U.S. Environmental Protection Agency
Region IX

Noyo River
Total Maximum Daily Load
for Sediment

Approved by:

original signed by *16 December 1999*

______________________ ____________

Alexis Strauss Date
Director, Water Division

TABLE OF CONTENTS

List of Tables

List of Figures

EXECUTIVE SUMMARY

The Noyo River watershed is a forested, coastal watershed in Mendocino County, California, that encompasses approximately 113 square miles (72,323 acres). Its logging history dates back to 1853 when the first water-powered mill was built in the lower Noyo River. Old growth logging continued into the early part of the 20^{th} century. Second growth logging began in the 1960s, primarily in the lower main drainage area, and continues today. Removal of residual old-growth stands began in the 1960s and continued into the mid-1980s (M. Jameson pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). The California Western Railroad operates the Skunk Train that traverses the Noyo River watershed along the mainstem channel. Other minor land uses found in the basin include ranching and recreation.

The U.S. Environmental Protection Agency (EPA) is establishing the Noyo River Total Maximum Daily Load (TMDL) for sediment to identify sediment loading allocations that, when implemented, are expected to result in the attainment of the applicable water quality criteria for sediment, which are established to protect the beneficial uses of the Noyo River. The primary beneficial use of concern in the Noyo River watershed is the salmonid fishery, particularly the coho salmon (*Oncorhynchus kisutch*) fishery.

A. SECTION 303(d) AND THE NOYO RIVER WATERSHED

The Noyo River watershed was listed on the 1998 303(d) list by the State of California as required by Section 303(d) of the Clean Water Act. This list describes water bodies that do not fully support all beneficial uses or are not meeting water quality objectives. It also describes the pollutant(s) for each water body that limit(s) its use or prevent(s) attainment of its water quality objectives. As required by Section 303(d), a TMDL must be developed for water bodies on the 303(d) list. For the Noyo River watershed, the listing was the result of water quality problems related to sedimentation throughout the watershed. Sedimentation was determined to be impacting the cold water fishery, a beneficial use of the Noyo River watershed, including the migration, spawning, reproduction, and early development of cold water fish such as coho salmon and steelhead trout. Cold freshwater and estuarine habitats are also designated beneficial uses of the Noyo River watershed.

B. COMPONENTS OF THE TMDL

The TMDL includes:

- Problem statement;
- Numeric targets;
- Source analysis;
- Linkage analysis;
- Load allocations; and
- Discussion of the margin of safety and annual and seasonal variation.

Problem Statement
The problem statement includes an assessment of existing in-stream conditions. The watershed is divided into four assessment areas: Headwaters, North Fork Noyo River, South Fork Noyo River, and Mainstem Noyo River. Historically, salmonids have been found in each of the assessment areas. Salmonid populations have declined in recent years, quantitatively demonstrated by data from the egg-taking station in the South Fork Noyo River Assessment Area. Pool frequency, pool depth, the lack of large woody debris, and the lack of other forms of shelter (particularly from high winter flows) appear to be factors currently limiting the success of salmonids (especially coho salmon) throughout the watershed. In addition, the data indicate that cobble may be too embedded and the substrate composed of too many fines for successful spawning and fry emergence.

Numeric Targets
The numeric targets interpret water quality standards and provide indicators of watershed health. In particular, they reflect in-stream and watershed conditions presumed to be suitable for the successful migration, spawning, rearing, and over-wintering of salmonids in the fresh water environment. The indicators and targets are identified in Table 1.

Source Analysis
The source analysis includes an assessment of sources of sediment historically and/or presently impacting water quality. Several factors have contributed to the increased sediment delivery above natural rates throughout the watershed. They include: high rates of timber harvest, a strong reliance on ground-based yarding methods (particularly in the Headwaters and North Fork Noyo River Assessment Areas), and high road densities. These factors have led to an increase in the rates of sediment delivery due to landsliding, fluvial erosion, and surface erosion related to land management activities. Estimates of the current rates of sediment delivery are compared to estimates for the period prior to 1958. Although large-scale tractor yarding had not occurred prior to 1958, sediment delivery prior to 1958 was influenced by historic land management practices (e.g., turn-of-the-century old growth logging) and is not considered to be entirely "natural."

Linkage Analysis
The linkage analysis defines the relationship between hillslope sediment production processes and in-stream effects. Thus, the linkage analysis provides the basis for the magnitude of sediment reductions and associated hillslope controls necessary to attain water quality standards and protect the beneficial uses.

EPA has determined that salmonids were relatively abundant in the period 1933 - 1957, compared to current levels, in the Noyo River. Thus, average sediment delivery rates from 1933 to 1957 represent conditions acceptable to salmonids. Accordingly, EPA has concluded that if average sediment delivery rates do not exceed the levels in the 1933-1957 period, then sediment will not impair beneficial uses of the Noyo River.

Table 1: Summary of Numeric and Other Targets

Indicator	Target	References
Turbidity	20% above background	Basin Plan, 1994; Reid, 1999
% fines <0.85 mm	14% (mean) as wet volume	Burns, 1970; CDF, 1994
Embeddedness	Increasing percentage of riffle habitat units that are less than 25% embedded	Flosi and Reynolds, 1994; DFG 1995 (a) and (b)
Pool frequency/depth	40% of habitat length in pools greater than 3 feet in depth at low flow in third and higher order streams	Flosi and Reynolds, 1994; G. Flosi pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999
V*	0.27 (mean)	Knopp, 1993
Backwater pools	Increasing percentage of backwater pools per habitat length	Dietrich, 1998
Large woody debris	Increase in the number and volume of key pieces of large woody debris per stream length	Bilby and Ward, 1989; Beechie and Sibley, 1997; USDA, 1994
Thalweg profile	Increasing variation in thalweg elevation around the mean thalweg slope	Trush, 1999; Madej, 1999
Stream crossings with diversion potential	1% of all stream crossings, as a result of a storm with a 100-year recurrence interval or less	Weaver and Hagans, 1994; D. Hagans pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999
Stream crossings with significant crossing failure potential	1% of all stream crossings, as a result of a storm with a 100-year recurrence interval or less	Flanagan et al., 1998
Hydrologic connectivity	Decrease in the miles of road hydrologically connected to a watercourse	Ziemer, 1998; Furniss, 1999
Disturbed area	Decrease in the area disturbed by facilities [+]	Lewis, 1998
Activity in unstable areas	No activities (e.g., roads, harvest, yarding, etc.) in unstable areas (e.g., steep slopes, headwall swales, inner gorges, streambanks, etc.) unless a detailed geological assessment is performed that shows there is no potential for increased sediment delivery to a watercourse as a result.	Dietrich et al., 1998; Weaver and Hagans, 1994; Pitlick, 1982; Pacific Watershed Associates, 1998

[+]A facility is defined as any management-related structure such as a road, railroad roadbed, skid trail, landing, harvest unit, animal holding pen, or agricultural field (e.g., pasture, vineyard, orchard, row crops). For the purpose of this target, a harvest unit or agricultural field that retains its natural characteristics with respect to rainfall interception, rainfall infiltration, and soil protection, is not considered a "facility."

Load Allocations

EPA is setting the TMDL equal to the loading capacity, at a level expected to result in attainment of the applicable water quality criteria for sediment. EPA is defining the current loading capacity of the Noyo River to be equivalent to the sediment loading rate for the period 1933-1957, which is 470 tons/mi^2/yr. Of this, 370 tons/mi^2/yr is attributable to background sources.

EPA has allocated the remaining 100 tons/mi^2/yr among individual land use activities that deliver sediment to the Noyo River. Meeting these load allocations is necessary to attain water quality criteria for sediment and protect beneficial uses. The allocations are also expressed as percent reductions from existing rates of management-related sediment delivery. Specific allocations are developed for each of the four assessment areas. The determination of loading allocations included consideration of the differences in management practices among the assessment areas. The allocations are set forth in Tables 15 and 16 in Chapter VII.

Margin of Safety and Seasonal Variation

Erosion is inherently variable, both temporally and spatially, and sediment delivery to streams does not always coincide with erosion. Therefore, the sediment load allocations are designed to apply to the sources of sediment, not the movement or delivery of the sediment to the streams. They are also applied as 10-year rolling averages.

Likewise, the condition of the in-stream environment displays temporal and spatial variability, and the Regional Water Quality Control Board, North Coast Region, (Regional Water Board) has expressed its intention to analyze the in-stream targets as 10-year rolling averages. In addition, the hillslope targets are specifically designed with variations in rainfall and peak flows in mind.

Also, the TMDL contains an implicit margin of safety in order to ensure that the allocations, when achieved, will result in attainment of the applicable water quality criteria for sediment, given the uncertainties.

CHAPTER I
INTRODUCTION

The Noyo River watershed (see Figure 1) is a forested, coastal watershed in Mendocino County, California, which encompasses approximately 113 square miles (72,323 acres) immediately west of Willits. The Noyo River flows through the coastal range and out to the Pacific Ocean at Fort Bragg. Its logging history dates back to 1853 when the first water-powered mill was built in the lower Noyo River. Old growth logging continued into the early part of the 20th century. Second growth logging began in the 1960s, primarily in the lower main drainage area, and continues today. Removal of residual old-growth stands began in the 1960s and continued into the mid-1980s (M. Jameson pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). The California Western Railroad operates the Skunk Train that traverses the Noyo River watershed along the mainstem channel. Other minor land uses found in the basin include ranching and recreation.

The primary purpose of the Noyo River TMDL for sediment is to identify sediment loading allocations that, when implemented, are expected to result in the attainment of the applicable water quality criteria for sediment. These criteria are established in order to protect beneficial uses. The primary beneficial use of concern is the salmonid fishery, particularly the coho salmon (*Oncorhynchus kisutch*) fishery.

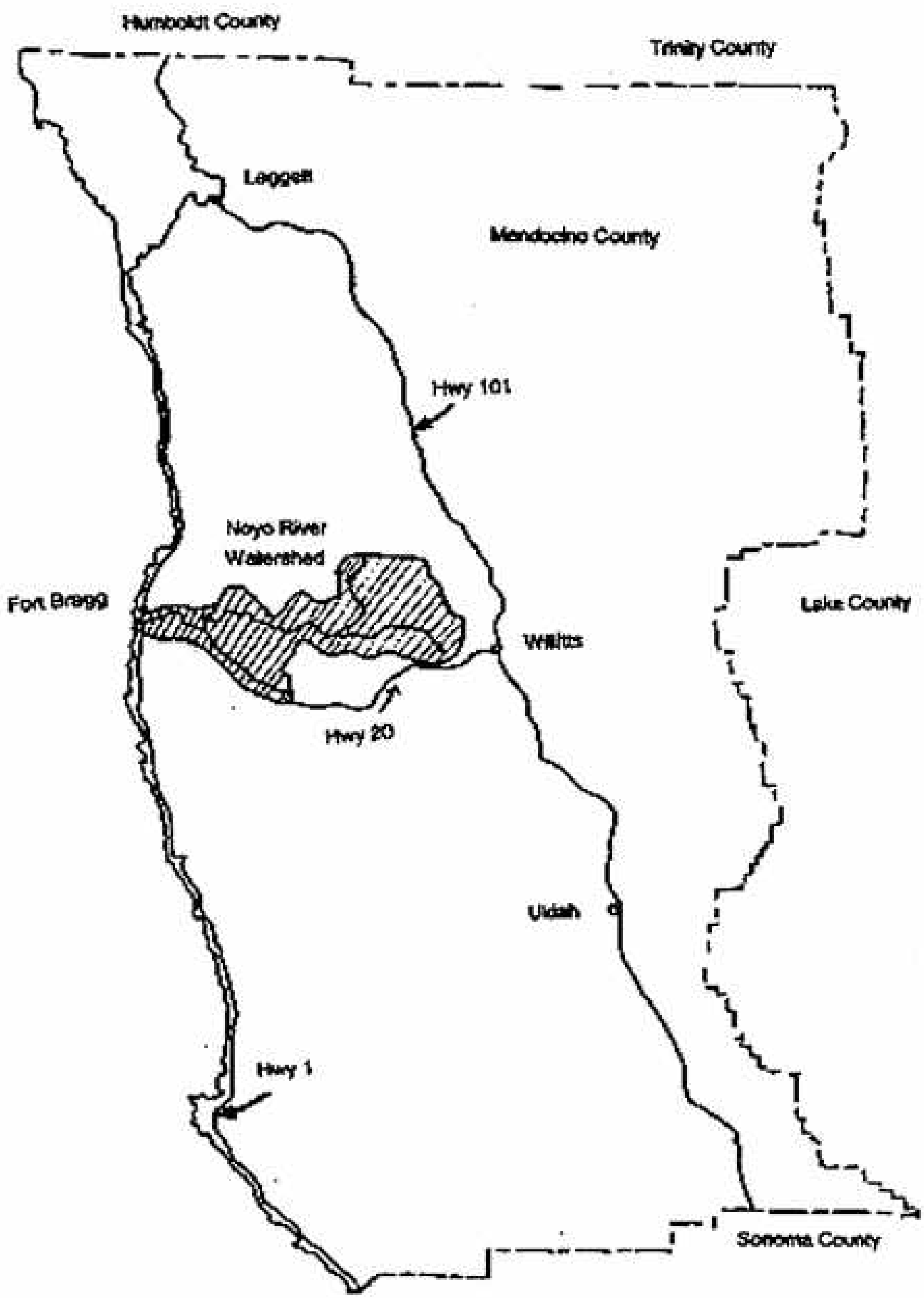
I.A. CHARACTERISTICS OF THE NOYO RIVER WATERSHED

The Noyo River watershed is unique to Mendocino County with respect to the large percent of it in public ownership. Approximately 19% of the basin is owned by the State of California and managed by the California Department of Forestry and Fire Protection (CDF) as a demonstration forest. Other major owners in the basin include the Mendocino Redwood Company (primarily in the upper watershed) and The Timber Company (primarily along the mainstem). There are numerous other small and moderately-sized timber operations in the basin, as well as a cattle ranch, summer camp, seasonal and year-round homes, the railroad, and miscellaneous activities.

I.B. APPLICATION OF SECTION 303(d) TO THE NOYO RIVER WATERSHED

The Noyo River watershed has been placed on the 303(d) list as required by Section 303(d) of the Clean Water Act. This list describes water bodies that do not fully support all beneficial uses or are not meeting water quality objectives, and describes the pollutants for each water body that limit its use or prevent attainment of its water quality objectives. Water quality objectives and beneficial uses are identified for all of the water bodies in the North Coast Region in the *Water Quality Control Plan for the North Coast Region* (the Basin Plan). As required by Section 303(d), pollutant loading allocations must be prepared for waterbodies on the 303(d) list. As stated above, the Noyo River watershed was listed due to water quality problems related to

FIGURE 1
NOYO RIVER WATERSHED LOCATION MAP



sedimentation. Sedimentation was determined to be impacting the cold water fishery, a beneficial use of the Noyo River watershed, including the migration, spawning, reproduction, and early development of cold water fish such as coho salmon and steelhead trout. Cold freshwater and estuarine habitats are also designated uses of the Noyo River watershed.

As discussed herein, management-related activities have contributed to an increase in sediment delivery to the Noyo River watershed above acceptable background levels. Existing salmonid habitat is limited by various erosion-influenced factors, including infrequent and shallow pools, few backwater pools and other overwintering habitat, embedded cobble, and elevated fines in potential spawning gravels. In addition, the limited availability of large woody debris in the channels of Noyo River watershed contributes to the problems associated with sedimentation.

I.C. DATA SOURCES

The technical analysis which forms the basis for this TMDL was originally developed by the Regional Water Board, as part of a work-sharing agreement with EPA. Their report was signed and submitted to EPA on 23 August 1999 (Regional Water Board, 1999).

EPA and Regional Water Board staff conducted an assessment of existing data with contractor support from Graham Matthews and Associates through a subcontract with Tetra Tech, Inc. Data were provide by many sources. The primary sources of data were: the California Department of Fish and Game (DFG), CDF, the Mendocino Redwood Company, and U.S. Geological Survey (USGS). DFG provided historic aquatic surveys. CDF provided Timber Harvest Plan (THP) data. The Mendocino Redwood Company provided fish distribution and aquatic habitat data. USGS provided stream flow and topographic data.

This TMDL is based on the best available information. Because of the limited precision of the analyses and the limitations of implementation monitoring, allocations expressed as percentage reductions are rounded to the nearest 5%.

Chapter VIII includes a discussion of uncertainties associated with this TMDL and the margin of safety included in the analysis to ensure that the TMDL, when implemented, will attain applicable water quality criteria for sediment.

I.D. COMPONENTS OF A TMDL

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the Clean Water Act, as well as in various guidance documents (e.g., EPA, 1991). A TMDL is defined as "the sum of the individual waste load allocations for point sources and load allocations for non-point sources and natural background" (40 CFR 130.2) such that the capacity of the water body to assimilate pollutant loadings (i.e., the loading capacity) is not exceeded. That is:

TMDL = WLAs + LAs + NB

where WLAs = sum of the wasteload allocations, LAs = sum of the load allocations, and NB = natural background. A TMDL must include consideration of seasonal variations and include a margin of safety to address uncertainty in the analysis.

This TMDL includes:

- Discussion of existing water quality requirements;
- Problem statement;
- Numeric targets;
- Source analysis;
- Linkage analysis;
- Load allocations;
- Discussion of the margin of safety and annual and seasonal variation;
- Recommendations pertaining to implementation, monitoring, and the time frame associated with implementation of the TMDL; and
- Discussion of public participation.

The problem statement includes an assessment of existing in-stream and hillslope conditions. The numeric targets interpret water quality standards and provide indicators of watershed health. The source analysis includes an assessment of sources of sediment historically and/or presently impacting water quality. The linkage analysis provides the basis for the magnitude of hillslope controls necessary to attain water quality standards and protect the beneficial uses. The load allocation(s) are the assignment of sediment loads to land use activities in individual assessment areas necessary to attain water quality standards and protect beneficial uses. The discussion of the margin of safety summarizes the qualitative and quantitative means by which the final load allocations account for any uncertainty in the data or data analysis. Seasonal variation in erosion and sediment delivery requires consideration of seasonal effects in the implementation of the load allocation(s). A discussion of recommendations for the future development of an implementation plan and monitoring plan is included, as well as a discussion of the schedule for implementing the TMDL. A discussion of public participation is also included.

CHAPTER II
EXISTING WATER QUALITY REQUIREMENTS

Existing water quality requirements are described in the *Water Quality Control Plan, North Coast Region-- Region 1* (Basin Plan). The Basin Plan describes the existing and potential beneficial uses of water in each of the watersheds throughout the North Coast Region. It also identifies both numeric and narrative water quality objectives, the attainment of which is intended to protect the identified beneficial uses. Further, the Basin Plan includes implementation plans that describe the means by which specific water quality issues will be addressed by the Regional Water Board.

II.A. BENEFICIAL USES

The Basin Plan identifies municipal, industrial, and recreational uses of the Noyo River. Notably, the Noyo River is an industrial water supply and the municipal drinking water supply for the City of Fort Bragg. The cold water fishery, though, appears to be the most sensitive series of beneficial uses in the watershed. Accordingly, protection of these beneficial uses is presumed to protect any of the other beneficial uses that might also be harmed by sedimentation.

In addition, the Basin Plan identifies the following existing beneficial uses that are related to the Noyo River's cold water fishery:

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

The COMM beneficial use applies to water bodies in which commercial or sport fishing occurs or historically occurred for the collection of fish, shellfish, or other organisms, including, but not limited to, the collection of organisms intended either for human consumption or bait purposes. The COLD beneficial use applies to water bodies that support or historically supported cold water ecosystems, including, but not limited to, the preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. The MIGR beneficial use applies to water bodies that support or historically supported the habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish. The SPWN beneficial use applies to water bodies that support or historically supported high quality aquatic habitats suitable for the reproduction and early development of fish. The EST beneficial use applies to water bodies that support or historically supported estuarine ecosystems, including, but not limited to, the preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

II.B. WATER QUALITY OBJECTIVES

The Basin Plan establishes four water quality objectives pertaining to suspended material, settleable material, sediment, and turbidity.

> "Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses."
>
> "Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses."
>
> "The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
>
> "Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof."

In addition to the water quality objectives, the Basin Plan includes two discharge prohibitions specifically applicable to logging, construction and other associated activities. These are included in the action plan for these activities.

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

CHAPTER III
PROBLEM STATEMENT

This chapter summarizes the life cycle of the coho salmon (*Oncorhynchus kisutch*), outlines the freshwater habitat factors that influence the success of coho salmon, and discusses the data that exist for the Noyo River watershed from which certain inferences can be made with respect to the problems currently facing coho salmon. Conservative assumptions have been made regarding the factors that are potentially limiting coho salmon in the basin to account for the limited amount of information available. The discussion in Chapter IV (Numeric and Other Targets) is based on the problems identified in this analysis. Should additional data be made available in the future that improves upon this analysis, the TMDL can be modified, including modifications to the numeric targets.

III.A. GENERAL BACKGROUND

Coho Salmon Life Cycle

Salmonids are anadromous fish that live part of their lives in freshwater and part in the ocean. The species of focus in this TMDL is the coho salmon (*Oncorhynchus kisutch*), which has been listed by the National Marine Fisheries Service as a threatened species along much of the California coast, including that in Mendocino County. Coho salmon generally return from the ocean to spawn in fresh water at the age of three years. In California, this typically occurs during the months of December and January. Once eggs are laid and fertilized, the incubation period usually lasts from 35 to 50 days. Coho fry emerge from their gravel nests from early March to mid-May. The fry first congregate along stream margins, in shallow pools, and in backwaters and eddies. They develop into parr (juveniles), eventually seek out deeper pools, and become aggressive and territorial. California coho generally remain in freshwater for one to two years before migrating to the ocean (CDF, 1994).

Sometime in April or May, when temperatures are rapidly warming, one- to two-year-old coho salmon parr begin their migration downstream to the estuary where they undergo “smoltification.” Smoltification is the process of physiological transformations that will allow them to survive in the saline environment of the ocean. The coho feed and grow in the ocean until they return to their natal stream for spawning (CDF, 1994).

Potentially Limiting Factors

As described by CDF (1994), the success of salmonids depends on many factors, including:

- Unimpeded access to spawning gravels;
- Cool stream temperatures (i.e., 4.4 to 9.4 °C for spawning and 4.4 to 13.3 °C for embryo incubation);
- Adequate dissolved oxygen levels in the water column (>6.3 mg/l for spawning);
- Availability of appropriately sized spawning gravels with few fines (i.e., < 5% fines for high fry emergence, <15% fines to avoid a sharp drop-off in emergence success);

- Adequate dissolved oxygen levels in the redds (8 mg/l for high embryo survival and fry emergence);
- Adequate food (Young fish feed on drifting terrestrial and aquatic insects. Older fish also feed on other salmonid fry. Insect production is a function of substrate composition, riffles, and riparian vegetation.);
- Adequate cover as protection from predators; and
- Protection from winter and spring freshets, including adequate availability of deep pools, backwater pools, and in-stream and bank cover.

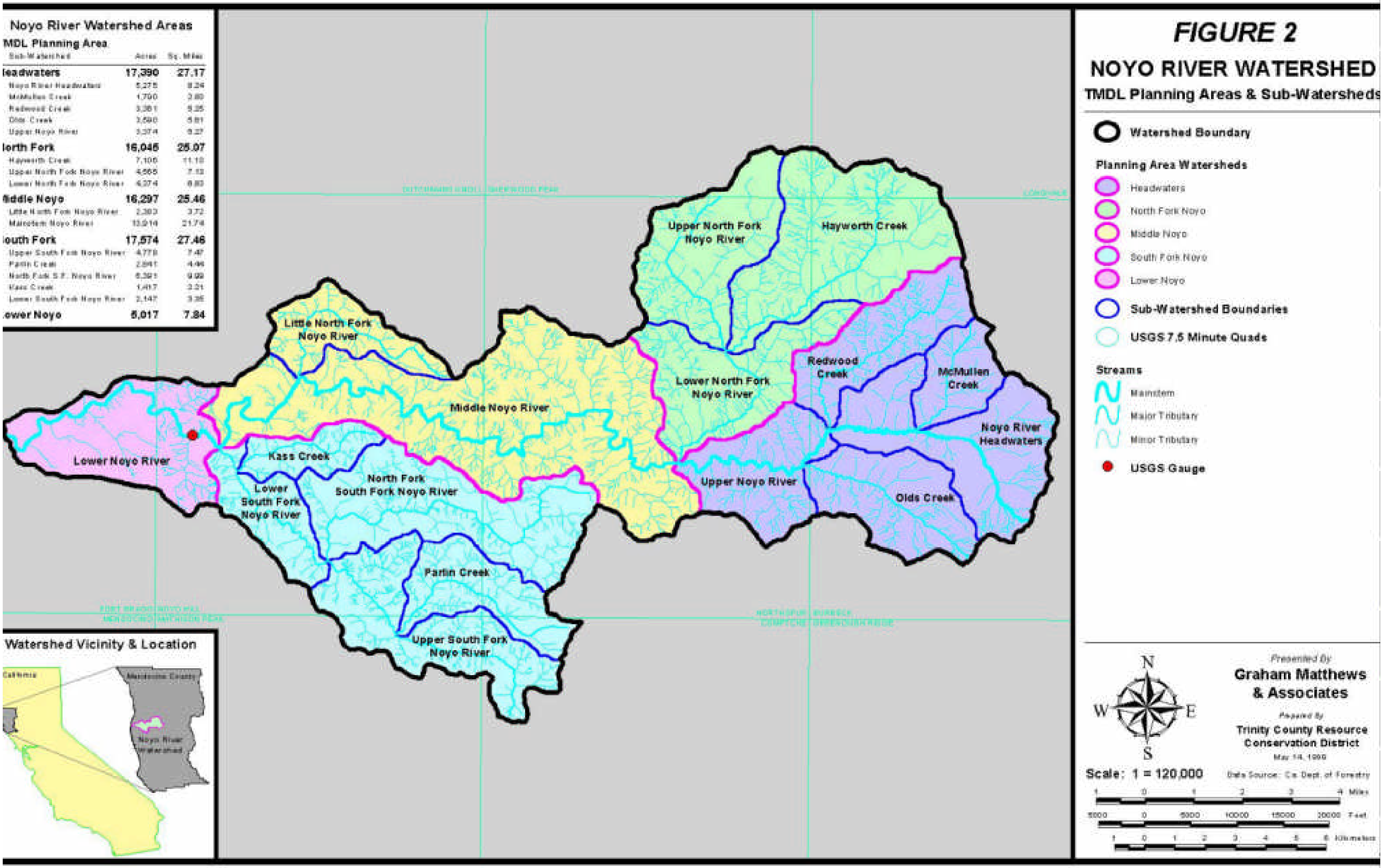
DFG has described a system for evaluating the quality of stream habitat, based on the ability of the habitat to provide shelter for fish (Flosi and Reynolds, 1994). They have determined that streams should have a shelter rating of at least 100 to provide adequate shelter for coho. Further, they suggest that good coho streams in California have 40% of their habitat length in primary pools. Primary pools are defined for 3rd and 4th order streams as those at least three feet deep.

Limitations in any of these factors can potentially limit the success of coho salmon. It should be noted, however, that in addition to freshwater habitat conditions, coho success also depends on ocean conditions, climate, disease cycles, and other controllable and uncontrollable factors.

III.B. DESCRIPTION OF THE NOYO RIVER WATERSHED

The Noyo River watershed is a forested, coastal watershed in Mendocino County that encompasses approximately 113 square miles (i.e., 72,323 acres) immediately west of Willits flowing through the coastal range and out to the Pacific Ocean at Fort Bragg. It has been divided into subwatersheds for the purpose of reviewing and assessing in-stream and hillslope data (see Figure 2). The four assessment areas are: Headwaters (HAA), North Fork Noyo River (NFAA), South Fork Noyo River (SFAA), and Mainstem Noyo River (MAA). MAA combines the Middle Noyo and Lower Noyo Planning Watersheds, as defined by Matthews (1999).

The assessment area boundaries were chosen because: (1) they result in areas of roughly the same geographic size; (2) they delineate hydrologic sub-basins; (3) they roughly delineate areas of differing rainfall intensities; and (4) they have different land management histories.



Sub-Watershed	Acres	Sq. Miles
Headwaters	**17,390**	**27.17**
Noyo River Headwaters	5,275	8.24
McMullen Creek	1,700	2.66
Redwood Creek	3,361	5.25
Olds Creek	3,590	5.61
Upper Noyo River	3,374	5.27
North Fork	**16,045**	**25.07**
Hayworth Creek	7,100	11.10
Upper North Fork Noyo River	4,566	7.13
Lower North Fork Noyo River	4,374	6.83
Middle Noyo	**16,297**	**25.46**
Little North Fork Noyo River	2,383	3.72
Mainstem Noyo River	13,914	21.74
South Fork	**17,574**	**27.46**
Upper South Fork Noyo River	4,778	7.47
Parlin Creek	2,841	4.44
North Fork S.F. Noyo River	6,391	9.99
Kass Creek	1,417	2.21
Lower South Fork Noyo River	2,147	3.35
Lower Noyo	**5,017**	**7.84**

Headwaters Assessment Area

HAA is composed of 17,390 acres or 27.17 mi^2, including the CDF's Planning Watershed numbers 113.20010, 113.20011, and 113.20012. It is located at the upper end of the basin, immediately west of the city of Willits, and includes the upper Noyo River, Olds Creek, McMullen Creek and Redwood Creek. It is primarily underlain by Coastal Belt Franciscan geology, though it also includes some Franciscan Melange at the upper end of the Noyo River main stem and Olds Creek. A thrust fault separates the Coastal Belt Franciscan from the Franciscan Melange. HAA contains large translational/rotational slides and earth flows (DMG, 1984). The average annual rainfall is approximately 65 inches, which falls primarily between October and April (Matthews, 1999). Mendocino Redwood Company is the largest landowner in HAA.

North Fork Noyo River Assessment Area

NFAA is composed of 16,045 acres or 25.07 mi^2, including CDF's Planning Watershed numbers 113.20013, 113.20014, and a portion of 113.20015. It is located at the upper end of the basin, immediately northwest of the city of Willits, and includes the North Fork Noyo River, the Middle Fork of the North Fork Noyo River, Hayworth Creek, and the North Fork of Hayworth Creek. NFAA is primarily underlain by Coastal Belt Franciscan geology. Many of the tributaries to the North Fork Noyo River and Hayworth Creek have steep inner gorges. Similarly, the areas drained by the upper reaches of nearly all the streams in this assessment area contain large translational/rotational slides, earth flows, and numerous debris slides (DMG, 1982). NFAA has an average annual rainfall of approximately 65 inches, which falls primarily between October and April (Matthews, 1999). Mendocino Redwood Company is the largest landowner in NFAA.

South Fork Noyo River Assessment Area

SFAA is composed of 17,575 acres or 27.46 mi^2, including CDF's Planning Watershed numbers 113.20030, 113.20031, and 113.20033. It is located near the lower end of the basin, immediately southeast of the city of Fort Bragg, and includes the South Fork Noyo River, Parlin Creek, the North Fork of the South Fork Noyo River, and Kass Creek. SFAA is primarily underlain by Coastal Belt Franciscan geology. Kass Creek, the North Fork of the South Fork and some of the South Fork Noyo River and Parlin Creek have steep inner gorges. The North Fork of the South Fork Noyo River also has extensive debris slide amphitheaters, as do various small tributaries throughout SFAA (DMG, 1982). SFAA has an average annual rainfall of approximately 50 inches that fall primarily between October and April (Matthews, 1999). The State of California is the largest landowner in SFAA (Jackson Demonstration State Forest).

Mainstem Noyo River Assessment Area

MAA is composed of 21,314 acres or 33.30 mi^2, including CDF's Planning Watershed numbers 113.20015 (partial), 113.20020, 113.20021, and 113.20040. It is located in the middle of the basin, between the cities of Fort Bragg to the west and Willits to the east. It is primarily underlain by Coastal Belt Franciscan geology, with the exception of Marine Terrace Deposits and Beach Deposits along the coast (DMG, 1983). Much of the Noyo River mainstem and its smaller tributaries have steep inner gorges from Northspur (at the confluence of the North Fork Noyo River and the mainstem) to the west. Similarly, the upper reaches of nearly all the streams in the upper reaches of this assessment area contain large translational/rotational slides, earth flows, and numerous debris slides, including reaches of the mainstem Noyo River (DMG, 1982). The average annual rainfall ranges from 40 inches at the coast to 55 inches further inland (Matthews, 1999). It falls primarily between October and April. MAA includes the mainstem Noyo River, Duffy Gulch, the Little North Fork Noyo River, and the lower estuary. The Timber Company is the largest landowner in MAA.

III.C. SUMMARY OF FINDINGS FOR THE NOYO RIVER WATERSHED OVERALL

Salmonid Abundance

Brown et al. (1994) report that coho salmon previously occurred in as many as 582 California streams from the Smith River near the Oregon border to the San Lorenzo River on the central coast. There are now probably less than 5,000 native coho salmon spawning in California each year, many in populations of less than 100 individuals. Coho populations today are probably less than 6% of what they were in the 1940s and there has been at least a 70% decline since the 1960s. Brown et al. (1994) conclude that the reasons for the decline of coho salmon in California include: stream alterations brought about by poor land-use practices and by the effects of periodic floods and drought, the breakdown of genetic integrity of native stocks, introduced diseases, over-harvest, and climatic change.

There are no quantitative estimates of coho populations in the Noyo River watershed in the earlier part of this century. Anecdotal information, however, indicates that the Noyo River once had a thriving population of coho and steelhead (Brown et al., 1994). Coho salmon have since been listed by the National Marine Fisheries Service as a threatened species due to a steep decline in their numbers. Evidence of continued, recent decline in their populations exists locally in the form of in-migrant fish trap data collected by DFG since 1963 at its egg-taking station on the South Fork of the Noyo River (see Table 2). The average numbers of returning coho to this hatchery-influenced system prior to the drought of 1977 were 2,819; 2,669; and 2,132 for each of the three respective populations.[1] The numbers of returning coho subsequent to the 1993 drought represent a decline of the pre-1977 numbers of 93%, 60%, and 27% for each of the three respective populations (A. Grass pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

Stream Gradients

The stream gradients (as well as the climate, geology and vegetation) in the Noyo River watershed are appropriate for the development of aquatic habitat suitable for salmonids, including coho salmon. For example, CDF has calculated that there are approximately 104 miles of Class I streams in the Noyo River watershed. Of these, 91 miles, or 88%, have gradients less than 5%, which is a gradient capable of supporting spawning and rearing for salmonids. There

[1] Coho salmon have a predictable life cycle in which three-year old fish return to their natal streams to spawn (W. Jones pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). For example, a fish returning to the Noyo River in 1963 spawned fish that then returned in 1966. Thus, there are three separate coho populations represented by the data in Table 1.

Table 2.

Data submitted by the Department of Fish and Game

Coho salmon captured at the Egg-taking Station in the South Fork Noyo River

NOYO COHO NUMBERS FOR 1962—63 thru 1998—99 SEASONS

Season	Males	Females	Grilse	Total
1962—63	775	416	2,501	3,692
1963—64	1,054	2,403	1,483	4,940
1964—65	326	745	1,006	2,077
1965—66	262	291	1,199	1,752
1966—67	951	1,124	925	3,000
1967—68	248	611	1,663	2,522
1968—69	1,120	1,796	166	3,082
1969—70	308	557	473	1,338
1970—71	278	440	1,193	1,911
1971—72	1,245	1,618	170	3,033
1972—73	184	221	1,872	2,277
1973—74	532	871	1,489	2,892
1974—75	888	1,152	496	2,536
1975—76	257	424	1,108	1,789
1976—77	457	620	183	1,260
1977—78*	204	187	120	511
1978—79*	190	200	49	439
1979—80*	103	155	334	592
1980—81*	123	90	125	338
1981—82	431	891	506	1,828
1982—83	214	327	54	595
1983—84	10	17	72	99
1984—85	365	429	230	1,024
1985—86	13	7	26	46

NOYO COHO NUMBERS FOR 1964--65 thru 1996--97 SEASON (continued)

Season	Males	Females	Grilge	Total
1986--87	227	169	634	1,030
1987--88	1,146	1,424	98	2,668
1988--89	49	85	584	708
1989--90	419	299	294	1,012
1990--91*	57	32	56	145
1991--92	173	179	157	509
1992--93*	74	66	24	164
1993--94[1]	26	20	81	127
1994--95[2]	293	316	326	93[illegible]
1995--96[2]	137	149	10	29[illegible]
1996--97[2]	101	523	1,254	1,07[illegible]
1997--98	374	751	123	1,25[illegible]
1998=99	6	11	355	37[illegible]

* Drought years

[1] No fish spawned this year—not a complete count

[2] Not a complete count

PLEASE BE ADVISED THAT MOST YEARS ARE NOT COMPLETE COUNTS, AND SOME NUMBER OF COHO ALWAYS SPAWN DOWNSTREAM OF THE NOYO STATION are approximately 149 miles of Class II streams, some of which may be restorable fish-bearing streams. (S. Lang pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999)

Channel Aggradation and Degradation

Data collected at the USGS gaging station (located just below the confluence of the South Fork Noyo River with the mainstem) indicate that the channel bed has aggraded about two to four feet from 1957 through 1970. From 1970 to 1992, the data indicate channel degradation on the order of one to two feet. Another sharp increase is noted in the period of 1993 through 1998 with three to four feet of aggradation. The data indicate that since 1998 there may be a new trend toward degradation (Matthews, 1999). Thus, in the period of 1957 to the present, net aggradation as measured at the USGS gaging station is estimated as one and a half to two feet.

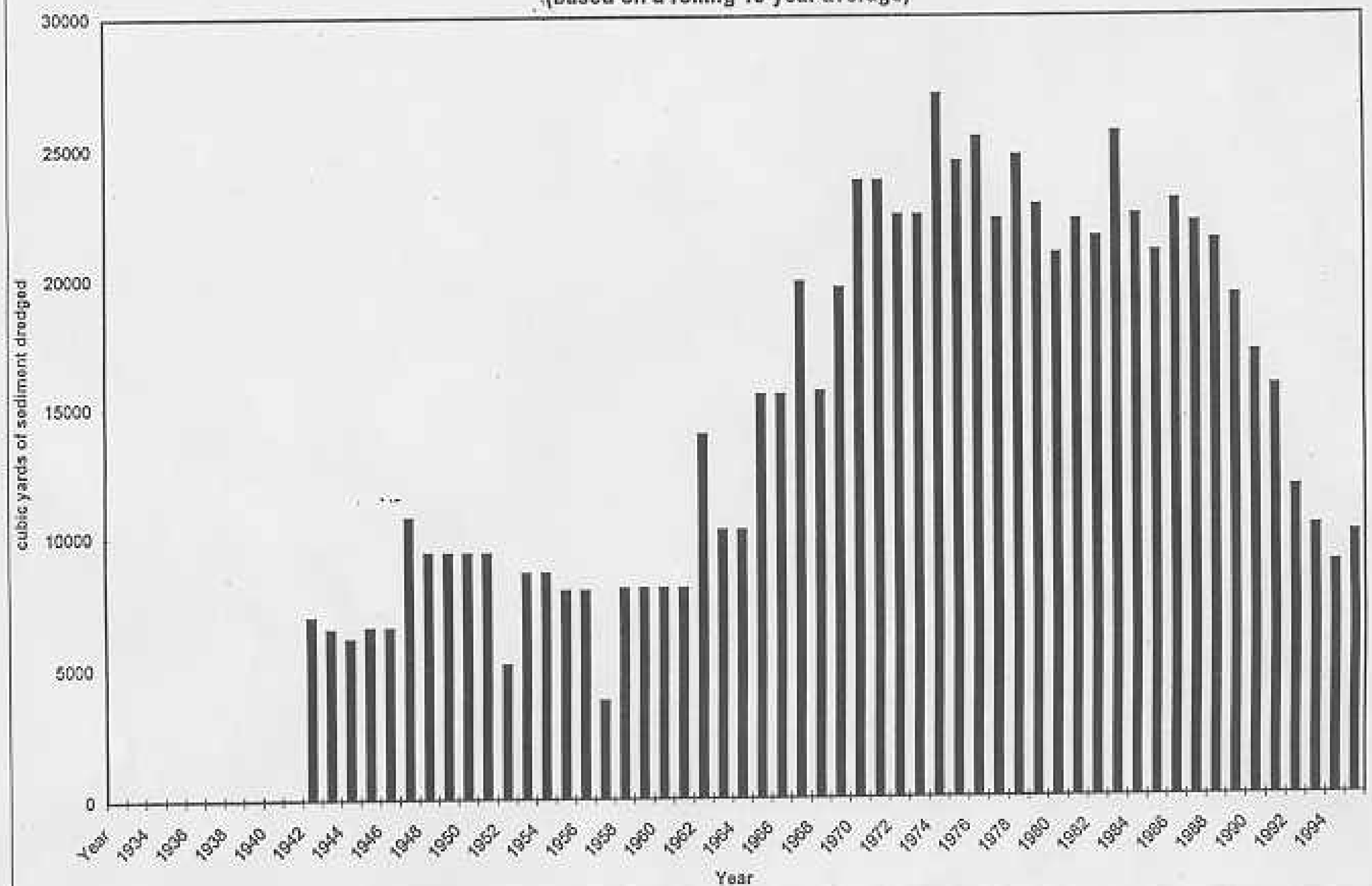
For comparison, dredging data from Noyo Harbor indicate two periods of elevated sedimentation (see Figure 3). Calculated as a 10-year rolling average and beginning in 1933, average dredging volumes peaked in 1947, then hit their lowest volume in 1957. From 1957 (the lowest average volume) to 1967, the average dredging volume climbed steadily, bypassing its 1947 peak and reaching a new peak in 1983. The 1983 average dredging volume was 158% of the 1947 peak dredge volume and 369% of the average dredging volume for the first ten years of dredging begun in 1933. Average dredging volumes steadily declined from 1983 to a low in 1994. The average dredging volume in 1994 was nonetheless 236% of the average volume in 1957 (the lowest average volume) and 127% of the average volume for the first ten years of dredging. The average dredging volume in 1995 climbed again and was 113% of that in 1994 (L. Graham pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

These two information sources indicate that sedimentation increased in the lower Noyo River from 1933 to 1942, then decreased to a low in 1957. From 1957 to sometime in the 1970s or early 1980s, sedimentation sharply increased and then decreased again through the early 1990s. Sedimentation in the lower river increased in the mid-1990s. It may be declining in the late-1990s.

Matthews (1999) concludes that estimates of sedimentation reflect far less dramatic changes in channel geometry as a result of high sediment production and delivery in the Noyo River watershed than has been seen in areas with less stable geology, less dense vegetation cover, and higher precipitation rates. He also observes that the noted changes in channel geometry appear to correlate well with changes in sediment production and delivery associated with land management activities in the basin. Thus, while sediment delivery appears to have impacted salmonid habitat (see summary of findings below), it does not appear to have substantially impacted the overall channel geometry throughout the watershed. If true, the restoration of the Noyo River watershed may be achievable in a shorter time frame than elsewhere.

Turbidity data collected by the City of Fort Bragg between 1993 and 1997 and provided to the Regional Water Board also indicate that turbidity values have increased steeply through this period. These data suggest either a lag in the downstream transport of sediment produced in 1993 or the production of new sediment in this period (Matthews, 1999). In addition, it appears

Figure 3
Annual Average Dredging Volume in the Noyo River Harbor
(based on a rolling 10-year average)



that turbidity levels have periodically obscured visibility and have remained elevated even after the cessation of rain. This can adversely affect fish and drinking water quality.

III.D. SUMMARY OF FINDINGS IN THE HEADWATERS ASSESSMENT AREA

The primary data available for assessing in-stream conditions in the Headwaters Assessment Area (HAA) come from the Mendocino Redwood Company, including:

- Fish distribution;
- % pool by stream length surveyed;
- % of all pools with residual depth 3 feet;
- Shelter rating (using Flosi and Reynolds, 1994);
- % embeddedness (using Flosi and Reynolds, 1994);
- % fine sediment in gravel cores <0.85 mm and <6.3 mm in diameter (as dry weight);
- Board feet of large woody debris per 100 m of stream; and
- Amount of woody debris removed by DFG between 1959-1964.

The fish distribution data are augmented with data and estimates provided by DFG.

Fish Abundance

Steelhead trout are found throughout the Headwaters Assessment Area (HAA), including eighteen sampling stations on: the Noyo River (three sites), unnamed tributaries to the Noyo River (three sites), Olds Creek (two sites), unnamed tributaries to Olds Creek (two sites), Redwood Creek (three sites), McMullen Creek (two sites), an unnamed tributary to McMullen Creek (one site), and Burbeck Creek (two sites) (Mendocino Redwood Company, unpublished). Coho have been found at eight of the eighteen stations sampled, including: two sites in the Noyo River, in three unnamed tributaries to the Noyo River, and all three sites in Redwood Creek (see Table 3). The most abundant populations were found in Redwood Creek (Mendocino Redwood Company, unpublished; DFG, unpublished (a); DFG, unpublished (b)). Both coho and steelhead were once more common in HAA (see Table 4). Redwood Creek may have been producing as many as 3,700 coho and 1,500 steelhead in the 1960s (DFG, unpublished (b)).

Table 3: Summary of the Results of Fish Distribution Surveys in the Upper Noyo River Watershed, Conducted by Louisiana-Pacific Corporation (now Mendocino Redwood Company) from 1994 to 1996

Survey Site Location	Survey Site No.	Survey Date	Steelhead Age Class	Steelhead Abundance	Coho Age Class	Coho Abundance
North Fork Noyo	70-6	7/27/94	0+, 1 yr, 2 yr	>40	0+	<10
“	“	6/13/95	0	10-40	NF	NF
“	“	6/20/96	0	<10	0	<10
Marble Gulch	70-7	7/24/96	0	<10	0	<10
“	70-8	7/24/96	0	<10	NF	NF
“	70-9	7/23/96	0,1	<10	NF	NF
Gulch 7	70-10	8/3/94	1	<10	NF	NF
“	“	7/14/95	1	<10	NF	NF
“	“	7/19/96	1	<10	NF	NF

Survey Site Location	Survey Site No.	Survey Date	Steelhead Age Class	Steelhead Abundance	Coho Age Class	Coho Abundance
Gulch 7	70-11	7/19/96	1	<10	NF	NF
Hayworth Creek	70-12	7/27/94	0,1	10-40	1	<10
"	"	6/14/95	0	<10	NF	NF
"	"	6/19/96	0,1,2	10-40	0	<10
Trib to Hayworth Creek	70-13	7/19/96	0,1	<10	NF	NF
Hayworth Creek	70-14	6/19/96	0,1	10-40	0	10-40
No. Fork Hayworth Creek	70-15	8/3/94	0,1	10-40	NF	NF
"	"	6/14/95	0,1,2	<10	NF	NF
"	"	6/19/96	0,1	<10	0	<10
"	70-16	8/3/94	1,2	<10	NF	NF
"	"	6/14/95	0,1,2	10-40	NF	NF
"	"	7/18/96	NF	NF	NF	NF
"	70-17	7/27/96	NF	NF	NF	NF
Hayworth Creek	70-18	8/3/94	0,1,2	10-40	NF	NF
"	"	6/14/95	0	<10	NF	NF
"	"	6/19/96	0,1,2	10-40	NF	NF
"	70-19	8/4/94	0,1	10-40	NF	NF
"	"	6/14/95	1	<10	NF	NF
"	"	7/19/96	0,1,2	<10	NF	NF
Trib. to Hayworth Creek	70-20	7/19/96	0,1,2	<10	NF	NF
Hayworth Creek	70-21	7/19/96	0,1,2	<10	NF	NF
Soda Creek	70-22	8/4/94	1,2	<10	NF	NF
"	"	8/3/95	0	<10	NF	NF
"	"	7/19/96	0,1	<10	NF	NF
"	70-23	7/19/96	NF	NF	NF	NF
North Fork Noyo	70-24	7/27/94	NF	NF	NF	NF
"	"	6/14/95	0	10-40	NF	NF
"	"	6/19/96	0,1	10-40	0	<10
Middle Fork North Fork Noyo	70-25	7/27/94	0,1	10-40	0	<10
"	"	7/14/95	0,1,2	<10	NF	NF
"	"	7/18/96	0,1	10-40	0	<10
"	70-26	8/4/94	0,1,2	10-40	0	<10
"	"	7/14/95	0,1	2	NF	NF
"	"	7/18/96	0,1,2	10-40	NF	NF
"	70-27	8/25/94	0,1	<10	NF	NF
"	70-28	8/3/95	0,1,2	10-40	NF	NF
"	"	7/23/96	0,1,2	10-40	NF	NF
North Fork Noyo	70-29	7/27/94	0,1	<10	NF	NF
"	"	7/14/95	0,1	<10	NF	NF
"	"	7/18/96	0,1,2	10-40	0	<10
"	70-30	7/27/94	0,1	10-40	NF	NF
"	"	7/14/95	0,1,2	<10	NF	NF
"	"	7/18/96	0,1,2	<10	NF	NF
DeWarren Creek	70-31	8/4/94	0,1	<10	NF	NF
"	"	7/14/95	0,1	10-40	NF	NF

Survey Site Location	Survey Site No.	Survey Date	Steelhead Age Class	Steelhead Abundance	Coho Age Class	Coho Abundance
DeWarren Creek	70-31	7/18/96	0,1,2	10-40	NF	NF
Trib. to DeWarren Creek	70-32	8/4/94	1	<10	NF	NF
"	"	7/14/95	0,1,2	10-40	NF	NF
"	"	7/18/96	0,1	<10	NF	NF
DeWarren Creek	70-33	8/3/94	1,2	<10	NF	NF
"	"	7/14/95	0,1,2	10-40	NF	NF
"	"	7/18/96	1	<10	NF	NF
Noyo River	70-34	7/27/94	0,1,2	10-40	0	<10
"	"	6/13/95	0	10-40	NF	NF
"	"	6/20/96	0,1	<10	0	<10
Trib. to Noyo	70-35	7/25/96	0,1	10-40	0	<10
Fork of trib. to Noyo	70-36	7/25/96	0,1,2	<10	0	<10
Trib. to Noyo	70-37	7/25/96	0,1,2	<10	0	<10
Olds Creek	70-38	7/24/96	0,1	10-40	NF	NF
Trib. to Olds Creek	70-39	7/25/96	0,1,2	<10	NF	NF
Olds Creek	70-41	7/25/96	0,1,2	>40	NF	NF
Redwood Creek	70-42	7/28/94	0,1	10-40	0	<10
"	"	7/14/95	0,1,2	10-40	0	10-40
"	"	6/5/96	0,1,2	<10	0,1	>40
"	70-43	7/28/94	0,1	<10	NF	NF
"	"	7/14/95	0,1	<10	NF	NF
"	"	7/22/96	0,1,2	<10	0	<10
"	70-44	7/28/94	1	<10	NF	NF
"	"	7/14/95	0	<10	NF	NF
"	"	7/22/96	0,1,2	10-40	0	<10
McMullen Creek	70-45	7/28/94	0,1,2	10-40	NF	NF
Trib. to McMullen	70-46	7/14/95	0	<10	NF	NF
"	"	7/22/96	0,1	<10	NF	NF
Noyo River	70-48	7/28/94	0,1	10-40	1	<10
"	"	6/13/95	0,1,2	10-40	NF	NF
Burbeck Creek	70-49	8/25/94	0,1,2	10-40	NF	NF
"	"	7/14/95	0,1	10-40	NF	NF
"	"	6/5/96	0,1	<10	NF	NF
"	70-50	7/23/96	1	<10	NF	NF
Noyo River	70-51	8/25/94	0,1,2	<10	NF	NF
"	"	6/13/95	0,2	10-40	0	<10
"	"	6/5/96	0,1	10-40	NF	NF
"	70-52	7/23/96	0,1,2	>40	NF	NF

NF = no fish
Shaded area = coho observations

Table 4: Summary of Salmonid Sitings Reported in Stream Surveys Conducted by the Department of Fish and Game in the 1950s and 1960s

Assess. Area	Location	Observation
HAA	Mainstem	1957: Steelhead and salmon noted throughout. Size and abundance increased farther up mainstem to headwaters. Past stocking noted at Northspur and in reach between the confluence with Redwood Creek up to Shake City.
	Redwood Creek	1957: Numerous 1-4 inch fish 1966: 112 salmon, 1.5-2.5 inches (avg. 2.25 inches) 496 steelhead, 1.5-7 inches (avg. 2 inches) Surveyor estimated stream producing about 3,700 silver salmon and 1,500 steelhead trout. No known past stocking.
NFAA	North Fork Noyo River	1957: 3-7 inch salmonids, not that numerous. 1966: 112 coho (avg. 2.25 inches) 238 steelhead (avg. 2 inches). Surveyor estimated stream producing 11,200 coho and 23,800 steelhead.
	Middle Fork of North Fork Noyo River	1967: Abundant coho and steelhead (150 of each per 100 feet of stream). Steelhead average 1.5 inches and coho average 2 inches.
	Hayworth Creek	1957: Fish up to 7 inches long above waterfall. 1967: 117 coho (avg. 2.25 inches) 582 steelhead (avg. 2 inches) Surveyor estimated stream producing 2,340 coho and 11,600 steelhead.
SFAA	South Fork Noyo River	1957: Steelhead and salmon "good" 1959: Coho most abundant followed by steelhead and then stickleback. Coho 1-2.5 inches (avg. 2 inches). Steelhead 2-24 inches (avg. 2 inches). 1967: Observed silver salmon, steelhead and sticklebacks. Coho ranged from 2-4 inches. Steelhead ranged from 2-7 inches.
	North Fork of South Fork Noyo River	1957: Steelhead and coho 2-6 inches (avg. 2 inches). Abundant and in "good" condition. 1959: Steelhead and coho 1-7 inches with 1-3 inch fish common.
	Parlin Creek	1957: Steelhead and salmon 1-6 inches. 1959: Coho and steelhead observed. Steelhead ranged from 2-7 inches (avg. 2 inches) and coho ranged from 1-2 inches (avg. 1.5 inches).
	Kass Creek	1957: Steelhead and coho 1-3 inches. Abundant and "good" success. 1959: Coho and steelhead observed throughout creek. 1966: 408 coho, 1.25-3 inches (avg. 1.75 inches) 0 steelhead Surveyor estimated stream producing 6,800 coho and no steelhead.
MAA	Mainstem	1957: Steelhead and salmon observed with lengths ranging from 1-4 inches. Adult steelhead ranging in size from 14-30 inches observed several miles east of estuary in February.

Table 5: Summary of In-stream Data Collected by Mendocino Redwood Company in the Noyo River Watershed

Stream Name	Assess. Area	Segment	% pools by stream length	% pools > 3'	Shelter rating	% embed.	Key LWD (bf/100m)	% fines <0.85 mm (mean)—as dry weight
Noyo	HAA	1	42	81	27	25-50	0.5	7%
North Fork Noyo	NFAA	3	34	20	14	25-50	0.4	NR
Marble Gulch	NFAA	12	50	13	25	<25	0.9	NR
Marble Gulch	NFAA	23	NR	NR	NR	NR	NR	7%
Gulch #7	NFAA	48	26	0	11	<25	0.0	NR
Noyo	HAA	56	38	16	55	<25	0.5	NR
Olds Creek	HAA	57	23	31	34	<25	0.0	NR
Unnamed trib	HAA	63	37	0	30	<25	3.2	NR
Unnamed trib	HAA	64	2	0	25	<25	0.3	NR
Burbeck Creek	HAA	80	5	0	150	<25	5.6	NR
Redwood Creek	HAA	92	55	13	30	25-50	1.2	NR
Redwood Creek	HAA	92(2)	64	89	16	<25	0.0	NR
Hayworth Creek	NFAA	104	63	59	93	<25	1.8	NR
Hayworth Creek	NFAA	106	61	7	36	25-50	1.3	7%
North Fork Hayworth	NFAA	112	50	0	90	25-50	0.0	NR
Hayworth Creek	NFAA	118	32	0	17	25-50	1.0	NR
Soda Creek	NFAA	119	31	0	25	<25	2.9	NR
North Fork Noyo	NFAA	152	79	21	39	<25	0.5	NR
North Fork Noyo	NFAA	152(2)	45	12	86	25-50	2.1	NR
Middle Fork North Fork Noyo	NFAA	153	34	0	15	<25	1.4	9%
Middle Fork North Fork Noyo	NFAA	153(2)	26	0	43	25-50	0.0	NR
Middle Fork North Fork Noyo	NFAA	156	70	0	34	<25	3.4	NR
North Fork Noyo	NFAA	159	24	0	24	25-50	9.8	10%
North Fork Noyo	NFAA	159(2)	23	0	45	25-50	14.2	NR
DeWarren Creek	NFAA	161	39	9	53	>50	10.5	NR

Spawning Habitat

Embeddedness measurements and substrate composition data describe spawning habitat conditions in HAA (see Table 5). The Mendocino Redwood Company rates other spawning habitat features (e.g., spawning gravel quantity), but they do not report actual measurements. There is one site on the Noyo River from which substrate composition data were collected. Embeddedness measurements were collected at two sites on the Noyo River, one site on Olds Creek, on two unnamed tributaries, one site on Burbeck Creek, and two sites on Redwood Creek.

The substrate composition data collected on the Noyo River were collected from one habitat reach, but from four separate pool tail-outs. The data indicate that fine sediment at all of the tail-outs in the 18-30 cm depth range is a higher proportion of the substrate core than may be necessary to ensure adequate oxygenation and waste removal from redds. At one of the tail-outs, the fine sediment in the 0-18 cm range was also elevated.

The embeddedness data indicate that cobble in one of the sites on Redwood Creek and one of the sites on the Noyo River are 25 to 50% embedded. The others sites are less than 25% embedded. This data set is limited, but it suggests that coho may have difficulty digging redds in reaches of the Noyo River mainstem and Redwood Creek.

Rearing Habitat
Rearing habitat is described by the percent of pools by stream length, the percent of all pools with residual depth greater than or equal to three feet, and shelter rating. These data were collected from two sites on the Noyo River, one site on Olds Creek, two unnamed tributaries, one site on Burbeck Creek, and two sites on Redwood Creek. Table 5 summarizes these data.

The “percent of pools by stream length” and “percent of all pools with residual depth 3 feet” were combined to determine the percent of pools with depths of at least three feet. Of the eight sites sampled, only one—on Redwood Creek—had numerous enough deep pools for coho rearing. Similarly, only one—on Burbeck Creek—had shelter well enough developed for coho rearing.

Overwintering Habitat
Overwintering habitat provides protection to young coho from being washed out in winter and spring freshets. Such habitat includes backwater pools and large woody debris, other large obstructions, and shelter. Large woody debris is also valuable for sediment metering, sediment grading, pool formation, and summer shelter. The Mendocino Redwood Company reports data with respect to the removal of large woody debris between 1959 and 1964. It also reports the results of a more recent large woody debris survey. There are no data with respect to the number, area or volume of backwater pool habitat in HAA. The Mendocino Redwood Company reports the percent of habitat units dominated by cobble or boulder as a factor relevant to overwintering.

According to the Mendocino Redwood Company, DFG removed from 1959 to 1964 a total of 1,111,284 board feet (bf) of large woody debris from streams in HAA. This includes:

- Burbeck Creek 67,800 bf;
- Olds Creek 153,900 bf or 2,224 bf/100 m of stream;
- Redwood Creek 590,244 bf or 7,053 bf/100 m of stream; and
- McMullen Creek 299,340 bf or 6,889 bf/100 m of stream.

Current levels of large woody debris have been measured at two sites in the Noyo River, one site in Olds Creek, two sites in Redwood Creek, one site in Burbeck Creek, and sites in two tributaries to the Noyo River. There are 1.8 bf/100 m of stream at each of the eight sites. Table 5 summarizes these data.

Potential Limiting Factors
Based on the available data, the following appear to be potentially limiting factors in HAA:

- Fine sediment intrusion of redds throughout HAA;

- Embedded spawning gravels in reaches of Redwood Creek and the Noyo River;
- Few deep pools throughout HAA, except in reaches of Redwood Creek;
- Poorly developed shelter throughout HAA, except in Burbeck Creek; and
- Limited large woody debris throughout HAA.

Due to the lack of data regarding the backwater pool habitat, a conservative approach requires that backwater pools be considered a potentially limiting factor until further data can be developed.

III.E. SUMMARY OF FINDINGS IN THE NORTH FORK NOYO RIVER ASSESSMENT AREA

The primary data available for assessing in-stream conditions in the North Fork Noyo River Assessment Area (NFAA) come from the Mendocino Redwood Company (Mendocino Redwood Company), including:

- Fish distribution;
- % pool by stream length;
- % of all pools with residual depth 3 feet;
- Shelter rating;
- % embeddedness;
- % fine sediment in gravel cores <0.85 mm and <6.3 mm in diameter (as dry weight);
- Board feet of large woody debris per 100 m of stream; and
- Amount of woody debris removed by DFG between 1959-1964.

The fish distribution data are augmented with data and estimates provided by DFG.

Fish Abundance

Steelhead trout are found throughout NFAA, except in Soda Creek, as demonstrated by samples collected at 28 stations located in: the North Fork Noyo River (four sites), Marble Gulch (three sites), Gulch 7 (two sites), Hayworth Creek (five sites), two unnamed tributaries to Hayworth Creek (two sites), the North Fork of Hayworth Creek (three sites), Soda Creek (two sites), the Middle Fork of the North Fork Noyo River (four sites), DeWarren Creek (two sites), and an unnamed tributary to DeWarren Creek (one site) (see Table 3). They were found in each year between 1994 and 1996, except in 1996 at a station on the North Fork of Hayworth Creek (#70-16)—two rainbow trout were identified—and at a station on Soda Creek (#70-23). Coho salmon were found at 10 of the 28 stations, and only sporadically over time. Coho were found in: the North Fork Noyo River, Marble Gulch, Hayworth Creek, the North Fork of Hayworth Creek, and the Middle Fork of the North Fork Noyo River (Mendocino Redwood Company, unpublished).

Both coho and steelhead were once more common in NFAA (see Table 4). The North Fork Noyo River may have been producing as many as 11,200 coho salmon and 1,500 steelhead trout in the 1960s. Similarly, Hayworth Creek may have been producing as many as 2,340 coho and 11,600 steelhead in this same time period (DFG, unpublished (c)).

Spawning Habitat
Embeddedness measurements and substrate composition data describe spawning habitat conditions in NFAA. The Mendocino Redwood Company rates other spawning habitat features (e.g., spawning gravel quantity), but they do not report actual measurements. Substrate composition data were collected from three to four tail-outs within four streams, including: Hayworth Creek, the North Fork Noyo River, Marble Gulch, and the Middle Fork of the North Fork Noyo River. Embeddedness measurements were collected at five sites on the North Fork Noyo River, one site on Marble Gulch, one site on Gulch #7, three sites on Hayworth Creek, one site on North Fork Hayworth Creek, one site Soda Creek, three sites on the Middle Fork of the North Fork Noyo River, and one site on DeWarren Creek. Table 5 summarizes these data.

Of the fifteen substrate cores collected, only two were free of elevated fines: Tail-out #5 on Hayworth Creek and Tail-out #5 on Marble Gulch. All the others had fines exceeding 14% wet volume (an estimated 7% dry weight using Shirazi et al., 1981).

The embeddedness data indicate that cobble in four of the five North Fork Noyo River sites are 25 to 50% embedded, as are two of the three sites in Hayworth Creek, and one of the three sites in the Middle Fork of the North Fork Noyo River. Cobble at the site on DeWarren Creek is more than 50% embedded. This data set suggests that coho may have difficulty digging redds in reaches of the North Fork Noyo River, Hayworth Creek, the Middle Fork of the North Fork Noyo River, and DeWarren Creek.

Rearing Habitat
Rearing habitat is described by: the percent of pools by stream length, the percent of all pools with residual depth greater than or equal to three feet, and shelter rating. These data were collected from the same sites from which embeddedness data were collected. Table 5 summarizes these data.

The "percent of pools by stream length" and "percent of all pools with residual depth 3 feet" were combined to determine the percent of pools with depths of at least three feet. None of the sixteen sites sampled had numerous enough deep pools or well enough developed shelter for coho rearing.

Overwintering Habitat
Overwintering habitat provides protection to young coho against being washed out in winter and spring freshets. Such habitat includes backwater pools and large woody debris, other large obstructions, and shelter. Large woody debris is also valuable for sediment metering, sediment grading, pool formation, and summer shelter. The Mendocino Redwood Company reports data with respect to the removal of large woody debris between 1959 and 1964. It also reports the results of a more recent large woody debris survey. There are no data with respect to the number, area or volume of backwater pool habitat in NFAA. The Mendocino Redwood Company reports the percent of habitat units dominated by cobble or boulder as a factor relevant to overwintering.

According to the Mendocino Redwood Company, DFG removed from 1959 to 1964 a total of 2,854,920 board feet of large woody debris from streams in NFAA. This includes:

- North Fork Noyo River 18,000 bf or 135 bf/100 m of stream;
- Hayworth Creek 2,232,480 bf or 23,512 bf/100 m of stream; and
- Marble Gulch 604,440 bf.

Current levels of large woody debris have been measured at four sites on the North Fork Noyo River, three sites on Hayworth Creek, one site on Marble Gulch, one site on Gulch #7, three sites on the Middle Fork of the North Fork Noyo River, one site on DeWarren Creek, one site on the North Fork Hayworth Creek, and one site on Soda Creek. With the exception of these last three, there are less than six board feet of large woody debris per 100 meters at each of the sites in NFAA. The sites in DeWarren Creek, North Hayworth Creek and Soda Creek each have 15 board feet of large woody debris per 100 meters of stream (see Table 5).

Potential Limiting Factors

Based on the available data, the following appear to be potentially limiting factors in NFAA:

- Fine sediment intrusion of redds throughout NFAA except reaches in Hayworth Creek and Marble Creek;
- Embedded spawning gravels in reaches of North Fork Noyo River, Hayworth Creek, Middle Fork of the North Fork Noyo River, and DeWarren Creek;
- Few deep pools throughout NFAA;
- Poorly developed shelter throughout NFAA; and
- Poorly developed overwintering habitat throughout NFAA, including limited large woody debris.

Due to the lack of information regarding backwater pool habitat, a conservative approach requires that backwater pools be considered a potentially limiting factor until further data can be developed. The V-shaped valleys of NFAA may preclude the development of an abundance of backwater pool habitat in this region, however.

III.F. SUMMARY OF FINDINGS IN THE SOUTH FORK NOYO RIVER ASSESSMENT AREA

The primary data available for assessing in-stream conditions in the South Fork Noyo River Assessment Area (SFAA) come from DFG, including:

- Annual count of upstream migrants;
- Pool frequency;
- % of all pools with residual depth 2 feet and 3 feet;
- Pool type;
- Shelter rating; and
- % embeddedness.

These data are augmented with the Mendocino Redwood Company's estimates of large woody debris removal between 1959-1964 and Knopp's V* data from 1992 (Knopp, 1993).

Fish Abundance
Coho salmon raised in DFG hatcheries from eggs collected on the South Fork Noyo River have been released to the South Fork Noyo River since 1963 (A. Grass pers. comm. with A. Mangelsdorf as reported in Regional Water Board, 1999). As such, coho populations have been highly managed in SFAA. Returning coho fish counts are included in Table 2. Table 4 indicates that Kass Creek may have been producing as many as 6,800 coho in the 1960s (DFG, unpublished (d)). Steelhead trout and coho salmon have been found throughout SFAA during the 1980s and early 1990s, including the North Fork of the South Fork Noyo River, the South Fork Noyo River and Kass Creek (see Table 6) (DFG, 1995(a) and (b); DFG, unpublished (d)).

Table 6: Summary of Aquatic Surveys Conducted by the Department of Fish and Game from 1983 to 1989 in the Noyo River Watershed (Contained in DFG's Biosample Database)

Stream	Date	Steelhead trout populations		Coho salmon populations		Shelter ratings				
		Density (fish/m^2)	Biomass (kg/ha)	Density (fish/m^2)	Biomass (kg/ha)	Turbu-lence	Instream object	Under cut bank	Veg.	Total
Redwood Creek (HAA)	5/12/89	0.46	5.17	0.02	0.14	60	70	5	1	136
South Fork Noyo River (SFAA)	9/13/83	0.17	11.35	0.01	0.39	NR	NR	NR	NR	NR
South Fork Noyo River (SFAA)	9/12/86	NR	NR	NR	NR	0	10	2	1	13
Kass Creek (SFAA)	10/4/83	0.42	6.85	0.28	9.10	NR	NR	NR	NR	NR
North Fork South Fork Noyo River (SFAA)	9/12/86	NR	NR	NR	NR	1	10	25	1	37
Duffy Gulch (MAA)	6/25/86	0.88	9.50	NR	NR	60	50	0	0	110
Little North Fork Noyo River (MAA)	8/22/84	1.16	26.92	0.09	4.00	5	25	20	15	65

Spawning Habitat
Spawning habitat conditions in SFAA are primarily described by embeddedness measurements collected by DFG in habitat inventories conducted in the Parlin Creek watershed and South Fork Noyo River watershed.

In Parlin Creek, DFG measured the embeddedness of cobbles in 249 pool tail-outs. Of these pool tail-outs, 16% were less than 25% embedded, 49% were between 25-50% embedded, 28% were between 50-75% embedded, and 7% were more than 75% embedded. In three tributaries to Parlin Creek, 11%, 29%, and 3% of the pool tail-outs, respectively, had cobble less than 25% embedded (DFG, 1995(b)). In the South Fork Noyo River, DFG measured the embeddedness of cobbles in 351 pool tail-outs. Of these pool tail-outs, 29% were less than 25% embedded, 37% were between 25-50% embedded, 28% were between 50-75% embedded, and 6% were more than 75% embedded. In two tributaries to the South Fork Noyo River, 22% and 3% of the pool tail-outs had cobble less than 25% embedded (DFG, 1995(a)). These data indicate that coho may have difficulty digging redds in a majority of the pool tail-outs in SFAA.

Rearing Habitat

Rearing habitat conditions in SFAA are described by pool frequency, the percentage of pools deeper than three feet, and the shelter rating as collected by DFG in habitat inventories in Parlin Creek and the South Fork Noyo River.

In Parlin Creek, 45% of the habitat length inventoried (20,736 feet) were pool units, 31% were flatwater, and 21% were riffle units. The mean pool depth was 1.0 foot. Approximately 12% of the pools had depths greater than or equal to three feet. Pool habitat types had a mean shelter rating of 24 and flatwater habitat had a mean shelter rating of seven. The main channel pools had the highest mean shelter rating at 30. Large woody debris (49%) followed by bedrock ledges (15%) and undercut banks (12%) dominated shelter in pools. DFG concluded that shelter was generally lacking in complexity and extent. In the three tributaries to Parlin Creek, pools made up 52%, 40% and 30% of the habitat units (5,036 feet) surveyed, respectively. No more than 18%, 8%, and 8% of the pools in each tributary, respectively, had depths greater than two feet. The mean shelter ratings were 38, 42 and 33, respectively (DFG, 1995(b)). These data indicate that the infrequency of deep pools may be limiting coho rearing success in the Parlin Creek watershed as may the lack of adequate shelter.

In the South Fork Noyo River, 56% of the habitat length surveyed (49,762 feet) was in pool units, while 32% were in flatwater and 12% in riffles. The mean pool depth was measured at 1.4 feet. Approximately 32% of the pools had a maximum depth 3 feet. Pool habitat units had a mean shelter rating of 21. Flatwater habitats had a mean shelter rating of 7. Undercut banks were the dominant cover type (35%) followed by bedrock ledges (22%). DFG concluded that large and small woody debris were lacking in nearly all habitat types. In two tributaries to the South Fork Noyo River, pools made up 30% and 43% of the habitat units surveyed (2,922 feet). No more than 19% and 12% of the pools had maximum depths greater than 2 feet. The mean shelter ratings for pools were 37 and 69 (DFG, 1995(a)). These data indicate that the infrequency of deep pools may be limiting coho rearing success in the South Fork Noyo River watershed as may the lack of adequate shelter. The lack of large woody debris was particularly noted.

In a study of North Coast streams, Knopp collected, among other parameters, V* measurements in the North Fork of the South Fork Noyo River, Parlin Creek and Kass Creek. V* is a measure, of the ratio of the volume of sediment filling a pool to the scoured volume of a pool, originally developed by Lisle and Hilton (1992). A V* measurement of 0.50, therefore, indicates that 50% of the pool is filled with sediment. The sediment residing in pools is thought to be annually mobile. V* measurements for the North Fork of the South Fork Noyo River, Parlin Creek and Kass Creek were 0.35, 0.31, and 0.60, respectively (Knopp, 1993). Reference data were collected from the North Fork Caspar Creek. The mean V* measurement there was 0.27. These data indicate that pools in the North Fork of the South Fork Noyo River, Parlin Creek and Kass Creek have excessive sediment filling them.

Overwintering Habitat
Overwintering habitat provides protection to young coho from being washed out in winter and spring freshets. Such habitat includes backwater pools and large woody debris, other large obstructions, and shelter. Large woody debris is also valuable for sediment metering, sediment grading, pool formation, and summer shelter. DFG reports backwater pool frequencies and mean depths. The Mendocino Redwood Company reports data with respect to the removal of large woody debris between 1959 and 1964. There are no data with respect to current levels of large woody debris in SFAA, with the exception of DFG's observation that large woody debris is lacking in the South Fork Noyo River (DFG, 1995(a)).

In Parlin Creek, backwater pools make up 7% of the pool units identified. The mean backwater pool depth is 1.5 feet (DFG, 1995(b)). In the South Fork Noyo River, backwater pools make up 5% of the pool units identified. The mean backwater pool depth is 1.4 feet (DFG, 1995(a)).

According to the Mendocino Redwood Company, DFG removed from 1959 to 1964 a total of 132,024 board feet (or 2,413 bf/100 m of stream) of large woody debris in Kass Creek. Additional large woody debris is reported to have been removed in later years, as well (P. Cafferata pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

Potential Limiting Factors
Based on the available data, the following appear to be potentially limiting factors in SFAA:
- Embedded spawning gravels throughout SFAA;
- Few deep pools throughout SFAA, including excessive filling by sediment;
- Poorly developed shelter throughout SFAA; and
- Infrequent backwater pools throughout SFAA.

Due to the lack of data regarding substrate composition and large woody debris, a conservative approach requires that these factors be considered potentially limiting, as well, until further data can be developed.

III.G. SUMMARY OF FINDINGS IN THE MAINSTEM NOYO RIVER ASSESSMENT AREA

There is no primary data source for assessing in-stream conditions in the Mainstem Noyo River Assessment Area (MAA). Instead, individual pieces of data are combined from DFG, CDF, The Timber Company, and the Mendocino Redwood Company. Data include:
- Fish distribution (DFG and the Mendocino Redwood Company);
- Pool frequency (DFG);
- Mean pool depth (CDF);
- Shelter rating (DFG);
- Substrate composition (DFG and CDF); and
- Large woody debris (CDF).

Salmonid Abundance
Burns of DFG studied conditions in the Little North Fork Noyo River before and after road building and logging in the late 1960s. Valentine and Jameson of CDF replicated elements of Burns' study in the early 1990s. With respect to salmonid abundance, Valentine and Jameson (1994) report that total salmonid biomass was similar between the two studies. The difference, however, was that steelhead trout made up 80% of the 1992 sample, but only 17% of the 1966-1969 samples (averaged).

W. Jones (DFG) has surveyed Duffy Gulch, the Little North Fork Noyo River, and the mainstem Noyo River at Matson Hole for the presence of coho salmon and steelhead trout. Steelhead trout were observed at all three locations. Coho salmon were observed only in the Little North Fork Noyo River (see Table 6).

The Mendocino Redwood Company surveyed two locations on the Noyo River and locations on two unnamed tributaries to the Noyo River less than two miles above the gaging station in MAA. Steelhead were observed at all eight stations. Coho salmon were observed at three of the eight stations.

Spawning Habitat
Spawning habitat conditions in MAA are primarily described by substrate composition data collected in the Little North Fork Noyo River by Burns (1970) and Valentine and Jameson (1994).

Burns (1970) measured substrate composition using a McNeil-like core sampler before and after road building and logging in the late 1960s. Fine sediment < 0.8 mm in diameter was 20.0% (mean) of the total substrate sample (wet volume) in 1966 prior to the construction of a new road for logging second growth forest. In 1968, the mean was 31.0%. In 1969, the mean was 33.3%. For particles < 3.3 mm in diameter, the mean in 1968 was 42.1% and 44.4% in 1969. No data were reported for particles < 3.3 mm in diameter in 1966. Valentine and Jameson (1994) reproduced Burns' study and found that fine sediment <0.85 mm in diameter was 25.4% (mean) of the total substrate sample (wet volume) in 1992. These data indicate that fine sediment may be too high a proportion of the substrate composition to ensure adequate oxygenation and waste removal from redds. They also indicate that the proportion of fine sediment in the substrate in 1992 was lower than in 1968 and 1969, but higher than in 1960. The mechanism by which fine sediment has been reduced since 1969, however, is unclear. It could be related to changes in management practices. It could also be related to the difference in climatic regime represented by the two study periods. For example, Burns conducted his study immediately after two large peak flows in Water Years 1965 and 1966 (the 2nd and 5th largest annual peak flows, respectively). Valentine and Jameson (1994), on the other hand, conducted their study at the tail end of a drought year.

Rearing Habitat
Rearing habitat conditions in MAA are described by pool frequency, mean pool depth, and shelter ratings. Burns (1971) reported a pool frequency of 68% in the Little North Fork Noyo River in 1966. Valentine and Jameson (1994) report a mean pool depth of 1.4 feet as measured

in 1992. Jones (DFG, unpublished (a)) reports a pool frequency in the Little North Fork Noyo River of 50% as measured in 1984 and in Duffy Gulch of 5% as measured in 1986. He also reports shelter ratings for the Little North Fork Noyo River and Duffy Gulch of 65 and 110, respectively. These data are limited, particularly in that data for all the parameters were not collected in all of the studies, but they indicate that the frequency of deep pools in the Little North Fork Noyo River may be limiting the rearing success of coho salmon as may poor shelter. The frequency of pools of any sort in Duffy Gulch also may be limiting the rearing success of coho salmon.

Overwintering Habitat

Overwintering habitat provides protection to young coho from being washed out in winter and spring freshets. Such habitat includes backwater pools and large woody debris, other large obstructions, and shelter. Large woody debris is also valuable for sediment metering, sediment grading, pool formation, and summer shelter. The Mendocino Redwood Company reports data with respect to the removal of large woody debris between 1959 and 1964. Valentine and Jameson (1994) report large woody debris volumes and site lengths in the Little North Fork Noyo River. There are no data with respect to the availability of backwater pools in MAA.

According to the Mendocino Redwood Company, a total of 563,460 board feet of large woody debris was removed from MAA in the period of 1959 to 1964:

- Little North Fork Noyo River 201,420 bf or 2,503 bf/100 m of stream; and
- Duffy Gulch 362,040 bf.

In 1992, Valentine and Jameson (1994) measured 89 m^3 of large woody debris in 518 m of stream in the Little North Fork Noyo River (e.g., 17 m^3/100m or 7208 bd ft/100m, where 1 m^3 = 424 board feet).

Potential Limiting Factors

Based on the available data, the following appear to be potentially limiting factors in MAA:

- Fine sediment intrusion of redds in the Little North Fork Noyo River, and throughout MAA;
- Few deep pools throughout MAA; and
- Poorly developed shelter in the Little North Fork Noyo River and throughout MAA (except Duffy Gulch).

Due to the limited availability of data regarding substrate composition, embeddedness, backwater pools, and large woody debris throughout MAA (except the Little North Fork Noyo River), a conservative approach requires that these factors be considered potentially limiting throughout MAA, until further data can be developed.

III.H. RELEVANT FINDINGS IN THE CASPAR CREEK WATERSHED

Long-term studies have been conducted in the Caspar Creek watershed, immediately south of the Noyo River watershed. Caspar Creek is similar in many respects to the coastal sub-basins of the Noyo River watershed, such as the South Fork Noyo River. In addition, Caspar Creek, the South

Fork Noyo River, and portions of the Big River now comprise the Jackson Demonstration State Forest, owned by the State of California and managed by CDF. Thus, there are similarities in the management practices that have been employed over time. A summary of relevant findings from the Caspar Creek watershed is provided here so as to highlight additional issues, beyond the potential limiting factors identified above, that should be considered in the Noyo River watershed. These issues, where not addressed as numeric targets or load allocations, should be considered in the development of a TMDL implementation plan.

The Caspar Creek watershed has been the subject of paired watershed studies in the 1960s and 1970s. The South Fork Caspar Creek was roaded and selectively logged and tractor yarded in the late 1960s and early 1970s. Hillslope and in-stream measurements in the South Fork Caspar Creek were compared to those for the unlogged second-growth forest in the North Fork Caspar Creek watershed. The North Fork Caspar Creek was clear-cut in patches and cable and tractor yarded in the late 1980s and early 1990s. Comparisons between pre-Forest Practices Act logging and post-Forest Practices Act logging have since been made (Lewis, 1998).

Several relevant issues are illuminated by the Caspar Creek studies.

- Activities which increase peak flows or decrease the stability of the armor layer may elevate the risk of poor ova survival (Lisle, 1989).
- Cable yarding substantially reduces the risk of immediate landsliding as well as post-harvest landsliding (Cafferata and Spittler, 1998).
- Suspended sediment loads increase after road building and logging but return to normal levels after seven years of rest (Lewis, 1998).
- There is a statistically significant, positive relationship between ground disturbance and suspended sediment (Lewis, 1998; J. Lewis pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).
- Suspended sediment discharges resulting from pre-Forest Practices Act logging are an average of three times greater than those resulting from post-Forest Practices Act logging when no more than 50% of the basin is logged and cable yarding is used on at least 80% of the harvest area (Lewis, 1998).
- Post-Forest Practices Act-related excess sediment loads are mostly related to increases in storm flow volumes. Reductions may be achieved by reducing or preventing disturbance to small drainage channels (Lewis, 1998).
- Peak flows, except those during very large storms, and annual runoff increase as a result of logging. Clear-cutting causes greater such increases than selective harvest. These effects subside within 15 years of rest as the trees re-grow (Ziemer, 1998).
- Deep pools are important to salmonid success in small, low-gradient streams where water depth and habitat complexity are otherwise reduced (Harvey and Nakamoto, 1996).
- The presence of juvenile steelhead has a negative effect on the growth of 0+ coho salmon which may have population-level ramifications. When the species are found together, coho occupy the middle of pools whereas steelhead are more widely distributed. The availability of large pools, then, is vital to coho successful competition (Harvey and Nakamoto, 1996).
- While windthrow and bank erosion are the most common *known* sources of large woody debris to the channel, *unknown* sources are responsible for the largest percentage of noted large woody debris (O'Connor and Ziemer, 1989; Surfleet and Ziemer, 1996).

Studies conducted in the Caspar Creek watershed, therefore, suggest that when the Regional Water Board develops an implementation plan for the Noyo River TMDL, they should consider including measures to reduce clear-cutting, increase cable yarding, increase periods of rest between harvests, reduce overall ground disturbance, and reduce or prevent disturbance in small drainages.

CHAPTER IV
NUMERIC AND OTHER TARGETS

Numeric targets interpret water quality objectives, provide indicators of watershed health, and represent habitat conditions adequate for the success of salmonids. The water quality objectives of concern, as noted in Chapter II (Existing Water Quality Requirements), are narrative standards for suspended material, settleable material, sediment, and turbidity. In addition, two prohibitions on sediment discharge from logging, construction and related activities further define water quality-related requirements. Indicators allow resource managers and others to assess the degree to which positive changes are occurring in the watershed that, over time, will result in a greater abundance and quality of habitat necessary to support the cold water fishery.

A TMDL is intended to result in attainment of water quality suitable to support beneficial uses. To this end, it is necessary to monitor in-stream parameters to determine if water quality is in fact improving over time. Many in-stream parameters, identified in the scientific literature as critical to coho success, vary as a result of both natural and anthropogenic changes. Thus, using in-stream parameters as a means of quantifying the benefits to water quality that are derived from changes in hillslope management practices is difficult. Hillslope targets define watershed conditions which are associated with well-functioning watersheds which are needed to protect water quality and assist in assessment of sediment control. Thus, both in-stream and hillslope targets are identified for the Noyo River watershed.

Although the Noyo River watershed was included on the 303(d) list for sedimentation and its threat to water quality and the salmonid fishery, many factors affect salmonid populations. In particular, the amount, type, size and placement of large woody debris in the watercourse and the timing, rate and duration of water flow are other watershed processes which interact with sediment to affect salmonid habitat. California coastal streams are especially dependent on the presence of large woody debris to provide ecological functions, such as sediment metering, sediment grading, pool formation, and shelter. Therefore, a numeric target for large woody debris is identified for the Noyo River watershed.

IV.A. SUMMARY OF NUMERIC AND OTHER TARGETS

Table 7 summarizes the in-stream numeric targets. The in-stream numeric targets are developed for parameters identified in Chapter III (Problem Statement) as potentially limiting the success of coho salmon. The turbidity, % fines <0.85 mm, and embeddedness targets are intended to reflect the likely impacts due to elevated sediment delivery, particularly sediment from roads. The pool frequency/depth, backwater pools, and large woody debris targets are intended to reflect the likely impacts due to elevated sediment delivery, particularly in conjunction with limited large woody debris recruitment. The thalweg profile target is intended to reflect more general changes in channel complexity as they relate to the interaction of sediment delivery, large woody debris recruitment, and flow.

Table 7: Summary of Numeric Targets

Parameter	Target	Reference(s)
Turbidity	No greater than 20% above background	Basin Plan, 1994; Reid, 1999
% fines <0.85 mm	14% (mean) as wet volume	Burns, 1970; CDF, 1994
Embeddedness	Increasing percentage of riffle habitat units which are less than 25% embedded	Flosi and Reynolds, 1994; DFG, 1995 (a) and (b)
Pool frequency/depth	40% of habitat length in pools greater than 3 feet in depth at low flow in third and higher order streams	Flosi and Reynolds, 1994; G. Flosi pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999
Backwater pools	Increasing percentage of backwater pools per habitat length	Deitrich, 1998
V*	0.27	Knopp, 1993
Large woody debris	Increase in the number and total volume of key pieces of large woody debris per stream length	Bilby and Ward 1989; Beechie and Sibley 1997; USDA, 1994
Thalweg profile	Increasing variation in the thalweg elevation around the mean thalweg profile slope	Trush, 1999; Madej, 1999

Table 8 summarizes the hillslope targets established to define watershed conditions needed to protect water quality. Hillslope targets are developed for management-related parameters identified in Chapter III (Problem Statement) that are important to the delivery of sediment to a watercourse. The stream crossing targets are intended to focus on road-related sediment delivery, particularly sediment delivery that is highly controllable. The hydrologic connectivity target is intended to focus on the problem of an expanded channel network, particularly the accompanying issues of elevated sediment (as scour) and flow. The disturbed area target is intended to focus on the problem of increased erosion and flow potential accompanying unvegetated and/or

Table 8: Summary of Other Targets

Parameter	Target	Reference(s)
Stream crossing with diversion potential	1% of all stream crossings, as a result of a storm with a 100 year recurrence interval or less	Weaver and Hagans, 1994; D. Hagans pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999
Stream crossing with significant crossing failure potential	1% of all stream crossings, as a result of a storm with a 100 year recurrence interval or less	Flanagan et al., 1998
Hydrologic connectivity	Decrease in the miles of road (including railroad) hydrologically connected to a watercourse	Ziemer, 1998; Furniss, 1999
Disturbed area	Decrease in the area disturbed by facilities*	Lewis, 1998
Activity in unstable areas	No activities (e.g., roads, harvest, yarding, etc.) in unstable areas (e.g., steep slopes, headwall swales, inner gorges, stream banks, etc.) unless a detailed geological assessment is performed that shows there is no potential for increased sediment delivery to a watercourse as a result.	Dietrich et al., 1998; Weaver and Hagans, 1994; Pitlick, 1982; PWA, 1998.

*A facility is defined as any management-related structure such as a road, railroad roadbed, skid trail, landing, harvest unit, or agricultural field (e.g., pasture, vineyard, orchard, row crops). For the purpose of this target, a harvest unit or agricultural field that retains its natural characteristics with respect to rainfall interception, rainfall infiltration, and soil protection, is not considered a "facility."

compacted soil surfaces. The unstable area target is intended to focus on the problem of the increased risk of erosion and sediment delivery that is likely from unstable areas.

IV.B. DISCUSSION OF NUMERIC AND OTHER TARGETS

What follows is a brief discussion of each of the targets summarized above. Chapter III (Problem Statement) provides the data or data references from which these numeric targets were chosen. Several of the targets are expected to be sensitive to the type of channel, especially channel slope and the preceding rainfall patterns. Therefore, the target should be used within an analysis of the preceding hydrological conditions and channel type.

Turbidity

The turbidity data collected in the lower Noyo River by the City of Fort Bragg from 1992 to the present indicate that the turbidity occasionally obscures visibility and remains elevated even once rainfall has ceased. As described in Chapter III (Problem Statement), Matthews (1999) concludes that turbidity values have increased steeply in recent years. No study has yet been conducted by which the natural background levels of turbidity have been determined. Accordingly, it is difficult to determine the degree to which the existing water quality objective for turbidity has been exceeded. To better ensure a thorough evaluation of this matter, the numeric target for turbidity is simply a reiteration of the water quality objective for turbidity, as described in the Basin Plan. Future monitoring for turbidity should be able to assist in identifying tributary watersheds requiring immediate hillslope erosion control.

Percent Fines

McNeil samples were collected at several locations throughout NFAA and HAA, as well as in the Little North Fork Noyo River. Valentine and Jameson (1994) demonstrated a positive curvilinear relationship between coho biomass and percent fines in the Little North Fork. In addition, the Fredle Index calculation predicted a range of 0-80% coho survival-to-emergence as a function of particle size.

Burns (1970) developed substrate composition data for the Little North Fork Noyo River, the South Fork Caspar Creek, and North Fork Caspar Creek prior to second growth logging and road building. In the Little North Fork Noyo River, 27 samples were collected in 1966. In the South Fork Caspar Creek, 20 samples were collected in 1967. In the North Fork Caspar Creek, 100 samples were collected between 1967 and 1969. The mean percentage of particles <0.8 mm in diameter in each year and in each stream ranged from 17.5% (as calculated from data collected in 1967 from North Fork Caspar Creek) to 23.2% (as calculated from data collected in 1969 from North Fork Caspar Creek). The mean of all years and all streams is 19.4%.

Burns (1970) began his study in October 1966 following the second largest annual peak flow in the Noyo River in December 1964 and the fifth largest in January 1966. These flows have recurrence intervals of 24 and 10 years, respectively. With respect to annual runoff, Water Years 1965 and 1969 were the 7^{th} and 11^{th} wettest years of record. With respect to magnitude and duration, Water Years 1965, 1966 and 1969 were the 2^{nd}, 12^{th}, and 16^{th} wettest years of record, respectively. With respect to annual precipitation, Water Year 1969 was wetter than either 1965 or 1966 with a rainfall of 66 inches in Willits (compared to a 50-inch mean) and 51 inches in Fort Bragg (compared to a 39-inch mean). The highest ranked storm of record with respect to 1-day precipitation intensity occurred in Water Year 1965 with 8.8 inches of rain in Willits. Indeed, a quarter of the 20 most intense 1-day precipitation events in Willits occurred in the 1960s, a greater proportion than in any other decade of the 120-year record (Matthews, 1999).

There is uncertainty regarding the degree to which the mean of Burns' pre-logging and control stream data from the 1966 to 1969 represent a reasonable target for the protection of coho salmon today. Indeed, CDF (1994) reports that, in all other studies on this matter, emergence of coho fry was high at < 5% fines but dropped sharply at 15% fines. For this TMDL, a conservative target of 14% fines <0.85 mm is established so as to maximize the potential for coho fry emergence.

Burns' Caspar Creek and Little North Fork Noyo River data appear to represent sediment conditions resulting from unusually inclement weather conditions and elevated sediment delivery. Accordingly, it cannot be used as a mean target level across the range of possible rainfall and flow events. Since it was collected prior to second growth logging activities, however, it provides a realistic snapshot of background conditions resulting from a particular series of events. As such, analysis of substrate composition data in the future should take into account rainfall, flow, and sediment delivery preceding and during data collection. A mean stream reach value that exceeds 14% but not 19% fines < 0.85 mm, for example, might represent adequate water quality if the data were collected following a large storm (e.g., 20-year event) or a series of moderately large storms (e.g., 10-year events).

Cobble Embeddedness

Excessive cobble embeddedness was noted as an issue at several sampling locations in the Noyo River watershed. DFG generally looks for embeddedness measurements of less than 25% as an indicator of unembedded substrate (DFG, 1995 (a) and (b)). Unembedded substrate is necessary for the building of salmonid redds.

Current research appears insufficient to determine the number or area of riffles that must be unembedded to provide adequate potential spawning habitat. As such, the embeddedness target requires an increasing trend in the number of riffle habitat units that are less than 25% embedded.

Pool Frequency/Depth

Habitat data in HAA, NFAA, SFAA, and MAA all indicate that pool frequency and/or pool depth may be factors limiting the success of salmonids. Deep and frequent pools are necessary as summer rearing habitat, particularly for coho salmon, which are less able than steelhead trout to compete for food supplies in the absence of deep pools (Harvey and Nakamoto, 1996).

Flosi and Reynolds (1994, p. V-12) report that:

> "DFG habitat typing data indicate that the better coastal coho streams may have as much as 50 percent of their total habitat length in primary pools. In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at

least half the width of the low-flow channel, and be as long as the low-flow channel width. In third and fourth order streams the criteria is the same, except maximum depth must be at least three feet."

Habitat typing data collected since 1993 indicates that better coho streams in California may rather have about 40 percent of their total habitat length in primary pools (G. Flosi pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). Thus, the numeric target requires that 40% of total habitat length be at least three feet in depth at low flow in third and higher order streams. This target applies in streams with pool/riffle morphology.

Backwater Pools

The availability of overwintering habitat may be an important factor limiting the success of salmonids in the watershed. To the degree that large woody debris is important to the formation of adequate overwintering habitat, such habitat is almost certainly lacking. Specific data, such as abundance of backwater pools, are not currently available. A conservative approach requires that backwater pools be considered a potentially limiting factor until further data can be developed.

Backwater pools are generally formed by boulders, root wads or logs (Flosi and Reynolds, 1994). As these channel roughness elements are removed or buried by sediment, the habitat becomes less diverse, including the loss of backwater pools. Dietrich (1998) identified the condition of the floodplain, particularly with respect to the availability of backwater pools, as critical to the success of coho salmon in California, in a letter to the Regional Water Board commenting on the proposed TMDL for sediment in the Garcia River. There does not appear to have been sufficient research on overwintering habitat, however, to identify a specific number of backwater pools, for example, that is necessary for coho success. Therefore, the numeric target for the Noyo River TMDL is simply an increasing trend in the number of backwater pools per habitat length.

This target will only apply where the channel morphology otherwise supports development of backwater pools. In steep, V-shaped valleys with little floodplain connection, such as found in tributaries in NFAA for example, a significant number of backwater pools would not be expected as a part of the natural array of habitat units. In such regions, the large woody debris and thalweg profile targets are presumed to adequately address the issue of overwintering habitat.

V*

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). A study conducted on over 60 streams representing different levels of disturbance in the North Coast found that a mean V* value of 0.21 (21%) represented good stream conditions (Knopp, 1993). Sample sites for this study were located in Franciscan geology.

The data available in the Noyo River watershed indicate that pool depth and frequency are factors limiting success of salmonids throughout the basin. Chapter V (Source Analysis) indicates that excessive fine sediment is delivered due to surface erosion throughout the basin, as well. The existing V* data include samples in the North Fork of the South Fork Noyo River, Parlin Creek, and Kass Creek. All Noyo River watershed V* data indicate excessive filling of pools by fines.

One of the control streams studied by Knopp (1993) was the North Fork Caspar Creek. The mean V* value in this stream was 0.27. As a general matter, numeric targets developed from local reference streams are preferable to those derived from the literature or from distant reference streams. Accordingly, the numeric target established for V* is 0.27 even though it is higher (29% higher) than the coast-wide mean for control streams.

Large Woody Debris

Large pieces of woody debris in streams influence the physical form of the channel, the movement of sediment, the retention of organic matter and the composition of the biological community (Bilby and Ward, 1989). According to Bilby and Ward (1989) debris can be instrumental in forming and stabilizing gravel bars (Lisle, 1986) or in accumulating fine sediment (Zimmerman et al., 1967; Megahan, 1982). Debris also can form pools by directing or concentrating flow in the stream in such a way that the bank or bed is scoured or by impounding water upstream from the obstruction (Lisle and Kelsey, 1982). Large woody debris plays a more significant role in routing sediment in small streams than in large ones (Bilby and Ward, 1989).

A large woody debris survey is conducted by counting and measuring the number and volume of woody debris pieces that meet certain criteria regarding size, location and orientation and are found within representative reaches of stream. Data collected in the Noyo River watershed indicate that large woody debris is generally lacking throughout the watershed. In the 1960's DFG began an aggressive campaign to remove log jams that were potentially blocking the migration of anadromous fish to upstream spawning grounds. They apparently removed a total of 4,661,688 board feet of woody debris from the Noyo River watershed in the period of 1959 to 1964 (Mendocino Redwood Company, unpublished). Undocumented amounts of large woody debris continued to be removed up through the 1980s (P. Cafferata pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

A comparison of data from the 1960s to that of the 1990s indicates in the North Fork Noyo River, for example, 135 board feet of large woody debris per 100 meters of stream was removed between 1959 and 1964 while somewhere between 0.4 and 14.2 board feet/100 meters exists there now. In Hayworth Creek, 23,512 board feet/100 meter was removed in the period of 1959 to 1964 while no more than 1.8 board feet/100 meters exists now.

Large woody debris, like sediment, is delivered to a stream and transported through the system. It either moves through the channel network, decays in place, or moves intermittently in and out of short and/or long-term storage on the floodplain or in the stream channel until it decays. Its routing is much more difficult to predict than sediment because of the immense variation in size and composition. The degree to which large woody debris influences sediment routing, however, makes it an important factor.

The numeric target for large woody debris calls for an increase in the number and volume of key large woody debris pieces in those locations where the lack of large woody debris is currently limiting salmonid success. The definition of a key piece of large woody debris is based on the debris' diameter and length, but varies by stream width.

Thalweg Profile
The thalweg profile is a profile, measured parallel to stream flow, of the lowest elevation of each of many channel cross sections. As a stream descends from its headwaters to its mouth, the mean thalweg profile slope also descends. As the number of pieces and volume of large woody debris increases as well as the number and depth of pools, the thalweg profile develops more dramatic variation around the mean profile slope, which generally indicates better habitat conditions.

The availability of large woody debris and deep pools appear to be two of the main factors limiting the success of salmonids in the Noyo River watershed. The techniques proposed by the Forest, Fish and Farm Committee at its 1999 Workshop ("Using Stream Geomorphic Characteristics as a Long-term Monitoring Tool to Assess Watershed Function) include the measurement of the channel thalweg to determine the variation around the mean thalweg profile slope. Not enough research appears to have been conducted to establish a specific number that reflects a satisfactory degree of variation. Therefore, the numeric target is simply an increasing trend in variation from the mean thalweg profile slope.

Stream Diversion Potential and Stream Crossing Failures
Truck roads, skid roads, and railroad roads generally cross ephemeral or perennial streams. Stream crossing structures are built to capture the stream flow and safely convey it through or around the roadbed. The Forest Practice Rules (CDF, 1997) require that: (1) the number of watercourse crossings be minimized; (2) crossing structures allow for unrestricted passage of fish, where fish are present; (3) crossings be constructed or maintained to prevent the diversion of stream overflow down the road; (4) crossings be constructed to allow a 50-year flood event pass; and (5) trash racks be installed to prevent debris from reducing the flow capacity of the crossing structure.

There is no existing data in the Noyo River watershed regarding the current rate of stream diversions or stream crossing failures or the contributions of sediment to the watercourse from these processes. In other North Coast basins (Rolling Brook, a tributary of the Garcia River, and Redwood Creek in Redwood National Park), sediment from stream diversions and other sources associated with haul road and skid trail crossings have been estimated to contribute from 25-38% of the overall sediment budget. As such, this sediment process is likely to be a significant component of the Noyo River watershed sediment budget as well.

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. As described in the South Fork Trinity TMDL (EPA, 1998), the potential delivery of sediment to a watercourse can be eliminated from almost all potential road diversions by identifying and correcting sites with diversion potential. Correction measures include eliminating inboard ditches, outsloping roads, and/or installing rolling dips at crossings. No more than 1% of potential road diversion sites are expected to be either physically impossible to correct or of such a nature that their correction would make the road unsafe for travel.

Stream crossing failures are generally related to undersized, poorly placed, plugged or partially plugged culverts. When a culvert fails, the sediment associated with the crossing is delivered directly into the watercourse. Indeed, in most crossing failures, the total sediment volume delivered is the volume of road fill associated with the crossing as well as sediment from collateral failures such as debris torrents that scour the channel and stream banks (EPA, 1998). The Forest Practices Act requires that road crossings be designed to pass a 50-year flood and be protected from damage by debris with trash racks. Given the large percentage of seasonal roads in the Noyo River watershed, however, maintenance of culverts and trash racks following storm events is likely to be irregular. The target, therefore, is being established based on the 100-year flood. No more than 1% of all culverts are expected to fail as a result of a 100-year flood or less, if all the culverts are properly sized, installed, and maintained. Only those crossings where modification would endanger travelers, or where there are other physical constraints, should fall within this 1%.

Hydrologic Connectivity
Increased flows result in increased suspended sediment discharge and can result in the destabilization of the stream channel's armor layer (Lewis, 1998; Ziemer, 1998). A decrease in a stream channel's armor layer, particularly during early spring flows, can have a devastating effect on salmonid redds and growing embryos (Lisle, 1989).

Stream flows are increased as a result of logging, in part, because of the *de facto* increase in the channel network that often accompanies the construction of roads, particularly those with inboard ditches. Water that on a naturally graded hillside would be either intercepted by tree cover or infiltrate through the duff and into groundwater, instead hits an inboard ditch to become surface water delivered directly to a watercourse. Groundwater is also intercepted by inboard ditches.

The reduction of road densities and the reconstruction of roads (including the railroad) to reduce the miles of inboard ditches, for example, can reduce the amount of water that is directly delivered to watercourses, including any associated sediment load. Current research appears insufficient to identify a specific number of miles of road or road with inboard ditch that would adequately prevent excessive stream flows and sediment discharge. Accordingly, the target calls for a reduction in the hydrologic connectivity of roads to watercourses.

Disturbed Area
Studies in Caspar Creek (Lewis, 1998) indicate that the disturbed area in the South Fork Caspar Creek is 15% while that in the North Fork is 3.2%. There is a statistically significant relationship between the difference in the disturbed areas and the corresponding suspended sediment discharge rate (Lewis, 1998; J. Lewis pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). In addition, studies in Caspar Creek indicate that clearcutting causes greater increases in peak flows (and by extension suspended sediment loads) than does selective harvest (Ziemer, 1998). As with the "hydrologic connectivity" target above, increases in peak flows, annual flows, and suspended sediment discharge rates negatively affect the potential survivability of ova in redds (Lisle, 1989).

The available information is insufficient to identify a threshold below which effects (such as increases in peak flows, annual flows and suspended sediment discharge) on the Noyo River watershed would be insignificant. Accordingly, the target calls for a reduction in the amount of disturbed area. With respect to this target, "disturbed area" is defined as the area covered by management-related facilities of any sort, including: roads, landings, skid trails, firelines, harvest areas, animal holding pens, and agricultural fields (e.g., pastures, vineyards, orchards, row crops, etc). The definition of a facility is intentionally made broad to include managed agricultural areas, such as pastures and harvest areas, where the management activity (e.g., logging or grazing) results in substantially enough removal of vegetation to significantly reduce important rainfall interception and soil protection functions. Agricultural fields or harvest areas in which adequate vegetation is retained to perform these ecological functions can be excluded from consideration as "facilities." Dramatic reductions in the amount of disturbed area, then, can be made by reducing road densities, skid trail densities, clearcut areas, and other management-induced bare areas.

Activity in Unstable Areas

Unstable areas are those areas that have a high risk of landsliding and include: steep slopes, inner gorges, headwall swales, stream banks, existing landslides, and other locations identified in the field. Because of the high risk of landsliding inherent in these features, any activity that might trigger an erosional event should be kept to a minimum. Such activities include: road building, harvesting, yarding, terracing for vineyards, etc.

Dietrich et al. (1998) validated the SHALSTAB model[2] using data collected in the Noyo River watershed and elsewhere. The model predicts areas of chronic landsliding based on the ratio of effective precipitation to soil transmissivity (q/T). The data indicate that landslides in the Noyo River watershed observed on aerial photographs largely coincide with predicted chronic risk areas. Chronic risk areas include steep slopes, inner gorges and headwall swales, as well as other locations.

Weaver and Hagans (1994) suggest methods for eliminating or decreasing the potential for road-related sediment delivery. They recommend avoiding construction of roads in unstable areas unless construction involves professional geotechnical assistance. Studies in the lower Eel River basin suggest that landslides in recently harvested second growth areas underlain by Franciscan geology are larger and more common than those in areas of unharvested second growth (PWA, 1998). In Redwood Creek basin, Pitlick (1982) found that slides in harvested inner gorge areas were no more common but were much larger than those in uncut inner gorge slopes. Thus, the target calls for avoidance of unstable areas, unless the activity involves professional geotechnical assistance.

---

[2] SHALSTAB is a coupled, steady-state runoff and infinite-slope stability model that can be used to map the relative potential for shallow landsliding across a landscape. Dietrich, et al., 1998 state that shallow landslides are a major source of sediment delivered to streams. Individual landslides may mobilize in the form of a debris flow, and subsequently travel several kilometers downstream, scouring stream channels of all sediment and wood, then depositing it in a large accumulation when the debris flow comes to rest in a low gradient channel.

CHAPTER V
SOURCE ANALYSIS

The Source Analysis provides an assessment of the sources of sediment to the Noyo River watershed that may be contributing to the impairment of aquatic habitat and salmonid success. It includes a history of land use in the watershed with respect to increased erosion and elevated sediment delivery. It also includes an assessment of landsliding, surface erosion, fluvial erosion, and changes to in-channel stored sediment over time. This is given in the form of a sediment budget, including supporting discussion.

V.A. LAND USE HISTORY

Early Industrial Activity

The first industrial activity on the Noyo River watershed began with the development of the Richardson-Hegenmeyer water-powered sawmill in 1853. The mill was washed out by a spring freshet the following year. However, the lower Noyo River mainstem still has the remnants of several mid-channel booms which were erected to assist in the floating of logs down the river to the mill (Stebbins, 1986).

A second sawmill was built on the Noyo River in 1858. By 1880, it was estimated that the mill owners had cut about 5,700 acres of timber land to supply the mill, producing approximately 120,000,000 board feet of lumber in that time (Stebbins, 1986). As with the Richardson-Hegenmeyer mill, logs reached this second mill via transport down the Noyo River. The history is unclear, but splash dams may have occasionally been used to assist in river transportation (M. Jameson pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

In 1885, the Fort Bragg Lumber Company was formed and included the purchase of property on the Noyo River, as well as the site of Fort Bragg itself. Relying exclusively on ships for the transport of logs to market, the Fort Bragg Lumber Company formed the Fort Bragg Railroad (the precursor to the current-day Skunk Train) in hopes of improving transportation (Crump, 1998). In 1893, the Fort Bragg Lumber Company incorporated with White and Plummer, a partnership owning substantial stands of redwoods, to form the Union Lumber Company. Production increased substantially (Crump, 1998).

By 1930, more than half of the Noyo River watershed had been logged, with yarding conducted in the watercourse channels. During the 1960s, logging of second-growth began, primarily in the lower main drainage area. The harvesting of second growth continues today. Removal of residual old-growth stands began in the 1960s and continued into the mid-1980s (M. Jameson pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999).

Modern Industrial Activity

Today, the Noyo River watershed is primarily owned by three large land owners: Mendocino Redwood Company, The Timber Company, and the State of California (Jackson Demonstration

State Forest). Property now owned by Mendocino Redwood Company was previously owned by Louisiana-Pacific Corporation, and The Timber Company was previously known as Georgia-Pacific Corporation and Rex Timber Company. Together the three major land owners own approximately 70% of the basin (Jones & Stokes, 1997; Mendocino Redwood Company, unpublished; P. Caferrata pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). The predominant land use in the Noyo River watershed is timber production and harvest.

Since 1986, the Department of Forestry and Fire Protection has been digitizing Timber Harvest Plans (THP), submitted and approved in the Noyo River watershed, into a Geographic Information System (GIS). Among other data, included in the GIS are: landowner, road location and type, hydrography, topography, harvest location and type, and yarding type. Below is a summary of these data. The GIS does not distinguish between harvest activities that were permitted and those that actually occurred. That is, THPs may have been submitted that were never implemented or were implemented only in part. Similarly, the data contained in the GIS do not indicate the degree to which approved THPs were faithfully implemented. For the purpose of this assessment, however, all permitted activities are assumed to have occurred in the year and in the manner in which they were permitted.

Timber Harvest Activity

THPs approved by CDF from 1986 through 1998 allowed for timber harvest activity on 44,764 acres of a 72,323-acre basin (62%). Harvest activity occurred on:

- 54% of the Headwaters Assessment Area;
- 76% of the North Fork Noyo River Assessment Area;
- 64% of the South Fork Noyo River Assessment Area; and
- 56% of the Mainstem Noyo River Assessment Area.

Rates in individual sub-basins, however, are higher. For example, the rate of harvest in the Little North Fork Noyo River, a tributary in the Mainstem Noyo River Assessment Area, was approximately 229% from 1964 to 1993 (Valentine and Jameson, 1994). This means that 29% of this 2,443-acre tributary sub-basin was harvested three times in 28 years, while the rest was harvested twice. Thus, impacts in the Little North Fork Noyo River are likely to be even greater than would be assumed by an average harvest rate since 1986 in MAA of 56%.

As depicted in Table 9, the five largest landowners conducted 83% of the timber harvest activity from 1986 through 1998:

- Mendocino Redwood Company (formerly Louisiana-Pacific Corporation)-- 30%;
- The Timber Company (formerly Georgia-Pacific Corporation and Rex Timber Company)-- 28%;
- The State of California at Jackson Demonstration State Forest-- 17%;
- Congaree River, Ltd.-- 5%; and
- Barnum Timber-- 3%.

Table 9: Summary of the Logging Activity Permitted by Timber Harvest Plans Submitted to the California Department of Forestry and Fire Protection by the Five Largest Landowners/Managers from 1986-1998 in the Noyo River Watershed

LANDOWNER	HEADWATERS		NORTH FORK NOYO		SOUTH FORK NOYO		MAINSTEM NOYO		TOTAL	
	ACRES	%	ACRES	%	ACRES	%	ACRES	%	ACRES	%
Barnum Timber	0	0	1243	10	0	0	0	0	1242	3
Congaree River Ltd.	2381	25	10	0	0	0	0	0	2391	5
Georgia-Pacific Corp./ The Timber Company	0	0	0	0	2206	20	5969	49.48	8174	18
Louisiana-Pacific Corp./ Mendocino Redwood Co.	2938	31	9770	80	209	2	515	4.27	13431	30
Rex Timber Company/ The Timber Company	0	0	0	0	505	5	4170	34.56	4674	10
State of California-- JDSF	0	0	0	0	7862	70	0	0.00	7862	17
TOTAL HARVEST	9466	100	12236	100	11191	100	12063	100.00	44956	100
TOTAL ACRES AND PERCENT ACRES HARVESTED	17390	54	16045	76	17574	64	21314	55.81	72323	62

Table 10 shows the number of acres of property permitted for harvest in each assessment area and the percentage of the harvest conducted by each of the silivicultural methods described in the Forest Practices Act. These are categorized, following the categories contained in the Forest Practices Act, as: evenaged management, unevenaged management, intermediate treatments, special prescriptions, and alternative prescriptions. Several points can be noted from Table 10.

- In HAA, silvicultural methods practiced are generally divided among evenaged methods (38%), unevenaged methods (28%), and alternative prescriptions (27%).
- In NFAA, evenaged management is the predominant series of methods practiced (61%) with the subdominant methods including unevenaged methods (19%) and alternative prescriptions (13%).
- In SFAA, unevenaged management is the predominant series of methods practiced (47%) with evenaged management as the subdominant series of methods (31%).
- In MAA, evenaged management is the predominant series of methods practiced (60%) with unevenaged management as the subdominant series of methods (35%).

Yarding Activity

Table 11 shows the yarding methods used per area and per year in the Noyo River watershed. According to CDF's GIS, tractor yarding is the predominant yarding method used in the Noyo River watershed. It accounts for 66% of the yarding conducted since 1986. Further, tractor yarding accounts for the majority of yarding conducted in each of the assessment areas except the SFAA. It accounts for 75% of the yarding in HAA, 83% in NFAA, and 64% in MAA.

Cable yarding methods have been used in the SFAA and MAA since 1986. This method of yarding accounts for 56% of the yarding in the SFAA and 36% in the MAA since 1986. Cable yarding accounts for 32% of the yarding conducted in the watershed, overall.

Table 10: Summary of Silvicultural Practices used in the Noyo River Watershed as Derived from Timber Harvest Plans Submitted to the Department of Forestry and Fire Protection from 1986 to 1998

Silvicultural Managemen t	Prescription	HAA		NFAA		SFAA		MAA	
		Acres	% of total	Acres	% of total	Acres	% of total	Acres	% of total
Evenage	Clearcut	78	1	573	5	1,496	13	4,158	35
	Shelterwood	3,245	34	6,035	64	1,379	12	2,878	34
	Seed Tree	287	3	421	3	558	5	698	6
	SUBTOTAL	**3,610**	**38**	**7,029**	**61**	**3,432**	**31**	**7,734**	**60**
Unevenage	Selection	2,422	26	1,777	15	3,790	34	3,608	22
	Transition	235	2	378	3	1,497	14	952	8
	SUBTOTAL	**2,658**	**28**	**2,155**	**19**	**5,287**	**47**	**4,560**	**35**
Intermediat e	Commercial Thinning	289	3	308	3	2,030	18	285	2
	Sanitation Salvage	45	0	194	2	3	0	0	0
	SUBTOTAL	**334**	**4**	**502**	**4**	**2,033**	**18**	**285**	**2**
Special	Rehabilitation	314	3	463	4	0	0	0	0
	SUBTOTAL	**314**	**3**	**463**	**4**	**0**	**0**	**0**	**0**
Alternative	Alternative	2,551	27	1,449	12	438	4	340	3
	SUBTOTAL	**2,551**	**27**	**1,449**	**13**	**439**	**4**	**340**	**3**
Grand Total		9,466	100	11,599	100	11,191	100	12,919	100

Table 11: Summary of Yarding Statistics for Timber Harvest Activity in the Noyo River Watershed as Compiled from Timber Harvest Plans Submitted to the California Department of Forestry and Fire Protection from 1986-1998

Assessment Area	Logged Area Yarded by Tractor		Logged Area Yarded by Cable Skyline		Logged Area Yarded by Helicopter		Total Logged Area
	Acres	% of logged area yarded by tractor	Acres	% of logged area yarded by cable	Acres	% of logged area yarded by helicopter	Acres
HAA	7141	75	1550	16	775	8	9466
NFAA	10072	83	2052	17	75	1	12199
SFAA	4667	42	6313	56	212	2	11191
MAA	7623	64	4295	36	0	0	11919
Total	29503	66	14209	32	1063	2	44774

Helicopter yarding was first used in the Noyo River watershed by Louisiana-Pacific Corporation in 1994. Several other operations have since used helicopter yarding in the NFAA and SFAA. In all, 1,062 acres (or 2% of the area logged) were yarded by helicopter in the period between 1986 and 1998.

The relationship between yarding technique and sediment delivery is well established. As described in Chapter III (Problem Statement), there is a statistically significant, positive relationship between ground disturbance and suspended sediment (Lewis, 1998; J. Lewis pers.

comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). Further, it is clear that cable yarding substantially reduces the risk of immediate landsliding as well as post-harvest landsliding, compared to tractor yarding (Cafferata and Spittler, 1998). Thus, it can be generally concluded that tractor yarding causes the most ground disturbance and sediment delivery while cable and helicopter yarding cause the least. Accordingly, reductions in sediment delivery due to yarding are best accomplished by altering current management practices in favor of greater use of cable and helicopter yarding.

Roads
Table 12 shows the density and classification of roads proposed for use in timber harvest operations permitted since 1986. Aerial photographs going back to 1942, where available, were used to estimate the miles of road added in each period up to the present. The calculated road densities are similar to those estimated using aerial photographs. The analysis of aerial photographs resulted in estimates for HAA, NFAA, SFAA, and MAA that differ from CDF's GIS estimates by –0.1%, -9.3%, +0.3%, and +5.1%, respectively, so the amount of roads may be underestimated or overestimated by five to ten percent.

Table 12: Summary of Road Length and Density Data Derived from Timber Harvest Plans Submitted to the Department of Forestry and Fire Protection From 1986-1998

ROAD TYPE	HEADWATERS SUB-BASIN (27.17 mi^2)		NORTH FORK NOYO SUB-BASIN (25.07 mi^2)		SOUTH FORK NOYO SUB-BASIN (27.46 mi^2)		MAINSTEM NOYO SUB-BASIN (33.30 mi^2)		NOYO RIVER WATERSHED (113.00 mi^2)	
	Length (mi)	Density (mi/mi^2)	Length (mi)	Density (mi/mi^2)	Length (mi)	Density (mi/mi^2)	Length (mi)	Density (mi/mi^2)	Length (mi)	Density (mi/mi^2)
Primary route	0	0	0	0	0	0	0	0	0	0
Secondary route	2	0	0	0	11	0	11	0	24	0
Existing permanent	13	1	11	0	19	1	57	2	101	1
Existing seasonal	115	4	147	6	96	3	184	6	542	5
Existing temporary	12	0	7	0	6	0	1	0	26	0
Proposed permanent	0	0	0	0	0	0	0	0	0	0
Proposed seasonal	14	1	18	1	26	1	2	0	59	1
Proposed temporary	0		0	0	5	0	0	0	5	0
Bridge	0		0	0	0	0	0	0	0	0
Abandoned seasonal	0		1	0	0	0	0	0	1	0
TOTAL	156	6	184	7	163	6	255	8	758	7

According to CDF's GIS, the road density is highest in MAA at 7.67 mi/mi^2. The lowest road density is found in HAA with 5.74 mi/mi^2. The average road density for the watershed overall is 6.71 mi/mi^2. Road densities in individual tributary basins, however, are higher. For example, the road density in the lower portion of the South Fork Noyo River is 10.04 mi/mi^2; and it is 9.97 mi/mi^2 in the Little North Fork Noyo River (Matthews, 1999).

According to CDF's GIS, the roads are classified as per the Forest Practices Act as permanent, seasonal, or temporary. CDF's data indicate that the majority (72%) of recently used roads (since 1986) were classified in individual THPs as "existing seasonal roads." Only 13% of the miles of road contained in THPs were classified as "existing permanent roads." Less than 0.01% of the roads were classified as "proposed permanent roads" while more than 8% were classified as either "proposed seasonal roads" or "proposed temporary roads." Only 0.2% of the roads were identified for abandonment.

Road density and road classification adds fundamental information regarding the potential for sediment delivery from roads.

- The higher the road density, the higher the ground disturbance, and therefore the higher the potential management-related sediment delivery (Lewis, 1998).
- Permanent roads are theoretically designed for all-season use and theoretically receive regular wet-weather maintenance. Seasonal roads are designed primarily for non-wet weather use and do not receive regular winter maintenance. Both permanent and seasonal roads are intended to have watercourse crossings capable of passing a fifty-year flood event. However, because of the difference in maintenance, the failure of a watercourse crossing on a seasonal road is more likely to go unchecked than one on a permanent road.
- Permanent roads are more likely to be surfaced than a seasonal road and therefore theoretically contribute less sediment from the road surface, as long as the surfacing is well designed.

The Regional Water Board was provided road-related data regarding hillslope and proximity to Class I streams (S. Lang pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). Based on their review of available data and information Regional Water Board staff (1999) identified several sediment-related factors.

- Roads on steep or convergent hillslopes are more likely to fail and/or deliver sediment than those on ridge tops or above wide, flat riparian zones.
- Streamside roads are more likely to deliver sediment generated by road-related causes than those outside a riparian buffer.
- Roads with well-placed rolling dips are less likely then those with numerous culverts (particularly if they are undersized or prone to blockage by debris) to divert streams and deliver eroded road fill.
- Roads with well-engineered outsloping are less likely than those with miles of inside ditch and waterbars to deliver eroded fill and elevated flow.

Several conclusions regarding roads in the Noyo River watershed are appropriate.

- The road densities indicate a substantial degree of ground disturbance within individual sub-basins, within individual assessment areas, and throughout the Noyo River watershed overall.
- The density of seasonal roads (which is substantially greater than that of permanent or temporary roads) indicates a significant potential for minimally maintained crossings and other road-related facilities. This suggests the possibility of failed crossings that go unfixed

for some period. Further, as a general matter, unsurfaced roads have a greater potential for surface erosion than do surfaced ones.

- The lack of any significant road abandonment since 1986 indicates the potential for numerous old or poorly built, unused roads to chronically deliver sediment.

Public Transportation Routes

Several public transportation routes exist within the Noyo River watershed. Highway 1 crosses the Noyo River at its estuary. Highway 20 follows the ridgetop at the Noyo River's headwaters before crossing into the Big River watershed and then back into the Noyo River watershed along the South Fork Noyo River. Other major and minor county roads also exist. The California Western Railroad operates the Skunk Trains from Willits to Fort Bragg following the Noyo River mainstem.

Public Roads

The Highway 1 bridge may introduce various issues with respect to sediment transport through the Noyo River watershed. Bridge abutments often serve to constrict a river channel causing flooding upstream and channel erosion downstream. At this time, however, the specific effects of Highway 1 are not known.

Highway 20 crosses from the Noyo River watershed into the Big River watershed and back before intersecting Highway 1 at the coast. In the Noyo River watershed headwaters, Highway 20 runs primarily along the ridgetop and is not expected to contribute significantly to the problem of sedimentation. Where it returns from the Big River watershed to the Noyo River watershed along the South Fork Noyo River, however, Highway 20, like any road in the watershed, may have the potential to contribute sediment via failed stream crossings, the downcutting of inside ditches, water diversions onto fill or unstable soils, etc. These potential issues may also face the various minor and major county roads in the watershed, as well.

Skunk Train

Laying the tracks for what is now known as the Skunk Train began in the 1880s and was completed in 1911 (Crump, 1998). The tracks begin at the Fort Bragg railroad depot just south of Pudding Creek, follow lower Pudding Creek, and then travel a tunnel through a mountain dividing the Pudding Creek drainage from the Noyo River drainage. Most of the length of the track follows the Noyo River mainstem corridor, until a second tunnel that delivers the train to Willits.

Forty miles of track were laid to reach a destination of only 22 airline miles (Crump, 1998). It originally required 113 bridges and trestles as it crossed back and forth over the river channel. That number has been reduced to 31 bridges and trestles at present (M. Scribner pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). Landsliding associated with the railroad steadily increased from 1933 to 1957 when it was the largest cause of management-related landsliding. By 1996, the aerial photographs show no landslides specifically related to the railroad (Matthews, 1999).

Current maintenance primarily calls for the replacement of culverts and repair of damage due to gullies and chronic landslides.

V.B. SEDIMENT BUDGET

Graham Matthews and Associates conducted a desk-top analysis, during the spring of 1999, of sediment delivery and transport in the Noyo River watershed. They estimated the inputs of sediment to streams in the Noyo River watershed and they estimated the output of sediment from the Noyo River to the Pacific Ocean. They prepared a sediment budget by comparing the sediment inputs and outputs. The results of their study are reported in *Sediment Source Analysis and Preliminary Sediment Budget for the Noyo River* (1999).

Matthews (1999) evaluated landsliding throughout the watershed using 1:24,000 scale aerial photographs for the years: 1942, 1952, 1957, 1963, 1965, 1978, 1988, 1996, and 1999[3]. Complete photo sets for 1942, 1952, 1957 and 1999 were not available for every region of the watershed. The 1942 aerial photos were assumed to give a snapshot of landscape events occurring over a 10-year period (i.e., back to 1933). For each additional photo year, only new features (i.e., those not seen on the previous year's photo) were tabulated. The following are the time periods evaluated via aerial photographic analysis: 1933-1942, 1943-1952, 1953-1957, 1958-1963, 1964-1965, 1966-1978, 1979-1988, 1989-1996, 1997-1999.

Surface erosion was estimated for roads and skid trails based on road/skid trail density and use patterns. Streamside fluvial erosion was estimated using data collected by Mendocino Redwood Company on its property in the upper watershed. Background surface erosion was estimated using regional figures described by CDF for Jackson Demonstration State Forest (P. Caferrata, pers. comm. w/ A. Mangelsdorf as reported in Regional Water Board, 1999). Fluvial erosion related to roads, skid trails and harvesting were not estimated due to the lack of information.

Table 13 summarizes the sediment budget prepared by Matthews (1999). Conceptually, the sediment budget can be described as:

Sediment Inputs - Sediment Outputs = Change in Storage.

In this case, the sediment budget indicates that sediment inputs are 40% less than sediment outputs, which would lead to the conclusion that there has been a net decrease in the amount of sediment stored within the streams of the Noyo River watershed. However, as described in Chapter III (Problem Statement), from 1957 to present the lower Noyo River appears to have aggraded one and a half to two feet. Thus, rather than representing an overall sediment deficit, the discrepancy between inputs and outputs is more likely an artifact of the uncertainty in the analyses and time lags from sediment delivery to transport through the system. Indeed, with desk-top analytical tools that tend to under-estimate sediment inputs and over-estimate sediment outputs, such a discrepancy is to be expected.

---

[3] Only landslides greater than 75 feet in width or length were evaluated due to the photo scale used. Landslides were associated with harvest units, roads, the railroad, or natural forest based on the judgement of the analyst.

The sediment inputs determined by Matthews probably underestimate actual sediment delivery (Matthews, 1999). This is because of the scale of aerial photos used, the lack of data or desk-top tools with which to evaluate fluvial erosion rates and changes in channel storage, and the lack of time for field verification. Nonetheless, this is the best available data with which to assess sediment inputs and develop load allocations.

Table 14 includes estimates for sediment inputs to the Noyo River watershed in nine time periods from 1933 through 1999 as described above. It includes estimates of sediment outputs for those periods, as well. Sediment inputs are divided into the following categories:

- Mass wasting;
- Background surface erosion;
- Surface erosion from skid trails;
- Surface erosion from roads;
- Bank erosion; and
- Changes in channel storage.

The estimate of mass wasting is a compilation of the estimates of mass wasting due to natural causes, harvest units, roads, and the railroad. Table 14 segregates the estimates into these finer categories. Bank erosion is estimated at 200 tons/mi^2/yr. This is likely an over-estimate, but it is based on reasonably good data collected by the Mendocino Redwood Company and is the best available information. The 200 tons/mi^2/yr rate is not applied to the length of the Noyo River mainstem where limited field observations indicate little streamside mass wasting occurs (Matthews, 1999). Changes in channel storage are estimated based on analysis of historic removal of large woody debris. The estimate does not include consideration of other means by which channel storage is altered over time. Again, this is due to the lack of available information regarding other changes in channel storage.

In general, sediment input can be calculated as:

$$\text{Sediment Input} = MW + SE_B + SE_{ST} + SE_R + BE + STOR$$

where: MW = mass wasting, SE_B = background surface erosion, SE_{ST} = surface erosion from skid trails, SE_R = surface erosion from roads, BE = bank erosion, and STOR = changes in channel stored sediment.

Using data displayed in Table 13 for the Noyo River watershed for the period 1933 to 1999:

mass wasting = 1,276,800 tons,
background surface erosion = 567,900 tons,
surface erosion from skid trails = 114,900 tons,
surface erosion from roads = 836,100 tons,
bank erosion = 1,515,000 tons, and
changes in storage = 146,000 tons.

TABLE 13

NOYO RIVER WATERSHED SEDIMENT SOURCE ANALYSIS

Preliminary Sediment Budget

PERIOD YEAR	INPUTS							OUTPUTS	
	MASS WASTING (tons)	SURFACE EROSION BACKGROUND (tons)	SURFACE EROSION SKID ROADS (tons)	SURFACE EROSION ROAD (tons)	FLUVIAL EROSION BANK EROSION (tons)	CHANGE IN STORAGE (tons)	TOTAL INPUTS (tons)	OUTFLOW SSL AND BL (tons)	YIELD (tons/mi2/yr)
1933-1942	220,000	84,800	500	27,500	226,000		558,000	1,080,000	955
1943-1952	52,600	84,800	4,600	31,300	226,000		399,000	695,000	615
1953-1957	148,000	42,400	10,900	40,500	113,000	+30000	385,000	824,000	1458
1958-1963	243,000	50,900	21,500	66,900	136,000	+36000	554,000	508,000	749
1964-1965	116,000	17,000	15,200	22,300	45,200	+12000	228,000	643,000	2845
1966-1978	61,200	110,000	24,100	233,000	294,000	+78000	800,000	1,880,000	1283
1979-1988	356,000	84,800	13,900	178,000	226,000		858,000	984,000	871
1989-1996	56,300	67,800	16,900	172,000	181,000		494,000	797,000	882
1997-1999	23,700	25,400	7,300	64,600	67,800		189,000		
TOTAL	1,276,800	567,900	114,900	836,100	1,515,000	-	4,465,000	7,411,000	Mean Yield 979

Notes:

-- All values rounded to three significant figures

-- Mass Wasting derived from landslides mapped from aerial photographs taken at the end of each budget period Certain areas were not covered by the phtograpgs in 1942, 1952, 1957, and 1999. See text for details.

-- Background rates (containing creep, surface erosion by sheetwash and rilling, and deep-seated landslide components) based on work of Roberts and Church (1986) and Cafferata/Stillwater Sciences (pers. Comm. 1999).

-- Skid roads based on measured harvest areas on the 1942, 1957, 1965, and 1978 aerial photographs, delineated into 3 classes of skid road density. Harvest areas after 1986 are computed from GIS coverages developed by CDF.

-- Road erosion computed from measured road miles in 1942, 1952, 1957, 1965, 1978 aerial photographs, and 1985 USGS topographic maps. Roads after 1985 are based on GIS coverage developed from THP submitted to CDF.

-- Bank erosion is based on a rate of 200 tons/mi2/yr, and includes bank erosion and small streamside mass movements generally under the canopy and not visible on aerial photography. Adjusted from data by MRC (C. Surfleet, pers. Comm 1999) and USDA (1972).

-- Change in storage represents estimates of loss of storage through LWD removal between 1950-1980. Rate of 100 tons/mi2 based on calculations by Cafferata/Stillwater Sciences (pers. comm. 1999).

-- Sediment Outflow computed from regional suspended sediment and bedload transport equations developed as described in the text and applied to the USGS gage#11468500 for the period 1952-1997. Pre-1952 values based on correlation with annual precipitation.

Table 14: Summary of Sediment Inputs to the Noyo River Watershed as Derived from Data Presented by Matthews (1999)

Time period	Background Sediment Delivery (tons/mi²/yr)			Management-related Sediment Delivery (tons/mi²/yr)						Total (tons/mi²/yr)
	Mass wasting	Surface erosion	Stream bank erosion*	Mass wasting--Railroad	Mass wasting--Harvest	Mass wasting--Roads	Surface erosion--Roads	Surface erosion--Skid trails	Fluvial erosion--Roads	
HAA (27.17 mi²)										
1933-1957	24	75		0	2	0	41	18	unknown	160+
1958-1978	67	75		8	25	83	156	46	unknown	460+
1979-1999	140	75		9	8	106	162	17	unknown	517+
NFAA (25.07 mi²)										
1933-1957	6	75		0	0	6	11	1	unknown	99+
1958-1978	145	75		0	35	78	142	55	unknown	530+
1979-1999	157	75		0	5	106	182	21	unknown	546+
SFAA (27.46 mi²)										
1933-1957	305	75		13	9	14	74	3	unknown	493+
1958-1978	94	75		7	2	19	132	5	unknown	334+
1979-1999	98	75		0	5	18	148	13	unknown	357+
MAA (33.3 mi²)										
1933-1957	46	75		157	0	2	17	2	unknown	299+
1958-1978	40	75		100	0	37	118	4	unknown	374+
1979-1999	22	75		12	53	76	201	13	unknown	452+
NOYO RIVER WATERSHED										
1933-1957	95	75	200	49	3	5	35	6	unknown	468+
1958-1978	83	75	200	33	14	53	136	26	unknown	620+
1979-1999	99	75	200	6	20	76	175	16	unknown	667+
1933-1999	91	75	200	31	12	42	111	15	unknown	577+

*Stream bank erosion was estimated by applying a regional figure to all but about 30% of Noyo River watershed stream miles. The 30% excluded from the calculation represent the Noyo River itself that from limited observation appears to have relatively stable banks. The calculation was not broken down by assessment area. As such, the total sediment delivery for each assessment area does not include streambank erosion and is therefore underestimated. The total estimates of sediment delivery per assessment area and for the whole watershed are also lacking figures for fluvial erosion from roads. For this reason, too, the calculation results are underestimates.

** Any discrepancies between Table 13 and Table 14 are the result of rounding numbers up and down.

Thus, the total loading can be calculated as:

Sediment Input (tons) = 1,276,800 + 567,900 + 114,900 + 836,100 + 1,515,000 + 146,000 = 4,456,700.

The average sediment loading over the 67 year period from 1933 to 1999 and over the 113 mi^2 watershed can be calculated as:

Sediment Input ($tons/mi^2/yr$) = (4,456,700 tons)/(113 mi^2)/67 years = 589.

Table 14 summarizes the assessment of sources of sediment to the Noyo River watershed over a period of 67 years from 1933 to 1999. The 67-year period of study has been divided into three periods: 1933-1957, 1958-1978, and 1979-1999. The period of 1933-1957 includes a quiescent period between the logging of old growth at the turn of the century and logging of second growth in the middle of the 20th century. The period of 1958-1978 includes an intensive period of second growth logging, prior to the enactment and implementation of the California Forest Practices Act. The period of 1979-1999 includes an intensive period of second growth logging, conducted under the California Forest Practices Act.

Sediment input data have been evaluated for each assessment area. Sediment delivery rates have been compared between time periods. In addition, the rate of change in sediment delivery within a specific time period is used to compare the various source categories, because the aerial photo sets for the various assessment areas are incomplete for some time periods. Land management-related fluvial erosion was not evaluated because of the lack of existing data.

Headwaters Assessment Area

With respect to landslides, the data show that the rate of sediment delivery from background sources increased from the 1933-1957 period to the 1958-1978 period by 179% and then from the 1958-1978 period to the 1979-1999 period by 109%. By comparing the rate of change in management-related categories of sediment delivery to the rate of change in background sediment delivery, we can make several observations regarding management influence with respect to landsliding in HAA.

- The rate of sediment delivery due to the activities of the railroad also increased through these periods. The increase in the rate of sediment delivery from the 1958-1978 period to the 1979-1999 period, however, is only an eighth of the rate of increase in background sources.
- The rate of sediment delivery from harvest sites increased from the 1933-1957 period to the 1958-1978 period by 1150% or almost 6 times the background rate. However, harvest-related sediment delivery decreased from the 1958-1978 period to the 1979-1999 period by 68% at the same time that the background rate increased by 109%.
- The rate of sediment delivery from landslides associated with roads also increased through these periods. The increase in the rate of sediment delivery from the 1958-1978 period to the 1979-1999 period, however, is only a quarter of the rate of increase in background sources.

The background rate of surface erosion was estimated using a uniform rate of sediment delivery across the watershed and over time. The estimate does not take into account fluctuations in the timing of rainfall, rainfall volumes, or rainfall intensities, so the relationship between background rates of surface erosion and management-related rates of surface erosion is undetermined. Nonetheless, the following can be said with respect to surface erosion.

- The rate of sediment delivery due to surface erosion from roads has increased over time. However, the rate of increase has slowed from 280% to 4% in the most recent period.
- The rate of sediment delivery from skid trails increased from the period of 1933-1957 to 1958-1978. However, it decreased from the period of 1958-1978 to 1979-1999.

In summary, the background rate of sediment delivery due to landsliding increased throughout the 1933-1999 period. The rate of management-related sediment delivery due to landsliding increased from the 1933-1957 period to the 1958-1978 at rates significantly greater than that associated with background sources. In the transition from the 1958-1978 period to the 1979-1999 period (Forest Practices Act period), however, the rate of management-related sediment delivery due to landsliding changed at rates significantly less than that associated with background sources. Indeed, harvest-related sediment delivery due to landsliding actually decreased in the 1979-1999 period. Given the direct relationship between management practices and rates of sediment delivery due to landsliding, EPA reaches several conclusions.

- Management practices conducted during the Forest Practices Act period (1979-1999) have contributed to a reduction in the rate of sediment delivery due to landsliding in harvest areas in HAA.
- Management practices conducted during the Forest Practices Act period (1979-1999) have contributed to a deceleration in the rate of sediment delivery due to landsliding from roads in HAA; but they have not controlled it.
- Management practices conducted since 1979 have contributed to a deceleration in the rate of sediment delivery due to landsliding from the railroad in HAA; but they have not controlled it.

With respect to surface erosion, sediment delivery from roads has increased from 1933-1999. However, the rate of increase has slowed since 1979. Sediment delivery due to surface erosion from skid trails, on the other hand, increased up through 1978; but it has decreased since then to a rate less than that estimated for the 1933-1957 period. Given the direct relationship between management practices and rates of sediment delivery due to surface erosion, EPA draws several conclusions.

- Management practices conducted in the Forest Practices Act period (1979-1999) have contributed to a deceleration in the rate of sediment delivery due to surface erosion from roads; but they have not controlled it.
- Management practices conducted in the Forest Practices Act period have contributed to the reduction in the rate of sediment delivery due to surface erosion from skid trails.

North Fork Noyo River Assessment Area

With respect to landslides, the data show that the rate of sediment delivery from background sources increased from the 1933-1957 period to the 1958-1978 period by 2317% and then from the 1958-1978 period to the 1979-1999 period by 8%. By comparing the rate of change in management-related categories of sediment delivery to the rate of change in background sediment delivery, EPA makes several observations regarding management influence with respect to landsliding in NFAA.

- The rate of sediment delivery from harvest sites increased from the 1933-1957 period to the 1958-1978 period at a rate greater than that of background sources. However, it decreased from the 1958-1978 period to the 1979-1999 period by 63% during the same period in which background sources increased by 8%.
- The rate of sediment delivery due to landsliding from roads increased from the 1933-1957 period to the 1958-1978 period at a rate less than that of background sources. However, it increased from the 1958-1978 period to the 1979-1999 period and from the 1933-1978 period to the 1979-1999 period at a rate greater than that of background sources.

The background rate of surface erosion was estimated using a uniform rate of sediment delivery across the watershed and over time. The estimate does not take into account fluctuations in the timing of rainfall, rainfall volumes, or rainfall intensities. Therefore, the relationship between background rates of surface erosion and management-related rates of surface erosion is undetermined. Nonetheless, the following can be said with respect to surface erosion.

- The rate of sediment delivery from roads increased from the period of 1933-1957 to 1958-1978 but decelerated from the period of 1958-1978 to 1979-1999. It increased from the period of 1933-1978 to 1979-1999.
- The rate of sediment delivery from skid trails increased from the period of 1933-1957 to 1958-1978 but decreased from the period of 1958-1978 to 1979-1999. It decreased from the period of 1933-1978 to 1979-1999.

In summary, the background rate of sediment delivery due to landsliding increased throughout the 1933-1999 period. On balance, the rate of management-related sediment delivery due to landsliding increased at rates comparable to those from background sources from the 1933-1957 period to the 1958-1978, the 1958-1978 period to the 1979-1999 period, and the 1933-1978 period to the 1979-1999. However, this balance was achieved by reductions in the rate of harvest-related landsliding as the rate of road-related landsliding increased at rates greater than those of background sources. Given the direct relationship between management practices and rates of sediment delivery due to landsliding, EPA draws several conclusions.

- Management practices conducted during the Forest Practices Act period have contributed to a reduction in the rate of sediment delivery due to landsliding in harvest areas in NFAA.
- Management practices conducted during the Forest Practices Act period have contributed to a deceleration in the rate of sediment delivery due to landsliding from roads in NFAA; but they have not controlled it.

With respect to surface erosion, sediment delivery from roads has increased from 1933-1999. However, the rate of increase has slowed since 1979. Sediment delivery due to surface erosion from skid trails, on the other hand, increased up through 1978, but it has decreased since then. Given the direct relationship between management practices and rates of sediment delivery due to surface erosion, EPA draws several conclusions.

- Management practices conducted in the Forest Practices Act period have contributed to a deceleration in the rate of sediment delivery due to surface erosion from roads; but they have not controlled it.

- Management practices conducted in the Forest Practices Act period have contributed to the reduction in the rate of sediment delivery due to surface erosion from skid trails.

South Fork Noyo River Assessment Area
With respect to landslides, the data show that the rate of sediment delivery from background sources decreased from the 1933-1957 period to the 1958-1978 period by 69% and then increased from the 1958-1978 period to the 1979-1999 period by 4%. By comparing the rate of change in management-related categories of sediment delivery to the rate of change in background sediment delivery, EPA makes several observations regarding management influence with respect to landsliding in SFAA.

- The rate of sediment delivery due to the activities of the railroad have decreased since 1993 and is now 0.
- The rate of sediment delivery from harvest sites decreased more steeply than background sources from the 1933-1957 period to the 1958-1978 period; and it increased more steeply than background sources from the 1958-1978 period to the 1979-1999 period.
- The rate of sediment delivery due to landsliding from roads increased from the period of 1933-1957 to 1958-1978; but it decreased slightly from the period of 1958-1978 to 1979-1999.

The background rate of surface erosion was estimated using a uniform rate of sediment delivery across the watershed and over time. The estimate does not take into account fluctuations in the timing of rainfall, rainfall volumes, or rainfall intensities. Therefore, the relationship between background rates of surface erosion and management-related rates of surface erosion is undetermined. Nonetheless, the following can be said with respect to surface erosion.

- Surface erosion from both roads and skid trails has increased since 1933, though more steeply from skid trails.

In summary, the background rate of sediment delivery due to landsliding decreased significantly from the 1933-1957 period to the 1958-1978 period but has increased since then. The rate of management-related sediment delivery due to landsliding has steadily decreased since 1933. This has occurred because of decreases in sediment delivery due to landsliding from railroad sites and harvest areas even while there have been increases due to roads. Nonetheless, the decrease in management-related sediment delivery due to landsliding from 1933-1978 to 1979-1999 is still only half of that experienced from background sources. Given the direct relationship between management practices and rates of sediment delivery due to landsliding, EPA draws several conclusions.

- Management practices conducted since 1979 have contributed to a decrease in the rate of sediment delivery from management-related sources overall.
- Management practices conducted since 1979 have contributed to a decrease in the rate of sediment delivery from railroad sites.
- Management practices conducted in the Forest Practice Act period (1979-1999) have contributed to a decrease in the rate of sediment delivery from road sites.
- Management practices conducted in the Forest Practice Act period (1979-1999) have been unsuccessful in reducing sediment delivery from harvest areas.

With respect to surface erosion, sediment delivery from roads has increased from 1933-1999. However, the rate of increase has slowed since 1979. Sediment delivery due to surface erosion from skid trails, on the other hand, has accelerated up through 1999. Given the direct relationship between management practices and rates of sediment delivery due to surface erosion, EPA draws several conclusions.

- Management practices conducted in the Forest Practice Act period (1979-1999) have contributed to the deceleration in surface erosion from roads; but they have not controlled it.
- Management practices conducted in the Forest Practice Act period (1979-1999) have been unsuccessful in reducing sediment delivery from skid trails.

Mainstem Noyo River Assessment Area

With respect to landslides, the data show that the rate of sediment delivery from background sources decreased from the 1933-1957 period to the 1958-1978 period by 13% and then from the 1958-1978 period to the 1979-1999 period by 45%. By comparing the rate of change in management-related categories of sediment delivery to the rate of change in background sediment delivery, EPA makes several observations regarding management influence with respect to landsliding in HAA.

- The rate of sediment delivery due to the activities of the railroad also decreased through these periods, but at a greater rate than the decrease from background sources.
- Landslides associated with harvest units were not identified in the aerial photographs until the 1979-1999 period. Accordingly, the increase from the early periods to the 1979-1999 is infinite.
- The rate of sediment delivery due to landsliding from roads increased from the 1933-1957 period to the 1958-1978 period by 1750% and from the 1958-1978 period to the 1979-1999 period by 105%. These are enormous rates of increase when compared to the decrease in sediment delivery from background sources in these same periods.

The background rate of surface erosion was estimated using a uniform rate of sediment delivery across the watershed and over time. The estimate does not take into account fluctuations in the timing of rainfall, rainfall volumes, or rainfall intensities. Therefore, the relationship between background rates of surface erosion and management-related rates of surface erosion is undetermined. Nonetheless, the following can be said with respect to surface erosion.

- The rate of sediment delivery from roads has increased over time. The rate of increase has slowed from 594% to 70% in the most recent period.
- The rate of sediment delivery from skid trails has increased over time. The increase has accelerated from 100% to 225% in the most recent period.

In summary, the background rate of sediment delivery due to landsliding decreased throughout the 1933-1999 period. The rate of management-related sediment delivery due to landsliding also decreased from the 1933-1957 period to the 1958-1978 period and at a comparable rate (e.g., 14% vs. 13%). The rate of management-related sediment delivery due to landsliding increased, however, from the 1958-1978 period of the 1979-1999 period as compared to the decrease in background sediment delivery. Given the direct relationship between management practices and rates of sediment delivery due to landsliding, EPA draws several conclusions.

- Management practices conducted during the 1979-1999 period have contributed to a deceleration in the delivery of sediment due to mass wasting associated with the railroad.
- Management practices conducted during the Forest Practices Act period have been unsuccessful in controlling sediment delivery due to mass wasting from harvest areas and roads.

With respect to surface erosion, sediment delivery from roads has increased from 1933-1999. However, the rate of increase has slowed since 1979. Sediment delivery due to surface erosion from skid trails, on the other hand, has accelerated through 1999. Given the direct relationship between management practices and rates of sediment delivery due to surface erosion, EPA draws several conclusions.

- Management practices conducted in the Forest Practices Act period have contributed to a deceleration in the rate of sediment delivery increase due to surface erosion from roads; but they have not controlled it.
- Management practices conducted in the Forest Practices Act period have been unsuccessful in controlling the acceleration in sediment delivery due to surface erosion from skid trails.

Noyo River Watershed in General

In summary, the data presented in Table 14 indicate that sediment delivery in the Noyo River watershed has generally increased over time: from an estimated 468 tons/mi^2/yr in the 1933-1957 period to 620 tons/mi^2/yr in the 1958-1978 period and to 667 tons/mi^2/yr in the 1979-1999 period. Estimates of management-related sediment delivery indicate that rates increased from the 1933-1957 period to the 1958-1978 period by 167% and from the 1958-1978 period to the 1979-1999 period by 12%. As a general matter, it appears that practices conducted in the Forest Practices Act period of 1979-1999 have contributed to a deceleration in the rate of sediment delivery from management-related sources, but they have not controlled them.

Based on these data, EPA draws several conclusions regarding individual sediment source categories in the Noyo River watershed.

- The estimated rate of sediment delivery from mass wasting associated with the railroad was at its greatest in the 1933-1957 period and has steadily declined since then. This is the only source category in which estimated rates of sediment delivery in the 1979-1999 period are equivalent to or less than the 1933-1957 rates. The estimated rate of sediment delivery in the 1979-1999 period for all other source categories ranges from 167% to 1420% greater than the estimated rates in the 1933-1957 period.
- The estimated rate of sediment delivery from mass wasting associated with harvest areas is at its greatest in the 1979-1999 period.
- The estimated rate of sediment delivery from mass wasting associated with roads is at its greatest in the 1979-1999 period.
- The estimated rate of sediment delivery from surface erosion associated with roads is at its greatest in the 1979-1999 period.
- The estimated rate of sediment delivery from surface erosion associated with skid trails was at its greatest in the 1958-1978 period and has declined since then. (It remains at its greatest in two of the assessment areas for the period of 1979-1999.)

CHAPTER VI
LINKAGE ANALYSIS

This chapter analyzes the relationship between hillslope processes and in-stream effects. In Chapter IV targets are defined that interpret the applicable water quality criteria for sediment. Load allocations are established in Chapter VII that establish limits on the allowable sediment loading from various hillslope sources. The linkage analysis provides the basis for calculating load allocations that, when met, will result in attainment of the applicable water quality criteria for sediment.

Hillslope activities affect in-stream habitat, although the processes are not understood in sufficient detail at this time to be able to describe the relationships mathematically. The linkage analysis for the Noyo River TMDL is based on: (1) the determination that salmonids were abundant (relative to today) prior to 1958, and (2) the conclusion that achieving a rate of sediment delivery equivalent to the rate in the period prior to 1958 is expected to result in attainment of water quality criteria for sediment.

Salmonid Abundance in the Early Part of this Century

Brown et al. (1994) report that coho salmon previously occurred in as many as 582 California streams from the Smith River near the Oregon border to the San Lorenzo River on the central coast. There are now probably less than 5,000 native coho salmon spawning in California each year, many in populations of less than 100 individuals. Coho populations today are probably less than 6% of what they were in the 1940s and there has been at least a 70% decline since the 1960s. Brown et al. (1994) conclude that the reasons for the decline of coho salmon in California include: stream alterations brought about by poor land-use practices and by the effects of periodic floods and drought, the breakdown of genetic integrity of native stocks, introduced diseases, over-harvest, and climatic change. Many factors may have contributed to the decline in salmonid populations, but EPA has concluded that impacts to freshwater habitat from an overabundance of sediment is an important one.

There are no quantitative estimates of coho populations in the Noyo River watershed in the earlier part of this century, but anecdotal information available to the Regional Water Board indicates that the Noyo River once had a thriving population of coho and steelhead. As indicated by data from the South Fork egg taking station, coho populations have declined since 1963 by an average of 68%. If coho populations today are less than 6% of what there were in the 1940s as suggested by Brown et al. (1994), then there may have existed an average of 19,000 coho in the South Fork of the Noyo River watershed at that time.

This linkage analysis is based on two determinations. First, EPA has determined that the freshwater habitat found in the Noyo River watershed in the early part of this century supported coho salmon, based on the information discussed above. Second, EPA has determined that the freshwater habitat conditions found in the Noyo River watershed in the early part of this century correspond to those described by the in-stream targets in Chapter IV. Quantitative targets are identified for substrate composition (e.g., % fines < 0.85 mm), pool frequency/depth, and V*. All the other identified in-stream targets simply call for an improving trend. The % fines target represents the results of a myriad of in-stream and laboratory studies and is conservatively based specifically on coho fry emergence success. The pool frequency/depth target is based on a large data set representing today's "good" coho streams. And the V* target is based on conditions in a local reference stream. With respect to habitat conditions in the early part of the century, then, the % fines target may be slightly over-estimated, the pool frequency/depth may be slightly under-estimated, and the V* target is probably accurate. Overall, EPA believes that the targets are consistent with habitat conditions early in the century.

Sediment Delivery Rates Over Time

The assessment of sources of sediment to the Noyo River watershed covers a period of 67 years from 1933 to 1999 (Matthews, 1999). The 67-year period of study has been divided into three periods: 1933-1957, 1958-1978, and 1979-1999.

The period of 1933-1957 includes a quiescent period between the logging of old growth at the turn of the century and logging of second growth in the middle of the 20th century. The average sediment delivery during this period is estimated at 468 tons/mi^2/yr (see Table 14).

The period of 1958-1978 includes an intensive period of second growth logging, prior to the enactment and implementation of the California Forest Practices Act. Our understanding is that this is the period in which the most significant modifications to hillslope and in-stream processes had occurred. The average sediment delivery during this period is estimated to be 620 tons/mi^2/yr (see Table 14).

The period of 1979-1999 includes an intensive period of second growth logging, which has been mitigated by the enactment and implementation of the California Forest Practices Act. The average sediment delivery in this period is estimated at 667 tons/mi^2/yr (see Table 14).

Linkage

For the purpose of the linkage analysis, the period of 1933-1957 is considered to be the period just prior to the steep decline in salmonid populations, most notably coho salmon. Since coho salmon were successful (relative to today) in the Noyo River prior to 1958, as suggested by Brown et al. (1994), the habitat conditions in that period must have been adequate to support coho salmon. Though the specific habitat conditions of that period are unknown, it is reasonable to conclude that they were consistent with those defined by the numeric targets in Chapter IV, as described above. Therefore, achieving a rate of sediment delivery equivalent to the rate of sediment delivery in the period of 1933-1957 is expected to achieve the in-stream targets, protect water quality, and attain the applicable water quality criteria for sediment.

CHAPTER VII
LOAD ALLOCATIONS

This chapter establishes the loading capacity of the Noyo River for sediment, based on the linkage analysis in Chapter VI, and apportions it among the various sources of sediment to the system. EPA is apportioning the total load among several non-point sources of sediment, after accounting for background loading. The TMDL and the load allocations are expressed as 10-year rolling averages due to the considerable variability in sediment loading rates.

VII.A. CALCULATION OF THE TMDL

For the Noyo River, EPA is defining the TMDL as the current loading capacity (i.e., the total loading of sediment that can be delivered to the river and still attain the applicable water quality criteria for sediment). EPA has determined that the current loading capacity is equivalent to the sediment loading rate for the period 1933-1957, as discussed in the linkage analysis (Chapter VI). Sustainable populations of salmonids, coho salmon in particular, appear to have existed in this period, so the sediment delivery rate at that time was capable of supporting salmonids. Therefore, achieving a sediment delivery rate comparable to that of this period is expected to result in attainment of the applicable water quality criteria for sediment.

The estimate of the average sediment delivery from the Noyo River watershed from 1933 to 1957 is 468 tons/mi^2/yr (from Table 14), which is rounded to 470 tons/mi^2/yr. This is the TMDL for the Noyo River.

The loading capacity (i.e., the TMDL) is apportioned among the various sources of the pollutant so as to focus attention on the sources that are influenced by human activities. In establishing TMDLs, EPA generally apportions the loading capacity among: (1) the background loading; (2) the wasteload allocations for point sources; and (3) the load allocations for non-point sources. For this TMDL, there are no point sources, so the wasteload allocations equal zero. Therefore, the TMDL for the Noyo River can be divided into the background loading and the load allocations:

TMDL = Background Loading + Load Allocations = 470 tons/mi^2/yr.

VII.B. CALCULATION OF BACKGROUND LOADING

The background sediment delivery rate is calculated using data from the entire period analyzed for this TMDL (1933-1999). Using the data presented in Table 14, background rates for mass wasting (91 tons/mi^2/yr), surface erosion (75 tons/mi^2/yr), and stream bank erosion (200 tons/mi^2/yr) are summed to derive the total background sediment delivery rate of 366 tons/mi^2/yr, which is rounded to 370 tons/mi^2/yr:

Background Loading = 370 tons/mi^2/yr.

VII.C. CALCULATION OF LOAD ALLOCATIONS

EPA considered several factors in setting load allocations for various source categories, including the effectiveness of available methods of controlling sediment from the particular source category, equity in imposing needed controls, and the feasibility of monitoring to determine compliance with the allocations.

EPA is establishing load allocations for mass wasting from the railroad, mass wasting from harvest areas, and surface erosion from skid trails. The allocations are set at levels which will necessitate reductions from current sediment delivery rates for those areas where current rates are elevated.

EPA is establishing load allocations for roads which will necessitate aggressive sediment control efforts. This is appropriate because roads appear to be the greatest source of management-related sediment delivery, in the most recent period, in the watershed. Also, most sediment delivery due to roads (including mass wasting, surface erosion, and fluvial erosion) is readily controllable.

Load Allocations for Sources other than Roads

EPA has identified several sources of management-related sediment delivery, in addition to roads, that may be significant: mass wasting from the railroad, mass wasting from harvest areas and surface erosion from skid trails. EPA has determined that, for a particular source category, no assessment area should have a loading rate that is more the 25% above the watershed average for that source category, as calculated in this report. Limiting the allocation to 25% above the basin-wide average is appropriate, because those rates are elevated and have significant potential to impair water quality. By addressing the elevated railroad, harvest area, and skid trail sources, implementation of the requirements ensures that landowners throughout the basin are treated equitably. The maximum allowable loading, therefore, is 125% of the watershed average. Thus, any assessment area which has a more elevated loading is given an allocation equal to 125% of the watershed average. Any assessment area whose loading is not elevated above 125% of the watershed average is given an allocation equal to its current loading.

The current levels of sediment loading and allocations for these sources are presented in Table 15 for the four assessment areas and for the overall watershed.

All loading rates are expressed in terms of tons/mi^2/yr. These figures are meant to be average figures for the entire assessment area. These allocations can be converted to total tons/yr by multiplying the loading allocation by the area of the assessment area. For example, the allocation of 8 tons/mi^2/yr applies to the entire HAA, not just the harvest areas within the HAA. This can be expressed in terms of tons/yr:

Allocation for harvest areas in HAA = (8 tons/mi^2/yr)(27.2 mi^2) = 220 tons/yr.

Table 15: Calculation of Load Allocations for Railroad, Harvest Area, and Skid Trail-related Sources

	Mass wasting from the railroad	Mass wasting from harvest areas	Surface erosion from skid trails	Total
Estimated current sediment delivery rate in HAA	9 tons/mi^2/yr	8 tons/mi^2/yr	17 tons/mi^2/yr	34 tons/mi^2/yr
Estimated current sediment delivery rate in NFAA	0 tons/mi^2/yr	5 tons/mi^2/yr	21 tons/mi^2/yr	26 tons/mi^2/yr
Estimated current sediment delivery rate in SFAA	0 tons/mi^2/yr	5 tons/mi^2/yr	13 tons/mi^2/yr	18 tons/mi^2/yr
Estimated current sediment delivery rate in MAA	12 tons/mi^2/yr	53 tons/mi^2/yr	13 tons/mi^2/yr	78 tons/mi^2/yr
Estimated watershed average	7 tons/mi^2/yr	20 tons/mi^2/yr	16 tons/mi^2/yr	N/A
Maximum allowable loading (125% of average)	9 tons/mi^2/yr	25 tons/mi^2/yr	20 tons/mi^2/yr	N/A
Load Allocation for HAA (27.2 mi^2)	9 tons/mi^2/yr	8 tons/mi^2/yr	17 tons/mi^2/yr	34 tons/mi^2/yr
Load Allocation for NFAA (25.1 mi^2)	0 tons/mi^2/yr	5 tons/mi^2/yr	20 tons/mi^2/yr	25 tons/mi^2/yr
Load Allocation for SFAA (27.5 mi^2)	0 tons/mi^2/yr	5 tons/mi^2/yr	13 tons/mi^2/yr	18 tons/mi^2/yr
Load Allocation for MAA (33.3 mi^2)	9 tons/mi^2/yr	25 tons/mi^2/yr	13 tons/mi^2/yr	47 tons/mi^2/yr

Because the size of the assessment areas varies, the values for the individual areas are weighted by size to determine the watershed average, which is the overall load allocation for other sources.

Load Allocation for Sources Other than Roads = (AA area/watershed area)(AA loading rate)
= (27.2 mi^2/113 mi^2)(34 tons/mi^2/yr) + (25.1 mi^2/113 mi^2)(25 tons/mi^2/yr)
+ (27.5 mi^2/113 mi^2)(18 tons/mi^2/yr) + (33.3 mi^{2}113 mi^2)(47 tons/mi^2/yr)
= 32 tons/mi^2/yr.

Load Allocation for Roads (including mass wasting, surface erosion, and fluvial erosion)
The source analysis (Chapter V) discusses three categories of road-related sources of sediment: mass wasting, surface erosion, and fluvial erosion. Loading estimates were derived for mass wasting and surface erosion. No estimate was made for fluvial erosion from roads, because no field data were available.

EPA is establishing a load allocation for roads that applies to the sum of all road-related sediment sources. Thus, the load allocation for roads includes fluvial erosion, as well as mass wasting and surface erosion.

Knowing the allocation for other sources, the TMDL, and the background loading rate, the allocation for roads, which applies to all assessment areas, is determined by difference. It is reasonable to limit the allocation for roads to that remaining after allocations have been made for other sediment sources because sediment delivery due to roads is readily controllable.

Load Allocation for Roads = TMDL - Background Loading - Load Allocation for Other Sources
$= 470$ tons/mi^2/yr - 370 tons/mi^2/yr - 32 tons/mi^2/yr
$= 68$ tons/mi^2/yr.

Aggressive action to reduce sediment delivery from roads will be needed to meet this allocation. This is appropriate because roads appear to be the greatest source of management-related sediment delivery in the watershed. Also, improved methodologies for conducting road inventories and “storm-proofing” roads are now available to land managers which, if implemented, will lead to dramatic reductions in sediment from historic road-related loading rates (Weaver and Hagans, 1994). EPA has identified roads as a source amenable to aggressive sediment reduction efforts in other North Coast TMDLs, including the South Fork Trinity River TMDL (EPA, 1998).

VII.D. SUMMARY OF LOAD ALLOCATIONS AND REQUIRED REDUCTIONS

Table 16 presents a summary of the load allocations. It also expresses the allocations in terms of the percentage reductions needed from the estimates of current levels described in this analysis. The load allocations pertain to entire assessment areas, whereas implementation actions may be focused at a smaller scale, and percent reductions can be applied at any scale. Because of the limited precision of the analysis and the limitations of implementation monitoring, allocations expressed as percentage reductions are rounded to the nearest 5%.

Table 16: Summary of Load Allocations and Necessary Reductions

	Current Estimate (1979-1999)	Load Allocation	Percent Reduction Necessary
Headwaters Assessment Area			
- Roads: Mass Wasting Surface Erosion Fluvial Erosion Subtotal for Roads	106 tons/mi^2/yr 162 tons/mi^2/yr unknown 268 tons/mi^2/yr	68 tons/mi^2/yr	75%
- Mass Wasting from Railroad	9 tons/mi^2/yr	9 tons/mi^2/yr	none
- Mass Wasting from Harvest Areas	8 tons/mi^2/yr	8 tons/mi^2/yr	none
- Surface Erosion from Skid Trails	17 tons/mi^2/yr	17 tons/mi^2/yr	none
North Fork Assessment Area			
- Roads: Mass Wasting Surface Erosion Fluvial Erosion Subtotal for Roads	106 tons/mi^2/yr 182 tons/mi^2/yr unknown 288 tons/mi^2/yr	68 tons/mi^2/yr	75%
- Mass Wasting from Railroad	0 tons/mi^2/yr	0 tons/mi^2/yr	none
- Mass Wasting from Harvest Areas	5 tons/mi^2/yr	5 tons/mi^2/yr	none
- Surface Erosion from Skid Trails	21 tons/mi^2/yr	20 tons/mi^2/yr	5%
South Fork Assessment Area			
- Roads: Mass Wasting Surface Erosion Fluvial Erosion Subtotal for Roads	18 tons/mi^2/yr 148 tons/mi^2/yr unknown 166 tons/mi^2/yr	68 tons/mi^2/yr	60%
- Mass Wasting from Railroad	0 tons/mi^2/yr	0 tons/mi^2/yr	none
- Mass Wasting from Harvest Areas	5 tons/mi^2/yr	5 tons/mi^2/yr	none
- Surface Erosion from Skid Trails	13 tons/mi^2/yr	13 tons/mi^2/yr	none
Mainstem Assessment Area			
- Roads: Mass Wasting Surface Erosion Fluvial Erosion Subtotal for Roads	76 tons/mi^2/yr 201 tons/mi^2/yr unknown 277 tons/mi^2/yr	68 tons/mi^2/yr	75%
- Mass Wasting from Railroad	12 tons/mi^2/yr	9 tons/mi^2/yr	25%
- Mass Wasting from Harvest Areas	53 tons/mi^2/yr	25 tons/mi^2/yr	50%
- Surface Erosion from Skid Trails	13 tons/mi^2/yr	13 tons/mi^2/yr	none

CHAPTER VIII
MARGIN OF SAFETY AND SEASONAL VARIATION

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. The regulations also require that TMDLs account for critical conditions for stream flow, loading, and water quality parameters. The margin of safety can be incorporated into conservative assumptions used to develop the TMDL or added as a separate, quantitative component of the TMDL (EPA, 1991).

Annual and Seasonal Variation

There is inherent annual and seasonal variation in the delivery of sediment to stream systems as the result of variation in rainfall patterns. There is also considerable spatial variation resulting from numerous factors, including: slope, geology, aspect, vegetation, soil type, etc. Surface erosion, including erosion from roads, occurs on an annual basis, but primarily as a result of winter rains. Surface erosion from ridge top roads, however, is much less likely to enter a watercourse than that from stream-side roads. Mass wasting occurs as a result of large storms, but is more likely in inner gorges and headwall swales, for example, than on gently sloping terrain.

Because of the large temporal and spatial variation in erosion and sediment delivery, the sediment load allocations are designed to apply to the *sources* of sediment, not the movement of sediment across the landscape or delivery of sediment to the stream channel. Also, the load allocations are applied as 10-year rolling averages. If implemented as envisioned, using the allocations expressed as percent reductions at the scale of individual sediment production sites, potential and existing sediment delivery sites will be identified and the quantity of sediment associated with each site measured or estimated. Then, as a result of mitigation or altered land management, the amount of potential sediment saved from delivery to waters of the State will be measured or estimated. The relationship between the original measurement or estimate and the amount saved by mitigation will indicate the degree to which the allocation (as a percent reduction) has been achieved. Applied in this way, the effects of spatial and temporal variation on the implementation of load allocations are minimal. Only following mitigation, when large storms occur, will the effects of temporal and spatial variation be important. Mitigation measures that do not hold up to the variation in rainfall patterns, for example, should be redesigned and re-implemented, as appropriate.

There is also inherent annual and seasonal variation in the condition of the in-stream environment resulting from variation in sediment delivery, flow, and the longevity of large woody debris, for example. In addition, there is considerable spatial variation resulting from variation in channel slope, geology, aspect, vegetation, topography, etc. The in-stream and hillslope targets established as part of this TMDL take into account this variation, but in different ways. The in-stream targets are indicators that are generally collected during the summer months when stream flows are low and field crews can safely enter the stream for monitoring. (Turbidity is the exception.) The indicators are ones that are directly related to factors potentially limiting the success of coho salmon in the Noyo River watershed. And they are all related to the issue of sedimentation, either as a primary factor (e.g., % fines) or as a secondary factor (e.g., pool depth/frequency, large woody debris). If the monitoring plan is developed and implemented as envisioned, monitoring will be conducted on an annual basis for some parameters (e.g., % fines) and after storms of a specific recurrence interval for other parameters (e.g., % large woody debris). The data will be analyzed with respect to mean and maximum values per stream reach. They will be analyzed as a long-term rolling average (e.g., 10 years). And they will be analyzed in conjunction with rainfall and/or stream flow data to ensure that climatic influences are considered. Finally, the monitoring plan will locate or propose a process for locating monitoring sites appropriate for answering specific critical questions regarding habitat value, changes in habitat over time, and impacts on habitat from hillslope activities.

The hillslope targets, on the other hand, are specifically designed with variation in rainfall and peak flows in mind. The road crossing failure and flow diversion targets will require regular assessment of road facilities before and after the effects of storms of a specific recurrence interval (e.g., 10 years). Conformance with the disturbance area and hydrologic connectivity targets can be assessed remotely via GIS, for example. However, they specifically track critical changes in the landscape over time that influence the rates of erosion and peak flows resulting from variable climatic events.

It is difficult to accurately predict the specific impacts of sediment loading at particular times and places on particular salmonid life stages as they occur throughout a watershed. There are substantial and poorly defined spatial and temporal lags between sediment delivery and the occurrence of sediment–related impacts on beneficial uses. Therefore, the approach taken in this TMDL is to:

- Establish conservative in-stream targets that interpret narrative water quality standards and address the factors potentially limiting the success of salmonids in the Noyo River watershed, including factors that are secondarily related to sedimentation such as large woody debris and peak flows;
- Select hillslope indicators that are directly related to management-induced sedimentation, including targets associated with sediment delivery and hydrologic modification;
- Establish conservative hillslope targets based on scientific literature, reference streams, and best professional judgement; and,
- Establish conservative load allocations based on estimates of current and historic rates of sediment delivery.

Similarly, this TMDL does not explicitly estimate critical flow conditions. Sediment impacts may occur long after sediment is discharged, often at locations far downstream of the sediment source. Also, it is impractical to measure accurately sediment loading and transport, and the resulting short term effects, during high magnitude flow events that produce most channel modifications. Rather, the TMDL accounts for critical conditions by establishing targets and allocations based on net long term effects.

Margin of Safety
As set forth in EPA guidance (EPA, 1991) the margin of safety can be incorporated into conservative assumptions used to develop the TMDL or added as a separate, quantitative component of the TMDL. This TMDL incorporates an implicit margin of safety through use of the conservative assumptions discussed in this chapter.

An important factor in the implicit margin of safety is that the calculation of the TMDL and the load allocations is based on an estimate of sediment loading in the 1933-1957 period, derived using a conservative methodology. The methodology used most likely results in an underestimate of sediment loading, as described below, for this period. Since salmonids were relatively abundant in this time period, and the sediment delivery estimate is probably low, salmonids can likely tolerate a higher sediment delivery rate than the one estimated for this period. Since the TMDL and load allocations are established based on this estimate of sediment loading, the TMDL and load allocations are conservative.

That the estimates of sediment loading used in this analysis are conservative is illustrated by a comparison between the calculated sediment budget and actual observations. The calculated sediment budget indicates that sediment inputs are 40% less than sediment outputs, whereas actual data (as discussed in Chapter III) indicate that the lower Noyo River appears to have aggraded by one and half to two feet from 1957 to present. Matthews (1999) indicates that the calculated sediment output has been somewhat overestimated, and the calculated inputs have likely been underestimated, because of limitations with the available data and analytic techniques.

For example, Matthews (1999) lists the following reasons why the mass wasting analysis is likely an underestimate: (1) there was a lack of data regarding landslides that were smaller than the resolution of the aerial photos used; (2) continuing sediment delivery from old slides was ignored; (3) the subsequent reactivation of old slides was ignored; and (4) slides in inner gorge areas were assumed to deliver sediment to the stream at the same rate as slides in other areas, when they probably deliver at higher rates.

There are additional factors that contribute to the implicit margin of safety, including:
- Consideration of limiting factors that are both primarily and secondarily related to sedimentation, such as percent fines (primary), V* (primary), pool depth/frequency (secondary), and number and volume of key pieces of large woody debris (secondary);
- Development of conservative numeric targets where the scientific literature supports them (e.g., percent fines);
- Conservative assumptions, where data are sparse, regarding which limiting factors are potentially affecting coho salmon; and
- Conservative assumption with respect to the direct nature of the relationship between hillslope sediment production and in-stream effect.

Some of the relationships between uncertainties in the analysis and the corresponding adjustments made by EPA are summarized in Table 17.

Table 17: Supporting Information for Margin of Safety

UNCERTAINTIES IN TMDL SUPPORTING DOCUMENTATION	ADJUSTMENTS TO ACCOUNT FOR UNCERTAINTIES
Existing data is limited.	The targets represent the optimal conditions for beneficial use support (salmonids) and include targets for watershed conditions (hillslope and roads).
Considerable uncertainty exists in the source analysis, including a lack of information on fluvial erosion from roads.	A single allocation for roads was established. Because there is no estimate of fluvial erosion from roads, the roads allocation is conservative.
Linkages between hillslope sediment sources and in-stream conditions are poorly understood, and temporal/spatial lags associated with the movement of sediment from source to stream impact could result in irreversible sediment impacts.	A broad range of indicators were selected, including those that will address: (1) a protected beneficial use (salmonids) directly; (2) advancement of our understanding of the processes defining the linkages (including continued trend monitoring); (3)in-stream conditions; and (4) protection of water quality at the sources of delivery to the stream (e.g., hillslope and road conditions). In addition, assuming a linear relationship between targets and loads is conservative.

CHAPTER IX
IMPLEMENTATION, MONITORING, AND TIME FRAME

Federal regulations require states to identify measures needed to implement TMDLs in state water quality management plans (40 CFR 130.6). EPA has established policies which emphasize the importance of timely development of measures to implement TMDLs that address nonpoint source discharges (memorandum from Robert Perciasepe, Assistant Administrator for Water, to EPA Regional Division Directors, August 8, 1997). EPA expects the State of California to develop and ensure the prompt implementation of source control measures adequate to achieve the allocations in this TMDL.

EPA expects that the State of California will incorporate the TMDL, and associated implementation measures, into the Basin Plan, as required by 40 CFR 130.6. The State of California should also establish a monitoring and evaluation plan that identifies parties responsible for implementation and monitoring and establishes a time frame for Regional Water Board review of monitoring results.

EPA understands that the Regional Water Board intends to implement the TMDL using data to be collected through baseline surveys (Regional Water Board, 1999). The Regional Water Board intends to apply the sediment allocations, expressed as percent reductions, to field-based assessments of sediment sources conducted by individual landowners on their properties. EPA supports this approach to implementation, as long as the load allocations set in the TMDL are attained. Furthermore, EPA expects that the data collected will be useful in periodically reviewing the sediment budget for the Noyo River and revising the TMDL as appropriate. EPA believes that review of the TMDL after five to ten years would be appropriate.

The technical analysis prepared by the Regional Water Board in support of the TMDL (Regional Water Board, 1999) describes in broad terms factors related to implementation, monitoring, and schedule that they plan to consider during the development of an implementation plan. EPA supports the general approach described by the Regional Water Board, as outlined below.

The Regional Water Board has expressed its intention to consider the following issues during the development of an implementation plan.

- The analysis based on existing data under-estimates current sediment delivery rates. The implementation plan should include a means of identifying, mapping, and measuring and estimating actual and potential sediment delivery sites through on-the-ground, baseline surveys.
- The implementation plan should provide procedures for identifying immediate threats to water quality, especially potential refuge streams, and a means of reducing or eliminating those threats as soon as physically possible.
- The implementation plan should focus primarily on the control of sediment delivery from road sites (i.e., timber, ranch, public, and railroad), including procedures for: inventorying roads, abandoning or obliterating roads, maintaining roads, upgrading roads, and building new roads.

- The implementation plan should include procedures for estimating the amount of disturbed area on a given property and reducing the disturbed area over time. Similarly, it should include procedures for estimating the miles of road (i.e., timber, ranch, public and railroad) hydrologically connected to watercourses and reducing that hydrologic connection over time. Further, the implementation plan should include procedures for inspecting stream crossings, evaluating causes of failure and diversion, and reducing the rate of stream crossing failures and diversions over time.
- The implementation plan should include procedures for identifying unstable areas and reducing the risk of sediment delivery from them, including existing landslides, inner gorges, headwall swales, other potential landslide-prone areas, and stream banks.
- The implementation plan should include procedures for characterizing the potential of the riparian zone to produce large woody debris for ensuring an increase in the number and volume of key pieces of large woody debris over time. Similarly, it should include procedures for evaluating the need for large woody debris installations in potential refuge streams and identify options for their funding/implementation.
- The implementation plan should include procedures for characterizing the potential of the riparian zone to filter eroded soil prior to its discharge as sediment and increase the filtering potential, as possible.
- The implementation plan should include procedures for evaluating appropriate lag times between timber harvests, timber harvest rates, and timber harvest locations (e.g., in small drainages) to determine likely effects on peak flows, annual flows, and suspended sediment. It should include procedures for increasing lag times, reducing harvest rates, and reducing harvest in small drainages over time.

The Regional Water Board has expressed its intention to consider the following issues during the development of a monitoring plan.

- The monitoring plan should specifically state the hypotheses that are to be tested via monitoring as a way of assessing, over time, the degree to which the program as designed is accomplishing the goals.
- The monitoring plan should include methods, locations, and frequency of monitoring necessary to determine compliance with the load allocations.
- The monitoring plan should include methods, locations, and frequency of hillslope and/or in-stream monitoring necessary to assist landowners in the identification of tributaries requiring immediate modification to management practices or mitigation.
- The monitoring plan should include methods, locations, and frequency of monitoring necessary to establish trends in habitat and stream channel conditions over time.
- The monitoring plan should include methods, locations, and frequency of monitoring necessary to characterize regions of the watershed for which there is little or no existing data.

The Regional Water Board has expressed its intention to consider the following issues during the development of an implementation schedule.

- An implementation schedule should ensure that immediate threats to water quality, especially to potential refuge streams, are reduced or eliminated as soon as physically possible.
- An implementation schedule should be as short as possible to ensure timely protection of endangered and threatened species.

- An implementation schedule should provide adequate time for landowners to assess their property and design a TMDL-sensitive management strategy.
- An implementation schedule should provide adequate time for landowners to fix existing and potential sediment delivery sites.
- An implementation schedule should ensure that any activities conducted after the adoption of a Basin Plan amendment are conducted in a manner consistent with the TMDL.
- An implementation schedule should provide adequate time for monitoring data to reflect hillslope changes and changes in the in-stream environment, including changes to management-related facilities (i.e., roads, skid trails, etc.), the riparian zone, the stream bank, and in-stream habitat.

CHAPTER X
PUBLIC PARTICIPATION

Federal regulations require that TMDLs be subject to public review (40 CFR 130.7). The State of California and EPA have provided for public review through several mechanisms.

To date, the Regional Water Board has solicited the following public involvement.

- A newsletter (*Noyo River Watershed News: Watershed Planning for the Future,* Winter 1998/99) was sent to the Noyo River mailing list requesting information and data relevant to the development of the TMDL (January 1999).
- Telephone and face-to-face meetings were conducted with those who responded to the request for information/data (February-May 1999).
- A rough draft of the Regional Water Board's technical analysis in support of developing the TMDL and summary of existing supporting data were circulated to interested parties for review and comment (May 1999).
- Comments were considered in the development of the final draft of the Regional Water Board's report (May-June 1999).
- A newsletter (*Noyo River Watershed News: Watershed Planning for the Future,* Summer 1999) was sent to the Noyo River mailing list announcing the availability of the final draft of the TMDL for review (June 1999).
- The final draft of the Regional Water Board's report and supporting document were circulated to interested parties for review.
- Comments were considered in the development of the final Regional Water Board report (June-August 1999).

The EPA draft TMDL was based on the report submitted by the Regional Water Board on 23 August 1999.

EPA provided several opportunities for public participation in the review of the draft TMDL. EPA invited public comment on the EPA draft TMDL in a public notice, dated 8 October 1999. The public notice was published in the *Santa Rosa Press Democrat*, the *Ukiah Daily Journal,* and the *Eureka Times Standard* and mailed to a list of interested parties identified by the Regional Water Board. EPA held an informal public meeting, on 12 October 1999, at the Fort Bragg Town Hall, to present the document to interested persons. EPA held a public hearing, on 26 October 1999, in Redway to receive oral and written comments from the public on the draft TMDL. Written comments were also mailed to EPA.

EPA considered all written comments and oral testimony at the hearing on the proposed TMDL. EPA prepared a responsiveness summary (EPA, 1999) which shows how EPA considered the public comments in its final decision. In response to comments, EPA clarified language in several sections of the TMDL, including the Numeric and Other Targets chapter.

REFERENCES

Beechie, Timothy J., and Thomas H. Sibley. 1997. "Relationships between channel characteristics, woody debris, and fish habitat in northwestern Washington streams." *Transactions of the American Fisheries Society*, 126. Pp. 217-229.

Bilby, Robert E., and James W. Ward. 1989. "Changes in characteristics and function of woody debris with increasing size of streams in western Washington." *Transactions of the America Fisheries Society*, 118. Pp. 368-378.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. "Historical decline and current status of coho salmon in California." *North America Journal of Fisheries Management*. Vol. 4, No. 2. Pp. 237-261.

Burns, James W. 1970. "Spawning bed sedimentation studies in northern California streams." *Calif. Fish and Game*, 56(4). Pp. 253-270.

Burns, James W. 1971. "The carrying capacity for juvenile salmonids in some northern California streams." *Calif. Fish and Game*, 57(1). Pp. 44-57.

Cafferata, Peter H., and Thomas E. Spittler. 1998. "Logging impacts of the 1970's vs. the 1990's in the Caspar Creek watershed." In *Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, May 6, 1998*. Robert R. Ziemer, editor. Pp. 103-116.

California Department of Forestry and Fire Protection (CDF). 1994. "Coho salmon habitat impacts: Qualitative assessment technique for Registered Professional Foresters (Draft No. 2)." Prepared for the Board of Forestry. Sacramento, CA. November 1994.

California Department of Forestry and Fire Protection. 1997. "California Forest Practice Rules." *Title 14, California Code of Regulations, Chapters 4 and 4.5 with the Z'Berg Nejedley Forest Practice Act.* January 1997 version.

Crump, Spencer. 1998. <u>The California Western "Skunk" Railroad</u>. Zeta Publishers Company. Fort Bragg, CA.

Department of Fish and Game. 1995(a). "Stream Inventory Report: South Fork Noyo River." Yountville, CA.

Department of Fish and Game. 1995(b). "Stream Inventory Report: Parlin Creek." Yountville, CA.

Department of Fish and Game. Unpublished (a). Biosample database.

Department of Fish and Game. Unpublished (b). Stream surveys of the upper Noyo River in 1957 and of Redwood Creek in 1957 and in 1966.

Department of Fish and Game. Unpublished (c). Stream surveys of the North Fork of Noyo River, Hayworth Creek, and North Fork of Hayworth Creek in 1957 and North Fork Noyo River, Hayworth Creek and Middle Fork of North Fork Noyo River in 1967.

Department of Fish and Game. Unpublished (d). Stream surveys of Kass Creek in 1957, 1959, and 1966; North Fork of South Fork Noyo River in 1957 and 1959; South Fork Noyo River in 1957, 1959 and 1967; and Parlin Creek in 1957 and 1959.

Dietrich, William. 1997. Presentation at a meeting held by Louisiana-Pacific Corporation on 15 and 16 May 1997, entitled "Forest Management: Keeping sediment out of the streams." Calpella, CA.

Dietrich, William. 1998. Letter to Robert Klamt of North Coast Regional Water Quality Control Board transmitting comments on the draft Garcia River Water Quality Attainment Strategy for Sediment. 19 January 1996 (sic).

Dietrich, W.E., R. Real 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.” Prepared for Louisiana-Pacific Corporation, Calpella, CA. 29 June 1998.

Division of Mines and Geology. 1982. “Geology and geomorphic features related to landsliding, Glenblair NE 7.5’ quadrangle (NE ¼ Comptche 15’), Mendocino County. Compiled by Richard T. Kilbourne, Geologist.

Division of Mines and Geology. 1983. “Geology and geomorphic features related to landsliding, Fort Bragg 7.5’ quadrangle, Mendocino County.” Compiled by Richard T. Kilbourne, Geologist.

Division of Mines and Geology. 1984. “Geology and geomorphic features related to landsliding, Willits NW 7.5’ quadrangle, Mendocino County, California.” Compiled by Richard T. Kilbourne, Geologist.

Environmental Protection Agency. 1991. “Guidance for water quality-based decisions: The TMDL process. EPA 440/4-91-001.

Environmental Protection Agency. 1998. “South Fork Trinity River and Hayfork Creek sediment total maximum daily loads.” Region IX Water Division. San Francisco, CA. December 1998.

Environmental Protection Agency. 1999. “Noyo River total maximum daily load for sediment; comment responsiveness summary.” Region IX Water Division. San Francisco, CA. 16 December 1999.

Flanagan, S.A., M.J. Furniss, T.S. Ledwith, M.A. Love, K. Moore, and J. Ory. 1998. “Methods for inventory and environmental risk assessment of road drainage crossings.” Water/Road Interaction Technology Series (in press). USDA Forest Service, Technology and Development Program, Draft. 17 September 1994. 54 pp.

Flosi, Gary, and Forrest L. Reynolds. 1994. “California salmonid stream habitat restoration manual.” Sacramento, CA.

Furniss, Mike. 1999. “Case Study #3: Putting channel monitoring in context.” In *Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop.* Co-sponsored by Fish, Farm, Forests, and Farm Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

Harvey, Bret C., and Rodney J. Nakamoto. 1996. “Effects of steelhead density on growth of coho salmon in small coastal California stream.” *Transactions of the American Fisheries Society*. Vol. 125. Pp. 237-243.

Jones & Stokes Associates, Inc. 1997. “Georgia-Pacific Fort Bragg timberlands sustained yield plan.” April 8, 1997. (JSA 96-087.) Sacramento, CA. Prepared for Georgia-Pacific Corporation, Fort Bragg, CA.

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

Lewis, Jack. 1998. “Evaluating the impacts of logging activities on erosion and suspended sediment transport in the Caspar Creek watersheds.” In *Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, May 6, 1998*. USDA Forest Service Gen. Tech. Rep. PSW-GTR-168.

Lisle, T. E. 1986. “Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern California.” *Geological Society of America Bulletin* 8:999-1011.

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

Lisle, T.E., and S. Hilton. 1992. “The volume of fine sediment in pools: an index of sediment supply in gravel-bed streams.” *Water Res. Bulletin*, 28:2. Pp. 371-383. Paper No. 981120. April 1992.

Lisle, T.E. and H.M. Kelsey, 1982. “Effects of large roughness elements on the thalweg course and pool spacing.” In *American geomorphological field group field trip guidebook, 1982 conference, Pinedale, Wyoming*. L. B. Leopold, editor. American Geophysical Union, Berkeley, California.

Madej, Mary Ann. 1999. “Time, space, and rates of change in channel monitoring.” In *Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop.* Co-sponsored by Fish, Farm, Forests, and Farm Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

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

Megahan, W.F.1982. “Channel sediment storage behind-obstructions in forested drainage basins draining the granitic bedrock of the Idaho Batholith. In *Sediment budgets and routing in forested drainage basins*. F.J. Swanson, R.J. Janda, T. Dunne, and D.N. Swanston, editors. U.S. Forest Service Research Paper PNW-141.

Mendocino Redwood Company. Unpublished. “ Draft Noyo River watershed analysis.”

North Coast Regional Water Quality Control Board. 1994. *Water quality control plan for the North Coast region.* Adopted 9 December 1993. Santa Rosa, CA.

North Coast Regional Water Quality Control Board. 1999. *Analysis of sediment-related sources and water quality impacts in the Noyo River watershed.* Dated 23 August 1999.

O’Connor, Matthew, and Robert Ziemer. 1989. “Coarse woody debris ecology in a second-growth *Sequoia sempervirens* forest stream.” USDA Forest Service Gen. Tech. Rep. PSW-110.

Pacific Watershed Associates. 1998. “Sediment source investigation for the lower Eel River (draft).” Prepared for U.S. Environmental Protection Agency, San Francisco, CA. January 1998.

Pitlick, John. 1982. “Sediment routing in tributaries of Redwood Creek basin, Northwestern California, Redwood National Park, Arcata, California.”

Reid, Leslie. 1999. “Case Study #1.” In *Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop.* Co-sponsored by Fish, Farm, Forests, and Farm Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

Shirazi, M.A., W.K. Seim, and D.H. Lewis. 1981. “Characterization of spawning gravel and stream system evaluation.” In *Proceedings from the conference on salmon spawning gravel: a renewable resource in the Pacific Northwest.* Washington State University. Washington Water Research Center Report 39, Pullman. Pp. 227-278.

Stebbins, Beth. 1986. The Noyo. Bear and Stebbins. Mendocino, CA.

Surfleet, Christopher, and Robert Ziemer. 1996. “Effects of forest harvesting on large organic debris in coastal streams.” In *Proceedings of the Conference on Coast Redwood Forest Ecology & Management*, 18-20 June 1996. John LeBlanc, Technical Coordinator and Editor, U.C. Cooperative Extension, Forestry.

Trush, Bill. 1999. “Know your X’s and Y’s.” In *Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop.* Co-sponsored by Fish, Farm, Forests, and Farm Communities Forum; Simpson Timber Company; National Marine Fisheries Service; Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

USDA Forest Service. 1994. “Environmental assessment for the implementation of interim strategies for managing anadromous fish-producing watershed in eastern Oregon and Washington, Idaho, and portions of California.” Washington, D.C.

Valentine, Bradley E., and Marc Jameson. 1994. “Little North Fork Noyo Fishery Study, 1992.” California Department of Forestry and Fire Protection: Coast Cascade Region. Santa Rosa, CA.

Weaver, W.E., and D.K. Hagans. 1994. “Handbook for forest and ranch roads: a guide for planing, 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. 149 pages + appendices.

Ziemer, Robert. 1998. “Flooding and stormflows.” In *Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, May 6, 1998.* USDA Forest Service Gen. Tech. Rep. PSW-GTR-168. Pp. 15-24.

Zimmerman, R.C., J.C. Goodlet, and G.H. Comer, 1967. “The influence of vegetation on channel form of small streams. In *Symposium on river morphology*. International Association of Scientific Hydrology Publication 75, Wallingford, England.

GLOSSARY

Aggradation	To fill and raise the elevation of the stream channel by deposition of sediment.
Alternative prescriptions	Timber harvesting methods, including site-specific regeneration or intermediate treatment methods, that accomplish the goals of the Forest Practices Act in a more effective or more feasible way than the standard silvicultural methods.
Anadromous	Refers to aquatic species which migrate up rivers from the sea to breed in fresh water.
Areas of instability	Locations on the landscape where land forms are present which have the ability to discharge sediment to a watercourse.
Baseline data	Data derived from field-based monitoring or inventories used to characterize existing conditions and used to establish a database for planning or future comparisons.
Beneficial Use	Uses, as designated in the Basin Plan, of waters of the state that may be protected against quality degradation including, but not limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and the preservation and enhancement of fish, wildlife and other aquatic resources or preserves.
Basin Plan	The *Water Quality Control Plan, North Coast Region*-- *Region 1.*
Cable yarding	That system of skidding (transporting) logs by means of cable (wire rope) to the yarding machine (yarder) or a landing while the yarder remains stationary.
CDF	The California Department of Forestry and Fire Protection.
Controllable source	Any source of sediment with the potential to enter a water of the state which is caused by human activity and will respond to mitigation, restoration, or altered land management.
Debris torrents	Long stretches of bare, generally unstable stream channel banks scoured and eroded by the extremely rapid movement of water-laden debris, commonly caused by debris sliding or road stream crossing failure in the upper part of a drainage during a high intensity storm.
Deep seated landslide	Landslides involving deep regolith, weathered rock, and/or bedrock, as well as surficial soil. Deep seated landslides commonly include large (acres to hundreds of acres) slope features and are associated with geologic materials and structures.
DFG	The California Department of Fish and Game.
DMG	The California Department of Conservation, Division of Mines and Geology.
Drainage structure	A structure or facility constructed to control road runoff, including (but not limited to) fords, inside ditches, water bars, outsloping, rolling dips, culverts or ditch drains.
EPA	The United States Environmental Protection Agency.
Embeddedness	The degree that larger particles (boulders, rubble or gravel) are surrounded or covered by fine sediment. It is usually measured in classes (<25%, 25-50%, 50-75%, and >75%) according to percentage of random large particles that are covered by fine sediment.

Evenaged management	Timber harvesting techniques, including clearcut regeneration, seed tree regeneration, and shelterwood regeneration. In a clearcut, timber is removed in one harvest and regeneration is accomplished by direct seeding, planting, sprouting or by natural seed fall. In seed tree regeneration, timber is removed in one harvest; but, seed trees are left distributed throughout the harvest area for natural regeneration. In shelterwood regeneration, timber is removed in three harvests: the preparatory step improves crown development; the seed step promotes natural reproduction from seed; and the removal step removes timber, including the protective overstory trees.
Facility	For purposes of the target for disturbed area, a facility is defined as any management-related structure such as a road, railroad roadbed, skid trail, landing, harvest unit, animal holding pen, or agricultural field (e.g., pasture, vineyard, orchard, row crops). A harvest unit or agricultural field that retains its natural characteristics with respect to rainfall interception, rainfall infiltration, and soil protection, is not considered a facility.
Flooding	The overflowing of water onto land that is normally dry.
Fluvial erosion	Essentially synonymous with gully erosion, it includes: downcutting in roadside ditches, streams diverted out of culverts and through road fill as a result of plugged culverts, gullies resulting from "shot gun" culverts, etc.
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
GIS	Geographic Information System.
Grilse	A young salmon which returns early to fresh or brackish waters.
Habitat inventory	The identification of individual habitat units (e.g., pool, riffle, or flatwater) that are further defined by their origin and/or orientation (e.g., backwater pool, boulder-formed), as described by Flosi and Reynolds (1994). A basin-level habitat inventory is designed to produce a thorough description of the physical fish habitat.
HAA	Headwaters Assessment Area
Habitat length	The entire length of stream surveyed during a habitat inventory.
Inner gorge	A geomorphic feature formed by coalescing scars originating from mass wasting and erosional process caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream, having a slope generally over 65% and being situated below the first break in slope above the channel.
Inside ditch	The ditch on the inside of the road, usually at the foot of the cutbank.
Intermediate treatments	Timber harvesting techniques, including commercial thinning and sanitation salvage logging. Commercial thinning is the removal of trees in a young-growth stand to maintain or increase average stand diameter, promote timber growth, and/or improve forest health. Sanitation salvage logging is the removal of insect attacked or diseased trees in order to maintain or improve the health of the stand.
Landslide	Any mass movement process characterized by downslope transport of soil and rock, under gravitational stress by sliding over a discrete failure surface-- or the resultant landform.
Large woody debris	A piece of woody material having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) located in a position where it may enter the watercourse channel.

MAA	Mainstem Noyo River Assessment Area.
Mass wasting	Downslope movement of soil mass under force of gravity-- often used synonymously with "landslide." Common types if mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents.
NFAA	North Fork Noyo River Assessment Area.
Numeric targets	A numerical expression of the desired in-stream or hillslope environment. For each pollutant or stressor addressed in the problem statement, a numeric target is developed.
Permanent drainage structure	A road drainage structure designed and constructed to remain in place following active land management activities while allowing year round access on a road.
Permanent road	A road planned and constructed to be part of a permanent all-season transportation facility. These roads have drainage structures, if any, at watercourse crossings that accommodate the fifty-year flood flow and have a surface that is suitable for hauling forest products throughout the winter period. Normally they are maintained during the winter period.
Planning Watershed	The uniform designation and boundaries of sub-basins within a larger watershed. These watersheds are described by CDF as Cal Water Watersheds.
Redd	A gravel nest or depression in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and incubated.
Regional Water Board	Regional Water Quality Control Board, North Coast Region.
Seasonal road	A road planned and constructed as part of a permanent transportation facility; but has a surface adequate for hauling forest products only in non-winter periods and extended dry periods or hard frozen conditions occurring during the winter period. It has drainage structures, if any, at watercourse crossings that will accommodate the fifty-year flood flow. Some maintenance usually is required.
Sediment	Fragmented material that originates from weathering of rocks and decomposed organic material that is transported by, suspended in, and eventually deposited by water or air.
Sediment budget	An accounting of the sources, movement, storage and deposition of sediment produced by a variety of erosional processes, from its origin to its exit from a basin.
Sediment delivery	Material (usually referring to sediment) which is delivered to a watercourse channel by wind, water or direct placement.
Sediment discharge	The mass or volume of sediment (usually mass) passing a watercourse transect in a unit of time.
Sediment erosion	The group of processes whereby sediment (earthen or rock material) is loosened, dissolved and removed from the landscape surface. It includes weathering, solubilization and transportation.
Sediment source	The physical location on the landscape where earthen material resides which has or may have the ability to discharge into a watercourse.

Sediment yield	The sediment yield consists of dissolved, suspended and bed loads of a watercourse channel through a given cross section in a given period of time.
SFAA	South Fork Noyo River Assessment Area.
Shallow seated	A landslide produced by failure of the soil mantle on a steep slope (typically to a depth of one or two meters; sometimes includes some weathered bedrock). It includes debris slides, soil slips and failure of road cut-slopes and sidecast. The debris moves quickly (commonly breaking up and developing into a debris flow) leaving an elongated, concave scar.
SHALSTAB	A coupled, steady-state runoff and infinite-slope stability model that can be used to map the relative potential for shallow landsliding across a landscape.
Skid trail	Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.
Smolt	A young salmon at the stage at which it migrates from fresh water to the sea.
Special prescriptions	Timber harvesting techniques, including: (1) site-specific treatments for special areas such as ecological reserves, historical sites, or archaeological sites and (2) the rehabilitation of understocked areas. Rehabilitation includes the harvesting of an understocked area and subsequent restocking to meet stocking standards.
Steep slope	A hillslope, generally greater than 50% that leads without a significant break in slope to a watercourse. A significant break in slope is one that is wide enough to allow the deposition of sediment carried by runoff prior to reaching the downslope watercourse.
Stream	See watercourse.
Stream class	The classification of waters of the state, based on beneficial uses, as required by the Department of Forestry in Timber Harvest Plan development. See definitions for Class I, Class II, Class III, and Class IV for more specific definitions.
Stream order	The designation (1,2,3, etc.) of the relative position of stream segments in the drainage basin network. For example, a first order stream is the smallest, unbranched, perennial tributary which terminates at the upper point. A second order stream is formed when two first order streams join. Etc.
Sub-basin	A subset or division of a watershed into smaller hydrologically meaningful Watersheds. For example, the North Fork Noyo River watershed is a sub-basin of the larger Noyo River watershed.
Swale	A channel-like linear depression or low spot on a hillslope which rarely carries runoff except during extreme rainfall events. Some swales may no longer carry surface flow under the present climatic conditions.
Tail-out	The lower end of a pool where flow from the pool, in low flow conditions, discharges into the next habitat unit.
Temporary road	A road that is to be used only during the timber operation. It must have a surface adequate for seasonal logging use and have drainage structures, if any, adequate to carry the anticipated flow of water during the period of use.

Thalweg	The deepest part of a stream channel at any given cross section.
Thalweg profile	Change in elevation of the thalweg as surveyed in an upstream-downstream direction against a fixed elevation.
THP	Timber harvest plan.
TMDL	Total Maximum Daily Load.
Tractor yarding	That system of skidding (transporting) logs by a self-propelled vehicle, generally by dragging the logs with a grapple or chokers.
Transition regeneration	Timber harvesting method used to create an unevenaged stand from a stand with an unbalanced, irregular or evenaged structure.
USGS	The United States Geological Survey.
Unevenaged management	Timber harvesting techniques whose attributes include the establishment and/or maintenance of a multi-aged, balanced stand structure, promotion of growth on leave trees throughout a broad range of diameter classes, and encouragement of natural reproduction. Unevenaged management techniques include the selection regeneration method and transition regeneration method. In the selection method, trees are removed individually or in small groups sized from 0.25 to 2.5 acres. The transition method is used to create an unevenaged stand from a stand with an unbalanced, irregular or evenaged structure.
Unstable areas	Characterized by slide areas, gullies, eroding stream banks, or unstable soils. Slide areas include shallow and deep seated landslides, debris flows, debris slides, debris torrents, earthflows and inner gorges and hummocky ground. Unstable soils include unconsolidated, non-cohesive soils and colluvial debris.
V*	A numerical value which represents the proportion of fine sediment that occupies the scoured residual volume of a pool. Pronounced "V-star."
Watercourse	Any well-defined channel with a distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil.
Waters of the state	Any ground or surface water, including saline water, within the boundaries of the state.
Watershed	Total land area draining to any point in a watercourse, as measured on a map, aerial photo or other horizontal plane. Also called a basin, drainage area, or catchment area.
Water quality criteria	Limits or level of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.
Water quality objective	Water quality criteria as described in the Basin Plan.
Water quality standard	Consist of the beneficial uses of water and the water quality objectives as described in the Basin Plan.
Water Year	An annual period used to record rainfall, beginning on 1October and ending on 30 September of the following year. For example, Water Year 1999 began on 1 October 1998 and ended 30 September 1999.