Comments on DRAFT Mad River Total Maximum Daily Load (TMDL) for Sediment and Turbidity

By Patrick Higgins
Consulting Fisheries Biologist
791 Eighth Street, Suite N
Arcata, CA 95521
(707) 822-9428

Performed under Contract to:

Environmental Protection Information Center
3501 Redwood Dr # 3
Redway, CA 95565

Over View

The *Draft Mad River Total Maximum Daily Loads for Sediment and Turbidity (Draft TMDL)* appears technically sound and properly assigns a substantial pollution load to land use activity, particularly logging and associated road building. The U.S. Environmental Protection Agency (U.S. EPA) is to be commended for funding collection of sediment transport and turbidity data to plug data gaps and to truly assess the magnitude and origin of the Mad River sediment pollution problem. The *Draft TMDL* sets appropriate targets for indicators of sediment pollution and recommends their use for long term trend monitoring with the only exception being a reluctance to set a numeric standard for mainstem Mad River turbidity.

The Draft TMDL makes strong recommendations for pollution abatement, calling for a 98% reduction of sediment loading from human activities. The U.S. EPA defers to the California State Water Resources Control Board on TMDL implementation, but none the less, the final *Mad River TMDL* needs to be explicit with regard to setting prudent risk thresholds for timber harvest, road densities and the number of road crossings so that further damage from cumulative watershed effects can be prevented. Prioritization for action should reflect a "best science" approach to Pacific salmon restoration similar to that put forth by Bradbury et al. (1995). Alteration of sediment transport processes by gravel mining in the lower Mad River has also compromised attainment of beneficial use with regard to fisheries; therefore, the need for changes in gravel management practices should be discussed in the final *Mad River TMDL*.

While the *Draft TMDL* recognizes overall declines in Pacific salmon populations, there is no recognition that coho salmon may go extinct, if emergency actions to remediate pollution are not implemented. The final *Mad River TMDL* needs to take immediate steps to prevent pollution in sub-basins critical to coho salmon recovery.

Sediment Source Analysis/Cumulative Watershed Effects

The *Draft TMDL* uses standard techniques for devising a sediment budget and assessing sources. The findings indicate that only 26% of sediment is from natural sources and that loading is 400% over background levels primarily as a result of watershed disturbance due to timber harvest and road building. The most highly disturbed sub-basin is the Middle Mad, where sediment yield was estimated to be 1103% over background.

Figure 1 shows the triggering mechanisms of various types of recent landslides within the Mad River watershed. Roads triggered the most earthflows and were significantly linked to debris flow and debris slide initiation as well. Previous, recent timber harvest activity also triggered debris flows, debris slides, earthflows and inner gorge failures. Chronic erosion from roads is an even greater source of sediment in some sub-basins.

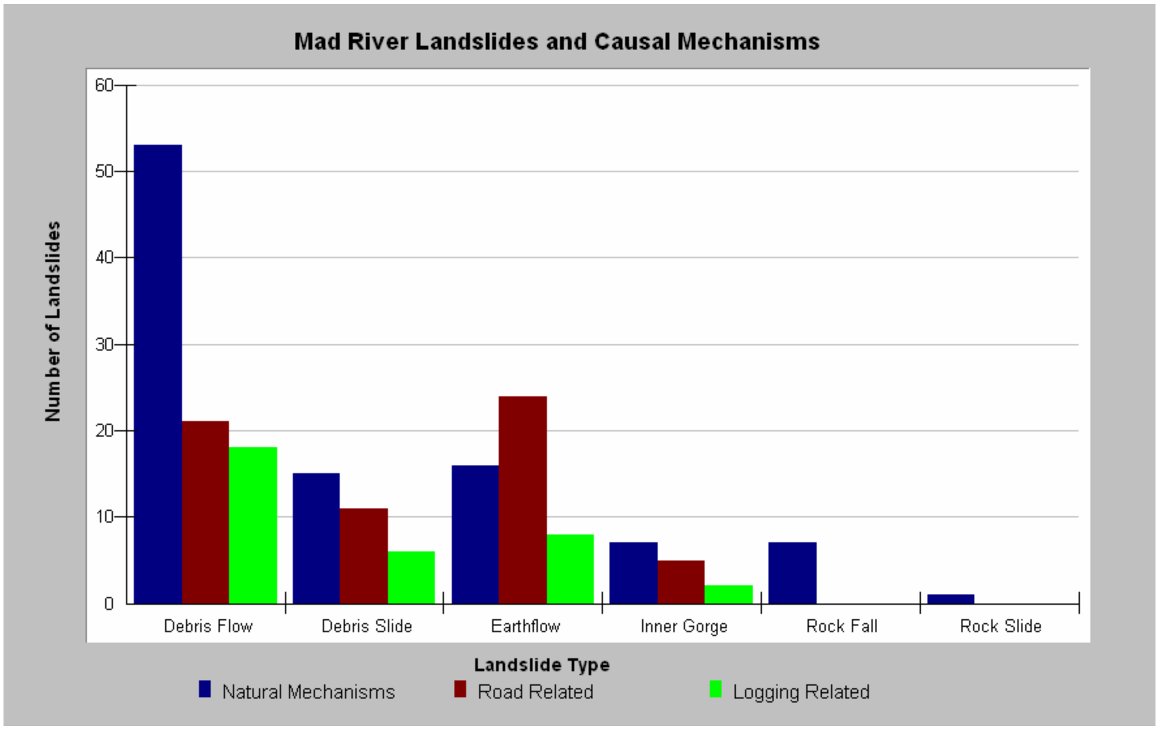

Figure 1. This chart shows the number of landslides and mechanisms that triggered them within the Mad River watershed. Data from Graham Matthews and Associates (Appendix A) for U.S. EPA.

Montgomery and Buffington (1993) point out that major storm events may cause previously managed hillslopes to fail and that sediment entrained as bedload in streams can increase inner gorge failure risk downstream. Jones and Grant (1996) found that roads profoundly alter watershed hydrology, becoming extensions of the streams, thereby increasing peak flows during major storm events. The widespread logging and associated increasing road densities in the Middle Mad River watershed have likely elevated both bedload transport and peak flows and contributed to streamside landslides along the Mad River and its tributaries during major storm events. It was beyond the scope of sediment analysis associated with the *Draft TMDL* to assess cumulative effects; however, it is likely that human caused factors likely played a role in some inner gorge failures ascribed to natural causes.

Dunne et al. (2001) studied cumulative watershed effects related to timber harvest in northern California. They point the problems that arise when timber harvests or road segments are looked at individually and not in conjunction with all activities in a watershed and warn that at risk populations can be lost, if cumulative effects are ignored and anthropogenic stressors continued:

> "The concern about cumulative effects arises because it is increasingly acknowledged that, when reviewed on one parcel of terrain at a time, land use may appear to have little impact on plant and animal resources. But a multitude of independently reviewed land transformations may have a combined effect, which stresses and eventually destroys a biological population in the long run."

Dunne et al. (2001) also point out that effects of disturbance are not necessarily linear and are sometimes hard to quantify but known to occur:

> "Generally speaking, the larger the proportion of the land surface that is disturbed at any time, and the larger the proportion of the land that is sensitive to severe disturbance, the larger is the downstream impact. These land-surface and channel changes can: increase runoff, degrade water quality, and alter channel and riparian conditions to make them less favorable for a large number of species that are valued by society. The impacts are typically most severe along channels immediately downstream of land surface disturbances and at the junctions of tributaries, where the effects of disturbances on many upstream sites can interact."

The geologic setting of the Mad River makes the landscape highly susceptible to erosion and patterns of land use on industrial timber lands within the Middle, Lower and North Fork Mad River sub-basins are well over those recognized as triggering watershed and water quality degradation. Consequently, the final *Mad River TMDL* should specifically note the prior failure of the timber harvest review process to prevent water pollution, loss of fish habitat and the decline of Pacific salmon and call for a change in approach to future timber harvest oversight to reverse these problems.

<u>Timber Harvest</u>: Ligon et al. (1999) and Dunne et al. (2001) recognized that a critical shortcoming of the California Forest Practice Rules (CFPR) was the lack of prudent limit or threshold for timber harvest to avoid cumulative watershed effects. Reeves et al. (1993) studied eight Oregon Coastal basins that were less than 25% timber harvested and compared them to adjacent watersheds with greater harvest levels. They found that streams draining watersheds cut in over 25% of their area within a 30 year period were usually dominated by one Pacific salmon species, while basins with less disturbance maintained several species. Reeves et al. (1993) traced the root cause to channel simplification associated with pool filling and large wood depletion. The value of 25% harvest in a 30 year period is roughly equivalent to a harvest rate of 1% of a watershed per year or 1% of inventory (POI). Klein (2003) found elevated turbidity in watersheds with greater than 1.5% POI, a slightly higher harvest rate wherein a basin would be harvested in roughly 35% of its area in a 25 year period.

Age class data provided as part of the Simpson Timber (2002) *Coho Salmon Habitat Conservation Plan* indicates that timber stands in the Mad River and North Fork Mad River are primarily early seral stage, indicating a very rapid rate of recent logging (Figure 2). The aerial image below (Figure 3) indicates that timber harvest within the Lindsay Creek watershed is approaching or exceeding the threshold recognized by Reeves et al. (1993) as causing damage to fish habitat and a decline of Pacific salmon species diversity. The *Draft TMDL* mentions that Lindsay Creek is one of the last of Mad River tributaries supporting coho salmon, but makes no recommendation regarding limiting further timber harvest in this sensitive watershed or elsewhere.

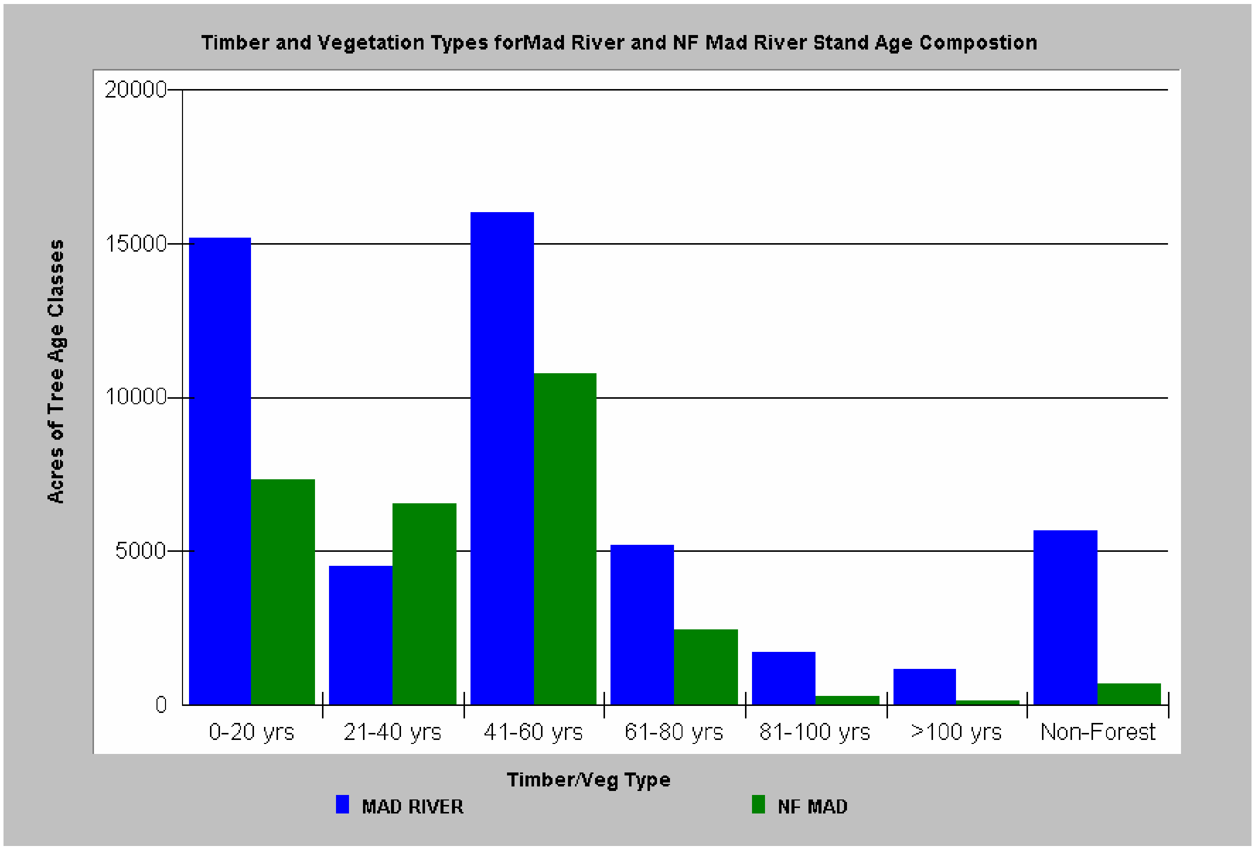

Figure 2. This chart of tree age classes of Simpson Timber holdings in lower Mad River and North Fork Mad River show a paucity of trees over 80 years old and indicate extensive timber harvest in recent decades, especially in the last two in Mad River.

Roads: Cedarholm et. al. (1981) found that road densities greater 4.2 miles (mi) of road per square mile (mi^2) of watershed yielded sediment levels 260% to 430% over background and increased fine sediment in salmon spawning gravels by 2.6 - 4.3 times. U.S. Forest Service (1996) studies in the interior Columbia River basin discovered that bull trout were absent in basins with road densities greater than 1.7 mi/mi^2. They ranked road-related cumulative effects risk as Extreme when road densities exceed 4.7 mi/mi^2 (Figure 4). National Marine Fisheries Service (1996) guidelines for salmon habitat characterize watersheds with road densities greater than 2.5 mi/mi^2 as "Not Properly Functioning" while "Properly Functioning Condition" is defined as less than or equal to 2 mi/mi^2 with few or no stream side roads. The *Draft TMDL* indicates that the Mad River watershed as a whole has 4.6 miles of road per square mile of watershed and much higher densities in sub-basins with recent, active timber harvest (Figure 5). This is well above density thresholds known to cause sediment and flow related cumulative watershed effects. Figure 6 shows high road density in Canon Creek in the Middle Mad River sub-basin.

Armentrout et al. (1999) noted the increased risk of sediment delivery from failed road crossings when there were multiple (or stacked) crossings on one stream channel. Failure of a culvert and road prism near the top of a drainage can cause successive failures of

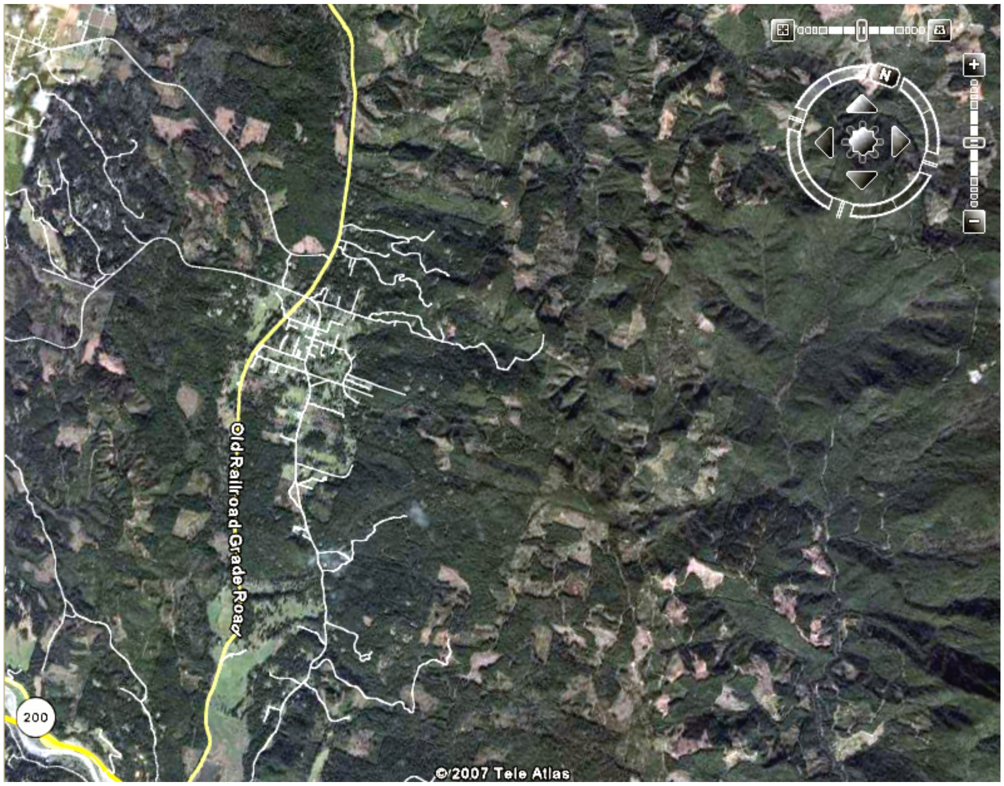

Figure 3. This Google Earth image shows extensive patch clearcuts in the Lindsay Creek watershed approaching or exceeding the threshold of prudent risk for maintaining salmon (Reeves et al., 1993).

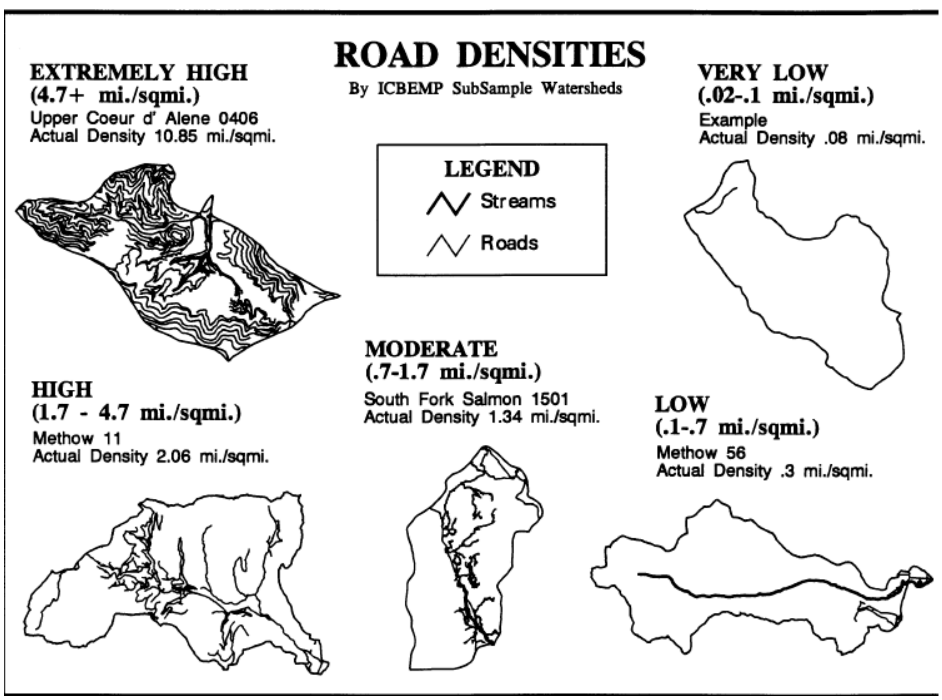

Figure 4. The USFS (1996) Interior Columbia River basin criteria for ecological and hydrologic risk from road densities. Mad River watershed wide road density is 4.6 mi/mi^2.

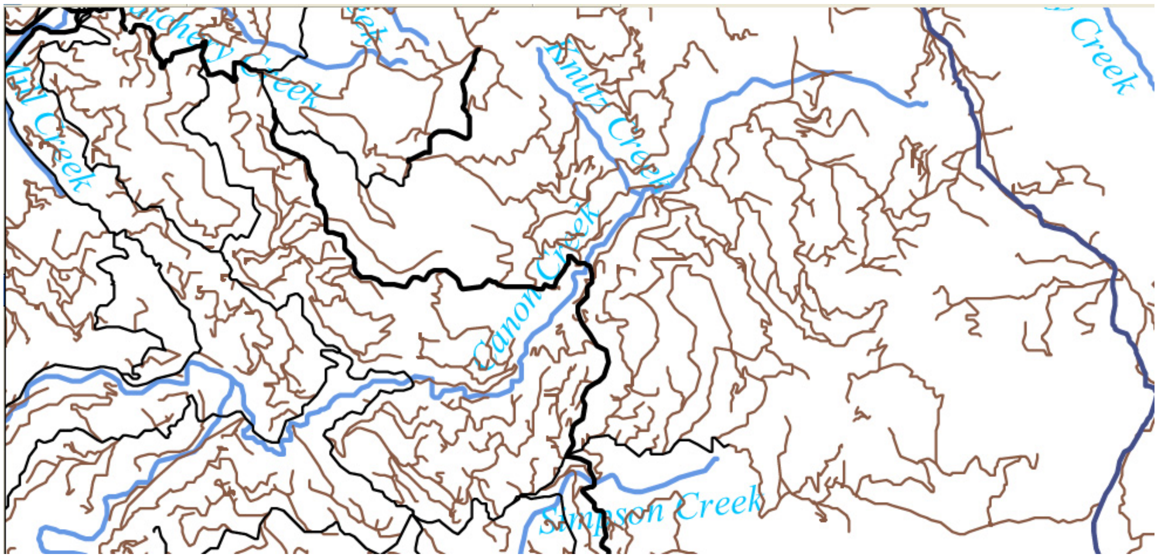

Figure 5. This map is a zoom of Plate 7 from the Draft TMDL showing high road density in the Canon Creek watershed.

culverts with resulting catastrophic sediment yield and channel scour in downstream reaches. Armentrout et al. (1999) recommended no more than 1.5 crossings per mile of stream to lessen the risk of cumulative effects in major storms.

Management of Steep Slopes/Inner Gorges: The *Draft TMDL* notes that the Mad River is a highly erodible watershed with many sub-basins having steep slopes that are subject to landsliding. Lavin and Lahre (1977) reported that management of steep unstable areas next to streams lead to massive inner gorge landslides on the South Fork Smith River. Steep slopes have much greater risk of failure when disturbed and computer models can be used to predict risk of shallow debris slides (Montgomery and Dietrich, 1994; Dietrich et al., 1998). Spence et al. (1996) note that inner gorge failures can cause catastrophic and long term damage to stream channels fish habitat. There are several steep inner gorge locations in the Middle Mad sub-basin with old growth forests owned by industrial timber companies that, if logged, may lead to catastrophic failures. This elevated risk should be recognized in the final *Mad River TMDL* and land use on steep unstaable areas discouraged.

Middle Mad Sub-Basin Tributary Cumulative Effects Case Study: The changes in Cañon Creek following extensive logging demonstrate significant cumulative effects. On a hike to Sweasey Dam in September 1966, I walked lower Cañon Creek just above its convergence with the Mad River. Although flow was only slight between pools, the depth within the pools was 4-6 feet and there were numerous salmonid juveniles of several size classes. More than 50% of the watershed was logged from 1980-1995. Pools in lower Cañon Creek were obliterated by sediment transport and channel widening killed riparian trees in low gradient response reaches that were formerly extremely productive for spawning and rearing salmonids (Figure 6). The convergence of Cañon Creek and the Mad River is occupied by a large delta. I attended a presentation at Humboldt State University in 1999 where a consulting statistician for Simpson Timber reported increases in channel width of Cañon Creek from 50 feet to 150 feet wide from 1985-1999.

Figure 6. The landscape of lower Canon Creek shows recent timber harvest and an extensive road network. Sediment avulsed from the creek formed a delta at the convergence with the Mad River (upper left) and aggradation in lower reaches of the creek killed riparian trees. Image from Google Earth.

This stream was a coho salmon index stream for the Pacific Fisheries Management Council, but returns have averaged only five coho adults per year after logging (Zuspan and Sparkman, 2002). The delta at the mouth was impeding fish during low flows so that adult coho could not enter during dry falls in the early 1990's, but USFWS has since funded a project to restore passage (Golightly, 1998).

Turbidity

The turbidity data collected for the *Mad River TMDL* and the combined analysis with existing data from Klein (2003; 2006) are a major highlight of the report and a significant contribution to regional scientific understanding. The conclusion that "turbidity values for the Mad River sites are orders of magnitude greater than the background rates" is correct and well founded. The *Draft TMDL*, however, does not sufficiently discuss the implications of the elevated turbidity on Mad River coho salmon and steelhead nor does it set a sufficiently specific target for turbidity.

Sigler et al. (1984) found that turbidity above 25 nephlometric turbidity units (NTU) inhibited feeding of juvenile coho salmon and steelhead trout juveniles and therefore reduced their growth rates. Most coho and steelhead must spend one or two winters in freshwater, respectively. The NCRWQCB (2004) pointed out that: "reductions in growth decrease the chance of smolts to mature and return as spawning adults, which cumulatively jeopardizes population sustainability (Trush 2001)." The extremely high chronic turbidity documented in the *Draft TMDL* showed that the lower Mad River exceeds 25 FNU (formalin turbidity units) over 80% of the period of record (Figure 7). For assessing the impact to coho and steelhead juvenile growth NTU and FTU are used interchangeably here because there is only a minor difference between these metrics at low levels (0-25) (Randy Klein, personal communication).

In addition, because much of the Lower Mad, North Fork and Middle Mad are in private ownership and intensively managed, there are no lightly managed sub-basins where fish may find refugia of clear water during winter periods of high flow. Collison et al. (2003) characterized this pattern of homogeneous watershed disturbance as a "press disturbance" and distinguished it from natural "patch" disturbance regimes that only affected small areas in varying sub-basins during periodic disturbance from fire, floods or earthquakes. The lack of clear water refugia and extreme, chronic turbidity can be directly linked to coho salmon population falling to levels of fewer than 100 adults annually. The CDFG (Sparkman, 2003) finding that 88% of steelhead in the angler catch are of hatchery origin is consistent with poor survival of wild steelhead juveniles due to highly turbid over-wintering conditions.

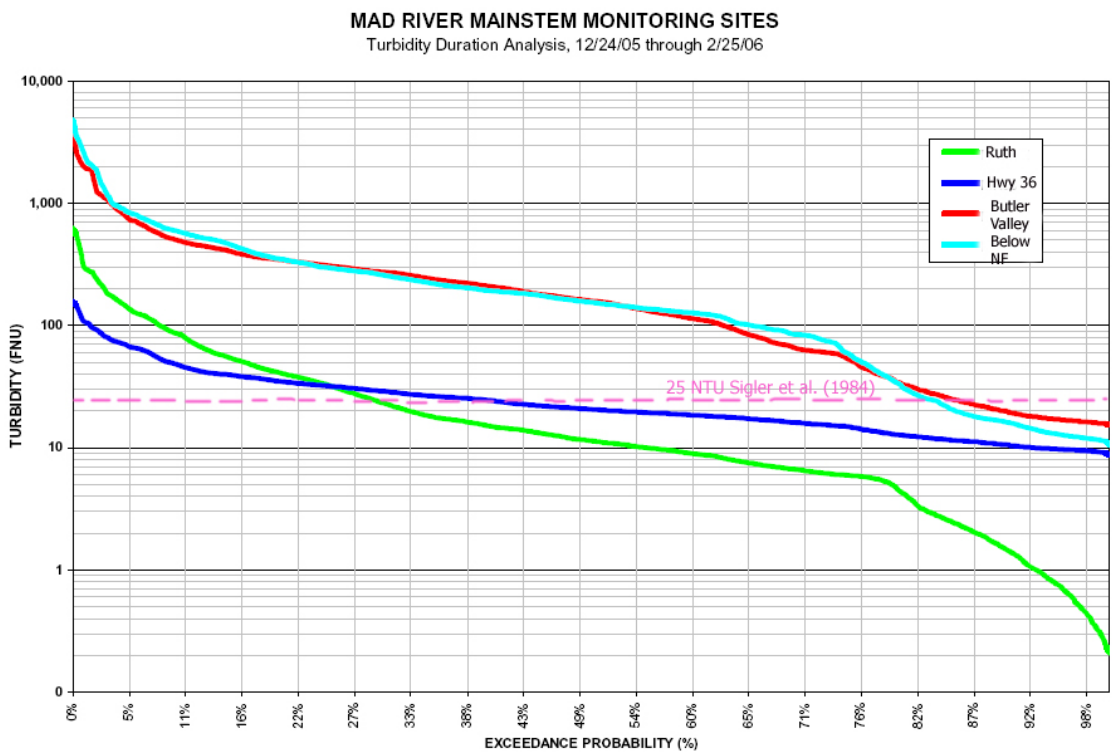

Figure 7. This chart from the *Draft TMDL* shows that turbidity exceeded levels known to inhibit coho and steelhead feeding greater than 80% of the time during the period of record in late 2005 and early 2006.

Setting a Target for Turbidity: The *Draft TMDL* notes that reference data for turbidity (Klein, 2003; 2006) are from small watersheds (<10 sq. mi.) and, therefore, cannot be directly applied to the mainstem Mad River. Surely, setting a standard for the mainstem similar to small pristine watersheds (less than 1% exceedence of 25 NTU/FNU) might not be achievable or necessarily appropriate. However, setting a limit of 10% exceedence of the 25 NTU/FTU level should be considered. The Oregon Department of Environmental Quality's (ODEQ, 2005) exhaustive review of literature on turbidity concurs with Newcombe (2003) that while the duration of exposure is important, 25 NTU should be a benchmark for impairment for salmonids:

> "This is not out of line with Newcombe's (2003) assessment model regarding clear water fishes which predicts that a long-term turbidity level of 25 NTUs would be at the threshold for 'severely impaired' or 'poor' water quality conditions."

The NRCWQCB (2006) acknowledged that the work of Klein (2003) suggests that a threshold for turbidity of a number of days over 27 NTU or a 10% exceedence limit for this value might be appropriate. They also take note of a different approach suggested by Trush (2001) that would require that turbidity be below 27 NTU "when the measured flow rate is at ten percent of the daily average late-winter baseflows…This criteria allows reliable measurements for the development of baseflow turbidity rating curves."

Status of Pacific Salmon Populations and Extinction Risk

The Draft TMDL does acknowledge the beleaguered condition of Mad River salmon and steelhead populations:

> "Information indicates that the populations have declined in numbers and their geographic extent has been reduced. Excessive sediment has contributed to salmonid problems in the Mad River watershed. For example, spawning gravel filled with fine sediment has caused decreased survival to emergence, pool filling has reduced juvenile carrying capacity, and high turbidity levels have led to reduced feeding and growth (NMFS 2004). Thus the available information indicates problems with the COLD beneficial use."

What *Draft TMDL* fails to do is to provide a regional context for extinction risk for species like coho salmon and information on known climate and ocean productivity cycles that will influence recovery. Brown et al. (1994) noted that populations of coho salmon in California were at less than 5% of historic levels and that there were only seven streams with adult returns numbering in the hundreds and the Mad River did not number among them. The California Department of Fish and Game (CDFG, 2002) *Status Review of Coho Salmon North of San Francisco* stated that "California coho salmon populations have been individually and cumulatively depleted or extirpated and the natural linkages between them have been fragmented or severed." This means that any additional loss of populations is extremely undesirable and that recovery of coho without substantial human intervention is unlikely.

The *Draft TMDL* states that “recent studies conducted during the winter months of 1999-2003 by CDFG estimated only 46 coho salmon in the Mad River (Sparkman 2003),” but fails to recognize that this represents an extreme risk of loss of the Mad River coho salmon population. Cañon Creek adult coho salmon returns have showed a declining trend from 1985-2000 (Figure 8), representing the decline of one production unit or Mad River sub-population in response to habitat loss due excess sediment produced by logging and roads.

Higgins et al. (1992) provided the following information on assessing critically low Pacific salmon populations and extinction risk:

> “When a stock declines to fewer than 500 individuals, it may face a risk of loss of genetic diversity which could hinder its ability to cope with future environmental changes (Nelson and Soule 1986). A random event such as a drought or variation in sex ratios may lead to extinction if a stock is at an extremely low level (Gilpin and Soule 1990). The National Marine Fisheries Service (NMFS, 1987) acknowledged that, while 200 adults might be sufficient to maintain genetic diversity in a hatchery population, the actual number of Sacramento River winter run Chinook needed to maintain genetic diversity in the wild would be 400-l 100.”

Summer steelhead are not recognized specifically as a distinct species in the *Draft TMDL*, but they are a separate stock and qualify as a species under ESA. NMFS (2005) estimated annual adult returns of summer steelhead as 162-384, but Halligan (2003 in NMFS, 2004) estimated adults at a much lower level (8-59 fish). Therefore, the summer steelhead population is also at elevated risk of loss.

Collison et al. (2003) note that northwestern California climate and ocean productivity for Pacific salmon species varies greatly with ocean current cycles that occur on a scale of decades (Hare et al., 1999). Positive ocean cycles and wet on-land conditions (1900-1925, 1950-1975) can be positively correlated to Pacific Northwest coho salmon abundance (Hare et al., 1999) and alternate with dry-on land and less favorable ocean conditions (1925-1950, 1975-1995). Collison et al. (2003) point out that the switch to wet on-land and productive ocean conditions occurred in 1995 and that a reversion to less favorable conditions is likely sometime between 2015 and 2025. They warn that unless freshwater habitat conditions are substantially improved by that time, Pacific salmon stock loss is likely. The U.S. EPA should make note of Collison et al. (2003) and stress the need for urgent action to reverse sediment pollution.

The *South Fork Trinity and Hayfork Creek Sediment TMDL* (U.S. EPA, 1998b) set numeric targets for recovery of spring and fall Chinook because “diminished fish population is the strongest indication of impaired habitat conditions; thus, recovered populations are the strongest indication of recovered habitat conditions.” The final *Mad River TMDL* should have explicit targets for minimum viable populations of all Pacific salmon (>500 adults annually) and higher targets for species where historic baseline data support them.

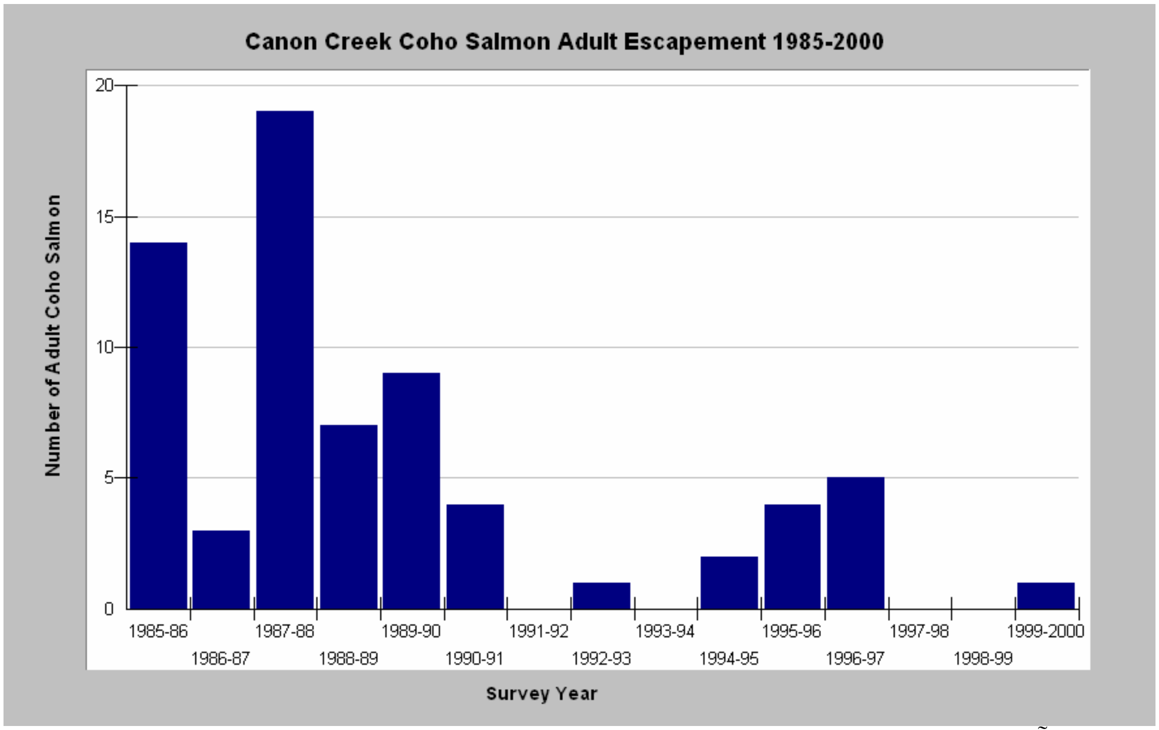

Figure 8. This chart shows the results of CDFG adult coho salmon surveys in Cañon Creek from 1985-2000. High flows and turbidity may confound surveys, so estimates should be considered conservative. Data from Trinity Associates and HBMWD, 2004.

Lower Mainstem Conditions and Gravel Mining

There is no precedent for a TMDL to assess contributions to sediment pollution from gravel mining and it was not dealt with in this *Draft TMDL*. However, Leopold and McBain (1995) pointed out that gravel mining flattens the profile of a stream for a considerable distance upstream and downstream of operations. Cessation of gravel mining on the Garcia River, as well as reduction of sediment from uplands through successful TMDL implementation (U.S. EPA, 1998a), has lead to a recovery of pool depth in the lower mainstem (IFR, 2003).

If gravel mining harvests more material than is being supplied, bed degradation may also occur. The *Draft TMDL* notes that

> "The California Department of Transportation (CalTrans) has surveyed channel cross sections at the Highway 101 and Highway 299 bridges since 1928, showing significant bed degradation, although one of the gravel operators also conducted a survey and came to a different conclusion."

I have personally witnessed major flattening of the stream profile of the lower Mad River and indications of down-cutting. Pool frequency and depth have dropped dramatically since 1985. A pool just above the Highway 101 bridge has decreased from greater than 15 feet deep to 6 feet. Summer steelhead used to hold in pools just upstream from this location all summer long from 1985-1988, but pools have become too shallow to allow such behavior since the mid-1990's.

I used to stand on a car body at the head of a pool near Azalea Park on the lower Mad River, which later protruded 3-4 feet above the bed. When wading the lower Mad River in recent years, the extremely small average particle size of the bed is noticeable and pool tail crest areas, formerly suitable for spawning, are now highly mobile and unsuitable for egg deposition. Continual disturbance of the river bar for gravel mining retards colonization by willows, alder and cottonwood trees thereby perpetuating extremely poor channel definition and fish habitat conditions.

Summer fog blankets the lower Mad River offsetting water temperature problems and, the lower river and estuary should be acting as one of the centers of recovery for Pacific salmon species. Instead this reach has become too shallow to hold adult fish or to allow for substantial rearing capacity. USFWS (1960) noted that 1,000 Chinook salmon spawned in the lower Mad River mainstem and that suitable spawning habitat was available for 2500 fish. As noted above, spawning conditions are now poor due to bed load mobility.

Figure 9 shows the flood terrace of the Mad River between Blue Lake and Glendale with an extremely wide and unstable gravel bar. Eggs deposited would likely be scoured from the bed or buried so deeply that survival to emergence would be unsuccessful (Nawa et al., 1990). Changes in the course of the river, as meander patterns change with high flows, might also leave the nest isolated from the active channel.

Improvement Needed in Implementation Section

The U.S. EPA makes clear in the *Draft TMDL* that implementation is the responsibility of the California SWRCB, however, the final *Mad River TMDL* should be more explicit in the direction it gives for implementation given the need for urgent action to prevent irretrievable and irreversible loss of species like coho salmon, a key beneficial use.

The *Draft TMDL* needs to be commended for recognizing that 74% of sediment pollution stems from land use activities and calling for a 98% reduction in human caused sediment sources. Kaufmann et al. (1999) and Rieman et al. (1993) point out that salmonids cannot be recovered unless the anthropogenic sources of stress on habitat are lessened or abated. Unfortunately, the *Draft TMDL* completely avoids any suggestion that timber harvest or road densities be reduced in the implementation section. In order to recovery Pacific salmon habitat, timber harvest should be limited to 1-1.5% POI (Reeves et al., 1993; Klein, 2003), road densities should be reduced to less than 2.5 mi/mi^2 with streamside roads decommissioned (USFS, 1996; NMFS, 1996) and road crossings should be reduced to less than 1.5 per mile of stream (Armentrout et al., 1999). Furthermore, the final *Mad River TMDL* should recommend that road building and timber harvest be discontinued on steep unstable slopes, particularly in the inner gorge of the mainstem Mad River or its major tributaries, pending further study that is part of implementation.

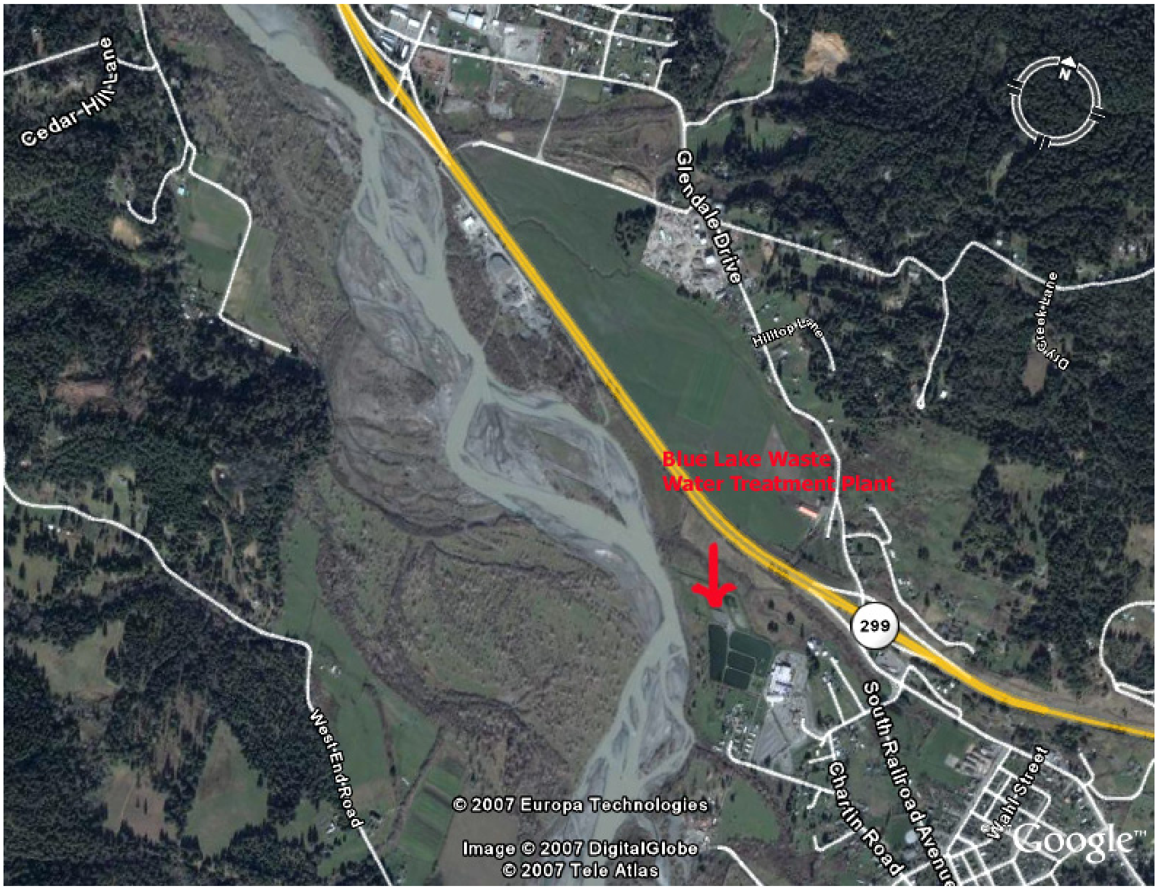

Figure 9. The aerial image above shows the Mad River between Blue Lake and Glendale with meander patterns on the river bar indicating a high degree of channel instability. This area is actively gravel mined, which flattens the stream profile and retards establishment of riparian trees that could stabilize the channel. From Google Earth.

The implementation section should recommend prioritizing action in watersheds known to be critical to persistence of coho salmon, such as Lindsay Creek, which Trinity Associates and HBMWD (2004) noted as "the primary spawning and rearing habitat for coho and coastal cutthroat trout." Bradbury et al. (1995) defined the steps for recovering Pacific salmon populations with one of the principal rules being to protect habitats that are least degraded (i.e. Upper Mad, Upper Middle Mad, Pilot Creek) and restore watersheds that are adjacent. Using this method of hierarchy, Maple Creek should be recommended as an early implementation target.

Restoration activities also are needed for the lower mainstem Mad River, including reduction in disturbance from gravel mining and immediate action to accelerate riparian recovery. As mentioned above, the timeline for recovering coho habitat should be not more than 10 years. The implementation section of the final *Mad River TMDL* should restate the preference for use of monitoring techniques consistent with the indicators presented in earlier sections. The Blue Lake Rancheria and the Humboldt Bay Municipal Water District should be specifically referenced as potential participants in cooperative monitoring activities as part of implementation and adaptive management.

References

Armentrout, S., H. Brown, S. Chappell, M. Everett-Brown, J. Fites, J. Forbes, M. McFarland, J. Riley, K. Roby, A. Villalovos, R. Walden, D. Watts, and M.R. Williams. 1998. Watershed Analysis for Mill, Deer, and Antelope Creeks. U.S. Department of Agriculture. Lassen National Forest. Almanor Ranger District. Chester, CA. 299 pp.

Bradbury, W., W. Nehlsen, T. Nickleson, K. Moore, R. Hughes, D. Heller, J. Nicholas, D. Bottom, W. Weaver, R. Beschta. 1995 . Handbook for Prioritizing Watershed Protection and Restoration to Aid Recovery of Native Salmon. Published by Pacific Rivers Council, Eugene, OR. 47 p.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical Decline and Current Status of Coho Salmon in California. North American Journal of Fisheries Management. 14(2):237-261.

California Department of Fish and Game (CDFG). 2002. Status Review of California Coho Salmon North of San Francisco . Report to the California Fish and Game Commission. California Department of Fish and Game, Sacramento , CA. 336pp.

Cederholm, C.J., Reid, L.M., & Salo, E.O. 1980. Cumulative Effects of Logging Road Sediment on Salmonid Populations in the Clearwater River, Jefferson County, Washington. Contribution No. 543, College of Fisheries, University of Washington.

Collison, A., W. Emmingham, F. Everest, W. Hanneberg, R. Martston, D. Tarboton, R. Twiss. 2003. Phase II Report: Independent Scientific Review Panel on Sediment Impairment and Effects on Beneficial Uses of the Elk River and Stitz, Bear, Jordan and Freshwater Creeks. Independent Science Review Panel performed analysis on retainer to the North Coast Regional water Quality Control Board, Santa Rosa, CA.

Dietrich, W.E., R.R de Asua, J. Coyle, B. Orr, and M. Trso. 1998. A validation study of the shallow slope stability model, SHALSTAB, in forested lands of Northern California. Stillwater Ecosystem, Watershed & Riverine Sciences. Berkeley, CA. 59 pp.

Dunne, T., J. Agee, S. Beissinger, W. Dietrich, D. Gray, M. Power, V. Resh, and K. Rodrigues. 2001. A scientific basis for the prediction of cumulative watershed effects. The University of California Committee on Cumulative Watershed Effects. University of California Wildland Resource Center Report No. 46. June 2001. 107 pp. http://www.krisweb.com/biblio/gen_ucb_dunneetal_2001_cwe.pdf

Gilpin, M.E. and M.E. Soule. 1990. Minimum Viable Populations: Processes of Species Extinction. In: M. Soule (ed) Conservation Biology: The Science of Scarcity and Diversity University of Michigan Press. pp 19-36.

Golightly, P. 1999. Lower Canon Creek Restoration - effectiveness of Fish and Wildlife Service's Jobs-in-the-Woods Watershed Restoration Program in Northern California and Oregon. U.S. Fish and Wildlife Service, Arcata, CA.

Graham Matthews & Associates. 1999. Sediment source analysis and preliminary sediment budget for the Noyo River. (Contract 68-C7-0018. Work Assignment #0-18.) Prepared for Tetra Tech, Inc. Fairfax, VA. 98 PP

Graham Matthews & Associates. 2000a. Sediment source analysis and preliminary sediment budget for the Ten Mile River, Mendocino County, CA. Prepared for Tetra Techby Graham Matthews and Associates, Inc. Weaverville, CA. VOLUME 1: Text, Tables, and Figures. Fairfax, VA. 143 pp.

Graham Matthews & Associates. 2000b. Sediment source analysis and preliminary sediment budget for the Ten Mile River, Mendocino County, CA. Prepared for Tetra Tech by Graham Matthews and Associates, Inc. Weaverville, CA. VOLUME 2: Appendices. Fairfax, VA. 59 pp.

Graham Matthews & Associates. 2001. Preliminary Sediment Budget Analysis for the Big River. Performed under contract for Tetra Tech and the U.S. EPA. Graham Matthews and Associates, Weaverville, CA. 74 pp.

Graham Matthews & Associates. 2001. Sediment source analysis for the mainstem Trinity River, Trinity County, CA. Volume 1: Text, tables, figures. Prepared for Tetra Tech by Graham Matthews and Associates, Inc. Weaverville, CA. 190 pp.

Hare, S. R.; Mantua, N. J.; Francis, R. C. 1999. Inverse production regimes: Alaska and the west coast Pacific salmon. Fisheries, Vol. 24 (1): 6-14.

Higgins, P.T., S. Dobush, and D. Fuller. 1992. Factors in Northern California Threatening Stocks with Extinction. Humboldt Chapter of American Fisheries Society. Arcata, CA. 25 p.

Higgins, P. T. 2001. Freshwater Creek Watershed Analysis dissenting report: Fisheries module. Arcata, CA. 95 pp.
http://www.krisweb.com/biblio/hum_xxxx_higgins_2001_freshwater.pdf

Higgins, P.T. 2002. Comments on Simpson Timber Aquatic HCP and Draft EIS. Letter to James Bond and Amedee Brickey, USFWS, Arcata, CA. Patrick Higgins, Consulting Fisheries Biologist, Arcata, CA. 31 p.
http://www.krisweb.com/biblio/ncc_xxxx_higgins_2002_simpsonhcpcomments.pdf

Higgins, P.T. 2006. Comments on Jackson Demonstration State Forest Management Plan and the Associated Environmental Impact Statement. Letter to Chris Rowney, CDF, Sacramento. Patrick Higgins, Fisheries Consultant, Arcata, CA. 10 p.
http://www.jacksonforest.com/EIR/Comments/higgins_final.pdf

Institute for Fisheries Resources. 2003. KRIS Garcia database project. Performed under contract to the Sonoma County Water Agency, Santa Rosa, CA. Available on CD or on-line at www.krisweb.com.

Jones, J.A. And G.E. Grant. 1996. Peak flow response to clear-cutting and roads in small and large basins, Western Cascades, Oregon. Water Resources Research, April 1996. Vol. 32, No. 4, Pages 959-974.

Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An Ecological Perspective of Riparian and Stream Restoration in the Western United States. Fisheries 22(5):12-24.

Kier Associates. 1991. Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program. U.S. Fish and Wildlife Service, Klamath River Fishery Resource Office. Yreka, CA. 403 pp.

Kier Associates. 1999. Mid-term evaluation of the Klamath River Basin Fisheries Restoration Program. Sausalito, CA . Prepared for the Klamath River Basin Fisheries Task Force. 303 pp.

Klein, R. 2003. Duration of Turbidity and Suspended Sediment Transport in Salmonid-Bearing Streams, North Coastal California. A Report to the U.S. EPA, Region IX.

Klein, Randy. Personal communication. Redwood National Park Hydrologist. Arcata, CA.

LaVen, R and A. Lehre. 1977. The effects of timber harvest and roads on sediment yield and channel morphology in the Fox Planning Unit. Six Rivers National Forest, Eureka, CA.

Leopold, L. and S. McBain. 1995. Geomorphic Investigation of Garcia River Estuarine Reach. Subcontract to Moffatt & Nichol Engineers for Mendocino RCD. 19 p.

Ligon, F., A. Rich, G. Rynearson, D. Thornburgh, and W. Trush. 1999. Report of the Scientific Review Panel on California Forest Practice Rules and salmonid habitat. Prepared for the Resources Agency of California and the National Marine Fisheries Service. Sacramento, CA. 181 pp.
http://www.krisweb.com/biblio/cal_nmfs_ligonetal_1999_srprept.pdf

Mendocino County Resource Conservation District (MCRCD). 1992. Garcia River watershed enhancement plan. Prepared for the California State Coastal Conservancy. Prepared by MCRCD, written by Jack Monschke and D. Caldon, Kier Associates. MCRCD, Ukiah, CA. 207 p.

Montgomery, D. R. and J.M. Buffington, 1993. Channel classification, prediction of channel response, and assessment of channel condition. TFW-SH10-93-002. Prepared for the SHAMW committee of the Washington State Timber/Fish/Wildlife Agreement. Seattle, WA. 110 pp.

Montgomery, D.R. and W.E. Dietrich. 1994. A physically based model for the topographic control on shallow landsliding. Water Resources Research, Vol.30, No.4. April 1994. Pages 1153-1171.

National Marine Fisheries Service. 1987. Endangered and threatened species, winter run Chinook salmon. Federal Register 52: 604 I-6048.

National Marine Fisheries Service. 1996. Coastal Salmon Conservation: Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast. US Dept. Commerce, NOAA. 4p.

National Marine Fisheries Service. 2001. Status Review Update for Coho Salmon (Oncorhynchus kisutch) from the Central California Coast and the California portion of the Southern Oregon/Northern California Coasts Evolutionarily Significant Units. Southwest Fisheries Science Center, Santa Cruz, CA. 43 p.

National Marine Fisheries Service. 2004. NOAA Fisheries Proposes to Designate Critical Habitat for Seven Evolutionarily Significant Units (ESUs) of Salmon and Steelhead in California. 69 FR 74572; December 14, 2004.

Nawa, RK, C.A. Frissell, and W.J. Liss. 1990. Life history and persistence of anadromous salmonid stocks in relation to stream habitats and watershed classification. Oak Creek Labs, Oregon State University. Corvallis, OR Performed under contract for Oregon Department of Fish and Wildlife.

Nelson, K. and M. Soule. 1987. Genetic Conservation of Exploited Fishes. In: N. Ryman and Fred Utter (ed.). Population Genetics and Fisheries Management. University of Washington Press. Seattle, WA.

Newcombe, C.P.(2003). Impact Assessment Model for Clear Water Fishes Exposed to Excessively Cloudy Water. Journal of the American Water Resources Association. Pages 529 – 544.

North Coast Regional Water Quality Control Board. 2000. Navarro River watershed technical support document for the total maximum daily load for sediment and technical support document for the total maximum daily load for temperature. CRWQCB, North Coast Region. Santa Rosa, CA. 231 pp

North Coast Regional Water Quality Control Board. 2001. Gualala River watershed technical support document for sediment. CRWQCB, Region 1. Santa Rosa, CA. 147 pp.

North Coast Regional Water Quality Control Board. 2002. Mattole River watershed technical support document for total maximum daily loads for sediment and temperature . North Coast Region, CRWQCB. Santa Rosa, CA. 133 pp

North Coast Regional Water Quality Control Board. 2005. Watershed Planning Chapter of North Coast Basin Plan. NCRWQCB, Santa Rosa, CA. 257 p. North Coast Regional Water Quality Control Board. 2006. Desired Salmonid Freshwater Habitat Conditions for Sediment Related Indices. NCRWQCB, Santa Rosa, CA. 60 p.

North Coast Regional Water Quality Control Board. 2005. Shasta River Water Quality Related Investigations – 2004. April 2005. Assistance from U.C. Davis Aquatic Ecosystems Analysis Laboratory John Muir Institute of the Environment. NCRWQCB, Santa Rosa, CA. 68 p.

North Coast Regional Water Quality Control Board. 2006. Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices. NCRWQCB, Santa Rosa, CA. 60 p.

Pacific Watershed Associates. 1994. Action plan for the restoration of the South Fork Trinity River watershed and its fisheries. Prepared for U.S. Bureau of Reclamation and the Trinity River Task Force, Contract No. 2-CS-20-01100. Arcata, CA.

Pacific Watershed Associates (PWA). 1998. Sediment Source Investigation and Sediment Reduction Plan for the Bear Creek Watershed, Humboldt County, California. Prepared for The Pacific Lumber Company Scotia, California. Arcata, California. 57 pp.

Quartz Valley Indian Community. 2006a. Comments Concerning the Klamath River TMDL Approach and Progress to Date. Memo to the U.S. EPA and North Coast Regional Water Quality Control Board of August 15, 2006. Quartz Valley Indian Reservation, Ft. Jones, CA. 35 p. http://www.klamathwaterquality.com/QVIC_LowerKlamath_TMDL_Comments_08.15.06.pdf

Quartz Valley Indian Community. 2006b. Review of public draft Shasta River Temperature and Dissolved Oxygen TMDLs. Quartz Valley Indian Reservation, Ft. Jones, CA. http://www.klamathwaterquality.com/Shasta_TMDL_ActionPlan_Comments_QVIR1.pdf

Quartz Valley Indian Community. 2006. Comments on the Final Draft Scott River Total Maximum Daily Load (TMDL) Work Plan. Letter to the North Coast Regional Water Quality Control Board. Quartz Valley Indian Reservation, Ft. Jones, CA. 35 p. http://www.klamathwaterquality.com/QVIC_Scott_TMDL_11_05.pdf

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of Juvenile Anadromous Salmonid Assemblages in Coastal Oregon Basins with Different Levels of Timber Harvest. Transactions of the American Fisheries Society. 122(3): 309-317.

Resighini Rancheria. 2004. Memo re: Total Maximum Daily Load (TMDL) analysis for, and the proposed de-listing of the Upper Lost River from California's 303(d) list. From Chairman Frank Down to Catherine Kuhlman, NCRWQCB Executive Director. Resighini Rancheria, Klamath, CA. 9 p. http://www.klamathwaterquality.com/Resighini_Upper%20Lost%20Comments.pdf

Rieman, B., D. Lee, J. McIntyre, K. Ovetton, and R. Thurow 1993. Consideration of Extinction Risks for Salmonids. As FHR Currents # 14. US Forest Service, Region 5. Eureka, CA. 12 pp.

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.

Simpson Timber, Inc. 2002. Draft Simpson Resource Company Aquatic Habitat Conservation Plan/Candidate Conservation Agreement with Assurances and Draft Environmental Impact Statement, Del Norte and Humboldt Counties, California. Submitted to the National Marine Fisheries Service.

Sparkman, M.D. 2003. Annual Report: Recreational Angler Use and Catch in the Mad River, Humboldt County, California, November 2002 – March 2003. California Department of Fish and Game, Anadromous Fisheries Resource Assessment and Monitoring Program. December 2003.

Spence, B.C., G.A. Lomnicky, R.M. Hughes and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. Funded jointly by the U.S. EPA, U.S. Fish and Wildlife Service and National Marine Fisheries Service. TR-4501 96-6057. Man Tech Environmental Research Services Corp., Corvallis, OR. 356 p.

Trinity Associates and the Humboldt Bay Municipal Water District. 2002. Habitat Conservation Plan For HBMWD Mad River Operations. 171 p.

Trush, W.J. 2001. Testimony of William J. Trush Before the State Water Resources Control Board. June 25 and 26, 2001. Exhibit G.

U.S. Environmental Protection Agency (USEPA). 1998a. (Final) Garcia River Sediment Total Maximum Daily Load. Dated 16 March 1998. USEPA, Region IX. San Francisco, CA. 51 pp.

U.S. Environmental Protection Agency (USEPA). 1998b. South Fork Trinity River and Hayfork Creek Sediment Total Maximum Daily Loads (with attached comment responsiveness summary). USEPA, Region IX. San Francisco, CA. 109 pp.

U.S. Environmental Protection Agency (USEPA). 1998c. Total maximum daily load for sediment - Redwood Creek, California. USEPA Region 9. San Francisco, CA. 72 pp.

U.S. Environmental Protection Agency. 2007. DRAFT Mad River Total Maximum Daily Loads for Sediment and Turbidity. U.S. EPA Region 9, San Francisco, CA. 91 p.

U.S. Fish and Wildlife Service. 1960. Survey of Chinook salmon spawning habitat in northwestern California Natural Resources of Northern California US Fish and Wildlife Service, Pacific Southwest Field Committee.

Yurok Tribe. 2006. Memo re: Yurok Tribe comments on Lower Lost River TMDL. From Kevin McKernan, Yurok Tribe Environmental Program Director, to Noemi Emeric of U.S. Environmental Protection Agency.
http://www.klamathwaterquality.com/lower%20lost%20comments_Yurok.pdf

Zuspan, M.G. and M.D. Sparkman. 2002. Annual Report: Mad River Winter-Run Adult Steelhead Run-Size Estimate, 2000-2001 Season, Project 1a3. State of California. The Resources Agency. Department of Fish and Game. Steelhead Research and Monitoring Program.