albion has the highest density of roads in the watershed, that difference alone does not account for the higher amount of road-related sediment in the South Fork. MRC attributes much of the difference to the placement of more roads in the South Fork planning watershed along and crossing watercourses, compared to the rest of the watershed. The Middle Albion and the Lower Albion planning watersheds had comparable rates of sediment input – 551 tons/mi$^2$/yr and 540 tons/mi$^2$/yr, respectively. The Middle Albion, however, had relatively higher sediment input attributed to roads than did the Lower Albion. MRC attributed this to the placement of roads in the Lower Albion along uplifted marine terraces with few stream crossings. Table 6.16, summarizing sediment input from 1978 to 1998, was taken from MRC 1999a Section G.

**TABLE 6.16**
**Estimated Sediment Inputs by Process in the Albion River Watershed, 1978 – 1998**
**(Taken from MRC 1999a, Section G)**

| PLANNING WATERSHED | ROAD SURFACE EROSION (tons/mi$^2$/yr) | HILLSLOPE MASS WASTING (tons/mi$^2$/yr) | ROAD-ASSOCIATED MASS WASTING (tons/mi$^2$/yr) | SKID TRAIL EROSION (tons/mi$^2$/yr) | TOTAL (tons/mi$^2$/yr) |
|---|---|---|---|---|---|
| Lower Albion | 36 | 434 | 64 | 6 | 540 |
| Middle Albion | 98 | 284 | 148 | 21 | 551 |
| Upper Albion | 16 | 84 | 48 | 0 | 148 |
| South Fork Albion | 246 | 299 | 400 | 34 | 979 |

| | AVERAGE 20-YEAR INPUT RATE (tons/mi$^2$/yr) | 20-YEAR TOTAL VOLUME (tons) |
|---|---|---|
| Albion River Watershed Sediment Input (for entire watershed) | 633 | 236,705 |

MRC (1991a) characterized stream channel conditions as discussed in Section 6.3.4 (stream channel condition). As part of the stream channel analysis, MRC observed and measured the particle size of streambed material throughout the watershed. In the tidally-influenced lower

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[109] MRC 1999a, page G1.

Albion, fine sediment accumulations created broad flat terraces; the connected floodplain with its grass and willow vegetation slows the water flow allowing sediment to settle. In confined, depositional segments of the Albion River and tributaries, fine sediment was found at the top of gravel bars, along the bed of plane bed reaches and in pools. Moderate to high accumulations of fine sediment were observed in unconfined, depositional channel segments of the Albion River; MRC states that deposition of fine sediment is natural in such reaches. Moderate gradient transport reaches of the Albion River were observed to contain sparse to high accumulations of fine sediment on top of gravel bars and in isolated pockets in pools. In high gradient transport reaches of the Albion River, fine sediment accumulation ranged from sparse to moderate.

MRC concluded that the percentage of fine sediment was not high in the Albion River watershed. “Almost all of the locations sampled had percent fine particles less than 0.85 mm under 14-20 percent, which is considered within a properly functioning range…”[110] MRC does not cite a source for their conclusion that this amount of fine sediment is within a properly functioning range, and the sediment analysis by Graham Matthews Associates may provide additional information about this issue. The information regarding fine sediment abundance is presented as part of one of the MRC 1999(a) data summary tables and is summarized in Table 6.17 below.

**TABLE 6.17**
**ALBION RIVER WATERSHED SEDIMENT CHARACTERISTICS (MRC 1999a, Section E)**

| PLANNING WATERSHED | SAMPLE REACH # | STREAM NAME | FINE SEDIMENT ABUNDANCE |
|---|---|---|---|
| Lower Albion | 3 upper | Lower Albion | sparse |
| | 3 lower | Lower Albion | medium – abundant |
| | 4 | Railroad Gulch | medium – abundant |
| | 5 | Railroad Gulch | medium |
| | 6 | Railroad Gulch | medium |
| | 15 | Pleasant Valley Creek | medium |
| | 20 | Duck Pond Gulch | medium |
| | 21 | Duck Pond Gulch | medium |
| Middle Albion | 43 upper | Mid Albion | sparse |
| | 43 lower | Mid Albion | sparse |
| | 44 | Mid Albion | sparse |
| | 45 | East Railroad Gulch | sparse |
| | 50 | Tom Bell Creek | medium |
| South Fork Albion | 76 | South Fork Albion | sparse |
| | 77 | South Fork Albion | sparse |
| | 78 | South Fork Albion | abundant |
| | 79 | South Fork Albion | abundant |
| | 80 | South Fork Albion | medium |
| North Fork Albion | 114 | North Fork Albion | sparse |

Note: The terms sparse, medium and abundant are not defined by MRC. These appear to be based on a qualitative, visual assessment.

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[110] MRC 1999a, page F-21.

## 6.4 SYNTHESIS

### 6.4.1 LOWER ALBION RIVER

MRC (1999a) reported that the best spawning gravel is found on the mainstem below the confluence with the South Fork Albion River, while the gravels on the mainstem above the South Fork confluence are moderate to good. MRC (1999a) assessed the rearing habitat quality of the Lower Albion as fair; the rearing habitat being most adversely affected by the low shelter complexity. Compared to the rest of the watershed, only in the Lower Albion do pools of at least three feet deep comprise a sizeable portion of the reach (40% of the habitat by length). The canopy closure was fair to good with closure in the mainstem Albion River ranging from 67% to 84% and in Railroad Gulch ranging from 77% to 82%. The lower canopy closure on the mainstem was attributed to the width of the stream, a streamside road, forest harvest, and extensive wetlands. Two Lower Albion tributaries, Railroad Gulch and Pleasant Valley Creek, contain densities of wood and "key" pieces of LWD that exceed the basin wide averages based on the MRC (1999a) watershed analysis. The MRC data do not indicate whether the existing density of LWD in these streams is sufficient to provide properly functioning conditions.

Reported stream temperature data indicate that Railroad Gulch in the Lower Albion planning watershed generally has lower temperatures than the rest of the Albion River Watershed.

Coho were reported in the Lower Albion planning watershed, including the mainstem, Deadman Gulch, Railroad Gulch, Pleasant Valley Creek, Slaughterhouse Gulch, and Duck Pond Gulch.

### 6.4.2 MIDDLE ALBION RIVER

MRC (1999a) rated the Middle Albion River spawning habitat as fair with moderate to low levels of embeddedness and fair to good gravel quality. East Railroad Gulch has relatively unembedded spawning gravels. The overall rating for spawning habitat in the Middle Albion was negatively affected by the amount of fine particles in the watercourses. Rearing habitat was negatively affected by the low percentage of pools with residual depth greater than three feet. Although, overall, the Middle Albion watershed is judged to have sparse LWD, two Middle Albion tributaries, East Railroad Gulch and Tom Bell Creek, each contain densities of wood and "key" pieces of LWD that exceed the basin wide averages based on the MRC (1999a) watershed analysis. The MRC data do not indicate whether the existing density of LWD in these streams is sufficient to provide the stream habitat function that is necessary to support salmonids.

Coho were reported in the Middle Albion planning watershed, including Kaisen Gulch, East Railroad Gulch, and Tom Bell Creek.

### 6.4.3 SOUTH FORK ALBION RIVER

The South Fork planning watershed has, by far, the highest sediment input to watercourses in the Albion River watershed, with most of its sediment coming from roads, not hillslope processes. The MRC rating for the South Fork Albion was influenced by the amount of embeddedness of spawning gravels and the abundant deposition of fine sediment. The condition of spawning gravels on the South Fork Albion River has a lower quality than the mainstem and other areas in the watershed. Most of the South Fork Albion and the Little North Fork were shown to have gravel embeddedness greater than 50%, indicating poor conditions.

In spite of ample LWD and pools, rearing habitat was judged to be only fair due to the high levels of embeddedness and lack of shelter complexity. The middle portion of the South Fork Albion River contained a high proportion of deep pools to shallow pools, but the total number of pools in the reach was small. In spite of the low total number of pools, the availability of deeper pools in the South Fork Albion River may partially explain the greater density of coho salmon in the South Fork Albion River as compared to other tributaries in the Albion River watershed. The South Fork Albion canopy closure ranged from 85% to 87%. Reaches of South Fork Albion River contains densities of wood and "key" pieces of LWD that exceed the basin wide averages based on the MRC (1999a) watershed analysis, but the MRC data do not indicate whether the existing density of LWD in these streams is sufficient to properly functioning conditions. Stream temperature data for much of the South Fork Albion River planning watershed are at, or above, the preferred range for steelhead and coho.

Coho were reported in the South Fork Albion planning watershed, including the South Fork Albion, the Little North Fork, Bull Team Gulch, and Winery Gulch. In various L-P and MRC population surveys, the numbers of observed coho were highest or second highest in the streams of the South Fork planning watershed, in spite of the high sediment input and the low number of pools – perhaps due to the depth of the available pools. Steelhead also have been reported in the South Fork Albion.

### 6.4.4 UPPER ALBION RIVER

There is little information on stream conditions and salmonid population in the Upper Albion River planning watershed. Only a small section of the Upper Albion River watershed was assessed in the MRC (1999a) watershed analysis. The reach surveyed by MRC was judged to have good spawning habitat with relatively unembedded gravels. The CLT survey (Dolphin1996) on the upper reaches that are not within MRC lands, however, found that the majority of the gravels in the surveyed reaches are moderately embedded. The lack of deep pool and low shelter complexity result in a judgement of only fair rearing habitat. The overwintering habitat in this segment was good, providing LWD and frequent pools. North Fork Albion canopy closure was reported as 84%. The North Fork Albion River contains densities of LWD and "key" pieces of LWD that exceed the basin wide averages based on the MRC (1999a) watershed analysis, however, the MRC data do not indicate whether the existing density of LWD in the North Fork is sufficient to provide the properly functioning conditions.

Compared to the rest of the Albion River watershed, the North Fork planning watershed has lower stream temperatures, although the summer time temperatures provided by Dolphin (1996) are on the higher end of the preferred range.

Coho were reported in the North Fork Albion River. Little data are available but steelhead have been reported in the North Fork Albion watershed. Hatchery steelhead were planted in Marsh Creek to supplement the steelhead population in the early 1980s, but information about supplementation practices is not readily available.

## 6.5 CONCLUSIONS AND RECOMMENDATIONS

### 6.5.1 GENERAL SUMMARY AND CONCLUSIONS

The Albion River is listed on the state's CWA 303(d) list for sediment. The most sensitive beneficial use of concern is the protection of the cold freshwater fishery.

Available data about much of the watershed is limited. MRC conducted a watershed analysis on their holdings in the watershed, which covered many of the main watercourses in the basin (except for the estuary and most the Upper Albion Planning Watershed), however, much of the analysis was qualitative in nature and was not described in sufficient detail to re-evaluate the data. A systematic watershed analysis of the upper watershed and the estuary should be performed, including information developed for sedimentation and salmonid population. Stream temperature data should be assessed to determine its effects on the salmonids in the Albion River watershed. Additionally, a monitoring strategy should be developed to provide data that would better describe the habitat and population, including spawning, rearing, and outmigration events. Information that would help elucidate the issues presented by sediment in the watershed include longitudinal profiles, V* data, and a full sediment analysis.

### 6.5.2 COHO AND STEELHEAD ABUNDANCE

Data on the salmonid population in the Albion River watershed is sparse, but show that coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) spawn and rear in the watershed, although at low numbers. Both of these species are listed as threatened under the federal Endangered Species Act. There are not sufficient data from which to estimate the size of the historic population of coho and steelhead in the Albion River watershed although there is general agreement that the populations of both species have decreased substantially. While some historic population sampling data are available from a variety of sources, the data, for the most part, were not collected in a manner that would allow a quantitative analysis.

Coho and steelhead populations appear to be in decline. In a summary of fish monitoring data on MRC lands in Mendocino and Sonoma counties, MRC (1999b) concluded that steelhead populations in the Albion River are on a downward trend. The NMFS status reviews of West Coast steelhead (Busby et al. 1996) and coho (Weitkamp et al. 1995) concluded that steelhead and coho stocks in the ESUs that include the Albion watershed are very low relative to historic estimates and are trending downward.

### 6.5.3 ESTUARY

The depth of the estuary has reduced from 20 to 25 feet deep in the 1940s to be less than six feet deep with a heavily silted bottom in 1979. Maahs and Cannata (1998) found that steelhead outmigrants spent little time in the estuary (compared to steelhead in the neighboring Navarro River estuary). Maahs and Cannata believe that the salmonid use of the estuary should be greater in order to provide optimal growth for ocean survival, although it is not clear if what they observed signals a low population of fish in the watershed or that the fish merely do not use the estuary. Maahs and Cannata hypothesized that use of the estuary by salmonids may be limited by the low D.O. concentrations in the estuary as well as poor habitat conditions upriver of the estuary, especially the limited number of large, deep, complex pools.

### 6.5.4 SHELTER & POOLS

Shelter is poor throughout the basin. None of the reported shelter ratings in the MRC (1999a) watershed analysis meet or exceed the criteria used by CDFG when recommending habitat restoration. Shelter in pools was found to be far less complex than generally recommended for coho salmon and other salmonids in the mainstem and the tributaries surveyed.

Although Maahs and Cannata (1998) focused on the estuary, they postulated that the Albion freshwater habitat, perhaps due to a limited number of large, deep, complex pools, may not be sufficient to produce a sizable population of large steelhead smolts. Maahs and Cannata suggested that the best opportunity for enhancing the salmonid population is erosion control, which could lead to better pools in the freshwater areas and improved substrate in the estuary.

Pools are too shallow in most of the basin to provide adequate rearing habitat for coho salmon. The MRC (1999a) watershed analysis supports this conclusion showing that only in the Lower Albion do pools of at least three feet deep comprise a sizeable portion of the reach (40% of the habitat by length). The middle portion of the South Fork Albion River contained a high proportion of deep pools to shallow pools, but the total number of pools in the reach was small. The availability of deeper pools in the South Fork Albion River may partially explain the greater density of coho salmon in the South Fork Albion River as compared to other tributaries in the Albion River watershed.

### 6.5.5 SPAWNING GRAVELS

The MRC (1999a) watershed analysis showed that spawning gravels are moderately embedded throughout much of the Albion River basin. Only in three locations are gravels relatively unembedded: (1) the lower Albion River; (2) East Railroad Gulch; and, (3) the North Fork Albion River. The South Fork Albion River and the Little North Fork Albion River showed embeddedness greater than 50%, indicating poor spawning gravel conditions.

### 6.5.6 CANOPY & LARGE WOODY DEBRIS

MRC (1999a) assessed the canopy closure over streams on their lands in the Albion River watershed. The canopy closure in the mainstem Albion River ranged from 67% to 84%; Railroad Gulch canopy closure ranged from 77% to 82%; the South Fork Albion canopy closure ranged from 85% to 87%; and the North Fork Albion canopy closure was reported as 84%. The lower numbers on the mainstem were attributed to the width of the stream, a streamside road, forest harvest, and extensive wetlands.

Railroad Gulch, East Railroad Gulch, Pleasant Valley Creek, Tom Bell Creek, North Fork Albion River, reaches of the Albion River and reaches of South Fork Albion River each contain densities of wood and “key” pieces of LWD that exceed the basin wide averages based on the MRC (1999a) watershed analysis. The MRC data do not indicate whether the existing density of LWD in these streams is sufficient to provide the properly functioning conditions that are necessary to support salmonids.

## Chapter 7
## Gualala River Watershed

*NOTE This chapter was excerpted from the Gualala River Watershed Technical Support Document for the Total Maximum Daily Load for Sediment (CWQCB 2001). For more details about information presented in Chapter 7, see that document.*

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## 7.0 BRIEF CONCLUSIONS

Available data suggest that the success of salmonid spawning, incubation, and emergence success in the Gualala River watershed may be limited by the following factors:

- Impact of fine sediments on spawning and rearing habitats
- Lack of pool habitat provided by large woody debris
- Increased stream temperature possibly due to canopy removal and an oversupply of sediment

If chinook have ever resided in the watershed, they have long ago disappeared. Coho certainly were present in the watershed, but have all but disappeared. Steelhead are present throughout the watershed, but their numbers have been declining since the 1970s. One area that should be considered a refuge area for salmonids is the Little North Fork Gualala River.

Data reviewed in this chapter indicate that aquatic habitat throughout the watershed is impaired by excessive fine sediments. $D_{50}$ and V* data suggest that upslope disturbances have impacted stream substrates with excessive fine sediments, and impaired the ability of the aquatic habitat to support salmonid spawning, incubation, and emergence. The exception is Dry Creek where both $D_{50}$ and percent fines data indicate good spawning habitat. Regional Water Board staff observations of conditions existing in the spring of 2001 indicate that stream channels are still greatly impacted by fine sediment.

Stream temperatures also may be a factor limiting salmonid production in the Gualala River watershed. Stream temperatures may be affected by increased sedimentation. For example, thermal refugia, such as deep thermally stratified pools and cold water seeps where fish are able to escape warmer water, can be eliminated by increased sedimentation. Temperature data from 1993 through 1998 gathered by Gualala Redwoods Inc. (see GRI 1998-2000) and Mendocino Redwood Company (MRC, unpublished data) suggest that stream temperatures for most of the watershed exceed preferred juvenile rearing temperature ranges for steelhead and coho. Exceedance of short-term maximum lethal temperatures for steelhead and coho occur throughout the watershed.

Results of CFL surveys provide evidence that, with the exception of Fuller Creek, stream reaches throughout the Gualala River watershed lack essential habitat provided by LWD. Two indices measured for the survey, LWD pieces per bankfull width and LWD volume index, measured for the survey, fell short of criteria established by Peterson et al (1992). Past land management involving logging and associated practices such as splash dam log transportation, as well as previous CDFG projects that removed migration barriers throughout the watershed, have led to the dearth of salmonid habitat provided by LWD.

## 7.1 GENERAL BACKGROUND

### 7.1.1 BASIN PLAN – BENEFICIAL USES

The primary beneficial use of concern in the Gualala River watershed, as described in the *Water Quality Control Plan, North Coast Region* ("the Basin Plan," California North Coast Regional Water Quality Control Board 1994), is the cold freshwater fishery which supports steelhead trout (*O. mykiss*) and, possibly, coho salmon (*Oncorhynchus kisutch*), both listed as threatened under the federal Endangered Species Act.[111] The Basin Plan identifies municipal, industrial, agricultural, recreational, commercial and sport fishing, cold water habitat, migration, spawning, estuarine and wildlife habitat, groundwater recharge and navigational uses of the Gualala River watershed. The beneficial uses of water related to rare, threatened or endangered species has been proposed for this basin. As with many of the north coast watersheds, the cold water fishery appears to be the most sensitive of the beneficial uses in the watershed because of the sensitivity of salmonid species to habitat changes and water quality degradation. Accordingly, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation.

### 7.1.2 LOCATION

The Gualala River watershed, located in Northern California, flows into the Pacific Ocean near the Town of Gualala approximately 114 miles north of San Francisco (U.S. Bureau of Reclamation 1974) and 17 miles south of Point Arena (see Map 1.1). The Gualala River drains approximately 296 square miles (189,440 acres) of mostly mountainous and rugged terrain in both Sonoma and Mendocino Counties. The Mendocino-Sonoma county boundary runs down the center of the Mainstem Gualala River and through the Rockpile Creek subwatershed.

The Gualala River watershed (Calwater Number 113.8) consists of five principle tributaries (see Map 7.1). These include the North Fork (113.81), Rockpile Creek (113.82), Buckeye Creek (113.83), Wheatfield Fork (113.84), and the South Fork (113.85). The Mainstem Gualala River runs for approximately three miles from the confluence of the South Fork and North Fork to the Pacific Ocean. The Mainstem Gualala River flows from the confluence of the South Fork and North Fork to the Pacific Ocean. This reach is greatly influenced by seasonal closures of the river mouth, which typically occur in early summer and last until the first heavy rains of October or November, although it may also close briefly during the winter months (CDFG 1968 and EIP 1994).

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[111] 61 FR 56138 and 65 FR 36074.

**TABLE 7.1**
**PLANNING WATERSHEDS WITHIN THE GUALALA RIVER WATERSHED (Interagency California Watershed Mapping Committee 1999)**

| Planning Watershed Number | Subwatershed | Area (square miles) | Area (acres) | % of Watershed |
|---|---|---|---|---|
| 113.81 | North Fork | 48 | 30,700 | 16% |
| 113.82 | Rockpile Creek | 35 | 22,400 | 12 |
| 113.83 | Buckeye Creek | 40 | 25,800 | 14 |
| 113.84 | Wheatfield Fork | 112 | 71,500 | 37 |
| 113.85 | South Fork and Mainstem | 64 | 40,800 | 21 |
| TOTAL | | 299 | 191,200 | 100 |

Elevations in the Gualala River watershed range from sea level at the mouth to over 2,650 feet along the ridges and peaks. The primary population centers in the Gualala River watershed are the towns of Gualala, Sea Ranch, Stewarts Point, Annapolis, and Plantation.

The Gualala River watershed has few public roads crossing it. Highway 1 crosses the Mainstem Gualala River at its estuary just south of the Town of Gualala. Stewarts Point/Skaggs Springs Road is a Sonoma County Road that connects Stewarts Point on the coast to Lake Sonoma, running along the Wheatfield Fork and Wolf Creek. Other public roads include the Annapolis Road, King Ridge Road in the South Fork subwatershed, and Fish Rock Road, which is a Mendocino County road that runs along the north boundary of the Gualala River watershed.

### 7.1.3 CLIMATE

The climate in the Gualala River watershed is temperate, especially on the coast, while more extreme temperatures occur inland. According to the Fort Ross climate station (located on the coast), the average annual temperature from 1948 to 2000 is 12.1°C (53.7°F), with an annual minimum of 7.1°C (44.7°F) and an annual maximum of 17.0°C (62.6°F) [Western Regional Climate Center (WRCC) 2000b]. In comparison, inland temperatures range from a low of below freezing to a high of 26-32°C (80-90°F) (CDFG 1968).

Throughout the Gualala River watershed more than ninety percent of the annual precipitation falls between October and April, with the greatest amounts falling in January (EIP 1994). The average annual precipitation recorded at the Fort Ross climate station between 1948 to 2000 is 38.69 inches per year (WRCC 2000c). The amount of precipitation recorded at Fort Ross has varied from 71.27 inches in 1983 to 17.98 inches in 1976 (WRCC 2000b). Inland precipitation is higher than at the coast, with an average annual amount of approximately 65 to 70 inches per year (CDFG 1968 and EIP Associates 1994). Map 7.3 shows the estimated average rainfall distribution throughout the Gualala River watershed.

### 7.1.4 VEGETATION

Map 7.4 illustrates the distribution of the types of vegetation found in the Gualala River watershed. Generally speaking, the headwaters area of the South Fork and Wheatfield Fork subwatersheds are characterized by steep slopes forested by redwood, douglas fir, madrone, and tan oak. Open grasslands are also interspersed throughout the headwaters of the North Fork, Rockpile Creek, Buckeye Creek, and Wheatfield Fork subwatersheds (CDFG 1968). Streamside vegetation consists primarily of red alder, California laurel, and redwood. Dense stands of redwood and some fir and hardwoods occur to within one-quarter mile of the coast. A very narrow coastal prairie strip is present near the mouth and along the coast (CDFG 1968).

### 7.1.5 SOILS AND GEOLOGY

The Gualala River watershed is typical of watersheds in:[112]

> The California Coast Ranges between San Francisco and the Oregon border [which] contain the most rapidly eroding, large-order, non-glaciated drainage basins of comparable size in the United States (Judson and Ritter, 1964). The combination of the underlying pervasively sheared and often folded Franciscan rocks (Bailey et. al., 1964), recent uplift, and a distinctive climate accounts for the large sediment yields.

Soil types within the Gualala River watershed are varied. The predominate soil is the Hugo-Josephine-Laughlin Association which occurs inland. The Hugo-Josephine-Laughlin Association is well-drained with gently sloping to very steep gravely loams (Miller 1972). Loams are soils consisting of a friable mixture of clay, silt, and sand. The soils of this association are formed in material derived from weathered, fine-grained, hard sandstone and shale (Miller 1972). Hugo and Josephine soils are the best in Sonoma County for commercial timber production. Laughlin soils are used extensively as range and pasture (Miller 1972). The Soil Survey of Sonoma County (Miller 1972) describes the Empire-Caspar-Mendocino Association as a well-drained and moderately well-drained soil that consists of strongly sloping sandy loams and sandy clay loams. These soils are found in the coastal uplands and terraces that run parallel to the coast. Soils of the Yorkville-Suther Association are found in patches in the upper areas of Wolf Creek, a tributary to Wheatfield Fork, and Marshall Creek, a tributary to the South Fork. These soils are moderately well drained with moderately sloping to very steep loams and clay loams (Miller 1972). The Yorkville-Suther Association is found on ultrabasic rock intrusions, other igneous rock, and on sedimentary rock. Yorkville and Suther soils are used primarily for pasture and range (Miller 1972). Map 7.2 illustrates the distribution of the soil types found in the Gualala River watershed.

Alluvial Terrace Deposits (Qrt) are found along most of the watercourses of the Gualala River watershed. This surficial formation consists of poorly consolidated flat-lying deposits of silt, sand, and gravel elevated above present streams and rivers (Davenport 1984). Within the channel itself, Stream/River Channel Deposits (Qsc) are found. Consisting of silt, sand, and gravel, these deposits are characteristically unvegetated (Davenport 1984). Marine Terrace Deposits (Qmtd) are also found at the mouth of the Gualala River. These deposits are poorly to moderately consolidated deposits of marine silts, sands, and quartz-rich pea gravels (Davenport 1984).

One of the most striking geomorphic features of the landscape is the San Andreas Rift, an active fault that traverses the Gualala River watershed, running directly under the South Fork and Little North Fork of the Gualala River. " . . . The San Andreas fault zone has formed the 1 to 1.5 mile wide rift valley along which the Garcia and Gualala Rivers flow".[113] The Gualala Ridge, an elongate, forested, northwestward trending ridge, forms the drainage divide between the short streams that flow directly westward to the ocean and the rift valley containing the South Fork Gualala River (Williams and Bedrossian 1976). Knox and Huffman (1980) show that many

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[112] Kelsey et. al. 1981.

[113] Williams and Bedrossian 1976.

other faults are located within the Gualala River watershed, although none besides the San Andreas Fault is known to be active. One such fault runs from the mouth of Buckeye Creek under the length of Miller Ridge. Several other smaller faults are found in the highly fractured areas of Skyline Ridge, Table Mountain, and Mohrhardt Ridge. The Mount Jackson Fault cuts through the eastern Gualala River watershed on a northwestward trend paralleling the coast approximately ten miles inland.

Bedrock west of the San Andreas Fault consists of sedimentary sandstone, mudstone, shale, and conglomerate (Williams and Bedrossian 1976). These units are, in many places, are interfingered and very difficult to distinguish from each other on the basis of appearance. The German Rancho Formation (Tg) can be found on the slopes on the west side of the San Andreas Fault. This formation is composed of well bedded sandstone, mudstone, and conglomerate and contains abundant potassium feldspar (Knox and Huffman 1980). Also present west of the San Andreas Fault are minor amounts of the Anchor Bay Formation (Ka) and the Stewarts Point Formation (Ks and Ksb) (Knox and Huffman 1980).

Bedrock east of the San Andreas Fault is almost entirely composed of the heterogeneous Franciscan assemblage, of Late Jurassic through Cretaceous age. One sub-unit of the Franciscan assemblage is the Coastal Belt Franciscan, the youngest and least sheared and broken sub-unit, which contains mostly sandstone. Generally, slopes are steep, as they are underlain by hard rock. Debris slides are common. The Coast Belt of the Franciscan Complex is the predominate formation east of the San Andreas Fault and is found extensively in each of the sub-watersheds (Knox and Huffman 1980 and McKittrick 1995).

The Central Belt of the Franciscan Assemblage is the most unstable sub-unit. The Central Belt melange unit is characterized by grassy and brushy slopes and contains a huge expanse of sheared rock which forms the matrix that envelopes rock blocks of various sizes and types, including sandstone, shale, blue schist, metavolcanic, amphibolite, and sepentinite (Huffman 1972). The Central Belt of the Franciscan Assemblage is found in the Gualala River watershed in ribbons that run parallel to the coast. These ribbons can be found in the eastern portions of the North Fork, Rockpile Creek, and Buckeye Creek subwatersheds (Knox and Huffman 1980 and McKittrick 1995). Another ribbon runs from the mouth of Buckeye Creek, under Miller Ridge, and along Marshall Creek. The Central Belt of the Franciscan Assemblage becomes more prominent in the area between House and Pepperwood Creeks of the Wheatfield Fork and Marshall Creek of the South Fork subwatershed (Knox and Huffman 1980).

Scattered throughout the Gualala River watershed are patches of the Ohlson Ranch Formation, which is composed of sandstone, siltstone, and conglomerate (Knox and Huffman 1980). These patches are most often located on ridges and upland slopes near the coast. Several of the larger patches of the Ohlson Ranch Formation are found around Annapolis and along Miller Ridge (Knox and Huffman 1980).

### 7.1.6 LAND AND WATER USE

The Town of Gualala has always been a mill town (Mendocino County Historical Society 1965) and the surrounding forested lands of the Gualala River watershed supported the mills. Logging has been an ongoing activity in the watershed since 1862, when harvesting of the old growth began in the lower portion of the watershed (White-Parks 1980). The Mendocino County Historical Society (1965) counted seven mills along the coast near to and including Gualala between 1862 and 1869, with many more built in 1904. A railroad was built in 1872 and 1873 to move timber to Bourne's Landing located approximately 2.5 miles north of the Town of Gualala (Mendocino County Historical Society 1965).

Logging activity slowed after 1908 until after World War II when a second logging boom began, aided by the advent of modern machinery, and fueled by a tax on standing timber. During the intervening period, extraction of tan oak bark for use in the leather tanning industry kept workers in the woods.

Evidence of the post-war logging boom was just beginning to show up in the northern parts of the watershed when aerial photos were taken in 1952. For the most part, the photos show mature stands of trees in the forested areas of the watershed, with very few roads. By 1965, aerial photos of the watershed show large areas denuded of trees and intensively scarred by roads and skid trails. The logging practices of the time had little consideration for water quality and fisheries, as evidenced by the common practice of using stream channels as roads and landings. In 1968, major timber harvesting in the watershed had slowed with active harvesting activities confined to the selective harvest of relatively small areas of second growth Redwood and Douglas Fir (CDFG 1968).

Forestry is still a major land use today. Approximately thirty four percent (34%) of the Gualala River watershed is owned by timber companies (Parish 1999). Pioneer Resources owns approximately 34,000 acres (approximately 18% of the total area of the Gualala River watershed), formerly owned by Coastal Forestlands, with around 6,000 acres in the North Fork, 9,000 acres in Rockpile Creek, 10,000 acres in Buckeye Creek, and 8,000 acres in other portions of the Gualala River watershed. Gualala Redwoods owns approximately 30,000 acres (approximately 16% of the total area of the Gualala River watershed) distributed across the mainstem and tributaries of the Gualala River watershed. Mendocino Redwoods Company owns approximately 4,500 acres (approximately 2% of the total area of the Gualala River watershed), formerly owned by Louisiana-Pacific, primarily in the Wheatfield Fork.

Agriculture also has been a significant land use in the Gualala Watershed (EIP 1994). Orchards were a significant agricultural activity in the past. Today, vineyards are beginning to become more common throughout the watershed and are likely to become more widespread. In the past, sheep and cattle ranching were prominent industries. Today grazing has become less significant.

The Gualala River watershed has a history of instream gravel mining. The Draft EIR prepared for Gualala Aggregates, Inc. by EIP Associates (1994) states that instream extraction of gravel in the 1950s for use on logging roads was between 1,000 and 5,000 cubic yards per year. In the early 1960s, commercial extraction began and rates rose to approximately 20,000 cubic yards per year. In the latter half of the 1960's, the construction of residential roads at The Sea Ranch created an increased demand for aggregate, and rates rose to approximately 40,000 cubic yards per year. From 1974 to the present, a 40,000 tons per year gravel extraction limit has been in place for commercial extraction. Gravel extraction since 1993 has been below the 40,000 ton per year gravel extraction limit. Gravel extraction has mainly been through gravel bar skimming. In the mid-1960's, trenching was tried but discontinued due to the high amounts of organic material encountered. Currently, gravel bar skimming is the method used to mine gravel.

Gualala Aggregates, Inc. manages a mining operation at a plant located beside the Gualala River near the confluence of the Wheatfield Fork and the Upper South Fork. Gualala Aggregates, Inc., which has extracted gravel from the South Fork Gualala River and Wheatfield Fork Gualala River since 1969, has performed most of their mining on two main gravel bars totaling about 26 acres. One gravel bar is located at the confluence of the two river forks, while the other is located two miles downstream of the confluence.

US Geological Survey ("USGS") flow gages were located approximately 540 feet and 2,200 feet downstream of the confluence of the South Fork of the Gualala River and the Wheatfield Fork of the Gualala River from 1950-1961 and 1962-1971 respectively. Gage height data indicate:

- 1.5 feet of aggradation occurred from 1950 to 1960 when extraction rates were approximately 1,000 to 5,000 cubic yards/year (EIP Associates 1994).
- 1.0 feet of degradation occurred from 1960 to 1964 when extraction rates were approximately 20,000 cubic yards/year (EIP Associates 1994).
- 0.75 feet of degradation occurred from 1964 to 1971 when extraction rates were approximately 40,000 cubic yards/year (EIP Associates 1994).

Given the limited gage height data available, the impact of gravel mining on channel aggradation/degradation cannot be determined. Observations in other rivers in Sonoma County have shown that in-stream gravel bar skimming may be responsible for a change in channel cross-section towards a more flattened bar form with relatively shallower pools (EIP Associates 1994). Cross-sectional data are available in the Gualala Aggregates Draft EIR (EIP Associates 1994). Cross-sectional data are not adequate to indicate whether a change in cross-section to a more flattened channel bar has taken place in the vicinity of Gualala Aggregates mining operation.

## 7.2 SALMONID DISTRIBUTION AND ABUNDANCE

Short- and long-term trends in abundance are a primary indicator of risk in salmonid populations (Weitkamp et al. 1995). Trends may be calculated from a variety of quantitative data, including dam or weir counts, stream surveys, and catch data (Weitkamp et al. 1995). When data series are lacking, general trends may be inferred by comparing historical and current abundance estimates (Weitkamp et al. 1995).

Insufficient information exists from which to draw quantitative conclusions about the current abundance and distribution of salmonids in the Gualala River watershed. The information presented in this chapter collected during the last two decades, offers a qualitative perspective.

Data sources considered in this assessment include:

- CDFG electrofishing (summer-rearing) surveys
- Fish presence/absence surveys

- Spawning surveys
- CDFG stream inventory of McKenzie Creek watershed
- Coastal Forestland's Watershed and Aquatic Wildlife Assessment

Very little information on the historical presence of chinook in the Gualala River watershed was discovered. Some anecdotal evidence exists for their presence early in the last century, but other information was not found.

Historically, steelhead have been observed throughout the entire Gualala watershed. Available information indicates that the populations show a pattern of decline over time. However, it appears that steelhead continue to be present in most tributaries throughout the watershed. Data support the hypothesis that the steelhead populations were in a declining trend as early as the 1970s. The latest estimate of the total Gualala river steelhead population was made in 1977 when California Department of Fish and Game ("CDFG") estimated the winter steelhead population at 4,400 (Sheahan 1991). It is not possible to determine how the number of hatchery steelhead planted in various streams has affected the overall population. Presence/absence surveys conducted in the South Fork Gualala River and in the Wheatfield Fork in the early 1990s indicate that the fish community is now dominated by Gualala roach and three-spine stickleback in many areas. In addition, a large percentage of the steelhead observed appear to be young-of-the-year ("YOY") that may not be surviving to mature and propagate. Additional studies would be necessary to confirm this.

It was not possible to estimate the population size of coho salmon in the Gualala River watershed due to the limited data. It appears that the coho were once plentiful but now have all but vanished from this watershed. Available data indicates that coho began to decline rapidly in the Gualala River watershed by the latter part of the 1960s. Few coho were observed in the stream surveys of the early 1970s and coho were last noted in CDFG stream surveys in Fuller Creek (Wheatfield Fork) and its tributaries in 1970 and 1971. Coho were also observed in Haupt Creek, a tributary to the Wheatfield Fork in 1970. Coho were not observed during surveys in the 1980s and 1990s, other than in the Little North Fork. Juvenile coho that were observed during the 1997 surveys of Doty Creek and the Little North Fork Gualala River could be the result of CDFG plants in 1995 (Higgins 1997). It is possible that their progeny continue to exist in this sub-watershed. The last reported sighting of coho salmon in the Gualala River may have been the observed entry of nine adult coho into the Gualala River when the sand bar opened at the mouth during the winter of 1999-2000.

### 7.2.1 HISTORIC SALMONID ABUNDANCE AND DISTRIBUTION

The following information is partially extracted from the Gualala River Watershed Literature Search and Assimilation (Higgins 1997), a compilation of Gualala River watershed data completed by Patrick Higgins under contract to the Redwood Coast Land Conservancy.

The Gualala River historically has been an important stream for its runs of steelhead, rainbow trout and coho salmon. Steelhead trout still provide a viable sport fishery. In the last decade coho salmon have been reported only in the Little North Fork and its tributaries where coho have been planted by CDFG as recently as 1997 (CDFG, unpublished data 'm'). Rainbow trout are noted to exist above impassible barriers (Cox 1989). It is likely that chinook salmon were native to the Gualala River as they were to the Garcia and Russian Rivers to the south and to coastal watersheds to the north.

The only known estimate of historic salmonid abundance in the Gualala River watershed was developed by the California Department of Fish and Game ("CDFG") in the early 1960s. CDFG reported 16,000 steelhead, 4,000 coho, and zero chinook (California Fish and Game Commission 1965).

Other fish species native to the Gualala River (Higgins 1997) include the Gualala roach (*Lenvenia parvipinnis*), three-spined stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*), Coast Range sculpin (*Cottus aleuticus*), and Pacific Lamprey (*Lampetra tridentata*). The Gualala roach has been designated as a "Species of Special Concern" because they are a distinct subspecies, apparently endemic to the Gualala River system, and their life history and population status are poorly understood. Moyle (1976, as cited by Higgins 1997) states that Gualala roach prefer water temperatures less than 23 °C to 24 °C for long-term survival, but can survive temperatures up to 35 °C (95 °F).

### 7.2.2 CHINOOK – DISTRIBUTION AND ABUNDANCE

Very little information exists on the historical presence of chinook in the Gualala River. A long-time resident of the Gualala watershed was interviewed in 1997 (Spacek, unpublished) and recalled catching a 34-pound salmon in 1919. Higgins (1997) explained that a fish of this size would be much too large to be a coho, and therefore was likely a chinook. Other residents who were interviewed reported that it was uncommon to catch a chinook even in the 1930s. Small runs of chinook reportedly were observed in the last decade [Coastal Forestlands ("CFL") communication with W. Jones, as cited in CFL 1997].

### 7.2.3 COHO – HISTORIC DISTRIBUTION AND ABUNDANCE

The coho population was recently estimated for Mendocino County at 4,950 fish (Brown et al. 1994; Weitkamp et al. 1995). Adams et al. (1999) report that coho are found in 51% of the streams in which they were historically present in California and 64% of the streams in Mendocino County in which they were historically present.

While there is a paucity of data on coho salmon abundance in the Gualala River, there are indications that they were once numerous. Bruer (1953, as cited by Higgins 1997) asserted that there were millions of steelhead and coho juveniles in arguing for re-opening summer "trout" fishing. The California Fish and Game Commission (1965) reported an estimated 4,000 coho in the mid-1960s in the Gualala River. Boydstun (1974a) reported that 831 adult coho salmon were caught in the 1972-73 angling season with 244 released. The high catch in 1972-73 may have been due, at least in part, to coho planting by CDFG (Barracco and Boccione 1977, as cited by Higgins 1997). In contrast, the 1976-77 creel census reported only 10 coho.

In the last decade, coho have been found only in the Little North Fork (Halligan, personal communication, as cited by Higgins 1997) and Doty Creek, where they were planted by CDFG as recently as 1997. Historically, coho have been reported to spawn and rear in the tributaries listed below, and possibly others (Cox 1994 and Ambrose 2000).

Gualala River Tributaries with Historic Coho Presence:

- North Fork Gualala River
    - Robinson Creek
    - Dry Creek
    - Little North Fork
    - Doty Creek
- South Fork Gualala River
    - Marshall Creek
    - Sproule Creek
    - Buckeye Creek
        - Francini Creek
- Wheatfield Fork Gualala River
    - Haupt Creek
    - House Creek
    - Fuller Creek
        - North Fork Fuller Creek
        - South Fork Fuller Creek

### 7.2.4 COHO – CURRENT DISTRIBUTION AND ABUNDANCE

Michael Maahs and the Salmon Troller's Marketing Association performed redd surveys in the Little North Fork and the North Fork Gualala three times during February 1991 (February 1 through 15). No live coho or carcasses were observed and only two redds were observed in the Little North Fork. Five redds were found on the North Fork just downstream from the mouth of the Little North Fork. These redds were most likely laid by fish headed for the Little North Fork which did not spawn due to low flow conditions (Maahs and Gilleard 1994). CDFG planted yearling coho in this stream in 1988 (see Table 7.9 below). However, this spawning activity was not believed to be due to returning adult coho from this release since they were not found until the second February survey (Maahs and Gilleard 1994).

CDFG conducted electrofishing (summer-rearing) surveys in several tributaries of the Gualala River between 1983 and 1998 (see Table 7.3 below). Coho were only observed at the upper and lower Little North Fork stations during October 1988, at 0.36 and 0.92 fish/m$^2$, respectively. Coho were not previously observed at these locations during the October 1983 sampling, nor were they observed in subsequent sampling events during the 1989 – 93, 1995 and 1998 surveys at these same locations.

During the previous season surveys (1989-90), there were as many as 17 redds (or 2.06 redds/mile of stream) observed in the Little North Fork Gualala (Nielsen et al. 1990), many of which were observed during the month of January (indicating that they were likely coho redds).

Coho were not observed during the snorkel, electrofishing or stream surveys conducted in the watershed during the 1990s, as described above.

### 7.2.5 STEELHEAD TROUT– HISTORIC DISTRIBUTION AND ABUNDANCE

Prior to the 1940s, there appears to be little to no data for the Gualala fishery. In 1945, there was an estimated 200-300% increase in anglers on the Gualala River (Taft 1951), compared to pre-WWII figures. Concern about the effect of fishing on juvenile steelhead populations led CDFG to close portions of the Gualala and several other rivers for summer and winter fishing, from 1948 through 1982 (Cox, personal communication 2001). The general trend during that time period was that the upper river was open for summer fishing while the lower river was open for winter steelhead fishing. With the passage of new regulations in 1982, waters of the Gualala River watershed are closed to fishing year-round, with the exception of the Mainstem and the South Fork below Valley Crossing (Cox, personal communication 2001).

CDFG files include a series of historical stream surveys in which field staff walked portions of streams noting their observations. Detailed field notes taken during these surveys, performed in various streams from the late 1950s through the late 1980s, indicate the presence of steelhead in the majority of streams surveyed. The majority of streams where steelhead were notably absent were in minor tributaries to the Wheatfield Fork. These tributaries were reported to have little to no water during the summer months.

Creel census surveys and mark-and-recapture techniques were used by CDFG in the 1950s through the 1970s to estimate populations of adult steelhead on the Gualala River. The highest catches were estimated at 1700 steelhead in 1974-75, 1590 steelhead in 1953-54, 1418 steelhead in 1975-76, and 1352 steelhead in 1954-55 (see Table 7.2).

**Table 7.2**
**STEELHEAD ADULT CATCH BY YEAR, INCLUDING ANGLER HOURS AND CATCH PER HOUR**

| YEARS | CATCH | HOURS | CATCH/HR | ESTIMATED POPULATION |
|---|---|---|---|---|
| 1953-54 | 485 | 4515 | 0.28 | NR |
| 1954-55 | 570 | 7613 | 0.08 | NR |
| 1962 | NR | NR (single day) | 0.2 | NR |
| 1972-73 | 288 | 12,884 | 0.02 | NR |
| 1973-74 | 1700 | 13,218 | 0.13 | 2219, 2584 |
| 1974-75 | 793 | 14,593 | 0.05 | 7608 |
| 1975-76 | 1418 | 27,899 | 0.05 | 6300 |
| 1977 | NR | NR | NR | 4400 |

NR= Information not reported

From: CDFG Creel Census (Fisher 1957) and Coastal Steelhead Studies (Boydstun 1973; Boydstun 1974a; Boydstun 1974b; Boydstun 1976a; Boydstun 1976b)

In 1973, CDFG estimated that the steelhead population (for the entire Gualala system) was between 2,219 (“Park Hole”) and 2584 (estuary), based on recapture in two areas of the lower mainstem Gualala. The respective 95% confidence limits were 799 – 5,165 and 571 – 9,535. In 1974-75, CDFG estimated that the adult steelhead population was 7,608, with a 95% confidence interval of 6,126-10,379 (Boydstun, 1976b). In 1975-76 the population was estimated at 6,300 (Boydstun, 1976b). In 1977, CDFG estimated the winter steelhead population at 4,400 (Sheahan, 1991).

Boydstun (1974b) noted that while angler effort in 1972-73 was 60% greater than in 1953-54, the catch in the 1970s was just 25% of the 1950s catch. He attributed the decreased catch rate to decreased adult steelhead abundance. From 1970 to 1976, the CDFG supplemented Gualala River steelhead runs with hatchery fish which may have increased the escapement and catch. Higgins (1997) noted that it is also possible for external conditions to skew the catch per unit effort.

In addition to the creel census that were conducted by CDFG during the winters of 1953-54, 1954-55, 1972-73, 1973-74, 1974-75, and 1975-76, a single-day creel census was completed on January 24, 1962 (see Table 7.2). The 0.2 catch per angler hour that day compares favorably with the 1950s values and is higher than the 1970s values.

It is possible that conditions in 1973-74 where the catch numbers were high, may have been particularly favorable for angling. In years with high flows and turbidity, such as 1972-73, catch numbers may have been adversely affected (Higgins 1997). However, during the latter 1970s a downward trend in catch is plausible.

During the 1975-76 season, 17% of the total catch was estimated to be steelhead that were planted. The year prior, 23% of the total catch was estimated to be from plants (Boydstun 1976b). In-river harvest of steelhead in 1975-76 was estimated to be only 15% of the adult population (Boydstun 1976b). Based on this estimate, it was concluded that sportfishing most likely had a minimal impact on the adult steelhead population. Reavis (1983, as cited by Higgins 1997), made a similar conclusion, finding that only two of the estimated 535 salmonids caught by anglers in the spring and summer of 1982 were kept.

### 7.2.6 STEELHEAD TROUT– CURRENT DISTRIBUTION AND ABUNDANCE

#### 7.2.6.1 North Fork

The CDFG conducted electrofishing (summer-rearing) surveys in several tributaries of the Gualala River between 1983 and 1998 (See Table 7.3). The density of steelhead at the various locations over this time-period in the Little North Fork, where the majority of surveys were conducted, ranged from 0.19 to 1.49 fish per square meter of stream ($m^2$). The average density of steelhead in the Little North Fork from 1993 to 1998 was 0.44 fish/$m^2$.

**TABLE 7.3**
**STEELHEAD TROUT AND COHO SALMON POPULATION DATA (from CDFG unpublished data 'm')**

| STREAM REACH | DATE | STEELHEAD DENSITY (fish/$m^2$) | STEELHEAD BIOMASS (kg/ha) | COHO DENSITY (fish/$m^2$)* | COHO BIOMASS (kg/ha) |
|---|---|---|---|---|---|
| Little N. Fork Gualala River | 10/28/83 | 0.46 | 31.67 | 0 | 0 |
| Robinson Creek | 10/28/83 | 0.84 | 55.89 | 0 | 0 |
| Little N. Fork Gualala River | 9/23/86 | NR | NR | 0 | 0 |
| Doty Creek | 9/23/86 | NR | NR | 0 | 0 |
| Log Cabin Creek | 9/23/86 | NR | NR | 0 | 0 |
| Dry Creek | 9/24/86 | NR | NR | 0 | 0 |
| North Fork Gualala River | 9/24/86 | NR | NR | 0 | 0 |
| Robinson Creek | 9/24/86 | NR | NR | 0 | 0 |
| Little N. Fork Gualala River (upper) | 10/11/88 | 0.22 | 8.8 | 0.36 | 15.85 |
| Little N. Fork Gualala River (lower) | 10/12/88 | 0.64 | 19.65 | 0.92 | 29.85 |
| Little N. Fork Gualala River (lower) | 10/20/89 | 1.49 | 36.94 | 0 | 0 |
| Little N. Fork Gualala River (upper) | 10/20/89 | 0.29 | 12.43 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 11/2/90 | 0.47 | 17.06 | 0 | 0 |
| Little N. Fork Gualala River (upper) | 11/9/91 | 0.54 | 23.18 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 11/9/91 | 0.25 | 5.48 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 10/28/92 | 0.6 | 18.2 | 0 | 0 |
| Little N. Fork Gualala River (upper) | 10/28/92 | 0.19 | 9.8 | 0 | 0 |
| Little N. Fork Gualala River (upper) | 9/30/93 | 0.55 | 31.97 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 9/30/93 | 0.4 | 11.91 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 9/19/95 | 0.41 | 12.95 | 0 | 0 |
| Little N. Fork Gualala River (upper) | 9/19/95 | 0.53 | 15.96 | 0 | 0 |
| Soda Springs | 11/8/95 | NR | NR | 0 | 0 |
| Buckeye Creek –Unnamed Tributary | 11/8/95 | NR | NR | 0 | 0 |
| Osser Creek | 11/8/95 | NR | NR | 0 | 0 |
| Buckeye Creek- Flat Ridge | 11/8/95 | NR | NR | 0 | 0 |
| Buckeye Creek | 11/8/95 | NR | NR | 0 | 0 |
| Francini Creek | 11/8/95 | NR | NR | 0 | 0 |
| Little N. Fork Gualala River (upper) | 10/30/98 | 0.46 | 17.98 | 0 | 0 |
| Little N. Fork Gualala River (lower) | 10/30/98 | 0.27 | 21.87 | 0 | 0 |

NR= Not Reported
*all coho reported are young-of-the-year

Large numbers of juvenile steelhead were reportedly observed during the spawning surveys conducted in 1989-1990 in the Little North Fork Gualala River and its tributaries. Maahs and Gilleard (1994) concluded that the juvenile presence and spawning of steelhead indicated the production in these streams was quite good.

### 7.2.6.2 Wheatfield Fork

In addition to the data presented in Table 7.3, electrofishing was performed by the CDFG in August 1989 at four locations in the Fuller Creek drainage. Two of the same locations, on the mainstem and South Fork Fuller Creek, were sampled again in 1995. The resulting steelhead densities were 33.3 and 15.3 per 100 feet of stream, respectively. These densities were reported to be approximately half of the 1989 densities (Cox 1989 and 1995).

#### 7.2.6.3 South Fork

Juvenile steelhead were studied during the late 1980s in the lower South Fork Gualala River, below the Wheatfield Fork and in the estuary. Looking at the size of fish in the samples collected in the estuary during the spring of 1984-1986 (Brown 1986), it appears that young-of-the-year ("YOY") steelhead dominated the samples. This could indicate that the carrying capacity of the tributaries is low, as noted by Higgins (1997) or that there is a decrease in favorable living space upstream, forcing juveniles to emigrate prematurely (Graves and Burns 1970, as cited by Mangelsdorf et al. 1997). It is also possible that the high number of YOY steelhead were the result of late season spawning just upstream in the mainstem or lower reaches of the tributaries (Higgins 1997).

Additional studies were conducted on the South Fork Gualala River in the last decade. Electrofishing surveys were conducted in July and October 1991 at 16 stations along the Lower South Fork, extending approximately from its confluence with the Wheatfield Fork downstream, to the confluence with Buckeye Creek. Seven locations upstream and nine locations downstream of the Sea Ranch wells were identified, as the purpose was to study the effects of the water diversion. Streamflows were noted to be unseasonably low during the July portion of this study. The three most abundant species at all stations were steelhead trout, Gualala roach and three-spine stickleback (see Tables 7.4 and 7.5). Gualala roach were generally dominant, although sticklebacks were the most abundant in upstream riffle habitat in July and upstream run habitat in October. Steelhead trout were the most abundant species in upstream run habitat in July. Nearly all of the base steelhead population was age $1^+$ with a small percentage of age $2^+$. Conclusions of this study asserted that relatively low base populations of steelhead were present both upstream and downstream of the wells due to regional drought and seasonal low streamflow conditions.

**TABLE 7.4**
**SPECIES COMPOSITION AND RELATIVE ABUNDANCE (fish/100m) BY HABITAT TYPE UPSTREAM AND DOWNSTREAM OF SEA RANCH WELLS -- 1991 (from Entrix 1992)**

| HABITAT TYPE | SPECIES | JULY | | OCTOBER | |
|---|---|---|---|---|---|
| | | UPSTREAM | DOWNSTREAM | UPSTREAM | DOWNSTREAM |
| **Riffle** | Steelhead | 280 | 63 | 18 | 13 |
| | Gualala roach | 297 | 125 | 136 | 236 |
| | Three-spine stickleback | 615 | 69 | 63 | 68 |
| **Run** | Steelhead | 451 | 121 | 47 | 40 |
| | Gualala roach | 148 | 161 | 505 | 146 |
| | Three-spine stickleback | 116 | 52 | 690 | 63 |
| **Deep Pool** | Steelhead | 135 | 63 | 80 | 145 |
| | Gualala roach | 200 | 134 | 231 | 263 |
| | Three-spine stickleback | 116 | 110 | 147 | 115 |
| **Rootwad Pool** | Steelhead | 388 | 193 | 171 | 81 |
| | Gualala roach | 977 | 1,474 | 318 | 178 |
| | Three-spine stickleback | 380 | 30 | 326 | 0 |

**TABLE 7.5**
**AVERAGE JUVENILE STEELHEAD POPULATION ESTIMATES BY HABITAT TYPE UPSTREAM AND DOWNSTREAM OF SEA RANCH WELLS -- 1991 (from Entrix 1992)**

| JUVENILES | JULY | | OCTOBER | |
|---|---|---|---|---|
| | UPSTREAM | DOWNSTREAM | UPSTREAM | DOWNSTREAM |
| **BASE POPULATION** | | | | |
| Riffle | 8.0 | 3.3 | 0 | 2.5 |
| Run | 65.0 | 16.7 | 0 | 3.0 |
| Deep Pool | 44.5 | 20.0 | 29.0 | 24.0 |
| Rootwad Pool | 202.0 | 30.0 | 39.0 | 15.0 |
| | | | | |
| **YOY** | | | | |
| Riffle | 278.0 | 66.3 | 18.0 | 25.5 |
| Run | 386.0 | 105.7 | 47.0 | 34.7 |
| Deep Pool | 112.0 | 71.0 | 46.5 | 179.0 |
| Rootwad Pool | 210.0 | 178.0 | 132.0 | 67.0 |

Electrofishing surveys were performed in October 1993 for The Sea Ranch subdivision by Entrix, Inc. in the South Fork Gualala River above and below the confluence with the Wheatfield Fork, and in the Wheatfield Fork (EIP 1994). As noted by EIP (1994), these fish counts represent an index of fish abundance, rather than an estimate of the true population number. Gualala roach were the most abundant fish at the one site (A) that was sampled downstream of the confluence of the Wheatfield and South Forks. Steelhead trout were the most prevalent at the four sites sampled on the South Fork upstream of the confluence (sites B-E), ranging from 13 to 33 fish. Two sites sampled on the Wheatfield Fork (F, G) also had a slightly higher number of steelhead than roach.

Fourteen pools on the South Fork Gualala River were surveyed by snorkel during mid-October 1993 (see Table 7.6). These pools extended from approximately 75 meters upstream of the Wheatfield Fork confluence down to the confluence with Pepperwood Creek. Gualala roach and three-spine stickleback typically congregated in large schools; therefore, their abundance was visually estimated (EIP 1994).

**TABLE 7.6**
**SNORKEL SURVEY OPERATIONS IN THE GUALALA RIVER -- OCTOBER 1993 (from EIP 1994)**

| SITE NUMBER | STEELHEAD TROUT TOTAL | STEELHEAD TROUT BY AGE | | | GUALALA ROACH TOTAL | THREE-SPINE STICKLEBACK TOTAL |
|---|---|---|---|---|---|---|
| | | $0^+$ | $1^+$ | $2^+$ | | |
| 1 | 95 | 74 | 19 | 2 | 900 | 250 |
| 2 | 34 | 16 | 18 | 0 | 1,500 | 200 |
| 3 | 293 | 246 | 46 | 1 | 1,400 | 800 |
| 4 | 72 | 30 | 36 | 6 | 1,350 | 200 |
| 5 | 78 | 49 | 26 | 3 | 880 | 126 |
| 6 | 47 | 30 | 17 | 0 | 400 | 0 |
| 7 | 65 | 51 | 13 | 1 | 720 | 60 |
| 8 | 68 | 58 | 10 | 0 | 30 | 0 |
| 9 | 9 | 9 | 0 | 0 | 740 | 0 |
| 10 | 6 | 4 | 2 | 0 | 350 | 0 |
| 11 | 27 | 23 | 4 | 0 | 100 | 1 |
| 12 | 8 | 8 | 0 | 0 | 1,200 | 200 |
| 13 | 135 | 100 | 35 | 0 | 750 | 0 |
| 14 | 140 | 100 | 35 | 5 | 750 | 150 |
| **TOTAL** | 1,077 | 798 | 261 | 18 | 11,070 | 1,987 |

Steelhead were observed at all sites, ranging in abundance from 6 to 283 fish. Age $0^+$ steelhead accounted for 74 percent of the population overall. Age $1^+$ accounted for 24 percent of the population. The remaining 2% were comprised of age $2^+$ fish. The Gualala roach was the most abundant fish at the majority of sites, with population estimates of greater than 700 fish at ten of the 14 pools surveyed. The roach and stickleback were typically common in backwater areas. Stickleback typically inhabit shallow water habitats that could not be accurately assessed by snorkeling, and therefore may have been more abundant than the survey indicated (EIP 1994).

Halligan (2000) studied the densities of steelhead in the North Fork Gualala River under contract to the Gualala River Steelhead Project (“GRSP”) during the fall of 2000. The purpose of the study was to determine if the released steelhead would overwhelm the carrying capacity of the stream and have an adverse affect on the naturally reared fish. Unfortunately, there is very little information regarding optimal densities for salmonids in Northern California. The only report that comes close to suggesting an optimal upper limit is Harvey and Nakamoto (1996) when they observed a significant decline in juvenile steelhead survival rates when densities rose from 1.5 fish/$m^2$ to 3 fish/$m^2$ in South Fork Caspar Creek.

Four survey reaches were studied within the mainstem Gualala River and the North Fork Gualala River (Table 7.7). Underwater observations for this study were made by snorkeling. Several pool/riffle sequences were surveyed to obtain inter-reach habitat variability. The first set of dives was on September 16. On October 13, a second set of dives was made, after a rain when smolt may have migrated to the estuary.

**TABLE 7.7**
**JUVENILE STEELHEAD OBSERVATIONS IN THE GUALALA RIVER WATERSHED BY SIZE CLASS, DENSITY AND STREAM LENGTH (from Halligan, 2000)**

| REACH | AGE CLASS | NUMBER BY AGE CLASS | | DENSITY (fish/m$^2$) | | FISH PER METER OF STREAM LENGTH | |
|---|---|---|---|---|---|---|---|
| | | **Sept.** | **Oct.** | **Sept.** | **Oct.** | **Sept.** | **Oct.** |
| **1**<br>Mainstem -<br>100’ Downstream of N. Fork | YOY | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1+ | 0 | 3 | 0 | 0.0008 | 0 | 0.014 |
| | 2+ | 0 | 7 | 0 | 0.002 | 0 | 0.033 |
| | 3+ | 0 | 2 | 0 | 0.002 | 0 | 0.033 |
| | **TOTAL** | **0** | **12** | **0** | **0.005** | **0** | **0.08** |
| **2**<br>N. Fork -<br>100’ Upstream of Little N. Fork | YOY | 33 | 22 | 0.03 | 0.02 | 0.19 | 0.13 |
| | 1+ | 64 | 83 | 0.06 | 0.08 | 0.37 | 0.47 |
| | 2+ | 9 | 12 | 0.008 | 0.01 | 0.05 | 0.07 |
| | 3+ | 3 | 0 | 0.003 | 0 | 0.02 | 0 |
| | **TOTAL** | **109** | **117** | **0.101** | **0.11** | **0.63** | **0.67** |
| **3**<br>N. Fork -<br>2,500’ Downstream of Robinson Creek | YOY | 99 | 60 | 0.07 | 0.04 | 0.39 | 0.23 |
| | 1+ | 73 | 133 | 0.05 | 0.09 | 0.29 | 0.52 |
| | 2+ | 8 | 16 | 0.006 | 0.01 | 0.03 | 0.06 |
| | 3+ | 0 | 1 | 0 | 0.001 | 0 | 0.004 |
| | **TOTAL** | **180** | **210** | **0.126** | **0.14** | **0.71** | **0.81** |
| **4**<br>N. Fork -<br>3,500’ Upstream of Dry Creek | YOY | 18 | 37 | 0.017 | 0.035 | 0.08 | 0.16 |
| | 1+ | 34 | 65 | 0.03 | 0.062 | 0.15 | 0.28 |
| | 2+ | 10 | 18 | 0.009 | 0.017 | 0.04 | 0.08 |
| | 3+ | 7 | 2 | 0.007 | 0.002 | 0.03 | 0.009 |
| | **TOTAL** | **69** | **122** | **0.063** | **0.12** | **0.3** | **0.53** |

The resulting data from the Halligan (2000) study in the Gualala watershed are comparable to the fish population data collected by Entrix (1992), in the South Fork Gualala River in October 1991. The juvenile steelhead abundance in 1991 averaged 80 fish per 100 meters of stream length for all habitat types combined. The North Fork estimates averaged 30 to 71 fish per 100 meters (for all habitat units) in September, and 53 to 81 fish in October (Halligan 2000). Previous surveys performed in the North Fork Gualala River indicated steelhead densities between 0.19 and 1.5.

Based on the low density of juvenile steelhead and the presence of underutilized habitat units, Halligan (2000) concluded that the North Fork Gualala River may not be at carrying capacity. The winter survivability of steelhead parr may be greater in the North Fork than the lower mainstem. The fish densities in the North Fork and Gualala River appear to be relatively low when compared to data from other watersheds in the region (see Table 7.8). It is important to note that these types of data are highly variable and reflect only short periods in time, not actual populations.

**TABLE 7.8 JUVENILE STEELHEAD DENSITY FROM WATERSHEDS IN NORTHERN CALIFORNIA (from Halligan 2000)**

| YEAR | LOCATION | DENSITY (fish/$m^2$) |
|---|---|---|
| 1952 | Lower Gualala River | 0.39 |
| 1967-1969 | N.F. Caspar Creek | 0.54 – 1.39 |
| 1988-1991 | L.N.F. Gualala River | 0.22 - 1.48 (0.52) |
| 1993 | N.F. Caspar Creek | 1.5 |
| 1994-1995 | Little River & Tribs. Humboldt Co. | 0.3 – 0.58 |
| 1998 | Freshwater Creek Humboldt Co. | 0.32 |
| 1999 | Freshwater Creek Humboldt Co. | 2.01 |

A stream inventory was performed by the CDFG during the summer of 1999 (CDFG 2000) in McKenzie Creek (tributary to Marshall Creek), and its tributaries. The inventory indicated the presence of steelhead (mainly YOY), in McKenzie, Camper, and Carson Creeks; however, none were observed in Wild Hog Canyon Creek. Populations were not estimated as part of this survey. A 1964 survey of McKenzie Creek, performed by CDFG, indicated that it was an important tributary to the South Fork Gualala due to excellent steelhead and coho spawning areas (CDFG, unpublished data ‘n’). Coho were not observed during the 1999 survey. A 1964 stream survey of Marshall Creek noted the presence of 100 steelhead and 30 coho per 100 feet of stream.

### 7.2.7 SHIFTS IN FISH COMMUNITY STRUCTURE

Higgins (1997) described the shifts that appear to have taken place in the Gualala River community structure as the Gualala roach and the three-spine stickleback have become more prevalent in recent years. Brauer (1953, as cited in Higgins 1997) stated that although Gualala roach were present throughout the river basin, they were found only in small numbers. An electrofishing sample taken on the lower main stem Gualala River just below the North Fork by Kimsey (1953) indicated that steelhead were the most abundant species. Dive observations in July and October 1991 (EIP 1994) on the Lower South Fork below the Wheatfield Fork showed a community dominated by Gualala roach and stickleback (see Tables 7.3 and 7.4). CDFG stream surveys also indicate that the density of roach and stickleback have greatly increased since the 1960s. Halligan (1997), in comments on the draft of Higgins 1997 report, suggested that steelhead might make up a higher proportion of the community after a series of wet years. The 1991 samples were taken after a sequence of drought years.

### 7.2.8 HATCHERY SUPPLEMENTATION

CDFG planted steelhead juveniles from the Mad River Hatchery in the Gualala River from 1972 through 1976, and then again from 1985 through 1989. A hatchery was operated by the Gualala River Steelhead Project (“GRSP”) in the late 1980s using native Gualala River brood fish that were caught by anglers. In 1994, the GRSP changed the emphasis of their program to rescue, rearing, and release (Ackerman, personal communication 2001). However, records indicate that steelhead were planted annually through 1997. A total of approximately 435,000 steelhead were planted during that time period.

CDFG planted coho salmon in the Gualala River and its tributaries from 1969 through 1973 and then again in 1975, 1983, 1984, and 1988, and finally from 1995-1997 (see Table 7.9). Approximately 348,000 coho were planted during those years (CDFG, unpublished data). Coho juveniles also were planted in the North Fork Gualala River in 1988 because suitable habitat was present and electrofishing surveys showed that the stream had lost its historic coho run (CDFG, unpublished data 'm'). Unfortunately, the large numbers of coho planted were unable to prosper. Poor survival of coho planted in the late 1980s was ascribed to drought conditions, but the possibility of bacterial kidney disease, a disease fairly common to hatchery fish, was also raised (CDF 1994b). Higgins (1997) observed that although temperatures are cool enough for coho salmon introduction, spawning gravel stability and pool volume in the Gualala River may not be optimal for coho.

**TABLE 7.9**
**GUALALA RIVER FISH PLANTS (from CDFG unpublished data 'o')**

| YEAR | APPROXIMATE NUMBER OF FISH | | ENTITY RESPONSIBLE FOR PLANTING |
|---|---|---|---|
| | COHO | STEELHEAD | |
| 1969 | Gualala: 90,042 | | CDFG |
| 1970 | Gualala: 30,000 | | CDFG |
| 1971 | Gualala: 30,000 | | CDFG |
| 1972 | Gualala: 15,003 | Gualala:1,950 & 10,800 | CDFG |
| 1973 | Gualala: 20,007 | Gualala: 20,345 | CDFG |
| 1974 | | Gualala: 15,634 | CDFG |
| 1975 | South Fork Gualala: 10,005 | Gualala: 10,036 & 14,600 | CDFG |
| 1976 | | Gualala: 10,070 | CDFG |
| 1983 | Gualala: 11,500 | Walker Creek: 12,500 | GRSP, GRSP |
| 1984 | Gualala: 12,000 | Walker Creek: 13,400 | GRSP, GRSP |
| 1985 | | Gualala: 4,725; Gualala: 5,000 | CDFG, GRSP |
| 1986 | | Gualala: 27,450; Doty Creek: 30,000 | CDFG, GRSP |
| 1987 | | Gualala: 11,250; Gualala: 13,000 | CDFG, GRSP |
| 1988 | Little N. Fork Gualala: 84,000 | Gualala: 79,000; Gualala: 29,750 | CDFG; GRSP, CDFG |
| 1989 | | Gualala: 42,700; Old Bridge Hole (Son. Co. Park) 31,000 | CDFG; GRSP |
| 1990 | | Gualala River, Regional Park: 20,025; Gualala River, County Park 21,312 | GRSP; GRSP |
| 1991 | | Robinson Creek: 2,000 | GRSP |
| 1994 | | North Fork Gualala: 4,600 | GRSP |
| 1995 | Little N. Fork Gualala: 20,000 | North Fork Gualala: 3,500 | CDFG; GRSP |
| 1996 | Little N. Fork Gualala: 12,480; N. Fork Gualala 3,500 | | CDFG; GRSP |
| 1997 | Little N. Fork Gualala: 12,880; Doty Creek: 4,200 | | CDFG; GRSP |

GRSP= Gualala River Steelhead Project Plant
CDFG= California Dept. of Fish & Game
Location was not reported if *Gualala* is noted in location column

## 7.3 AQUATIC HABITAT

### 7.3.1 HABITAT STRUCTURE

CDFG conducted a number of stream surveys from the 1950s to the 1980s. Few recent habitat inventories exist for streams in the Gualala watershed. CDFG conducted a fisheries inventory of McKenzie Creek and its tributaries in 1999. A moderate amount of data describing stream conditions that relate to salmonid habitat conditions is contained in the Coastal Forestlands, Ltd. *Watershed and Aquatic Wildlife Assessment* (1997). In addition, Gualala Redwoods, Inc. reported some habitat information in recent timber harvest plans ("THP").

#### 7.3.1.1 CFL Channel Assessment Data

Results of the CFL surveys indicate that the stream reaches surveyed are LWD deficient. Values of two indices, LWD pieces per bankfull width and volume index, are well below targets developed by Peterson et al. (1992) for the State of Washington (Table 7.10). A notable exception is Fuller Creek, where indices were much higher than the Washington standards. The Washington State targets are based on values taken from unmanaged streams in western Washington, where forests are dominated by Douglas Fir. Rates of decomposition of Douglas Fir are higher than Redwood; therefore, it is reasonable to assume that LWD abundance would be higher in unmanaged Redwood forest streams.

**TABLE 7.10**
**LARGE WOODY DEBRIS CONDITIONS OF THE GUALALA SUBWATERSHEDS (from CFL 1997)**

| Planning Subwatershed | CFL LWD Frequency (# LWD/ Bankfull Width) | Washington LWD Frequency Target | Volume Index ($m^3$/LWD) | Washington Volume Index Target |
|---|---|---|---|---|
| Fuller Creek | 5.1 | **2.21** | 1.6 | **1.45** |
| Buckeye Creek | 1 | **2.07** | 0.9 | **2.99** |
| NF Gualala | 0.7 | **2.04** | 1.3 | **3.36** |
| Mid Rockpile | 0.5 | **2.01** | 2.0 | **3.93** |
| Lower Mid Rockpile | 0.3 | **1.99** | 1.9 | **4.39** |
| Lower Buckeye Creek | 0.7 | **1.95** | 1.3 | **5.22** |

The low volume and frequency of LWD in the Gualala Watershed may be reflective of the early beginnings of logging in the watershed. The first mill in Gualala was built in 1862 and logging continued in earnest until 1906 when the mill at Gualala burned down and logging decreased. Logging picked up once again after World War II. Second growth logging began as early as 1894, and it is likely that many stands are in their fourth or fifth cycle (White-Parks 1980). The riparian timber stands were most likely logged most extensively, given the fact that they were closest to the railroads and skid trails that were used to move the trees to the mills. In the earliest days of Gualala logging the method of transporting logs was the "splash dam, " which was breached after enough water was behind the dam to float the many logs placed in the channels to the mill at the river mouth. Removal of obstructions, such as submerged logs, was a common practice in the splash dam era. Logging in the later half of the twentieth century has undoubtedly limited recruitment of LWD since.

CFL evaluated canopy conditions on Class I streams on their ownership by analysis of aerial photos (Table 7.11). Photos from 1965 and 1995 were analyzed to evaluate the degree of recovery during the 1965-1995 period. The results show recovery ranging from approximately 61-73% for four of the stream reaches (Billings, middle Rockpile, lower middle Rockpile, and lower Rockpile). The North Fork Gualala reach was anomalous in that from 1965-1995 canopy opening on the reach had increased 102 % since 1965.

**Table 7.11**
**Canopy Conditions on Select Stream Reaches (from CFL 1997)**

| Planning WS | % Valley Canopy Opening (1965 photo) | % Valley Canopy Opening (1995 photo) | % Decrease in Valley Opening 1965-95 | % Canopy Closure (field) 1965-95 |
|---|---|---|---|---|
| NF Gualala | 12.9 | 26 | -102% | 33 |
| Billings Creek | 26.3 | 7 | 73% | N/A |
| Mid Rockpile | 68.4 | 18 | 74% | 40 |
| Lower Rockpile | 69.2 | 47.7 | 31% | N/A |
| Lower Mid Rockpile | 76.7 | 29.7 | 61% | 30 |
| Fuller Creek | N/A | 29.6 | N/A | 21 |
| Buckeye Creek | N/A | 18.2 | N/A | 28 |
| Lower Buckeye Creek | N/A | 9.5 | N/A | 29 |
| Flat Ridge Creek | N/A | 12.4 | N/A | N/A |
| NF Buckeye | N/A | 14 | N/A | N/A |
| Wolf Creek | N/A | 16.3 | N/A | N/A |
| Tobacco Creek | N/A | 35.6 | N/A | N/A |

CFL (1997) also reported the average residual pool depth at three “prominent” pools in each of the field sampled reaches. It is unclear how “prominent” was defined. It is possible that the three “prominent” pools surveyed were the three largest pools. Of the twelve reaches surveyed, three had average residual pool depths ranging from 1.25 to 1.6 feet, three ranged from 3.3 to 3.9 feet, and the other six ranged from 2.0 to 2.7 feet. Although the data are poorly defined, if one assumes that the three “prominent” pools sampled were the deepest pools in the reach, the data indicates pool depths are less than desirable for salmonid habitat.

#### 7.3.1.2 EIP Data

In 1991 EIP Associates surveyed approximately 4.1 miles of the lower South Fork Gualala from the confluence of the South Fork and Wheatfield Fork at Valley Crossing to the Confluence of the North and South Forks. The most common aquatic habitat type was shallow pools (see Table 7.12). Higgins (1997) suggests that a portion of the habitat reported by EIP Associates would have been classified better as run or glide, rather than shallow pool. Higgins then concluded, “the low pool frequency and high occurrence of flat water habitats clearly indicates major aggradation problems in the lower reaches of the Gualala River.”

**TABLE 7.12**
**LOWER SOUTH FORK GUALALA HABITAT TYPING DATA BY PERCENT OF STREAM REACH (from EIP 1994)**

| Reach | Shallow Pool | Deep Pool | Root Wad Pool | Glide | Riffle | Run |
|---|---|---|---|---|---|---|
| Valley Crossing - Sea Ranch Road | 59.6 | 7.1 | 0.9 | 21.1 | 9.1 | 2.2 |
| Sea Ranch Road – Buckeye Creek | 77.2 | 9.1 | 0.3 | 4.6 | 4.9 | 4.1 |
| Buckeye Creek – North Fork | 72 | 13.2 | 0 | 5.2 | 4.1 | 5.2 |

#### 7.3.1.3 Gualala Redwoods, Inc. Timber Harvest Plans

Baseline data collected by Gualala Redwoods, Inc. ("GRI") on Pepperwood and Buckeye Creeks were summarized in a recent timber harvest plan (GRI 1999g). Big Pepperwood Creek was found to contain "good quantities of gravels which do not appear embedded." The stream was reported to have 90 to 100 percent canopy cover in the lower reaches of the creek, with an average high stream temperature of 60.6°F (15.9°C). In Buckeye Creek, pools were found to comprise 20% of all habitat types, with pool depths of greater than 3 feet. The overall mean shelter rating for pools was 126 (of a maximum 300-- an average shelter rating of 100 is considered desirable for good salmonid habitat). Pool tailings were found generally to be moderately embedded (25 to 50%) with fine sediments (as discussed in previous chapters, embeddedness ratings are a measure of spawning substrate suitability). Buckeye Creek was estimated to have 65% canopy cover, and an average high temperature of 71.9°F (22.1°C), above the preferred range of coho salmon.

#### 7.3.1.4 California Department of Fish and Game

The California Department of Fish and Game conducted a fisheries inventory of approximately 2.6 miles of McKenzie Creek and its tributaries in July and August of 1999. The surveyed tributaries included Carson Creek, Camper Creek, and Wild Hog Canyon. The objectives of the inventory were to document presence and distribution of salmonid species, as well as their available habitat (CDFG 2000). The results of the inventory showed that habitat conditions in the surveyed streams were below desirable levels. For instance, pools were found to be shallow, averaging 1.2 feet deep, with only 15% deeper than three feet. Pool shelter ratings were also found to be low, with a mean shelter rating of 23 (of a maximum 300). An average shelter rating of 100 is considered desirable for good salmonid habitat. Embeddedness ratings, a measure of spawning substrate suitability, generally showed spawning substrates of poor quality due to excess fine sediments. Water temperatures measured during the survey were suitable for steelhead in all streams. Camper Creek was the only stream found to have temperatures suitable for coho salmon, however. The report suggests that higher riparian canopy densities in Camper Creek are responsible for the better temperature conditions. Two pools in McKenzie Creek and one pool in Carson Creek were electrofished. Juvenile steelhead and California roach were found in both creeks, and a threespine stickleback was found in McKenzie Creek. No coho salmon were found.

#### 7.3.1.5 Regional Water Quality Control Board Staff Observations

A range of channel complexity conditions was noted during field visits in the watershed in the spring of 2001. In some reaches, a lack of deep pools and woody debris, and a high proportion of runs and glides diminished channel complexity. In other observed stream reaches, especially reaches of Buckeye Creek, the channel is mostly flat and shallow, with little complexity. Many areas lacked a defined thalweg and were flat from bank to bank. In general, channel complexity was noted to be poor. Stream reaches with moderate to high complexity were found in Fuller creek and the upper South Fork.

The main subwatershed streams and their immediate tributaries that were observed had very few LWD pieces in the active channel. However, smaller tributaries were observed to have substantial quantities of LWD, mostly stumps and cull logs from earlier logging activities, which, in certain locations have created large debris jams. In contrast to other observed tributaries where aggradation was more extreme, the North Fork Gualala River had some LWD pieces that had been buried in the past are now partially exposed and there appeared to be adequate LWD on the floodplains where they exist. In general, an adequate amount of LWD was noted in first and second order stream channels, while a dearth of LWD was noted in higher order streams.

#### 7.3.1.6 Anecdotal Information

The “Gualala River Watershed Literature Research and Assimilation” (Higgins 1997) contains an 1898 photo of sailboats near the mouth of the Gualala River, which Higgins interpreted to indicate deeper lagoon conditions than at present. His interpretation is supported by Ken Spacek’s memories of river conditions when he was a boy, which would contrast stream conditions prior to the Forest Practice Rules and the 1964 flood to conditions of today. Spacek recalls the challenge of driving off-road vehicles up and down the river and the extreme difficulty of crossing the river due to the depth of flow, whereas now the same stretches can be driven without getting axles wet. Spacek also recalls jumping off of boulders into swimming holes where sediment has now buried both the pools and the boulders (Spacek, personal communication 2001).

In 1997 Ken Spacek interviewed seven elders from the Gualala River watershed about historical stream and fishery conditions. The following list summarizes the recollections of the interviewees (Spacek, unpublished):

- Fish were abundant in the past and now are scarce,
- The Gualala has filled in with sediment, particularly on the South Fork downstream of Valley Crossing,
- Brush willow is much more common today,
- Log and driftwood accumulations are less common,
- River otters are now more common in the Gualala than in the past,
- The mouth of the river stays closed longer and takes more rain to breach
- Chinook Salmon used to be found in the Gualala.

### 7.3.2 SEDIMENT

In-stream substrate samples taken by CFL (1997), GRI (1998-2000), and Knopp (1993) indicate that aquatic habitat throughout the watershed is impaired by excessive fine sediments. Median surface particle diameter ($D_{50}$) measurements were made by both CFL and GRI at numerous locations; GRI also measured percent fines data for the North Fork and some of its tributaries. V* data was provided by Knopp (1993). The data suggest that upslope disturbances have impacted stream substrates with excessive fine sediments, and impaired the ability of the aquatic habitat to support salmonid spawning, incubation, and emergence. The exception is Dry Creek where both $D_{50}$ and percent fines data indicate good spawning habitat. Regional Water Board staff observations of conditions existing in the Spring of 2001 indicate that stream channels are still greatly impacted by fine sediment.

The effect of excess sediment on the salmonid lifecycle and habitat is discussed in Chapter 2 and, in greater detail, in other references such as Spence et al. (1996) and Meehan (1991). Information about in-stream sediment conditions in the Gualala River watershed was compiled from these sources:

- Coast Forestlands, Ltd. (CFL) Watershed and Aquatic Wildlife Assessment published in 1997.
- Gualala Timber Harvest Plans submitted in 1999 and 2000.
- Testing Indices of Cold Water Fish Habitat, Knopp (1993).
- Gualala River watershed literature search and assimilation by Higgins (1997).
- Observations by the Regional Water Quality Control Board staff.

#### 7.3.2.1 Coastal Forestlands, Ltd. Assessment Data

Until the summer of 1998, Coast Forestlands, Ltd. ("CFL") owned approximately 35,000 acres in the Gualala watershed. CFL collected stream data at twelve sites in the Gualala watershed. Parameters collected include particle size distribution in riffles, residual depth of pools, canopy conditions, and large woody debris frequency and volume. Data were collected both in the field and by remote sensing techniques.

CFL measured surface particle size distributions by Wolman pebble counts in 1996 on three "prominent riffles which represented potential spawning sites" in each study reach, including reaches on the North Fork Gualala, lower Rockpile Creek, and lower Buckeye Creek. The pebble count data shows the study reaches having an overabundance of fine sediment. Median surface particle diameter ("$D_{50}$") measurements ranged from 8 to 38 millimeters (estimated from graphically presented data). In addition, CFL reported "percent sand on riffles," which measured percentage fine sands in the samples with less than 2 millimeter diameter (which correlates with percent fines, described in the next section). CFL noted that samples from Upper Buckeye Creek exceeded 15% sand for this parameter.

Criteria for evaluating $D_{50}$ data presented by CFL can be taken from Knopp (1993), who measured a suite of habitat variables, including median surface particle diameter of riffles, in 60 streams draining the Franciscan geologic formation in northwest California (including Grasshopper and Fuller Creeks in the Gualala Watershed). Sampled streams were divided into three categories of increasing upslope erosion potential to assess whether measured variables were affected by that condition. The results of the study showed statistically significant differences between the $D_{50}$ values of managed and unmanaged streams. The mean $D_{50}$ of unmanaged streams was 80.6 mm, while the mean of highly disturbed watersheds was 37.6 mm.

Comparing the Knopp data and the CFL data, instream conditions measured by CFL are similar to highly disturbed watersheds as described in Knopp (1993).

#### 7.3.2.2 Gualala Redwoods, Inc. Stream Monitoring Data

Gualala Redwoods, Incorporated ("GRI") owns approximately 30,000 acres in the Gualala watershed and has monitored sediment conditions on streams in its ownership. A portion of its data, including median particle size ($D_{50}$) and percent fines < 0.85 mm, has been reported in timber harvest planning ("THP") documents. These results are summarized in Table 7.13. As shown in Table 7.13, $D_{50}$ values ranged from 14 to 89 mm for sampling locations throughout the watershed between 1997 and 1999. With the exception of Dry Creek, an upland tributary to the North Fork Gualala River, the median particle sizes were found to be 40 mm or less. The data are similar to CFL data and further indicate highly disturbed watersheds and widespread impact of upslope disturbances throughout the watershed.

GRI measured percent fine sediments using a McNeil sampler from riffles in North Fork tributaries. The results are given in Table 7.13. GRI data show a range of percent fines for the five North Fork tributaries sampled (Little North Fork, Doty, Dry, McGann Gulch, and Robinson Creeks) from 11% to 28%. With the exception of Dry Creek, all of the tributaries, on average, have percent fines greater than 15%, and thus fall within the range for salmonid habitat that is less than ideal. At Dry Creek, both $D_{50}$ and percent fine data for this stream indicate that the substrate for this creek provides suitable salmonid spawning habitat with respect to these two parameters.

**TABLE 7.13 PERCENT FINES (<0.85 MM DIAM.) AND $D_{50}$ OF STREAMBED SAMPLES AT VARIOUS LOCATIONS IN THE GUALALA RIVER WATERSHED (from: various GRI THP documents – see GRI 1998-2000)**

| Stream | Station | Year | % fines (<0.85mm) | $D_{50}$ (mm) | | Stream | Station | Year | % fines (<0.85mm) | $D_{50}$ (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Little North Fork** | 201 | 92 | 10.9 | - | | **Dry Creek** | 211 | 95 | 16.8 | - |
| | | 93 | 21.0 | - | | | | 96 | 14.7 | - |
| | | 94 | 20.4 | - | | | | 97 | 11.5 | 31 |
| | | 95 | 20.8 | - | | | | 98 | - | 45 |
| | | 96 | 15.4 | - | | | | 99 | - | 62 |
| | | 97 | 16.0 | - | | | 212 | 97 | - | 89 |
| | 202 | 93 | 11.4 | - | | | 405 | 97 | - | 65 |
| | | 94 | 14.6 | - | | **McGann Gulch** | 209 | 95 | 19.2 | - |
| | | 95 | 18.8 | - | | | | 96 | 26.8 | - |
| | | 96 | 17.2 | - | | | | 97 | 19.9 | - |
| | | 97 | 21.5 | 18 | | **Robinson Creek** | 207 | 95 | 15.2 | - |
| | 203 | 93 | 17.1 | - | | | | 96 | 18.1 | - |
| | | 94 | 20.4 | - | | | | 97 | 17.9 | 38 |
| | | 95 | 11.6 | - | | | | 99 | - | 36 |
| | | 96 | 19.6 | - | | | 208 | 97 | - | 29 |
| | | 97 | 18.8 | 35 | | **Buckeye Creek** | 223 | 97 | - | 25 |
| | | 98 | - | 34 | | | 224 | 97 | - | 26 |
| | | 99 | - | 36 | | | 231 | 97 | - | 24 |
| | 255 | 93 | 19.4 | - | | | | 98 | - | 24 |
| | | 94 | 17.2 | - | | **North Fork** | 204 | 97 | - | 14 |
| | | 95 | 11.9 | - | | | 406 | 97 | - | 18 |
| | | 96 | 24.4 | - | | **Big Pepperwood** | 218 | 97 | - | 31 |
| | | 97 | 27.8 | - | | | | 98 | - | 40 |
| **Doty Creek** | 256 | 93 | 16.2 | - | | | | 99 | - | 31 |
| | | 94 | 11.4 | - | | | 219 | 97 | - | 39 |
| | | 95 | 16.9 | - | | **Gualala** | 217 | 98 | - | 25 |
| | | 96 | 16.9 | - | | **Rockpile Creek** | 221 | 97 | - | 27 |
| | | 97 | 17.0 | - | | | | 98 | - | 25 |
| | | | | | | | 275 | 97 | - | 26 |
| | | | | | | | 401 | 97 | - | 28 |

### 7.3.2.3 Knopp (1993)

As discussed in previous chapters, Knopp (1993) conducted a study to develop indices for cold water fish habitat in coastal Northern California. Knopp reported the following data for Fuller and Grasshopper Creeks in the Gualala River watershed:

| Stream | V* | $D_{50}$ (mm) |
|---|---|---|
| Fuller Creek | 0.37 | 43.2 |
| Grasshopper Creek | 0.59 | 36.8 |

V* is a parameter that represents the proportion of fine sediments that occupy the scoured residual volume of a pool (Lisle and Hilton 1992). The values for the parameters listed above corresponded to watersheds that the report categorized as having moderate to high levels of disturbance.

### 7.3.2.4 Regional Water Board Staff Observations

Regional Board Staff were able to observe approximately 4.5 miles of streams during random sample plot field work in the spring of 2001. An additional, approximately 1.5 miles of streams scattered throughout the watershed were also visited.

A thin to non-existent armor layer (surface layer that is more coarse than the subsurface sediments) underlain and embedded with fine sediment typified observed riffles. The absence of an armor layer is indicative of an oversupply of sediment (Dietrich et al. 1989). Sand is the dominant substrate in many of the observed reaches. Spawning size gravels are overlain and embedded with fine sediment in observed riffles of the North Fork, Rockpile Creek, Wheatfield Fork, and the South Fork while Buckeye Creek was characterized by relatively more embeddedness and fine sediment without an armoring layer. Francini Creek, a tributary to Buckeye Creek, has fine sediment almost completely burying cobble.

The pools observed in the Gualala watershed are typically shallow and contained substantial volumes of fine sediments. Pools in areas expected to be deep, such as at abrupt bends or pools formed by boulders, were observed to be shallow with a substrate of sand and fine sediment. A substantial portion of the observed reaches were runs and glides with small substrate (sand to pea-size) that presumably would contain pool habitats if the sediment load were lower. While the North Fork Gualala River contained the most substantial pools of the observed stream reaches, there is a lack of pools suitable for rearing salmonids in observed reaches throughout the Gualala watershed.

Buckeye creek, Rockpile Creek, and the lower Wheatfield Fork appear to be aggraded as indicated by the wide, flat channel geometry, lack of an armor layer, scarcity of pools, and exposed tree roots in the streambanks. Notable exceptions are the areas of Fuller Creek and the upper South Fork that were observed to be recovering from prior aggradation. The observed reaches of the North Fork Gualala also appear to be recovering from prior aggradation, as indicated by the presence of partially buried logs, vegetated mid-channel bars (now floodplains or terraces), and exposed bedrock sills. The channel does, however, show evidence of an over-abundance of fine sediment indicated by sand to pea-size accumulations in pools and flatwater habitats.

### 7.3.3 TEMPERATURE

The effect of temperature on the salmonid lifecycle is complex and is discussed in Chapter 2. Briefly, the salmonid life cycle processes affected by temperature include: metabolism; food requirements (appetite and digestion); growth rates; development of embryos and alevin; timing of life history events (such as adult migration, fry emergence, smoltification); competitor and predator-prey interactions; disease-host and parasite-host interactions; and, the development of aquatic invertebrate food sources (Spence et al. 1996). Stream temperature also determines the amount of dissolved oxygen that can be carried by a stream, with higher temperatures resulting in lower dissolved oxygen concentrations.

Stream temperature data have been collected in the Gualala River watershed by several entities. Often the sources do not report the methods of data collection, or complete data sets or statistics that would allow further analysis.

The Gualala River Watershed Council ("GRWC") installed hobo temperature data loggers on the North Fork of Fuller Creek, the South Fork of Fuller Creek, and the Wheatfield Fork in the summer of 1997 (Higgins 1997). Data are available in graphical format showing daily minimum and maximum temperature. The probes were placed in a shaded portion of the stream in flowing water and recorded temperature at a regular interval, numerous times a day for the period of record. Monthly temperature ranges are shown below in Table 7.14. Additionally, numerous hobo temperature loggers were installed by the GRWC from 1998 to 2000, although the 1998-99 data were not available at the time this report was prepared.

Temperature data are also available from Gualala Redwoods Incorporated ("GRI") timber harvest plan monitoring. Hobo temperature data loggers were placed in various streams at the inlets of pools in well-mixed areas by GRI from 1993 through 1998. The period of monitoring for each station in each year is unknown, but low flow periods (approximately May through September) are expected. Seasonal daily maximum and maximum weekly average temperature ("MWAT") statistics are reported for each temperature probe on an annual basis while daily data are available for a limited number of stations (GRI 1998; 1999a; 1999b; 1999c; 1999d; 1999e; 1999f; 1999g; 1999h; 1999i; 1999j; 2000). MWAT values reported by GRI are the highest of the seven-day moving average of the daily maximum temperature for a single station in a single season. Summary data are given below in Table 7.14. Plate 5 in appendix A of the Gualala River Watershed Technical Support Document for the Total Maximum Daily Load for Sediment (CWQCB 2001) shows GRI sampling locations.

Mendocino Redwood Company ("MRC") monitored stream temperature using Stowaway data loggers on Annapolis Falls Creek and Fuller Creek, both tributaries to the Wheatfield Fork (MRC, unpublished data). Monitoring was performed in the summer of 1995 and 1996 on Annapolis Falls Creek. Monitoring was performed in the summer of 1994 and 1995 on Fuller Creek. Temperature probes were placed in shallow pools (<1 meter in depth) directly downstream of riffles. Data are reported for each temperature probe location on a line graph showing minimum, maximum, and mean daily temperature. Summary statistics are also included. Monthly temperature ranges for MRC temperature data are given below in Table 7.14.

Based on temperature data available, the following observations can be made for each subwatershed:

- **Mainstem Gualala River**: One station was monitored in the mainstem of the Gualala River. Seasonal daily maximum temperatures in excess of the upper lethal temperature (75°F) for rearing coho salmon and steelhead are not noted on the mainstem of the Gualala River. However, exceedance of the MWAT metric for juvenile coho salmon growth (64°F) and juvenile steelhead growth (66°F) are noted at the monitoring location.
- **South Fork Gualala River Subwatershed**:
  - *MAINSTEM* - Temperature ranges for continuous monitoring stations on the South Fork Gualala River indicate temperatures in excess of preferred rearing temperatures for coho salmon and steelhead. Seasonal daily maximum temperatures in excess of the upper lethal temperature (75°F) for rearing coho salmon and steelhead are noted on the mainstem South Fork Gualala River. Exceedance of the MWAT metric for juvenile coho salmon growth (64°F) are noted at each location where MWAT values were calculated, while exceedance of the MWAT for juvenile steelhead growth (66°F) are noted at all but one location where the MWAT was calculated on the mainstem South Fork Gualala River. No clear trend for a spatial temperature distribution is noted on the South Fork Gualala River.
  - *TRIBUTARIES* - Non-exceedance of the MWAT metric for juvenile coho salmon growth (64°F) and juvenile steelhead growth (66°F) are noted at all but one monitoring point. No seasonal daily maximums exceeding the upper lethal temperature (75°F) for rearing coho salmon and steelhead were noted at monitoring locations on tributaries of the South Fork Gualala River.
- **Wheatfield Fork Gualala River Subwatershed**:
  - *MAINSTEM* - Exceedance of the upper lethal temperature (75°F) for rearing coho salmon and steelhead is noted at each location where the Wheatfield Fork was monitored (from just upstream of Fuller Creek to the just upstream of the confluence with the South Fork Gualala River) except at one location. Exceedance of the MWAT metric for juvenile coho salmon growth (64°F) and juvenile steelhead growth (66°F) is also noted at all but one monitoring point on the Wheatfield Fork. The location (GRI station 228) where upper lethal temperatures and the MWAT metric for juvenile salmonid growth are not exceeded may be located in an area where temperatures were less than average due to pool stratification, emergent groundwater, shading, and/or temperature probe placement. Temperature ranges indicate exceedance of preferred coho salmon and steelhead rearing temperatures on the Wheatfield Fork. No clear trend for a spatial temperature distribution is noted on the Wheatfield Fork.
  - *TRIBUTARIES* - Fuller Creek exhibits temperatures in excess of the upper lethal temperature (75°F) for rearing steelhead and coho salmon at two out of five locations, while temperatures on Annapolis Falls Creek are relatively lower, with no exceedance of the upper lethal temperature (75°F) for coho salmon and steelhead. MWAT values in excess of MWAT metrics for juvenile coho salmon (64°F) and steelhead growth (66°F) are noted at two locations where this parameter is evaluated. Temperature ranges indicate exceedance of preferred coho salmon and steelhead rearing

temperatures on Fuller Creek, while Annapolis Falls Creek may have temperatures within the preferred range for rearing steelhead.

- **Buckeye Creek Subwatershed**: *MAINSTEM* - Monitoring was performed only on Buckeye Creek in this subwatershed. Monitoring data indicate that temperatures are greater in upstream reaches than in downstream reaches, possibly due to cool tributary inflow, increased stream depth, coastal proximity, emergent groundwater, and/or shading in downstream reaches. Seasonal daily maximum temperatures in excess of the upper lethal temperature for rearing coho salmon and steelhead (75°F) were measured three of six monitoring locations. Reported MWAT values are in excess of the MWAT metric for juvenile steelhead growth (66°F) and juvenile coho salmon growth (64°F).
- **Rockpile Creek Subwatershed**: *MAINSTEM* - Monitoring was performed only on Rockpile Creek in this subwatershed. No clear trend is noted for temperature increase in the downstream or upstream direction. Significant variation in maximum daily temperature is noted in the middle reach of Rockpile Creek, possibly due to cool tributary inflow, emergent groundwater, shading, and/or temperature probe placement. No exceedance of the upper lethal temperature for rearing coho salmon and steelhead (75°F) is noted on the monitored reaches of Rockpile Creek. However, MWAT values exceeding the MWAT metric for coho salmon growth (64°F) and juvenile steelhead growth (66°F) were measured at three of four locations.
- **North Fork Gualala River Subwatershed**:
  - *MAINSTEM* – Data indicate that temperatures within the North Fork Gualala River subwatershed are lower than temperatures in other subwatersheds. Further, seasonal daily maximum temperatures and MWAT values indicate that North Fork Gualala River tributaries are generally cooler than the North Fork Gualala River. Exceedance of the upper lethal temperature (75°F) for rearing coho salmon and steelhead is noted at only one location on the North Fork Gualala River. Exceedance of the MWAT metric for juvenile steelhead growth (66°F) and juvenile coho salmon growth (64°F) are noted at two of five and four of five locations respectively on the North Fork Gualala River.
  - *TRIBUTARIES* – No exceedances of either the upper lethal temperature (75°F) for rearing coho salmon and steelhead, or of the MWAT metric for juvenile steelhead growth (66°F) and juvenile coho salmon growth (64°F) are noted at any locations on monitored North Fork Gualala River tributaries.

**Table 7.14 Temperature Data Reported for Gualala River Watershed Streams**

| Stream | Sampling Location | Reference | When Sampled | Temperature Range (Continuous Data Only) | Maximum Weekly Average Temperature | Seasonal Daily Maximum |
|---|---|---|---|---|---|---|
| **MAINSTEM** | | | | | | |
| **Main Stem Gualala River** | Just downstream of South Fork, North Fork confluence | GRWC 2001 | Jun-Oct 2000 | 56.7 - 73.1°F<br>(13.7 - 22.9°C) | 72.5°F (22.5°C) | 73.1°F (22.9°C) |
| **SOUTH FORK SUBWATERSHED** | | | | | | |
| **South Fork Gualala River** | Upper South Fork Gualala River, ~2000 feet upstream of Fort Ross Road | GRWC 2001 | July-Oct 2000 | 49.9 - 66.9°F<br>(10.0 - 19.4°C) | 64.9°F (18.3°C) | 66.9°F (19.4°C) |
| | ~2 miles upstream of confluence with Wheatfield Fork | GRI 1999a | Jun-Oct 1995 | 53 – 73°F<br>(12 – 23°C) | | |
| | ~0.5 miles upstream of confluence with Wheatfield Fork | GRI 1999a | Jun-Aug 1995 | 57 – 74°F<br>(14 – 23°C) | | |
| | South Fork just downstream of Big Pepperwood | GRWC 2001 | Jun-Oct 2000 | 55.3 - 73.8°F<br>(12.9 - 23.2°C) | 72.8°F (22.9°C) | 73.8°F (23.2°C) |
| | Station 229 | GRI 1999g | 1995,1996,1997 | | 68°F, 66°F, (19.9°C, 19.0°C)<br>69°F (20.5°C) | 74°F, 72°F, (23.4°C, 22.1°C)<br>78°F (25.6°C) |
| | Station 225 | GRI 1999g | 1995,1997 | | 69°F, 69°F (20.8°C, 20.6°C) | 77°F, 72°F, (24.8°C, 22.1°C) |
| | Station 217 | GRI 1999h | 1994,1995<br>1996,1997 | | 67°F, 69°F, (19.2°C, 20.6°C)<br>68°F, 71°F (20.1°C, 22.4°C) | 73°F, 78°F, (22.7°C, 25.3°C)<br>76°F, 76°F (24.4°C, 24.6°C) |
| | Station 230 | GRI 1999g | 1995,1996,1997 | | 66°F, 65°F, (18.9°C, 18.4°C)<br>72°F (22.3°C) | 73°F, 71°F, (22.9°C, 21.8°C)<br>76°F (24.4°C) |

| STREAM | SAMPLING LOCATION | REFERENCE | WHEN SAMPLED | TEMPERATURE RANGE (CONTINUOUS DATA ONLY) | MAXIMUM WEEKLY AVERAGE TEMPERATURE | SEASONAL DAILY MAXIMUM |
|---|---|---|---|---|---|---|
| **SOUTH FORK SUBWATERSHED** (CONTINUED) | | | | | | |
| BIG PEPPERWOOD | Station 218 | GRI 1999h | 1994,1995,1996<br>1997,1998 | | 58°F, 59°F, (14.4°C, 15.0°C)<br>58°F, 60°F, (14.3°C, 15.6°C)<br>60°F (15.2°C) | 61°F, 62°F, (15.9°C, 16.5°C)<br>61°F, 63°F, (16.2°C, 17.3°C)<br>63°F (17.2°C) |
| | Station 219 | GRI 1999h | 1995,1996<br>1997,1998 | | 59°F, 58°F, (14.9°C, 14.7°C)<br>59°F, 59°F (15.0°C, 14.9°C) | 63°F, 62°F, (17.0°C, 16.7°C)<br>64°F, 63°F (17.8°C, 17.3°C) |
| | Station 248 | GRI 1999h | 1994 | | 58°F (14.6°C) | 63°F (17.2°C) |
| LITTLE PEPPERWOOD | Station 220 | GRI 1999h | 1994,1995,1996,<br>1997,1998 | | 58°F, 61°F, (14.3°C, 16.0°C)<br>59°F, 61°F, (15.0°C, 16.0°C)<br>60°F (15.6°C) | 60°F, 67°F, (15.8°C, 19.4°C)<br>64°F, 62°F, (17.8°C, 16.7°C)<br>64°F (17.8°C) |
| GROSHONG GULCH | Station 250 | GRI 1999j | 1996 | | 56°F (13.1°C) | 57°F (14.1°C) |
| MCKENZIE CREEK | McKenzie Creek | GRWC 2001 | Aug-Oct 2000 | 53.2 - 60.8°F<br>(11.8 - 16.0°C) | 60.2°F (15.7°C) | 61°F (16.0°C) |
| | McKenzie Creek 1290 ft u/s Carson Creek | GRWC 2001 | July-Oct 2000 | 51.9 - 69.3°F<br>(11.1 - 20.7°C) | 67.7°F (19.8°C) | 69.3°F (20.7°C) |
| **WHEATFIELD FORK SUBWATERSHED** | | | | | | |
| WHEATFIELD FORK | ~1.5 miles upstream of Fuller Creek | GRWC 2001 | Jul-Oct 2000 | 58.4 – 82.0°F<br>(14.7 – 27.8°C) | 79.9°F (26.6°C) | 82.0°F (27.8°C) |
| | ~2.5 miles upstream of confluence with SF Gualala River | GRI 1998 | Jun-Oct 1995<br>Jun-Oct 1996<br>Jun-Oct 1997 | 57 - 79°F<br>57 - 75°F<br>55 - 78°F<br>(14 - 26°C)<br>(14 - 24°C)<br>(13 - 26°C) | | |

| STREAM | SAMPLING LOCATION | REFERENCE | WHEN SAMPLED | TEMPERATURE RANGE (CONTINUOUS DATA ONLY) | MAXIMUM WEEKLY AVERAGE TEMPERATURE | SEASONAL DAILY MAXIMUM |
|---|---|---|---|---|---|---|
| **WHEATFIELD FORK SUBWATERSHED** (CONTINUED) | | | | | | |
| **WHEATFIELD FORK** (CONTINUED) | At Valley Crossing above confluence with SF Gualala River | GRI 1998 | Jun-Oct 1995<br>Jun-Oct 1996<br>Jun-Oct 1997 | 57 - 78°F<br>53 - 75°F<br>57 - 73°F<br>(14 - 26°C)<br>(12 - 24°C)<br>(14 - 23°C) | | |
| | Just upstream of Fuller Creek | Higgins 1997 | Jun-Jul 1997 | 62 - 82°F<br>(17 - 28°C) | | |
| | Station 226 | GRI 1999g | 1995,1996,1997 | | 70°F, 69°F, (20.9°C, 20.3°C)<br>71°F (21.9°C) | 78°F, 75°F, (25.5°C, 23.8°C)<br>74°F (23.1°C) |
| | Station 227 | GRI 1999g | 1996,1997 | | 70°F, 72°F (21.2°C, 22.2°C) | 75°F, 78°F, (24.0°C, 25.3°C) |
| | Station 228 | GRI 1999g | 1995,1996,1997 | | 57°F, 56°F, (13.9°C, 13.4°C)<br>58°F (14.2°C) | 58°F, 57°F, (14.5°C, 14.0°C)<br>59°F (14.8°C) |
| | Station 273 | GRI 1999g | 1995 | | 72°F (22.0°C) | 80°F (26.4°C) |
| **FULLER CREEK** | Just upstream of confluence with Wheatfield Fork | MRC undated | Jun-Sept 1994<br>Jul-Sept 1995 | 55 - 75°F<br>56 - 77°F<br>(13 - 24°C)<br>(13 - 25°C) | | |
| | South Fork Fuller Creek | Higgins 1997 | Jun-Sept 1997 | 56 - 76°F<br>(13 - 24°C) | | |
| | North Fork Fuller Creek | Higgins 1997 | Jun-Sept 1997 | 55 - 74°F<br>(13 - 23°C) | | |
| | South Fork Fuller Creek ~500' upstream of North Fork Fuller Creek | GRWC 2001 | Jun-Oct 2000 | 54.3 – 72.5°F<br>(12.4 – 22.5°C) | 70.9°F (21.6°C) | 72.5°F (22.5°C) |
| | North Fork Fuller Creek ~400' upstream of South Fork Fuller Creek | GRWC 2001 | Jun-Oct 2000 | 54.4 – 72.8°F<br>(12.4 –22.7°C) | 71.1°F (21.7°C) | 72.8°F (22.7°C) |

| Stream | Sampling Location | Reference | When Sampled | Temperature Range (Continuous Data Only) | Maximum Weekly Average Temperature | Seasonal Daily Maximum |
|---|---|---|---|---|---|---|
| **WHEATFIELD FORK SUBWATERSHED** (CONTINUED) | | | | | | |
| Annapolis Falls Creek | ~ ¾ mile upstream of confluence with Wheatfield Fork | MRC undated | Jun-Sept 1995<br>Jul-Sept 1996 | 53 - 67°F<br>52 - 64°F<br>(12 – 19°C)<br>(11 – 18°C) | | |
| **BUCKEYE CREEK SUBWATERSHED** | | | | | | |
| Buckeye Creek | 240 feet upstream of Soda Springs Creek | GRWC 2001 | Jun-Oct 2000 | 56.0 – 78.7°F<br>(13.3 - 26.0°C) | 78.0°F (25.6°C) | 78.7°F (26.0°C) |
| | Just upstream of confluence with Flat Ridge Creek | GRWC 2001 | Jun-Oct 2000 | 53.9 – 78.0°F<br>(12.2 - 25.6°C) | 75.2°F (24.0°C) | 78.0°F (25.6°C) |
| | Station 231 | GRI 1999g | 1994,1995<br>1996,1997 | | 67°F, 70°F, (19.7°C, 20.9°C)<br>69°F, 70°F (20.8°C, 21.1°C) | 71°F, 76°F (21.7°C, 24.4°C)<br>75°F, 75°F (23.7°C, 23.7°C) |
| | Station 224 | GRI 1999g | 1995,1996,1997 | | 68°F, 67°F, (19.9°C, 19.3°C)<br>68°F (19.8°C) | 75°F, 72°F, (23.9°C, 22.1°C)<br>73°F (22.7°C) |
| | Station 223 | GRI 1999g | 1995,1996,1997 | | 66°F, 66°F, (19.0, 18.8)<br>67°F (19.5) | 73°F, 71°F, (23.0°C, 21.4°C)<br>72°F (22.4°C) |
| | Station 235 | GRI 1999g | 1994 | | 65°F (18.3) | 70°F (21.1°C) |
| **ROCKPILE CREEK SUBWATERSHED** | | | | | | |
| Rockpile Creek | Station 222 | GRI 1999i | 1994,1995<br>1996,1997 | | 67°F, 67°F, (19.4°C, 19.7°C)<br>67°F ,68 (19.7°C,19.8°C) | 71°F, 74°F (21.9°C, 23.5°C)<br>72°F, 72°F (22.1°C,22.4°C) |
| | Station 276 | GRI 1999i | 1997 | | 57°F (14.1°C) | 59°F (15.2°C) |
| | Station 275 | GRI 1999i | 1997 | | 67°F (19.5°C) | 68°F (20.1°C) |
| | Station 221 | GRI 1999i | 1995,1996,1997 | | 67°F, 67°F, (19.6°C,19.3°C)<br>67°F (19.7°C) | 74°F, 72°F, (23.1°C,22.4°C)<br>72°F (22.4°C) |

| Stream | Sampling Location | Reference | When Sampled | Temperature Range (Continuous Data Only) | Maximum Weekly Average Temperature | Seasonal Daily Maximum |
|---|---|---|---|---|---|---|
| **NORTH FORK GUALALA RIIVER SUBWATERSHED** | | | | | | |
| North Fork Gualala River | Just upstream of confluence with South Fork | GRWC 2001 | Jun-Oct 2000 | 54.6-66.3°F (12.6-19.0°C) | 65.4°F (18.6°C) | 66.3°F (19.0°C) |
| | Station 204 | GRI 1999f | 1995,1996,1997 | | 64°F, 66°F, (17.5°C,18.7°C)<br>65°F (18.2°C) | 69°F, 68°F, (20.6°C,20.1°C)<br>67°F (19.4°C) |
| | Station 258 | GRI 1999f | 1994 | | 67°F (19.3°C) | 76°F (24.5°C) |
| | Station 205 | GRI 1999f | 1995,1996,1997 | | 64°F, 64°F, (17.7°C,17.8°C)<br>65°F (18.1°C) | 71°F, 69°F, (21.4°C,20.4°C)<br>70°F (21.1°C) |
| | Station 251 | GRI 1999f | 1996,1997 | | 62°F, 64°F (16.6°C, 17.5°C) | 66°F, 67°F (19.0°C,19.3°C) |
| Dry Creek | Station 213 | GRI 1999c | 1995,1996,1997 | | 61°F, 61°F, (16.0°C,16.1°C)<br>62°F (16.4°C) | 63°F, 63°F, (17.0°C,17.3°C)<br>64°F (17.8°C) |
| | Station 212 | GRI 1999c | 1995,1996,1997 | | 64°F, 64°F, (17.9°C,17.8°C)<br>64°F (17.9°C) | 70°F, 69°F, (20.9°C,20.7°C)<br>69°F (20.5°C) |
| | Station 269 | GRI 1999f | 1994 | | 60°F (15.7°C) | 61°F (16.2°C) |
| | Station 211 | GRI 1999c | 1995,1996,1997 | | 60°F, 61°F, (15.7°C,15.9°C)<br>59°F (15.2°C) | 64°F, 64°F, (17.7°C,17.7°C)<br>62°F (16.9°C) |
| Doty Creek | Station 256 | GRI 1999f | 1994 | | 55°F (12.9°C) | 57°F (14.1°C) |
| Little North Fork | Station 201 | GRI 1999f | 1994,1995<br>1996,1997 | | 58°F, 59°F, (14.7°C,15.1°C)<br>58°F, 60°F (14.6, °C 15.4°C) | 60°F, 62°F (15.8°C,16.7°C)<br>61°F, 62°F (15.9°C,16.7°C) |
| | Station 202 | GRI 1999f | 1994 | | 58°F (14.6°C) | 62°F (16.4°C) |
| | Station 203 | GRI 1999f | 1994,1995<br>1996,1997 | | 56°F, 58°F, (13.6°C,14.2°C)<br>57°F, 58°F (13.7°C,14.5°C) | 59°F, 60°F (15.1°C,15.8°C)<br>60°F, 60°F (15.3°C,15.8°C) |
| | Station 255 | GRI 1999f | 1994 | | 58°F (14.3°C) | 61°F (15.9°C) |
| | Station 274 | GRI 1999f | 1995,1996 | | 57°F, 58°F (14.6°C,14.1°C) | 62°F, 61°F (16.4°C,16.1°C) |

| **Stream** | **Sampling Location** | **Reference** | **When Sampled** | **Temperature Range (Continuous Data Only)** | **Maximum Weekly Average Temperature** | **Seasonal Daily Maximum** |
|---|---|---|---|---|---|---|
| **NORTH FORK GUALALA RIIVER SUBWATERSHED** (CONTINUED) | | | | | | |
| McGann Gulch | Station 209 | GRI 1999f | 1995,1996,1997 | | 61°F, 60°F, (15.9°C,15.6°C)<br>58°F (14.4°C) | 62°F, 62°F, (16.7°C,16.4°C)<br>60°F (15.5°C) |
| | Station 210 | GRI 1999f | 1995 | | 62°F (16.4°C) | 69°F (20.4°C) |
| Robinson Creek | Station 208 | GRI 1999f | 1995,1996,1997 | | 59°F, 59°F, (14.9°C,15.0°C)<br>59°F (14.9°C) | 62°F, 62°F, (16.6,16.4°C)<br>62°F (16.7°C) |
| | Station 263 | GRI 1999f | 1994 | | 60°F (15.5) | 64°F (17.7°C) |
| | Station 207 | GRI 1999f | 1995,1996,1997 | | 60°F, 60°F, (15.8°C,15.7°C)<br>61°F (16.2°C) | 67°F, 67°F, (19.6°C,19.6°C)<br>68°F (20.2°C) |
| | Station 260 | GRI 1999f | 1994 | | 57°F (13.8°C) | 58°F (14.6°C) |
| | Station 206 | GRI 1999f | 1995,1996,1997 | | 58°F, 58°F, (14.2°C,14.2°C)<br>57°F (13.8°C) | 69°F, 62°F, (20.4°C,16.9°C)<br>62°F (16.4°C) |

Table 7.15 shows summary data for upper lethal temperature and MWAT values for the Gualala River watershed.

**TABLE 7.15**
**SUMMARY OF UPPER LETHAL TEMPERATURE AND MWAT VALUES FOR THE GUALALA RIVER WATERSHED (data excerpted from Table 7.14)**

| SUBWATERSHED | | **Upper Lethal Temperature (75°F)** (locations with exceedance / total number of locations) | **MWAT metric for coho salmon growth (64°F)** (locations with exceedance / total number of locations) | **MWAT metric for steelhead growth (66°F)** (locations with exceedance / total number of locations) |
|---|---|---|---|---|
| Gualala River | Mainstem | 0 / 1 | 1 / 1 | 1 / 1 |
| South Fork Gualala River | Mainstem | 4 / 8 | 6 / 6 | 5 / 6 |
| | Tributaries | 0 / 7 | 1 / 7 | 1 / 7 |
| Wheatfield Fork | Mainstem | 6 / 7 | 4 / 5 | 4 / 5 |
| | Tributaries | 2 / 6 | 2 / 2 | 2 / 2 |
| Buckeye Creek | Mainstem | 3 / 6 | 6 / 6 | 5 / 6 |
| | Tributaries | 0 / 0 | 0 / 0 | 0 / 0 |
| Rockpile Creek | Mainstem | 0 / 4 | 3 / 4 | 3 / 4 |
| | Tributaries | 0 / 0 | 0 / 0 | 0 / 0 |
| North Fork Gualala River | Mainstem | 1 / 5 | 4 / 5 | 1 / 5 |
| | Tributaries | 0 / 17 | 1 / 17 | 0 / 17 |
| **Totals** | Mainstem | 14 / 31 | 24 / 27 | 19 / 27 |
| | Tributaries | 2 / 26 | 4 / 26 | 3 / 26 |

Collected data indicate that temperatures in most of the Gualala watershed exceed preferred juvenile rearing temperature ranges for steelhead and coho salmon. Limited exceedance of short-term maximum temperatures for rearing coho salmon and steelhead occur in monitored tributaries throughout the watershed while exceedance of short-term maximum temperatures occur in the mainstem of each subwatershed more frequently as indicated in Tables 7.14 and 7.15. Data describing the extent of pool stratification in the watershed would help understand the extent of thermal refugia available to salmonids.

## 7.4 CONCLUSIONS

Available data suggest that the success of salmonid spawning, incubation and emergence success in the Gualala River watershed may be limited by the following factors:

- Impact of fine sediments on spawning and rearing habitats
- Reduced channel complexity caused by elevated sediment loads
- Lack of pool habitat provided by large woody debris (LWD)
- Increased stream temperature possibly due to canopy removal and an oversupply of sediment

Information regarding much of the watershed is sparse and sporadic; much of the available information is collected by timber companies who own approximately 35% of the land.

### 7.4.1 SALMONID ABUNDANCE

This assessment evaluated existing data regarding the distribution and abundance of three life stages of salmonids in the Gualala River watershed as provided by spawning surveys, stream surveys, summer electroshocking and snorkel surveys (summer-rearing), and estimates of hatchery releases. Each of these data sources provided useful information on relative population structure and abundance; however, the data are insufficient to provide a quantitative picture of salmonid abundance and distribution in the individual tributaries to the Gualala River.

Due to the limited data, it is impossible to estimate the population size of coho salmon in the Gualala River watershed. However, it appears that the coho that were once plentiful have all but vanished from this watershed. Available data indicates that coho began to decline rapidly in the Gualala River watershed by the latter part of the 1960s. Few coho were observed in the stream surveys of the early 1970s and coho were last noted in stream surveys in Fuller Creek and Haupt Creek (Wheatfield Fork) and its tributaries in 1970 and in 1971. Juvenile coho that were observed during the 1997 surveys of Doty Creek and the Little North Fork Gualala River could be the result of CDFG plants in 1995. It is possible that their progeny continue to exist in this sub-watershed. The last reported sighting of coho salmon in the Gualala River may have been the observed entry of nine adult coho into the Gualala River when the sand bar opened at the mouth during the winter of 1999-2000.

Historically, steelhead have been observed throughout the entire watershed. Available information indicates that the populations show a pattern of decline. However, it appears that steelhead continue to be present in most tributaries throughout the watershed. Data supports the hypothesis that the steelhead populations were in a declining trend as early as the 1970s. If the CDFG estimate in the mid-1960s of 16,000 steelhead in the Gualala River is reasonable then a substantial decrease in run size occurred in just a few years. In addition, a large percentage of the steelhead observed appear to be YOY that may not be surviving to mature and propagate. Additional studies would be necessary to confirm this. One area identified that should be considered a refuge area for salmonids is the Little North Fork Gualala River. As stated earlier, Maahs and Gilleard (1994) concluded that the juvenile presence and spawning of steelhead in the Little North Fork Gualala River indicated that the production in these streams was quite good. It is also possible that the planting of steelhead in this sub-watershed was more successful, possibly due to the presence of adequate habitat.

Presence/absence surveys conducted in the South Fork Gualala River and in the Wheatfield Fork in the early 1990s indicate that the fish community is now dominated by Gualala roach and three-spine stickleback in many areas.

### 7.4.2 AQUATIC HABITAT

As noted earlier in this chapter, in-stream substrate samples taken by CFL (1997), GRI (1998-2000), and Knopp (1993) generally indicate that aquatic habitat throughout the watershed is impaired by excessive fine sediments. $D_{50}$ and V* data suggest that upslope disturbances have impacted stream substrates with excessive fine sediments, and impaired the ability of the aquatic habitat to support salmonid spawning, incubation, and emergence. The exception is Dry Creek where both $D_{50}$ and percent fines data indicate good spawning habitat. Regional Water Board staff observations of conditions existing in the spring of 2001 indicate that stream channels are still greatly impacted by fine sediment.

CDFG surveys have reported a watershed impacted by past logging practices (CDFG unpublished data 'o'). Recent data indicate that current streambed habitat remains impaired for salmonid spawning, incubation, and emergence.

Results of CFL surveys provide evidence that, with the exception of Fuller Creek, stream reaches throughout the Gualala River watershed lack essential habitat provided by LWD. Two indices measured for the survey, LWD pieces per bankfull width and LWD volume index fell short of criteria established by Peterson et al (1992). Past land management involving logging and associated practices such as splash dam log transportation, as well as previous CDFG projects that removed migration barriers throughout the watershed, have led to the dearth of salmonid habitat provided by LWD.

Temperature exceedances may be limiting salmonid production in the Gualala River watershed. Data from the Gualala River Watershed Council (GRWC 2001) Gualala Redwoods Inc. (GRI 1998-2000) and the Mendocino Redwoods Company (MRC, unpublished data) show that stream temperatures for most of the watershed exceed preferred juvenile rearing temperature ranges for steelhead and coho. Limited exceedance of short-term maximum lethal temperatures for steelhead and coho occur throughout the watershed. The causes of elevated stream temperatures (e.g., changes in channel morphology, reduced riparian canopy cover, aggradation) have not been thoroughly assessed.

### 7.4.3 POTENTIAL WATERSHED IMPROVEMENTS AND ADDITIONAL INFORMATION NEEDS

Available data indicate that aquatic habitat could be improved by reducing sediment delivery, increasing large woody debris for sediment metering and habitat, and enhancing the riparian canopy cover to reduce stream temperatures. In the Fuller Creek and McKenzie Creek watersheds, road-related erosion is believed to be a major source of sediments to the stream, and is the focus of ongoing restoration efforts. More detailed temperature data and analysis, such as that provided by Forward Looking Infrared Imagery and channel surveys, will help characterize temperature dynamics and thermal refugia within the watershed.

A comprehensive monitoring program to evaluate suspended fine sediments and turbidity is required to adequately determine the impacts of fine sediment on beneficial uses including municipal and domestic supply, water contact recreation, non-contact water recreation, spawning reproduction, and/or early development, and cold freshwater habitat.

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