U.S. Environmental Protection Agency
Region IX

North Fork Eel River Total Maximum Daily Loads for Sediment and Temperature

Approved by:

/ s / Laura Tom Bose for   30 December 2002

Catherine Kuhlman
Acting Director, Water Division

Date

Table of Contents

CHAPTER 1: INTRODUCTION

Overview of the TMDL program

The primary purpose of the Total Maximum Daily Load (TMDL) program in California's North Coast is to assure that beneficial uses (such as salmon habitat in streams and drinking water supplies) are protected from excess sediment, temperature and nutrient increases. The TMDLs set maximum levels of pollutants, an important step in achieving water quality standards for the North Fork Eel River and tributaries in Northern California.

The major water quality problem in the North Fork Eel River and tributaries (and the one addressed in this report) is the decline of salmon and steelhead populations. While many factors have been implicated in the decline of west coast salmon and steelhead, we are concerned here with two inland water quality considerations - increases to natural sediment and temperature patterns. The North Fork Eel (along with many other watersheds in California and throughout the nation) has been put on a list of "impaired" or polluted waters. In this watershed, the listing leads to the TMDL, which determines the "allowable" amount of sediment and temperature. Development of measures to implement the TMDL is the responsibility of the State of California.

Background

The North Fork Eel River Total Maximum Daily Loads (TMDLs) for sediment and temperature are being established in accordance with Section 303(d) of the Clean Water Act, because the State of California has determined that the water quality standards for the North Fork Eel River are exceeded due to excessive sediment and temperature. In accordance with Section 303(d), the State of California periodically identifies "those waters within its boundaries for which the effluent limitations . . . are not stringent enough to implement any water quality standard applicable to such waters." In 1992, EPA added the North Fork Eel River to California's 303(d) impaired water list due to elevated sedimentation and temperature, as part of listing the entire Eel River basin. The North Coast Regional Water Quality Control Board (Regional Water Board) has continued to identify the North Fork Eel River as impaired in subsequent listing cycles, the latest in 1998.

In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, 11 March 1997), December 2002 is the deadline for establishment of this TMDL. Because the State of California will not complete adoption of a TMDL for the North Fork Eel River by this deadline, EPA is establishing this TMDL, with assistance from Regional Water Board staff.

The primary adverse impacts associated with excessive sediment and temperature in the North Fork Eel River pertain to anadromous salmonid fish habitat. The populations of anadromous salmonid species present in the North Fork Eel River and its tributaries are in severe decline.

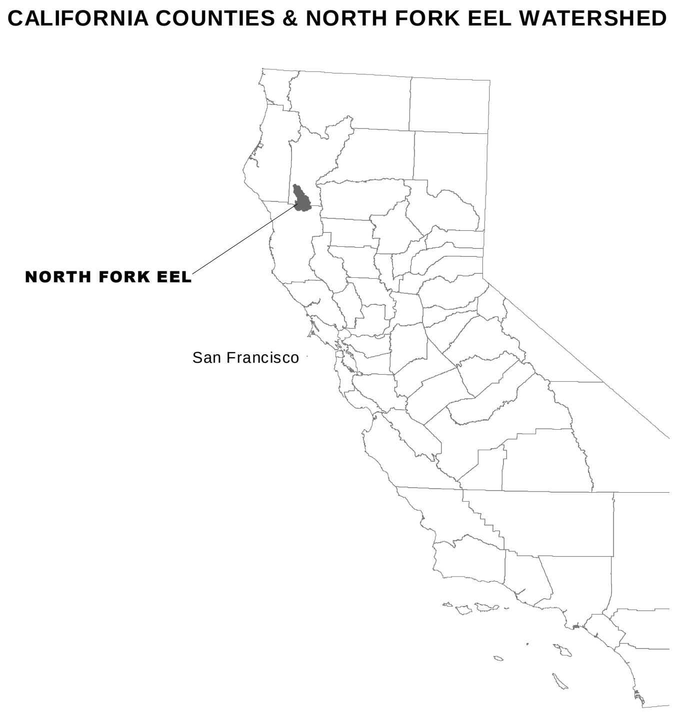
The purpose of the North Fork Eel River TMDL is to identify the total amount (or load) of sediment and heat which can be delivered to the North Fork Eel River and tributaries without causing exceedence of water quality standards, and then to allocate the total amount among the sources of sediment or heat in the watershed. Although factors other than excessive sediment and heat in the watershed may be affecting salmonid populations (e.g., ocean rearing conditions), this TMDL focuses on sediment and heat, the pollutants for which the North Fork Eel River is listed under Section 303(d). EPA expects the Regional Water Board to develop an implementation strategy which will result in implementation of the TMDL in accordance with the requirements of 40 CFR 130.6. The allocations, when implemented, are expected to result in the attainment of the applicable water quality standards for sediment and temperature for the North Fork Eel River and its tributaries.

These TMDLs apply to the portions of the North Fork Eel River watershed governed by California water quality standards. They do not apply to lands under tribal jurisdiction.

1.1. WATERSHED CHARACTERISTICS

North Fork Eel River watershed area is approximately 180,020 acres (289 square miles.) It is the smallest of the subbasins of the Eel River. The watershed is sparsely populated with a terrain that varies between forested areas, oak woodlands, oak savannahs and grasslands. (The USGS Hydrologic Code is 18010211; State hydrologic area 111.50.) The watershed is in northeast Mendocino county and southern Trinity county (see Figure 1-1).

Figure 1-1 Location of the North Fork Eel River Watershed



Ownership of the basin is approximately 50% federally managed (41% Six Rivers National Forest, 9% BLM), 2% Round Valley Tribe and 48% private (see Figure 1-2). Large ranches, interspersed small residences or summer or hunting cabins, and one industrial timber company form the mosaic of private landownership. Many landowners do not have their primary residence in the watershed.

The area's geology is underlain by the Franciscan terrane that dominates most of California's North Coast. Naturally unstable, this type of geology is sensitive to human disturbance. The North Fork Eel watershed is relatively dry and warm, away from the influence of coastal fog. Almost all of the estimated 50 inches of annual rainfall occurs between November and April. Many smaller tributaries dry up in late summer, and the mainstem North Fork is intermittently dry, in some summers, 22 miles from the mouth (Watershed Sciences, 2002.) In the winter, there is often snow in the higher elevations.

Land use activities in the North Fork Eel include grazing, timber harvest, recreation and a few residences. The North Fork Eel Watershed Analysis (USDA, 1996) reports that only 200 residents live in the North Fork Eel. There are only a few paved roads and recreational access and use on Forest Service lands, including the North Fork Wilderness and the Wild and Scenic river corridor, is very light.

The degree of land disturbance in the past few decades is relatively light. Timber harvest on public lands was relatively light prior to 1964 and logging peaked on Forest Service lands during the 1970s, with approximately 1200 acres clear cut (USDA, 1996.) Federal lands are currently managed under the Northwest Forest Plan, with 35% of federal lands "withdrawn" or designated wilderness; 21% classified as Late Successional Reserve and 44% of federal lands classified as matrix. The North Fork Eel has a relatively low road density (1.7 miles/square mile) on public lands. Louisiana-Pacific (L-P) estimated road densities of 4-5 miles/square mile in their ownership in the southern part of the watershed. This same area was estimated to have approximately 85% of its acreage in trees less than 11 inch diameter at breast height (L-P, 1995.) Given that recent fires have not been extensive (USDA, 1996) this likely indicates that the southern part of the watershed saw significant harvest. As L-P no longer owns land in the watershed, it is unknown if current estimates of land disturbance are similar. The level of disturbance of smaller private lands is unknown. The current grazing pressure is light compared to historical pressure. During the 1870s, it has been estimated that at least 60,000 sheep spent part of the year in the North Fork (USDA, 1995.) (For a complete review of the environmental and cultural history of the North Fork Eel, Thomas Keter of Six Rivers National Forest has written several extensive reports (USDA, 1995: Keter, 1992; Keter, 1993; Keter, 1997.)

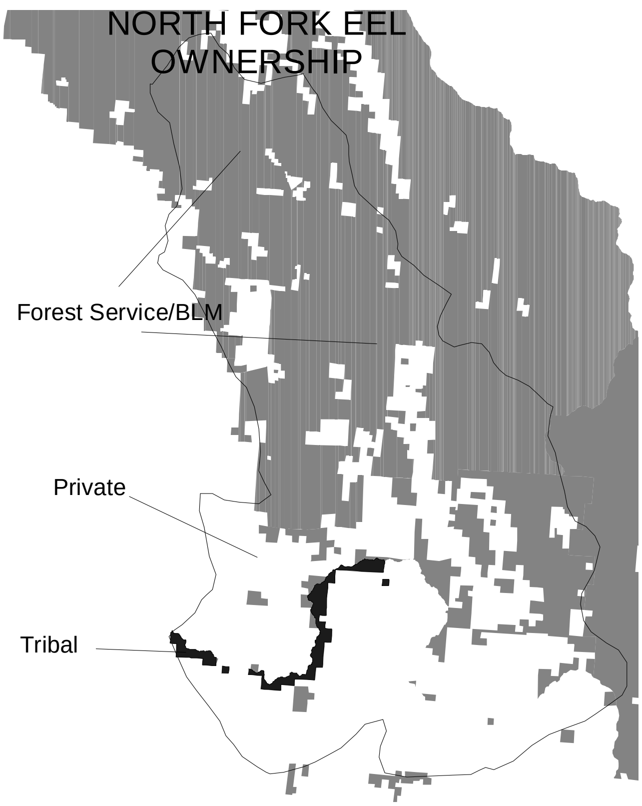


Figure 1-2 North Fork Eel River Ownership

1.2. ENDANGERED SPECIES ACT CONSULTATION

EPA has initiated informal consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service on this action, under Section 7(a)(2) of the Endangered Species Act. Section 7(a)(2) states that each federal agency shall ensure that its actions are not likely to jeopardize the continued existence of any federally-listed endangered or threatened species.

EPA's consultation with the Services has not yet been completed. EPA believes that it is unlikely that the Services will conclude that the TMDLs that EPA is establishing violate Section 7(a)(2) since the TMDL and allocations are calculated in order to meet water quality standards, and water quality standards are expressly designed to "protect the public health or welfare, enhance the quality of water and serve the purposes" of the Clean Water Act, which are to restore and maintain the chemical, physical and biological integrity of the Nation's water." Additionally, this action will improve existing conditions. However, EPA retains the discretion to revise this action if the consultation identifies deficiencies in the TMDL or allocations.

1.3. ORGANIZATION

This report is divided into chapters. Chapter 2 (Problem Statement) describes the nature of the environmental problems addressed by the TMDL. Chapter 3 (Temperature) describes the results of a model used to evaluate temperature conditions in the watershed; identifies specific targets for stream temperatures; and identifies the total load of heat that can be delivered to the North Fork Eel River and tributaries without causing exceedence of water quality standards, and describes how EPA is apportioning the total load of heat, in terms of necessary amounts of riparian shade. Chapter 4 (Sediment) identifies specific stream and watershed characteristics to be used to evaluate whether the North Fork Eel River is attaining water quality standards for sediment; describes what is currently understood about the sources of sediment in the watershed; and identifies the total load of sediment that can be delivered to the North Fork Eel and its tributaries without causing exceedence of water quality standards, and describes how EPA is apportioning the total load among the sediment sources. Chapter 5 (Implementation and Monitoring Measures) contains recommendations to the State regarding implementation and monitoring of the TMDL. Chapter 6 (Public Participation) describes public participation in the development of the TMDL.

CHAPTER 2: PROBLEM STATEMENT

This chapter summarizes how temperature and sediment are affecting the beneficial uses of the North Fork Eel River and its tributaries associated with the decline of the cold water salmonid fishery. It includes a description of the water quality standards and salmonid habitat requirements related to temperature and sediment.

2.1. FISH POPULATION PROBLEMS

In the entire watershed, there has been a decline, although unmeasured, of salmon and steelhead populations since the 1960s. Most definitively, the majority of summer stream temperatures measured exceed those tolerated by rearing steelhead. As for sediment, the stream channels were greatly damaged during the 1964 flood, where the streams filled with sediment, stream channels widened and many areas lost riparian vegetation. However, very little information exists on current sediment conditions of streams. While intensive monitoring has not taken place, the only available data show that sediment conditions for salmonid spawning and rearing vary from good to poor, depending upon the location.

Trends in salmon and steelhead populations over time have not been measured in the North Fork Eel. The available sources of information, while each limited, provide a clear indication that the salmon populations have declined in the post WWII years. Keter's archaeology research (Keter, 1992; USDA, 1995) documents a larger fishing effort and larger salmon runs, with the most substantial decline after the 1964 flood. Salmon were so abundant (before the settlement by Euro-Americans) that "on Horse Canyon Creek there was a waterfall where fish were harvested each season by three distant villages" (Keter, 1993). Keter's interviewees report it "was not uncommon" to see remains of salmon carcasses along the river banks and remains of fishing weirs (Keter, 1992.) An oft cited figure (DWR Bulletin 136, appendix C 1965) of 500 chinook and 4500 steelhead in the watershed was generated from available habitat and flow data, not fisheries information.

Current salmon population information indicates that chinook are restricted to the lower five miles of the river, below Split Rock, while steelhead are widely distributed (coho are not found presently in the watershed and were not likely historically.) Reports are that the barrier to migrating chinook at Split Rock was formed or greatly enlarged by the 1964 storm. This area is also a barrier to pike minnow, an exotic species that may be a competitor to juvenile salmon and steelhead. A recent spring fish survey (Scriven, 2002) of four stretches on the lower North Fork Eel, found no evidence of chinook or pike minnow. Evidence of adult steelhead, redds and juveniles were found in all four stream segments, but not in large numbers. DFG Stream Inventory Reports (CDFG, 1995 - 1996) report juvenile steelhead and/or trout in Bar, Panther, Bradburn, Bluff, Wilson, Kettenpom, Hoaglin, Salt, Soldier, Cox, Yellowjacket, Lightfoot, Red Mountain, Hulls, Brin, Horse Canyon and Asbill Creek. In both Red Mountain and West Fork juveniles were reported to be abundant. Only Rock, Willow and Who/Who creeks had no sightings of juveniles. In addition, L-P sampled 15 sites for fish presence in the summer and reported three sites on Hulls Creek with juvenile steelhead (L-P, 1995).

Two locations, Asbill Creek and North Fork Eel were sampled for aquatic invertebrates (insects) during spring and fall 1996. Using three measures of stream health, the two streams fell into the middle third of other Eel streams sampled in the spring, but were in the bottom third during the fall sampling.

Many different habitat conditions are crucial for the survival of salmon and steelhead. Salmonid populations are affected by a number of factors including commercial and sport harvest, adequate food, adequate cover and ocean conditions. This TMDL focuses <u>only</u> on the achievement of water quality standards related to sediment and temperature which will facilitate, but not guarantee, population recovery.

2.2. TEMPERATURE PROBLEMS

Temperature directly governs almost every aspect of the survival of Pacific Salmon (Berman, 1998.) Temperature is such an important requirement that coho, steelhead, chinook and rainbow trout are known as "cold water fish." Salmon are affected in many ways by stream temperatures including metabolism, food requirements, growth rates, timing of adult migration upstream, timing of juvenile migration downstream, sensitivity to disease and direct lethal effects (Spence et al, 1996.) In the North Fork Eel TMDL, the most sensitive period is the summer period when young salmon are growing before migrating to the ocean. Thus, this is the period analyzed in the temperature TMDL.

The scientific literature on temperature and salmon is very extensive, with laboratory and field studies conducted under many different conditions. (For a thorough review of the scientific literature please see information from scientific panels in the States of Oregon and Washington (ODEQ, 1995; WDOE, 2000; and EPA Region 10, 2001a & b.)) Based on these reviews, this TMDL uses five temperature ranges to categorize the quality of summer stream habitat in regard to temperature (see Table 2-1). This table uses steelhead temperature tolerances (chinook are not present in the summer) and the MWAT metric. MWAT, or the maximum weekly average temperature, is one way to measure the hottest period of the year (see box - What is MWAT?). These ranges should not be considered perfectly precise in the field because salmonids are affected by several factors including the fluctuation in temperature, the mean temperature, food supply and access to cool water pockets (called refugia). In addition, steelhead may likely respond gradually to sublethal effects (such as reduced growth); they are not likely to have clear thresholds in the natural environment.

WHAT IS MWAT?

Because temperatures in streams fluctuate daily and seasonally, it is useful to summarize this detailed variability with a summary measurement. To summarize summer stream temperatures in this TMDL (and other TMDLs in California's North Coast), we use the Maximum Weekly Average Temperature (MWAT), a widely used summary measurement. MWAT is calculated here as the maximum value of the 7 day running average of all monitored temperatures (temperature monitors often make hourly measurements.)

Readers should note that the term MWAT is not used consistently by researchers and agencies. For example, the State of Oregon uses MWAT which is calculated as the maximum week of the daily maximum. In addition, the term MWAT is occasionally used to denote a threshold of concern. This threshold of concern is the result of a formula that scales lab data upwards to compare to field data.

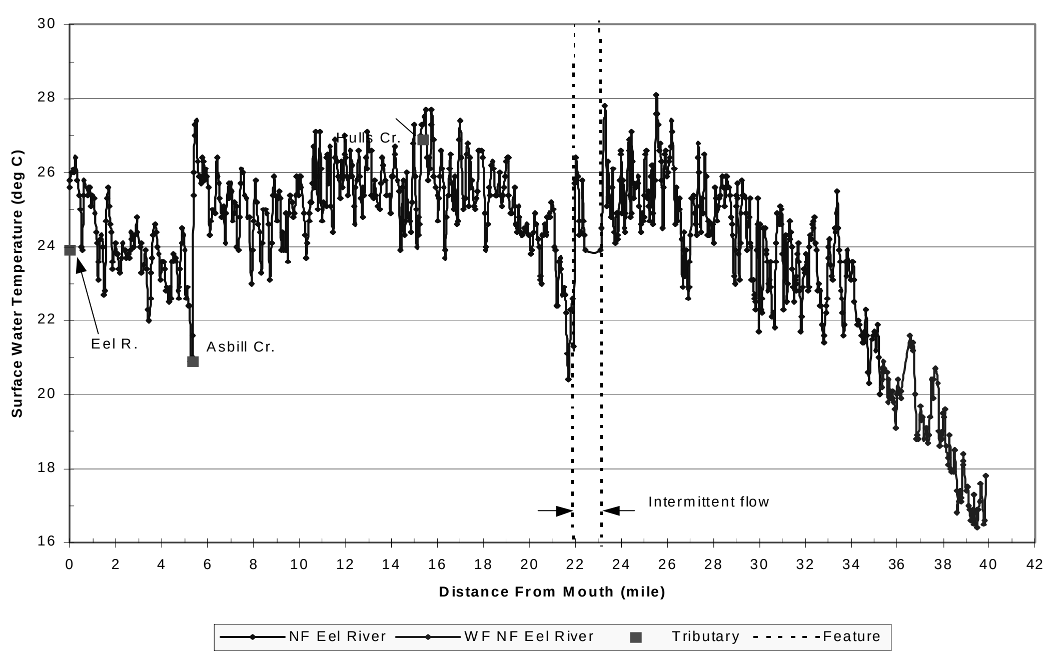
Table 2-1.
Summer temperatures (in MWAT) and steelhead rearing habitat quality

Good conditions	< 15° C	(59°F)
Adequate conditions	15 - 17° C	(59- 62.6°F)
Marginal	17 - 19° C	(62.6 - 66.2°F)
Inadequate	19 - 24° C	(66.2 - 69.8° F)
Lethal	>24° C	(75° F)

Measurements of summer stream temperature conditions for steelhead are available for approximately a dozen locations for 1996 - 1998 and 2001. These measurements show that conditions in the mainstem North Fork Eel are generally inadequate to near lethal for rearing steelhead, although there is evidence of additional cool water pockets (known as refugia) from intragravel flow, pools, springs or groundwater seeps. The tributaries of the North Fork Eel provide a range of conditions. Good summer conditions were measured at three spot locations - Panther Creek, above county road at 13.58°C; West Fork of the North Fork Eel, below Panther and Bar at 14.84°C, and Upper Bluff Creek at 14.76°C.) Marginal conditions (17 - 19°C) have been measured at spot locations on Asbill, Bradburn, Cox, Lower Hull and Who Who Creek. Inadequate conditions (19 - 24°C) have been measured at spot locations on Bear Creek Canyon, Cox Creek, Upper Hulls Creek, Kettenpom, West Fork, Pepperwood, Red Mountain, Rock, Salt, Wilson and Yellowjacket Creek.

Not much is known about the stream temperatures in the past. Two locations were compared to conditions during 1973. The North Fork Eel at Mina Road bridge showed the same maximum temperatures in 1973 and 1996. However, Asbill Creek cooled noticeably with a maximum temperature of 26°C in 1973 and a maximum temperature of 19°C in 1996. This dramatic change may either indicate a dramatic recovery from the 1964 flood or flawed data (HCRCD, 1998.) The only other historical temperature data is from 1966 at a location "near Mina". The maximum temperatures in July and August averaged around 80°F (which is 26.7C), above the short-term lethal limit (DFG, 1972.)

Figure 2-1. TIR Temperature Data for the North Fork Eel River and West Fork of the North Fork (degree Celsius)



A one time snapshot of stream temperatures on the entire stretch of the mainstem North Fork Eel during the week of July 18, 2001 at approximately 2:00 in the afternoon was obtained (see Figure 2-1). This time period corresponds with the warmest summer conditions. This data was obtained by the North Coast RWQCB using Thermal Infrared and Color Videography (TIR) technology (Watershed Sciences, 2002.) Figure 2-1 shows the TIR temperature data for the mainstem North Fork Eel River (from 0 to 35.3 miles from the mouth) and the mainstem West Fork of the North Fork Eel River (35.3 miles to 40 miles from the mouth). Note that the mainstem North Fork Eel was over 20°C (considered inadequate conditions) for its entire 35.3 mile extent and much of the mainstem North Fork was over 24°C (regarded as near lethal threshold for steelhead).

The TIR data also showed that the mainstem North Fork Eel stream temperatures were quite variable within short distances (0.1 mile). This was attributed to inputs of groundwater and the existence of stratified pools, where a cooler bottom layer of water exists. Other areas of cool water are mile 22 where the North Fork Eel emerges from the gravel and where a noticeably cooler Asbill Creek enters. The TIR data suggests strongly that there are areas of cool water that may provide important refugia during the hottest summer conditions.

In summary, the majority of the mainstem North Fork Eel has inadequate to near lethal summer temperatures for rearing steelhead. Stream temperature information is available for the entire mainstem. The TIR information suggests pockets of cool water are found throughout the system. Less information is available on stream temperatures in the tributaries of the North Fork Eel. Conditions measured have ranged from 3 locations with good conditions and approximately 10 locations with inadequate conditions.

2.3. SEDIMENT PROBLEMS

Salmon requirements related to stream sediment

Salmonids have a variety of requirements related to sediment. Salmonids have different water quality and habitat requirements at different life stages (spawning, egg development, juveniles, adults). Sediment of appropriate quality and quantity is needed for redd (i.e., salmon nest) construction, spawning, and embryo development. Excessive amounts of sediment or changes in size distribution (e.g., increased fine sediment) can adversely affect salmonid development and habitat.

Excessive fine sediment can reduce egg and embryo survival and juvenile salmonid development. Tappel and Bjornn (1983) found that embryo survival decreases as the amount of fine sediment increases. Excess fine sediment can prevent adequate water flow through salmon redds, which is critical for maintaining adequate oxygen levels and removing metabolic wastes. Deposits of these finer sediments can also prevent the hatching fry from emerging from the redds, resulting in smothering. Excess fine sediment can also cause gravels in the water body to become embedded (i.e., the fine sediment surrounds and packs-in against the gravels), which effectively cements them into the channel bottom. Embeddedness can also prevent the spawning salmon from building their redds.

An imbalance of fine or coarse sediment supply or transport rate can also adversely affect the quality and availability of salmonid habitat by changing the morphology of the stream. It can reduce overall stream depth and the availability of shelter, and it can reduce the frequency, volume, and depth of pools. Pools provide salmon with protection from predators and a resting location. In the North Fork Eel, pools can be the only place juvenile steelhead are found in the summer as steelhead leave areas with high temperatures. USFS staff (USFS, 2002) snorkled pools in the mainstem North Fork Eel in the summer of

2002. USFS found that numerous pools had no steelhead. However, dissolved oxygen levels measured at the bottom of pools were found to be detrimental to salmonids.

Excessive sediment can affect other factors important to salmonids. Stream temperatures can increase as a result of stream widening and pool filling. The abundance of invertebrates, a primary food source for juvenile salmonids, can be reduced by excessive fine sediment. Large woody debris, which provides shelter, can be buried. Increased sediment delivery can also result in elevated turbidity, which is highly correlated with increased suspended sediment concentrations. Increases in turbidity or suspended sediment can impair growth by reducing availability or visibility of food sources, and the suspended sediment can cause direct damage to the fish by clogging gills.

Sediment conditions in the North Fork Eel

Historical trends

Local residents and fisheries investigations report large changes to stream channels, particularly after the 1964 flood. One of Keter's (USDA, 1995) interviewees "indicated that the channel was so heavily filled with soil and debris that the river bed was level and vehicles could drive for miles up the river bed." These channel changes can negatively affect fish by increasing water temperatures (by stream widening, pool filling and removal of shade from riparian vegetation) and negatively affect spawning and rearing conditions by decreasing the depth and amount of pool habitat, filling spawning gravels with fine sediment.

The most information is known regarding historical changes on the USFS lands in the northern part of the watershed (e.g. north of Wilburn Ranch.) Dresser noted channel changes in his review of 1944, 1960, 1975, 1990 and 1998 photos. The mainstem North Fork Eel river's riparian canopy that existed in 1960 was about 90% removed in the 1964 flood and has since regrown. Both Panther and the West Fork North Fork Eel and Red Mountain followed this general trend. However, Salt Creek and Soldier Creek showed little change through the period.

Current conditions

Current conditions have been determined by a variety of methods, primarily qualitative observations from field reviews by Department of Fish and Game and USFS.

The only information found that reviewed areas throughout the watershed is the Department of Fish and Game's Stream Inventory Reports (DFG, 1995-1996.). Department of Fish and Game's reports provide qualitative information on stream conditions in many streams in the North Fork Eel. Using pool embeddedness (estimated visually) as an indicator, streams in the North Fork Eel were found to have variable conditions for salmon. Of the fifteen streams with relevant observations, five streams had over 60% of pools with good conditions (four of these on USFS lands), two streams had over 80% of pools in poor condition (both on private lands) and the majority were in between. These observations, while not a comprehensive inventory, covered large portions of tributaries including Asbill, Bar, Brin Canyon, Bluff, Casoose, Cox, East Fork, Horse Canyon, Hulls, Panther, Red Mountain, Salt Creek, Soldier, West Fork, Who Who and Yellowjacket.

USFS completed a observational report of the mainstem on USFS lands during the summer of 2002 (USFS, Draft 1.0, 2002.) From the Wilburn Ranch border of USFS lands to the West Fork of the North Fork Eel the mainstem is characterized by large boulders, cobbles and bedrock banks. The only exception is an area around Rock Creek where fines were noted. USFS observed the same dry area as noted in the TIR report; USFS reports the area appeared dry in the 1940 and 1960 photos. With the exception of the West Fork, tributary conditions were not part of the assessment.

Measurements have been obtained by Six Rivers National Forest at three spot locations (West Fork of the North Fork Eel, above Bradburn; North Fork Eel, near Tub Creek; and Kettenpom Creek, below Wilson Creek) during 1998. A "percent fines" measurement, which visually counts how many random points are composed of <2mm fines (many people think of sand), found that the West Fork and Kettenpom both had an average of 12-13% of area in fines, whereas the North Fork Eel (near Tub Creek) had approximately 25% of area in fines. This "percent fines" measurement protocol is significantly different than that used by many researchers. EPA is not aware of what constituted good habitat conditions for salmonids using this method. For the stream segment on the West Fork, mean pool depth was 1.15 meters (3.8 feet), with a couple pools approaching 9 feet deep. Kettenpom had much shallower pools (average 2 feet deep) and no very deep pools; the North Fork segment had pools an average of 4.7 feet deep, with some very deep pools.

In summary, sediment conditions in the North Fork Eel have been reported to be elevated, particularly after the 1964 flood. Elevated sediment after the 1964 flood was confirmed in portions of the basin through review of historical photos. However, these photos also showed that most of these areas have since recovered. In addition, very recent observations by USFS on the mainstem north of the USFS boundary found that fine sediment was not common, instead the channel was reported to be composed of bedrock, cobble and boulder except in a few areas.

2.4. WATER QUALITY STANDARDS

In accordance with the Clean Water Act, TMDLs are set at levels necessary to achieve the applicable water quality standards. Under the Clean Water Act, water quality standards consist of designated uses, water quality criteria to protect the uses, and an antidegradation policy. The State of California uses slightly different language (i.e., beneficial uses, water quality objectives, and a non-degradation policy). This section describes the State water quality standards applicable to the North Fork Eel River TMDL using the State's terminology. The remainder of the document simply refers to water quality standards.

The beneficial uses and water quality objectives for the North Fork Eel River are contained in the *Water Quality Control Plan for the North Coast Region* (Basin Plan) as amended in 1996 (Regional Water Board 1996). The Basin Plan does not identify beneficial uses for the North Fork Eel River specifically. Rather, the Basin Plan identifies beneficial uses for the Eel River and states that "the beneficial uses of any specifically identified water body apply to all its tributaries." Thus, the beneficial uses for the North Fork Eel are: Municipal and Domestic Supply; Agricultural Supply; Industrial Process Supply; Groundwater recharge; Navigation; Hydro power Generation; Water Contact Recreation, Non-contact Water Recreation, Commercial and Sport Fishing, Aquaculture, Warm Freshwater Habitat, Cold Freshwater Habitat, Estuarine Habitat, Wildlife Habitat; Rare, Threatened or Endangered Species; Migration of Aquatic Organisms; Spawning, Reproduction and/or Early Development.

In addition, the Regional Water Board is in the process of updating the Beneficial Uses chapter of the Basin Plan and could refine the Eel River (which now covers the North Fork Eel) to separately identify beneficial uses for the North Fork Eel River.

The water quality objectives pertinent to the North Fork Eel River sediment TMDL are listed in Table 2-2.

Table 2-2. Water Quality Objectives

Parameter	Water Quality Objective
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that cause nuisance or adversely affect beneficial uses.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such an alteration in temperature does not adversely affect beneficial uses.
	At no time or place shall the temperature of any COLD <water with a beneficial use of cold freshwater habitat> water be increased by more than 5°F above natural receiving water temperature.
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

In addition to water quality objectives, the Basin Plan includes two prohibitions specifically applicable to logging, construction, and other associated sediment producing nonpoint source activities:

o *the discharge of soil, silt, bark, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature into any stream or watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited; and*

o the placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.

CHAPTER 3: TEMPERATURE TMDL

Summary

Analysis conducted for the TMDL concludes that shade is important for the protection of summer stream temperatures in the North Fork Eel.   EPA concludes that attaining the water quality standard requires that there will be no human caused changes to "natural potential" shade.   The analysis focused on using a model to determine the extent of stream temperature changes resulting from riparian vegetation changes.   The analysis found that shade is very important to stream temperatures in the North Fork Eel. Upstream of Yellowjacket, the modeling indicates that this attainment of "natural potential vegetation" would result in approximately 7% of stream miles in good or adequate condition for steelhead, 52% in marginal habitat and the remaining 41% in inadequate condition. Thus the public and land managers can expect that even when water quality standards are attained, there will be a wide range of habitat conditions for steelhead - from good stream temperatures to lethal stream temperatures.

This chapter presents information pertinent to the temperature TMDL for the North Fork Eel in several sections. Section 3.1 provides EPA's interpretation of the water quality standards for temperature. Section 3.2 describes the modeling that was conducted to examine the role streamside vegetation plays in stream temperature changes. Section 3.3 describes water quality targets. Section 3.4 presents the TMDL and allocations.

3.1.   Interpreting the Existing Water Quality Standards for Temperature

This temperature TMDL is calculated so as to attain the applicable water quality standards. The Basin Plan identifies the following two temperature objectives for surface water:

> "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such an alteration in temperature does not adversely affect beneficial uses."

> "At no time or place shall the temperature of any COLD <i.e. water with a beneficial use of cold freshwater habitat> water be increased by more than 5 degree F above natural receiving water temperature."

In considering the first objective, EPA has examined whether alterations from natural temperature conditions would adversely affect the most sensitive beneficial use - that is, cold water fish.   As illustrated in the modeling, EPA concludes that the TMDL should be set at the level necessary to attain natural temperature conditions, because temperature conditions in most locations in the North Fork Eel are far from ideal for salmonids, even under natural conditions. Thus achieving the water quality standard, as interpreted in this TMDL, results from no alterations to natural stream temperatures.

As we have concluded that no alterations of natural conditions are appropriate for the first objective, it is clear that the first objective is more stringent than the second. Therefore, this TMDL is designed to meet the first objective.

Examining the Role of Shade on Summer Stream Temperatures

Although stream temperatures are affected by many factors, shade is the factor in the North Fork Eel that is most likely to be altered from natural conditions. The North Fork Eel does not have discharges of cooling water from industries, large water diversions, agricultural return flows nor dams. Only household diversions are present and given the low population density these are assumed to be insignificant. Interestingly, Keter (USFS, 1995) has speculated from historic research and interviews that the stream flow in the summer seems to have been reduced since the 1850 homesteading period. This could be due to changes in vegetation, fire or climate.

Alterations to shade in the North Fork Eel occur primarily through changes in riparian vegetation or through stream widening. The modeling done in support of TMDL development examines the effects of changes in riparian vegetation. The model uses existing stream widths, due to lack of information on potential stream widening from increased sediment. In addition, on USFS lands a review of historical photos at several locations (USFS, 2002) did not show channel changes through time. No information on channel widening through time was found on other areas in the southern part of the watershed.

Sediment control in the watershed is important for temperature for other reasons. Pools can provide important thermal refugia for salmonids. Stratified pools can provided a much needed refuge in hot periods of the day and the hottest times of the year. Neilsen & Lisle (1994) studied the Middle Fork Eel River and documented that cold pockets "were consistently about 3.5°C cooler than surface water and as great as 7.8°C cooler." USFS (USFS, 2002) observational review of the mainstem north of the USFS boundary notes several stratified pools. However, measurements of dissolved oxygen at the bottom of a large pool in the mainstem were very low. Flood damage related to sediment can affect riparian vegetation. Dresser (USFS, 2002) noted significant riparian vegetation losses presumably from the 1964 flood in the mainstem, West North Fork, Panther Creek and Red Mountain Creek. Soldier and Salt Creeks did not appear affected. Thus, sediment control is important for temperature by its influence on stream width, the frequency and depth of pools, and flood damage to riparian vegetation.

3.2. TEMPERATURE AND SHADE MODELING

Investigating the Influence of Shade with QUAL2E/Shade Model

EPA funded Tetra Tech to model the influences of shade in the North Fork Eel. Stream temperature modeling is a well developed area of inquiry and has been used throughout the Pacific Northwest. The model was used to calculate shade and resulting stream temperatures for several scenarios, including current riparian vegetation conditions and EPA's estimate of natural riparian vegetation conditions. The model QUAL2E was refined with a shade element to determine how shade is influencing stream temperatures in the North Fork Eel (see appendix A). The model was developed fully for the northern part of the watershed (above Yellowjacket Creek) because that is where the most information was available. Vegetation and resultant shade, but not stream temperatures, were also analyzed for Hulls Creek in the southern part of the watershed.

Figure 3-1 shows the vegetation information used in developing this model of the northernmost portion of the basin. The available information shows that the mainstem, north of Yellowjacket, has almost no conifer vegetation. This combination of a wider channel and shorter vegetation type results in lower shade and thus higher predicted temperatures. Again, the TIR data for this area (approximately mile 28 - mile 36, see page 7) corresponds well with the modeling for this area. The USFS photo log (USFS, 2002 draft) also notes an exposed channel with little conifer vegetation.

This page left blank for INSERT of
Figure 3-1: Type of Vegetation in North Fork Eel Modeling

The model uses available data to estimate the extent of shade and the resulting stream temperatures over a wide range of conditions. Four scenarios, that differ only in assumptions on vegetation, were examined.

#1: No Vegetation Scenario: Shade is provided only by topography.

#2: Existing Vegetation Scenario: Shade is provided by existing vegetation type and vegetation size as estimated using existing data (see appendix A.)

#3: Historical Full Growth/Fire Scenario: This scenario assumes that vegetation type does not change (hardwoods remain hardwoods, grasslands remain grasslands etc), however the size of the vegetation can change. For hardwoods and conifer vegetation, this scenario is based on an estimate of how large trees are expected to be in the watershed under their natural potential. This scenario includes a limit on size due to the occurrence of periodic fires. The scenario was developed from two independent analyses. Tetra Tech investigated general relationships on tree growth and height based on literature values and then assumed that all vegetation reached the maximum size currently found in the North Fork Eel, [33 meters (108 feet) for conifers; 19.6 meters (64 feet) for hardwoods]. In addition, Keter (1997) analyzed the age of Douglas Fir stands in the North Fork Eel as part of a historical analysis on vegetation changes. Of all stands examined, 80% were 120 years or less and usually 18-24" in diameter. This information was combined with size to height information for riparian vegetation types (on average 28" diameter = 108 feet). Thus 108 feet(33 meters) was used as an assumption for the estimate of tree height for this scenario.

#4: Old Growth/No Fire Scenario: This scenario also assumes the vegetation type does not change, only the size of the vegetation. This scenario differs only in its assumptions on the size of conifers, all other vegetation sizes (hardwood, grasslands etc) are the same as scenario #3. This scenario examines stream temperature conditions if all conifers reached an "old growth" condition. Although it is unlikely to ever be a common condition, old growth does exist in the North Fork Eel watershed, so this scenario was developed as a theoretical potential. Conifer size estimates were developed from Six Rivers National Forest information (45.72 meters /150 feet) (USDA, 1996.)

Results of the Model

Figure 3-2 shows a map of the modeled stream temperatures under scenario 2 (existing vegetation). Note that the entire mainstem in this area, as well as many tributaries on the eastern side are predicted to have inadequate conditions (shown in red). Many tributaries on the western side are predicted to provide marginal conditions, where growth of juveniles is likely reduced (shown in yellow). Two tributaries are estimated to provide adequate and good conditions (Panther and Bluff Creeks.) The estimates developed by the model correspond well with the TIR data (mile 28 to mile 36, see page 7) that shows the same general temperatures (inadequate conditions) in the mainstem, with cooler temperatures in the West Fork. This also corresponds well with other monitored temperatures (HRCD, 1998.) In some locations, the model over estimated stream temperatures. These areas are known to have substantial springs and other groundwater sources (USDA, 1996).

Figure 3-3 shows a map of stream temperatures for topographical shade only (no vegetation); Figure 3-4 a map of the Natural potential vegetation and Figure 3-5 for Old Growth conifers. Recall that in all scenarios the type of vegetation does not change (see Figure 3- 1.) Only the size of the vegetation changes.

This page left blank for insert of

Figure 3-2: Model Predicted Stream Temperatures
for streams north of Yellowjacket
- Existing Vegetation -

This page left blank for insert of

Figure 3-2: Model Predicted Stream Temperatures
for streams north of Yellowjacket

- Shade from topography only (no vegetation) -

This page left blank for insert of

Figure 3-2: Model Predicted Stream Temperatures
for streams north of Yellowjacket

- Shade from "natural potential" vegetation -

This page left blank for insert of

Figure 3-2: Model Predicted Stream Temperatures
for streams north of Yellowjacket

- Shade from "natural potential" vegetation, plus old growth conifers-

Figure 3- 6 summaries the data in Figures 3-2 - Figure 3-5. For all four scenarios the proportion of the northern watershed (streams north of Yellowjacket) by habitat quality (stream temperature) is summarized. For example, in the Historical Full Growth scenario, approximately 40% of the stream miles (in the area North of Yellowjacket)have stream temperatures between 17°C and 19°C. Table 3- 1 provides the same summary information in another format. Shade provided by riparian vegetation is clearly important. Inadequate or lethal habitat is reduced substantially from 65 miles (85% of total miles) under no vegetation to 35 miles (46%) under existing vegetation. It is interesting that even under old growth conditions everywhere, which is considered unlikely to ever develop, 21 miles (27% of total miles) remain in inadequate condition for steelhead rearing. Very little good or adequate habitat was estimated under any scenario. Almost no good or adequate habitat (1.2 miles, 1%) is provided when there is no vegetation, 4.3 miles (6%) under existing vegetation, 5.6 miles (8%) under full growth/fire and a maximum of 10.5 miles (14%) under old growth scenario.

Figure 3-6: Quality of Stream Temperatures for steelhead for different vegetation scenarios area north of Yellowjacket Creek - in stream miles -

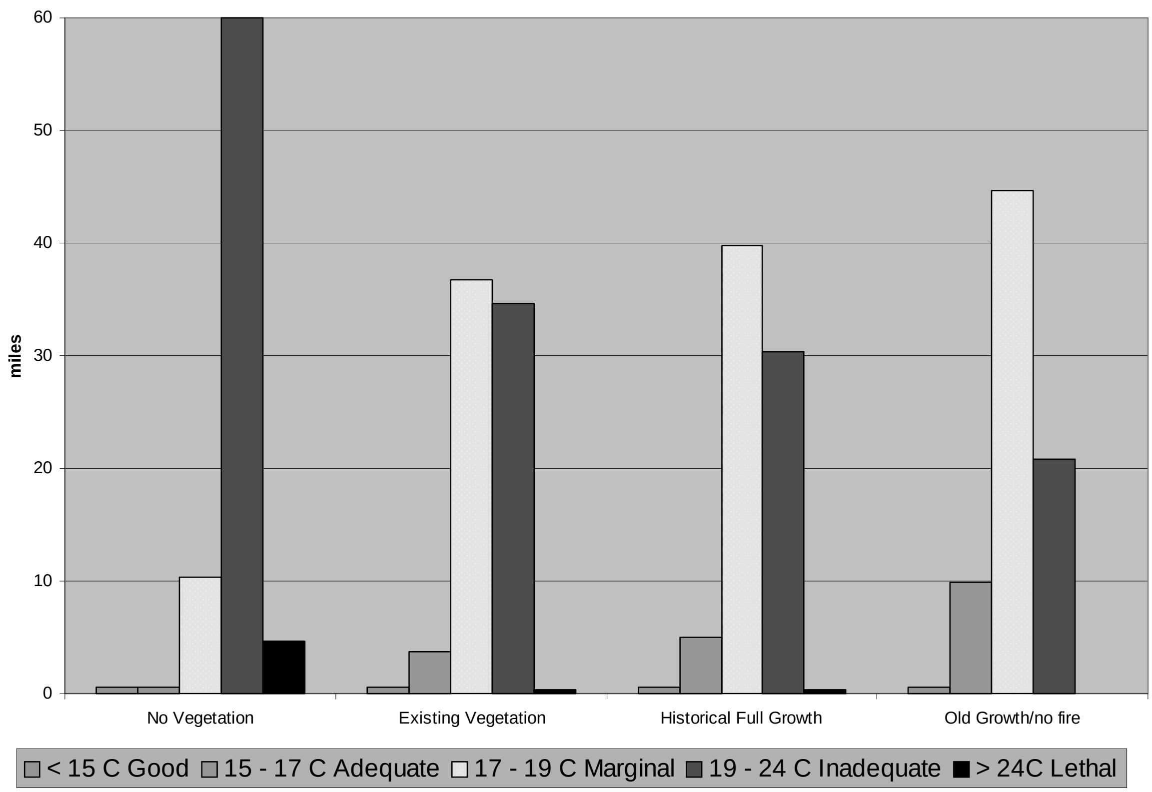


Table 3-1. Miles of Modeled Stream Habitat by Summer Habitat Quality

Habitat Quality Rating	Stream Temperature	Vegetation Scenario			
		No Vegetation	Existing Vegetation	Historical Full Growth/Fire	Old Growth
Good	< 15 C	0.6	0.6	0.6	0.6
Adequate	15 - 17 C	0.6	3.7	5	9.9
Marginal	17 - 19 C	10.3	36.7	39.8	44.7
Inadequate	19 - 24 C	60	34.7	30.4	20.8
Lethal	> 24C	4.7	0.33	0.3	0

Recall that these modeling results do not include additional cool water habitat provided by pools. Small, but important, portions of adequate habitat in pools may exist where surface water temperatures are marginal. The modeling suggests that the existing condition of the watershed is close to the historical/full growth scenario.

Selection of Scenario Corresponding to Water Quality Standards

The narrative water quality standard states “the natural...water temperature...shall not be altered unless it can be demonstrated...that such an alteration in temperature does not adversely affect beneficial uses.” The modeling of a portion of the basin, north of Yellowjacket, illustrates that stream temperatures in this watershed are expected to be primarily marginal, inadequate and lethal for juvenile steelhead during the summer months - under all scenarios. EPA concludes that given the small amount of adequate and good habitat, ANY alteration in stream temperatures would adversely affect beneficial uses. In addition, EPA is selecting scenario #3 (natural vegetation potential) to calculate the TMDL and allocations needed to attain the water quality standard.

EPA is selecting scenario #3 (Historical Full Growth/Fire), rather than scenario #4 (Old Growth) as the natural vegetation condition upon which to develop the TMDL. Under natural conditions, fire and storms would naturally impose variety in the riparian zone to some extent (Bureau of Land Management, 1996.) Although old growth conifers are present in the watershed, they are not common. Various factors, with fire prominent among them, appear to limit the size of conifers in the watershed. Keter (1997) states, “It was, in fact, impossible to find any stands of Douglas-Fir displaying old-growth characteristic within the research area.” Therefore, the Historical Full Growth/Fire scenario is selected as being representative of natural conditions.

Implications for land management

EPA concludes that attaining the water quality standard requires that there be no human caused changes to “natural potential” shade. The public and land managers can expect that even when water quality standards are attained, there will be a wide range of stream temperature conditions for steelhead - from good stream temperatures to lethal stream temperatures. In addition, land managers should examine their practices to see if they allow changes to natural potential vegetation. Both the Northwest Forest Plan, which does not allow harvest in the riparian zone under present management, and the Forest Practice Rules, which do allow limited harvest, should be explicitly examined during the implementation phase of the TMDL.

3.3. WATER QUALITY TARGETS

EPA has developed estimates of stream temperatures under natural conditions as an indicator of the extent to which stream conditions are meeting applicable water quality standards. Thus, for the five northern subwatersheds which were fully modeled, EPA has identified target stream temperatures. These target stream temperatures were developed using the model under the Historical Full Growth/Fire scenario. The results are presented in Table 3-2. These targets illustrate that the public and land managers should expect to see instream temperatures that vary from good to lethal - even with attainment of water quality standards.

Table 3-2. Stream Temperature Targets for North of Yellowjacket

Steelhead habitat quality (in MWAT)	Percent of Stream Length in Five Northern Subwatersheds
Good < 15°	**1%**
Adequate 15-17°C	**7%**
Marginal 17-19°C	**52%**
Inadequate 19-24°C	**40%**
Lethal >24°C	**0%**

Again, it should be noted that EPA is selecting the Historical Full Growth/Fire scenario as the scenario that corresponds to the applicable water quality standard, because we believe it is most representative of natural conditions, even though the resulting water temperatures are often quite warm for steelhead. We would also emphasize the importance of thermal refugia in the watershed.

3.4. TMDL AND ALLOCATIONS

TMDL or Loading Capacity

The loading capacity (i.e., the TMDL) is the total loading of the pollutant that the river can assimilate and still attain water quality standards for temperature. In this TMDL, the pollutant is heat.

In this case, the TMDL is the maximum amount of heat from solar radiation that can be added to streams in the North Fork Eel River watershed and not exceed water quality standards. This amount was calculated using an average of all modeled areas (the northern and Hulls Creek areas) and extrapolating the result to the entire watershed. In the model, potential solar radiation over each stream segment (695.8 langleys/day (ly/day)) is reduced by topography and vegetation to calculate heat reaching the stream for each stream segment. Averaged over the watershed, the heat actually reaching streams is 423.8 ly/day with existing vegetation, and 409 ly/day with historical full growth/fire vegetation. Thus:

the TMDL for the North Fork Eel = 409 ly/day averaged over streams in the entire watershed.

The unit of heat used in this TMDL is the langley (ly). It is a measure of energy per unit area, and can be converted to metric units such as joules (1 ly = 41850 joules/m^2). Since the langley is a measure of energy per unit area, the TMDL of 409 ly/day could be multiplied by the area of streams in the watershed to derive the total amount of energy that could reach streams in the watershed without exceeding water quality standards.

Allocations

In accordance with EPA regulations, the loading capacity (i.e. TMDL) is allocated to the various sources of heat in the watershed, with a margin of safety. That is:

TMDL = sum of "wasteload allocations" for individual point sources,
+ sum of the "load allocations" for nonpoint sources, and
+ sum of the "load allocations" for background sources.

The margin of safety in this TMDL is not added as a separate component of the TMDL, but rather is incorporated into conservative assumptions used to develop the TMDL, as discussed below. As there are no point sources of heat in the North Fork Eel River watershed, the wasteload allocation for point sources is set at zero.

For the load allocations for nonpoint and background sources, we have translated the TMDL of heat into shade along different stream segments. "Shade" in this case, is not the amount of stream in shadow or the amount of the stream surface shaded from direct sunlight. Shade is the percent reduction in solar radiation (light/heat) due to the filtering and buffering of heat and light by vegetation and topography. <This is not the same as the amount of the stream in shadow. The model calculates stream temperatures using several components in calculating reduction in solar heat, including direct sunlight, density of vegetation, which is never greater than 80%, albedo - a reflectivity element and diffuse radiation.> Using this definition, shade was calculated by the model as the percent reduction in solar radiation (for example, from 500 ly/day to 350 ly/day is 30% shade.) The allocations could be expressed in terms of heat, as is the TMDL, but they are not, because shade can be measured more directly, for example by using a solar pathfinder or by other methods of determining if human activities are reducing shade. Thus this approach is more useful to land managers.

The load allocations for shade are expressed differently for areas of the watershed that were modeled and those that were not. Five subwatersheds in the northern portion of the watershed were modeled for both stream temperature and shade. In addition, the Hulls Creek area was modeled for shade (but not temperature). For these areas, which comprise most of the North Fork Eel River watershed, the allocations are the shade values for individual stream segments as presented in Figures 3-7 (northern subwatersheds) and 3-8 (Hulls Creek area).

This page left blank for insert of

Figure 3-7: Model estimates of percent shade
area north of Yellowjacket Creek

- Shade based on “natural potential” vegetation -

This page left blank for insert of

Figure 3-7: Model estimates of percent shade
Hulls Creek area

- Shade based on “natural potential” vegetation -

For the remainder of the watershed, the allocation is the average value for the modeled watersheds. For the North Fork Eel watershed, the potential solar radiation over each stream segment is 695.8 ly/day. The TMDL is 409 ly/day (based on the modeled subwatersheds). Thus:

load allocation (remainder of watershed) = average amount of shade for the modeled watersheds
= blocked solar radiation/potential radiation
= (695.8 ly/day - 409 ly/day)/695.8 ly/day
= 41% average shade

Implications for land management

Although the load allocations are derived from modeling "natural potential" shade from riparian vegetation, EPA expects there are several ways that land managers can determine if current practices meet water quality standards for temperature (see Chapter on implementation and monitoring recommendations.) Land managers should focus on conserving "natural potential" shade which is the key element in deriving the TMDL and allocations.

Margin of Safety

The margin of safety is included to account for uncertainties concerning the relationship between pollutant loads and instream water quality and other uncertainties in the analysis. The margin of safety can be incorporated into conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL.

EPA is incorporating an implicit margin of safety into the North Fork Eel River temperature TMDL. Table 3-3 identifies the uncertainties in the TMDL and the adjustments or assumptions that were made to account for the uncertainty to ensure that the beneficial uses will be protected.

Table 3-3. Uncertainties in North Fork Eel River Temperature TMDL

Uncertainty	Adjustment to Account for Uncertainty
Effect of implementing the sediment TMDL on stream channel widths	Implementing the sediment TMDL will result in a narrowing of stream channels, thus improving temperature conditions. This effect was not quantified, but provides an implicit margin of safety.
Effect of implementing the sediment TMDL on frequency and depth of pools	Implementing the sediment TMDL will result in more frequent and deeper pools, which can provide thermal refugia for salmonids. This effect was not quantified, but provides an implicit margin of safety.
Effect of implement the sediment TMDL on extent of riparian vegetation	Implementing the sediment TMDL will reduce the impact of floods on riparian vegetation, thus improving temperature conditions. This effect was not quantified, but provides an implicit margin of safety.
Effect of larger riparian vegetation on stream microclimates	Implementing the temperature TMDL will result in larger riparian vegetation. Larger vegetation will tend to create microclimates that will lead to improvements in stream temperatures. These effects were not accounted for in the temperature analysis, but provide an implicit margin of safety.

Effect of larger riparian vegetation on large woody debris	Implementing the temperature TMDL will result in larger riparian vegetation. Larger vegetation will increase the potential for contributions of large woody debris to streams. Increases in large woody debris benefit stream temperatures and associated cool water habitat by increasing channel complexity, including the number and depth of pools, which can provide areas of cooler water for fish. These changes were not accounted for in the analysis, but provide an implicit margin of safety.

Seasonal Variation and Critical Conditions

The TMDL must account for seasonal variation and critical conditions. In the North Fork Eel watershed, the summer period is the period when stream temperatures are most likely to have adverse impacts on beneficial uses (young salmonids growing in the streams before migrating to the ocean). To account for seasonal variations and critical conditions, the analysis is based on the MWAT (i.e., the maximum weekly average of the 7 day running average of all monitored temperatures).

CHAPTER 4: SEDIMENT TMDL

Summary

The sediment source analysis for the North Fork Eel found that approximately 30% of total sediment was related to human activity. Most of the natural and human caused sediment was from landslides on private lands. USFS lands had a much smaller rate of landslides and a smaller proportion of human caused slides. Smaller sources were also largely natural, on both public and private lands. The sediment source analysis suggests that the North Fork Eel is less disturbed by human caused sediment than other watersheds studied in the North Coast. Also, EPA concludes that based on current information, USFS lands in the North Fork Eel are already meeting TMDL limits. This implies that under current practices and current intensity of use, USFS lands will continue to meet TMDL limits.

This chapter presents information specific to the sediment TMDL for the North Fork Eel River. The first section of this chapter identifies water quality indicators, which are proposed as interpretations of the water quality standards and used to evaluate stream conditions. The second section presents the results of the sediment source analysis. The third section presents the calculation of the TMDL, which is the total loading of sediment which the North Fork Eel River and its tributaries can receive without exceeding water quality standards, and apportions the total among the sources of sediment.

4.1. WATER QUALITY INDICATORS

This section identifies water quality indicators that are more specific to the North Fork Eel River and generally more quantifiable than the water quality standards for sediment contained in the Basin Plan. They are interpretations of the water quality standards expressed in terms of instream and watershed conditions. For each indicator, a numeric or qualitative target value is identified to define the desired condition for that indicator. EPA expects that these indicators, and their associated target values, will provide a useful reference in determining the effectiveness of the TMDL in attaining water quality standards. The indicators are not directly enforceable by EPA, but the turbidity indicator is enforceable by the NCRWQCB as a water quality objective.

No single indicator adequately describes water quality related to sediment, so a suite of instream and watershed indicators is identified. Because of the inherent variability associated with stream channel conditions, and because no single indicator applies in all situations, attainment of the targets is intended to be evaluated using a weight-of-evidence approach. When considered together, the indicators are expected to provide good evidence of the condition of the stream and attainment of water quality standards.

Instream indicators reflect sediment conditions that support salmonids. They relate to instream sediment supply and are important because they are direct measures of stream "health." In addition to instream indicators, we are including watershed indicators in this TMDL because watershed indicators focus on imminent threats to water quality that can be detected and located before the sediment is actually delivered to the stream, and because watershed indicators are often easier to measure than instream indicators. These watershed indicators are established to identify conditions in the watershed needed to protect water quality. They are set at levels associated with well functioning watersheds.

Watershed indicators assist with the identification of threats to water quality for both temporal and spatial reasons. Watershed indicators reflect conditions in the watershed at the time of measurement, whereas instream indicators can take years or decades to respond to changes in the watershed, because linkages between hillslope sediment production and instream sediment delivery are complicated by time lags from production to delivery, instream storage, and transport through the system. Also, watershed indicators tend to reflect local conditions, whereas instream indicators often reflect upstream watershed conditions as well as local conditions. Thus, watershed indicators help to identify more prospectively conditions in the watershed needed to protect water quality. Both instream and watershed indicators are appropriate to use in describing attainment of water quality standards.

4.1.1 Summary of Indicators and Targets

This section describes several sediment indicators for the North Fork Eel River TMDL. Table 4.1 summarizes the indicators, targets, description and purpose.

Table 4.1. Sediment Indicators and Targets

INDICATOR	TARGET	DESCRIPTION	PURPOSE
Instream			
Spawning Gravel Quality	≤14% < 0.85 mm ≤30% < 6.4 mm;	Bulk sample during low-flow period, at riffles heads in potential spawning reaches. Discussion of indicators and targets by Kondolf (2000), Chapman (1988).	Indirect measure of fine sediment content relative to incubation and fry emergence from the redd Indirect measure of ability of salmonids to construct redds
Turbidity and Suspended Sediment	Turbidity ≤ 20% above naturally occurring background (also included in Basin Plan)	Measured upstream and downstream of sediment discharging activity or between “paired” watersheds or reference streams.	Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities
Riffle Embeddedness	≤25% or improving (decreasing) trend toward 25%	Estimated visually at riffle heads where spawning is likely, during low-flow period (Flosi et al 1998)	Indirect measure of spawning support; improved quality & size distribution of spawning gravel
V*	≤0.21 (Franciscan) or <0.10 (other)	Residual pool volume. Measure during low-flow period. (Lisle and Hilton 1992)	Estimate of sediment filling of pools from disturbance
Aquatic Insect Production	Improving trends	EPT, Richness & % Dominant Taxa indices. Methods should follow CDFG-WPCL (1996) or refined methods currently under development.	Estimate of salmonid food availability, indirect estimate of sediment quality.
Thalweg profile	Increasing variation from the mean	Measured in deposition reaches during low-flow period.	Estimate of improving habitat complexity & availability
pool/riffle distribution & depth of pools	increasing trend toward >40% in primary pools	Trend or greater than % (by length), measured low-flow period.	Estimates improving habitat availability
Watershed Indicators			
Diversion potential & stream crossing failure potential	≤1% crossings in 100 yr storm	Conduct road inventory to identify and fix stream crossing problems (Weaver and Hagans 1994). See USDA (1999) Roads Analysis for assessing road network.	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Hydrologic connectivity of roads	Decreasing length of road	Conduct road inventory to identify and fix road drainage problems (Weaver and Hagans 1994).	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse

INDICATOR	TARGET	DESCRIPTION	PURPOSE
Annual road inspection & correction	Increased mileage inspected and corrected	Roads inspected and maintained, or decommissioned or hydrologically closed prior to winter- No migration barriers.	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Road location, sidecast	Reduce density next to stream, increased % outsloped	see text	minimized sediment delivery
Activities in unstable areas	avoid and/or /eliminate	Subject to geological/geotechnical assessment to minimize delivery and/or show that no increased delivery would result	minimized sediment delivery from management activities

4.1.2 Instream Indicators

Spawning Gravel Quality: **<u>Percent Fines < 0.85 mm: #14%; Percent Fines <6.4 mm # 30%</u>**
Streambed gravels naturally consist of a range of particle sizes from finer clay and sand to coarser cobbles and boulders. Kondolf (2000) described how various gravel sizes and mixtures can influence different salmonid life stages including redd construction, egg incubation and alevin emergence. In addition, spaces between clean cobbles provide important cover for salmonid and other fry at a critical and vulnerable time in their life history. The percent fines <0.85 mm is defined as the percentage of subsurface fine material in pool tail-outs < 0.85 mm in diameter. These indicators and targets represent adequate spawning, incubation, and emergence conditions relative to substrate composition. Excess fine sediment can decrease water flow through salmon redds. Sufficient water flow is critical for maintaining adequate oxygen levels and removing metabolic wastes. Deposits of these finer sediments can also prevent the recently hatched fry from emerging from the redds, resulting in entrapment. Monitoring should be conducted by bulk sampling during low-flow periods at the heads of riffles, in potential spawning reaches. The target of #30% for particles less than 6.4mm sizes is based on literature relating size classes survival to emergence (summarized in Chapman 1988, and Kondolf 2000).

Turbidity and Suspended Sediment<u>: <20% above naturally occurring background levels</u>
Turbidity is a measure of the ability of light to shine through water (with greater turbidity indicating more material in the water blocking the light). Although turbidity levels can be elevated by both sediment and organic material, in California's North Coast stream turbidity levels tend to be highly correlated with suspended sediment. High turbidity in the stream affects fish by reducing visibility, which may result in reduced feeding and growth. The deleterious effects on Salmonids were found not only to be a function of concentration of fine particles but also a function of duration of exposure. Sigler et al (1984) found that as little as 25 NTUs of turbidity caused a reduction in fish growth. The North Coast Basin Plan presently stipulates that turbidity shall not be increased more than 20 percent above naturally occurring background levels by an individual activity. This indicator should be measured during and following winter storm flows, and upstream and downstream of a management activity to compare changes in the turbidity levels that are likely attributable to that activity. Information should include both magnitude and duration of elevated turbidity levels.

Riffle Embeddedness<u>: <25% or improving (decreasing) trend</u>
Embeddedness is a measure of fine sediment that surrounds and packs-in gravels. A heavily embedded riffle section may limit the ability of an adult female to construct a redd. When constructing its redd, generally at a pool tail-out (or the head of the riffle), the spawning fish essentially slaps its tail against the channel bottom, which lifts unembedded gravels and removes some of the fine sediment. This process

results in a pile of cleaner and more permeable gravel, which is more suited to nurturing of the eggs. Embedded gravels do not generally lift easily, which prevents spawning fish from building their redds. Flosi et al. (1998) suggest that gravels that are less than 25% embedded are preferred for spawning. This target should be estimated during the low-flow period, generally at riffle heads, in potential spawning reaches.

V* <0.21 (Franciscan geology) or <0.10 (stable geology)
V* is a measure of the fraction of a pool's volume that is filled by fine sediment, and represents the in-channel supply of mobile bedload sediment (Lisle and Hilton 1992). It reflects the quality of pool habitat, because when less of the pool is filled (a lower pool volume) it reflects deeper, cooler pools offering protection from predators, a food source, and resting location. Lisle and Hilton (1992) also describe methods for monitoring, which should be conducted in low-flow periods. V* is not appropriate for large rivers, but in large river systems it is appropriate for tributaries. The target of V* values less than .21 (Franciscan geology) is based on Knopp (1993).

Aquatic Insect Production: Improving trends in EPT, % dominant taxa and species richness indices
Benthic macroinvertebrate populations are greatly influenced by water quality and are often adversely affected by excess fine sediment. This TMDL recommends several indices be calculated, following the CDFG Water Pollution Control Laboratory Stream Bioassessment Procedures (1996), until refined indices are available.

1) EPT Index. The EPT Index is the number of species within the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), more commonly known as mayflies, stoneflies and caddisflies. These organisms require higher levels of water quality and respond rapidly to improving or degrading conditions.
2) Percent Dominant Taxa. This index is calculated by dividing the number of organisms in the most abundant taxa by the total number of organisms in the sample. Collections dominated by one taxa generally represent a disturbed ecosystem.
3) Richness Index. This is the total number of taxa represented in the sample. Higher diversity can indicate better water quality.

Thalweg Profile: Increasing variation of elevation around the mean slope
Variety and complexity in habitat is needed to support fish at different times in the year or in their life cycle. Both pools and riffles are used through spawning, incubation of eggs, and emergence of the fry. Deeper pools, overhanging banks, or logs provide cover from predators. Measuring the thalweg profile is an indicator of habitat complexity. The thalweg is the deepest part of the stream channel at a given cross section. The thalweg profile is a plot of the elevation of the thalweg as surveyed in a series of cross sections. Harrelson et al. (1994) provide a practical guide for performing thalweg profiles and cross sections. The profile appears as a jagged but descending line, relatively flat at pool areas, and descending sharply at cascades. The comparison between the mean slope (i.e., the overall trend of the descending stream) and the details of the slope is a measure of the complexity of stream habitats. More variability in the profile indicates more complexity in stream habitat. Inadequate availability of pool-forming features, such as bedrock or large wood debris, can be revealed by this indicator of channel structure. Because the change in the profile will occur relatively slowly, and because not enough is yet known about channel structure to establish a specific number that reflects a satisfactory degree of variation, the target is simply an increasing trend in variation from the mean thalweg profile slope. This indicator should be measured during the low-flow period every 5-10 years, after large storm seasons.

Pool Distribution and Depth: Increasing inventory of reaches which are >40% pools
Pools generally account for more than 40% of stream length in streams with good salmonid habitat (Flosi et al. 1998). Frequent pools are important for providing feeding stations and shelter, and may also serve locally as refugia. This indicator should be measured during the low-flow period every 5-10 years, after large storm seasons. Information should include length and depth of pools. However, in this watershed deeper pools may important as temperature refugia and should be measured. Backwater pools are used by salmonids as overwintering habitats (Flosi et al. 1998). In particular, they provide shelter from high storm flows. Lateral scour pools (i.e., pools formed near either bank) tend to be heavily used by fish for cover and refugia.

4.1.3. Watershed Indicators

Stream Crossings with Diversion Potential or Significant Failure Potential: <1% of all stream crossings divert or fail as a result of a 100-year or smaller flood

Most roads, including skid roads and railroads, cross ephemeral or perennial streams. Crossings are built to capture the stream flow and safely convey it through, under, or around the roadbed. However, stream crossings can fail, adding sediment from the crossing structure (i.e., fill) or from the road bed directly into the stream. Stream crossings with diversion potential or significant failure potential are high risks for sediment delivery to streams. Stream crossing failures are generally related to undersized, poorly placed, plugged, or partially plugged culverts. When a crossing fails, the total sediment volume delivered to the stream usually includes both the volume of road fill associated with the crossing and sediment from collateral failures such as debris torrents that scour the channel and stream banks. An important problem is water draining down the road away from the stream crossing. This can result in water creating a new channel Diversion potential is the potential for a road to divert water from its intended drainage system across or through the road fill, thereby delivering road-related sediment to a watercourse. The potential to deliver sediment to the stream can be eliminated from almost all stream crossings by eliminating inboard ditches, outsloping roads, or installing rolling dips (US EPA 1998). Less than 1% of stream crossings have conditions where modification is inappropriate because it would endanger travelers or where modification is impractical because of physical constraints.

Hydrologic Connectivity: Decreasing length

A road is hydrologically connected to a stream when the road drains water directly to the stream. A hydrologically connected road increases the intensity, frequency, and magnitude of flood flows and suspended sediment loads in the adjacent stream, which can result in destabilization of the stream channel. This can have a devastating effect on salmonid redds and growing embryos (Lisle 1989). The connectivity can be reduced by outsloping roads, creating road drainage that mimics natural drainage as much as possible, and other factors (USDA 1999, Weaver and Hagans 1994).

The reduction of road densities and the reconstruction of roads to reduce the use of inboard ditches, for example, can reduce the amount of water that is directly delivered to watercourses, including any associated sediment load. McFadin (updated) found that 38% of the road length in the Six Rivers National Forest land in the North Fork Eel was estimated to be hydrologically connected. Current research appears insufficient to identify a specific target, so this TMDL calls for a reduction in the hydrologic connectivity of roads to watercourses.

Annual Road Inspection and Correction: Decreasing road length next to streams, increasing proportion outsloped or hard surfaced roads
EPA's analysis indicates that in watersheds with road networks that have not experienced excessive road-related sedimentation, roads are either (1) regularly inspected and maintained; (2) hydrologically maintenance free (i.e., they do not alter the natural hydrology of the stream); or (3) decommissioned or hydrologically closed (i.e., fills and culverts have been removed and the natural hydrology of the hillslope has largely been restored). If not, they are potentially large sources of sediment (D. Hagans, pers. comm., 1998, in EPA 1998). In general, road inspection should be undertaken annually, and could in most cases be accomplished with a windshield survey. The areas with the greatest potential for sediment delivery should be corrected prior to the onset of winter conditions. This target calls for an increase in the proportion of roads that are either (1) inspected annually and maintained prior to winter, (2) hydrologically maintenance free, or (3) decommissioned or hydrologically closed, until all roads in the North Fork Eel River watershed fall into one of these categories.

Road Location and Sidecast: Prevent sediment delivery
This indicator is intended to address the highest risk sediment delivery from roads not covered in other indicators. Roads located in inner gorges and headwall areas are more likely to fail than roads located in other topographic locations. Other than ephemeral watercourses, roads should be removed from inner gorge and potentially unstable headwall areas, except where alternative road locations are unavailable and the road is clearly needed. Sidecast on steep slopes can trigger earth movements, potentially resulting in sediment delivery to watercourses. These factors reflect the highest risk of sediment delivery from roads, and should be the highest priorities for correction (C. Cook, M. Furniss, M. Madej, R. Klein, G. Bundros, pers. comm., 1998, in EPA 1998).

This target calls for: (1) all roads alongside inner gorge areas or in potentially unstable headwall areas are removed unless alternative road locations are unavailable and the need for the road is clearly justified; and (2) sidecast or fill on steep (i.e., greater than 50%) or potentially unstable slopes, that could delivery sediment to a watercourse, are pulled back or stabilized.

Activity in Unstable Areas: Target: avoid or eliminate, unless detailed geologic assessment by a certified engineering geologist concludes there is no additional potential for increased sediment loading

Unstable areas are those areas that have a high risk of landsliding, including steep slopes, inner gorges, headwall swales, stream banks, existing landslides, and other locations identified in the field. Any activity that might trigger a landslide in these areas (e.g., road building, harvesting, yarding, terracing for vineyards) should be avoided, unless a detailed geologic assessment by a certified engineering geologist concludes there is no additional potential for increased sediment loading. An analysis of chronic landsliding in the Noyo River basin indicated that landslides observed on aerial photographs largely coincide with predicted chronic risk areas, including steep slopes, inner gorges and headwall swales (Dietrich et al. 1998). Several other studies have shown that landslides are larger or more common in some harvest areas, particularly in inner gorges (US EPA 2000). Weaver and Hagans (1994) also suggest methods for eliminating or decreasing the potential for road-related sediment delivery.

4.2. SEDIMENT SOURCE ANALYSIS

This section summarizes the results of the sediment source analysis, the purpose of which is to identify the various sediment delivery processes and sources in the watershed and to estimate the relative amount of sediment delivered to streams from those sources. Appendix B contains more information from the sediment source analysis. Of particular interest, is characterizing whether or not sediment is natural or related to human activity.

The sediment source analysis combined information from three studies to generate estimates of sediment in the North Fork Eel. The information from these studies is combined (i.e. summed, with considerations for weighted averages) to generate the overall estimate of sediment in the entire North Fork Eel. The three studies are as follows:

(1) Northern basin landslide analysis by Six Rivers National Forest;
(2) Southern basin landslide analysis by Pacific Watershed Associates (PWA);
(3) Entire basin, smaller sediment sources by PWA.

The first two studies are photo analyses, the third is based on field work. The photo analyses provide a full inventory of the entire basin for larger features - they are often called landslide analyses although large gullies can also be seen. The field study's purpose is to measure smaller erosional and sediment delivery features, such as culvert failures, gullies and road fill failures that are impossible to see on air photos. Each of the three pieces of information is described, followed by a presentation on the combined information for the entire watershed.

Northern basin - Landslide analysis by Six Rivers National Forest

This study looked at the area north of the Six Rivers National Forest boundary (at Wilburn Ranch.) This includes USFS lands and nearby private lands. The air photo study conducted by Six Rivers National Forest (see appendix B) mapped and quantified visible features of erosion on air photos through time. Photos from 1944, 1960, 1975, 1990 and 1998 were viewed. Some features were observed in the field to assist the photo interpretation. Dresser provides information on total sediment delivered over time, erosional processes, number of landslides and management/natural influence in the portion of the watershed managed by the Six Rivers National Forest and some private lands near Forest Service land in the northern part of the watershed (see Table 4-2 below). Dresser also subdivided the analysis into features > 5000 cubic yards, in order to facilitate comparisons and aggregation with the PWA analyses.

Table 4-2: Northern basin only - Landslides and large gullies in the Six Rivers National Forest and nearby private lands
North Fork Eel, by land use association
- all visible features -

Source	1944-1960		1960-1975		1975-1990		1990-1998	
	Tons	% (of tons)	Tons	% (of tons)	Tons	% (of tons)	Tons	% (of tons)
None	254,456	*90%*	662,369	*80%*	54,610	*94%*	68,501	*97%*
Road	27,793	*10%*	55,016	*7%*	524	*1%*	2,203	*3%*
Harvest	2,662	*1%*	18,445	*2%*	3,132	*5%*	0	*0%*
Cumulative	0	*0%*	18,241	*2%*	0	*0%*	0	*0%*
Road/Harvest	0	*0%*	76,225	*9%*	0	*0%*	0	*0%*
Total	284,911	*100%*	830,296	*100%*	58,266	*100%*	70,704	*100%*

Total Sediment 1944 - 1998 average

Source	Total Sediment - 1944-1998 average	
	Tons	% (of tons)
None	1,039,936	84%
Road	85,536	7%
Harvest	24,239	2%
Cumulative	18,241	1%
Road/Harvest	76,225	6%
Total	1,244,177	100%

Note: These numbers represent all features visible on aerial photographs. A subset of this analysis (features >5000 cu.yds) was used to calculate total sediment in the watershed by combining these estimates with estimates from the Southern basin/landslides study by PWA and estimates of small features for the entire basin also by PWA.
- cumulative refers to sediment delivery from indirect upstream/upslope management.
- road/harvest refers to sediment from a combination of roads and timber harvest

These tables indicate that during the time period of 1944-1998, 84% of sediment delivered to streams from landslides (in the Northern portion of the basin) was natural. During the more recent 1975-1998 period, which represents a period of lower intensity storms and better land management practices, 94 - 97% of sediment from landslides in the Northern part of the North Fork Eel was natural.

Dresser also provided EPA with additional analysis of landslides on Six Rivers lands only, to assist in determining sediment production on USFS Six Rivers lands only (a subset of the Northern basin landslide study in Table 4-2., see appendix B, Table 19.) The analysis showed the only significant difference was in the 1990 - 1998 period. In the most recent period, only 3 landslides (with only 1 > 5000 cu.yds) occurred on USFS lands and 100% of these landslides were attributed to natural causes.

Southern basin - Landslide analysis by PWA

The PWA air photo analysis mapped and estimated major sediment sources (> 5000 cubic yards) for the southern portion of the watershed, south of the USFS boundary (see appendix B.) The area viewed are mainly private lands with some lands managed by the BLM. Table 4-3 below shows the results of the study.

Table 4-3: Southern basin only - Landslides

Sediment yield (in yds^3/mi^2/year, $tons/mi^2$/year and %) by ownership and primary land use association, southern part of North Fork Eel River watershed: Landslides and other large features > 5000yd3 features from aerial photographs

Domain (Private and Public)[2] (mi^2)		No land use association	Road Related	Harvest	Cumulative offsite[2]	Total sediment yield
Private	$yds^3/mi^2/yr$	248	93	258	21	619
	$tons/mi^2/yr$	382	143	397	32	953
	%	40	15	42	3	100
Public	$yds^3/mi^2/yr$	1,610	57	383	0	2,050
	$tons/mi^2/yr$	2,479	88	590	0	3,157
	%	78	3	19	0	100
TOTAL for southern part of watershed	**$yds^3/mi^2/yr$**	**456**	**88**	**277**	**17**	**838**
	$tons/mi^2/yr$	**702**	**135**	**426**	**27**	**1,290**
	%	**54**	**11**	**33**	**2**	**100**

[2] The Cumulative Offsite land use category was collected for PWA >5,000 yds^3 features only.
[3] All >5,000yds^3 air photo identified features were assigned Public/Private ownership designations based on GIS and location of landslide.

Note that the Southern part of the watershed produces more sediment, and a larger proportion of landslides are associated with human activity than in the Northern part of the watershed. PWA found that this was true of both public and private lands in the southern part of the watershed (the public lands are primarily BLM lands)(see appendix B.) In addition, PWA also found that public lands (which are primarily BLM lands) have a smaller proportion of human-caused sediment from landslides compared to private lands (78% natural sediment for public lands compared to 40% natural sediment for private lands.)

Small features analysis - entire basin (PWA)

With cooperation of the Six Rivers National Forest and private landowners in the North Fork Eel, PWA measured small erosional features (< 5000 yd3) on 43 randomly chosen locations and then extrapolated these numbers to total sediment delivery from smaller sources of erosion and sediment in the entire watershed. The methodology, developed for the Van Duzen TMDL (PWA, 1999) first puts a grid on a map of the watershed, thus dividing the watershed into "plots". A sample of plots to be measured in the field is selected randomly by geology. Thus these plots are meant to be representative of general characteristics of the watershed. The measured sediment delivered to streams was then extrapolated to the entire North Fork Eel, based on geology.

The results of the field study, after the extrapolation to the entire watershed (Table 4-4) shows that most (82%) of the sediment delivered to streams in the North Fork Eel from smaller sources had no land use association and is considered natural. This could be the result of better road and harvest practices by landowners, a low road density, a smaller percentage of acres harvested or likely a combination of factors.

Table 4.4: Small sediment features - entire basin

Sediment yield (tons/mi^2/year and %) for <5,000 yds^3 plot features by primary land use association for the period of 1960 to 2000, North Fork Eel River watershed (from PWA field study)

	tons/mi^2/yr	%
No Land Use Association	**455**	**82%**
Road Related	**46**	**8%**
Tractor Harvest	**40**	**7%**
Cable Harvest	**1**	**1%**
Agriculture/Grazing	**12**	**2%**
Totals	**554**	**100%**

PWA also divided the analysis into public v private lands for small features. Unlike the landslide analysis, these calculations include USFS lands in the North Fork Eel. Public lands showed a larger percent of natural sediment (87%) compared to private (81%); this difference may be within the range of error for these types of studies. See Appendix B - Table 7 for more details.

Summary of sediment from USFS lands

The USFS lands in the northern part of the basin were estimated to have fewer landslides and a smaller proportion of human caused landslides than the southern part of the basin. The southern part of the basin also includes public lands, but these are managed by the BLM. For example, in the most recent period, only 3 (with only 1 > 5000 cu.yds) landslides occurred on USFS lands and 100% of these landslides were attributed to natural causes. This is in comparison to 36 landslides in the same period found by PWA in the Southern part of the basin in the same time period. Approximately 90% of sediment on USFS lands from landslides was estimated to be natural (see appendix B, Table 19.) Sediment from small sources on public lands are an additional component of sediment from USFS lands. Sediment from small sources was estimated to be 87% from natural causes.

Combined Sediment Source Analysis Results

The three studies described above - Northern basin, landslides + Southern basin, landslides + Entire basin , smaller features - were combined to generate estimates of total sediment delivery from all sources in the North Fork Eel. A basin wide estimate for sediment delivery from larger sources was obtained by combining the results of the two air photo analyses, after adjusting the Six Rivers analysis to features greater than 5000 cu. yds to avoid double-counting. The sediment source analysis was completed by adding the results from the study of smaller features. The results are presented in Table 4-5.

Table 4-5 . Entire basin (North + South); Landslides + small sources: Results of Sediment Source Analysis

SEDIMENT SOURCE	UNIT AREA SEDIMENT INPUT (tons/mi^2/yr)	PERCENTAGE OF TOTAL
NATURAL SEDIMENT SOURCES		
- Natural: Landslides - average entire basin (from PWA & USFS studies of North and South basins) for > 5000 cu.yd features	375	30%
- Natural: Smaller features	455	37%
TOTAL NATURAL	830	68%
Human (Land Management) Related Sources		
- TOTAL Human related Landslides > 5000 yd3 (from PWA& USFS aerial photo studies) includes both road and harvest related	300	24%
- Agriculture/Grazing (all ownerships)	12	1%
- Roads (smaller features - all ownerships)	46	4%
- Tractor Harvest (smaller features - all ownerships)	40	3%
- Cable Harvest (smaller features - all ownerships)	1	0%
TOTAL HUMAN RELATED	399	32%
TOTAL ALL CAUSES	1,229	100%

Approximately 32% of sediment was found to be associated with human activity. Of the human caused sediment, the majority was from large landslides. These landslides are related to both roads and timber harvest. The results indicate that approximately one third of sediment is from human related sources. This can be generally compared with watersheds which have been studied (Strauss, personal communication) where from 43% - 70% was attributed to land management. Thus the North Fork Eel watershed is less disturbed from human caused sediment than many other North Coast watersheds.

4.3. TMDL AND ALLOCATIONS

4.3.1. TMDL

This TMDL is set equal to the loading capacity of the North Fork Eel River. It is the estimate of the total amount of sediment, from both natural and human-caused sources, that can be delivered to streams in the North Fork Eel River watershed without exceeding applicable water quality standards. The TMDL is set equal to 125% of natural sediment delivery, as described below. This means that the if the watershed as a whole produces no more than 125% of the natural loading (i.e. natural rate x 1.25) from both natural and human causes it will meet the “loading capacity” and should not exceed applicable water quality standards for sediment on average.

The 125% has been derived from previous TMDL studies for the North Coast of California for sediment. For North Coast sediment TMDLs, EPA has used three approaches for deriving the loading capacity: (1) a comparison with a reference time period; (2) a comparison with a reference stream; and (3) the estimated needed improvement from existing loading rates, based on a comparison between current and target instream conditions. The approach used in a particular TMDL depends on the availability of data and the characteristics of the specific watershed. For the North Fork Eel River TMDL, EPA is using a combination and modification of the first two approaches, based on the results of TMDL analyses in other North Coast watersheds.

EPA used a reference time period to calculate the TMDL for the Noyo River. The TMDL for the Noyo River was set at the estimated sediment delivery rate for the 1940's, a period when salmonid populations were substantial in the Noyo River (NCRWQCB, 1999). The analysis of sediment sources during this period (which was assumed to be a quiescent period between the logging of old growth at the turn-of-the-century and logging of second growth in the middle of the 20th century) indicated that there was about one part human-induced sediment delivery for every four parts natural sediment delivery.

EPA used reference streams to calculate TMDLs for subwatersheds of the Trinity River. The reference watersheds with very little management-related sediment (due, in part, to the fact that most of the lands in these watersheds are designated Wilderness and have not been actively managed in the recent past) were excluded, and the remaining reference watersheds had sediment delivery rates that clustered around a ratio of one part human-induced sediment delivery for every four parts natural sediment delivery. This relationship formed the basis for calculation of TMDLs for subwatersheds in the Trinity basin.

Thus, in both cases, the TMDLs were set at a level equivalent to one part of human-caused sediment delivery for every four parts of natural sediment delivery (i.e., a 1:4 ratio). This can be expressed as either 125% of natural sediment, 1 part human caused to 4 parts natural sediment or 20 % human caused sediment and 80% natural sediment - as these are mathematically the same amount. Based on the reference period or reference streams, we concluded that these streams could increase sediment delivery by 25% over that natural amount and still support salmon habitat.

The ratio approach has several potential advantages. Stillwater Sciences (1999) indicates that looking at the ratio of human to natural sediment sources can detect the effects of land use changes better than an average annual sediment loading alone, because the ratio may vary with hydrology less than the annual sediment load. The ratio could be measured periodically and provide an indication of progress toward meeting sediment reduction goals. The ratio may also be less dependant upon spatial and hydrologic variability.

Based on the findings in the Noyo and Trinity River TMDLs, and the potential advantages of the ratio approach, EPA is using the ratio method to set the TMDL for the North Fork Eel River. A 1:4 ratio is equivalent to saying that total sediment delivery cannot be more than 125% of natural sediment delivery (or that natural sediment delivery should be at least 80% of total sediment delivery.) Using the estimated natural sediment delivery rate of 830 tons/mi2/yr , the TMDL for the North Fork Eel River is:

TMDL = Loading capacity = (125%) x (830 tons/mi2/year) = 1038 tons/mi2/year

The approach taken focuses on sediment delivery, rather than a more direct measure of salmonid habitat (i.e. instream conditions.) Sediment delivery can be subject to direct management by landowners (for example, roads can be well maintained), whereas instream conditions (pool depth, percent fines) are subject to upstream management that may not be under the control of local landowners. While it would be desirable to be able to mathematically model the relationship between salmon habitat and sediment delivery, these tools are not available for watersheds with landslides and road failure hazards. Sediment movement is complex both spatially and temporally. Sediment found in some downstream locations can be the result of sediment sources far upstream, instream sedimentation can also be the result of land management from decades past. Nevertheless, management activities can clearly increase sediment delivery and instream habitat can be adversely affected by increased sediment inputs. Therefore, it is reasonable to link increases in sediment delivery to decreased stream habitat quality.

The approach also implies that salmon populations can be self-sustaining even with the yearly variation of natural rates of erosion observed in the 20th century. Although the sediment delivered to the streams varied, salmon adjusted to the natural variability by using the habitat complexity created by the stream's adjustments to the naturally varying sediment loads. In addition, we are assuming that the natural amount of sediment can be increased to some extent and not adversely affect fish. We postulate this because there was human caused sediment throughout the North Coast when fish populations were thriving, including ranching, the tanbark industry and some logging.

4.3.2. Allocations

In accordance with EPA regulations, the loading capacity (i.e. TMDL) is allocated to the various sources of sediment in the watershed, with a margin of safety. That is:

TMDL = sum of "wasteload allocations" for individual point sources,
+ sum of the "load allocations" for nonpoint sources, and
+ sum of the "load allocations" for background sources

The margin of safety in this TMDL is not added as a separate component of the TMDL, but rather is incorporated into conservative assumptions used to develop the TMDL, as discussed in Section 4.3.3. As there are no point sources of sediment in the North Fork Eel River watershed, the wasteload allocation for point sources is set at zero.

In addition to ensuring that the sum of the load allocations equals the TMDL, EPA considered several factors related to the feasibility and practicability of controlling the various nonpoint sources of sediment. Most of the reduction needed comes from land slides. The PWA analysis shows that this is due to both roads and association with harvesting. In general, many cost-effective techniques exist to reduce sediment risk from roads. Risk from landslides during harvest can be reduced by avoiding certain silvicultural techniques on steep slopes. No changes in current grazing is needed under this proposal, due to the small contribution to sediment in the watershed.

The load allocations for the North Fork Eel River TMDL are presented in Table 4-6**.** The allocations clarify the relative emphasis and magnitude of erosion control programs that need to be developed during implementation The load allocations are expressed in terms of yearly averages (tons/mi^2/yr). They could be divided by 365 to derive daily loading rates (tons/mi^2/day), but EPA is expressing them as yearly averages, because sediment delivery to streams is naturally highly variable on a daily basis. In fact, EPA expects the load allocations to be evaluated on a ten-year rolling average basis, because of the natural variability in sediment delivery rates. In addition, EPA does not expect each square mile within a particular source category to necessarily meet the load allocation; rather, EPA expects the average for the entire source category to meet the load allocation for that category

Table 4-6. LOAD ALLOCATIONS
Tons/mi2/year averaged over entire basin (all lands, public and private)

SEDIMENT SOURCE	**Load Allocation**	**Current loading**	**Percent reduction**
Natural Sediment Sources:	375	375	none
- Smaller features	455	455	none
TOTAL NATURAL	830	830	none
Human related sources (land management related)			
- Basin total Landslides > 5000 yd3; includes both roads and harvest related	156	300	48%
- Agriculture/Grazing	12	12	none
- Roads (smaller features)	20	46	57%
- Tractor Harvest (smaller features)	20	40	50%
- Cable Harvest (smaller features)	1	1	none
TOTAL HUMAN CAUSED	209	399	47%
TOTAL ALL CAUSES	**1,038**	**1,229**	**16%**

USFS lands meet allocations

Our analysis of the data available at this time indicates that these allocations are already being achieved on USFS lands. Whereas this TMDL allows 20% of the total sediment delivery to be human-related, our data indicates that on USFS lands, only 10% of the sediment delivery from landslides is related to human activity (Appendix B, Table 19), and only approximately 13% of the sediment delivery related to small features on public lands is related to human activity (see Appendix B, Table 7.) This suggests that no changes in current management are needed on USFS lands.

EPA considered setting separate, lower allocations for USFS lands. This would be appropriate to reflect the more stable geology in the northern part of the watershed, where the USFS lands are located. It would also reflect feasible land practices, since the USFS has already demonstrated the ability to manage land with lower sediment delivery than is provided for in this TMDL. Another possibility would be to set lower allocations for the northern portion of the basin in general.

At this time, however, EPA is retaining the basin-wide average allocations because we have concluded that that approach is the most appropriate and feasible given the limitations of current data. The primary concern was how to set allocations for private lands nearby USFS lands. There is no separate analysis of these lands. EPA did not want to make assumptions regarding the inherent landsliding rates or current land management practices on these lands.

In addition, EPA's calculations imply that the watershed as a whole could meet TMDL limits without changing current grazing practices or cable harvest. This also means, however, the intensity of land use needs to stay stable. Intensity of land use means the amount of acres harvested or the amount of acres grazed and/or how often harvesting or grazing takes place.

4.3.3. Margin of Safety

The margin of safety is included in a TMDL to account for uncertainties concerning the relationship between pollutant loads and instream water quality and other uncertainties in the analysis. The margin of safety can be incorporated into conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL.

EPA is incorporating an implicit margin of safety into the North Fork Eel River TMDLs. Table 4-7 identifies the uncertainties in the TMDL and the adjustments or assumptions that were made to account for the uncertainty to ensure that the beneficial uses will be protected.

Table 4-7. Uncertainties in North Fork Eel River Sediment TMDL

Uncertainty	Adjustment to Account for Uncertainly
Interpretation of the amount of sediment delivery associated with management activities versus natural background sources.	The USFS and PWA generally attributed most or all of the sediment load of any landslide occurring within a recent harvest unit as being harvest or road related. This is a conservative assumption because some slides may have occurred naturally even if the land had not been harvested recently.

Instream habitat and watershed condition data were not available for the entire North Fork Eel River Basin	In areas where water quality or watershed condition data were lacking, EPA generally assumed that conditions were not meeting water quality standards. EPA encourages further watershed monitoring to fill data gaps.
There is inherent variability in the spatial scales and physical watershed conditions (terrain, channel type, slope, vegetation, etc.) of sediment delivery from the hillslope to the channel.	EPA does not expect each square mile within a particular source category to necessarily meet the allocation; rather, EPA expects the average for the entire source category to meet the allocation across the subarea for that category.
There is inherent annual and seasonal variation in the delivery of sediment to the stream channel from the source mechanisms.	The allocations are expressed as 10-year rolling averages to account for variability in delivery rates. The TMDL also includes watershed indicators to reflect sediment delivery risks.

4.3.4. Seasonal Variation and Critical Conditions

The TMDL must describe how seasonal variations were considered. Sediment delivery in the North Fork Eel River watershed inherently has considerable annual and seasonal variability. The magnitudes, timing, duration, and frequencies of sediment delivery fluctuate naturally depending on intra- and inter-annual storm patterns. Since the storm events and mechanisms of sediment delivery are largely unpredictable year to year, the TMDL and load allocations are designed to apply to the sources of sediment, not the movement of sediment a across the landscape, and to be evaluated on a ten-year rolling average basis. EPA assumes that by controlling the sources to the extent specified in the load allocations, sediment delivery will occur within an acceptable range for supporting aquatic habitat, regardless of the variability of storm events.

The TMDL must also account for critical conditions for stream flow, loading, and water quality parameters. Rather than explicitly estimating critical flow conditions, this TMDL uses indicators which reflect net long term effects of sediment loading and transport for two reasons. First, sediment impacts may occur long after sediment is discharged, often at locations far downstream of the sediment source. Second, it is impractical to accurately measure sediment loading and transport, and the resulting short term effects, during the high magnitude flow events that produce most sediment loading and channel modifications.

CHAPTER 5: IMPLEMENTATION AND MONITORING MEASURES

The main responsibility for water quality management and monitoring resides with the State. EPA fully expects the State to develop and submit implementation measures to EPA as part of revisions to the State water quality management plan, as provided by EPA regulations at 40 C.F.R. Sec. 130.6.

The State implementation measures should contain provisions for ensuring that the load allocations in the TMDL will in fact be achieved. These provisions may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs, including the State's recently upgraded nonpoint source control program.

Regarding sediment, EPA specifically recommends that more instream information be gathered on tributaries on USFS lands and all streams on private lands throughout the basin. EPA also suggests that the State consider using the information developed from the sediment source analysis in setting priorities for any new sediment reduction programs in the watershed. Specifically, given that the USFS lands in the North Fork Eel were estimated to meet load allocations, and, it appears that sediment loading on USFS lands is largely due to natural causes, the State might consider both voluntary and flexible implementation measures for these lands. EPA's analysis indicates that no changes in current management appear to be needed on USFS lands on a watershed wide basis. However, EPA emphasizes that USFS lands will only continue to meet sediment limits if future management practices and the intensity of management are not changed from the recent past. In addition, the State may wish to consider under what criteria delisting of USFS lands in the North Fork Eel can take place and work cooperatively with USFS experts on a monitoring plan.   A monitoring plan should take into account number of samples, location of samples, sampling strategy and cost-effectiveness.

Regarding temperature, EPA recommends that implementation programs for temperature be developed using site specific information on protection of "natural potential" shade.   The data, analysis and model used for the TMDL provide justification for the protection of "natural potential" shade, as well as the required TMDL loading capacity and allocations calculations. But actual protection of "natural potential" shade should be determined, not by modeled levels, but by either field review or an analysis of ownership wide management of the riparian zone.

USFS current standards and guides under the Northwest Forest Plan currently protect riparian areas from timber harvest. In this case, EPA does not believe it is necessary to prove on a site specific basis that natural shade is protected. The State, in cooperation with the USFS, should consider some type of further review of the standards and guides and their implementation in regard to natural shade.   EPA believes that this information will likely save the State significant resources, if the USFS standards and guides protect natural shade, because no new implementation programs may be needed for temperature. USFS grazing permits are currently undergoing an extensive review in the North Fork Eel.

In addition, an implementation and monitoring strategy should include a public participation process and appropriate recognition of other relevant watershed management processes, such as local source water protection programs, State programs under Section 319 of the Clean Water Act, or State continuing planning activities under Section 303(e) of the Clean Water Act.

EPA encourages the State and landowners to work together to fully develop an implementation and monitoring strategy that is appropriate for a watershed with a lower human caused disturbance than other watersheds.

CHAPTER 6: PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 C.F.R. 130.7). EPA provided public notice of the draft North Fork Eel River temperature and sediment TMDLs by placing a notice in the Willits News and Santa Rosa Press Democrat of general circulation in Mendocino and Trinity County. In addition, EPA sent a notice to those on the mailing list of the Upper Eel watershed forum. EPA prepared a written response to all written comments on the draft TMDLs received by EPA through the close of the comment period - October 28, 1998.

In addition, an informal meeting to discuss the draft TMDL was held on September 18, 2002 in Covelo. If readers have further questions or need clarification on the TMDL, please contact:

Palma Risler at the U.S. Environmental Protection Agency
415/972-3451
risler.palma@epa.gov

References

Berman, C. Berman, C. 1998. Oregon Temperature Standard Review. U.S. EPA, Region 10. Seattle, WA.

California Department of Fish and Game, 1995 & 1996. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Reports.

California Department of Fish and Game, March 1972. Water temperature Observations in the Eel River System 1957-1969.

CDFG-Water Pollution Control Laboratory. 1996. California stream bioassessment procedure. Rancho Cordova, CA.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society. Volume 117, No. 1.

Dietrich, W.E., R. Asua, Coyle, J. Orr, B., Trso, M. 1998 A Validation Study of the SHALSTAB model in forested lands in Northern California; prepared for the Louisiana Pacific Corporation, Calpalla, CA. June 29, 1998.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. USDA Forest Service, General Technical Report RM-245.

Humboldt County Resource Conservation District. May 1998. Eel River Water Quality Monitoring Project: Final Report. Fields Landing, CA.

Flosi, Gary, S. Downier, J. Hopelain, M. Bird, R. Coey and B. Collins. 1998. California salmonid stream habitat restoration manual, third edition. California Department of Fish and Game. Inland Fisheries Division. Sacramento, CA.

Knopp, Chris. 1993. Testing indices of cold water fish habitat. North Coast Regional Water Quality Control Board and California Department of Forestry, Santa Rosa. CA.

Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American fisheries Society 129:262-281.

Keter, Thomas J., April 1992. "The Effects of Historic Land-use Activities on the streams and aquatic Resources of the North Fork of the Eel River", Paper presented to the Society for California Archaeology. Six Rivers National Forest, Eureka, CA.

Keter, Thomas J., 1993. "Territorial and Social Relationships of the Inland Southern Athabascans: Some New Perspectives" Center for Archaeological Research at Davis. Publication No. 11

Keter, Thomas J., 1997. "Growing the Forest Backwards: Virtual Prehistory on the North Fork of the Eel River", Paper presented to the Society for California Archaeology, March 27, 1997, Eureka, California

Lisle, Thomas E. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. Water Resources Research. Vol. 25., no. 6. Pp. 1303-1319. June.

Lisle, T.E. and S. Hilton. 1992. The volume of fine sediment in pools: an index of sediment supply in gravelbed streams. Water Res. Bulletin. 28:2. Paper No. 981120. April 1992.

Louisiana-Pacific Corporation. July 1995. WWAA Reports: Sustained Yield Plan for Interior Mendocino County.

Louisiana-Pacific Corporation. 1996. Aquatic Species Surveys.

McFadin, B. (undated). Hydrologic Connection of Roads and Streams in the North Fork Eel River Watershed. Six Rivers National Forest Watershed Analysis Center. Eureka, CA.

Nielsen, J., Lisle, T. (1994) "Thermally Stratified Pools and their use by Steelhead in Northern California Streams" Transactions of the American Fisheries Society 123:613- 626

Oregon Department of Environmental Quality. June 1995. 1992 - 1994 Temperature Water Quality Standards Review

Scriven, J. 2002. North Fork Eel River Spring Snorkle Survey, Report to USDOI BLM. June 11, 2002.

Spence, B.C. et al. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp. Corvalis, OR.

Stillwater Sciences, 1999. "Numeric indicators analysis: recommendations on indicators and targets, South Fork Eel TMDL." prepared for Tetra Tech, Inc. Fairfax, VA.

Tappel, P.D. and T.C. Bjornn (1983. A new method of relating size of spawning gravel to salmonid embryo survival. North American Journal of Fisheries Management 3: 123-135.

Regional Water Board (North Coast Regional Water Quality Control Board). 1996. Water quality control plan for the North Coast Region. Adopted May 23, 1996. Santa Rosa. CA.

Sigler, J.W., T.C. Bjornn and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113:142-150.

Tappel, P.D. and T.C. Bjornn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. Idaho Cooperative Fishery Research Unit. North American Journal of Fisheries Management 2:123-135.

US Environmental Protection Agency, Region 10. Technical Synthesis Scientific Issues Relating to Temperature Criteria for Salmon, Trout and Char native to the Pacific Northwest. EPA 910-R-01-007. August 2001

Issue Paper 5. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids. EPA-910-01-005. May 2001

US EPA. 1998. South Fork Trinity river and Hayfork Creek sediment total maximum daily loads. Region IX Water Division. San Francisco, CA. December 1998.

US EPA. 1999. Noyo River TMDL for Sediment. San Francisco, CA.
Washington State Department of Ecology. December 2000. Evaluating Standards for Protecting Aquatic

Life in Washington's Surface Water Quality Standards Temperature Criteria. 00-10-070

Watershed Sciences. 2002. Preliminary Report, Aerial Survey of the North Fork Eel River Thermal Infrared and Color Videography. Corvallis, OR.

USFS. 1999. Roads Analysis: Informing Decisions about managing the National Forest Transportation System. Misc. Rep. FS-643. Washington, D.C.: U.S. Dept. of Agriculture Forest Service. 222 p.

United States Department of Agriculture, Forest Service. June 1996. North Fork Eel River Watershed Analysis, Version 1.0. Arcata, California.

United States Department of Agriculture, Forest Service. 1996. A Field Guide to the Tanoak and the Douglas-fir Plant Associations in Northwestern California. R5-ECOL-TP-009. Six Rivers National Forest, Eureka, CA.

United States Department of Agriculture, Forest Service. September 1995. Keter, T. Environmental History and Cultural Ecology of the North Fork Eel River Basin, California. USDA, Forest Service. R5-EM-TP-002.

United States Department of Agriculture, Forest Service. 2002. Draft Version 1.0, North Fork Eel River Mainstem Survey Report & Photo Log. Six Rivers National Forest, Arcata, CA.

Weaver, W.E. and D.K. Hagans. 1994. Handbook for forest and ranch roads: a guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads. Prepared for the Mendocino County Resource Conservation District, Ukiah, CA, in cooperation with the California Department of Forestry and Fire Protection and the USDA Soil Conservation Service.

.