U.S. Environmental Protection Agency

Region IX

FINAL

Upper Main Eel River and Tributaries (including Tomki Creek, Outlet Creek and Lake Pillsbury)

Total Maximum Daily Loads for Temperature and Sediment

Approved by date

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CHAPTER 1: INTRODUCTION

1.1 OVERVIEW OF THE TMDL PROGRAM

The primary purpose of the Total Maximum Daily Load (TMDL) program for California's Eel River is to assure that beneficial uses of water (such as salmonid habitat) are protected from adverse increases in natural sediment and temperature. The water quality problems in the Upper Main Eel River and tributaries (including the areas of Tomki Creek, Outlet Creek and Lake Pillsbury) addressed in this report are related to the decline of salmon and steelhead populations. While many factors have been implicated in the decline of west coast salmon and steelhead, we are concerned here solely with two inland water quality considerations - increases to the natural sediment and temperature patterns. The Upper Main Eel (along with many other watersheds in California and throughout the nation) has been put on a list of "impaired" or polluted waters. In this watershed, the listing leads to the TMDLs. The TMDLs set the maximum levels of pollutants that the waterbody can receive without exceeding water quality standards. Development of measures to implement the TMDL is the responsibility of the State of California.

The Upper Main Eel River Total Maximum Daily Loads (TMDLs) for sediment and temperature are being established in accordance with Section 303(d) of the Clean Water Act, because the State of California has determined that the water quality standards for the Upper Main Eel River are not met due to excessive sediment and temperature. In accordance with Section 303(d), the State of California periodically identifies *"those waters within its boundaries for which the effluent limitations... are not stringent enough to implement any water quality standard applicable to such waters."* In 1992, EPA added the Upper Main Eel River to California's 303(d) impaired water list due to elevated sedimentation and temperature, as part of listing the entire Eel River basin. The North Coast Regional Water Quality Control Board (Regional Board) has continued to identify the Upper Main Eel River as impaired in subsequent listing cycles, the latest in 2002.

In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus, No. 95-4474 MHP, 11 March 1997*), December 31, 2004 is the deadline for establishment of these TMDLs. Because the State of California will not complete adoption of TMDLs for the Upper Main Eel River by this deadline, EPA is establishing these TMDLs. Under this consent decree EPA has established TMDLs for many watersheds in the North Coast of California, including the South Fork Eel, North Fork Eel, Van Duzen and Middle Fork Eel. Additionally, the North Coast Regional Water Quality Control Board has established the Garcia River TMDL and associated action plan.

The purpose of the Upper Main Eel River TMDLs is to identify the total amount (or load) of sediment and heat that can be delivered to the Upper Main Eel River and tributaries without exceeding water quality standards, and then to allocate the total amount among the sources of sediment or heat in the watershed. EPA expects the Regional Board to develop an implementation strategy that will result in implementing the TMDLs in accordance with the requirements of 40 CFR 130.6. The allocations, when implemented, are expected to result in achieving the applicable water quality standards for sediment and temperature for the Upper Main Eel River and its tributaries.

These TMDLs apply to the portions of the Upper Main Eel River watershed governed by California water quality standards. They do not apply to lands under tribal jurisdiction. This is because tribal lands, as independent jurisdictions, are not subject to the State of California's water quality standards.

1.2 WATERSHED CHARACTERISTICS

The Upper Main Eel River watershed area is located primarily in Mendocino and Lake Counties in Northwestern California. It is primarily east of Highway 101, approximately 150 miles northeast from San Francisco, and includes the town of Willits. The Upper Main Eel watershed, as defined by this TMDL is the area from the headwaters of the Eel River in Mendocino National Forest above Lake Pillsbury down to Dos Rios, where the Upper Main Eel meets the Middle Fork Eel. The main tributaries are Tomki and Outlet Creeks (see Figure 1.) The Upper Main Eel River TMDL area is 688 square miles (approx. 440,384 acres) of which 359 square miles are in private ownership and 329 square miles in public ownership. There is no commonly used name of the area as a whole. This analysis includes all of the tributary streams of the Upper Main Eel from the headwaters to Dos Rios. The State hydrologic area naming convention is 111.60 Upper Main Eel River HA, consisting of 11.61 Outlet Creek, 11.62 Tomki Creek and 11.63 Lake Pillsbury.

The Potter Valley Project, a small hydroelectric plant and water diversion, is contained within the study area. The project has two dams - the larger Scott Dam and associated Lake Pillsbury and 12 miles downstream a smaller Cape Horn Dam and Van Arsdale reservoir, where water is diverted adding water supplies to the Potter Valley Irrigation District and Sonoma County through Lake Mendocino and the Russian River (see Figure 1). The Potter Valley Project has been in operation for approximately 90 years and is licensed by the Federal Energy Regulatory Commission (FERC.) Pacific Gas and Electric (PG&E) was issued a new hydro power license in 1983, which contained certain flow requirements. These flow requirements were changed with the most recent FERC order amending the license (FERC, Jan 2004) generally consistent with the National Marine Fisheries Service (NMFS) Biological Opinion under the Endangered Species Act. A June 2004 FERC order required PG&E to implement the new flow regime. The new flow regime has been in effect since the June 2004 order.

The area's geology is underlain by the Franciscan terrain that dominates most of California's North Coast. Naturally unstable, this type of geology is sensitive to human disturbance. The Upper Main Eel watershed is relatively dry and warm, away from the influence of coastal fog. Almost all of the estimated 40 inches of annual rainfall occurs between November and April. Many smaller tributaries dry up in late summer. Land use activities in the Upper Main Eel include rural development, ranching, recreation in Mendocino National Forest, timber production, agriculture and some urbanized areas in the Willits area.

<<This page intentionally left blank for insert of Figure 1 – Map of major features of Upper Eel River TMDL area>>

1.3 ENDANGERED SPECIES ACT CONSULTATION

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

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

1.4 ORGANIZATION

This report is divided into 6 chapters. Chapter 2 (Problem Statement) describes the nature of the environmental problems addressed by the TMDLs - fish population, stream temperature problems, sediment problems and water quality standards. Chapter 3 (Temperature TMDL) describes the modeling used to evaluate the temperature changes from differing amounts of shade and stream flow, and identifies the TMDL and allocations. Chapter 4 (Sediment TMDL) describes the sediment source analysis used to evaluate the proportion of human caused sources of sediment, sets the TMDL and allocations. Water Quality indicators for sediment are also identified. Chapter 5 (Implementation and Monitoring Recommendations) contains recommendations to the State regarding implementation and monitoring of the TMDLs. Chapter 6 (Public Participation) describes public participation in the development of the TMDLs.

CHAPTER 2: PROBLEM STATEMENT

This chapter summarizes temperature and sediment effects on salmonids in the Upper Main Eel River and tributaries. It includes a description of the water quality standards and salmonid habitat requirements related to temperature and sediment. In the near future, additional information concerning these issues may be available in the Department of Fish and Game's draft Watershed Assessment for Outlet Creek. The DFG assessment will provide additional information on stream sediment conditions, water temperature monitoring and other stream habitat conditions.

2.1 FISH POPULATION PROBLEMS

Both chinook and steelhead are widely distributed throughout the watershed. Historically their populations may have been more than ten thousand, but presently chinook and steelhead are at reduced levels. Coho are only found in a few streams tributary to Outlet Creek. Rainbow trout are found in streams above Lake Pillsbury in Mendocino National Forest.

Data on population trends for the entire California Coastal Chinook and Northern California steelhead are sparse (NMFS, 2003.) A recent preliminary scientific review of the information on salmonid abundance under the Endangered Species Act (NMFS, draft 2003) concluded that the California Coastal Chinook, Northern California Steelhead and California Coastal Coho (including salmonid populations in the Upper Main Eel TMDL area) are "likely to become endangered in the foreseeable future." The available data reviewed included adult spawner returns to Cape Horn Dam and surveys of Tomki Creek, both within the Upper Main Eel TMDL area. The general pattern is one of overall decline combined with a recent increase. The scientific review panel's preliminary conclusion is that "populations would have to maintain themselves for a longer period of time at levels considered viable before it could be concluded that they are not at significant continuing risk." (NMFS, 2003)

Figure 2 is the adult chinook returns to Cape Horn Dam (Van Arsdale) from 1946-2003 and the adult steelhead returns from 1922-2003. This data includes both hatchery returns and returns of wild salmonid populations. Returns from hatchery fish are strongly correlated to the numbers of juveniles planted in the system in previous years. The chinook data at Cape Horn Dam is considered inappropriate for determining population trends (NMFS, 2003) due to concerns regarding its location at the limit of spawning habitat.

Changes in fish distribution and abundance are also indicators of problems with protection of beneficial uses. Chinook salmon are widely distributed in the watershed, except for the areas blocked by Scott Dam since its construction in 1921. California Department of Fish and Game has conducted carcass surveys during the spawning season and reports that during 1987-1989; hundreds of spawners were counted in Ryan, Baechetl and Long Valley Creeks -- tributaries to Outlet Creek. Outlet Creek had nearly 1000 spawners during 1988. Estimates of the amount of miles blocked by Scott Dam vary from 35-40 miles (NMFS, 2002) to

100-150 miles of potential habitat (USFS, 1995.) Because chinook salmon juveniles do not rear in freshwater during the summer, the summer temperature problems of the Upper Main Eel are not relevant to chinook. Tomki Creek surveys from 1964-1996 indicate a wide variation (0-3600) in returning adult spawners. Historical personal accounts report that chinook spawners were more abundant before the 1964 flood (MCRCD, 1983.)

Coho are present in the watershed but only in a few locations and not every year. Coho salmon have been reported 4 times since the 1940's at the Van Arsdale, most recently four coho were identified in 2001. Department of Fish and Game stream inventory reports also report a few adult coho carcasses during 1987-1989 in Outlet Creek, and in several tributaries to Outlet Creek (Long Valley, Broaddus Creek, Baechtel Creek, Ryan Creek, and Haehl Creek). Juvenile coho were not reported by DFG in any of these streams during 1995. While the current observations are of coho in very small numbers, it appears this may also have been the case historically. EPA did not find any information indicating that coho were more widely distributed historically.

Steelhead are widely distributed throughout the watershed, except above Scott Dam where rainbow trout are resident. The distribution of juvenile steelhead is of special interest as summer temperatures are an important facet of their distribution and abundance. In the Upper Main Eel TMDL study area, juvenile steelhead are widely distributed. Department of Fish and Game stream survey reports detail the presence of juvenile steelhead in tributaries to Outlet Creek - Haehl Creek, Ryan Creek, Bear Pen Canyon Creek, Baechtel Creek, Cherry Creek, Bloody Run Creek, Broaddus Creek, and Long Valley Creek. They were also present in Willits Creek, Benmore Creek, Tomki Creek and Cave Creek. Mendocino National Forest trout streams include: Salmon, Smokehouse, Cold, Rice, Soda, Panther, Copper Butte, Hummingbird, Thistle Glade and Blue Slide Creeks. Again, historical personal accounts report that steelhead juveniles were more abundant before the 1964 flood: *"It was, at that time, very easy to catch 25 (the limit at that time) pan-size trout, 6"-7" long, out of these holes..."* (MCRCD, 1983.) The area between Lake Pillsbury and Van Arsdale is often reported to be productive for juvenile steelhead. Interested readers can also review previous detailed reports (SEC, 1998; NMFS, 2002) on salmonids in the Upper Main Eel.

Many different habitat conditions are crucial for the survival of salmon and steelhead. Salmonid populations are affected by a number of factors outside of the Upper Main Eel TMDL area, including commercial and sport harvest, and ocean conditions. Additional local habitat conditions such as large woody debris and possibly pike minnow predation may also be factors. These TMDLs focus only on the achievement of the water quality standards related to sediment and temperature, which will facilitate, but not guarantee, population recovery. In addition, the temperature TMDL focuses on summer stream temperatures, which are most relevant to steelhead, as chinook juveniles do not rear in fresh water streams and coho are only found in a few small tributaries. The following sections summarize how summer stream temperature affect salmonids and how sediment conditions affect salmonids.

2.2 STREAM TEMPERATURE PROBLEMS

This section presents the available information on stream temperature problems for salmonids in the Upper Main Eel and tributaries. Stream temperature directly governs almost every aspect of the survival of Pacific Salmon (Berman, 1998). Temperature is such an important requirement that coho, steelhead, chinook and rainbow trout are known as "cold water fish." Metabolism, food requirements, growth rates, timing of adult migration upstream, timing of juvenile migration downstream, sensitivity to disease and direct lethal effects are affected by stream temperatures (Spence et al, 1996.)

The most sensitive period in the Eel River is the summer, when young salmonids rear for several summers before migrating to the ocean and stream temperatures are hottest. Thus, this is the period analyzed in the temperature TMDL.

Stream temperatures in the Pacific Northwest naturally provide a wide range of summer conditions for rearing salmonids. However, removing riparian vegetation from timber harvesting, road building, grazing, and urbanization can increase stream temperatures. Changes in the timing and amount of the natural streamflow, such as water diversions and impoundments, can also change the water temperatures downstream. Increases in sediment input also change the stream channel by widening streams, filling pools and eliminating riparian vegetation during flood events. Of primary interest to water quality standards and this TMDL is determining the extent to which the summer stream temperatures are natural and to what extent they have been influenced by human activities. Chapter 3 investigates whether or not the stream temperatures monitored in the Upper Main Eel and tributaries are natural. This section summarizes the literature on stream temperatures and salmonids, regardless of whether or not those temperatures are natural.

In order to summarize stream temperatures, which are often monitored hourly or more and fluctuate daily and seasonally, this TMDL uses the maximum value of the 7-day running average of all recorded temperatures. Although the term MWAT (maximum weekly average temperature) is used often in the literature, it is an inexact term and used inconsistently. The abbreviation max7daat is used herein for the 7day running average of all recorded temperatures.

EPA summarizes the condition of streams for steelhead summer rearing based on the max7daat. This evaluation, shown in Table 1, categorizes the quality of summer stream habitat in regard to temperature based on previously compiled reviews of the literature. The literature on which this evaluation is based has investigated salmonid response in both the laboratory and the field. The primary literature reviews used by EPA to compile Table 1 are EPA Region 10, 2001a&b; Sullivan et al., 2000 and Myrick & Cech, 2001. This TMDL focuses on steelhead temperature tolerances because chinook are not present in the summer and coho are only found in a small area of Outlet Creek. These temperature habitat evaluations (adequate, lethal etc) are not precise in the stream or in the literature, because salmonids are affected by many factors, including the degree of fluctuation in temperature, presence of competition and disease, food availability and access to cool water refugia areas.

<<<This page left intentionally blank for insert of Figure 2 – Adult returns to Van Arsdale>>

EPA concludes that any increase to natural stream temperatures is adverse to the success of steelhead rearing when the monitored max7daat summer temperatures is between 13-27EC. It appears from the literature review that salmonids benefit from cooler summer temperatures, except at very high or low temperatures. Given that low summer temperatures do not exist in the Upper Main Eel TMDL area, EPA did not consider in detail issues regarding effects (beneficial or adverse) of raising temperatures cooler than optimal.

For this TMDL, incremental changes to very warm stream temperatures are a key concern. In the main channel of the Eel below Van Arsdale, monitored temperatures are between 24° - 27.8EC. Lowering these temperatures to good or adequate rearing temperatures (13-19EC) is not achievable. Thus, EPA scrutinized the literature to determine if more modest temperature changes were beneficial. For example, is it beneficial to lower the max7daat from 28EC to 27EC or from 26°C to 25EC? EPA determined that the evidence is that these decreases are beneficial, albeit they will not result in the presence of abundant steelhead.

EPA considered that for salmonids mortality is a function of magnitude and duration of exposure to stream temperatures (Sullivan, 2000.) Sullivan summarizes: *"continuous exposure of 3-30 hours are necessary to cause mortality at temperatures between 24EC to 26EC...The duration of time necessary to cause mortality decreases sharply with small increments of temperature above approximately 26EC. Short duration excursions (less than 2 hours) above 27EC are very likely to cause mortality of some individuals..."* The USEPA Seattle (USEPA, 2001) temperature project noted the following: "*With cautious acclimation…rainbow trout may not experience LT50 (50% mortality) until a week at 26°C. Even with careful acclimation, 27°C results in high or complete mortality in less than 24 hours… and temperatures of 29-30°C result in 50% mortality in 1-2 hours."* McCullough, 1999 (as reviewed in USEPA, 2001) found that: "in general, a maximum temperature of 22-24°C represents the normal upper temperature limit in the field…as this limit is approached, juvenile density declines to zero."

While it appears from the literature that streams with a max7daat of >26EC will cause mortality[1], field observations and some literature indicates that streams with these monitored temperatures are used by steelhead. Most of these observations included areas of cooler water refugia. Thermal refugia refers to cooler water areas within a stream. Streams often have a variety of areas that provide cooler water formed from cooler tributary inflow, groundwater or spring inflow, intergravel flow or stratification of pools. These thermal refugia can provide a much-needed refuge in hot periods of the day and during the hottest times of the year. Nielsen & Lisle (1994) noted that cold pockets in the nearby Middle Fork Eel "were consistently about 3.5E C cooler than surface water and as great as 7.8E C cooler." Nielsen also noted steelhead actively feeding in water with temperature of 24°C. Stream temperature monitoring does not often monitor these refugia conditions or localized variations. Advances in stream temperature monitoring, such as FLIR, show that localized cool patches are a common feature of many streams.

[1]Outlet Creek, with a 26.5EC max7daat, had 25 days with 2 hours over 26EC and 15 days with 6 hours over 26EC (HC RCD database 2000.)

These types of refugia areas exist in the Upper Main Eel. Steelhead are localized into refugia areas of cooler water in the Upper Main Eel between Tomki and Outlet Creek. Areas of cool spring flow were mentioned by Kubicek around Hearst where 'several' steelhead were also observed, and stratified pools were also noted at Fish Creek. In addition, there appear to be several cooler tributaries where stream temperatures are consistently low. Garcia Creek appears to provide cool conditions and National Marine Fisheries Service staff (Jahne, personal communication) noted that numerous juvenile steelhead use the main channel of the Eel despite the daily average temperature of 24EC near this cooler tributary inflow. DWR also monitored stratified pools with satisfactory bottom temperatures above Tomki Creek in 1973. Two ten foot pools were monitored and bottom temperatures ranged from 21 - 24.5C. Kubicek also noted spring flow in the area between Van Arsdale and Tomki Creek.

Based on the literature, EPA expects that the incremental reductions in temperature to warm streams, where the max7daat is 24E-27EC, are beneficial, although the improvements for in juvenile populations are expected to be modest..

Table 1 summarizes the literature concerning the effects of varying stream temperatures on juvenile steelhead.

There are approximately 35 locations with summer stream temperature monitoring data. Many of these locations have been monitored for multiple years from 1996-2003 (HCRCD, 1996-2003.) Figure 3 shows many monitoring locations and their associated max7daat during the summers of 1996 – 1999.

Figure 3 illustrates that most stream monitoring locations have summer stream temperatures which are categorized as marginal, stressful or lethal (19EC - >24EC). Only four smaller tributaries had summer stream temperatures evaluated as good (17EC.) When compared with other areas of the Eel (HCRCD, 2003) the monitoring indicates that the stream temperatures in the Upper Main Eel TMDL area are quite warm. In Chapter 3, Temperature TMDL, modeling results indicate that this warmer pattern is characteristic.

Observations of steelhead presence and stream temperatures in the Upper Main Eel TMDL area are generally consistent with Table 1 above. For example, the area between Lake Pillsbury and Cape Horn Dam has been considered a productive area for rearing steelhead, this area has a max7daat of approximately 20EC. In contrast, juvenile steelhead are not consistently observed between Tomki Creek and Outlet Creek on the Upper Main Eel where stream temperatures are monitored at 24-28C max7daat. When juvenile steelhead were observed in Tomki Creek and Outlet Creek only individuals or stressed steelhead were usually noted (DFG, 1997 – 1998.)

Table 1. Evaluation of Effects of Stream Temperatures on Juvenile Steelhead

Stream temperature evaluation	Stream temperature monitoring period (Max7daat) *maximum 7 day average of all monitored temperatures*	References/Notes (a) USEPA (2001a, b) (b) Sullivan et al, 2000 (c) Myrick, Cech (2001)
GOOD	13-15E C (59E F)	maximum growth - food limitation preferred range 13-15° C (a) protective threshold for summer rearing in the Pacific NW, adjusted from daily max to daily mean. 13°C applicable in Oregon at >3000 foot elevation
GOOD	15-16.99E C (59-63E F)	within preferred range
ADEQUATE	17-18EC (63-66EF) 18- 19	19C upper end of maximum growth – optimal conditions 17C maintenance of population abundance within 10% (b)
MARGINAL	19-20	20C upper end of preferred range
STRESSFUL	20 - 21 21- 22	increased risk of disease 22C cessation of feeding
STRESSFUL	22 - 23 23- 24	22-24°C maximum temperature, juvenile density declines to zero (a)
LETHAL (within days)	24 - 25EC (75E F)	Lethal -chronic conditions - upper incipient (7day LD50) within days (a, b, c) steelhead presence noted in water with temperatures >24C when cool water refugia areas are present
LETHAL	25 - 26	Lethal - 6 hour LT10 (a)
LETHAL (within hours)	> 26	Lethal - 26.5 1 hour LT10 (a) Critical thermal max (28 - 32C) instantaneous loss of equilibrium

Trends in stream temperature

The natural or historical stream temperatures are not known for the Upper Main Eel. No information on pre-dam conditions was uncovered, nor general stream temperatures before the 1964 flood. However, information regarding stream channel changes and riparian vegetation changes indicates that shade over certain channels is less than prior to the 1964 flood. Interviews with long time residents of the Tomki Creek area reported that *"Most of the deep pools (over 10 feet deep) were filled with gravels and sediment during the major flood events... During the 1920s to 1930s, most of Tomki Creek from Cave Creek to Wheelbarrow Creek had no perennial flow, with the riffles drying up during the summer and the holes remaining full. Above the Hearst-Willits Road ford crossing many of the pools were 15' - 20' in depth... It was impossible to see String Creek from the road because of the dense vegetation."* (MCRCD, 1983.) In addition to the general loss of riparian vegetation, Tomki Creek also experienced a loss of shade because of stream widening. Between the mouth of String Creek and Cave Creek, 1952 photos indicate maximum channel widths of 200 feet; around 1983 it was 400 feet, primarily due to gravel extraction during that time period.

Temperature monitoring for the Eel was conducted extensively during 1973 (Kubicek, 1977), but this was conducted after much of the shade and flow alterations had already taken place. In general, Kubicek reports the same patterns noted by the Humboldt County RCD database - stressful and lethal temperatures in the main channel, with limited cool water refugia noted. The Humboldt Country RCD temperatures are presented in Figure 3. A comparison of 1996 stream temperatures to the Kubicek 1973 temperatures in some locations in the Upper Main Eel TMDL area has been conducted (HCRCD, 1998.) Five locations were compared and none had significant variation.

<<<<This page intentionally left blank for insert of Figure 3 –
Map of temperature monitoring sites and max7daat in Upper Eel>>>>

2.3 SEDIMENT PROBLEMS

Salmon requirements related to stream sediment

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

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

An imbalance between fine or coarse sediment supply and transport can also adversely affect the quality and availability of salmonid habitat by changing the morphology of the stream. It can reduce overall stream depth and the availability of shelter, and it can reduce the frequency, volume, and depth of pools. Pools provide salmon a resting location and protection from predators.

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

Sediment conditions in the Upper Main Eel

Historical trends

The flow of the Eel River and its tributaries above Lake Pillsbury is unregulated and highly influenced by rain events. Downstream of the Scott Dam, which forms Lake Pillsbury, the river flows through a narrow canyon until much of the flow is diverted through a tunnel to a Pacific Gas and Electric Company powerhouse in Potter Valley where it converges with the East Fork of the Russian River and through Lake Mendocino. The un-diverted flow drains into the Van

Arsdale Reservoir, which is formed by the Cape Horn Dam. Flow is then released from the dam and continues downstream towards the ocean.

Much of the bedrock in the Upper Eel River watershed is sedimentary and metamorphic rock along with ultramafic and volcanic rocks from the Jurassic period. Weathering, which is impacted by slope, aspect, wind, rainfall, temperature, bedrock composition, and biological activity (decomposition of organic matter), produces soils that may be subject to landslides and erosion. Soils with a high hazard rating (higher tendency to slump or slide) cover about 40 percent of the watershed and only 3 percent is considered to have a low hazard rating. Slides, slumps, and erosion are fairly common in the watershed and nearly one-sixth of the area upstream of Van Arsdale Reservoir is prone to landslides (USFS 1995).

Lake Pillsbury has become a trap for the sediment that erodes from the most northern portion of the watershed, retaining 94 percent of sediments supplied from upstream (Brown and Ritter, 1971). Coarse materials are preferentially trapped, resulting in the lack of gravel recruitment to downstream areas (Brown and Ritter, 1971). The lake had an initial storage capacity of 94,400 acre-feet, which was reduced to 86,780 in 1959 (Porterfield and Dunnam 1964 in USFS 1995) and 80,700 in 1984 (Brooks et al. 1984 in USFS 1995), resulting in a 14.8 percent reduction in the storage capacity since 1921. Tracking the loss of storage capacity in Lake Pillsbury can be used as a surrogate measure of the amount of sediment deposited to the upstream tributaries over time. The sediment deposited to Lake Pillsbury also contributes to the turbidity problem in the lake, which is exacerbated by the presence of fine-grained clays that stay in suspension for extended periods of time (USFS 1995). Downstream of Lake Pillsbury, the Van Arsdale Reservoir is small enough and filled enough that it does not appear to impair sediment transport past Cape Horn Dam.

Other factors that have historically impacted erosion and sediment delivery in the watershed include trails, roads, grazing, and fire. For example, upstream of Van Arsdale, American Indians and ranchers historically used trails for traveling, while many roads were built in the 1930s and later became the backbone for today's transportation network. Increased logging operations forced the development of additional roads, many of which were not designed to withstand large rainfall events (USFS 1995). Grazing and fire both reduce vegetation, thus making soil available for erosion. Grazing controls have been in place since 1907 with the creation of the Mendocino National Forest; however, fire has increased erosion in several subwatersheds, especially during the 1987 fire season (USFS 1995).

In the winter of 1964, warm rain falling on the snowpack triggered the release of a tremendous amount of water in a short period of time, causing a great flood. This flood was very damaging to areas of the Mendocino National Forest and other forests in northwestern California. It has been estimated that the highest 3 days of the 1964 flood were responsible for moving over one-half of all sediment transported during a 10-year period upstream of Scott Dam (Brown and Ritter 1971 in USFS 1995).

Information regarding specific effects of the 1964 flood in the Upper Eel River watershed exist for Tomki Creek. As discussed in Section 2.2, Tomki Creek was greatly widened, lost much of its riparian cover and lost most of the deep pools that were present before the 1964 flood (MCRCD, 1983.) Additionally areas of Tomki Creek were used for gravel extraction and were greatly widened, from 200 foot maximum channel width to 400 foot maximum channel width.

Current conditions & evaluation of stream recovery

Very little information is available regarding the recovery of the Upper Eel River after the 1964 flood. The California Department of Fish and Game is scheduled to complete a draft watershed assessment on Outlet Creek during the Winter 2004/2005. This watershed assessment is expected to provide additional instream sediment measurements, as well as other information on the stream condition. The California Department of Fish and Game Stream Inventory Reports provided useful information regarding current sediment conditions in the watershed (CDFG Stream Inventory Reports 1991-1998). Using pool embeddedness (estimated visually) as an indicator, streams in the Upper Eel River were found to have variable conditions for salmon. Of the eighteen streams observed for embeddedness, only two streams had over 50% of pools with very good conditions and three streams had over 50% of pools with very poor conditions or conditions completely unsuitable for spawning. The majority of streams were in between, ranging from 26-75% embedded. These observations, while not a comprehensive inventory, covered large portions of tributaries including Alder Creek, Baechtel Creek, Bear Pen Canyon Creek, Benmore Creek, Bloody Run Creek, Broaddus Creek, Cave Creek, Cherry Creek, Haehl Creek, Long Valley Creek, Outlet Creek, Ryan Creek, String Creek, Tomki Creek, Unnamed Tributary #1 to Cave Creek, Unnamed Tributary #2 to Cave Creek, Unnamed Tributary #3 to Cave Creek, and Willits Creek.

Upstream of Van Arsdale Reservoir, in the Lake Pillsbury Hydrologic Unit Area (HUA), the USFS has noted that in some areas, the roads and trails often function as first order streams by transporting water and sediment to other drainages (USFS 1995). In particular, there are over 175 miles of trails (including about 100 miles of designated off-highway vehicle trails) and over 760 miles of road (about 3900 road/stream crossings). These conditions facilitate the transport of sediment to streams and without proper maintenance and planning, can increase erosion and sediment available for transport. In addition, approximately 70 percent of the roads in the watershed are insloped, which may cause the roads to deliver water and sediment to nearby drainages (USFS 1995). Many of the current roads have been designed to reduce their erosion potential; however, ongoing maintenance is required to control sedimentation. Overall, the Lake Pillsbury HUA is considered to be in better condition than other portions of the watershed and has a lower road density than many other regions of the North Coast.

Lake Pillsbury continues to trap sediments draining from the upstream area. In 1992, USFS personnel indicated that the rate of lake filling is similar to the 1959-1984 rate described previously (USFS 1995). The base of the sediment wedge from the Rice Fork tributary is approaching the base of the dam. The lake is not yet filled to a critical point; however, bathymetry measurements are expected to be taken in the coming years to better clarify the extent of the problem.

In summary, data regarding the sediment conditions for many streams in the Upper Eel indicate adverse impacts from the combined effects of the 1964 flood and land use practices at that time. It is likely that the widespread sedimentation and channel changes that occurred following the 1964 flood provided difficult conditions for salmonid survival (e.g., higher proportions of fine sediment, filling of pools, etc.). While there may be some recovery of the stream channel since the 1964 flood, an overall assessment of stream conditions is not available and the available information from DFG reports indicates variable conditions.

2.4 WATER QUALITY STANDARDS

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

The beneficial uses and water quality objectives for the Upper Main Eel River are contained in the Water Quality Control Plan for the North Coast Region (Basin Plan), as amended (NCRWQCB 2001). The Basin Plan identifies many beneficial uses for the Upper Main Eel River, specifically: Municipal and Domestic Supply; Agricultural Supply; Industrial Process Supply; Groundwater Recharge; Water Contact Recreation; Non-contact Water Recreation; Commercial and Sport Fishing; Cold Freshwater Habitat; Rare, Threatened or Endangered Species; Migration of Aquatic Organisms; and Spawning, Reproduction and/or Early Development.

The water quality objectives pertinent to the Upper Main Eel River temperature and sediment TMDLs are listed in Table 2. In addition to water quality objectives, the Basin Plan includes two prohibitions specifically applicable to logging, construction, and other associated sediment- producing nonpoint source activities:

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

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.

Table 2. Water Quality Objectives

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

CHAPTER 3: TEMPERATURE TMDLs

This chapter describes the analytical basis for the temperature TMDLs, along with the TMDLs and allocations. The TMDL is divided into two parts. The first analysis is for shade for all stream reaches in the Upper Main Eel area. The second analysis is for the stream reach between Van Arsdale and Outlet Creek where diversions from the Potter Valley Project are an additional concern.

The analysis described in this chapter indicates that alterations in shade result in alterations in stream temperature in the Upper Main Eel River and tributaries. Furthermore, the analysis indicates that temperature alterations are possible under some interpretations of the State's Forest Practices Rules. If harvesting of larger riparian conifers takes place extensively within the watershed, the cumulative effects will adversely affect steelhead.

The second part of the analysis -- the impacts of flow on stream temperature from Van Arsdale to Outlet Creek -- indicates that flow alterations result in temperature alterations under many conditions. In addition, EPA concludes that the stream temperatures likely to result from the new June 2004 FERC flow requirements will facilitate attainment of water quality standards.

This chapter first describes EPA's interpretation of the narrative water quality standard for temperature. The chapter then describes the temperature modeling for solar radiation and shade for all stream reaches and sets a TMDL for solar radiation (in terms of langleys/day) and allocations in terms of shade for all stream reaches. A instream heat TMDL (in terms of BTUs) is also set for the reach between Van Arsdale and Outlet Creek because temperatures in that reach are affected by hydrological modification as well as shade.

3.1 INTERPRETING THE EXISTING WATER QUALITY STANDARDS FOR TEMPERATURE

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

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

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

EPA interpreted the above standards for the TMDL as follows. EPA used a model to compare "natural stream temperatures" with current stream temperatures and temperatures under likely future management conditions. In considering the first objective, EPA then examined whether these alterations (changes in stream temperatures) would adversely affect the most sensitive beneficial use - that is, cold water fish during the summer rearing period. EPA's evaluation of "adverse" effects is based on the scientific literature on steelhead temperature tolerances (summarized in Table 1). EPA evaluated whether or not the changes in stream temperature also negatively affected the quality of stream temperatures. In general, any increase (warming) of natural summer stream temperatures is adverse to rearing steelhead.

The second objective (i.e., not increasing the stream temperature more than 5 degrees F) was evaluated by comparing every modeled point on the stream for exceedance of the 5 degree objective. This objective is more difficult to exceed than the first objective; therefore, the attainment of the first objective will meet the second objective.

3.2 TEMPERATURE MODELING

Stream temperature has been widely studied and the physics of heat transfer is one of the better understood processes in natural watershed systems (TFW, 2000.) Many factors affect stream temperature including solar radiation, air temperature, local shading, climate, stream flow and depth, channel morphology, groundwater inflow and upstream temperatures. Modeling of stream temperature is a well developed area of inquiry and many models are available to assist policymakers in understanding the factors controlling stream temperatures.

EPA funded Tetra Tech Inc. to develop and run the Q2ESHADE model to evaluate both the influences of different flow scenarios and different shade scenarios. The Q2ESHADE model allows EPA to examine how stream temperatures change in relation to different assumptions on flow, upstream temperatures, and shade (as influenced by the size of riparian vegetation, specifically conifers.) Appendix A provides a more complete discussion of the model components, assumptions and data. The Q2ESHADE combines elements of two models (Qual2E and SHADE) to examine cumulative effects on stream temperature throughout all modeled areas in a stream network. Qual2E, the first model, is a publicly available model and is widely used in analyzing many water quality problems. Chen, et al (1998) originally developed a model called SHADE that when linked to other models, can provide basinwide (e.g. cumulative effects) information regarding streamside vegetation changes. The Tetra Tech version of SHADE is a simplification of certain components of the Chen model (see appendix A.) Inputs from the SHADE model are linked to Qual2E to provide routing of local stream heating or cooling (from vegetation, flow changes, tributary cooling etc) downstream through the stream network.

Details on the models calibration performance is available in Appendix A. Calibration performance is available for hourly, daily and max7daat.

The model was applied to two separate subareas of the Upper Main Eel TMDL area - Tomki Creek and the main channel of the Eel between Van Arsdale and

Outlet Creek. Tomki Creek, including tributaries to Tomki Creek, was modeled for alterations in shade. Tomki Creek was chosen because the proportion of vegetation types represent a middle ground condition between the heavily forested subwatersheds in Mendocino National Forest and the less forested area of Outlet Creek. In addition, sufficient data was available for Tomki Creek. This modeling approach was used to develop a temperature TMDL for solar radiation for all stream reaches.

The main channel of the Upper Eel from Van Arsdale downstream to Outlet Creek was modeled separately to take into consideration the flow diversion at Van Arsdale. EPA wanted to explicitly analyze the different flow regimes for this reach to evaluate their attainment of the narrative water quality standard. An additional TMDL component for instream heat (in BTUs) is calculated for the main channel of the Eel between Van Arsdale to Outlet Creek. This is needed due to the additional influence of hydrological modification on stream temperature in this reach.

In response to comments on the draft TMDLs, EPA revised the modeling for the final TMDL for the reach between Van Arsdale and Outlet Creek. The revisions were a reinterpretation and averaging of the existing detailed data on stream width, depth and velocity. While this resulted in changes in the magnitude of the effect of flow on stream temperature, the basic relationships between scenarios is the same as in the draft TMDL.

3.2.1 Temperature and Solar Radiation Modeling

Tomki Creek was selected as a representative area of the entire Upper Main Eel to determine if changes in riparian vegetation allowed under current management practices alter natural stream temperatures in the Upper Main Eel TMDL area. The majority of stream riparian areas are managed either by private landowners or the Mendocino National Forest.

The Mendocino National Forest manages under the Northwest Forest Plan, which protects the riparian zone from timber harvest and promotes natural riparian vegetation. The Northwest Forest Plan does allow some harvest of larger diameter tree, however, not in the riparian reserves. Riparian reserves are approximately 300 feet on each side of the edge of the active stream channel for fish bearing streams and 150 feet for periennial, non-fish bearing streams.

The Mendocino National Forest prohibits timber harvest in riparian reserves except to further promote riparian restoration and only if large woody debris needs are met. Thus EPA's interpretation is that the Northwest Forest Plan will result in natural size of conifers in the riparian zone. For roads that may be affecting shade, the Mendocino National Forest standards also require minimizing road locations in riparian reserves. In addition, USFS projects are required to comply with the Regional Water Board's current Waiver for discharges related to Timber Operations. This waiver reiterates the water quality standard of no alteration of stream temperature.

Private lands are managed by private landowners, and riparian vegetation can be removed or altered by grazing, vineyard development, housing development or timber harvest. Timber harvest is permitted under the State's Forest Practices Rules. The Forest Practices rules specify a 85% canopy retention and the retention of the 10 largest conifers per 330 feet of stream, if the stream is anadromous fish bearing. Canopy retention for other streams is 50%. However, the canopy retention can be met while harvesting the tallest trees and depending upon the width of the stream and other site conditions, shade over the stream is potentially reduced.

The analysis below assumed that the type of vegetation currently present in riparian areas does not change (e.g. conifer, hardwood, grassland, brush areas remain in the same vegetation type.) An additional assumption is that all the riparian vegetation is managed the same way at the same time. EPA uses this assumption to analyze cumulative effects of different management styles. Actual stream temperature effects will be a combination of both the type of riparian management, the proportion of landowners choosing different types of riparian management and the timing and frequency of riparian management.

EPA evaluated the following five riparian management scenarios with the Q2ESHADE model described above for the Tomki Creek watershed. As described previously, the analysis for Tomki Creek is a surrogate for the effects in the entire Upper Eel TMDL area, including USFS and private lands:

1 - Current condition (baseline) This scenario is developed using the size of the vegetation as provided by the data and assumptions detailed in Appendix A. In the Tomki Creek area, there was significant timber harvest during the late 1940s through the 1960s affecting over 50% of the watershed (Mendocino County RCD, 1983). It appears the current condition includes a substantial recovery in vegetation from that period; there were no recent timber harvest plans in the area.

2 - Topographical shading only. This scenario was developed to determine the general importance of vegetation shade in the watershed; it is not meant to reflect current or future conditions. In this scenario, the only shade over the stream is from unvegetated topography such as adjacent hillslopes. All shade from trees (both conifer and hardwood) was eliminated from the model for the purposes of this scenario.

3 - 18 inch diameter at breast height (dbh) conifer- private timber management. Changes to the riparian area are generally at the discretion of private landowners, except for timber harvest for which permits are required under the State's Forest Practice Rules. This scenario was developed to illustrate the result under the State's Forest Practice rules. The rules have a requirement for 50-85% canopy retention, however it cannot be generalized what size tree is left in the riparian zone given this minimum requirement. Theoretically, an owner can harvest all trees as small as 12 inch dbh under the Forest Practice Rules, but generally it is not economical to do so. In addition, silvicultural management styles vary amongst different private landowners. This scenario represents the result if the entire watershed was harvested at the same time resulting in 18" dbh conifer trees after harvest. The riparian areas for grassland or brush are modeled without riparian tree species.

4 - 24 inch dbh conifer-alternative private timber management. Given the variety of private timberland management styles, EPA also modeled a stand of 24 inch dbh conifers as another possible representation of future conditions under private

timber management.   Again this scenario illustrates cumulative effects if the conifer areas in entire watershed were harvested at the same time. This is considered somewhat unlikely given that in Tomki and Outlet Creek there are many owners with smaller parcels..

5 – Natural (full growth conifer 48" dbh, plus significant riparian species recovery.) While it is difficult to generalize on the natural size of conifers, given the range of site conditions, 48 inch dbh conifers adequately represent "natural" growth for the purposes of determining shade (see appendix A for a discussion of potential conifer size.) This "natural" scenario is compared to different management scenarios to examine the incremental temperature increases from timber harvest in the area. In addition, this scenario also represents the expected future result of USFS management practices regarding timber harvest in riparian areas. The modeling was also designed to add riparian tree species in all areas modeled under grassland, brush or hardwood vegetation type. This type of riparian (alder, willow etc) cover did exist historically in Tomki Creek.

Tables 3 and 4 provide the results of the modeling. The model uses the riparian condition scenarios 1-5 described above. The model first calculates the resultant heat input into the stream channel (in Langleys). Langleys are a measure of heat energy per surface area per time (or gram calories per cubic centimeters.)

The solar radiation heat input, expressed as Langleys, can also be expressed as shade. Shade is calculated by dividing the total amount of heat energy from solar radiation at this latitude by the amount of heat energy input into the stream after shading provided by riparian vegetation and topography. This shade percentage can be thought of as the inverse of heat or a proportion of the available heat shaded. The heat input into the stream channel is then converted to a stream temperature which is then routed downstream to account for cumulative effects. The results are presented in Tables 3 and 4, summarized with EPA's evaluation of the effect of stream temperatures on juvenile steelhead.

The modeling results indicate that the size of riparian vegetation and specifically the height of the riparian trees strongly influence the existence of cooler stream temperatures in Tomki Creek. For example, topographical shading only (e.g. no trees) results in the smallest amount of the stream (4.4 miles) in the good/adequate/marginal categories (less than 20°C). These results indicate that juvenile steelhead populations in these areas would be adversely affected by the total loss of riparian vegetation. The size of conifers also alters stream temperatures, even though this watershed has a significant proportion of riparian area without conifers. There is an increase in the miles of stream with warmer temperatures, if the watershed were managed for smaller conifers (18 & 24 inch dbh) compared to the "natural" scenario where 48 inch dbh trees exist. This is illustrated in Table 3 by a slightly larger amount (approximately 2 stream miles) in the watershed greater than 24°C when there are 18 or 24" dbh conifers compared to a natural condition.

The modeling indicates that Tomki Creek is unusually warm, even under natural conditions, compared to other watersheds in the Eel. The proportion of stream miles in stressful and lethal stream temperatures predicted by the model, even under natural conditions for Tomki Creek, is unusual compared to the results of modeling conducted previously in other watersheds in the Eel. For example, 99% of stream miles were <19EC in the Upper Black Butte, and 84% were <19EC in the North Fork of the Middle Fork (USEPA, 2003), both in the Mendocino National Forest. In the North Fork of the Eel, there were no stream miles in the northern tributaries (USEPA, 2002) predicted to have lethal temperatures under natural conditions. Tomki Creek is most similar to Rattlesnake Creek in the South Fork of the Eel, where natural stream temperatures were modeled to result in 78% of stream miles >19EC (stressful and lethal). EPA's findings illustrate that a wide range of natural stream temperatures were likely to exist in the entire Eel basin.

3.2.2 Selection of Scenario Corresponding to Water Quality Standards

The narrative water quality standard states "the natural receiving water temperature ...shall not be altered unless it can be demonstrated...that such an alteration in temperature does not adversely affect beneficial uses."

EPA concludes that the natural scenario (scenario 5) corresponds best to the "natural stream temperatures shall not be altered" phrase in the State's Water quality standards. EPA examined the modeling results and concluded that private landowner practices in the riparian zone have the potential of adversely altering these natural stream temperatures, even under the restrictions of the State's Forest Practice Rules. EPA also finds that this amount of alteration in stream temperature is adverse to the beneficial use of COLD from increases in stream temperature during the summer that affect steelhead rearing. Given the small amount of adequate and good habitat, any degradation in stream temperatures from natural conditions would adversely affect beneficial uses. Note that the projected riparian condition of USFS management under the Northwest Forest Plan was modeled using the same assumptions as the natural condition. EPA considers this likely for the size of riparian conifers. The USFS riparian conditions regarding shade impacts from sediment in this TMDL area are not analyzed in this Chapter. Chapter 4 discusses sediment.

3.3 SOLAR RADIATION TMDL

Section 303d of the Clean Water Act and EPA regulations require that a TMDL be established. In this report, we are establishing the TMDL and allocations for the Upper Main Eel and tributaries in two parts. The first part addresses the effects of solar radiation from changes to riparian shade and applies to all of the stream reaches in the watershed. The second component is discussed is Section 3.4 and addresses the hydrological modifications in the area of the main channel Eel between Van Arsdale and Outlet Creek.

<<<This page left intentionally blank for insert of Tables 3 and 4 >>>>

3.3.1 Loading Capacity and TMDL – Solar Radiation for all stream reaches

The TMDL is the total loading of a pollutant that the river can assimilate and still attain water quality standards for temperature. In this TMDL, the pollutant is heat, measured in Langleys/day (ly/day). A Langley is a measure energy per unit area (equal to 1 gram calorie/cm2) and can be converted to metric units such as joules (1 ly = 41,850 joules/m^2) or watts or BTUs. We are setting the TMDL equal to the amount of heat the waterbody would receive under the natural scenario (e.g. scenario #5.)

In the model (see Appendix A) "global solar radiation" over each stream segment - i.e., the solar radiation that exists above the vegetation at this latitude –is reduced by topography and vegetation characteristics, resulting in a smaller amount of heat reaching the stream for each segment. The model calculates the actual amount of radiation/heat in langleys that would reach each stream segment after accounting for topographical shading, stream orientation, stream width and the potential height of the riparian vegetation. The model calculates the amount of heat for each stream sampling point, however, the TMDL is expressed as an average of all stream sampling points for summary purposes.

The TMDL for the Upper Eel and tributaries is set equal =

average of 289 langleys/day.

This is based on the modeled calculations for Tomki Creek. Tomki Creek is a generally representative vegetation condition, between the more heavily forested subwatersheds in Mendocino National Forest and the less forested area of Outlet Creek. The TMDL number is a mathematical average of the amount of heat that would reach the stream surface for each stream segment modeled after accounting for full natural growth of conifers and also riparian species for grassland, brush and hardwood areas.

This is the loading capacity of the stream, and will allow water quality standards for temperature to be achieved.

3.3.2 Shade Allocations

In accordance with EPA regulations, the loading capacity (i.e. TMDL) is allocated to the various sources of heat in the watershed, with a margin of safety. There are no point sources, therefore the wasteload allocations in the watershed is zero. This TMDL has an implicit margin of safety that is provided by assumptions rather than a direct calculation. Therefore, the TMDL is set equal to the loading capacity and the allocations result in the TMDL. The TMDL is set in langleys and the allocations are expressed in shade.

While it is theoretically possible to measure langleys/day for streams in practice, shade is more often measured by land managers. The concept of shade, as it relates to heat input, has a significant time component as it varies daily and seasonally. Shade as expressed here is the accumulated reduction in solar radiation from the daily amount of stream in shadow or shade. This can be measured directly with a solar pathfinder or less exactly with other shade measurements. We have calculated the allocations using the model, by translating the TMDL in langleys/day into an average shade allocation for the watershed.

For all stream reaches in the Upper Main Eel TMDL area

TMDL = sum of the allocations for each stream sampling point.

The allocations are an average of 49-50% shade for all stream segments

The allocations are expressed as percent shade. Percent shade for all stream segments is the amount of solar radiation reaching the stream surface divided by the potential solar radiation. This is after shading provided by natural vegetation. This will be an average of 49-50% shade for all stream segments.

3.3.3 Margin of Safety

Under EPA regulations, a margin of safety may be provided explicitly by not allocating a portion of the available TMDL or implicitly through use of using conservative analytical assumptions. In this TMDL, an implicit margin of safety is provided through the conservative analytical assumptions. First, the selected model scenario evaluated management effects throughout the entire Tomki Creek watershed for cumulative shade and temperature alterations when in fact, smaller, less frequent timber harvest plans are often normal. Thus if harvest plans that reduce shade are less frequent and small they may in fact not result in significant stream temperature effects. Second, implementing the temperature TMDL will result in larger riparian vegetation, which will increase the potential for contributions of large woody debris to streams. Increases in large woody debris benefit stream temperatures and associated cool water habitat by increasing the number and depth of pools, which provide areas of cooler water for fish. These indirect beneficial effects were not accounted for in the analysis, but provide an implicit margin of safety. Third, refugia from existing stratified pools or streams dominated by springs provide cooler temperatures than were accounted for in the TMDL analysis. As a result, we would expect more cool water habitat to exist than the TMDL analysis predicts. Finally, larger vegetation also will tend to create microclimates that will lead to improvements in stream temperatures. These effects were not accounted for in the temperature analysis, but provide an additional implicit margin of safety.

3.3.4 Seasonal Variation and Critical Conditions

In accordance with EPA regulations, the TMDL must account for seasonal variations and critical conditions. In the Upper Main Eel watershed, the summer period defines the critical period when stream temperatures are most likely to have adverse impacts on beneficial uses (young salmonids growing in the streams before migrating to the ocean). To account for seasonal variations and critical conditions, the analysis is based on the max7daat (i.e., the maximum weekly average of the 7 day running average of all monitored temperatures). Temperatures are not limiting to beneficial uses during the winter period.

3.4 INSTREAM HEAT TMDL- VAN ARSDALE TO OUTLET CREEK

This section describes the analysis supporting the calculations of a TMDL and associated allocations to address the effects of hydrological modification on stream temperatures for the section of the Upper Main Eel between Van Arsdale and Outlet Creek. This stream reach was selected for additional inquiry because stream flow is diverted during the summer at Van Arsdale. Given that flow is an important influence on stream temperature, EPA sought to investigate the extent and importance of the temperature alteration from the flow diversion. The modeling described below predicts that alterations in flow will alter downstream temperatures under many conditions in the Upper Main Eel. In addition, EPA concludes that the stream temperatures likely to result from the new flow requirements from the June 2004 FERC order are likely to result in attainment of water quality standards. EPA's conclusion is based upon a comparison of a construction of possible "natural" stream temperatures. Natural stream temperatures were not measured historically. Based on the analysis, EPA developed an instream heat TMDL and allocations for this portion of the Upper Main Eel.

The Potter Valley Project's influence on stream temperature and cold water habitat is complex. Temperatures upstream of Lake Pillsbury are warmer (approximately 22.5EC at the Rice Fork and inlet at Lake Pillsbury) than those below Lake Pillsbury (18E-20EC), because Lake Pillsbury stratifies and cool bottom water is released into the Eel during the summer. Scott Dam at Lake Pillsbury while it provides summer cooling along this 12 mile stretch, also blocks access to many miles of summer cold water habitat for steelhead, plus spawning habitat for chinook and steelhead. The 12 mile area between Lake Pillsbury and Van Arsdale has significant summer flow (100 cfs on average) and this large block of water resists heating and remains approximately 20EC max7daat. After the diversion, where approximately 7 cfs was released at Van Arsdale until the summer of 2004, the stream quickly heats and was measured to be 24EC as a max7daat around Tomki and 27EC by Outlet Creek under the pre-2004 summer flow regime.

There are two possible alterations in temperature that were not considered quantitatively in this portion of the analysis. First, the stream reach that is now Lake Pillsbury likely had some temperature alteration from natural conditions. There is a lack of information regarding the stream condition pre-project and Lake Pillsbury currently provides cold water and habitat for rainbow trout and does not appear to be temperature impaired. Therefore, EPA did not analyze changes in steam temperature in this reach related to the project. Second, temperature alterations on the stream reach between Lake Pillsbury and Van Arsdale were not modeled. EPA concluded that this alteration is beneficial to salmonids, as it provides cooler stream temperatures and is likely to continue under all future management scenarios.

EPA's analysis does not include an analysis of the alteration in habitat access by the Potter Valley Project. To recall the water quality standard - *"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."* This TMDL is designed to attain that water quality standard, and thus focuses on changes to stream temperatures. Although, both spawning habitat for chinook and rearing habitat for steelhead are blocked by Scott Dam, it would be beyond the scope of the TMDL to analyze the overall benefits to salmonids of a natural condition as compared to conditions with the Potter Valley project. This is an important difference between this analysis and other forums, such as the Endangered Species Act consultation or FERC proceedings concerning the Potter Valley Project.

Recall that the applicable water quality standard states "natural stream temperatures shall not be altered....". EPA sought to determine what was the range of "natural" stream temperatures compared to both the measured temperatures prior to summer 2004 and the temperatures predicted under the 2004 flow requirements. The June 2004 flow requirements are an increase in summer flow compared to the conditions from the 1920s - 2003. The temperatures resulting from those flows needed to be modeled as the monitoring results were not fully available for this analysis.

There are many difficulties in determining the natural stream temperatures in the area of the Potter Valley Project. The Potter Valley Project dates from the 1920's and almost no information regarding pre-project stream conditions and temperatures was uncovered by EPA. A historian with the USFS who studied the Mendocino National Forest reported an absence of detailed ethnohistoric period information about Gravelly Valley (now Lake Pillsbury) (Supernowicz, 1995.) Therefore, the "natural" stream temperatures used for comparison were modeled using a wide range of assumptions. These possible "natural" stream temperatures were then compared to both the 1975-2003 flow conditions and the flow conditions that are likely to result from the June 2004 FERC order.

The data and scenarios used for comparing "natural" stream temperatures with "altered" stream temperatures are as follows:

1975-2003 - baseline conditions: This scenario represents flow and temperature conditions that have been monitored in the recent past. The average flow below Van Arsdale was modeled as 7 cfs based on USGS records. The starting temperature at Van Arsdale modeled was 20.9EC based on temperature on the max7daat 2003 monitoring results. The 1975-2003 flow schedule did not vary between water year types.

FERC/NMFS. This scenario represents flow and temperatures conditions projected under the 2004 FERC order. Three water year types were modeled. The summer flow specified in the FERC order was used, along with the same 20.9EC temperature at Van Arsdale. EPA assumed that the FERC/NMFS flows would be at the current outlet temperatures. EPA did not make adjustments because the FERC proceedings did not resolve issues regarding the availability of current cool water from Lake Pillsbury. The summer flows specified in the FERC order are as follows:

Very Wet - 30 cfs

Wet - 15 cfs

Dry - 9 cfs

Natural Stream temperatures. To estimate natural stream temperatures from Van Arsdale to Outlet Creek, EPA considered available information on both natural flow and natural stream temperatures at Van Arsdale. Data on unimpaired (e.g. natural) flow were developed for the FERC proceedings and provided important natural flow assumptions to EPA. The FERC/NMFS water year types are triggered by a cumulative inflow to Lake Pillsbury as of May 15, but a precise relationship between the actual trigger and the unimpaired flow was not available therefore a review of the unimpaired flow record was used. Additionally, although two sets of unimpaired data are in existence, EPA was only able to acquire the PG&E dataset during the time frame available. Table 5 provides a summary of the flow and temperature assumptions used for these and all other scenarios.

The other important assumption concerns the starting stream temperature at Van Arsdale associated with the unimpaired flow. We could not use the available monitored temperatures at Van Arsdale because, as discussed below, these temperatures have been altered – in fact, lowered – as a result of the Potter Valley Project. As the project has been in existence for nearly a century, no record exists of natural stream temperatures. Thus the range of starting temperatures modeled was intended to represent the largest possible range and a discussion of how each lower (cooler) and upper (warmer) bound was generated follows. The lower bound is 22.5EC - which is the average of the max7daat of the 2 primary tributaries above Lake Pillsbury - Eel at the inlet of Lake Pillsbury and Soda Creek. This lower (coolest) bound scenario assumes that the stream does not heat during its approximate 20 mile flow from the Eel above Lake Pillsbury to Van Arsdale. This lack of downstream heating, EPA considers possible although with reservations. The area between Lake Pillsbury and Van Arsdale does have both topographic and vegetation shading and cooler subsurface water appears to be present (Jahne, personal communications.) It is also possible that the area of Hullville and Gravelly Valley (now Lake Pillsbury) was significantly influenced by subsurface flow. For example, the FLIR (Thermal Infrared and Color Videography) monitoring of the nearby North Fork Eel River has an area where the river reemerges from the subsurface gravel and has cooled from lethal temperatures by approximately 4-6EC to 21.3EC. In addition, the Scott River cools by 2-3°C over a distance of 4.3 miles as cooler ground water emerges at the downstream end of the alluvial Scott Valley. The geologic setting of Gravelly Valley is very similar to that of Scott Valley: a large alluvial valley with a bedrock canyon downstream. These types of valley settings often create conditions where a significant volume of ground water enters the stream channel draining the valley (McFadin, personal communication.)

However, both these examples provided cooling only for a limited distance. EPA uses this scenario to represent the coolest possible natural stream temperature. Natural stream temperatures cooler than this were extremely unlikely and EPA does not have any information on larger streams that cool as they flow downstream for significant distances, without the influence of significant cool tributary inflow or cooler coastal air temperatures.

The upper bound (warmest) possible "natural" stream temperature scenario was developed to reflect some downstream stream heating as follows. EPA used the modeled reach between Tomki Creek and Outlet creek as a surrogate of the upstream channel. The current channel morphology between Lake Pillsbury and Van Arsdale has been changed by the hydrological modification and sediment filling around Van Arsdale, thus the temperatures associated with this portion of the channel are not representative of the natural condition. The upper bound scenario accounts for the resistance to heating of increases in the bulk of water (10 cfs, 20 cfs and 50 cfs) with a stream in a similar climate and geography. The distance used was 20 miles (the approximate amount of stream inundated by Lake Pillsbury plus the distance from Lake Pillsbury to Van Arsdale.) EPA believes this to be the warmest stream temperatures likely for the reach between Van Arsdale and Outlet Creek. The rate of stream heating is characteristic of a less shaded stream than would likely exist, plus the river flows generally north/south in the modeled reach, whereas the "natural" channel generally flows east/west. For these reasons, EPA modeled these temperatures as the upper bound (warmest) natural stream temperatures. This also accounts somewhat for natural variations in stream temperature by water year type.

The following table summarizes the scenarios described above:

Table 5: Flow and temperature assumptions for Van Arsdale to Outlet Creek scenarios

YEAR TYPE	1975-2003		FERC/NMFS		Natural - lower		Natural - Upper	
	CFS	*EC at Van Arsdale*	*CFS*	*EC at Van Arsdale*	*CFS*	*EC at Van Arsdale*	*CFS*	*EC at Van Arsdale*
DRY	**7**	**20.9**E	**9**	**20.9**E	**10**	**22.5°**	**10**	**25C**
WET	**7**	**20.9**E	**15**	**20.9**E	**20**	**22.5**E	**20**	**24.3C**
VERY WET	**7**	**20.9**E	**30**	**20.9**E	**50 & 60**	**22.5**E	**50**	**23.5C**

Using the information in the table above, the resultant temperatures in the reach between Van Arsdale and Outlet Creek were predicted by modeling.

Modeling results are available for the three year types analyzed -- dry, wet and very wet. Detailed results from the dry year scenarios are presented in Appendix A. In dry years, the model predicts that there are no temperature alterations associated with the flow scenarios. The flow conditions for dry years range only slightly between 7 and 10 cfs. Thus the dry year results are not used in calculating the TMDL and allocations.

For wet and very wet years, the modeling results demonstrate alteration to stream temperatures and so wet and very wet years were used in calculating this TMDL component.

Figure 4 summarizes the results of different flow and natural stream temperature scenarios for wet years. Increased flow decreases downstream temperatures, however, this benefit of increased flow becomes minimal past Twin Bridges Creek. In addition, stream temperatures are warm (>24°C as a max7daat) under all scenarios, just past Tomki Creek. This is in the range of stream temperatures which will cause some mortality to juvenile salmonids given that the max7daat metric indicates sustained temperatures of >24°C. These conditions are predicted under both the coolest possible natural conditions and the warmer possible natural conditions and all management scenarios. The June 2004 flow requirements are predicted to provide the coolest possible stream temperatures. Importantly, the June 2004 flow requirements are in the range of possible natural stream temperatures. Therefore, the June 2004 flow requirements will likely attain water quality standards.

Figure 5, shows the modeling results for very wet years. In contrast to the dry and wet years, these larger changes in flow are predicted to result in a reduction in stream temperatures for the entire stream reach modeled - down to Outlet Creek. Compared to the flows prior to 2004, very wet year flows under the current flow regime are predicted to result in temperature reductions over the entire stream reach. Also during very wet years, the June 2004 flow requirements are predicted to result in approximately two kilometers of the stream less than 22°C.

However, for most of the stream reach, even though stream temperatures are predicted to be lowered under increased flow, stream temperatures will not normally result in abundant juvenile populations. Most of the main Eel between Tomki Creek and Outlet Creek is predicted to be warmer than 24°C as a max7daat. The literature suggests that these temperatures will cause some mortality and are above the stream temperatures associated with presence of steelhead in the field. Based on EPA's review of the literature on juvenile rearing and temperatures, given that the area has small refugia populations, lowering of stream temperatures is considered to be beneficial. This benefit is in addition to the benefit in the two kilometers less than 22°C below Van Arsdale. Again these warm temperatures were likely natural, as indicated by the predictions of the natural scenarios. Therefore, the June 2004 flow requirements are predicted to attain water quality standards.

<<<This page left intentionally blank for insert of Figures 4&5 –
Line graphs of stream temperatures for Upper Main Eel>>>

3.4.1 Selection of Scenario Corresponding to Water Quality Standards

EPA is using the 2004 FERC/NMFS flow schedule to calculate the instream heat TMDL for the stream reach of Van Arsdale to Outlet Creek. The TMDL is calculated using both wet and very wet years. EPA found that the current FERC/NMFS summer flow schedule likely results in stream temperatures cooler or nearly equal to the possible natural stream temperatures. This means that the FERC/NMFS flow schedule is projected to attain water quality standards.

3.4.2 Water Quality Indicators: Van Arsdale to Outlet Creek

Stream temperature monitoring can be used as a water quality indicator to determine if the TMDL is meeting water quality standards. Temperature monitoring at from 1999-2003 resulted in an average max7daat of 26.7EC. There was significant variation due to yearly differences in weather and possibly monitor placement (25.8E, 26.8E, 26.5E, 26.9E, and 27.7EC.) Within this natural variation, the State will need to consider using a complete set of information to assure that stream temperature monitoring is viewed in light of meterology, flow and starting temperatures at Van Arsdale. The model predicts that given similar meterological conditions the stream temperatures at will be approximately 26EC during wet years and 24.4EC during very wet years.

3.4.3 Instream Heat Loading Capacity and TMDL – Van Arsdale to Outlet Creek

Under EPA regulations, the Total Maximum Daily Load is "the sum of the individual Wasteload allocations, for point sources and Load allocations for nonpoint sources and natural background." The regulations governing TMDL development provide for the expression of TMDLs as "either mass per time, toxicity or other appropriate measures." (40CFR 130.2(h)). EPA is establishing the TMDL for the portion of the Upper Main Eel between Van Arsdale and Outlet Creek in terms of instream heat (in BTUs.) This TMDL is calculated to address heat inputs from changes in instream heat that result from hydrological modifications as well as solar radiation. This component of the TMDL is expressed in total BTUs and is referred to as the instream heat loading capacity. The TMDL is calculated using the FERC/NMFS flow regime, which was determined to attain water quality standards. The instream BTU TMDL is applicable at stream sampling point #56 for both wet and very wet year types.

TMDL Very Wet Year = 4.19 E+10 Total BTUs

TMDL Wet Year = 2.63 E+10 total BTUs

This total heat load is derived from the stream heat (in BTUs) for the stream sampling point #56. It is the total heat contained within that portion of the stream reach for the max7daat period. The TMDL calculation assumes the FERC/NMFS flow regime. Thus, if the flow or temperatures at Van Arsdale are significantly different than assumed, the TMDL, and water quality standards are not likely to be attained.

3.4.4 Instream Heat Allocation - Van Arsdale to Outlet Creek

In accordance with EPA regulations, the loading capacity (i.e. the TMDL) is allocated to the various sources of heat in the watershed, with a margin of safety. As there are no point sources in this stream reach, the wasteload allocation is set at zero and the TMDL equals allocations for nonpoint sources, plus natural sources. EPA is allocating the TMDL at between the Potter Valley Project and the other cumulative sources of stream heating along the stream reach between Van Arsdale and .   These other cumulative sources are primarily solar radiation and tributary inflow. EPA also expresses the solar radiation inputs in Section 3.3.2. The calculation was from the model given the total BTUs from stream sampling point 1 (Van Arsdale) for the Potter Valley Project. This amount was then subtracted from the total BTUs at stream sampling point #56. The load allocation for "other cumulative sources" including the solar radiation inherently includes the 50% shade allocation.

TMDL Very Wet Year =   4.91 E+10 Total BTUs

4.32 E+10 Potter Valley Project Load Allocation

+ 0.60 E+10 other cumulative source of stream heating at

Load Allocation

TMDL Wet Year =

2.63 E+10 total BTUs Load Allocation Potter Valley Project

+ 0.46 E+10 other cumulative sources of stream heating at

3.4.5 Margin of Safety

Under EPA regulations, a margin of safety can be provided by explicitly reserving a portion of the available loading capacity or included implicitly through analytical assumptions within the TMDL analysis. For the stream reach between Van Arsdale and Outlet Creek, EPA has included the following conservative assumptions in the TMDL analysis. In analyzing possible "natural" stream temperatures, EPA included a low (cold) and high (warm) range by which to compare current stream temperatures. In fact, the FERC/NMFS flow regime on which the TMDL is calculated is closest to the cooler possible natural stream temperatures.

3.4.6 Seasonal Variation and Critical Conditions

In accordance with EPA regulations, the TMDL must account for seasonal variations and critical conditions. In the Upper Main Eel watershed, the summer period defines the critical period when stream temperatures are most likely to have adverse impacts on beneficial uses (young salmonids growing in the streams before migrating to the ocean). To account for seasonal variations and critical conditions, the analysis is based on the max7daat (i.e., the maximum weekly average of the 7 day running average of all monitored temperatures). In addition, the TMDL set for the Van Arsdale to Outlet Creek stream reach specifically considered 3 different year types in order to account for variable hydrological conditions.

CHAPTER 4 – SEDIMENT TMDL

Summary

This chapter presents analysis supporting the sediment TMDL for the Upper Main Eel River. The first section identifies water quality indicators, which are interpretations of the water quality standards. These indicators can also be used to evaluate stream and watershed conditions and progress toward or achievement of the TMDL. The second section of this chapter summarizes the results of the sediment source analysis. The third section presents the calculations of the TMDL. The TMDL is the total loading of sediment that the Upper Main Eel River and its tributaries can receive without exceeding water quality standards. This third section also includes the distribution of the total load among the major categories of sediment sources in the watershed, i.e., the allocations.

The sediment source analysis for the Upper Eel River conducted by Pacific Watershed Associates (PWA) and the United States Forest Service (USFS) concluded that 33 percent of total sediment load was related to human activity. Sediment production from human disturbance appears to be associated primarily with road conditions and timber harvest. Human-related sediment delivery rates are higher on private lands than on public lands. Most of the naturally caused sediment-delivery was from landslides, which have a higher rate of delivery on public lands than on private lands. Although USFS lands had a higher rate of landslides than private lands, public lands have a smaller rate associated with human causes. The results suggest that the Upper Eel River watershed is less disturbed by human caused sediment than most other watersheds studied in the North Coast, probably due to the limited management activity in the basin.

4.1 WATER QUALITY INDICATORS AND TARGETS

Indicators and targets can be used to represent attainment with Basin Plan objectives. This section identifies numeric water quality indicators and targets specific to the Upper Main Eel River. Because of complexities associated with the effects of increased sediment loading on stream water quality, surrogate instream and watershed indicators are used to evaluate quantifiable Basin Plan objectives. For each indicator, a numeric or qualitative target value is identified to define the desired condition for that indicator.

Because of the inherent variability associated with stream channel conditions, and because no single indicator applies at all points in the stream system, attainment of the targets is intended to be evaluated using a weight-of-evidence approach. That is, when considered together, the indicators are expected to provide good evidence of the condition of the stream and attainment of water quality standards.

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

Watershed indicators reflect conditions in the watershed at the time of measurement, whereas instream indicators can take years or decades to respond to changes in the watershed. Specifically, time lags between sediment production and delivery make it difficult to predict when and how a stream will respond to sediment loading. Also, watershed indicators tend to reflect local conditions, whereas instream indicators often reflect upstream watershed conditions as well as local conditions. Thus, watershed indicators help to identify conditions in the watershed that will prevent water quality from deteriorating. Ultimately, both instream and watershed indicators are appropriate to use in describing the attainment of water quality standards. While the indicators are not directly enforceable by EPA, the turbidity indicator uses language similar to the Basin Plan turbidity water quality objective, which is enforceable by the NCRWQCB.

4.1.1 Summary of Indicators and Targets

This section describes several sediment indicators for the Upper Eel River TMDL. Table 6 summarizes the indicators along with their target, description and purpose. Very little information is available on current values of the indicators in the watershed; however, anecdotal information suggests that the watershed may be in relatively good condition when compared to other North Coast basins, although some subwatersheds may have greater sediment problems (D. Leland, personal communication, 2003). Regional Water Board staff have also developed additional information and detail on each of these indicators in developing implementation plans for other North Coast TMDLs (NCRWQCB, 2002). EPA expects that future monitoring of these indicators will provide additional information to assess whether the water quality standards are being attained and whether the TMDL is effective in meeting water quality standards.

Table 6. Sediment Indicators and Targets

INDICATOR	TARGET	DESCRIPTION	PURPOSE
Instream			
Spawning Gravel Quality	<14% < 0.85 mm ≤30% < 6.4 mm;	Bulk samples during low-flow period, at riffle heads in potential spawning reaches. Discussion of indicators and targets by Kondolf (2000), Chapman (1988).	Indirect measure of fine sediment content relative to incubation and fry emergence from the redd. Indirect measure of ability of salmonids to construct redds
Turbidity and Suspended Sediment	Turbidity ≤ 20% above naturally occurring background (also included in Basin Plan)	Measured upstream and downstream of sediment discharging activity or between "paired" watersheds or reference streams.	Indirect measure of fish feeding/growth ability related to sediment, and impacts from management activities
Riffle Embeddedness	≤25% or improving (decreasing) trend toward 25%	Estimated visually at riffle heads where spawning is likely, during low-flow period (Flosi et al 1998)	Indirect measure of spawning support; improved quality & size distribution of spawning gravel
V*	≤0.21	Residual pool volume. Measure during low-flow period. (Lisle and Hilton 1992)	Estimate of sediment filling of pools from disturbance
Macroinvertebrate community composition	Improving trends	EPT, Richness & % Dominant Taxa indices. Methods should follow CDFG-WPCL (1996) or refined methods currently under development, including USFS local methods.	Estimate of salmonid food availability, indirect estimate of sediment quality.
Thalweg profile	Increasing variation from the mean	Measured in deposition reaches during low-flow period.	Estimate of improving habitat complexity & availability
Pool/riffle distribution & depth of pools	Increasing trend toward >40% in primary pools	Trend or greater than % (by length), measured low-flow period.	Estimates improving habitat availability
Watershed Indicators			
Diversion potential & stream crossing failure potential	≤1% crossings in 100 yr storm	Conduct road inventory to identify and fix stream crossing problems (Weaver and Hagans 1994). See USDA (1999) Roads Analysis for assessing road network.	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Hydrologic connectivity of roads	Decreasing length of road	Conduct road inventory to identify and fix road drainage problems (Weaver and Hagans 1994).	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Annual road inspection & correction	Increased mileage inspected and corrected	Roads inspected and maintained, or decommissioned or hydrologically closed prior to winter- No migration barriers.	Estimates potential for reduced risk of sediment delivery from hillslope sources to the watercourse
Road location, sidecast	Reduce density next to stream, increased % outsloped	See text.	Minimize sediment delivery
Activities in unstable areas	Avoid and/or /eliminate	Subject to geological/geotechnical assessment to minimize delivery and/or show that no increased delivery would result	Minimize sediment delivery from management activities

4.1.2 Instream Indicators

Spawning Gravel Quality: Percent Fines <0.85 mm: ≤14%; Percent Fines <6.4 mm ≤ 30%

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

DFG Stream Inventory Report for Willits Creek (on the golf course in the Brooktrails Community Service District) reported that 5 sites were sampled for percent fines using a McNeil gravel sampler. The samples are then wet sieved to determine their size class. All of the samples were greater than 15% fine, with a combined sample mean of 24%. This indicates that fine sediment is a problem in Willits Creek; however, this urbanized land use is not typical of the watershed (CDFG, 1991).

Turbidity and Suspended Sediment: <20% above naturally occurring background levels

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

Eel River water is known for its high turbidity. Several factors contribute to this water quality problem. During high discharge events, heavy suspended sediment loads create turbid conditions. In the Upper Eel River, high turbidity levels in late fall and winter are also attributable to the continual suspension of montmorillionite clays (USFS, 1995).

The water in Lake Pillsbury is turbid through much of the year due to such fine-grained clays that are washed into the lake (USFS, 1995). These clays are weathered from volcanic bedrock generally located along the Rice Fork (Brooks, et al., 1984). Their settling rates vary depending on lake water chemistry, specifically sodium, calcium, and pH, in addition to the shape and management of the reservoir. Lake Pillsbury discharges the most turbid water during the fall when the lake level is lowest. During the winter months, the reservoir is refilled with turbid water from the surrounding tributaries. After some settling occurs, the deep water is often disturbed in the springtime as cold water from the tributaries drains into the lake, slipping below the warmer surface waters. Then, in the warmer months, the deeper waters of the lake tend to have high pH values, which keep some of the clays in suspension. Because some clays do tend to settle, there is generally a slow clearing of the deep waters during the summer months. The turbidity levels in Lake Pillsbury impact the downstream reaches of the Upper Eel River due to the discharge of highly turbid deep waters from Scott Dam, especially during the fall months when the water level is low (USFS, 1995).

Riffle Embeddedness<u>: <25% or improving (decreasing) trend</u>

Embeddedness is a measure of fine sediment that surrounds and packs-in gravels. A heavily embedded riffle section may limit the ability of an adult female fish to construct a redd. When constructing its redd, generally at a pool tail-out (or the head of a riffle), the spawning fish essentially slaps its tail against the channel bottom, which lifts unembedded gravels and removes some of the fine sediment. This process results in a pile of cleaner and more permeable gravel, which is more suited to nurturing the eggs. Embedded gravels do not generally lift easily, which prevents spawning fish from building their redds. Flosi et al. (1998) suggest that gravels that are less than 25% embedded are preferred for spawning. This target should be estimated during the low-flow period, generally at riffle heads, in potential spawning reaches.

Embeddedness is measured as part of the CDFG stream inventory program. Results from various stream inventory reports are presented in Table 7. Overall, the results indicate very few of the measured streams were dominated by pool tail-outs that were less than 25% embedded. To fully assess this indicator, follow-up studies are required at the same locations to characterize the trend in each stream. Additionally, more recent studies reported the percent of pool tail outs categorized as unsuitable due to the presence of boulders, bedrock, or sediment too small for spawning. As with most of the other categories, the results vary depending on the stream sampled, with some streams scoring poorly (unsuitable or highly unsuitable for spawning) and others scoring well (less embedded streams that are more suitable for spawning).

Table 7. Measures of Embeddedness in the Upper Eel River Basin

Waterbody Name	Number of Pool Tail-Outs Measured	Percent Embedded				Unsuitable for Spawning
		< 25%	26-50%	51-75%	76-100%	
Alder Creek	75	8%	57%	49%		Not reported
Baechtel Creek	436	3%	17%	13%	67%	Not reported
Bear Pen Canyon Creek	13	0%	31%	69%	0%	Not reported
Benmore Creek	51	6%	25%	27%	6%	10%
Bloody Run Creek	182	9%	49%	14%	28%	Not reported
Broaddus Creek	131	30%	18%	25%	26%	Not reported
Cave Creek	55	15%	38%	24%	2%	22%
Cherry Creek	144	4%	33%	24%	39%	Not reported
Haehl Creek	121	1%	28%	1%	59%	Not reported
Long Valley Creek	373	0%	24%	46%	30%	Not reported
Outlet Creek	164	9%	27%	32%	32%	Not reported
Ryan Creek	99	53%	22%	2%	23%	Not reported
String Creek	107	14%	42%	30%	14%	Not reported
Tomki Creek	133	21%	33%	8%	4%	34%
Unnamed Tributary #1 to Cave Creek	10	50%	30%	0%	0%	20%
Unnamed Tributary #2 to Cave Creek	4	0%	25%	25%	0%	50%
Unnamed Tributary #3 to Cave Creek	4	0%	25%	75%	0%	0%
Willits Creek	27	15%	30%	37%	18%	Not reported

Sources: California Department of Fish and Game Stream Inventory Reports, 1991-1998.

V* <0.21 (Franciscan geology)

V* is a measure of the fraction of a pool's volume that is filled by fine sediment, and represents the in-channel supply of mobile bedload sediment (Lisle and Hilton 1992). This is not an appropriate tool for use in large rivers, but in large river systems, it is suitable for use in tributaries. Lisle and Hilton (1992) describe methods for monitoring, which should be conducted during low-flow periods and the target of less than 0.21 (Franciscan geology) is based on Knopp (1993). V* quantifies the quality of the pool habitat; when less of a pool is filled (a lower pool volume) it is cooler and deeper, offering protection from predators, a food source, and a resting location.

Macroinvertebrate Community Composition: Improving trends in EPT, % dominant taxa and species richness indices

Benthic macroinvertebrate populations are greatly influenced by water quality and are often adversely affected by excess fine sediment. This TMDL recommends several indices be calculated, following the CDFG Water Pollution Control Laboratory Stream Bioassessment Procedures (1996) until refined indices are available. Alternatively, methods that are generally consistent with the CDFG procedures may be utilized, such as those employed by USFS (http://www.usu.edu/buglab/).

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

One USFS bioassessment sampling location was identified in the watershed (location R5BIO-001 on Bear Creek). Two different habitats at this site were sampled twice in 2001 (June 12 and June 22). The EPT Index calculated from these sampling events varied from 20-27.and the taxa richness varied from 41-54. The percent dominant taxa could not be calculated from the data reported.

Thalweg Profile: Increasing variation of elevation around the mean slope

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

Primary Pool Distribution and Depth: Increasing inventory of reaches which are >40% pools; increasing primary pool depth

Pools generally account for more than 40% of stream length in streams with good salmonid habitat (Flosi et al. 1998). Frequent pools are important for providing feeding stations and shelter and may also serve locally as temperature refugia. Backwater pools are used by salmonids as overwintering habitats (Flosi et al. 1998) by providing shelter from high storm flows and lateral scour pools (i.e., pools formed near either bank) tend to be heavily used by fish for cover and refugia. Primary pools are defined by Flosi et al. (1998) as follows: For 1st and 2nd order streams, they have a maximum residual depth (the maximum depth of a pool minus the maximum depth of its downstream riffle crest, or the depth of the pool at the point of zero flow) of at least two feet, occupy at least half the width of the low flow channel, and are as long as the low flow channel width. For 3rd and 4th order streams, they have a maximum residual depth of at least three feet, occupy at least half the width of the low flow channel, and are as long as the low flow channel width. (Small, un-branched, perennial tributaries that terminate at an outer point are designated 1st order; the junction of two 1st-order streams is designated 2nd order, and the junction of two 2nd-order streams is designated 3rd order, etc.). Information in this watershed should include the depth of pools because in this watershed deeper pools may also be important as temperature refugia. This indicator should be measured during the low-flow period every 5-10 years after large storm seasons.

4.1.3 Watershed Indicators

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

Most roads, including skid roads and railroads, cross ephemeral or perennial streams. Crossings are built to capture the stream flow and safely convey it through, under, or around the roadbed. Stream crossings can fail, depositing sediment from the crossing structure (i.e., fill) and/or from the roadbed directly into the stream. Crossings that are likely to fail or divert pose a significant threat to streams. Stream crossing failures are generally related to undersized, poorly-placed, plugged, or partially-plugged culverts. When a crossing fails, the total sediment delivered to the stream usually includes the volume of road fill associated with the crossing and the sediment from collateral failures, such as debris torrents, that scour the channel and stream banks. Diversion potential is the potential for a road to divert water from its intended drainage system across or through the road fill, thereby delivering road-related sediment to a watercourse. Another important problem occurs when water drains down the road away from the stream crossing, which can result in the creation of a new channel.

The potential to deliver sediment to the stream can be eliminated from almost all stream crossings by removing inboard ditches, outsloping roads, or installing rolling dips (USEPA, 1998). Less than 1% of stream crossings have conditions where modification is inappropriate because it would endanger travelers or where modification is impractical because of physical constraints.

Hydrologic Connectivity: <ins>Decreasing length</ins>

A road is hydrologically connected to a stream when the road drains directly into the channel. This causes an increase in the intensity, frequency, and magnitude of flood flows and suspended sediment loads in the adjacent stream, which can ultimately destabilize the stream channel and have a devastating effect on salmonid redds and growing embryos (Lisle, 1989). Outsloping roads and creating road drainages that mimic natural drainage, among other practices, can significantly reduce connectivity (USDA, 1999; Weaver and Hagans, 1994).

Annual Road Inspection and Correction:

EPA's analysis indicates that in watersheds containing road networks without excessive road-related sedimentation, roads are either (1) regularly inspected and maintained; (2) hydrologically maintenance free (i.e., they do not alter the natural hydrology of the stream); or (3) decommissioned or hydrologically closed (i.e., fills and culverts have been removed and the natural hydrology of the hillslope has largely been restored).

Road Location and Sidecast: Prevent sediment delivery

Roads located in inner gorges and headwall areas are more likely to fail than roads located in other topographic locations. Roads should be removed from inner gorges and potentially unstable headwall areas, except where alternative road locations are unavailable and the road is clearly necessary. In addition, sidecast soil on steep slopes can trigger earth movements and result in potential sediment delivery to watercourses. These factors reflect the highest risk of sediment delivery from roads and should be the highest priorities for correction (C. Cook, M. Furniss, M. Madej, R. Klein, G. Bundros, pers. comm., 1998; in EPA, 1998).

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

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

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

4.2 SEDIMENT SOURCE ANALYSIS

This section summarizes the results of the sediment source analyses conducted by PWA and the USFS. The purpose of the sediment source analyses was to identify and estimate the relative amounts of sediment from the various sediment delivery processes and sources in the watershed. This section is a summary of the methodology, results, and relevance of the PWA/USFS sediment source analysis. Appendix B contains additional information obtained during the sample collection and analysis efforts. Appendix C contains sediment tables for the entire watershed and subwatersheds. Sediment numbers in Tables 8 and 12 related to excel spreadsheets were corrected.

4.2.1 Sediment Source Analysis Methodology

The sediment source analysis for the Upper Eel River and tributaries was conducted to identify the relative contribution of sediment delivered to stream channels from various erosional processes that occur on hillslopes and in stream channels throughout the watershed. The source analysis provides gross estimates of sediment production at the order-of-magnitude accuracy. Sediment loads from private and public lands as well as human and natural sources are identified. There were two general components to the sediment source analysis: the quantification of "large" (sources >3,000 cubic yards [yds^3] that are most ameniable through air photography analysis) and "small" (sources <3,000 yds^3 that are more difficult to detect with air photo analysis) sediment sources. The large sources were mapped and quantified using aerial photographs, while the small sources were quantified during a stratified random sampling field study.

All erosional features mapped on the aerial photos or within the random sample plots had the same suite of data collected. These data include: 1) whether the feature was road-, skid trail- or hillslope-related, 2) terrain type (stratum) and dominant vegetation type, 3) type of sediment source, 4) volume of erosion, 5) an estimate of the volume of sediment delivered to streams, 6) hillslope location and average hillslope steepness where the erosion occurred, 7) any apparent land use/management associations, and 8) geomorphic association.

The USFS analyzed 1952, 1969, 1979, and 1998 photographs for part of the Tomki Creek, Rice Fork, Soda Creek, and Upper Main Eel CALWAA watershed units. Additionally, the USFS used 1981, 1988, and 2003 photographs in selected areas to evaluate landslide re-vegetation rates. PWA analyzed photos taken in 1952, 1965, 1981, and 1999 for the Outlet Creek and Tomki Creek CALWAA watershed units. These years were selected to allow analysis of at least two sets of aerial photos under different management conditions in the watershed, specifically pre-1970 and post-1970, with the goal of quantifying changes in erosion under different operating conditions. During this general time period, there were both formal shifts in management and changes instigated by the legal system. The formal shifts include the implementation of the Forest Practice Rules (FPR) on private lands in the 1970s and the Northwest Forest Plan on public lands in the early 1990s. In addition, there were several lawsuits filed in the early 1970s regarding timber harvesting and the Endangered Species Act that resulted in an immediate, informal change in management practices.

Aerial photographs for the entire watershed were analyzed to identify all visible large sediment sources. The following sediment sources were quantified if they exceeded 3,000 yds^3 of past erosion: shallow debris slides, debris flow sources, debris torrent tracks, active earthflows, gullies, and streambank erosion. This analysis estimated the sediment volume delivered to the stream system and then assigned a management association (road-related, harvest-related, etc.) to sources when there was a management activity visible above the feature in the photo. Sources with no management association were assumed due to natural causes. This information was verified at some locations if they were near plots sampled during the field study to identify small sources of sediment.

A stratified random sampling (STRS) study was performed to estimate small sediment sources (USEPA, 1999b, 2002). Before fieldwork was performed, plot sizes were identified and the watershed was stratified by terrain type. To determine the optimal plot size, data from Jordan Creek, a tributary of the lower Eel River that is geologically similar to the Upper Eel River, were used. This process is described in detail in the "Sediment Source Investigation for the Van Duzen River Watershed" (Pacific Watershed Associates, 1999). This statistical analysis determined that 41.8 acres (450 feet x 450 feet) is the optimal plot size for the STRS study. PWA stratified the Upper Eel River watershed into five strata or geologies by reviewing the USFS and State Geology maps of bedrock and lumping similar rock types into 5 basic geologies. These five strata are identified in Table 8 along with their total area and the number of sample plots within each stratum.

To achieve a statistically robust random sample that provides a satisfactory coefficient of variation (CV), a sample size of eighty (80) 41.8-acre plots per study is considered optimal. Due to cost constraints and the interest in treating the public and private ownership domains as separate analyses, a sample size of 40 plots in each of the ownership domains was selected for the Upper Eel River STRS study. Real estimates calculated for the Van Duzen TMDL revealed that the CV for erosion from features <5,000 yds^3 equaled 0.21 and the CV calculated for sediment yield from features <5,000 yds^3 equaled 0.17.

To select the location of the sample plots, a grid was developed for the entire basin area with each grid cell equal to 41.8 acres. The sample grid was overlain with the five terrain types to create a layer that identified the dominant terrain type for each grid cell. Two hundred grid cells were randomly selected for each ownership domain (public and private). The first consecutive forty (40) plots from each list of 200 plots were chosen for each ownership domain. Landowner permission for access was requested for private domain plots and those plots within the public domain that had some private ownership. When landowner permission could not be obtained, the next sequential cell on the list for the appropriate stratum was selected. In addition, if a cell was randomly selected, but contained a large sediment source (>3,000 yds^3), it was eliminated and another grid cell was systematically selected. All 40 of the public plots were sampled and 33 out of the 40 private plots were sampled (seven were not sampled due to lack of permission to access the land). The number of sample plots for each stratum was based on estimates from previous studies (Van Duzen, EPA 1999 and North Fork Eel, EPA 2001). These values are identified in Table 8.

For the STRS field study, small sediment sources (less than 3,000 yds^3) were placed in the following source categories: debris slide, debris torrent track, bank erosion, road related gully, non-road related gully, stream crossing, channel incision, surface erosion, debris flow source, and active earthflow. The primary natural and anthropogenic source not quantified in the STRS study was creep rate. In addition to mapping these small sources, the volume of erosion was quantified and the sediment delivered to streams was estimated before assigning a management association to the source.

Table 8. Strata Identified in the Upper Eel River Watershed *

Strata Area Number and Description	Area (mi^2)	Percent of Basin	Number of Grid Cells	Proposed Number of Sample Plots	Number of Plots Sampled
1. Franciscan Schist	145.1	21.1%	2,223	15	15
2. Franciscan Melange	64.4	9.4%	985	14	14
3. Alluvium	16.9	2.5%	259	6	5
4. Franciscan Coastal Belt	64.9	9.4%	994	15	13
5. Franciscan undifferentiated	396.8	57.7%	6,076	30	26
Totals	**688.1**	**100%**	**10,537**	**80**	**73**

*Appendix C contains tables for the entire watershed and for each subwatershed.

The results of the STRS study were extrapolated to estimate small source sediment yield for the entire basin. After the large and small sources were quantified, the estimated basin-wide small source and aerial photo data were combined to determine the total Upper Eel River sediment yield and rates of erosion for different management associations, time periods, and strata, which are presented in the following section.

4.2.2 Results

A total of 13,310,714 yds^3 of sediment yield is estimated as being delivered to the Upper Eel River basin mostly between 1940 and 2004. Table 9 summarizes earthflow (continuous, deep-seated, slow moving large features, often ground water driven) and non-earthflow (episodic, relatively rapid movement, often storm related) sediment yield for the small features (<3,000 yds^3) and large features (>3,000 yds^3) and Figure 6 illustrates the percent sediment production by terrain type. As identified in Table 9 and Figure 6, terrain type #5, Franciscan, delivers the most sediment (6,206,774 yds^3) of all the terrain types, nearly one-half of the total sediment yield. Schist (terrain type #1) delivers the second highest volume of sediment (3,384,536 yds^3) and when compared to the other terrain types, alluvium delivers a relatively small amount of sediment to the basin (227,024 yds^3).

Non-earthflow sources deliver nearly 94% of all sediment to the basin and large features (earthflow and non-earthflow) contribute 57% of the total sediment delivered. In addition, the data indicate that the primary source of sediment for the schist and mélange terrains are large features, while non-earthflow features are the primary source for the alluvium terrain. When compared to nearby watersheds (USEPA, 1999b, 2002), there is a more equal distribution between large and small sources in regards to sediment delivery rates. This is most likely due to both a decrease in the contribution from large features, such as landslides, and an increase in management-related sediment delivery from small features.

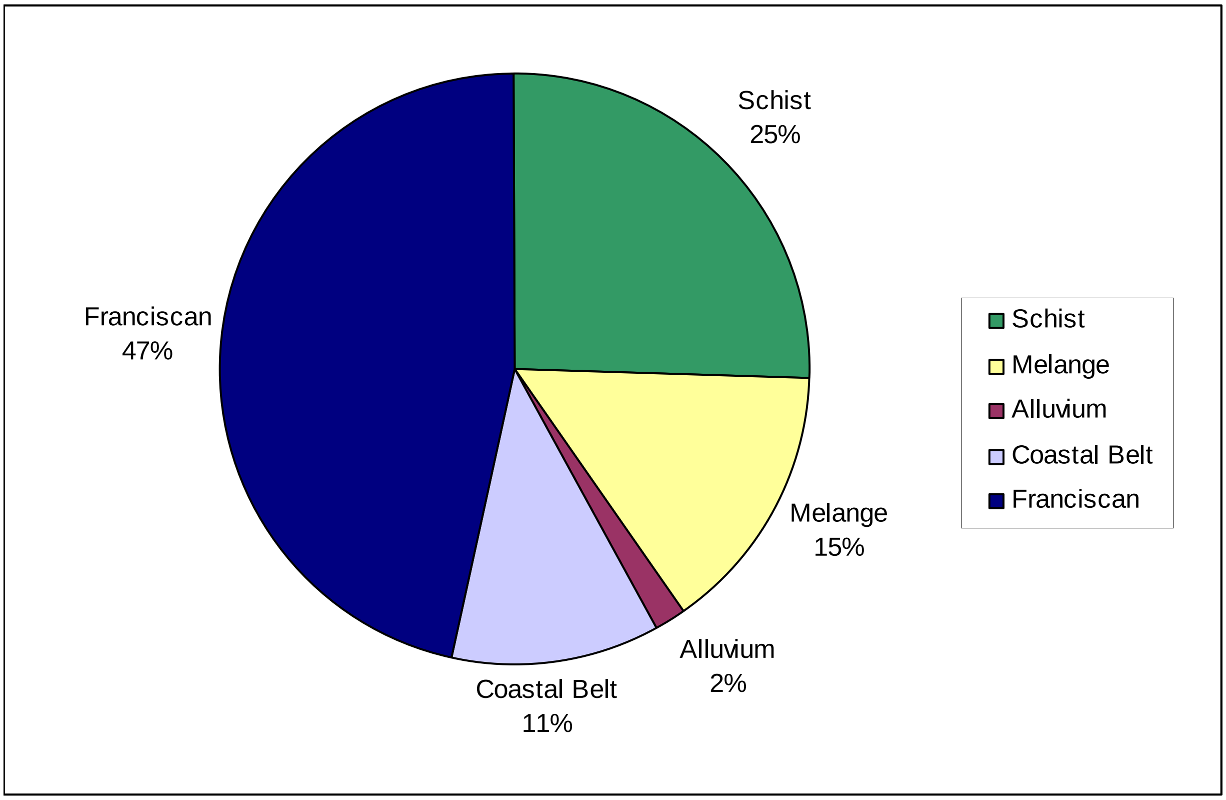

Figure 6. Percent sediment delivery by terrain type

Table 9. Total Erosion and Sediment Delivery from Small and Large Features by Terrain Type (1940-2004)

Terrain Type / Geology	Units	Small Features <3,000 yds^3 (Extrapolated from STRS study)		Large Features >3,000 yds^3 (Identified from aerial photos)		Total Sediment Delivery
		Non earthflow Sediment Delivery	Earthflow Sediment Delivery	Non earthflow sediment Delivery	Earthflow Sediment Delivery	
Schist	yds^3	467,783	0	2,830,120	86,633	**3,384,536**
	yds^3/mi^2/yr	50	0	305	9	**364**
Melange	yds^3	485,764	18,209	1,244,569	222,102	**1,970,644**
	yds^3/mi^2/yr	118	4	302	54	**478**
Alluvium	yds^3	207,674	0	19,350	0	**227,024**
	yds^3/mi^2/yr	192	0	18	0	**210**
Coastal Belt	yds^3	613,337	0	885,955	22,444	**1,521,736**
	yds^3/mi^2/yr	148	0	213	5	**366**
Franciscan	yds^3	3,627,160	320,428	2,095,365	163,821	**6,206,774**
	yds^3/mi^2/yr	143	13	83	6	**244**
Totals	yds^3	**5,401,718**	**338,637**	**7,075,359**	**495,000**	**13,310,714**
	yds^3/mi^2/yr	**123**	**8**	**161**	**11**	**302**

For all erosional features identified within the sample plots or on aerial photographs, PWA attempted to identify the decade in which the erosion was initiated and whether the feature was still actively eroding in 2004. The age of vegetation on or adjacent to an erosional feature provides the most useful information in deriving the origination age and activity level. Table 10 identifies all the management- and non-management-associated sediment delivery features that PWA estimated were initiated prior to 1970 and those that were initiated after 1970. PWA chose to separate the data around 1970 due to the shifts in management taking place in that time period. Any differences in sediment volumes may provide some indication as to the degree to which modern (post-1970) management practices have improved over past practices.

Table 10 and Figure 7 indicate the following: 1) 67% of all measured sediment yield occurred pre-1970; 2) management- and non-management associated sources accounted for nearly the same sediment yield on private lands pre-1970, whereas on the public lands, management-related sediment yield accounts for less than one-fourth of the total pre-1970 yield; and 3) post-1970 sediment yields are considerably lower than during the pre-1970 period. In both the private and public domains, non-management related yield accounts for approximately twice as much sediment as the management-associated yield during the post-1970 period.

The data suggest considerably less natural and management related sediment is being produced in the Upper Eel River basin in the post-1970 period (8,956,268 yds^3 pre-1970 compared to 4,360,730 yds^3 post-1970). This may reflect differences in the frequency and magnitude of storms, which trigger widespread watershed response, but also could be partially attributed to improvements in land management practices.

Table 10. Sediment Delivery by Time Frame and Potential Controllability (1940-2004)

Ownership domain		**Total Yield by Time Period for Management Sediment Yield (yds^3 & %)[1]**		**Total Yield by Time Period for Non- Management Sediment Yield (yds^3 & %)[1]**		**Total by Ownership**
		Non Earthflow	**Earthflow**	**Non Earthflow**	**Earthflow**	
Private	Pre-1970 (30 years)	2,299,049 (32%)	27,961 (<1%)	2,342,797 (33%)	439,219 (6%)	**5,109,026 (71%)**
	Post-1970 (34 years)	698,328 (10%)	3,703 (<1%)	1,139,359 (16%)	202,832 (3%)	**2,044,222 (29%)**
	Subtotals	2,997,377 (42%)	31,664 (<1%)	3,482,156 (49%)	642,051 (9%)	**7,153,248 (100%)**
Public	Pre-1970 (30 years)	711,708 (12%)	10,516 (<1%)	3,044,859 (49%)	80,159 (1%)	**3,847,242 (62%)**
	Post-1970 (34 years)	612,852 (10%)	8,748 (<1%)	1,628,123 (26%)	66,785 (1%)	**2,316,508 (38%)**
	Subtotals	1,324,560 (22%)	19,264 (<1%)	4,672,982 (75%)	146,944 (2%)	**6,163,750 (100%)**
Basin-wide Totals		**4,321,937 (32%)**	**50,928 (<1%)**	**8,155,138 (61%)**	**789,000 (6%)**	**13,316,99**

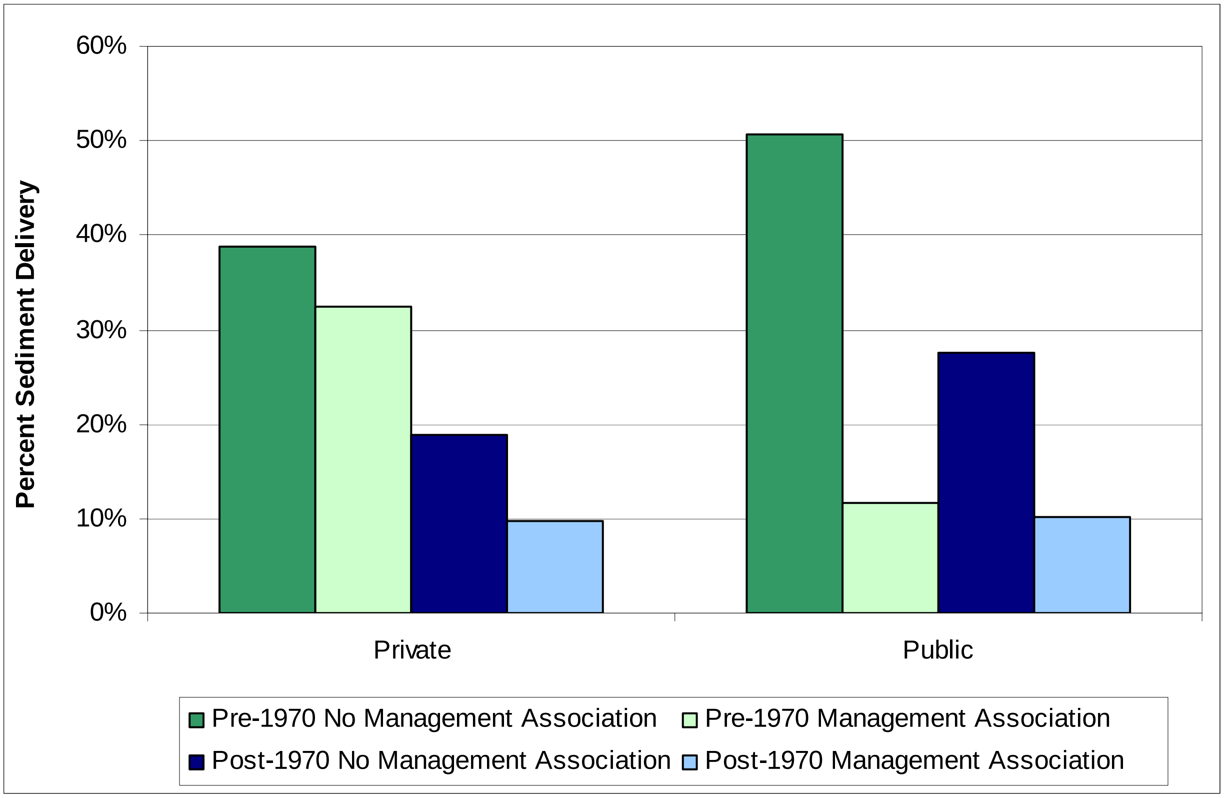

Figure 7. Percent sediment delivery by management association and time period

Table 11 summarizes the extrapolated estimates of Upper Eel River basin sediment yield by ownership according to the primary land use association. All erosional features mapped in the field sample plots or on the aerial photos were assigned a primary land use association based on field and air photo evidence. Table 11 categorizes erosional features as having the following land use associations: 1) no apparent land use linkage (naturally occurring), 2) road related (logging, ranch, county or CalTrans road), 3) timber harvest, 4) agriculture or grazing (includes erosion due to vegetation loss and the movement of animals), and 5) fire. Figure 8 illustrates the percent sediment delivery by land use association for public and private domains. The original data table (Table B-6), presented in Appendix B, also separates the results by large and small features.

While the sediment loading rates are similar for public and private lands (309 $yds^3/mi^2/yr$ for private and 290 $yds^3/mi^2/yr$ for public), the sources delivering sediment vary significantly. The data indicate that of the total past sediment yield (earthflow plus non-earthflow) from private and public domains, approximately 57% and 78%, respectively, were determined to be natural and not clearly associated with any past land management activities (Table 11). The management-associated rate of sediment delivery on private lands is nearly twice the rate on public lands. For private lands, management-associated sources of sediment yield account for about 133 yds^3/mi^2/year, which is approximately 43% of the total on private lands. These are divided between road sources (16%), timber harvest (20%), agriculture/grazing (7%), and fire (<1%). Management sources are less influential on public lands. Specifically, management-associated sources account for about 66 yds^3/mi^2/year on public lands, which is approximately 23% of the total (road sources (12%), timber harvest (11%), agriculture/grazing (<1%), and fire (<1%)). Non-earthflow sources account for a vast majority of the sediment delivery in both public and private lands with natural land uses contributing the greatest proportion of sediment for both earthflow and non-earthflow sources.

Table 11. Sediment Yield by Domain and Primary Land Use (1940-20040

Primary Land Use Association		Domain / Ownership (area) Private (359.4 mi^2) $yds^3/mi^2/yr$	Private %	Public (328.7 mi^2) $yds^3/mi^2/yr$	Public %	Basin-wide (688.1 mi^2) $yds^3/mi^2/yr$	Basin-wide %
Non-Earthflow	No land use	150	53	221	77	**184**	**65**
	Timber harvest	61	22	30	10	**46**	**16**
	Road Related	48	17	33	11	**41**	**14**
	Agriculture / Grazing	21	8	<1	<1	**11**	**4**
	Fire	2	<1	1	<1	**1.5**	**<1**
	Total non EF sediment yield	282	100	285	100	**283**	**100**
Earthflow	No land use	26	96	5	94	**16**	**95**
	Timber harvest	0	0	<1	<1	**<1**	**<1**
	Road Related	1	4	<1	<1	**0.7**	**4**
	Agriculture / Grazing	0	0	0	0	**0**	**0**
	Fire	0	0	<1	5	**<1**	**<1**
	Total EF sediment yield	27	100	5	100	**17**	**100**
Total sediment yield (non-Earthflow + Earthflow)		**309**	**100**	**290**	**100**	**300**	**100**

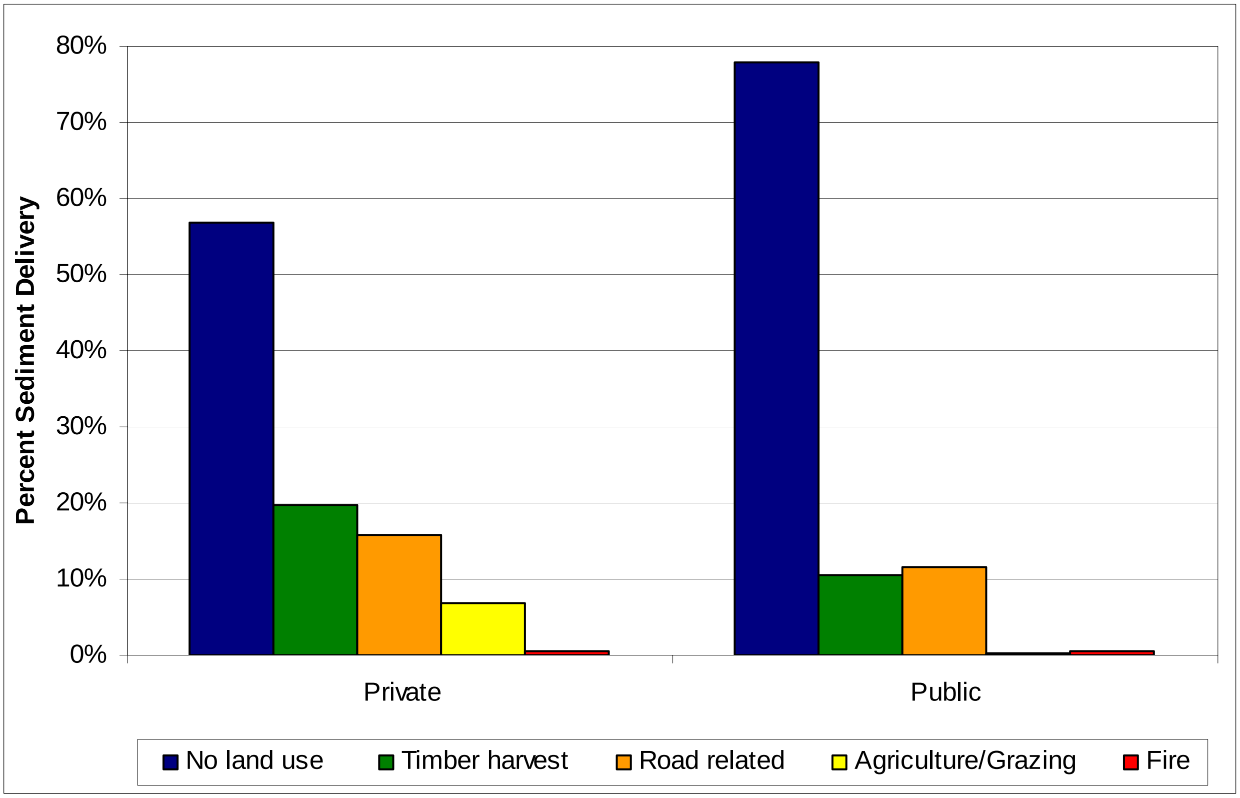

Figure 8. Percent sediment delivery by primary land use association (1940-2004)

4.2.3 Summary

Based on the results from the sediment source analyses, historical sediment delivery estimates can be generated from all sources in the basin. The results presented in Table 12 are a compilation of the data analyzed for the large and small sediment sources. Large sources (>3,000 yds^3) were quantified through the analysis of aerial photographs across the basin. Data collected during a stratified random sampling study were analyzed to determine the sediment input from small sources (<3,000 yds^3). These values were then extrapolated basin-wide and combined with the results from the large source analysis to obtain the unit area sediment input for the entire Upper Eel River basin (Table 12).

Table 12. Sediment Loading in the Upper Eel River (1940 – 2004)

Sediment Source	Private (359.4 mi^2)			Public (328.7 mi^2)			Basin-wide (688.1 mi^2)		
	$yds^3/mi^2/yr$	$tons/mi^2/yr$	% of Private	$yds^3/mi^2/yr$	$tons/mi^2/yr$	% of Public	$yds^3/mi^2/yr$	$tons/mi^2/yr$	% of Total
Natural Sediment Sources									
Large features (>3,000 yds^3)	69	106	22%	183	282	63%	**123**	**190**	**41%**
Small features (<3,000 yds^3)	109	168	35%	44	68	15%	**78**	**120**	**26%**
Total Natural Sources	**178**	**274**	**57%**	**227**	**350**	**78%**	**201**	**310**	**67%**
Human (Land Management) Related Sources									
Large features (>3,000 yds^3)	55	86	18%	36	55	12%	**46**	**71**	**16%**
Road related (small feature)	26	40	8%	9	14	3%	**18**	**28**	**6%**
Timber harvest (small feature)	30	46	10%	18	28	6%	**24**	**38**	**8%**
Agriculture/Grazing[1] (small feature)	19	30	6%	0	0	0%	**10**	**16**	**3%**
Total Human Related	**131**	**202**	**43%**	**63**	**97**	**22%**	**99**	**152**	**33%**
Total - All Causes	**309**	**476**	**100%**	**290**	**447**	**100%**	**300**	**462**	**100%**

[1]Agriculture/grazing causes less than 1 $yd^3/mi^2/yr$ of sediment delivery on public land and is therefore considered negligible.

4.3 TMDL AND ALLOCATIONS

4.3.1 Loading Capacity and TMDL

This TMDL is set equal to the loading capacity of the Upper Eel River. The TMDL is the estimate of the total amount of sediment, from both natural and human-caused sources, that can be delivered to streams in the watershed without exceeding applicable water quality standards. The approach taken focuses on sediment delivery rather than a more direct measure of salmonid habitat (i.e. instream conditions). Sediment delivery can be subject to direct management by landowners (i.e., roads can be well-maintained), whereas instream conditions (pool depth, percent fines) are subject to upstream management that may not be under the control of local landowners. While it would be desirable to mathematically model the relationship between salmon habitat and sediment delivery, these tools are not available for watersheds with landslides and road failure hazards.

Sediment movement is complex both spatially and temporally. Sediment found in some downstream locations can be the result of sediment sources far upstream. Instream sedimentation can also be the result of land management from decades past. Nevertheless, management activities can clearly increase sediment delivery, and instream habitat can be adversely affected by increased sediment inputs. Therefore, it is reasonable to link increases in sediment delivery to decreased stream habitat quality. The approach also assumes that salmon can be supported in streams even with the yearly variation of natural rates of erosion observed in the 20th century. Although sediment delivered to the streams has varied over time, salmon have adjusted to the natural variability by using the habitat complexity created by the stream's adjustments to the varying sediment loads. In addition, we are assuming that the natural amount of sediment can generally be increased to some extent and not adversely affect fish. We postulate this because historically, fish populations were thriving throughout the North Coast, even though there was human caused sediment from ranching, the tanbark industry, and some logging.

EPA is using a method of setting the TMDL and allocations similar to that employed in other basins (e.g., North Fork Eel, Noyo, Big and Albion Rivers, Middle Fork Eel [USEPA, 1999a, 2000, 2002 and 2003]). It is based on the assumption that a certain amount of loading greater than what is natural is acceptable, and will still result in meeting water quality standards. Most of the basins in the North Coast historically had some management activity occurring in the basin, while fish populations remained stable. Prior TMDL studies of the relationship between sediment loading rates and fish habitat effects found that many North Coast waters supported healthy fish habitat conditions during periods in which sediment loads were up to 125% of natural loading rates. In the Upper Main Eel River basin, EPA considers 125% to be appropriate because management activity is not high in the basin relative to other watersheds on the North Coast. We are basing the loading capacity and TMDL for the Upper Eel River basin on a calculation of 125% of natural loading.

TMDL = Loading Capacity = 125% x (310 tons/mi^2/year) **= 388 tons/mi^2/year**

The TMDL is set slightly higher than in the draft TMDL based on minor revisions in the source analysis calculation.

4.3.2 Allocations

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

TMDL = sum of "wasteload allocations" for individual point sources,

+ sum of the "load allocations" for nonpoint sources, and

+ sum of the "load allocations" for background sources

Although nonpoint sources are responsible for most sediment loading in the watershed, limited point sources may also discharge some sediment in the watershed. Current and prospective point sources that may discharge in the watershed and are therefore at issue in this TMDL include:

- CalTrans facilities (e.g., State Highway 162) that discharge pursuant to the CalTrans statewide NPDES permit issued by the State Water Resources Control Board, and
- Construction sites that discharge pursuant to California's NPDES general permit for construction site runoff.

Because the discharge from these point sources cannot be readily determined, and because possible loading from point sources is not distinguished from general management-related loading in the source analysis, EPA considers the rates set as load allocations (i.e., for nonpoint sources) to also represent wasteload allocations (i.e., for those point sources that would be covered by general NPDES permits). There are no other wasteload allocations, as there are no other individual point sources of sediment in the basin.

The load allocations for the Upper Eel River Sediment TMDL are presented in Table 13. The allocations clarify the relative emphasis and magnitude of erosion control programs that need to be developed during implementation planning. The load allocations are expressed in terms of yearly averages (tons/mi^2/yr). They can be divided by 365 to derive daily loading rates (tons/mi^2/day), but EPA is expressing them as yearly averages because sediment delivery to streams is highly variable on a daily basis. In fact, EPA expects the load allocations to be evaluated on a ten-year rolling average, because of the natural variability in sediment delivery rates. In addition, EPA does not expect each square mile within a particular source category throughout the watershed to necessarily meet the load allocation; rather, EPA expects the watershed average for the entire source category to meet the load allocation for that category.

Some of the load allocations are slightly changes from those in the draft TMDL because of the revised TMDL number.

Table 13. Load Allocations Averaged over the Entire Basin

SEDIMENT SOURCE	Load Allocation (tons/mi^2/yr)	1940-2004 Loading (tons/mi^2/yr)	Percent Reduction
Natural Sediment Sources			
Large features (>3,000 yds^3)	190	190	none
Small features (<3,000 yds^3)	120	120	none
Total Natural Sources	**310**	**310**	**none**
Human (Land Management) Related Sources			
Large features (>3,000 yds^3)	36	71	49%
Road related (small feature)	14	28	50%
Timber harvest (small feature)	20	38	47%
Agriculture/Grazing (small feature)	8	16	50%
Total Human Related	**78**	**152**	**49%**
Total - All Causes	**388**	**462**	**16%**

4.3.3 Margin of Safety

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

There is uncertainty concerning the interpretation of the amount of sediment delivery associated with management activities versus natural background sources.

The USFS and PWA generally attributed most or all of the sediment load of any landslide occurring within a recent harvest unit as being harvest or road related. This is a conservative assumption because some slides may have occurred naturally even if the land had not been harvested recently. Because the TMDL is calculated based on the amount of natural loading, this results in a more conservative TMDL calculation.

EPA does not expect each square mile within a particular source category to necessarily meet the allocation; rather, EPA expects the average for the entire source category to meet the allocation across the basin for that category.

There is inherent annual and seasonal variation in the delivery of sediment to the stream channel from the source mechanisms. The allocations are expressed as 10-year rolling averages to account for variability in delivery rates. The TMDL also includes watershed indicators to reflect sediment delivery risks.

This TMDL includes an implicit margin of safety based on EPA's conservative assumptions regarding the uncertainty associated with the sediment source analysis, as well as with the need to protect the resource. USEPA Region IX considered the lack of instream and watershed data, other than the source analysis, in making these conservative assumptions.

4.3.4 Seasonal Variation and Critical Conditions

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

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

CHAPTER 5: IMPLEMENTATION AND MONITORING MEASURES

The main responsibility for water quality management and monitoring resides with the State. EPA fully expects the State to develop and submit implementation measures to EPA as part of revisions to the State water quality management plan, as provided by EPA regulations at 40 C.F.R. Sec. 130.6. The State implementation measures should contain provisions for ensuring that the allocations in the TMDL will in fact be achieved. These provisions may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs, including the State's recently upgraded nonpoint source control program.

For the Temperature TMDL, EPA recommends that timber harvest permits on private lands be evaluated to assure that natural shade is protected in order to assure compliance with the TMDL and thus water quality standards. The State should also assure that adverse cumulative effects are avoided in watersheds where timber harvest plans are frequent or widespread. As a practical matter and one that accounts for site-specific information, the TMDL calculation can be simplified during implementation as setting the TMDL equal to no allowable changes to natural shade.

Current standards and guidelines under the North West Forest Plan may be sufficient to attain riparian vegetation characteristics consistent with the temperature load allocations for shade that apply to streams on USFS lands. All USFS management practices should be reviewed to assure that actual shade conditions are attained and that water quality standards are attained as a result.

EPA also has several recommendations regarding data collection and monitoring for stream temperature and flow. In reviewing the preliminary data from the 15 cfs flows during summer 2004, several unusual conditions were found. Specifically unusually warm temperatures were measured during July downstream of Scott Dam. This appears to result from maintenance activity at the dam. However, no temperature monitoring of the hypolimium in Lake Pillsbury was attempted. In addition, PG&E should attempt to document the management and mixing of the releases at Scott Dam.

For future temperature modeling to be validated and improved, EPA also recommends the following:

- Duplicating DFG temperature monitoring at nearby locations. This will assure that analysis is not compromised by the yearly problem of theft and loss of monitoring devices. EPA recommends that PG&E supplement DFG's monitoring to assure that resource problems are not an issue. This is especially important just below Van Arsdale. That site is essential to characterizing the system.

- Additional agencies monitor additional pool/riffle combinations to supplement DFG monitoring.

- PG&E might consider updating the hydrology/stream morphology information before additional stream temperature modeling is conducted. The current data is nearly 20 years old and was not directly collected for use in stream temperature models.

For the Sediment TMDL, EPA specifically recommends that more in-stream information be gathered on tributaries on USFS lands and all streams on private lands throughout the basin. EPA also suggests that the State consider using the information developed from the sediment source analysis in setting priorities for any new sediment reduction programs in the watershed. EPA recommends that timber harvest permits on private lands be evaluated to ensure consistency with sediment load allocations with the TMDL and thus water quality standards. The State should also assure that adverse cumulative effects are avoided in watersheds where timber harvest plans are frequent or widespread. On USFS lands, it appears that sediment loading is largely due to natural causes. USFS lands may meet sediment load allocations if future management practices and the intensity of management are not changed from the recent past, as provided under the NWFP.

CHAPTER 6: PUBLIC PARTICIPATION

EPA provided public notice of the draft Upper Main Eel River Temperature and Sediment TMDLs by placing a notice in the *Willits News* and *Santa Rosa Press Democrat*, papers of general circulation in Mendocino and Trinity Counties. EPA also met with major stakeholders – PG&E, Friends of the Eel River and NMFS during the Fall of 2003. EPA held an informational meeting in Willits in the summer of 2004 for landowners whose land was to be surveyed for the sediment source analysis. The public notice regarding availability of the draft Upper Main Eel TMDLs was posted on EPA's web site, along with the document. The public notice was also mailed or emailed to additional parties. EPA's response to the public comments received is available as a separate document.

References

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

Brooks, J., Ekman, E., Faust, B., and James, A. 1984. Lake Pillsbury Basin Watershed Analysis, under the direction of the California Department of Fish and Game, Region III; the Mendocino National Forest; the Mendocino County Fish and Wildlife Advisory Committee; the Pacific Gas and Electric Company; and the Sonoma County Water Agency.

Brown, W.M., III, and Ritter, J.R., 1971, Sediment transport and turbidity in the Eel River basin, California. U.S. Geological Survey Water Supply Paper 1986, 70 p.

California Department of Fish and Game (CDFG). 1995 - 1998. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Reports.

California Department of Fish and Game (CDFG). 1991. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Willits Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Alder Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Baechtel Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Bear Pen Canyon Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Bloody Run Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Broaddus Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Cherry Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Haehl Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Long Valley Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Outlet Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Ryan Creek.

California Department of Fish and Game (CDFG). 1995. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: String Creek.

California Department of Fish and Game (CDFG)-Water Pollution Control Laboratory. 1996. California stream bioassessment procedure. Rancho Cordova, CA.

California Department of Fish and Game (CDFG). 1997. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Cave Creek.

California Department of Fish and Game (CDFG). 1997. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Cave Creek.

California Department of Fish and Game (CDFG). 1997. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Unnamed Tributary #1 to Cave Creek.

California Department of Fish and Game (CDFG). 1997. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Unnamed Tributary #2 to Cave Creek.

California Department of Fish and Game (CDFG). 1997. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Tomki Creek.

California Department of Fish and Game (CDFG). 1998. Salmon and Steelhead Restoration and Enhancement Program, Stream Inventory Report: Unnamed Tributary #3 to Cave Creek.

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

Chen, Y.D. et al. 1998. Stream Temperature Simulation of Forested Riparian Areas. I. Watershed Scale Model Development. Journal of Environmental Engineering, 124(4), 304-315.

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

Department of Water Resources, State of California (DWR). October 1982. Middle Fork Eel River Watershed Erosion Investigation. DWR, Northern District - Red Bluff, CA.

Federal Energy Regulatory Commission. January 28, 2004. Pacific Gas and Electric Company, Project No. 77-110. Order Amending License.

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

Garman, S.L., S.A. Acker, J.L. Ohmann, T.A. Spies. 1995. Asymptotic height-diameter equations for twenty-four tree species in western Oregon. Oregon State University Forest Research Laboratory, College of Forestry. Research Contribution 10. September.

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

Herbst, D. 2003. Summary of recent findings regarding a comparison of data generated by CDFG, USFS, Lahontan RWQCB, and EPA-EMAP macro invertebrate field protocols. Presentation given to the Surface Water Ambient Monitoring Program (SWAMP) Bioassessment Monitoring Committee, Lahontan Regional Water Quality Control Board Office, South Lake Tahoe, September 25.

Humboldt County Resource Conservation District. May 15, 1998. Final Report, Eel River Water Quality Monitoring Project. Fields Landing, CA.

Humboldt County Resource Conservation District. 1996-2003. Temperature monitoring data (available on CDs.)

Jones, W.E. 1992. Historical distribution and recent trends of summer steelhead, Oncorhynchus mykiss in the Eel River, CA. Paper presented for the Eel River Workshop, Redding, CA, February 6, 1992. Region 3, California Department of Fish and Game.

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

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

Kubicek, P.F. August 1977. "Summer Water Temperature Conditions in the Eel River System, with reference to Trout and Salmon". Masters Thesis, Humboldt State University.

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

Lisle, T.E. 1993. The fraction of pool volume filled with fine sediment in northern California: relation to basin geology and sediment yield. Final report to Calif. Dept. of Forestry and Fire Protection. Aug. 20.

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

Mendocino County Resource Conservation District. December 1983. North Coast Erosion and Sediment Control Pilot Project, Tomki Creek Watershed. Ukiah, CA.

Morford Consultants. 1995. Eel River hydrology and Chinook salmon: An analysis of USGS streamflow data collected at Scotia, Humboldt County, California with emphasis on fisheries. Willits, CA. September 1995.

Myrick, C. A., and J.J. Cech, Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A review focusing on California's Central Valley Population*. Bay Delta Modeling Forum Technical Publication 01-1.

National Marine Fisheries Service (NMFS). February 20, 2003. Draft Report. "Preliminary Conclusions regarding the updated status of listed ESUs of West Coast salmon and steelhead, B. Steelhead Trout". Northwest Fisheries Science Center. Seattle, WA.

National Marine Fisheries Service (NMFS). November 26, 2002. Final. Biological Opinion on the Proposed License Amendment for the Potter Valley Project (FERC 77-110). Southwest Region. Long Beach, CA.

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

North Coast Regional Water Quality Control Board (NCRWQCB). 2002. Action Plans for the Albion River, Big River, Noyo River, and Ten Mile River Sediment TMDLs.

North Coast Regional Water Quality Control Board (NCRWQCB). 2001. Water Quality Control Plan for the North Coast Region. Last amended June 28, 2001.

Ode, P.R. 2003. Summary of recent findings regarding a comparison of data generated by CDFG, USFS and EPA-EMAP macro invertebrate field protocols. Presentation given to the Surface Water Ambient Monitoring Program (SWAMP) Bioassessment Monitoring Committee, Lahontan Regional Water Quality Control Board Office, South Lake Tahoe, September 25.

Pacific Watershed Associates. 1999. Sediment source investigation for the Van Duzen River watershed: An aerial photo analysis and field inventory of erosion and sediment delivery in the 429 mi2 Van Duzen River Basin, Humboldt County, California. Arcata, CA. November 1999.

Porterfield, G. and Dunnam, C.A. 1964. Sedimentation of Lake Pillsbury, Lake County, California. U.S. Geological Survey Water Supply Paper 1619-EE. 46 pp.

SEC (Steiner Environmental Consulting). 1998. Potter Valley Project monitoring program (FERC no. 77, Article 39): Effects of operations on upper Eel River Anadromous Salmonids, March 1998 Final Report. Prepared for Pacific Gas and Electric Company, San Ramon, CA.

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

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

Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. December 2000. “An analysis of the Effects of Temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria “ Sustainable Ecosystems Institute, Portland, OR.

Supernowicz, D. April 1995. Heritage Resource Investigations along the Upper Eel River Watershed within the Mendocino National Forest, including Portions of Mendocino and Lake Counties. Mendocino National Forest, Willows, CA.

Timber - Fish - Wildlife Project, December 2000. Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington. Washington Department of Natural Resources, Olympia, WA

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

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

US Environmental Protection Agency (USEPA). 1999b. Van Duzen River and Yager Creek Total Maximum Daily Load for Sediment. San Francisco, CA. December 1999.

US EPA. 2000. Big River total Maximum Daily Load for Sediment. San Francisco, CA. December 2000. P32

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

US Environmental Protection Agency (USEPA), Region 10. 2001b. Issue Paper 5. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids. EPA-910-01-005. May 2001

US Environmental Protection Agency (USEPA). 2002. North Fork Eel River total Maximum Daily Loads for Sediment and Temperature. San Francisco, CA. December 2002.

US Environmental Protection Agency (USEPA). 2003. Middle Fork Eel River total Maximum Daily Loads for Sediment and Temperature. San Francisco, CA. December 2003.

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

USDA Forest Service (USFS). May 1995. Watershed Analysis Report for the Upper Main Eel River Watershed.

VTN Oregon, Inc. 1982. Potter Valley Project (FERC No. 77) Fisheries Study. Final Report Vols. I & II. Prepared for Pacific Gas and Electric Company, San Ramon, CA. 320 pp. + app.

Washington State Department of Ecology (WDOE). December 2000. Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards Temperature Criteria. 00-10-070

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

Personal Communications

Hope, D. and Feiler, S. NCRWQCB. 2003; Hope, D., Wright-Shacklett, C. Macedo, R., Ambrose, C.. Communications with Palma Risler

Jahne, J. NMFS Santa Rosa. 2004. Communications with Palma Risler.

Leland, D. NCRWQCB. October 2003. Communications with Janet Parrish.

McFadin, B. NCRWQCB. 2004. Communications with Palma Risler

APPENDICES

Appendix A: Temperature Modeling

available as a separate document

Appendix B: Sediment Source Analysis

available as a separate document

Appendix C: