U.S. Environmental Protection Agency
Region IX

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

Approved by:

original signed by	*16 December 1999*
Alexis Strauss Director, Water Division	Date

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Introduction

These TMDLs (Total Maximum Daily Loads) are water quality attainment plans for the sediment and temperature problems of the South Fork Eel River in Northern California. The TMDLs are established at levels that will meet State water quality standards for sediment and temperature, including protection of beneficial uses for native cold water fish populations. Increased sediment and summer temperatures are detrimental to native cold water fish, such as coho and chinook salmon, and steelhead. There are two complementary objectives for the report. First, the report meets legally required deadlines to identify levels of pollution control necessary to meet water quality standards. Second, the report provides the State of California's Regional Water Quality Control Board (Regional Board) with information needed to develop and implement programs to address temperature and sediment problems.

A TMDL (Total Maximum Daily Load) analysis is required by the Federal Clean Water Act, Section 303(d) because the South Fork Eel is listed as "water quality limited" due to sediment and temperature by the State of California. Under a schedule established in conjunction with a consent decree (Pacific Coast Federation of Fisherman's Association, et. al v. Marcus), the TMDL analysis for the South Fork Eel River must be approved or established by December 31, 1999. This TMDL for the South Fork Eel is the first step of a two-step process with the federal EPA establishing the TMDL and the State of California establishing the implementation plan.

These TMDLs do not include implementation and monitoring plans. EPA expects the State of California to develop an implementation strategy which will result in implementation of the TMDL pursuant to the requirements of 40 CFR 130.6.

These TMDLs for the South Fork Eel River are the first step of the following two-step process:

1) Establishment of TMDLs by U.S. EPA, and;

2) Implementation plan by the State of California 's North Coast Regional Water Quality Control Board and SWRCB.

The report is in four sections. Section One contains a Problem Statement which summarizes the environmental issues, provides a basin description, and provides an overview of the legal and regulatory context. Section Two is the TMDL for temperature. Section Three is the TMDL for sediment. Section Four describes public participation in development of the TMDLs. Appendix A is the model documentation for the Stillwater Sciences Temperature model for temperature. Appendix B is the executive summary of the sediment source analysis for the South Fork Eel.

Problem Statement

The South Fork of the Eel River is an important salmon and steelhead spawning and rearing area. The major water quality problem, and the one addressed in this report, is the decline of cold water fish populations. While many factors are involved in the decline of the coastal salmon and steelhead populations, we are concerned here with two inland water quality considerations - excessive sediment and increased water temperature. Not only is the fisheries' decline a significant economic and cultural loss for the region, but environmental laws are triggered when environmental degradation occurs. Under the federal Clean Water Act (Section 303(d)) in 1998 the State listed the South Fork Eel, along with many other water bodies, as water quality limited due to sediment and temperature concerns.

Figure 1

Basin Description

The South Fork Eel River watershed covers northern Mendocino and southern Humboldt counties in northern California. The 689 square mile basin stretches approximately 58 miles from the Laytonville area in Mendocino County, up U.S. highway 101 through Humboldt Redwoods State Park and the famed Avenue of the Giants in Humboldt County. The river itself winds for nearly 100 miles, flowing northward joining the Eel River near Weott. The Eel then meets the Pacific Ocean in 40 miles, about six miles south of Humboldt Bay. The watershed is known for its recreational opportunities: State Parks, white water kayaking, fishing and summer festivals draw international and local visitors alike. The landscape is varied - from gentle grassland areas and open oak woodlands removed from the coastal fog to steep slopes with deep and dense forests of redwood and fir. The land ownership is also varied as Illustrated on Figure Two. Approximately 20% is publically owned by the California State Park system or the U.S. Department of Interior, Bureau of Land Management. Large timber companies own a relatively small percent of the watershed compared with many other north coast watersheds, mainly west of highway 101. Ranches, dispersed rural residential areas and townships make up the bulk of the area east of highway 101.

South Fork Eel - Land Ownership

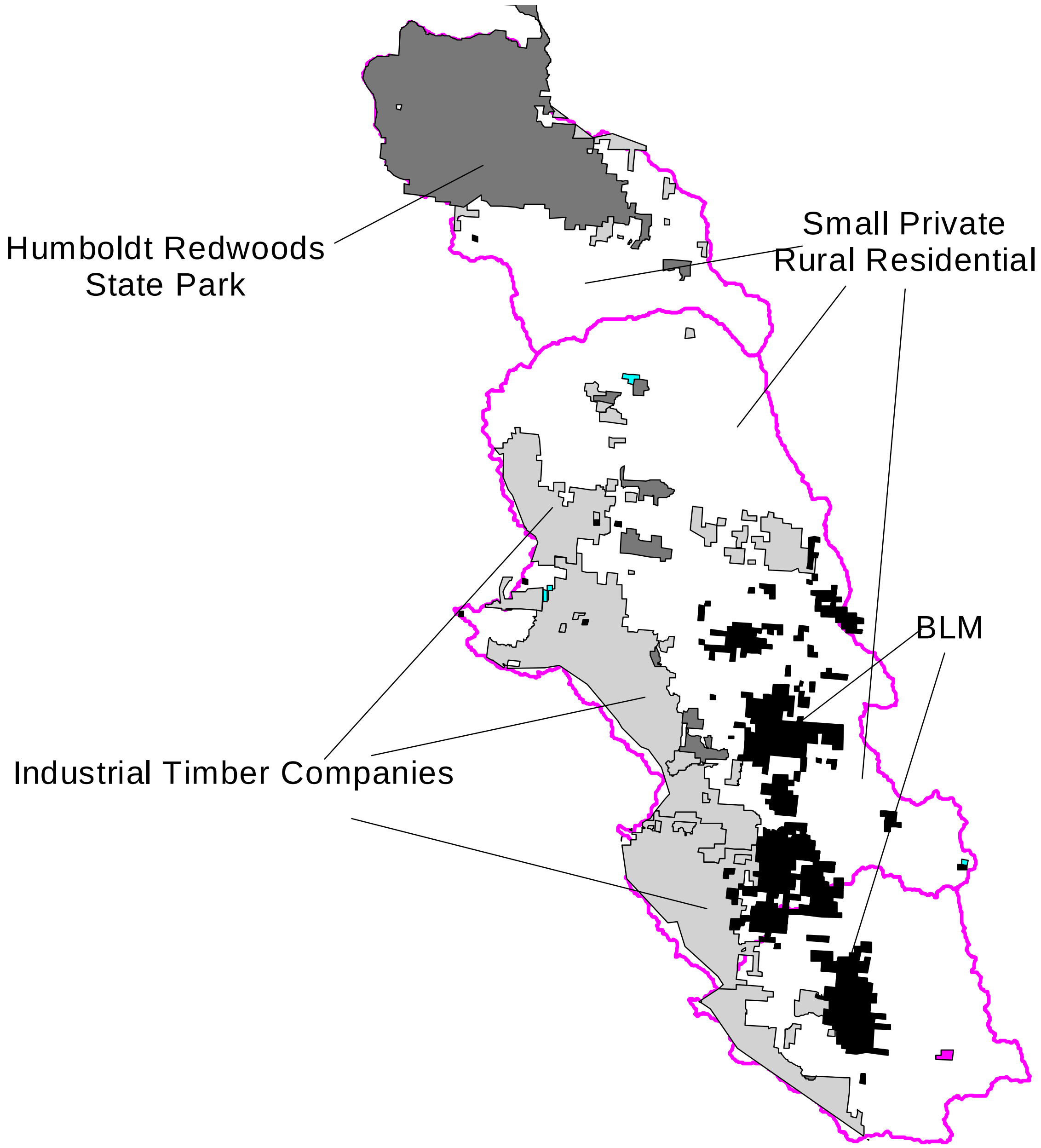


Figure 2

Decline of the Cold Water Fishery

The South Fork Eel River is part of the Eel River system, the third largest river system in California. Two phases of declines have befallen the Eel River salmon. Historically, Eel River salmon production equaled that of the Sacramento River in 1857 (Lufkin, 1996) possibly exceeding 500,000 fish (DFG, 1997); in 1904 345,800 Eel River salmon were taken (Lufkin, 1996.) The fish harvest techniques of the era -- no restrictions on harvest and netting salmon in the rivers as they returned to their spawning grounds -- were disastrous. Already by 1910, there was concern about salmon population declines and calls to limit harvest. After crashing salmon populations made it economically difficult to compete with Sacramento salmon, the commercial inland fishery died. In 1922 the State of California officially closed the industry, albeit after the fishery was depleted. A recreational fishery still exists; however, both declining populations and the corresponding protections for endangered species allow for only a fraction of the past fishery.

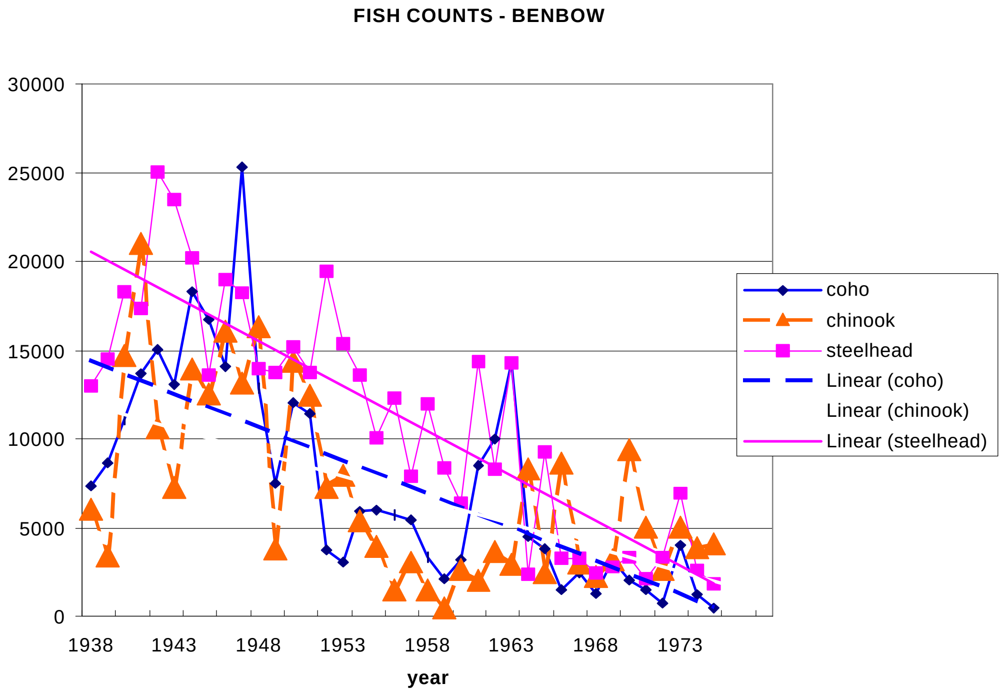
It is believed that fish populations recovered somewhat during the 1930-50s. However, a second wave of population declines followed. The Department of Fish and Game estimates that the entire Eel system, including the South Fork Eel, produced around 160,000 salmon & steelhead in 1964. By the late 1980s, only 30,000 fish were estimated to exist in the entire Eel River basin (Department of Fish and Game, 1997).

Some of most reliable fish population trend numbers in all of northern California come from a South Fork Eel location (see Figure 3). The Department of Fish and Game had a fish counting station from the 1940's to 1975 at Benbow, just south of Garberville. These fish abundance numbers would be a minimum population for the entire South Fork Eel watershed given that the Benbow location would not include salmon bound for more northern tributaries of the South Fork Eel. Coho salmon show the most serious declines. Approximately 17,000 coho were counted in 1945-46, but only 509 were counted in 1975, the last year the station was funded (Steiner, 1998.)

Despite the decline, the Department of Fish and Game considers the South Fork Eel to have a significant remnant population of coho salmon (DFG, 1996.) University of California fisheries experts (Brown, 1994) found that the South Fork Eel population is important because it has little hatchery influence and thus is important for the genetic integrity of the stock. Small hatcheries like the Cedar Creek facility existed but their size was small relative to overall native populations (Downie, 1999). Many biologists believe that native stocks are more resilient over time in their native habitats.

This TMDL for the South Fork Eel focuses on sediment and temperature. Fish populations are influenced by many other factors, such as ocean and estuary conditions, adequate dissolved oxygen in the water column, adequate food, and adequate cover (CDF, 1994.) While this report is concerned with only sediment and temperature constraints, each limiting factor should be improved to increase fish populations. Limiting factors such as large woody debris may additionally need to be addressed, however, the existence of problems with large woody debris do not negate better understood problems of sediment and temperature.

Figure 3



Sediment Problems

The amount of sediment washed through the Eel River is legendary, a process known as sediment production or yield. Most geology students are acquainted with the 1971 Brown & Ritter study that found that the Eel River was one of the highest sediment producing rivers in the world, carrying fifteen times as much sediment as the notoriously muddy Mississippi (Brown & Ritter, 1971). While the Brown & Ritter study calculated that the South Fork Eel had proportionally less sediment than other Eel tributaries, the levels calculated are substantial. The study measured sediment yield during a time of widespread soil disturbance from road building and highly erosive timber harvest practices.

The geology of the area is naturally unstable and is generally thought to produce high natural rates and great sensitivity to human disturbance (DWR, 1983.) As in much of northern California, the large winter storms in 1955 and 1964 led to widespread flooding, landsliding and extreme changes in the rivers and streams. In the South Fork Eel, these same processes led also to the loss of old growth redwoods in the Bull Creek area (now Humboldt Redwoods State Park.) Studies conducted since that time have concluded that certain timber harvest practices and road building activities exacerbate the natural condition. This led the State Park System to acquire the entire Bull Creek watershed.

The main channel of the South Fork Eel River has filled with sediment substantially since 1964, a process known as stream aggradation. The U.S. Army Corps of Engineers measurements of aggradation show four sections of the river increased in elevation from 1.6 feet to approximately 11 feet between 1968 and 1998 (USACE, 1999.)[1] The elevation at one cross section decreased by 1.3 feet. The Army Corps report states that channel widening also appears to be continuing (1992 compared to 1996) although the trend is less evident. These types of channel changes result from both local and upstream sediment inputs.

Sedimentation of tributary streams in the South Fork Eel has also reached notable levels. Sediment from Cuneo Creek, a tributary of Bull Creek, has buried two bridges with more than 10 meters of sediment and the channel widened from 10s to 100s of meters (LaVen, 1987 and Short, 1987.) The 1964 flood resulted in widening of Bull Creek by up to 400 feet (Jager and LaVen, 1981.) Because such precise historical measurements of stream changes are rarely undertaken, there is uncertainty about the spatial extent of similar channel changes within tributaries of the South Fork Eel. DFG observers (DFG, 1996 and DFG, 1996-1998) find that some channel changes (e.g. filling of pools with sediment) that reduce the habitat complexity needed by salmon, are frequent.

With or without changes in the channel from increases in coarse sediment, salmon are negatively affected by the additions of fine sediment. Fine sediment smothers spawning sites, reducing the ability of salmon to reproduce successfully.

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[1] One cross section increased 23 feet, however, the report recommends remeasurement of this section.

Temperature Problems

Temperature directly governs almost every aspect of the survival and life history of Pacific salmon (Berman, 1998.) Temperature is such as an important requirement of fish that coho and chinook salmon, and steelhead are known as “cold water fish”. Many physiological processes of salmon are affected by temperature including metabolism, food requirements, growth rates, developmental rates of embryos and young, timing of life-cycles such as adult migration, emergence from gravel nests, proper life stage development and sensitivity to disease (Spence et al, 1996.) In general, the types of effects are usually divided into lethal and sublethal effects. These effects are relevant for all the life stages of salmon. However, in the South Fork Eel, the most sensitive period is the summer rearing period, when young coho and steelhead stay in freshwater streams while they mature.

Stream temperatures have been measured at many locations in the South Fork Eel. It is well documented that many locations in the South Fork Eel have summer temperatures that exceed the tolerances of cold water species (see page 27 for a discussion on temperature tolerances.) Prior to this TMDL, neither the natural geographic extent of cool temperatures nor the role of human activities in reducing the amount of good cool water habitat for salmon had been established. The role of shading in preventing stream temperature increases is well established for forested ecosystems in the Pacific Northwest. However, prior to this TMDL, the role of changes in riparian vegetation has not been widely investigated for the South Fork Eel. For the South Fork Eel, given that many streams have become wider and shallower and many riparian areas have been cleared for roads or timber production, human induced changes are thought to play a large role. This TMDL evaluates the role of vegetation changes in altering natural stream temperatures for the South Fork Eel.

Legal/Regulatory Context

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in various guidance documents (e.g., US. EPA 1991). The TMDL is a plan to achieve water quality standards by establishing appropriate load allocations and, if necessary, load reductions based on an analysis of the best existing available information. A TMDL is defined as “the sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background” (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (the loading capacity) is not exceeded.

TMDLs have the following components:

- **Problem Statement**

- **Water Quality Standards**: Description of applicable numeric and/or narrative criteria. Interpretation of water quality standard as numeric water quality target(s) for TMDL.

- Source Analysis: Point, nonpoint, and background sources of pollutants of concern are described, including the magnitude and location of sources.

- **Loading Capacity**: Determination of the amount of the pollution that a stream can assimilate and still meet water quality standard; discussion of the link between the water quality standard and the pollutant loading capacity.

- **Allocations:** Identification of appropriate "wasteload allocations" for point sources and "load allocations" for nonpoint sources.

- Consideration of a margin of safety, seasonal variations and critical conditions, and public participation.

publicpublicparticipation.

Application of Section 303(d) of the Clean Water Act to the South Fork Eel River Watershed

EPA regulations provide that TMDLs are to be established at levels necessary to attain and maintain water quality standards. In other words, the goal of a TMDL is to assure that all "beneficial uses" are protected and water quality objectives are met. Water quality objectives and beneficial uses are identified for all of the water bodies in the North Coast Region in *the Water Quality Control Plan, North Coast Region*- Region 1 (Basin Plan.)

In addition to drinking water, municipal, industrial, and recreational uses of the South Fork Eel River, the Basin Plan identifies the following beneficial uses that relate to the cold water fishery:

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

The cold water fishery is the most sensitive of beneficial uses in the watershed. As such, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation or increased temperature.

Water quality objectives further define the goals for the South Fork Eel. The Basin plan for the North Coast Region has objectives related to both the sediment in and the temperature of North Coast streams, including the South Fork Eel. These objectives are described in the sections on temperature and sediment.

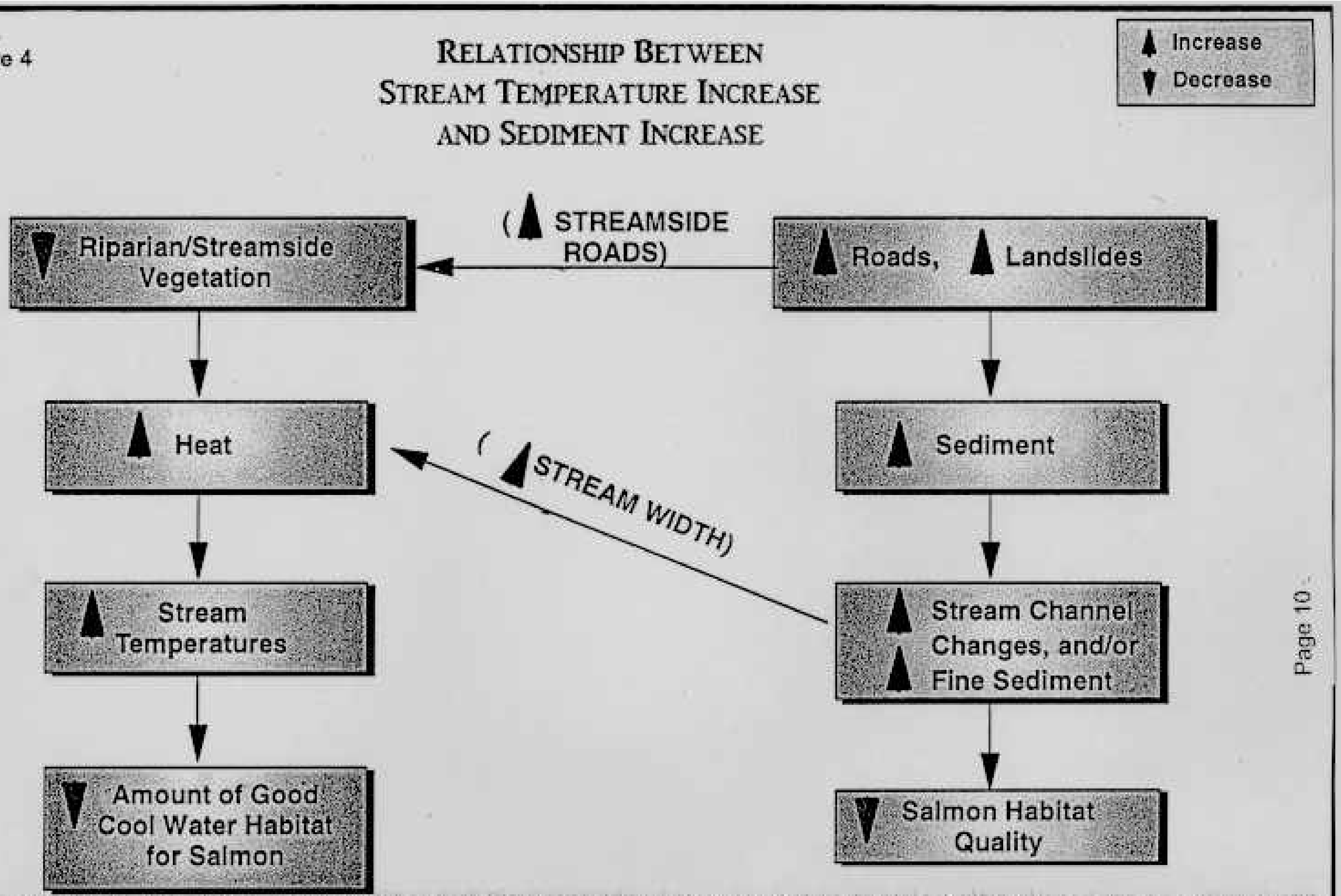
Analytic Framework

This report contains separate TMDLs for both sediment and temperature. These problems are interrelated because sediment problems can also lead to increased stream temperatures primarily by widening the stream. Figure 4 illustrates these interrelationships. In addition, loss of riparian vegetation (the major reason for increased stream temperature in the South Fork Eel) can also lead to increased sedimentation by changing bank stability.

The primary technical information underlying both temperature and sediment TMDLs is a study funded by EPA in 1998-1999. EPA funded a study by Stillwater Sciences for additional data collection, analysis and modeling of sediment and temperature problems in the South Fork Eel.

Figure 4

RELATIONSHIP BETWEEN STREAM TEMPERATURE INCREASE AND SEDIMENT INCREASE



Temperature TMDL

The State of California listed the South Fork Eel as impaired due to both sediment and temperature problems. This section will address the temperature problems that affect cold water fish; sediment problems will be addressed in Section Three. A TMDL identifies the amount of a pollutant a water body can receive and still meet water quality standards. The State of California has established two water quality objectives that must be met for temperature in the South Fork Eel. The following steps were used to develop the temperature TMDL for the South Fork Eel - each step will be described later in this section.

1- Analysis of the source of stream temperature increases focused on modeling the effects of changes in streamside (e.g. riparian) vegetation. Existing stream temperatures were modeled for three representative subbasins - Bull Creek, Rattlesnake Creek and Elder Creek.

2- The narrative temperature standard was interpreted into stream temperature targets for all three subbasins. For example, 38% of stream length in the Bull Creek subbasin should support good cool water habitat.

3- Stream temperature targets were translated into a modeled **heat load** to meet the loading capacity requirement of a TMDL.

4- Effective shade allocations were determined for types of streams to meet the requirements for setting TMDL allocations. These allocations show the percentage of shading needed over each stream segment to attain the heat loading capacity and associated stream temperature targets. These effective shade allocations vary by stream width and vegetation.

Step One: Investigating the source of stream temperature increases

Stream temperature can be affected by many variables, including changes in flow from diversions and dam releases, increases from heated water entering the stream (for example, in the case of irrigation return flows), groundwater flow changes and solar radiation. In the South Fork Eel, a river without any major dams, diversions, or return flows, the primary heat inputs are from direct solar radiation and groundwater flow. Stream heating in excess of natural levels arises primarily from local increases in solar radiation due to removal of streamside vegetation, and stream widening due to increased sedimentation, and the transport of excess heat downstream.

Local residents commented to EPA that small diversions for household use may be dewatering some tributary streams leading to temperature problems. EPA notes that no information was provided to confirm the importance of such diversions, therefore it was not possible to address this potential factor in the TMDL. Overall, EPA does not believe this factor to be significant at the basin scale.

To determine the cause of stream temperature increases in the South Fork Eel, EPA used a model developed by Stillwater Sciences, called Stillwater Sciences Temperature (SST) model. Although, field measured stream temperatures were available for many locations in the South Fork Eel, it is useful to supplement this information with modeled information. A model can predict stream temperatures over all the stream lengths and a model can be used in testing different management scenarios. Modeling of stream temperatures is a credible, well-developed field of scientific endeavor with many practical applications to societal decisions, including TMDL establishment.

Using field data collected at a variety of locations in the South Fork Eel by the Humboldt County Resource Conservation District, SST modeled the temperatures for the entire stream network in three subbasins that represent stream and vegetation types in the entire South Fork Eel - Bull Creek, Rattlesnake Creek and Elder Creek. SST expresses stream temperatures using the Maximum Weekly Average Temperature (MWAT) metric. Although many models exist, the SST model was developed to allow for examination of stream temperature changes at the basin scale when little field measured data exists besides stream temperature data.

Summary of Stillwater Model

Appendix A provides a technical description of the model and data sources. The summary of the model presented here is intended for a more general audience and many aspects of the model are simplified. The SST model estimates stream temperatures for the months of July and August when stream temperatures are at their maximum and of most concern to salmon production. The SST model uses existing computerized maps of data (known as GIS data) on topography, the stream channel network, and vegetation to determine the heat from direct solar radiation reaching each individual stream segment. Vegetation data was simplified and converted from tree diameter classes to assumed heights. The model then solves a heat balance equation for each stream segment, calculating the net effects of direct solar radiation, heat exchange processes at the water surface, and water flow in and out of the water segment.

Data collected by Humboldt County Resource Conservation District and cooperators allowed the model development and validation of the model’s predictive capabilities. SST model concentrated on three subbasins - Bull Creek, Elder Creek and Rattlesnake Creek. The stream temperatures and vegetation characteristics in the three subbasins modeled are representative of the range of conditions found in the South Fork Eel.

Model Results

Statistical analysis of the predicted versus measured temperatures shows that the model is performing well in these three subbasins. This means the SST model accurately predicts stream temperature as a function of the modeled variables. Figures 5-7 show the predicted current stream temperatures in each of the three basins, along with statistics on model performance. The performance of the model demonstrates that we are capturing the major factor influences stream temperature in the South Fork Eel - riparian vegetation. These maps have divided up stream temperatures into 2°C temperature classes with the color codes matching our general assessment of habitat conditions for salmon (see page 27 for a discussion on MWAT temperature thresholds for Salmonids.)

Blue = good cold water habitat, <15°C	(59°F)
Green = marginal cool water habitat, 15°C-17°C	(59°F-62.6°F)
Yellow = poor cool water habitat, 17°C-19°C	(62.6°F-66.2°F)
Pink/red = inadequate habitat. >19°C	(>66.2°F)

The maps show that the South Fork Eel provides a variety of habitat conditions currently, from good to marginal to poor to inadequate. Figure 8 shows the model's performance over the range of stream temperatures modeled.

Summarizing Stream Temperature - Use of the Maximum Weekly Average Temperature Metric (MWAT)

Because temperatures in streams fluctuate daily and seasonally, it is useful to summarize this detailed variability with a summary measurement. To assess stream temperatures in this TMDL, we use the Maximum Weekly Average Temperature (MWAT), the most widely used measurement. MWAT is calculated here as the 7 day period with the highest temperatures calculated as a 7 day running average of all monitored temperatures. Readers should note that the term MWAT is not used consistently by researchers and agencies.[2] Examination of MWATs in South Fork Eel streams allowed Stillwater to simplify modeling by using the last week in July as the most sensitive period, after finding that the vast majority of stream temperatures in the South Fork Eel had MWAT during this week.

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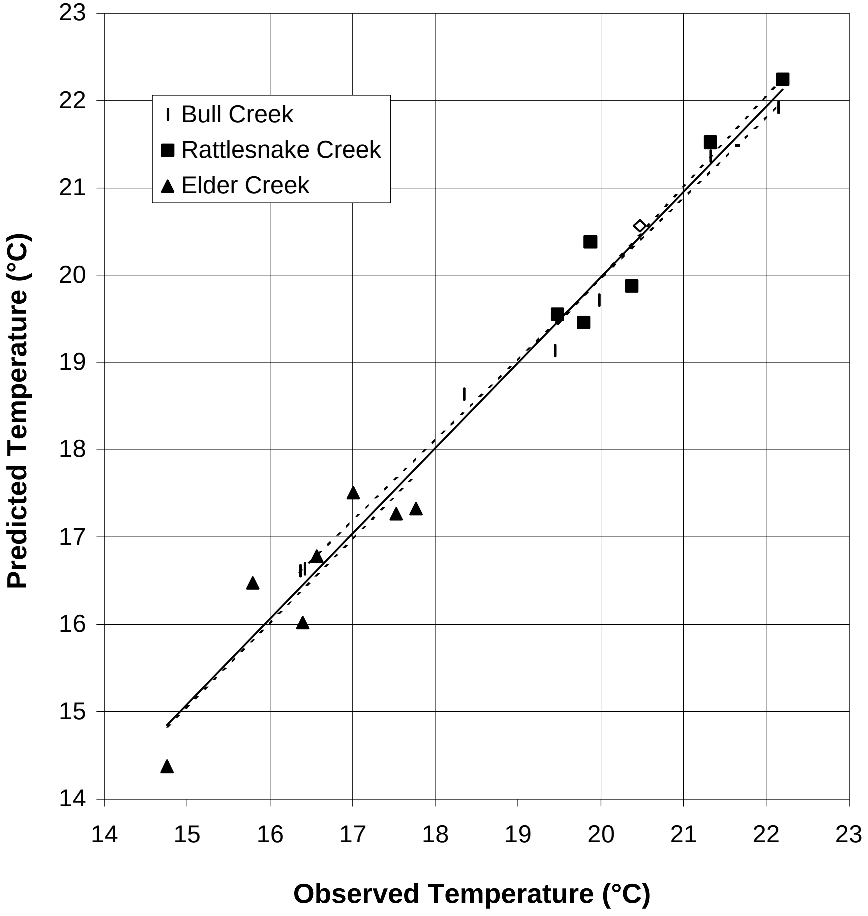
[2] Contrast this with Oregon DEQ's MWAT which is the highest 7 day period calculated as an average of the daily maximum temperature.

Insert Figures 5-

figure 6

figure7

Simultaneous Fit to Bull Creek, Rattlesnake Creek, and Elder Creek Subbasins
Stillwater Sciences Water Temperature Model v.6



Bull Creek

Site	Observed	Predicted
1305	16.4	16.6
1511	20.0	19.7
1512	22.1	21.9
1513	20.5	20.6
1518	19.4	19.1
1528	18.3	18.6
1532	16.4	16.6
1590	21.3	21.4
	RMS error:	0.23
	r²:	0.99

Rattlesnake Creek

Site	Observed	Predicted
1463	19.5	19.6
1542	20.4	19.9
1558	19.8	19.5
1608	19.9	20.4
1609	21.3	21.5
1610	22.2	22.2
	RMS error:	0.33
	r²:	0.90

Elder Creek

Site	Observed	Predicted
1456	15.8	16.5
1457	16.4	16.0
1458	16.6	16.8
1460	17.5	17.3
1461	17.8	17.3
1480	14.8	14.4
1540	17.0	17.5
	RMS error:	0.43
	r²:	0.82

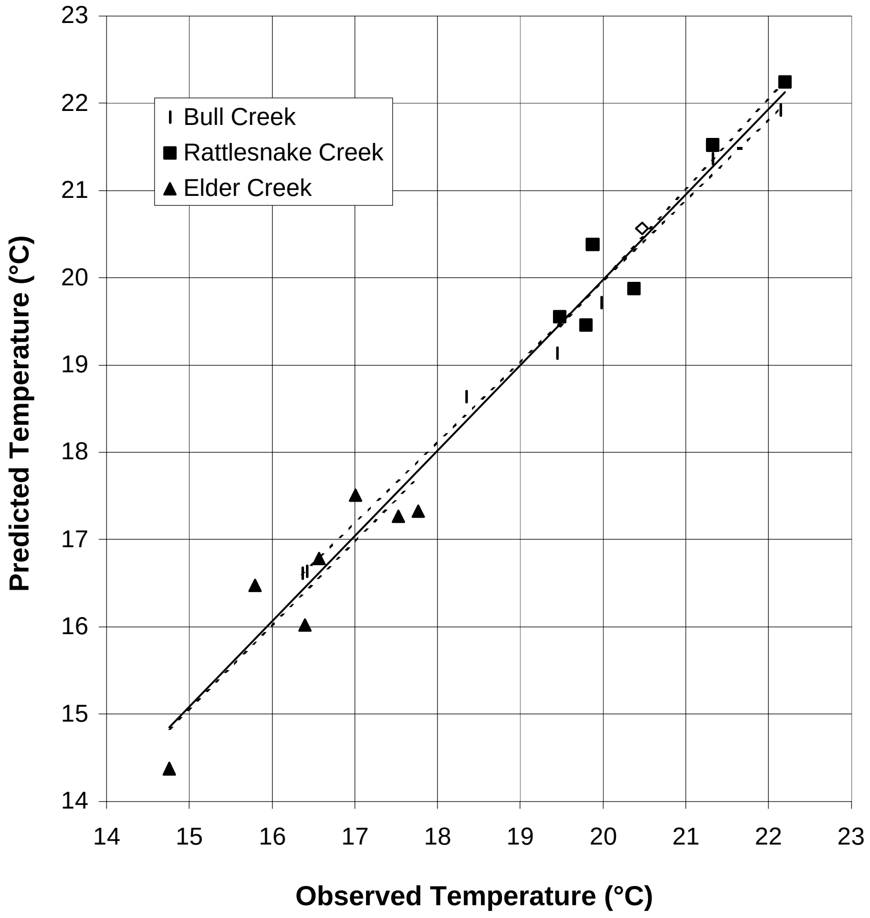
Combined

RMS error:	0.34
r²:	0.98

FIGURE 8:

SSTM performance over a range of stream temperatures

Simultaneous Fit to Bull Creek, Rattlesnake Creek, and Elder Creek Subbasins
Stillwater Sciences Water Temperature Model v.6



Bull Creek

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Rattlesnake Creek

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	r^2:	0.90

Elder Creek

Site	Observed	Predicted
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1457	16.4	16.0
1458	16.6	16.8
1460	17.5	17.3
1461	17.8	17.3
1480	14.8	14.4
1540	17.0	17.5
	RMS error:	0.43
	r^2:	0.82

Combined

RMS error: 0.34
r^2: 0.98

FIGURE 8:

SSTM performance over a range of stream temperatures

Interpreting the existing water quality standards for temperature for the South Fork Eel

The second step in the temperature TMDL analysis was to develop a quantitative interpretation of the State of California’s water quality standard. 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 water be increased by more than 5 degree F above natural receiving water temperature.”***

Using these water quality objectives for temperature for the South Fork Eel, EPA conducted the following analysis:

Because most manageable stream temperature increases in the S.F. Eel are the result of reductions in riparian vegetation conditions, SST first modeled a series of vegetation conditions.

SST then modeled stream temperatures for the various vegetation conditions.

EPA determined which of the vegetation conditions was most appropriately considered “natural.” The stream temperatures associated with those “natural” conditions were considered to be the “natural receiving water temperature” referenced in the water quality objectives.

Those modeled “natural receiving water temperatures” were established as stream temperature targets for this TMDL.

Comparison of the stream temperatures of current conditions and natural conditions show that improvements are needed in order to meet first narrative standard.

TABLE ONE:
Stream Temperature Targets
- percent of stream length by cold water habitat type -

Cold water habitat	Bull Creek	Elder Creek	Rattlesnake Creek
Good < 15	37%	38%	0%
Marginal 15-17 C	31%	52%	1%
Poor 17-19 C	18%	10%	21%
Inadequate 19-21 C	14%	0%	55%
>21 C	0%	0%	23%

These instream temperature targets were developed by defining the "natural receiving water temperature" stated in the state's narrative objectives through analysis of natural vegetation condition. EPA then examined this natural condition in context of "shall not be altered unless it can be demonstrated that such an alteration does not adversely affect beneficial uses." EPA determined that the natural condition cannot be altered without adversely affecting beneficial uses - that is, cold water fish. Therefore, the natural condition is used to set stream temperature targets, loading capacity and allocations in this TMDL as discussed below.

How can "natural receiving water temperature" clause of the narrative water quality standard be defined?

The SST model was used to examine the likely natural conditions on Bull, Elder and Rattlesnake Creeks. We found that:

o Even under the most idealized potential vegetation conditions, stream temperatures in the South Fork Eel varied from 13 to more than 21 C. This range of stream temperature spans the range of good to marginal to poor conditions for salmon.

o One vegetation condition was chosen to represent the achievement of the standard. Stream temperature targets were developed from this "natural condition" scenario, as was the heat loading capacity and effective shade allocations in upcoming sections.

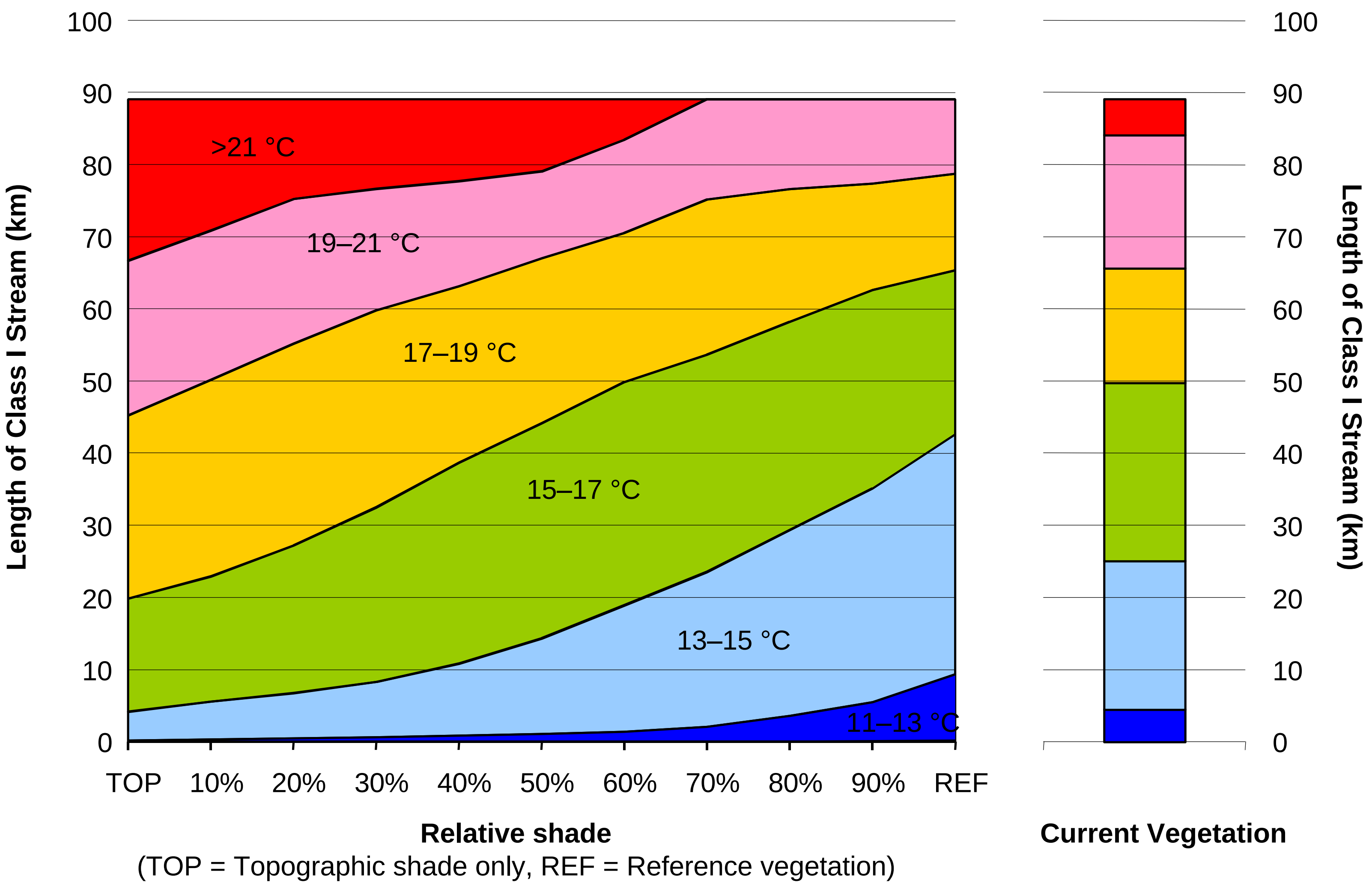
o Changes in riparian vegetation result in significant changes in stream temperatures in the South Fork Eel.

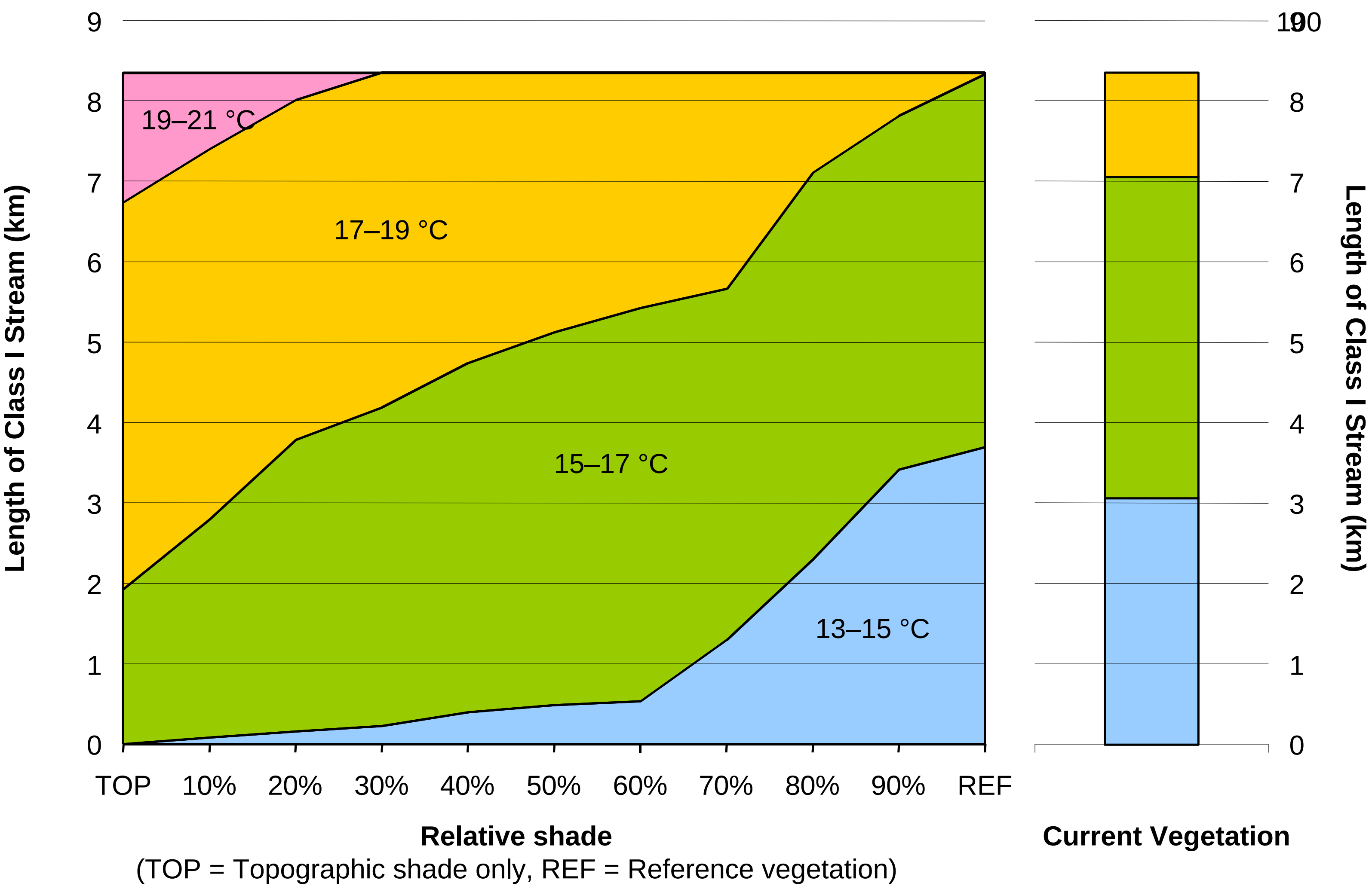
The SST model developed a series of curves for all possible vegetation scenarios. The curves represent how much stream temperatures change in response to vegetation changes. “Natural” was interpreted as natural vegetation characteristics of the South Fork Eel. Because no GIS data exists on the natural vegetation of the South Fork Eel, different scenarios were developed to analyze the natural vegetation changes. These scenarios were called “relative shade scenarios”. The scenarios ranged from removing all riparian vegetation, where topography provides all the available shade (labeled 0% relative shade) to “100% relative shade”, where the current type of vegetation was modeled to reach its oldest and tallest state. Figures 9-11, display the results of all scenarios. For example, Figure 9 for Bull Creek, shows the length of stream with different maximum weekly temperatures (MWAT). If all vegetation was removed, more than 20 kilometers of stream would be greater > than 21 C, very poor conditions for survival of juvenile cold water fish. However, as the relative shade percentage increases (as vegetation height becomes taller) stream length with this poor condition for salmon shrinks until it disappears at approximately 70% relative shade. These curves illustrate that there is no vegetation scenario that provides either all poor habitat or all good habitat in all three subbasins. Table 2 displays the same results numerically. Bull Creek has only 4 kilometers of stream with MWAT 13-15 C when no vegetation exists and topography provides the only shade. When relative shade is increased to 100% (modeled as the entire stream length is in late seral stage, an unlikely condition), this good habitat condition is increased to 33 kilometers of stream.

To determine achievement of water quality objectives, EPA examined these modeled vegetation scenarios and then chose one scenario as interpreting the State’s narrative for “natural receiving water temperature” condition. The idealized vegetation scenario was <u>not</u> chosen as the “natural” condition. The idealized vegetation scenario (modeled by SST model as 100% relative vegetation) assumes a landscape prior to livestock grazing, timber harvesting and road building in the South Fork Eel. This involved converting existing vegetation data to the oldest and tallest vegetation stage, known as late seral, for each existing type of vegetation. The potential riparian vegetation of grassland areas is modeled as alder and willow. However, under natural conditions, fire and storms would naturally impose variety in the riparian zone to some extent (Bureau of Land Management, 1996.) EPA used conditions in Elder Creek as a point of comparison because Elder Creek is a relatively undisturbed stream in the South Fork Eel. Therefore, Elder Creek’s vegetation and resultant temperature regimes are natural. Although Elder Creek has not been harvested, it is not an untouched watershed; small residential areas and dirt roads managed by the University of California are present. Current conditions in Elder Creek were compared to modeled idealized conditions. Current stream temperature conditions in Elder Creek are approximately equal to a riparian condition of 85% of idealized modeled potential shade. Thus, the 85% potential shade condition was used to interpret the “natural” clause of the water quality standard. Using Elder Creek as a reference does not impose Elder Creek vegetation or stream temperatures on the entire basin, rather the 85% target is applied to whatever vegetation type exists currently in other tributary basins.

Distribution of Temperatures in Class I Streams of Bull Creek, S. F. Eel River

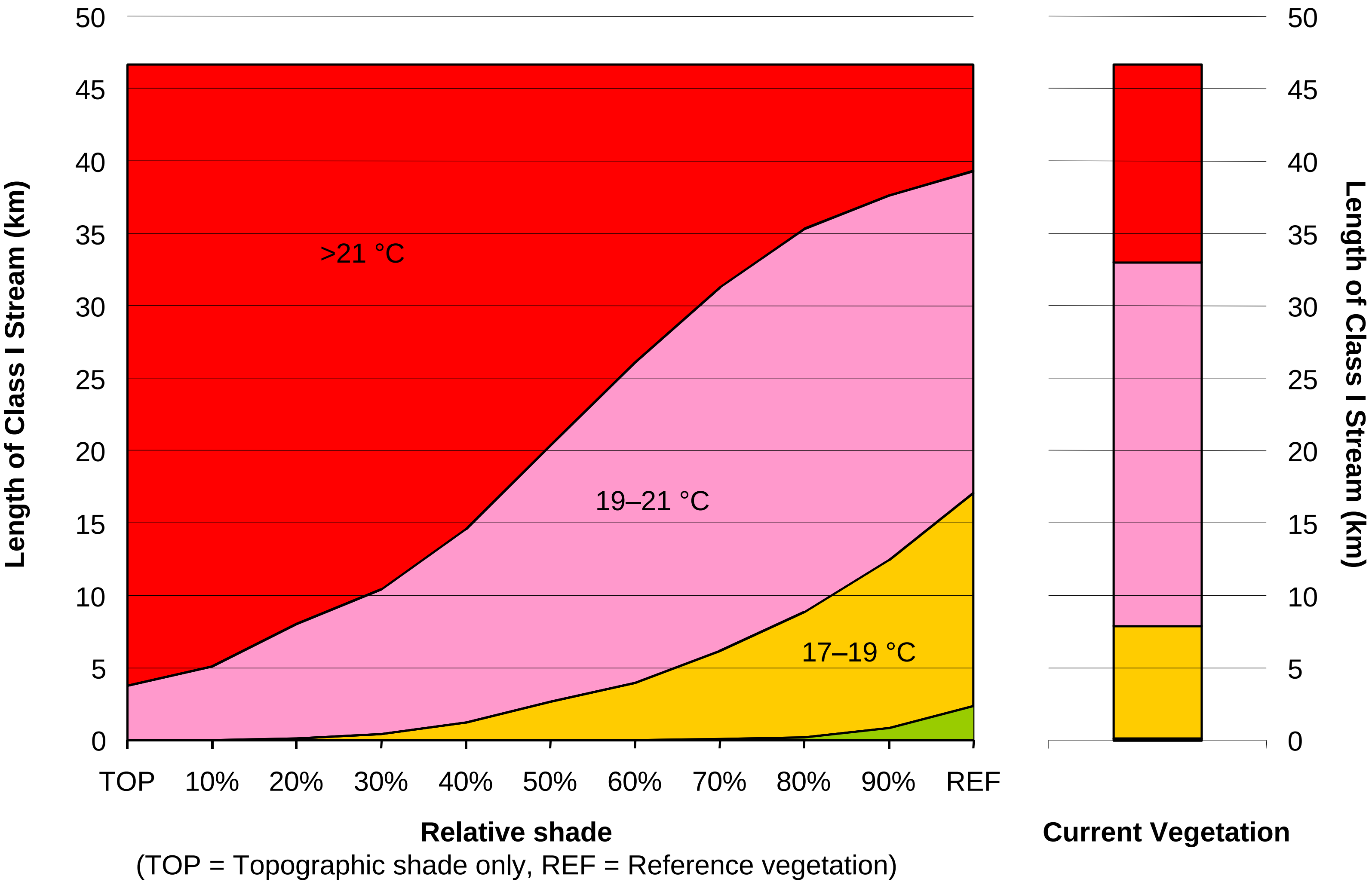
Stillwater Sciences Temperature Model v.6a, fitted to WE 7/31/96 data





Distribution of Temperatures in Class I Streams of Elder Creek, S. F. Eel River

Stillwater Sciences Temperature Model v.6a, fitted to WE 7/31/97 data


Distribution of Temperatures in Class I Streams of Rattlesnake Creek, S. F. Eel River

Stillwater Sciences Temperature Model v.6a, fitted to WE 7/31/97 data

Table II: SHADE SCENARIO RESULTS

Predicted distribution of water temperature in Class I streams under various shade conditions

kilometers of stream by temperature interval

(0% Relative Shade = topographic shade only, 100% Relative Shade = idealized shade conditions)

Bull Creek (89 km of Class I stream)

Temperature Interval	Relative Shade											Current Shade
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
<11	0	0	0	0	0	0	0	0	0	0.05	0.16	0
11-13	0.12	0.31	0.45	0.62	0.82	1.1	1.3	2.0	3.6	5.4	9.2	4.5
13-15	4.0	5.2	6.3	7.6	10	13	18	22	26	30	33	21
15-17	16	17	20	24	28	30	31	30	29	27	23	25
17-19	25	27	28	27	24	23	21	22	18	15	13	16
19-21	21	21	20	17	15	12	13	14	12	12	10	18
>21	22	18	14	12	11	10	5.6	0	0	0	0	4.9

Elder Creek (8.3 km of Class I stream)

Temperature Interval	Relative Shade											Current Shade
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
<11	0	0	0	0	0	0	0	0	0	0	0	0
11-13	0	0	0	0	0	0	0	0	0	0	0	0
13-15	0	0.08	0.16	0.22	0.40	0.48	0.53	1.3	2.3	3.4	3.7	3.1
15-17	1.9	2.7	3.6	4.0	4.3	4.6	4.9	4.4	4.8	4.4	4.6	4.0
17-19	4.8	4.6	4.2	4.2	3.6	3.2	2.9	2.7	1.2	0.54	0.01	1.3
19-21	1.6	0.95	0.34	0	0	0	0	0	0	0	0	0
>21	0	0	0	0	0	0	0	0	0	0	0	0

Rattlesnake Creek (47 km of Class I stream)

Temperature Interval	Relative Shade											Current Shade
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
<11	0	0	0	0	0	0	0	0	0	0	0	0
11-13	0	0	0	0	0	0	0	0	0	0	0	0
13-15	0	0	0	0	0	0	0	0	0	0	0	0
15-17	0	0	0	0	0	0	0	0.05	0.18	0.82	2.4	0.10
17-19	0	0	0.11	0.43	1.2	2.6	3.9	6.1	8.7	12	15	7.8
19-21	3.8	5.1	7.9	10	13	18	22	25	26	25	22	25
>21	43	42	39	36	32	26	21	15	11	9.0	7.4	14

Assessing if “natural” temperatures can be increased without adverse effects on salmon

After defining the term “natural” in the State water quality objective, EPA investigated whether or not temperatures could be increased without “adversely affecting beneficial uses” as is required for the standard to be met. The “natural” condition scenario would be chosen to determine the temperature targets, and load allocations in the TMDL unless it can be shown that increases above this “natural” condition do not adversely affect beneficial uses. As discussed below, based on our examination of stream temperatures for the “natural” condition scenario, the science on adverse effects on salmon, and the limited amount of cold water habitat in the South Fork Eel, we conclude that natural temperatures **cannot** be altered without adversely affecting beneficial uses.

As discussed previously, the beneficial use at issue in this TMDL is cold water fish. Temperature directly governs almost every aspect of the survival and life history of Pacific salmon (Berman, 1998.) Many physiological processes of salmon are affected by temperature including metabolism, food requirements, growth rates, developmental rates of embryos and young, timing of life-cycles such as adult migration, emergence from gravel nests, proper life stage development and sensitivity to disease (Spence et al, 1996.) When stream temperatures increase, the viability of native cold water fish decreases. In the South Fork Eel, the most sensitive period is the summer rearing period, when young coho and steelhead stay in freshwater streams while they mature. This is the life stage analyzed in this TMDL and the only period where this assessment applies.

From our review of temperature tolerances for salmon and steelhead, EPA used the following assessments of the suitability of stream temperature for cold water habitat Using the above information, we display our MWAT information in 2 C temperature breakpoints with the color convention generally matching our assessment of the quality of cool water habitat.

Blue = good cold water habitat < 15 C,
Green = marginal cool water habitat, 15 - 17 C
Yellow = poor cool water habitat, 17 - 19 C
Pink/red = inadequate habitat, > 19 C

Summer Rearing Temperatures - what is an “adverse effect on beneficial uses”?

The habitat classifications used in this TMDL are based on prior assessments of the literature regarding temperature tolerances for salmon. While this literature provides a well-founded basis for determining good habitat conditions for salmon, there is not a consensus on precise thresholds for “adverse effects” on salmon. For the purposes of this TMDL, we are setting 17 degrees C as the maximum “marginal” habitat relying primarily on the Regional Board’s proposed MWAT threshold of concern for the Garcia River of 17.1 degrees C (Manglesdorf, 1998, based on the procedure from Armour, 1991). In determining our 2 degree C. categories, we are also taking into consideration NMFS’ characterization of anything under 14 degrees as “properly functioning,” 14-17.8 degrees as “at risk” and more than 17.8 degrees as “not properly functioning.” As discussed below, whether we focus on temperatures in the 17 degree range or the 15 degree range, what is significant is that good cold water salmon habitat in the SF Eel is very limited. It is also not necessary for the purposes of this TMDL to determine precisely what constitutes “good” or “marginal” salmon habitat because the allocations of effective shade, as discussed below, are based on the varying “natural”

EPA reviewed the amount of habitat (stream length) provided under the “natural” condition scenario (i.e. 85% relative shade). As shown on Figures 9-11, the natural condition (85%) scenario provides for only limited good and marginal cool water habitat. Therefore, EPA finds that the natural condition cannot be increased in the South Fork Eel basin without affecting beneficial uses - thus **the natural condition scenario is the interpretation of the water quality objective** and is the target used to generate the loading capacity and allocations in this TMDL.

Using the above interpretation of the water quality standard for temperature for the South Fork Eel, the stream temperature targets are presented again in Table One:

TABLE ONE:
Stream Temperature Targets
- percent of stream length by cold water habitat type -

Cold water habitat	Bull Creek	Elder Creek	Rattlesnake Creek
Good < 15	37%	38%	0%
Marginal 15-17 C	31%	52%	1%
Poor 17-19 C	18%	10%	21%
Inadequate 19-21 C	14%	0%	55%
>21 C	0%	0%	23%

These goals are based on the natural condition scenario, using Elder Creek as a reference

EPA also used the SST model to investigate the second basin plan objective for temperature which states, *"At no time or place shall the temperature of any cold water be increased by more than 5 F above the natural receiving water temperature."* Mapping the changes in temperature between current conditions and idealized potential vegetation showed the 5 F condition is not a concern. Therefore, the second water quality objective is not exceeded and was not investigated further.

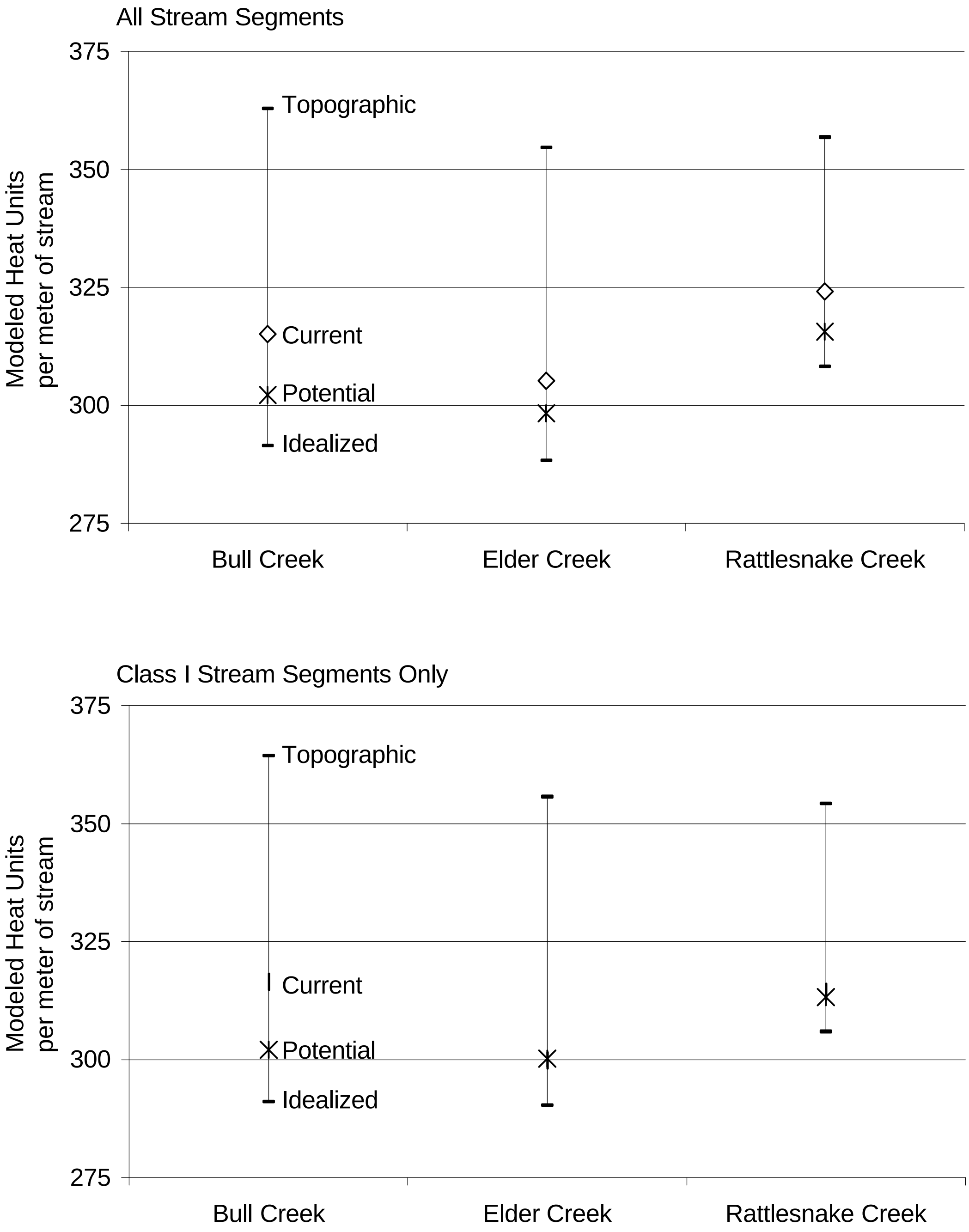
Determination of Pollutant Load Capacity

Under the TMDL framework, identification of the "loading capacity" is a required step. The loading capacity is the total loading of the pollutant that the river can assimilate and still attain water quality standards. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to meet water quality standards. In this TMDL, we express the loading capacity as heat units. Heat is a pollutant under the Clean Water Act. (Recall that the model links the 85% "natural" condition shade scenario to heat through translation of heat into stream temperatures. Shade and heat can be translated into each other. The resultant stream temperatures are a function of local shade/heat and upstream heat.) These heat units do not have a management purpose. Rather, as discussed below, the management unit is the effective shade. The loading capacity is expressed as heat (and not shade) to clarify the role of modeled heat, a pollutant, in stream temperature.

Stillwater calculated the nominal heat energy content of direct sunlight for the vegetation scenarios. Figure 12 shows the loading capacity for the three representative subbasins for topography only, current conditions, natural conditions (the basinwide target) and the idealized scenario as a subbasin average. **The loading capacity for this TMDL is represented by the natural scenario for all stream segments in each subbasin**. The loading capacity differs from the actual energy that would be observed in the field, because of the scale of the model. Because the relationship between modeled values and true values has not been determined, the loading capacity (in heat units) is not directly measurable. Rather, the loading capacity, and the stream temperature target upon which it is based, are used to derive the individual stream segment allocations, which are directly measurable. However, the loading capacity is useful for making relative comparisons between basins or between scenarios. Recall that this natural condition scenario is the interpretation of the water quality standard; therefore, the loading capacity will meet this same standard. This calculation meets the CWA requirement to determine the “greatest amount of loading that a water body can receive without violating water quality standards.”

FIGURE 12: **Loading capacity**

Modeled Insolation under Various Shade Assumptions



Pollutant load allocations - Effective shade

The load allocations in this TMDL are expressed as percent effective shade for individual stream segments.   Oregon Department of Environmental Quality introduced the approach of using effective shade requirements in several proposed and final TMDLs (ODEQ, 1999.) Effective shade is a function of vegetation height, stream width and/or topographical barriers. Effective shade is measurable and site specific variables, such as potential riparian vegetation, can be determined during implementation.

Effective shade allocations meet the legal requirement to set pollutant load allocations. The South Fork Eel TMDL incorporates measures other than “daily loads” to fulfill the requirements of the Clean Water Act 303(d). Alternative measures to mass/time are known as “other appropriate measures” and are allowed under EPA regulations (40CFR 130.2.)” Although a loading capacity for heat is derived, it is of limited value in guiding management activities needed to solve identified water quality problems.   Therefore, the load allocations are expressed as effective shade, which can be measured with various devices, such as solar pathfinders or fish eye lenses. Table 3 indicates the effective shade allocations for the South Fork Eel. As Table 3 illustrates, narrow streams need to be almost totally shaded (1-2 meter streams at 95-96% shade), in order to meet water quality standards, while wider streams would not be totally shaded even under natural vegetation conditions.

TABLE 3: Effective shade allocations by vegetation type and stream width

	Effective Shade Allocations - percent of stream shaded on each stream segment					
Vegetation Type	1-2 meter stream width	2-5m	5-10m	10-15m	15-20m	20-30m
Mixed Conifer	96	91	82	68	52	37
Mixed Hardwood/Conifer Conifer dominated	96	90	79	67	49	33
Mixed Hardwood/conifer Hardwood dominated	96	90	79	66	49	33
Mixed Hardwood	95	90	78	65	47	33
Mixed Oak Woodlands	95	89	78	64	44	26

The effective shade allocations are for the entire basin, not just the three representative subbasins. In response to several comments, EPA is defining stream width here in the TMDL as bankful width. Although EPA understands that the measurement of bankful width has some field variability, we defer a more precise measurement to the Regional Board implementation process.

Stillwater Sciences calculated these effective shade allocations using the "natural condition" scenario and an appropriate formula for rescaling values from the model's 30 meter scale to the stream width classes shown on Table 3. It may be useful to reiterate that a primary factor used in calculating the "natural condition" scenario is the 85% relative shade discussed previously. The 85% relative shade factor was developed by using the current conditions in Elder Creek. This approach does not impose the vegetation characteristics of Elder Creek on the entire watershed, rather the 85% scenario is applied to whatever vegetation type exists. In addition, the model implicitly accounts for shading provided by topography.

Given that fully field verified site conditions were not available to EPA, the effective shade allocations are defined for specific vegetation types (based on vegetation classes as discussed in Appendix A). These vegetation types rely on default vegetation assumptions as described in Table 4. However, EPA recommends that during implementation planning, a process for using site specific data be instituted. During implementation, site specific data on forest type and late seral stage vegetation height would be determined and used to identify the appropriate effective shade allocation from Table 3. In addition, site specific data could be used to refine the default assumptions in Table 4.

Table 4: Default vegetation assumptions

Vegetation type	proportion of SF Eel Watershed	Current - mean height	Site Potential - mean height
Mixed Conifer	14%	37m	37m
Mixed Hardwood/Conifer Conifer dominated	41%	23m	30m
Mixed Hardwood/conifer Hardwood dominated	36%	19m	34m
Mixed Hardwood	5%	15m	30m
Mixed Oak Woodlands	4%	9m	25m

EPA also investigated what should be covered under the definition of a stream. We investigated whether Class II streams, non-fish bearing streams, were important to the temperatures of fish bearing streams. Specifically, Bull Creek was modeled under different scenarios to determine the magnitude of influence from Class II streams. Table 5 and Figure 13 show the results of this analysis. The results indicate that Class II streams are important to the temperatures of Class I streams and should be protected. As Table 5 shows streams with good habitat (<15°C) increase from 25 to 43 kilometers when all perennial streams are protected and not just fish bearing streams. This is because stream temperature is a function of both local shading and upstream stream heat.

However, based several comments, EPA is defining the stream segments to be protected by effective shade allocations as streams that have flow on June 1st and are tributary to fish-bearing streams. The Class II designation is too broad because it can cover streams which are dry in summer.

TABLE 5:
Modeled Effects of Upstream vs Downstream Shading on Distribution of Aquatic Habitat in Bull Creek, South Fork Eel River*

Kilometers of stream meeting given temperature criteria under various shade conditions

Topographic Shade Only

Criterion	Class I	Class II
None	89	47
<21 °C	67	47
<19 °C	45	47
<17 °C	20	40
<15 °C	4.1	27
<13°C	0.1	10
<11 °C	0.0	0.6

**Topographic Shade in Class I Streams
Reference Vegetation in Class II Streams**

Criterion	Class I	Class II
None	89	47
<21 °C	68	47
<19 °C	50	47
<17 °C	30	47
<15 °C	12	43
<13	2.7	28
<11 °C	0.0	6.9

**Reference Vegetation in Class I Streams
Topographic Shade in Class II Streams**

Criterion	Class I	Class II
None	89	47
<21 °C	89	47
<19 °C	78	47
<17 °C	62	40
<15 °C	25	27
<13°C	0.7	10
<11 °C	0.0	0.6

Reference Vegetation Throughout

Criterion	Class I	Class II
None	89	47
<21 °C	89	47
<19 °C	79	47
<17 °C	65	47
<15 °C	43	43
<13	9.3	28
<11 °C	0.2	6.9

* Stillwater Sciences Water Temperature Model version 6.0a, fitted to WE 7/31/96 data.

figure 13 - class I/II

Margin of Safety, Seasonal Variations and Critical Conditions

The Clean Water Act Section 303(d) program and the regulations at 40 CFR 130.7 require that TMDLs include a margin of safety to account for uncertainties concerning the relationship between pollutant loads and instream water quality. A margin of safety can be an explicit number incorporated into the TMDL calculation and/or conservative assumptions used to develop the TMDL. In this TMDL a series of conservative assumptions were made which accounts for the uncertainties in the analysis.

Margin of Safety

This report analyzes sediment and temperature effects separately. Any improvements in stream temperature from reduced sedimentation (or vice versa) are not calculated explicitly, instead the cumulative benefits are a major portion of the margin of safety.

1. Proposed changes in riparian vegetation toward larger trees will likely provide, over time, increased large woody debris. Increased large woody debris benefits cool water habitat by increasing the number and depth of pools, and other changes in channel complexity. These changes were not accounted for in the analysis and the benefits provide a margin of safety.

2. Likely improvements in channel morphology, such as stream narrowing, due to reductions in human -induced sediment could also reduce stream temperatures. These possible stream temperature reductions are not accounted for in the analysis and would be additional to those detailed in the separate analyses on sediment and temperature.

3. Improved riparian areas may increase summertime flow by increasing the volume of water stored in riparian areas and slowly released during low flow conditions. Water stored as groundwater is cooler because it is not heated by solar radiation.

In addition, EPA concludes that uncertainties associated with the use of MWAT metric will not influence the TMDL analysis. Researchers are questioning whether MWAT metric captures the most important temperature conditions for fish to thrive. Researchers are concerned because averages can hide very different temperature fluctuations, including higher biologically stressful temperatures. Salmonids respond not only to daily maximum temperatures, but also to daily maximum fluctuation and cumulative temperature exposure (Berman, 1998.) Thus weekly averages could theoretically be supplemented with calculations on the duration and magnitude of exposures to different temperatures (Coutant, 1999; Berman, 1998). However, because this TMDL focused on the “natural condition” of the riparian vegetation and set allocations accordingly, any measurement of cold water habitat would also meet the “natural condition” determination.

Seasonal Variation and Critical conditions

This TMDL is set to achieve water quality standards in the season considered to be most problematic in the South Fork Eel - summer maximum temperatures. EPA also maintains that the use of summer temperatures as the period of analysis will provide protection for any other life stages that may be affected by changes in temperature. This is because changes toward more natural vegetation conditions will change the temperature regime during all seasons to a more natural condition, thus protecting any other disrupted temperature regimes. In the South Fork Eel, salmon are adversely affected by summer temperatures. The summer rearing period analyzed is the critical condition and thus critical conditions were accounted for in the TMDL.

Monitoring and Implementation Recommendations

Monitoring questions were not investigated for the TMDL. However, the implementation phase needs to address questions of: What is the best measurement technique for riparian condition allocations? What would be appropriate stream length or averaging? How would stream width be measured?

In addition, an underlying assumption is that effective shade allocations are set equally across the landscape, dependant only upon potential vegetation and stream width. EPA used this assumption because of equity concerns and analytic simplicity. Using this strategy, every stream segment has the same potential shade target (85% of idealized). Implementation planning will need to determine how the 85% effective shade is measured in the field, including the size of a stream segment. Using an average 85% on a large scale can be considered, if it is consistent with the TMDL.

EPA recommends that an implementation plan include provisions to improve the underlying default assumptions on vegetation characteristics and site potential. These assumptions underlie the temperature goals for the basin and need to be widely examined. In addition, even with a widely reviewed characterization of vegetation and potential, the implementation plan should include provisions to use site specific information instead of the default assumptions on vegetation.

EPA recommends continued monitoring of stream temperatures in the South Fork Eel. We have found that analysis of stream temperature data could benefit from several considerations in the monitoring phase. First, very meticulous mapping of the location of the temperature monitors is needed. This is in addition to GPS coordinates and especially important when monitors are located near the junction of two streams. Explicit recording of the upstream/downstream location is needed. In addition, spot measurements of summer low flow conditions would improve analysis effects as would groundwater temperature measurement.   More temperature gauges should also be located in non-fish bearing streams (Class II streams) because these areas have an influence on temperatures further down in the stream network.

Sediment TMDL

The State of California has identified the South Fork Eel as water quality limited due to sediment as well as temperature. The primary environmental concern is the decline of populations of native cold water fish, such as coho salmon, chinook salmon, and steelhead. Increases in sediment affect these fish in a variety of ways. Fine sediment diminishes spawning success by reducing the survival of salmon young (egg stage to their emergence from their gravel nests, called redds). Coarse sediment can overload the ability of the stream to process sediment load and change the stream's shape (or morphology). These structural changes simplify the natural complexity and stability of instream habitat resulting in reduced survival of salmon. For example, juvenile rearing success is diminished by reducing pools and cover as streams become shallow and wide, and spawning success is reduced as unstable streams scour and wash away the gravel nests of salmon (Bauer & Ralph, 1999).

The primary purpose of the South Fork Eel River Total Maximum Daily Load for Sediment (TMDL) is to identify the maximum allowable amount of sediment that the stream can receive and still meet water quality standards. The State water quality standards related to sediment require that sediment "not adversely affect beneficial use." The primary beneficial use of concern is native cold water fish.

EPA funded a sediment source analysis (Stillwater Sciences, 1999) in order to provide information on the sources and magnitude of sediment in the South Fork Eel. (The executive summary of the sediment source analysis is included as Appendix B.) A pollutant source analysis demonstrates that all pollutant sources have been considered and significant sources estimated. Information from the sediment source analysis was used in setting TMDL loading capacity and load allocations.

The major components of the TMDL analysis are:

Narrative water quality standards were interpreted into a small set of measurable indicators: percent fines, V*, and thalweg profile.

Existing sediment loading was calculated based on the source analysis performed by Stillwater. The results of these calculations demonstrate that existing sediment loading is approximately two times the natural rate. In other words, for every metric ton per square kilometer per year (t/km2/year) of natural sediment, there is one t/km2/year of human-induced sediment. The study found that sediment loading is variable in the South Fork Eel basin and roads are the largest contributors of human-induced sediment.

The loading capacity for this sediment TMDL was set based on estimates of increases above natural sediment loading from the hillslope. The TMDL is set at 1:4 ratio of human to natural sediment.

Load allocations were established. These calculations illustrate that meeting basin sediment reduction goals necessitate ambitious erosion control plans. In order to meet a 1:4 ratio of human to natural sediment, sediment from roads will need to be reduced by 80% and sediment from increased landslides by 55%, based on levels for the most recent period estimated.

NUMERIC TARGETS FOR SEDIMENT: Interpreting the water quality standards

In order to analyze how much sediment is too much, the water quality standards for the North Coast need to be interpreted in light of what "does not adversely affect" salmon. For a recent examination of the proper role of these types of numeric targets see "Aquatic Habitat Indicators and their Application to Water Quality Objectives within the Clean Water Act" (Bauer & Ralph, 1999).

The approach taken for the South Fork Eel is to propose relatively few indicators that interpret water quality standards for sediment. In addition, these indicators should be interpreted as a whole, along with measures of preceding rainfall and channel type, in order to draw conclusions regarding trends in habitat quality.

Numeric targets interpret water quality objectives, provide indicators of watershed health, and represent habitat conditions adequate for the success of salmonids. The applicable water quality objectives are found in the North Coast Regional Water Quality Control Board's Basin Plan. The water quality objectives for erosion-related concerns are: suspended material, settleable material, sediment, and turbidity. In addition, two prohibitions on logging, construction and related activities further define water quality-related requirements.

The water quality objectives for the four sediment-related pollutants are as follows:

> *"Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses."*

> *"Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses."*

> *"The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses."*

> *"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."*

The Basin Plan includes two discharge prohibitions specifically applicable to logging, construction and other activities associated with increased erosion are:

> *"The discharge of soil, silt, bark, slash, 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."*
>
> *"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."*

Three broad categories of sediment can have important adverse effects: coarse sediment, fine sediment, and suspended sediment. Coarse sediment can affect channel structure. Fine sediment can adversely affect salmon production, even without changes in channel structure. All three types of change affect salmon spawning and rearing success. EPA is establishing indicators for fine sediment, coarse sediment/channel structure, and suspended sediment. The indicators are: percent fines; V* (vee-star); thalweg profile; and turbidity.

Indicators of Fine Sediment: Percent Fines and V*

Fine sediment can negatively affect both salmon spawning and rearing. Many researchers have identified relationships between the amount of fine sediment in spawning gravel and salmonid survival to emergence (see Stillwater Sciences, 1999, for a review of the literature). Different methods of determining the quality of spawning gravel exist, as do different sampling methods and a variety of summarizing statistics. These indices include: measures of the mean diameter, different measures of percent fines, and the fredle index. Some researchers caution against using just one measure of gravel quality. However, because gravel measurements are costly, we are proposing percent fines as the only indicator for the South Fork Eel.

Percent Fines

Percent fines is defined, for purposes of this TMDL, as the percent of subsurface fines <0.85 mm. Monitoring methods (sample location, reach length, frequency, extraction method, size of sampler) are not standard at this time, but need to be thoroughly researched and reported. The numeric target for fines <0.85 mm is less than or equal to 14%. The target should be monitored at stream riffles. The target is selected as the midpoint between the percentage of fines reported in unmanaged streams in the

Peterson (1992) and Burns (1970) studies. EPA determined that the target should take into account that the 11% fines observed by Peterson et al. is probably lower than would be expected in California. However, the 17% fines <0.85 mm which was seen in unmanaged streams in California by Burns is high given that the measurements started in 1967, after high sediment loads from the large 1965 storms. This indicator is expected to be sensitive to the type of channel, especially channel slope and the preceding rainfall patterns. Therefore, the indicator should be used within an analysis of the preceding hydrological conditions and channel type. EPA recognizes that there will be spatial and temporal variability around the target for instream indicators.

V*

V* (pronounced "vee star") is a measure of the fraction of a pool's volume that is filled by fine sediment and is an indicator of the in-channel supply of mobile fine sediment (Lisle and Hilton, 1992). This measure may also be a good indicator of rearing habitat, as mobile bedload sediment fills pools and simplifies the complex habitat needed for salmon rearing. This indicator is also sensitive to channel type, preceding flow events and local variations in sediment supply (Stillwater, 1999). Some previous TMDLs used Knopp's findings of V* values of 0.21 (21%) which represent good stream conditions (Knopp, 1993). Sample sites for Knopp's study were located in Franciscan geology. However, Knopp's data were collected following 5-7 years of below-normal precipitation, which may result in relatively high levels during this period compared to higher rainfall periods. In a recent Lisle and Hilton (1999) study, Elder Creek, an undamaged basin in the South Fork Eel was sampled. The average V* was approximately 0.09 (9%). Stillwater Sciences sampled 24 pools in 11 streams in the South Fork Eel in September 1998, including Elder Creek. This period was after substantial high El Nino flows. Elder Creek had V* of 1-2%. This illustrates the substantial natural variability that exists with any sediment indicator. Bauer and Ralph (1999) recommend that future indicators be expressed in terms of the central tendency and spread in the data to better account for natural variability and improve the interpretation of the data. We are establishing a V* target of <0.10 (10%) threshold for concern for streams in the South Fork Eel, based on the highest Elder Creek data presented above. Given the sensitivity to preceding flows, V* should be monitored over time. In the September 1998 Stillwater sampling, several streams with much historical disturbance had V* under the proposed threshold of concern of <10% (Bond, Bear Wallow and Hollowtree) possibly indicating that these areas are recovering from prior sedimentation. On the other hand, Bull Creek, South Fork Salmon Creek and the East Branch of the South Fork Eel all had V* of 20-25% indicating areas with fine sediment concerns.

Indicator of Channel Changes and Coarse Sediment: Thalweg profile

Complexity in channel structure is very important to salmon survival. Habitat complexity within channels (e.g., pools, cover, large woody debris, backwater pools) is needed to provide salmon with good rearing habitat and, possibly, overwintering survival.

The gross simplification of habitat, as evidenced by streams becoming wide and shallow and filling with sediment, is a measurable phenomenon, albeit within much natural variability, both within and among streams. Measures of channel complexity include: pool frequency, residual pool depth, pool/riffle ratio, width/depth ratio, large woody debris frequency and thalweg profile. Bauer and Ralph recommend the use of residual pool depth as an effective numeric indicator of habitat conditions, particularly if stratified by basin size and stream gradient. However, given that no stream stratification scheme for the South Fork Eel has been developed, EPA is establishing thalweg profile as a target, because this measurement has fewest measurement concerns of the indicators of channel structure. Many pool and large woody debris measurements are not standard, prone to measurement inaccuracies and are flow dependant. Repeated surveying of cross sections is a widely accepted, standardized method, and has proven its utility in evaluating channel stability and sedimentation effects (Klein, 1998). Thalweg profiles can also be used to evaluate pool frequency and depth (Klein, 1998, reporting Madej).

The thalweg profile is a profile, measured parallel to stream flow, of the lowest elevation of each of many channel cross-sections. As a stream descends from its headwaters to its mouth, the mean thalweg profile slope also descends. As the number of pieces and volume of large woody debris increases as well as the number and depth of pools, the thalweg profile develops more dramatic variation around the mean profile slope. We are using increasing variation as the target condition, defined as increasing variation in the thalweg elevation around the mean thalweg profile slope.

Indicator of Suspended Sediment: Turbidity

EPA reiterates the basin plan objective for turbidity as a target: “Turbidity shall not be increased more than 20% above naturally occurring background levels.

SEDIMENT SOURCE ANALYSIS

Watershed Characteristics

Sediment production is a function of geology, topography, rainfall and land use. The South Fork Eel has three major types of land uses - timber production, rural residential and grazing areas. Figure 2 (page 3) illustrates the relative proportions of land in public ownership, large timber companies or small private residential ownership. The actual uses of the lands characterized as mixed residential are difficult to determine because centralized information is not available and local residents have privacy as a deeply held value. It is generally assumed that these privately held lands are composed of grazing, and private residential areas. Both these private parcel types may occasionally harvest timber.

Geology and topography are both important in understanding sediment production. The sediment source analysis stratified the basin into three major “geomorphic terrains” (see Figure 14), which are areas that are expected to have similar rates of sediment production due to their similarity in geology and topography. The Yager and coastal belt franciscan terrains are characterized by moderate to steep slopes and forested hillsides with straight profiles. The melange area’s character is open grasslands and oak woodland with land forms that are often described as rolling, hummocky, and “melted ice-cream scoops”. The melange is found in the eastern portion of the basin and has little, if any, associated timber production.

Summary of the Sediment Source Analysis

The sediment source analysis combined several methods to generate estimates of sediment in the South Fork Eel. Earlier studies were summarized, limited photo analysis and field work was conducted, existing data was supplemented by several modeling techniques, and GIS data analysis was used. A major focus of the sediment source analysis is to better characterize the proportion of human-induced sediment. The analysis intensively studied three areas representative of different types of geology and hillslope stability within the South Fork Eel (see Figure 15). Certain information from these “geomorphic terrains” was part of the extrapolation of sediment estimates to the entire basin. Appendix B, the executive summary of the Sediment Source Analysis, is a detailed description of the study, methodology and results.

The most recent time period analyzed in the Sediment Source Analysis, 1981-1996, is used for this TMDL. The emphasis on more recent events was deliberate. Given limited time and resources, estimating more recent periods allows an investigation into current land use practices and erosion rates. The benefit of understanding current erosion problems was thought to outweigh the concern that the more recent period was characterized by milder winter storms (intense storms are triggers for sediment movement).

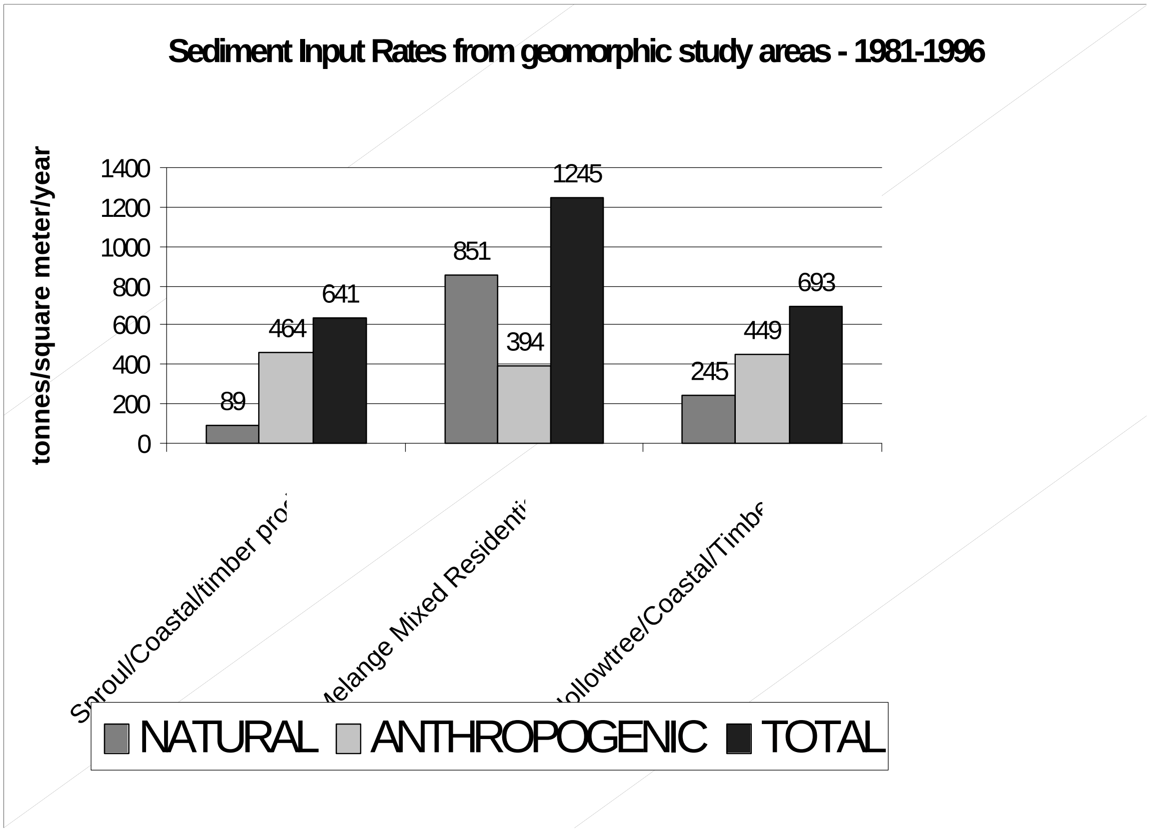
The location of the three intensive study areas is shown on Figure 15. The Sproul Creek area is representative of coastal geomorphic terrains that are more stable. These areas have had recent timber harvest. The Hollowtree area is representative of a steeper coastal belt geomorphic terrain, also in industrial timber production. The Tom Long area is in mixed melange terrain. This area is primarily rural residential mixed with grazing, with a small amount of timber production (see Appendix B).

Figure 16 displays the variability of sediment loading in the three intensive areas in the South Fork Eel. The total amount of sediment varies with geomorphic terrains from 640 to 1200 t/km2/year for the most recent period. The mixed melange area studied had nearly twice the estimated sediment loading to streams as the other areas studied. This area is in the eastside of the basin and overlaps with the mixed residential use. There is little timber production in these mixed areas. (For more information see Appendix B.)

Figure 14 - terrains

Figure 15 Intensive areas

Figure 16


Sediment Input Rates from geomorphic study areas - 1981-1996
tonnes/square meter/year
1400
1200
1000
800
600
400
200
0
89
464
641
851
394
1245
245
449
693
Sproul/Coastal/timber pro
Melange Mixed Residenti
Hollowtree/Coastal/Timbe
NATURAL
ANTHROPOGENIC
TOTAL

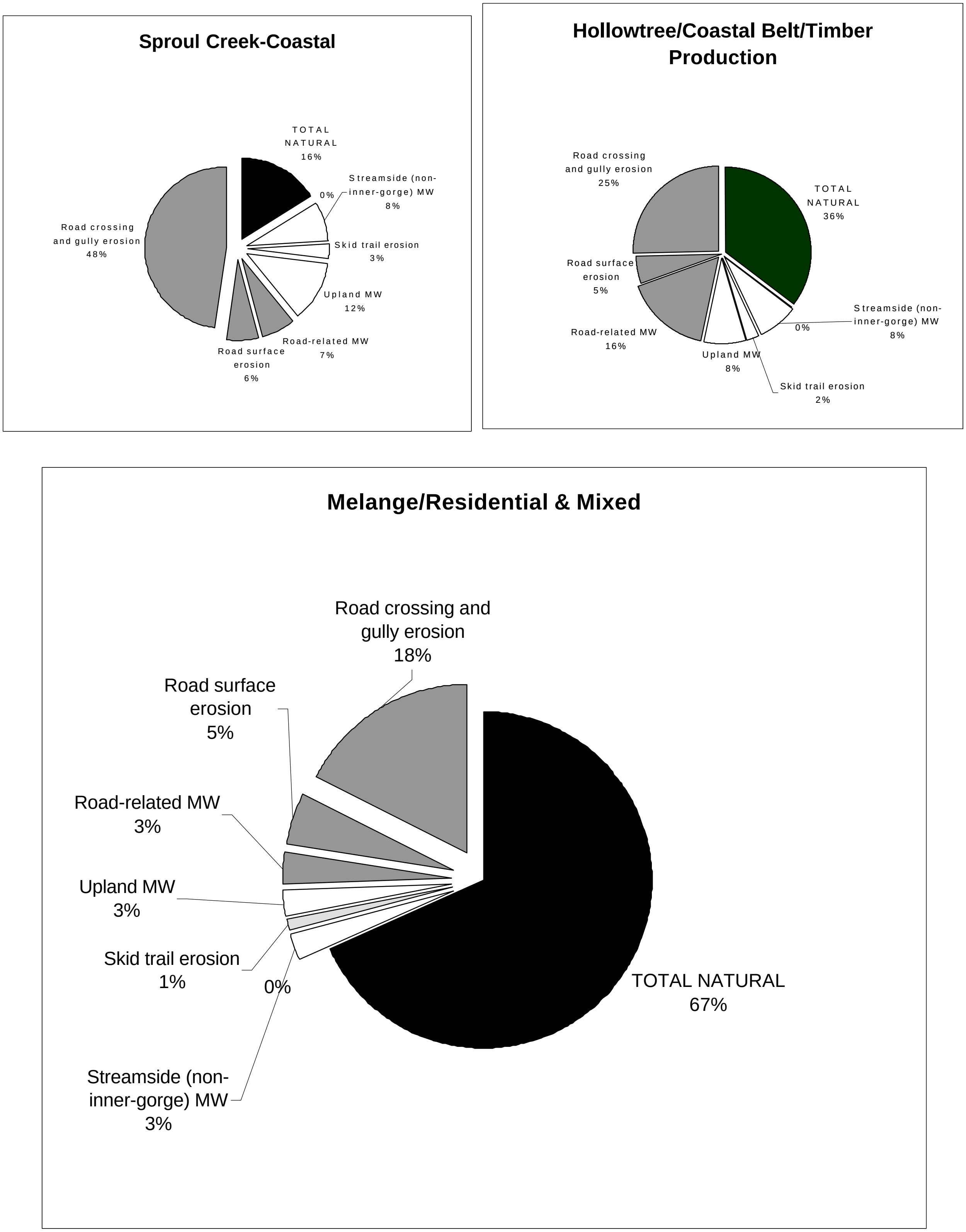


Figure _: Proportion of sediment produced in three representive areas

The relative importance of sediment sources varies by subbasin. Figure 17 shows the relative magnitude of different erosion sources in each subbasin. Natural inputs range from 16 - 67%. Geology and topography influence these natural processes. The large amount of natural sediment production in the mixed melange area is from earthflow toes and associated gullies. Timber harvest inputs (exclusive of roads) range from 7% (in areas with little harvest) to 23% of total sediment production, and are affected by the technique used for timber harvesting, as well as the rate of harvest. The areas studied either did not have much recent harvest activity or improved harvest techniques had been used. The relatively low proportion observed from harvest (exclusive of roads) would not be representative of all harvest techniques. Roads account for the largest amount of human-induced sediment and are the largest overall sediment contributor (46 - 62%). Unlike the harvest estimates, which inherently include current practices, these numbers were generated using models that did not account for current road maintenance practices. In particular, the actual proportion in the Sproul Creek area is thought to be overestimated because actual road maintenance practices are believed to be better than assumed for modeling. However, these are the best quantitative data available. This caveat does not apply to the mixed melange residential; field work in those areas found maintenance practices were poor. More work needs to be done to characterize the road construction and maintenance practices of other residential areas.

Figure 18 shows the estimated magnitude of sediment from roads, including roads associated with timber production. The road related sediment estimates are dominated by stream crossing failures and hillslope gullying. This gullying refers to hillslope gullies caused by road diversions of runoff, rather than gullying of the road surface. The method used to generate these estimates is not precise (see Appendix B),

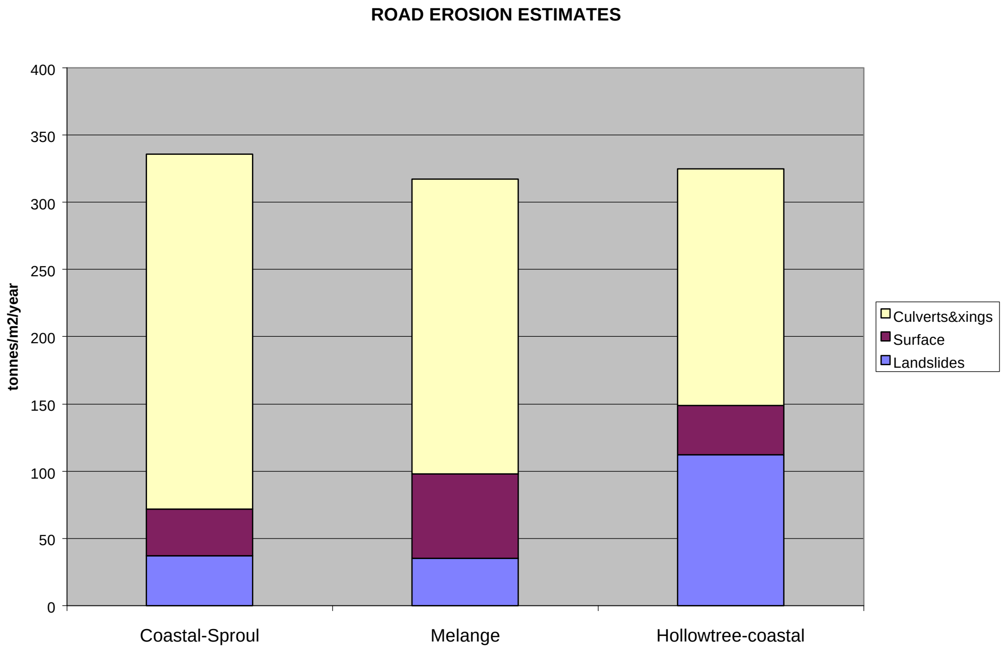
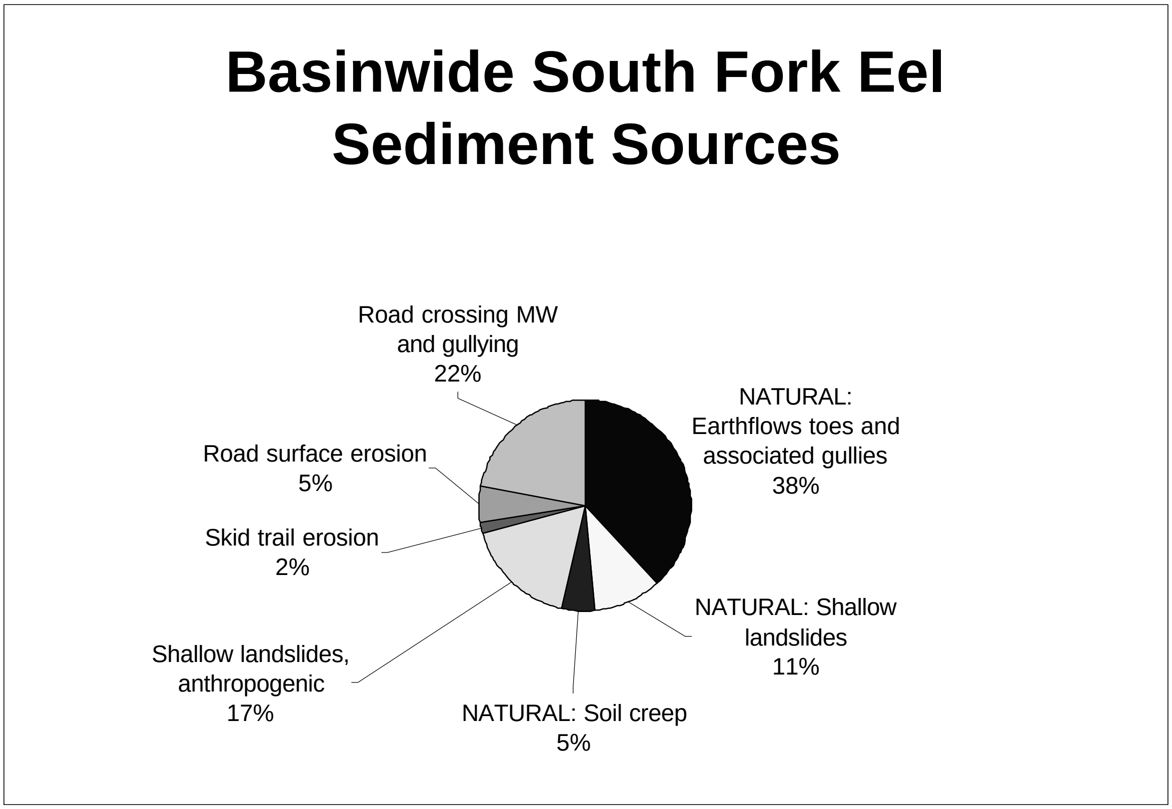


Figure 18

and erosion is likely over-estimated. The estimates were derived using the best method available, after searching for an improved method of compiling existing data. Interestingly, studies of Redwood Creek basin indicate that gullying is an important contributor of sediment. Weaver (1996) indicates that this gullying is caused mainly by improper or badly maintained culverts. Mendocino Redwood Company's watershed analysis for the Albion, however, shows much lower proportional rates of fluvial erosion for similarly managed lands (MRC, 1999). Rural residential roads were estimated to cause as much erosion as roads associated with timber production. Although more work needs to be done to characterize the density, maintenance and construction of roads on residential land, the results strongly imply that erosion control funding and implementation plans must take this land use into account in the South Fork Eel.

Basinwide Estimates

The extrapolation of the results from the intensive study areas to the entire South Fork Eel basin resulted in an estimated basinwide rate of sediment production of approximately 700 t/km2/year and a ratio of human-induced to natural sediment of 1:1. Thus, current sediment production is approximately twice the natural sediment production in the basin. Figure 19 displays the proportion of natural and human-induced sediment by source category.



Calculation and extrapolation methods are described fully in "Sediment Source

Analysis of the South Fork Eel" (Stillwater Sciences, 1999). Major techniques used to produce the estimates included mapping of earthflow toes in the entire basin and mapping the entire basin in shallow landslide hazard categories using the SHALSTAB model. In addition, the intensive study areas provided rates of landsliding, road crossing failure and road surface erosion.

As noted above, the results for the basin were generated for the 1981-1996 period. Table 6 describes the results.

TABLE 6

SOUTH FORK EEL - BASINWIDE SEDIMENT ESTIMATES

Sediment Source	Total sediment input, t/yr	Unit area sediment input (t/km2/yr)	Fraction of total
Natural Sediment Sources			
- Earthflow toes and associated gullies	478800	269	38%
- Shallow landslides	132500	74	11%
- Soil creep	62980	35	5%
- Subtotal		378	54%
Anthropogenic Sources			
- Shallow landslides, anthropogenic (roads & harvest)	216200	121	17%
- Skid trail erosion	21534	12	2%
- Road surface erosion	67512	38	5%
- Road crossing failures and gullying	276500	155	22%
- Subtotal		326	46%
Total	1256026	704	100%

Stillwater Sciences notes that the absolute sediment estimates (approximately 700 t/km2/yr total and 350 t/km2/year natural loading) is a fairly low estimate compared to rates estimated by other studies for earlier periods. EPA concludes that although the magnitude of sediment may be underestimated, the general conclusions are not affected - a significant proportion of sediment is still coming from human-induced sources, roads are the largest source of sediment and residential areas are important. This is primarily because the management related sources have been estimated, while alluvial bank and terrace erosion, particularly along the mainstem were underestimated.

LOADING CAPACITY: Setting goals for sediment reduction

The TMDL program sets out a framework for meeting water quality standards. The *loading capacity* estimates the amount of a pollutant that a stream can assimilate and still meet water quality standards. The water quality standards for sediment-related concerns in the South Fork Eel all require that sediment not “adversely affect beneficial uses.” The most sensitive beneficial use in the South Fork Eel is the protection of native cold water fish. For this TMDL, EPA is establishing a loading capacity, or TMDL, that is based on the ratio of human-induced sediment to natural sediment.

Precisely estimating the link between the amount of sediment from hillslopes (t/m2/year) and the numeric indicators of conditions in streams (V*, % fines, thalweg profile) is difficult, due to the nature of sediment movement in a system with variable rainfall and variable channel structure and slope. 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 hillslope processes from decades past. Thus, there is inherent complexity in linking the routing and timing of particular habitat effects to particular increases in loadings from particular hillslopes. Nevertheless, management activities can clearly increase sediment delivery and instream habitat can clearly be adversely affected by increased sediment inputs. Therefore, it is reasonable to link increases in hillslope sediment to decreased stream habitat quality.

Three general approaches have been used by EPA and Regional Board in setting a loading capacity for sediment TMDLs in the North Coast. They include:

- Comparing current conditions to reference streams (streams in good condition);
- Comparing current conditions to conditions in a time period that had good habitat conditions; and
- Relating qualitatively the proportion improvements in instream indicators to proportional hillslope erosion reduction.

For the South Fork Eel, EPA is using a different approach. For this TMDL, we are using the information developed in the Stillwater study on the ratio of human-caused to natural sediment to determine sediment reduction goals. This approach assumes that there is some increase over “natural” sediment that will not “adversely affect” salmon. EPA finds this a reasonable assumption because salmon populations were substantial during the 1940s, a period that included some human disturbance.

The ratio approach has several potential advantages. Researchers (Stillwater, 1999) indicate that the ratio 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 of human-induced to natural sediment 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.

Two types of information were used in developing the target ratio, historical data and measurement sensitivity. The analysis using historical data involves a link between fish populations in the 1940s and upslope land use. This assumes that sediment habitat conditions in the stream and sediment production on the hillslope during the 1940s did not *in and of themselves* adversely affect salmon. This does not claim that improving sediment condition alone will lead to the salmon populations of the past, rather we expect that every limiting factor (e.g., temperature) must be addressed to restore salmon populations. This 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 naturally to the stream over history varied, salmon adjusted to the natural variability by using the habitat complexity created by the stream's adjustment to the natural variability. In addition, we are assuming that the natural amount of sediment can be increased by some unknown proportion and not adversely affect fish. We postulate this because there was human caused disturbance throughout the North Coast when fish populations were thriving, including ranching, the tanbark industry and some early logging.

EPA used information from the Noyo River to develop the target ratio. Given that fish populations in the South Fork Eel were substantial during the 1940s, it would have been ideal to locate data on the ratio of human to total sediment during the 1940s in the South Fork Eel. Unfortunately, quantitative historical information for the South Fork Eel was not available. Therefore, quantitative estimates available from the Noyo River were used, the only estimates of human to natural sediment found in similar geology during the desired time period. Photo analysis of the 1933-1957 period is assumed to include 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. The fish populations in the Noyo were substantial during this period (NCRWQCB,1999). The estimated rate of sediment delivery in the Noyo River watershed for the period of 1933-1957 is about 470 tons/mi2/yr. Of this, about 370 tons/mi2/yr is attributable to natural sources. (In reality, some of this rate is attributable to pre-industrial logging but we group all "pre-industrial" disturbances with natural causes.) The remaining portion of the overall sediment delivery in this period (about 100 tons/mi2/yr), is the anthropogenic proportion. This results in a ratio of approximately **one part human-induced to four parts natural.** This 1:4 ratio can also be expressed as 0.25.

Another consideration is measurement sensitivity. Researchers (Stillwater, 1999) indicate that sediment sources cannot be precisely measured. Thus, a change from the current 1:1 ratio to 1:4 ratio would be considered relevant by researchers, but smaller changes would likely be considered in the range of measurement uncertainty.

The loading capacity is calculated for the South Fork Eel using the 1:4 ratio and the estimated current natural loading rate. The allowable human-induced loading rate is 1/4 of the estimated natural loading rate of 378 t/km2/yr, which is 95 t/km2/yr (378 t/km2/yr * 0.25 = 95 t/km2/yr). The loading capacity, which is averaged over a long time period under a variety of hydrological conditions, is the sum of the natural and allowable human-induced loading rates. Thus, the loading capacity, which equals the TMDL is 473 t/km2/yr (378 t/km2/yr + 95 t/km2/yr = 473 t/km2/yr).

LOAD ALLOCATIONS

The load allocation portion of a TMDL is intended to identify the maximum allowable loads from individual sediment source categories that are necessary to meet the TMDL and loading capacity. For sediment in the South Fork Eel, the major sources of sediment were found to be road-related, including roads associated with timber harvest. The load allocations in the South Fork Eel clarify the relative emphasis and magnitude of erosion control programs that need to be developed in the implementation phase. However, as we discuss further in the implementation recommendations section, EPA recommends that actual sediment reduction programs, as implemented by the Regional Board, utilize field-based assessments of sediment sources, conducted by individual landowners on their properties, which are consistent with the load allocations.

In the South Fork Eel, load allocations emphasize erosion from roads. The load allocation for roads is 41 t/km2/year, based on an 80% reduction from current levels (205 t/km2/year * 0.2 = 41 t/km2/year). The roads category includes road surface erosion, road crossing failures and gullies, and skid trails. Landslides, the remaining source of anthropogenic sediment, would then need a 55% reduction from the levels calculated here (121 t/km2/year * 0.45 = 54 t/km2/year). This includes landslides from roads and landslides from harvest. Together these types of programs will result in the South Fork Eel loading capacity of 1:4 human to natural sediment production (or 473 t/km2/year). The waste load allocation is zero as there are no permitted point sources of sediment discharge to the watershed.

473 t/km2/year = 378 t/km2/year + 41 t/km2/year + 54 t/km2/year
total allocations = natural + roads + landslides

EPA considered the potential for decreasing erosion, based on the availability of improved practices for reducing erosion from roads and unstable areas. Based on methods for storm-proofing roads (Weaver and Hagans, 1994), as well as the professional judgment and experience in North Coast watersheds by Pacific Watershed Associates (as referenced in EPA, 1998), the South Fork Eel TMDL uses a 80% reduction in erosion from roads. EPA has established similar levels of controllability for roads on other North Coast watersheds, such as the South Fork Trinity and Van Duzen. The remaining load was allocated to landslides, which resulted in a 55% reduction.

MARGIN OF SAFETY, SEASONAL VARIATIONS AND CRITICAL CONDITIONS

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs include a margin of safety to account for major uncertainties concerning the relationship between pollutant loads and instream water quality. The margin of safety can be incorporated into conservative assumptions used to develop the

TMDL, or added as a separate, quantitative component of the TMDL (EPA, 1991).

The regulations also require that TMDLs account for seasonal variations and critical conditions.

Margin of Safety

This TMDL incorporates an implicit margin of safety based on conservative assumptions. A major conservative assumption is that sediment reduction efforts can reduce the width/depth ratio of streams, which in turn is expected to reduce stream temperatures. This positive effect was not accounted for in the analysis. Local residents have commented that Rattlesnake Creek, in particular, historically contained cool water habitats, possibly because it was narrower.

In addition, EPA concludes that major sources of uncertainty in the analysis will not have an influence on meeting water quality standards. The largest source of uncertainty is the conclusion by Stillwater Sciences that the sediment source analysis underestimates the total sediment loading in the basin. Prior estimates for the 1942-1966 period were almost three times higher than the current estimated sediment production. The difference could be due to both the reduced runoff in the period estimated, especially the absence of the 1964 flood, and the omission of mainstem sources such as alluvial bank and terrace erosion. In addition, vegetative cover has recovered in many parts of the South Fork Eel, probably leading to lower rates of sediment delivered to streams (see Appendix B). Because of this uncertainty, EPA set the loading capacity and allocations calculations also omitting mainstem sources. This results in more restrictive allocation calculations and provides a margin of safety.

In addition, uncertainty exists in the setting of instream numeric targets. EPA has accounted for this uncertainty by using a conservative interpretation of the science on percent fines and V*.

Overall, collection of site-specific data and refinement of the source analysis in the future will help reduce the uncertainty and eventually allow for fewer conservative assumptions.

Seasonal Variation and Critical Conditions

TMDLs by law and regulation must describe how seasonal variations were considered. There is inherent annual and seasonal variation in the delivery of sediment to stream systems. For this reason, the TMDL is designed to apply to the sources of sediment, not the movement of sediment across the landscape.

The regulations also require TMDLs to account for critical conditions for stream flow, loading and water quality parameters. This TMDL does not explicitly estimate critical flow conditions for several reasons. First, sediment impacts may occur long after sediment is discharged, often at locations far downstream from the sediment source. Second, it is impractical to accurately measure sediment loading and transport, and the resulting short term effects, during high magnitude flow events that produce most channel modifications. Therefore, the approach chosen to account for critical conditions is to use indicators which are reflective of the net long term effects.

IMPLEMENTATION AND MONITORING RECOMMENDATIONS - SEDIMENT

Federal regulations require the State to identify measures needed to implement TMDLs in the state water quality management plan (40 CFR 130.6). EPA expects the State to promptly develop implementation measures and ensure the implementation of erosion prevention and control measures which are adequate to achieve the TMDL. This requirement may be met through State adoption of a TMDL and implementation plan in the Basin Plan, or through incorporation of EPA-established TMDL and State-adopted implementation measures.

EPA recommends that all three major land uses should be considered in developing an implementation plan. Timber production lands can be addressed through either an erosion control program similar to that developed for the Garcia River, or possibly through the THP process, if revisions proposed in 1999 to the forest practice rules are established. EPA believes that rural residential uses, specifically roads, need to be addressed as well.

While the calculations in this TMDL are based on the best information available at this time, sediment reduction programs for the South Fork Eel could be made more effective by making information collection, and possible TMDL revision, a key part of the implementation program.

In addition, to be consistent with the TMDL, sediment source ratios should be calculated on a tributary basin or smaller scale and exclude mainstem alluvial bank and terrace erosion in estimates of future man-made to natural sediment estimates.

Public Participation

A TMDL must include public participation, including: public notice, public comment, and consideration of public comment. Outreach activities by EPA included two informal public meetings in Garberville, a radio show, several meetings with interested parties, a public hearing and responding to public comments through changes to the TMDL and a comment response summary. In addition, notices of the availability of the draft report were sent to local newspapers and radio stations, generating several newspaper articles in the Eureka Times Standard and Santa Rosa Press Democrat. The draft report was available on USEPA Region 9's web site.

When the Regional Board conducts the implementation planning process for the TMDL, there will be additional State-sponsored public participation for the implementation plan.

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