California Regional Water Quality Control Board
San Francisco Bay Region

Napa River Sediment Total Maximum Daily Load

Staff Report

Michael Napolitano
Sandia Potter
Dyan Whyte

June 30, 2006

California Regional Water Quality Control Board, San Francisco Bay Region
1515 Clay Street, Suite 1400
Oakland, CA 94612

Cover Photo: Napa River near St. Helena
Photo by: Stillwater Sciences, Inc.

ACKNOWLEDGEMENTS

Martin Trso, working as a contractor to the University of California at Berkeley (UCB), Department of Earth and Planetary Sciences, was the lead investigator for the sediment source analysis presented herein (Chapter 3). Jeremy Thomas and Matt Deitch, graduate students at UCB, collected much of the field data used to develop the source assessment. Professor Bill Dietrich at UCB provided critical guidance and review of the study plan, interim products, and results of the source assessment.

Rafael Real de Asua, Stillwater Sciences, Inc., and Dino Bellugi and Douglas Allen at UCB, developed the channel and reservoir maps and GIS layers that were essential to the development of the source assessment. This work was funded in part by a CALFED Watershed Program Grant.

Many individuals provided ideas and insights that improved the quality of our report. We offer our special thanks to: Todd Adams, Phillip Blake, Richard Camera, Laurel Collins, Andrew Collison, Joe Dillon, Charles Dewberry, Volker Eisele, Leslie Ferguson, Richard Fitzgerald, Tom Gamble, David Garden, David Graves, Robin Grossinger, Bill Grummer, Linda Hanson, Ellie Insley, Rainer Hoenicke, Lee Hudson, Paul Jones, Jonathan Koehler, Kallie Kull, Robert Leidy, Jim Lincoln, Frank Ligon, Laurel Marcus, Greg Martinelli, Bryan McFaddin, Austin McInerny, Lester McKee, Matt O'Connor, Sarah Pierce, Davie Pina, Don Ridenhour, James Robbins, Leigh Sharp, Dave Steiner, Gary Stern, Gail Seymour, Jeremy Thomas, John Tuteur, Eileen Weppner, and Robert Zlomke.

We thank the staff of the Napa County Resource Conservation District and Napa County Office of the US Natural Resources Conservation Service for sharing results of their recent and ongoing investigations of sediment, water quality, and fisheries in the watershed, and for allowing us to review historical aerial photographs and channel cross-sections of the Napa River in their collection.

We also express our thanks to all of the landowners who provided us with permission for access for this study. A clearer and more representative picture of the watershed was produced as a result of your assistance and involvement.

CONTENTS

Chapter 1: Introduction 1
1.1. Background 1
1.2. Document Organization 4

Chapter 2: Problem Statement 5
2.1. Summary 5
2.2. Detailed Problem Statement 8

Chapter 3: Source Analysis 12
3.1. Introduction 12
3.2 Key Attributes that Influence Sediment Input into Napa River and its Tributaries 15
3.3 Definition and Delineation of Terrain Types 18
3.4 Approach to Measurement of Sediment Input to Channels 21
3.5 Tributary and Mainstem Study Areas 29
3.6 Findings 37

Chapter 4: Water Quality Standards and Numeric Targets for Sediment 54
4.1. Introduction 54
4.2. Streambed Scour 55
4.3. Streambed Permeability 58

Chapter 5. Linkage Analysis and Allocations 63
5.1. Introduction 63
5.2. Approach 63
5.3. Allocations 65
5.4. Margin of Safety 66
5.5. Seasonal Variation and Critical Conditions 67

Chapter 6. Implementation Plan 68
6.1. Introduction 68
6.2. Key Considerations 69
6.3. Legal Authority and Requirements 71
6.4. Implementation Strategy 71
6.5. Approaches to Achieve Allocations 73
6.6 Habitat Enhancement Plan 79

Chapter 7. Regulatory Analyses 86
7.1. Overview 86
7.2. Environmental Checklist 86
7.3. Alternatives 110
7.4. Economic Considerations 113
7.5. Agricultural Water Quality Program Costs 119
7.6. Sources of Funding 121

References......122

List of Figures and Tables

Figures

1. Relationship Between Fine Sediment Deposition and Streambed Permeability 13
2. Channel Incision Between 1940 and 1998 in the Napa River at Soda Creek......14
3. Gully Formed by Discharge of Concentrated Runoff from Hillside Vineyard 17
4. Rills and Gullies on a Compacted Dirt Road......18
5. Ground Surface Topography in Milliken Canyon 30
6. Alternating Boulder Step and Pool Bedforms in Upper Milliken Creek......31
7. Ground Surface Topography in Carneros Creek Watershed 33
8. Extensive Bank Erosion and Deep Entrenchment Along Mainstem Carneros Creek......34
9. Step-Pool and Cascade Reaches Along Ritchie Creek 35
10. Sulphur Creek in its Headwaters......36
11. Plane-Bed Reach of Sulphur Creek 36
12. Streambed Permeability Is a Function of Sediment Supply and Transport......38
13. Sediment Input into Channels in Milliken Creek Watershed (1994-2004) 49
14. Sediment Input into Channels in the Carneros Creek Watershed (1994-2004)......49
15. Sediment input into Channels in the Ritchie Creek and Sulphur Creek Watersheds (1994-2004)......50
16. Total versus Natural Sediment Input Rate to Channels Tallied at Four Locations Along Napa River......51
17. Influence of Sediment Supply on Streambed Scour at Spawning Sites (Redds)......58

Tables

1. Water Quality Objectives and Sediment-Related Beneficial Uses......6
2. Terrain Types Defined Based on Predicted Sediment Supply......20
3. Upland Measurement Sites 22
4. Terrain Type Sediment Size Distribution 27
5. Sediment Supply from Upland Terrain Types......39
6. Sediment Supply from Channel Incision......45
7. Mean Annual Sediment Delivery to Napa River at Soda Creek (1994-2004)......53
8. Streambed Permeability Measurements......60
9. Total Maximum Daily Load and Load and Wasteload Allocations 66
10. Implementation Actions Subject to Environmental Review......100
11. Cost Estimates for Napa River Sediment Reduction and Habitat Enhancement......115
12. Cost Estimates for Control of Road-related Erosion 116
13. Cost Estimates forAdditional Stormwater Runoff Program Measures......117
14. Cost Estimates for Implementation Measures to Control Surface Erosion in Pastures 118
15. Cost Estimates for Erosion Control and Prevention in Unstable Areas......119
16. Agricultural Water Quality Control Program Costs 120

CHAPTER 1: INTRODUCTION

Key Points

- Section 303(d) of the Clean Water Act requires states to compile a list of "impaired" water bodies that do not meet water quality standards.
- In 1990, the Water Board listed Napa River as impaired by sedimentation based on evidence of widespread erosion, and concerns regarding adverse impacts to fish.
- This report contains Water Board staff analyses and findings pertaining to sediment impairment in the Napa River.

We prepared this report to provide an opportunity for interested parties to comment on the scientific basis for the TMDL, and to provide a framework for discussion of implementation actions that may be needed to resolve sediment impairment and enhance steelhead and salmon populations within Napa River watershed. Prior to considering any changes in regulatory policy, we plan to present and discuss the proposed TMDL during upcoming public meetings. We expect the proposed regulatory policy to be improved as a result of the knowledge and involvement of the stakeholders of the Napa River watershed.

1.1 Background

In 1967, the California Legislature established the State Water Resources Control Board (State Board), and the nine Regional Water Quality Control Boards (Regional Boards) to regulate and protect water resources for the use and enjoyment of the people of the state. The State Board administers water rights, water pollution control, and water quality functions as part of the California Environmental Protection Agency. The State Board provides guidance to the Regional Boards, which conduct regulatory planning, permitting, and enforcement activities to protect water resources from pollution. Water pollution control regulatory authorities of the State Board and the Regional Boards are shared and derived from the state Porter-Cologne Act and federal Clean Water Act. The California Regional Water Quality Control Board, San Francisco Bay Region (Water Board) regulates surface and groundwater quality throughout the Bay Area including Napa River and its tributaries. By law, the Water Board is required to develop, adopt, and implement a Water Quality Control Plan (Basin Plan) for the San Francisco Bay region. The Basin Plan specifies and describes:

- Designated beneficial uses of water
- Water quality objectives, which are parameters that can be evaluated to determine whether the designated beneficial uses are protected
- Implementation plans and policies to protect water quality

Designated beneficial uses of water for the Napa River include the following:

- Water supply (agricultural, municipal, and domestic)
- Recreation (fishing, swimming, boating, etc.)
- Navigation
- Fish migration and spawning
- Cold and warm freshwater habitats
- Wildlife habitat
- Preservation of rare and endangered species

Beneficial uses adversely affected by excess sediment in the Napa River are recreation (i.e., fishing), cold freshwater habitat, fish spawning, and preservation of rare and endangered species.

As designated in the federal Clean Water Act, the State Board and the Regional Boards share several water pollution control responsibilities, including establishment of ambient water quality standards. Ambient water quality standards include beneficial use protection and water quality objectives (described above), and an anti-degradation policy. The anti-degradation policy requires that where water quality is better than needed to protect beneficial uses, that such superior water quality be maintained. Furthermore, Section 303(d) of the Clean Water Act also requires biennial assessments to determine whether ambient water quality standards are being achieved in individual water bodies throughout the United States.

In 1990, based on evidence of widespread erosion and concern regarding adverse impacts to fish habitat, the Water Board listed the Napa River as impaired by sedimentation. The primary impetus for listing was a concern regarding substantial decline since the 1940s in abundance and distribution of steelhead and salmon in the Napa River and its tributaries. As a result of the sediment impairment listing, the Water Board is required to prepare a total maximum daily load (TMDL). A TMDL involves development of a pollutant budget and a control plan to restore the health of a polluted water body. Key components of a TMDL include the following:

- Problem statement
- (Pollutant) Source analysis
- Numeric targets (e.g., specification of water quality parameter[s] that can be measured to evaluate attainment of water quality standards)
- Linkage analysis (between pollutant sources and numeric targets)
- Pollutant load allocations
- Implementation plan (to attain and maintain water quality standards)
- Monitoring plan (to evaluate progress in achieving pollutant allocations and numeric targets)

To improve understanding of the significance of sediment pollution relative to other factors that may be limiting steelhead and salmon populations, the Water Board partnered with the State Coastal Conservancy to fund the *Napa River Basin Limiting Factors Analysis* (Stillwater

Sciences and Dietrich, 2002). The limiting factors analysis documented two adverse impacts of erosion and sedimentation on salmon and steelhead habitat:

- Low permeability values indicating a high concentration of fine sediment in the streambed
- Channel incision in mainstem Napa River

Channel incision, which occurs in Napa River and lower reaches of its tributaries, has greatly reduced the quantity and quality of spawning and rearing habitat for salmon, and appears to be the most important factor limiting Chinook salmon reproductive success and smolt survival under current conditions (Stillwater Sciences and Dietrich, 2002). High concentrations of fine sediment deposited in the streambed at potential spawning and rearing sites for salmon and/or steelhead in Napa River and its tributaries causes high rates of egg and larval mortality during incubation, and also degrade the quality of juvenile rearing habitat for steelhead and salmon. Increases in the amount of fine sediment deposited in the streambed are contributing to the decline of what appears to be a very small run of steelhead. Other factors including poor flow persistence during the dry season and poor habitat access appear to be the most important factors that limit steelhead productivity and survival in the Napa River watershed at present (Stillwater Sciences, 2002). We conclude that progress towards resolution of all factors limiting steelhead productivity and survival in the Napa River watershed is needed to conserve and recover steelhead populations. Therefore, we recommend actions to reduce sediment supply, and protect or enhance baseflow, stream temperature, habitat complexity, and fish passage as elements of the implementation plan that is presented in Chapter 6.

1.2 Document Organization

Chapter 1. Introduction. Provides background regarding the responsibilities of the Water Board, the TMDL program, and the problems of sediment and other limiting factors. The introduction also describes the purpose of the draft technical report, and outlines subsequent steps in the TMDL process.

Chapter 2. Problem Statement. Describes the relationships between the identified pollutant (sediment), applicable water quality objectives and beneficial uses, and current water quality conditions in Napa River and it is tributaries. The problem statement also describes factors limiting steelhead run-size in the Napa River watershed.

Chapter 3. Sediment Source Analysis. Presents the approach, methods, and results of the sediment source analysis

Chapter 4. Numeric Targets. Presents the rationale to support proposed water quality parameters and numeric targets, and their relation to the attainment of applicable water quality standards

Chapter 5. Linkage Analysis and Allocations. Describes hypothesized linkages between sediment loads and habitat conditions, and therefore provides the rationale for estimating the assimilative capacity for sediment in the Napa River. Allocations are amounts of sediment allocated to each source category, including a margin of safety to account for uncertainty in estimating loads and assimilative capacity, and allowance for future growth.

Chapter 6. Implementation Plan. Discusses actions needed to attain water quality standards for sediment and to protect and/or enhance other stream habitat conditions and includes a monitoring plan.

Chapter 7. Regulatory Analysis. Contains legally required analyses of potential environmental impacts and costs that may be associated with the adoption of the proposed Basin Plan amendment.

CHAPTER 2: PROBLEM STATEMENT

Key Points

- Fine sediment clogs spawning gravels and degrades rearing habitat contributing to decline of salmon and steelhead in the Napa River watershed.
- Channel incision is the key factor in the decline of Chinook salmon.
- Channel incision is a controllable water quality factor.
- Low summer base flow and poor habitat access appear to be the most important factors in the decline of steelhead.
- The Water Board is obligated under the Clean Water Act to develop a sediment TMDL for the Napa River.

2.1 Summary

The TMDL problem statement describes the relationships between the identified pollutant (sediment), applicable water quality standards, and current water quality conditions in the Napa River. Water quality standards are composed of three parts:

- A statement of designated uses for a specified body of water (beneficial uses)
- One or more water quality parameters that can be evaluated to determine whether beneficial uses are protected (water quality objectives)
- An anti-degradation policy, which requires that where water quality is better than needed to protect beneficial uses, those superior water quality conditions must be maintained

Water quality standards for the Napa River and its tributaries are specified in the Water Quality Control Plan for the San Francisco Bay Basin (Water Board, 1995). Water quality objectives related to sediment and aquatic life and relevant beneficial uses are listed in Table 1.

Table 1. Water Quality Objectives and Sediment-Related Beneficial Uses		
Beneficial Uses	**Water Quality Objectives**	
Cold Freshwater Habitat Fish Migration Preservation of Rare and Endangered Species[1] Fish Spawning Warm Freshwater Habitat Wildlife Habitat Recreation	Turbidity	Increase from background <10% where natural turbidity is >50 NTU*
	Sediment	Should not cause a nuisance or adversely affect beneficial uses
	Settleable Material	Should not cause a nuisance or adversely affect beneficial uses
	Suspended Material	Should not cause a nuisance or adversely affect beneficial uses
Cold Freshwater Habitat Fish Migration Preservation of Rare and Endangered Species Fish Spawning	**Population And Community Ecology**	The health and life history characteristics of aquatic organisms in water affected by controllable water quality factors shall not differ significantly from those for the same waters on areas unaffected by controllable water quality factors
Note: Bold text indicates water quality objective is not being attained. *NTU Nephelometric Turbidity Unit		

With regard to the problem of sediment in Napa River, we find that:

- Populations of steelhead and salmon in the Napa River and its tributaries have declined substantially since the late 1940s (USFWS, 1968; Leidy et al., 2003).

- There is evidence of accelerated erosion and sedimentation in the Napa River and its tributaries (Soils Conservation Service, 1985; White, 1985; WET, 1990; and Stillwater Sciences and Dietrich, 2002).

- The problem of sediment is expressed by high concentrations of fine sediment deposited in the streambed at potential spawning and rearing sites for steelhead and salmon[2]. Excess fine sediment in the streambed can cause poor incubation conditions for fish eggs,

[1] Preservation of rare and endangered species listed under state or federal law as rare, threatened, or endangered. Steelhead within the Central California Coast, including the Napa River and its tributaries, are listed as threatened under the federal Endangered Species Act (ESA). Fall-run Chinook salmon in the Napa River are not listed as threatened or endangered under the state or federal ESA, however, they are rare in Bay Area streams. California freshwater shrimp have been found in the Napa River and a few of its tributaries. These shrimp are federally listed as endangered species.

[2] Adverse impacts may include: a) reduction in biomass of aquatic insect prey species that provide food for juvenile steelhead and salmon; and b) significant reduction in quality of winter rearing habitat for juvenile steelhead, which use the open spaces between clusters of cobbles and boulders as winter refuge from predators and high flows.

resulting in high mortality prior to emergence. When large amounts of fine sediment are deposited, the streambed is also more vulnerable to deep scour during storms, which can wash away eggs and thereby further reduce survival during incubation. High concentration of fine sediment in the streambed also decreases the growth and survival of juvenile salmon and steelhead.

- Rapid and active channel incision, or downcutting, in mainstem Napa River and its lower tributary reaches and associated rapid and intensive erosion of stream terrace banks are causing significant adverse changes to salmon habitat and are a significant sources of fine sediment in the Napa River (Stillwater Sciences and Dietrich, 2002). The discharge of sediment and the process of channel incision are occurring, in part due to controllable water quality factors.[3]

Regarding sediment impairment we conclude that the narrative water quality objectives for sediment and settleable material are violated because large amounts of fine sediment are deposited in the streambed with significant adverse affects to cold freshwater habitat, wildlife habitat, fish spawning, recreation, and preservation of rare and endangered species beneficial uses. We find that channel incision harms physical habitat structure of the river by reducing the quantity of gravel bars, riffles, side channels, and sloughs, which threatens Chinook salmon, and other fish and aquatic wildlife species (Stillwater Sciences and Dietrich, 2002). Channel incision is a controllable water quality factor that results in a violation of the narrative water quality objective for population and community ecology (Table 1).

We have prepared a total maximum daily load (TMDL) for sediment in Napa River to quantify the impact of excess erosion and sedimentation on fish populations and to develop an implementation plan to achieve sediment-related water quality objectives to resolve threats to Chinook salmon and steelhead. Resolution of sediment impairment in Napa River watershed is one of several factors that need to be addressed to conserve and enhance the size of the steelhead run. Other factors include the following:

- Poor baseflow persistence occurring in combination with stressful water temperatures that appear to severely limit the growth of juvenile steelhead

- Poor access to-and-from potential spawning and rearing habitat, as a result of human structures in channels and water uses that directly or indirectly block or impede migration by adult and/or juvenile fish

- Habitat simplification, as a result of a reduction in the amount of large woody debris in the channels (Stillwater Sciences and Dietrich, 2002)

In the implementation plan (Chapter 6), we present actions that are recommended to address all of the above stressors on growth and survival of steelhead and salmon in Napa River watershed.

[3] Controllable water quality factors are those actions, conditions, or circumstances resulting from human activities that may influence the quality of the waters of the state and that may be reasonably treated.

2.2 Detailed Problem Statement

We reviewed available information to conclude that there has been a significant decline in the distribution and abundance of steelhead and coho salmon in the Napa River and its tributaries since the late 1940s (U.S. Fish and Wildlife Service, 1968; Anderson, 1969; and Leidy, 2003). The U.S. Fish and Wildlife Service (1968) estimates that the Napa River watershed once supported runs of 6,000–8,000 steelhead, and 2,000–4,000 coho salmon, and that by the late 1960s, coho salmon were extinct in the watershed, and the steelhead run had reduced to about 1,000 adults.[3] At present, the steelhead run is estimated at less than a few hundred adults (Emig and Rugg, pers. com., 2000 and Leidy et al., 2003).

Much less information is available to evaluate status and trends in population of Chinook salmon in Napa River. We are not aware of any historical research that has been conducted to determine whether Chinook salmon are native to Napa River. However, recent studies in Sonoma and Putah creeks, which border Napa River, document the historical occurrence of native fall-runs of Chinook salmon in both streams (Dawson, 2002 and Yoshiyama et al., 2000). These streams have flow regimes that are similar to Napa River, and up until recent decades, Sonoma, Putah, and Napa all had gravel-beds and bar-pool channels that could have provided abundant spawning and rearing habitat for Chinook salmon. Considering the above information, we conclude that it is likely that the Napa River also supported a native fall-run of Chinook salmon. In recent years, we estimate that a few hundred or more Chinook salmon spawned in the Napa River.[4]

In 1990, based on evidence of widespread erosion (USDA Soil Conservation Service, 1985; White, 1985) and the resulting threat to fish habitat (Cordone and Kelly, 1961), the Water Board listed the Napa River as impaired by sedimentation. The primary impetus for listing was concern regarding the decline since the 1940s in abundance and distribution of steelhead trout.

To improve understanding of current fisheries habitat conditions and the significance of sediment pollution relative to other factors that may be limiting populations of steelhead and salmon, the Water Board partnered with the State Coastal Conservancy to provide funding for the *Napa River Basin Limiting Factors Analysis* (Stillwater Sciences and Dietrich, 2002). The limiting factors study documented two adverse impacts of sediment pollution on steelhead and salmon habitat. The first impact is due to a high concentration of fine sediment deposited in the streambed, which adversely affects spawning and rearing habitat for both species. The second impact is due to channel incision, which occurs primarily in the mainstem and lower tributaries and affects Chinook salmon to a much greater extent (because most steelhead spawn further upstream in the tributaries). These sediment-related impacts are discussed below:

- Documentation of low permeability values at potential spawning sites for salmon indicates a high concentration of fine sediment in the streambed. Successful salmon and steelhead reproduction depends on adequate water flow through gravel in order for eggs

[3] Similarly, Anderson (1969) estimated that the steelhead run in the Napa River watershed numbered 1,000 to 2,000 in the late 1960s.
[4] The Napa County RCD conducted formal surveys to estimate number of adult Chinook salmon entering the river to spawn, and to estimate number of spawning sites. These surveys were conducted in November and December of 2004 within a three-mile long reach of the mainstem near Rutherford (J. Koehler, unpublished data). During the fall–winter of 2004, Napa County RCD documented over 100 adult salmon in the Rutherford sub-reach.

to hatch and larvae to grow. If fine sediment clogs the gravels, flow is very slow, egg mortality can be very high, and few young fish (fry) may emerge from the streambed. Low gravel permeability is predicted to cause high rates of mortality between spawning and emergence at potential spawning sites in Napa River and its tributaries.

- High concentration of fine sediment in the streambed also can cause significant decreases in growth and survival of juvenile salmonids during freshwater rearing by reducing availability of vulnerable prey species and increasing activity level, aggressive behavior, and attacks between juvenile salmonids (Suttle et al., 2004).

- Juvenile steelhead use open spaces between clusters of large cobbles and/or boulders as winter refuges from predators and high flows (Hartman, 1965; Chapman and Bjorn, 1969; and Meyer and Griffith, 1997). As the concentration of fine sediment in streambed increases, quality of winter rearing habitat is significantly diminished with consequent adverse impacts to survival.

- Scour of spawning gravel during commonly occurring peak flows (e.g., bankfull) can be a significant source of mortality to incubating eggs and larvae of salmon and trout species (McNeil, 1966; Montgomery et al., 1996). Human actions that increase rate of sediment supply, and/or cause it to become finer, will cause the streambed to become finer, facilitating an increase in mean depth and/or spatial extent of scour (Carling, 1987).

- Active and rapid channel incision in mainstem Napa River and lower reaches of its major tributaries has greatly reduced quantity of gravel bars, riffles, side channels, and sloughs, and has greatly decreased frequency of inundation of adjacent flood plains. These features and processes provide essential spawning and juvenile rearing habitat for Chinook salmon, which reside primarily in the mainstem Napa River. Therefore, channel incision appears to be a key factor limiting Chinook salmon run size. Channel incision, and associated bank erosion in areas underlain by thick alluvial deposits, also appears to be a significant source of sediment delivery to Napa River.

In addition to the threat high concentrations of fine sediment in the streambed pose to fish populations, the Limiting Factors Analysis identified other factors that are critically important to the health of steelhead populations. Each of the following stressors can adversely affect steelhead growth and survival in Napa River watershed:

Habitat Access: A large number of structures (dams, road crossings, weirs, etc.) have been constructed in Napa River tributaries (Dietrich et al., 2004). Many of these structures present direct or indirect (e.g., flow-related) barriers and/or impediments to adult steelhead spawning migration into the tributaries and/or the migration of juvenile steelhead (smolts) out of the tributaries on their journey to rear in the ocean.

Physical Habitat Structure: The occurrence and frequency of deep pools in Napa River tributaries has decreased during the historical period. Deep pools with good cover provide high quality holding habitat for adult steelhead during their spawning migrations, essential summer habitat for older juvenile steelhead, and may also provide important winter high-flow refuge habitat for older juvenile steelhead. The number of older and/or larger, juvenile steelhead that can be produced is quite important because there is a strong relationship between size of juvenile steelhead (smolts) when they migrate to the ocean, and proportion that successfully return to spawn. This is because larger fish are better able to evade predators and to survive the long migration to the ocean. Pools appear to be less frequent in tributaries than we would expect to have occurred under historical conditions, when large woody debris would have created obstructions in the channels and caused deep pools (with good cover) to be formed. The amount of large wood in channels also appears to be low when compared to similar streams draining watersheds covered by mixed evergreen forests. Large wood is a primary agent for the formation of deep pools, complex cover, and retention of spawning gravels in channels that provide significant amounts of potential habitat for steelhead. Habitat in tributary streams draining mixed evergreen forests, primarily those located on the west side of the watershed and those draining Howell Mountain, have been simplified as a result of a reduction in amount of large wood in the channels (Stillwater Sciences and Dietrich, 2002).

Low Summer Flow and Elevated Temperature: Typical summer water temperatures in tributaries[5] are stressful to juvenile steelhead and flow persistence over riffles is poor. Low or no flow over riffles greatly reduces the supply of drifting aquatic insects produced in riffles, which typically provide the primary source of food for juvenile steelhead. Poor baseflow persistence and stressful water temperatures act in a synergistic fashion, and appear to severely limit growth of juvenile steelhead during the summer months. Reduction in growth rate is important because smaller juvenile trout experience much higher rates of mortality during all phases of freshwater rearing, ocean migration, and during ocean rearing life stages. Therefore, poor juvenile growth rate during the summer in the freshwater environment has the potential to greatly reduce the number of adult steelhead that ultimately return from the ocean to spawn in the Napa River watershed[6].

Following completion of the *Napa River Basin Limiting Factors Analysis*, University of California, Berkeley, in partnership with the University of Florida and with the assistance of Napa County, developed a high-resolution digital topographic map to accurately map the locations and extent of channels and reservoirs throughout the Napa River watershed. Dietrich et al. (2004) identified over 1,000 dams within the watershed, over 400 of which are located on tributary channels that drain approximately 30 percent of the total land area (Map 1). These dams exert a significant influence on routing of physical products (water, heat, nutrients, sediment, and wood), and the movement of fish and aquatic wildlife through channels in the Napa River

[5] As part of the Limiting factors analysis, stream temperatures were continuously monitored from early August 2000 through early October 2001 at 22 sites in 13 tributaries, and 5 sites in 3 reaches of mainstem Napa River. Typical daily average temperatures during summer were between 59-68°F. Temperature data and analysis are presented in *Napa River Basin Limiting Factors Analysis* (Stillwater Sciences and Dietrich, 2002).

[6] We have not determined the extent to which poor baseflow persistence can be explained by natural conditions versus human water uses. However, considering the ecological significance of reduction in growth rate, follow-up research is now in progress to confirm whether poor summer growth is a spatially extensive phenomena in some or all water year types, and whether poor summer growth can be offset by high rates of growth during the spring and fall. These studies will be completed by the fall of 2006.

watershed[7]. Because dams capture all of the coarse sediment delivered to channels above dams (and some of the fine sediment), it likely that dams are affecting or influencing the channel incision and associated bank erosion that has been documented in the mainstem of the Napa River and along the lower reaches of its tributaries.

Based on the results of the *Napa River Basin Limiting Factors Analysis* and the other sources cited above, we conclude that the narrative water quality standards for sediment, settleable material, and for population and community ecology are not attained as a result of erosion and sedimentation in the Napa River and its tributaries. As such we are required to develop a total maximum daily load (TMDL) for sediment.

In Chapter 3, we present the sediment source analysis to further refine our description of current channel conditions with regard to erosion and sedimentation, and to address the following sediment-related questions:

- What are the relationships between sediment input to channels, channel sediment transport capacity, and streambed permeability values in Napa River and its tributaries?

- How important are natural processes and human alteration of the land with regard to input of fine sediment to channels?

- Is channel incision and associated bank erosion, a large source of sediment input to channels? How do this source compare/rank in relation to other natural and human generated (anthropogenic) sediment sources?

[7] Because most on-channel dams are upstream of natural limits of steelhead spawning, only a small percentage of the dams are direct structural barriers to steelhead migration. However, considering the large number of dams and large percentage of watershed draining into reservoirs, it appears that dams may exert significant indirect influence(s) on steelhead and salmon migration through a reduction in baseflow magnitude and/or duration downstream of the dams in some tributaries and/or reaches of mainstem Napa River.

CHAPTER 3: SOURCE ANALYSIS

Key Points

- Sediment loads vary depending on geologic terrain, land uses, and dams.
- More than half of all sediment delivered to channels comes from roads, erosion of the bed and banks of Napa River and lower tributary reaches, vineyards, and intensive historical grazing.
- 30 percent of the watershed drains into dams, capturing a significant fraction of all sediment input to channels, nevertheless fine sediment load remains substantially elevated in Napa River.
- In addition to being a significant sediment source, erosion of the river's bed and banks is degrading aquatic habitat.

3.1 Introduction

This section identifies sediment sources linked to: 1) the high concentration of fine sediment in the streambed (Figure 1); 2) active-and-rapid incision of mainstem Napa River and lower reaches of its tributaries, which causes significant degradation of physical habitat structure and also appears to be a significant sediment source (Figure 2). The problems of high concentrations of fine sediment in the streambed and channel incision are described in detail in the problem statement and numeric targets chapters.

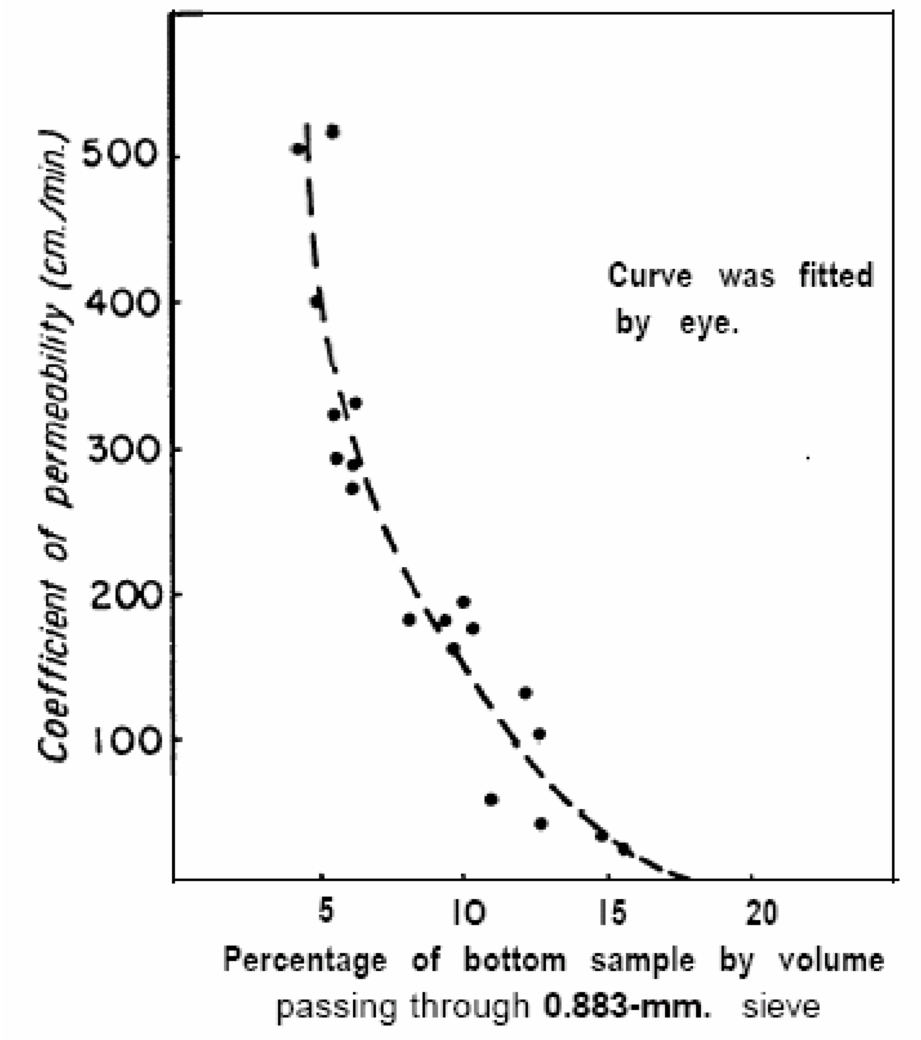
A TMDL must identify pollutant source categories and estimated loads associated with each source. We used a "rapid sediment budget approach" to identify significant processes that deliver sediment to Napa River and its tributaries, and to estimates rates and sizes of sediment input to the channel network during the most recent decade.[8] Reid and Dunne (1996) define a sediment budget as follows:

> "A sediment budget is an accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin."

We chose the most recent decade (1994–2004) as our measurement period because it follows enactment of Napa County's Hillside Conservation Regulations and therefore reflects current land use practices. Complicating the analysis of sediment inputs to Napa River and its tributaries is the occurrence of over 400 dams located on tributaries to the Napa River (Dietrich et al., 2004; Maps 1 and 2). Considerable effort was expended by scientists at Stillwater Sciences and UC Berkeley to map locations of dams in relation to the channel network, which we then used to

[8] A rapid sediment budget is a measurement technique that can be performed over a short period of time to provide approximate estimates of rates and sizes of sediment input to channels. Estimated rates are expected to be within a factor of two of actual values. See Reid and Dunne (1996) for more information on this topic.

identify portions of the channel network located upstream of dams, and the effects of dams on sediment supply to downstream reaches.

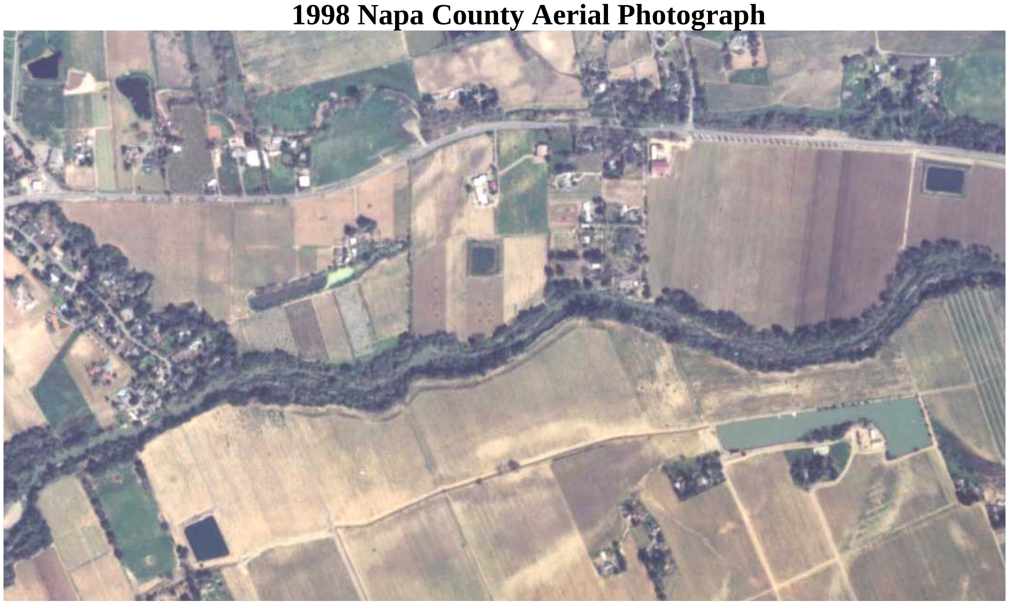


Source: McNeill and Ahnell (1964).

Figure 1. Relationship Between Fine Sediment Deposition and Streambed Permeability.

1940 Soils Conservation Service Aerial Photograph

1998 Napa County Aerial Photograph



Source: Stillwater Sciences and Dietrich (2002).

Figure 2. Channel Incision between 1940 and 1998 in the Napa River at Soda Creek

In the 1940 photograph, the channel bed alternates between gravel bars (light-colored arcs) and pools (dark areas). In the 1998 photograph, with the exception of the left edge of the photograph, no gravel bars are evident, the channel has narrowed, and it is straighter.

The Napa River sediment source analysis identifies key sediment sources and sheds light on the following questions:

- What are the relationships between sediment input to channels, channel sediment transport capacity, and streambed permeability values in Napa River and its tributaries?
- How important are natural processes and human alteration of the land with regard to input of fine sediment to channels?
- Is channel incision and associated bank erosion, a large source of sediment input to channels? How does this source compare/rank in relation to other natural and human generated (anthropogenic) sediment sources?

In the following section we describe our approach, present data we collected, and report estimated rates of human caused and naturally occurring sediment inputs to channels.

3.2 Key Attributes that Influence Sediment Input into Napa River and its Tributaries

Primary controls on rates and sizes of sediment input to Napa River watershed channels are: 1) geology or the hardness of bedrock and sediment deposits; and 2) influences of land-use activities on vegetation cover, soil attributes, and topography.[9] The potential significance of these attributes on sediment supply is discussed below. An introduction to the recent history of mountain building in the watershed is first provided to set the stage for exploring why variability in bedrock hardness is particularly important in Napa and other parts of the California Coast Range.

Napa Valley and its surrounding ridges, the Vaca and Mayacama mountains, are geologically recent features, formed within the last three million years in response to slight shifts in the direction of movement of the Pacific Plate. This movement caused a small component of compression along the San Andreas Fault system, and the formation of the California Coast Range (Swinchatt and Howell, 2004). The Vaca Mountains, Mayacama Mountains, and Napa Valley are being actively shaped and changed by ongoing movement along active faults and folds. In such active landscapes, hills underlain by erosion resistant bedrock types (hard rocks) maintain steep slopes and low erosion rates as uplift occurs. In contrast, bedrock types that have a low resistance to erosion (soft rocks) as they are uplifted respond much more rapidly, erode into gentle and more deeply dissected slopes, and deliver much greater quantities of sediment to the channels that drain them.

Hardness of common bedrock units found in Napa River watershed varies substantially in relation to texture and structure of the rock types, conditions under which the rocks were formed, and amount of subsequent weathering and tectonic deformation (faulting and folding of rocks). For example, lava flows of the Sonoma Volcanics Formation are hard because they are formed from molten rock (lava) that is rapidly cooled and hardened when it reaches the earth's surface.

[9] Changes in vegetation cover, soil attributes (e.g., infiltration capacity and permeability), and topography (e.g., road cuts and inboard ditches) may cause significant changes in runoff rate and locations, and significant changes in the resistance of the landscape to erosion.

Also, these lava flows are hard because they are geologically recent deposits that have experienced low to moderate amounts of subsequent weathering and tectonic deformation. In contrast, another unit within the Sonoma Volcanics Formation, air-fall deposited volcanic ashes (ash-flow tuffs), although also recently deposited, are composed primarily of very fine-grained material that was erupted into the air, and then deposited shortly thereafter as unconsolidated air-fall deposits. Fine texture and poor consolidation, in contrast to lava flows, promotes much more rapid weathering of the ash flows into soft clays that are easily eroded when vegetation or soils are disturbed.

The importance of environmental conditions during bedrock formation in influencing hardness is also illustrated by examining the Franciscan mélange and sheared serpentinite units, which underlie most of the Sulphur Creek and Bear Canyon tributary watersheds. The fine-grained ocean-floor rock types that form the bulk of the mélange have been intensively sheared and they are composed of a mechanically incompetent matrix that engulfs occasional large pieces of hard rock referred to as blocks. Given the intensive tectonic deformation during the formation of the mélange and sheared serpentinite units, large deep-seated landslides are common features in these units, which we believe are caused primarily by the natural attributes of these bedrock types versus historical and/or recent disturbances from land-use activities.

In addition to bedrock, extensive areas of the watershed are underlain by thick deposits of sediment, derived from erosion of upland bedrock units and soils. Swinchatt and Howell (2004) suggest that most of these sediments were deposited during the past 10,000 to 15,000-years, in response to worldwide sea-level rise associated with the end of the most recent glacial epoch. These deposits are composed primarily of sand and coarser-grained sediments that typically are not cemented, and hence are classified as soft deposits. Although most fan and valley fill deposits are soft, sediment accumulation was favored over erosion at these sites up until the historical era. As the watershed was developed, upslope disturbances of vegetation and soil likely increased runoff rates and sediment input to channels. These historical and recent impacts, in combination with direct alterations of channels and adjacent flood basins, have destabilized channels where they traverse alluvial fan and valley deposits. This has led to active and rapid channel down-cutting and accompanying bank erosion that is widespread along Napa River and lower reaches of many of its tributaries today.

Within a given bedrock or sediment deposit type, we hypothesize that land-use activities exert a significant influence on total rate and sizes of sediment input to channels (hereafter referred to as sediment supply). This point is illustrated by describing some specific mechanisms by which common land uses in Napa River watershed may increase erosion rates. For example, intensive grazing has the potential to reduce ground-cover vegetation density, change vegetation structure and species assemblage, and compact soils causing infiltration capacity and permeability to be reduced. The above effects of grazing, in turn, may greatly increase overland flow runoff during storms, leading to significant increases in the rates of surface erosion from sheetwash, rilling, and gullies. Gully erosion may also cause significant local changes in hillslope topography and mass, which has the potential to activate landslides.

Other common land uses also may cause significant changes in rate, volume, and locations of storm runoff. For example, where hillside vineyards replace mature mixed evergreen forests, peak runoff rate and volume from the vineyard site may be increased substantially because mature conifers intercept a significant proportion of the total rainfall in a storm, greatly reducing the rate of delivery (and in some cases total amount) of rainfall that is input into the soil. Furthermore, if vineyard development involves installation of subsurface drainage pipes, more storm runoff, at a faster rate, may be discharged off-site than under natural conditions. Finally, if discharges from drainage pipes are collected at a single point of discharge, there is the potential to further concentrate runoff volume (Figure 3). The above effects have the potential to cause off-site gully erosion and/or shallow landslide failures, most often at or near the points of discharge from the site and in locations where hillslope soils and bedrock are soft (easily eroded).

Figure 3. Gully Formed by Discharge of Concentrated Runoff from Hillside Vineyard

A third example of the effects of land use on sediment supply is illustrated by examining the effects of roads. Road cuts intercept subsurface drainage, speeding up runoff rate. Roads also usually change the distribution of runoff from the hillslope. Inboard ditches and compacted road surfaces substantially increase the rate, volume, and locations of direct runoff from these areas, which can cause the road surfaces and ditches to rapidly erode (Figure 4). Road cuts and fills alter drainage pathways, and the distribution of mass on the hillslope, often contributing to greater rates of landslide activity. Also, road crossings (over channels), may be undersized for the conveyance of peak runoff rates, and/or may be easily plugged by large debris during storms causing overtopping and/or diversion of channel flows, with resulting channel crossing erosion, and/or gully erosion through diversion of channel flows to another channel or hillslope location.

Figure 4. Rills and Gullies on a Compacted Dirt Road
Gully forms where runoff depth and slope are sufficient to erode soft colluvium at this site, which is underlain by the mélange bedrock unit.

3.3 Definition and Delineation of Terrain Types

As described above, hardness of bedrock units and sediment deposits, and land-use activities exert primary influences on sediment supply to channels. To confirm this relationship and provide a basis for watershed-wide sediment supply extrapolation from a limited sample of sites, we defined and delineated a suite of sediment supply terrain types that occur within Napa River watershed. We hypothesize that within each defined terrain type, key attributes that influence sediment supply to channels are similar in response to natural disturbances and land-use activities. We then test our hypothesis by measuring sediment input rates to channels at sites grouped by terrain type, and within each defined terrain type, at sites that vary with regard to primary land-use activities.

We defined and delineated sediment supply terrain types based on review of existing information (WET, 1990; Ellen and Wentworth, 1995; and Stillwater Sciences and Dietrich, 2002), recent aerial photographs (Napa County, 1993 and 2002), and extensive field reconnaissance over much of the watershed during the summer and fall of 2003 to identify significant active processes that deliver sediment to channels, and relationships to land uses, topography, and underlying bedrock types and/or sediment deposits.[10] Based on field reconnaissance and review of available information, we identified four major categories of active and potentially significant processes that deliver sediment to channels[11]:

---

[10] Field reconnaissance sites included Ritchie Creek, Mill Creek, Sulphur Creek, upper Conn Creek, Chiles Creek, Milliken Creek, Suscol Creek, Tulocay Creek, Dry Creek, Carneros Creek, and mainstem Napa River between Calistoga and St. Helena.

[11] Although large, active deep-seated landslides are an important erosion process in some terrain units in Napa River watershed, they do not directly deliver sediment to channels. Instead, sediment delivery occurs, primarily through bank erosion, gullies, and shallow landslides that are located on the toes of deep-seated landslides.

- Colluvial bank erosion[12], gullies, and shallow landslides formed by natural processes, and/or by land-use activities (e.g., concentrated or diverted runoff from roads, hillside vineyard runoff, intensive grazing, etc.)

- Channel incision where human actions have destabilized streams underlain by deep alluvial deposits

- Sheetwash and rill erosion associated with natural processes (e.g., drought and fire), and land-use activities (e.g., vineyards and grazing)

- Road surface and channel crossing induced erosion

We then defined and delineated terrain types (Table 2) that are similar with regard to sediment supply to channels under similar natural processes and human disturbances. The terrain types we defined are derived from "hillside materials units" defined by Ellen and Wentworth (1995) based on analysis of engineering properties of mapped geological formations. We modified their classification by lumping together several units into four upland terrain types defined based on bedrock hardness and/or amount of tectonic deformation and weathering, and which we list below in order from lowest to highest predicted erosion potential:

- Hard rocks, primarily hard volcanic lava flows (low to moderate erosion potential)

- Sedimentary rocks of variable hardness and deformation (medium to high erosion potential)

- Ash-flow tuffs (medium to high erosion potential)

- Intensively deformed Franciscan mélange and sheared serpentine (high to extreme erosion potential)

We also defined a lowland terrain type, which lumps together all gently sloping to flat lying alluvial fan and valley deposits. We predicted that the lowland terrain type has a high erosion potential based on frequent observation of deeply incised channels and steep poorly vegetated banks in alluvial valleys. Table 2 describes terrain types in further detail. Map 3 shows the aerial extent and location within the Napa River watershed of each of our terrain types.

[12] Colluvial refers to hillslope soil. Where channel banks are hillslopes, colluvial bank erosion delivers sediment to channels.

Table 2. Terrain Types Defined Based on Predicted Sediment Supply						
Terrain Type*	**Hillside Materials Units¥**	**Drainage Area (km^2)**	**Percent Study Area**	**Key Attributes with Regard to Erodibility**	**Predicted Sediment Input Rate**	**Units Surveyed to Estimate Sediment Input Rates**
Sonoma Volcanic Lava Flows (primarily hard lava flows)	202, 204, 218, 219, 220, 234, 238, 240, 253, 261, 262	257	26.3	Hard (little deformation and low to moderate modification by weathering	Low	218, 219, 234, 238, 240
Other Hard Bedrock Units	511 (Franciscan chert) 900 (Unsheared)	5.4	0.5	Hard (little deformation and low to moderate modification by weathering	Low	Not surveyed
Alluvial Valley Fills and Fans	N/A—Alluvial Lowlands	299	30.6	Flat lying or gently sloping, commonly unconsolidated and non-cohesive	High	Extensive surveys along mainstem and all major tributaries
Sonoma Volcanic Ash Flows and Tuffs (primarily air-fall ash, some welded tuff)	270, 272, 273, 290	112	11.5	Medium to low hardness	Medium	270
Sandstones and Clayey Rocks (variable hardness and deformation)	100, 123, 141, 153, 358, 381, 384, 410, 415, 417, 439, 470, 519, 683, 686, 703	239	24.5	100s are poorly consolidated; all other units are medium to low hardness and/or have moderate to high fracturing as a result of weathering and/or deformation	Medium	683/686§
Franciscan Mélange and Sheared Serpentinite	801, 802, 805	64.6	6.6	Intensively deformed	High	801, 805
	Total	**978**	**100.0**			

* Terrain types are defined by rock type (geological units) and slope category (upland or lowland)

¥ Units as defined and delineated by Ellen and Wentworth, 1995, who classify hardness of geological units as follows: hard - [rock] hammer bounces with solid sound; medium hardness - [rock] hammer dents material with thud, and pick point dents or slightly penetrates material; low - pick point penetrates material.

§ Units 683/686 - Great Valley Formation constitutes about 2/3 of the total land area in the sandstone and clayey rocks land type.

NOTE: Does not include urban land cover categories (commercial, residential, industrial, parks, roads, etc.), which cover about 116 km^2 or about 10% of the watershed.

3.4 Approach to Measurement of Sediment Input to Channels

Colluvial bank erosion, gully erosion, and shallow landslide erosion processes are active and potentially significant processes that deliver sediment to channels in all of the upland terrain types. Channel incision and accompanying stream terrace bank erosion occurs solely in the alluvial valley and fan deposits. Sheetwash erosion occurs in all terrain types, and appears to be a significant active process, where land uses such as intensive livestock grazing and vineyards disturb soil and vegetation cover. Sheetwash erosion is also prevalent on earth-surfaced roads, ditches, and cut banks of roads. Roads crossing erosion, and gullies and landslides caused by road-related changes in hillslope runoff and/or distribution of mass, are also significant active processes that deliver sediment to channels.

We organized our approach to the measurement and/or modeling of sediment input rates by the above four major categories of active and potentially significant processes that deliver sediment to channels as described below. Methods are described in Appendix I.

1) Gullies, Shallow Landslides, and Bank Erosion in Uplands

We conducted field surveys at nineteen upland sites to measure rates of sediment input to channels during the most recent decade from erosion of gullies and shallow landslides. We also conducted reservoir sedimentation surveys that together with other field observations and measurements were used to estimate longer-term rates of total sediment input to upland channels (Table 3). We also estimated colluvial bank erosion rates, which involved measurement of channel network length using channel maps derived from the three-meter digital elevation model, estimation of average rate of downslope movement of sediment on hillslopes based on review of literature (Fleming and Johnson, 1975, McKean et al., 1993), observations of the depth of colluvium exposed in hillside channels, and the assumption that over the long-term rates of downslope movement on hillslopes are equal to rates of colluvial bank retreat.

The location of field survey sites was not random, and constrained primarily by our ability to obtain permission for access to privately owned land, and by our available budget and schedule. Nevertheless, for three of the four upland terrain types we defined (Franciscan mélange and sheared serpentinite, lava flows and other hard rocks, sedimentary rocks) we surveyed one or more sites where natural cover, vineyards, and/or livestock grazing are predominant cover types or uses. At sites underlain by the ash-flow and tuff, we surveyed three sites, all of which are currently dominated by natural land cover.

We also measured reservoir sedimentation rates and estimated trap efficiency at ten sites that capture runoff from upland sites. Five of these sites are located immediately downstream of sites where we also measured or modeled sediment inputs to channels from colluvial bank erosion, gullies, and shallow landslides (Table 3). Because we did not observe any significant sediment storage sites in channels draining into the reservoirs, we assume that sediment yields to reservoirs match rates of sediment input to channels at the sites where we conducted surveys. Therefore, reservoir sites provide a basis for estimating total sediment yields from the defined terrain types under various combinations of land use.

Table 3. Upland Measurement Sites

Site	DA (km^2)	Time Period	Predominant Land Uses and intensity/disturbances	Type of Measurement Surveys	Key Upland Erosion Process(es)
Terrain Type: Hard Flow Rocks					
Spence Creek Pond	0.21	1958–2004	Natural grasslands	Reservoir sedimentation	Soil creep and sheetwash
Kreuse Creek	3.14	1994–2004	Natural grasslands; recent large fire	Upland sediment inputs	Soil creep, sheetwash, gullying
Milliken Reservoir	25.1	1926–2003	1981 Atlas Peak fire; very low road density, large cattle ranch in upper watershed; minor vineyard dev.	Reservoir sedimentation	…
Bell Canyon Reservoir	13.9	1959–2001	Minor amount roads and vineyards; historical logging	Reservoir sedimentation	…
Conn Creek stock pond	0.17	1977–2004	High intensity grazing over small portion of the site	Reservoir sedimentation, upland sediment inputs	Soil creep, gullying, sheetwash, shallow landslides
Redwood Pond 1	0.18	1981–2004	Vineyard	Reservoir sedimentation, upland sediment inputs	Gullies, shallow landslides, soil creep
Redwood V Creek	0.12	1994–2004	Vineyard	Upland sediment inputs	Gullies, shallow landslides, soil creep
South Creek	1.0	1993–2003	Low-intensity grazing	Upland sediment inputs	Soil creep and sheetwash
Central Creek	1.4	1993–2003	Low-intensity grazing	Upland sediment inputs	Gullying, sheetwash, soil creep
Terrain Type: Volcanic Tuff and Ash Flows					
Kimball Canyon Dam	7.8	1940–2003	Historical: logging/grazing Present-day: low intensity land uses, water supply	Reservoir sedimentation	Did not perform upland surveys
Ritchie Creek	6.4	1994–2004	Historical: logging Present-day: protected parkland with low-density of roads and trails	Upland sediment inputs	Deep-seated landslides, soil creep, channel incision, and bank erosion
York Creek—St. Helena Upper Dam	5.9	1993–2003	Historical: logging/grazing; Present-day: low-intensity roads, rural residential, and vineyard development	Reservoir sedimentation	Did not perform upland surveys
Terrain Type: Great Valley Formation and Associated Sedimentary Rocks					
Redwood Swale 2	0.37	1994–2004	Vineyard covers 100% of site	Upland sediment inputs	Gullying, soil creep
Redwood Swale 1 and Pond	0.16	1981–2004	Vineyard	Reservoir sedimentation, upland sediment inputs	Gullying, soil creep
Carneros—Scott Creek Dam	0.52	1949–2003	Intensive historical grazing; actively grazed at present	Reservoir sedimentation	Earthflows, gullying, soil creep, and shallow landslides
Carneros—Scott Creek Downstream of dam	1.9	1994–2004	Land-use as above; gullies primarily from historical grazing	Upland sediment inputs	Earthflows, gullying, soil creep, and shallow landslides
Terrain Type: Mélange and Sheared Serpentinite					
Conn (R pond)	0.03	1997–2004	Intensive grazing at present	Reservoir sedimentation, upland sediment inputs	Gullying, sheetwash, soil creep
Sulphur #1	5.1	1994–2004	Historical grazing; Present-day: low-intensity vineyard development	Upland sediment inputs	Deep-seated landslides, gullies, soil creep, shallow landslides
Sulphur #2	1.0	1994–2004	Historical grazing; roads traverse unstable slopes	Upland sediment inputs	Deep-seated landslides, gullies, soil creep, shallow landslides

Using all of the above information, we calculated:

- Median and average annual rates of cumulative sediment input to channels from colluvial bank erosion, gullies, and shallow landslides during the most recent decade, for each of the four defined terrain types

- Median and average ratios of anthropogenic to total sediment input (A/T) by the above processes, during the most recent decade, and for each terrain type based on the range of land-use activities at the sites where we conducted surveys

- Total sediment input rates from all delivery processes (or sediment yields) to reservoirs over longer periods of time

2) Channel Incision and Stream Terrace Bank Erosion in the Alluvial Valleys and Fans

We use the term channel incision to refer to the progressive lowering of the streambed over multiple decades-or-longer often accompanied by rapid rates of bank erosion. Mean annual volume of sediment input to channels from channel incision was calculated as follows:

Average annual volumetric rate of channel incision (since start of incision) =

> (width of incision) x (channel incision depth) x (channel length, where incision was recently or is currently active) ÷ (estimated number of years since start of incision).

In order to identify reaches, where channel incision was recently or is currently active, we interpreted time-sequential aerial photographs (1940, 1952, 1985, 1993, 1998, and 2002), which provide coverage for the Napa Valley[13]. We also used these time sequential photographs to estimate the timing of the initiation of channel incision in mainstem channel reaches, and in some reaches of its larger tributaries. An example of how we estimated number of years since the start of incision is described below.

In a reach where incision was noted for the first time on the 1993 photographs, considering the dates of the time-sequential photographs used in our analysis (e.g., 1940, 1952, 1985, 1993, 1998, and 2002), we inferred that incision could have started as early as water year 1986. Therefore, by our approach, we estimate that channel incision has been active for 18 years in the above reach. Note, that our approach yields a maximum estimate for the number of years since the start of incision.

Width of incision is assumed to equal width of the channel between left and right bank terraces as measured in the channel at the base of the terrace. Channel width was measured in the field by surveying tape or pace. Depth of channel incision was defined based on field observations of differences in height between perched features and current streambed elevation (e.g., perched tributary channels, perched former gravel bars that now are terrace benches covered by mature even-age trees, bank stabilization structures and culverts that have been undercut, etc.). Height

---

[13] All of the aerial photographic surveys were conducted in the spring or summer months of the indicated year of the survey.

differences between the current elevation of the streambed and the perched features were measured with a surveying rod.

Field surveys were conducted between the fall of 2003 and the winter of 2004 throughout 1-to-5-kilometer-long alluvial reaches of Carneros, Heath Canyon, Mill, Milliken, Ritchie, and Sulphur Creeks to observe and interpret channel features, as needed to estimate channel incision depth, width, and age. The Principal Investigator also collected channel incision width, depth, and age estimates throughout a 15-kilometer-long reach of mainstem Napa River, between Myrtledale Road in Calistoga and Zinfandel Lane in St. Helena during the summer of 2000. We also used data collected during a recent survey of the alluvial reaches of Huichica Creek to estimate channel incision rates in this tributary (Collins, unpublished report, 1996). In addition to the extensive channel surveys described above, we also surveyed short reaches of mainstem Napa River and its tributaries where public roads follow or cross stream courses where stream reaches can be observed and interpreted from the road (all public roads within the watershed that follow stream courses were included in our survey).

3) Sheetwash Erosion from Land Uses

In the Napa River watershed, sheetwash erosion appears to be a significant active process for sediment delivery to channels, where livestock grazing and vineyards disturb soil infiltration capacity and/or vegetation cover. We used USGS land cover/use classification mapping, derived from 1992 satellite imagery, to identify locations of vineyards and grasslands and estimate land areas in each category. For each of these land use/cover types, we used the three-meter digital elevation model to subdivide each vineyard and grassland site into sub-areas based on slope steepness category (<5 percent, 5 to 30 percent, >30 percent). We then used the USLE model to estimate soil erosion rates, and field surveys to estimate sediment delivery ratios to channels. We assume that the vineyard and rangeland sites that we observed during watershed reconnaissance and field surveys are representative of typical conditions throughout the watershed. In our analysis of sheetwash erosion caused by grazing, we also assume only one-third of delineated grassland and/or pasture areas (13,718 acres) are managed at present to provide forage for livestock. This assumption is based on comparison of known areas of cattle grazing to mapped areas of grasslands in Carneros Creek and Sulphur Creek watersheds, where mapped grassland areas appear to be 2-to-4 times greater than areas currently being grazed. USLE model parameter values (and basis for estimates) are presented and discussed in Appendix I.

4) Road Erosion Processes

We reviewed and interpreted recent road erosion surveys conducted by Pacific Watershed Associates (PWA) in three Napa River tributary watersheds: Carneros, Dry, and Sulphur, where we applied the tributary specific rates developed by PWA. Elsewhere in the Napa River watershed, we estimated sediment delivery from road surface and crossing erosion, as follows.[14] We compared road length and crossing frequency estimated from overlap of the channel network map with the Napa County GIS layer for roads, which does not include most private roads, to the complete maps of roads developed by PWA in the above three tributaries. We found the Napa County road layer on average underestimates total road length by a factor of three, and total crossing frequency by a factor of 1.5. Therefore, in using the Napa County GIS road layer to

[14] Road-related gullies and landslides that are located downslope of the roads are tabulated within the upland gully, landslide, and colluvial bank erosion category.

estimate road surface and crossing erosion in other parts of the watershed, we multiplied road length by three and crossing frequency by 1.5. In our modeling of road surface erosion, outside of the three surveyed areas, we estimate that 50% of the road length is hydrologically connected to channels, which corresponds to the average value measured by PWA in the three tributary survey areas. Methods used to estimate sediment delivery from road-related erosion, including data sources and assumptions, are described detail in a separate report titled *Methods for Estimating Rates and Sizes of Sediment Input to Channels and Spawning Gravel Permeabilit*y (Napolitano, 2006).

5) Sediment Supply from Urban Stormwater Runoff

In developing an estimate for sediment supply from urban stormwater, we consider inputs from construction activities for structural development projects, highway maintenance activities by the California Department of Transportation, soil erosion at industrial facilities. We do not consider soil erosion from existing residential and/or commercial parcels, and/or urban parklands. Furthermore, considering the nature of construction activities, we assume that construction site erosion dominates the total sediment supply from the urban stormwater runoff category. Therefore, we did not separately estimate loads from highway maintenance activities or industrial facilities. These inputs combined are assumed to be less than or equal to the total input associated with construction activities.

In estimating sediment supply from construction activities for structural development projects, we have assumed a typical sediment delivery ratio of 50 percent (e.g., 50 percent of the eroded sediment is actually delivered to a stream channel). We also assume on average between 1994 and 2004, ground disturbance associated with construction was 100 hectares or less per year (e.g., 40 acres per year), and average soil erosion rates were 250 metric tons per hectare (e.g., about 100 English tons per acre). Using these values, we calculate that average annual sediment supply from construction activities was approximately 2000 metric tons per year. Assuming the combined inputs from industrial facilities and highway maintenance are less than or equal to this amount, we estimate that average annual supply from urban stormwater runoff was less than or equal to 4000 metric tons per year between 1994 and 2004.

6) Size Distributions for Sediment Input from all Significant Delivery Processes

For sediment input to channels from gullies, shallow landslides, colluvial bank erosion, and road-crossing erosion, during the summer of 2003, we collected and analyzed samples of colluvium from toes of landslides at 12 sites selected to describe sediment grain-size distributions for each of the four upland terrain units. Soil pits about 0.5-to-1.0 meters in diameter were dug with a pick and/or shovel. Samples were collected on tarps, and dried in the field as needed. Hand pressure was used to break apart cohesive aggregate of finer particles. Samples were then processed by hand and wire brush in the field through 64 mm, 11.2 mm, and 2 mm sieves. Particles collected on the 64 mm sieve were inspected visually to confirm that they were gravels, and not cohesive aggregates of finer soil particles, prior to weighing in the field. Samples by size class were then weighed with a hanging balance suspended from a tree. Splits, representing about one-eighth of the total sample weight collected on the 11.2-and-2 mm sieves were also wet sieved in the lab to insure that cohesive aggregates of finer particles were not represented in our 64-to-11.2 mm, and 11.2-to-2 mm size classes. The average weight of the sample collected at each site was approximately 100 kilograms.

For sediment input to channels from stream terrace bank erosion and channel bed erosion (channel incision), we used available information describing grain size distributions for bed and bank deposits collected at several locations along Napa River during the late 1980s (WET, 1990).

For sediment input to channels from road surface erosion (e.g., cut bank, inboard ditch, and the surface of dirt roads), based on field observations of fine gravel deposits in inboard ditches, and review of soil survey information for Napa County (USDA, 1978), we assume that inputs from sheetwash erosion of cutbanks, inboard ditches, and surfaces of dirt roads are composed of 50 percent fine gravel, and 50 percent sand, silt, and clay.

For sediment input to channels from surface erosion of hillsides in vineyards and/or rangelands, based on review of soil survey information (USDA, 1978) and field observations of grain sizes comprising coarse lag deposits in the channels of rills and/or small alluvial fans, we estimate that inputs are composed of 25 percent fine gravel, and 75 percent sand, silt, and clay.

Table 4. Terrain Type Sediment Size Distribution					
Terrain Type	**Samples**	**Cobbles and Boulders > 64mm (percentage)**	**Coarse Gravel = 64 to 11.2 mm (percentage)**	**Fine Gravel =11.2 to 2mm (percentage)**	**Sand, Silt, and Clay <2mm (percentage)**
Sandstones and clayey rocks (Great Valley formation)	two samples; mean wt.= 108.1 kg	2	12	19	67
Sandstones and clayey rocks (Franciscan metagreywacke)	one sample; wt. = 224.7 kg	18	25	14	43
Franciscan mélange and sheared serpentinite	two samples; mean wt. = 197.3 kg	4	32	55	9
Sonoma Volcanic lava flows	two samples; mean wt. = 97.7 kg; Trso (2003)	12	17	6	65
Sonoma Volcanic ash flow and tuff	two samples; mean wt. = 30.9 kg	11	50	Not measured	Not measured
Alluvial fans and valley fills	Based on WET (1990)	10	20	40	30

NOTES: Considering small number of samples and small sample sizes, expected accuracy of estimated grain size distributions is poor. In the absence of additional data, we assume that Sonoma volcanic tuff/ash-flows have identical size distribution as Sonoma volcanic flows. We did not use our sample data because sample sizes were too small and sampling was truncated at 11.2 mm. We hypothesize that actual size distribution for tuffs/ash flows is richer in fine gravel and poorer in coarse gravel than Sonoma volcanic flows.

Note: The above four size classes may have distinct influences on fisheries habitat conditions. Cobbles and boulders provide potential winter rearing habitat for steelhead. Coarse gravel, 64 to 11.2 mm, is in the preferred size range for steelhead and salmon spawning. Fine gravel, < 11.2 to 2 mm, may degrade quality of spawning and rearing habitat for steelhead and salmon by filling in the spaces between coarse substrate. Fine sediment (e.g., sand, silt, and clay) may also degrade spawning and rearing habitat quality (e.g., primarily the sand fraction; very little silt or clay is deposited in gravel-bedded reaches of Napa River and its tributaries), and/or contribute to suspended sediment concentration and/or turbidity. Boulders, cobbles, and gravels derived (especially soft bedrock types) may be rapidly worn down into small grain sizes during transport through the channel.

Calculation of Total Sediment Input Rate to Mainstem Napa River

The distribution and frequency of terrain types and occurrence of dams varies by position along mainstem Napa River (Maps 1, 2, and 3). Therefore, to examine how geography of terrain types and dams influences sediment supply to Napa River, we calculated total sediment delivery to the channel network upstream of four locations along the Napa River: 1) Napa River near St. Helena, at the USGS streamflow gage near Zinfandel lane; 2) Napa River at its confluence with Conn Creek; 3) Napa River at its confluence with Soda Creek; and 4) Napa River at San Pablo Bay. Napa River near St. Helena was chosen because it corresponds to the USGS gage site, it occurs within the primary habitat area in Napa River for Chinook salmon, and because the effect of dams on runoff and sediment delivery is low relative to downstream sites (20 percent of upstream drainage area drains into dams). Napa River at Conn Creek also occurs within the spawning and rearing habitat area for Chinook salmon, however in contrast to the site near St. Helena, this site corresponds to the point of maximum influence of dams on runoff and sediment delivery (49 percent of upstream drainage area drains into dams). Napa River at Soda Creek corresponds approximately to the downstream boundary of spawning and rearing habitat for salmon, and it is located a short distance upstream of the tidal reach. Napa River at San Pablo Bay was chosen because it provides a basis for watershed-wide calculation of total sediment input into the channel network.

Calculation of Total Sediment Input Rate into Four Representative Tributaries

We also calculated total sediment input rates into the channel network from all sources into four tributaries at their confluences with the Napa River (Map 4): Carneros Creek, Milliken Creek, Sulphur Creek, and Ritchie Creek. We selected these tributary watersheds for analysis because:

- One defined upland terrain type predominates in each watershed (sedimentary rocks in Carneros; mélange and sheared serpentinite in Sulphur; ash-flows and tuffs in Ritchie; and volcanic lava flows in Milliken), from which we could examine influence of terrain type on sediment supply under varying land-use activities;

- Recent and/or historical fish census and/or habitat surveys suggest that all of these tributaries provide habitat for steelhead;

- Previous studies conducted in Carneros and Sulphur creeks, provide significant amounts of useful information; and

- We were able to obtain permission for access to extensive portions of each tributary watershed.

The four tributaries selected drain about 10 percent of the land area in the Napa River watershed. Grape growing, cattle grazing, rural residential development, reservoirs, and roads are common in these tributary watersheds.

In the tributary study areas, we measured or modeled all sediment input rates to channels as described earlier in this section. There was one difference in how we calculated sediment input rates into three of the tributaries we studied—Carneros, Sulphur, and Ritchie—as compared to the remainder of the Napa River watershed. In these three tributary study areas, within the predominant terrain type, we estimated sediment input from colluvial bank erosion, gullies, and shallow landslides, based on measurements made locally within sub-areas of these tributary watersheds, as compared to measurements made at sites elsewhere in the Napa River watershed. In Milliken Creek watershed, we did not conduct upland field surveys, and therefore, we used average values (for input from colluvial bank erosion, gullies, and shallow landslides) that are derived from field measurements at seven upland sites in other locations within the Napa River watershed. Upland survey areas totaled 1.9 km^2 in Carneros Creek watershed, 6.1 km^2 in Sulphur Creek watershed, and 5.9 Km^2 in Ritchie Creek watershed.

Relationship Between Sediment Supply, Transport Capacity, and Streambed Permeability
To explore the relationship between sediment input to channels and streambed permeability[15], we compared average annual sediment input rates to reach-median values for streambed permeability measured in seven reaches of the four study tributaries, and in one reach of mainstem Napa River, located near Rutherford.

Streambed permeability values typically reflect a balance between fine sediment supply and transport capacity, therefore, we also estimated stream power. Stream power is defined as the rate of energy expenditure by water as it flows through a channel. Stream power is directly proportional to the product of streamflow discharge multiplied by water surface slope. In our analysis, we define a stream power index that is equal to streambed slope multiplied by drainage area, which we use as a proxy for streamflow discharge in our analysis.[16] We measured streambed slopes throughout the length of each reach where we measured permeability. All of the reaches we surveyed were greater than 40 bankfull channel widths long. We also calculated the land area draining into each reach using the three-meter digital elevation model. We did not estimate values for bankfull discharge because streamflow gaging data were not available at most of our sites.

3.5 Tributary and Mainstem Study Areas

Milliken Creek
Milliken Creek drains a 53-km^2 tributary watershed located on the east side of Napa River watershed. The City of Napa operates Milliken Reservoir, which captures runoff from almost half of the land area of the watershed, and a diversion located about two miles downstream to provide water supply within its service area. Other large on-channel dams are located on tributaries to Milliken Creek and in its lower reach within the Silverado Country Club. Altogether, dams capture runoff from about three-quarters of the land area of the watershed. Low density residential and resort development predominate in the lower part of the watershed, and natural cover and rangeland uses predominate in the upper and middle parts of the watershed.

---

[15] Considering constraints of funding, we selected streambed permeability as a response variable for comparison to sediment input rate because: a) permeability measurement is fast and repeatable, allowing us to collect data throughout the watershed; and b) there is an inverse relationship between concentration of fine sediment (primarily sand grains) in the streambed and permeability (McNeil and Ahnell, 1964).

[16] Our estimates of total stream power provide only a rough estimate of the fraction available to transport sediment. This is because flow energy is also expended through internal friction within the fluid, and friction along the channel boundaries caused by grain roughness, large obstructions (like debris jams, bedrock outcrops, bridge piers, etc.), and/or other changes in channel width, depth, and direction of flow encountered along the length of the channel.

This watershed is underlain primarily by very hard volcanic flows of the Sonoma Volcanics Formation. 66 percent of the total land area is underlain by hard volcanic lava flows. A gently sloping plateau dominates the upper watershed, which then abruptly transitions into deep canyon in the middle reach of Milliken Creek, and which opens up again in its lower reach in the Napa Valley (Figure 5).

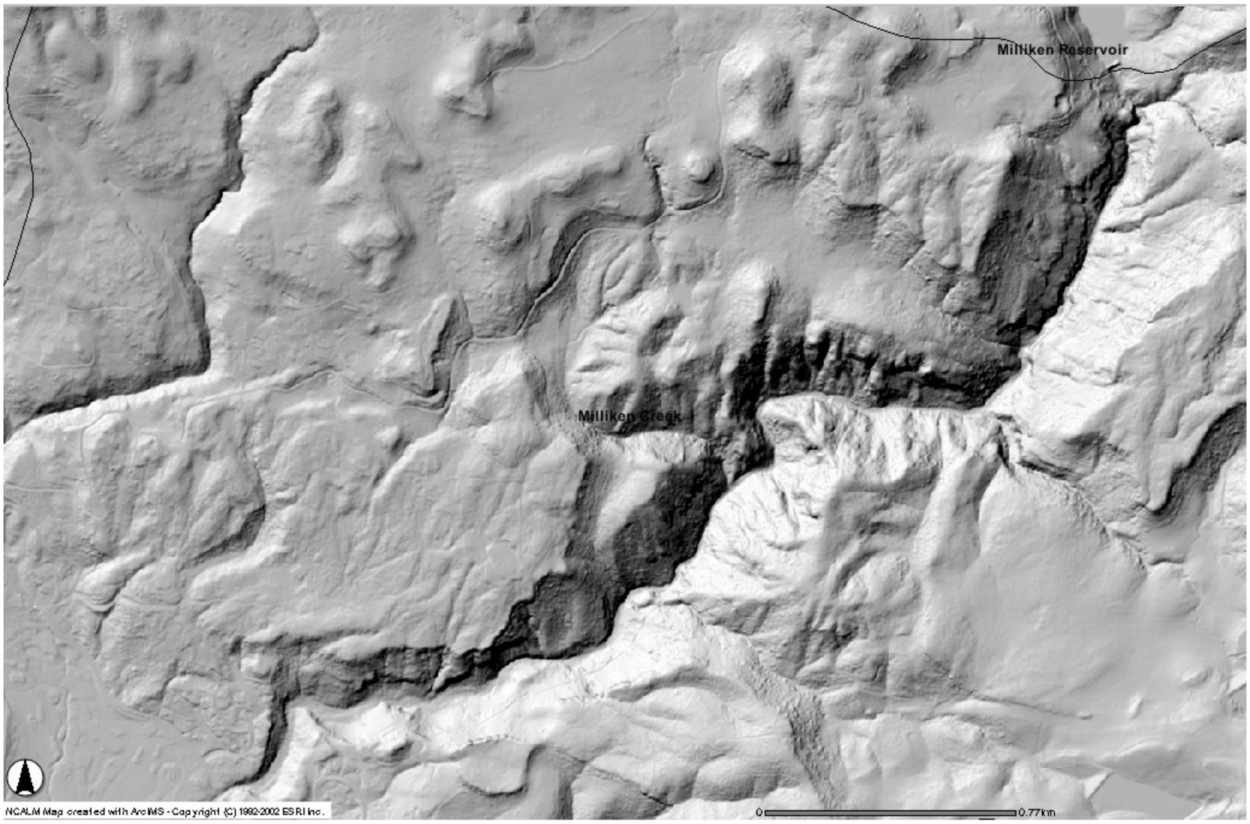


Figure 5. **Ground Surface Topography in Milliken Canyon** .
Generated using 1-meter laser altimetry (LIDAR) topographic data, and data filtering to remove most vegetation cover. Hard bedrock forms steep slopes in the canyon. Gentle plateau in upper watershed was formed during an earlier geologic period when uplift rates were much lower (Swinchatt and Howell, 2004).

In Milliken Canyon, boulder and cobble deposits predominate, in steep reaches that alternate between cascade and step-pool channel types (Figure 6). We measured streambed permeability at all potential spawning sites for steelhead and/or rainbow trout in two reaches located within the gorge, one located a short upstream of Milliken Dam (eight potential spawning sites within a 215 m reach; streambed slope = 0.035; upstream drainage are = 18.9 km^2), and the other reach located a short distance downstream of the diversion operated by the City of Napa (six potential spawning sites located within a 135 m reach; streambed slope = 0.058; upstream drainage are = 30.3 km^2). Based on geology (hard volcanic flow rocks), predominance of natural cover and low density of roads, and the steep and confined nature of channel reaches in Milliken Canyon, prior to measuring sediment inputs or permeability, we hypothesized that fine sediment supply in

Milliken Canyon was low and stream power was very high, and therefore, that streambed permeability should also be high[17].

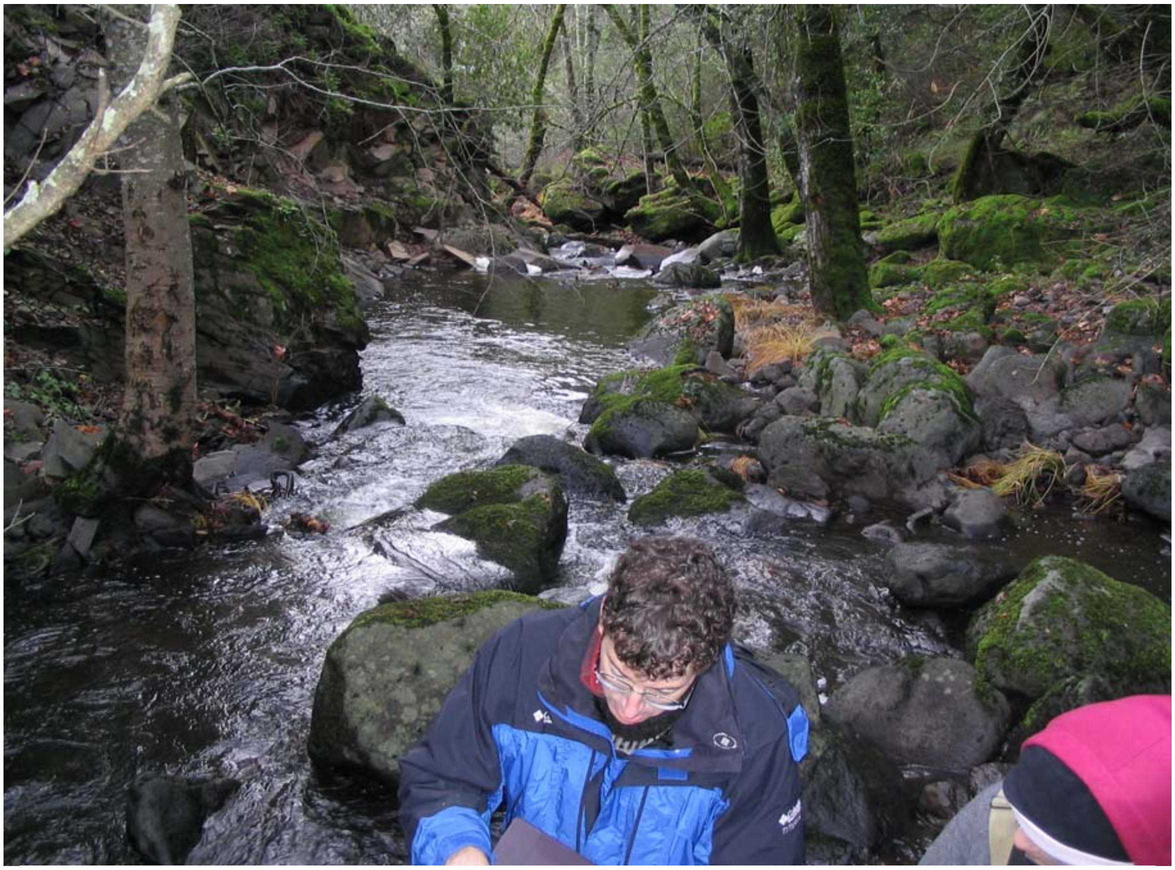


Photo by Bill Dietrich, UC Berkeley.

Figure 6. Alternating Boulder Step and Pool Bedforms in Upper Milliken Creek.
Photo taken upstream of Milliken Canyon Reservoir.

Other Napa River tributaries with similar land cover that are underlain primarily by hard volcanic flows, and where dams capture runoff from most of the watershed area, include Rector Creek, Tulocay Creek, and Sarco Creek. We would expect these tributary watersheds to have sediment budgets that are similar to that calculated for Milliken Creek watershed. Other east-side tributaries underlain primarily by hard volcanic flow rocks, and with similar land cover and uses include Soda Creek and Suscol Creek watersheds. These differ from Milliken and the above group of tributaries, in that no large on-channel dams have been identified on Suscol Creek or Soda Creek, and therefore, we would expect higher sediment supplies in these channels.

Carneros Creek

Carneros Creek drains a 23-km^2 tributary watershed located in the southwestern part of the Napa River watershed. Natural vegetation cover and vineyards predominate. Cattle ranching, low-density rural residential development, and wineries are also common. Intensive stocking of cattle and/or other types of livestock was common throughout large parts of the watershed from early nineteenth century up until recent decades (Grossinger et al., 2003). Sixty-six percent of the

[17] In referring to predicted values for permeability, high corresponds to ≥ 7000 cm/hr, fair equals 3000-to-6999 cm/hr, and poor < 3000 cm/hr.

watershed is underlain by mechanically weak sedimentary rocks, which are distinguished by gentle slopes that are often hummocky where they are being sculpted by landslides and gullies (Figure 7). Lesser but significant sub-areas of the watershed are underlain by hard volcanic lava flows or thick alluvial fan and valley deposits that flank the mainstem of Carneros Creek throughout its course. Dietrich et al. (2004) identified 40 small to medium sized dams that have been constructed on intermittent and ephemeral tributaries to Carneros Creek, which capture runoff from 22 percent of the land area in the watershed. Mainstem Carneros Creek is a deeply entrenched gravel-bedded stream, which alternates between pool-riffle, bedrock, and plane-bed reaches within its perennial reach (Figure 8). Bedrock channel reaches are also common in the middle of the watershed (upstream of Dealy Lane).

We measured streambed permeability at all potential spawning sites for steelhead and/or rainbow trout in two reaches of Carneros Creek, one located in the middle of the watershed (five potential spawning sites within a 340-m reach; streambed slope = 0.013; upstream drainage area = 10.4 km^2), that maintains perennial surface water, and the second located downstream of Old Sonoma Road (six potential spawning sites within a 280-m reach; streambed slope = 0.006; upstream drainage area = 18.2 km^2), in a freshwater reach that usually goes dry in the spring or summer of each year. Based on our review of available information and extensive field reconnaissance, prior to measuring sediment inputs or permeability, we hypothesized that Carneros Creek had a medium-to-high total and fine sediment supply in both reaches, and that stream power is moderate in the middle reach and low in the lower reach. Therefore, we predicted that typical values for streambed permeability should be fair-to-poor in the middle reach, and poor in the lower reach.

Other Napa River tributaries with similar land cover that are also underlain primarily by sedimentary rocks include Dry Creek and Redwood Creek tributary watersheds. These watersheds differ from Carneros Creek, however in that smaller proportions of their land areas drain into reservoirs, and average annual precipitation is higher. Erosion response to land use disturbances in Dry Creek and Redwood Creek watersheds may be similar to that described and measured in Carneros Creek.

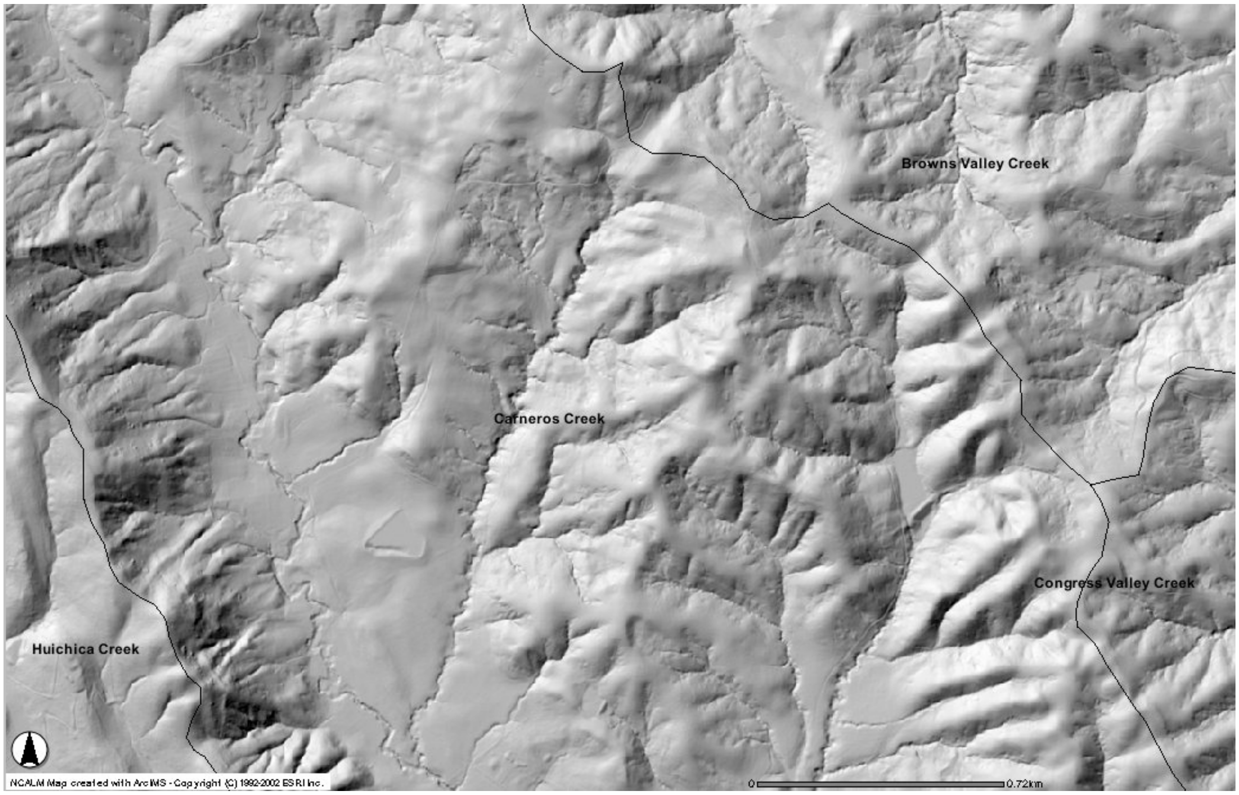


Figure 7. Ground Surface Topography in Carneros Creek Watershed. Generated using 1-meter resolution laser altimetry (LIDAR) data, and filtering to remove most vegetation cover. Gentle hummocky slopes developed on soft sandstones and clayey rocks that are being rapidly eroded by earthflows and gullies. Two dams can be seen on the image, one built on a channel (near center right-half of image), and the second, which is built off-channel (and visible at left center of image).

Ritchie Creek

Ritchie Creek drains a 6.4-km^2 tributary watershed underlain almost entirely by tuff and ash flow deposits of the Sonoma Volcanics Formation. Almost all of this watershed area has been in public ownership since the creation of Bothe State Park in 1960, and except for a very small amount of vineyard development in its headwaters and in its lower (Napa Valley) reach, the watershed is covered primarily by a natural mixed evergreen forest. Road density is also very low (1 km/km^2). Within Bothe State Park, Ritchie Creek typically is a steep cobble- or boulder-bedded channel that alternates between step-pool and cascade channel types within its canyon (Figure 9). Forced pool-riffle reaches also occur, primarily within the alluvial fan reach, which begins in the campground and extends downstream of the park boundaries into the Napa Valley. Based on reconnaissance of channel reaches and hillsides in the lower part of the watershed within Bothe Park, prior to measuring sediment inputs or permeability, we hypothesized that Ritchie Creek had a medium to high sediment supply with high channel sediment transport capacity, and consequently, we predicted that streambed permeability values should be poor to fair. We measured streambed permeability at all potential spawning sites for steelhead in one stream reach located near in the uppermost reach of the mainstem of Ritchie Creek (4 potential spawning sites; streambed slope = 0.05; drainage area = 4.0 km^2).

Photo by Bill Dietrich, UC Berkeley

Figure 8. Extensive Bank Erosion and Deep Entrenchment Along Mainstem Carneros Creek.
Bar in foreground formed by obstruction of flow by large bay trees that recently fell into the channel. Flow direction is from background to foreground in the picture.

Sulphur Creek
Sulphur Creek drains a 23-km^2 tributary watershed underlain primarily by mélange and sheared serpentine types of the Franciscan Formation, that is renown for its high to extreme rates of erosion (Brown and Ritter, 1971; Kelsey, 1980; and Lehre, 1982). Natural vegetation cover, vineyards, and rural residential land uses predominate. Mixed evergreen forest is the most common vegetation cover type. Extensive grasslands and woodlands are located in the upper part of the watershed. Beginning in the mid-nineteenth century and up until the last few decades, most of this area was managed to provide forage for livestock. In recent decades many former rangelands and some forested areas have been converted to vineyards. During the mid to late nineteenth century, most of the large redwood trees in Sulphur Creek watershed were logged (Grossinger et al., 2003b).

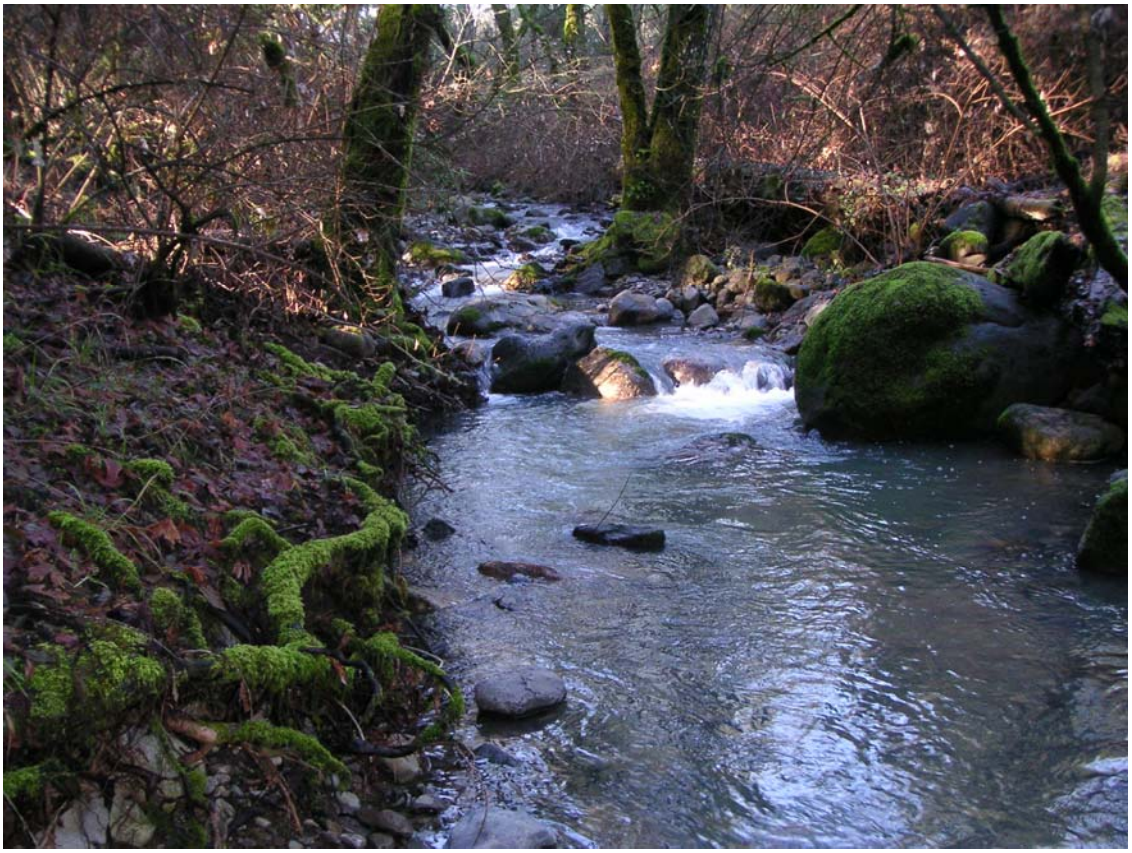


Figure 9. Step-Pool and Cascade Reaches Along Ritchie Creek.
The pool located in the foreground occurs at the boundary of channel-bridging boulder step (step-pool sequence). The steeper reach, in the background, where large boulders and cobbles are scattered about the channels and flow is turbulent throughout is referred to as a cascade.

Hillside topography alternates between steep slopes underlain by large hard blocks of bedrock and hummocky gentle slopes where intensively deformed rock types that form the bulk of the mélange and sheared serpentine deposits are sculpted by deep-seated landslides and large gullies (Figure 10). Perennial reaches of Sulphur Creek and its tributaries that provide potential habitat for steelhead trout are typically gravel-bedded with step-pool, plane-bed, or pool-riffle channels that are confined by adjacent slopes or moderately confined within narrow alluvial valleys (Figure 11).

Figure 10. Sulphur Creek in its Headwaters.
Sulphur Creek in its headwaters cutting through a large deep-seated landslide formed in the mélange.

Photo by Bill Dietrich, UC Berkeley

Figure 11. Plane-Bed Reach of Sulphur Creek
Long riffle and low-elevation gravel bar dominate this plane-bed reach of Sulphur Creek. Pools are spaced far apart and are shallow in plane-bed channels. A small and shallow pool occurs at the downstream bend in the background of the photo.

We conducted extensive field reconnaissance in three perennial tributaries of Sulphur Creek and in its mainstem channel within the canyon reach. Based on our reconnaissance and review, prior to measuring sediment inputs or permeability, we hypothesized that Sulphur Creek had a high to extreme total and fine sediment supply. Based on channel conditions described above and field observations, we selected four reaches of Sulphur Creek which we classified as medium to high sediment transport capacity, and where we measured streambed permeability at all potential spawning sites for steelhead that were identified in each reach (35 potential spawning sites in four reaches that varied in length between 125 and 300 meters with streambed slopes that vary between 0.012 and 0.024; upstream drainage area varied between 4.5 km^2 and 9.6 km^2). Based on channel and watershed attributes, we predicted measured permeability values should be poor to fair.

Mainstem Napa River
Mainstem Napa River is a gravel-bedded channel upstream of the City of Napa. As a result of active and progressive down-cutting of the channel throughout much of its length during the past 40 to 50 years, the frequency of gravel bar, riffle, side channel, and slough habitat has been greatly reduced, and the frequency of long-deep pool-run habitats has increased substantially with significant adverse impacts to salmonids, and other native fish and wildlife species (Stillwater Sciences and Dietrich, 2002). Stillwater Sciences and Dietrich conducted extensive surveys throughout an approximately 15-kilometer reach of mainstem Napa River located between Calistoga and St. Helena during 2001 and 2002. We rely upon the data they collected in their extensive survey of mainstem Napa River, and also upon the data we collected for this study at several additional locations throughout the mainstem Napa River and in its tributaries to estimate channel incision rates. Based on field reconnaissance and review of available information, prior to measuring sediment inputs or permeability, we hypothesized that mainstem Napa River had a medium total and high fine sediment supply, and a medium to high sediment transport capacity. Therefore, we predicted that streambed permeability should be poor to fair. To test this hypothesis, we used streambed permeability data collected by Napa County RCD staff at ten potential spawning sites for salmon and trout located in the 7-km long Rutherford Reach of the mainstem of the Napa River (streambed slope = 0.002; drainage area = 200 km^2).

3.6 Findings

- Streambed permeability values are influenced at least in part by rates of fine sediment input to channels (Figure 12), and where stream power available to transport sediment is relatively high, streambed permeability will rise by a greater amount in response to reduction in fine sediment supply than in reaches where stream power is relatively low.

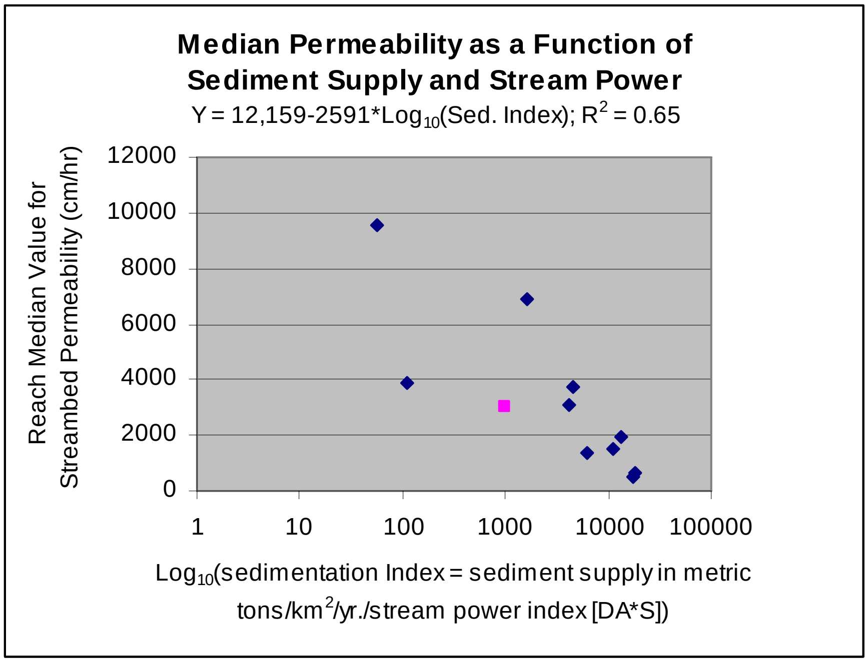


Figure 12. Streambed permeability as a function of sediment supply and transport. Diamond symbol corresponds to tributary measurement site. Square corresponds to Rutherford Reach in mainstem Napa River.

- Bedrock hardness exerts a significant influence on total sediment supply to channels (Table 5). Total sediment supply was lowest at sites underlain by the hard lava flow, 50 to 400 t/km^2/year. At sites underlain by soft ash flow and tuff, and soft sandstones and clayey rocks, total sediment supply was about 500 to 1000 t/km^2/year. We measured the highest rates of total sediment supply at sites underlain by the intensively deformed Franciscan mélange and sheared serpentinite, where total sediment supply was about 900 to greater than 1700 t/km^2/year.

- Within defined upland terrain types, land uses have the potential to greatly increase rates of sediment input to channels. At sites underlain by hard lava flows and sedimentary rocks we conclude that more than half of sediment input to channels during the most recent decade was caused by land-use activities (Table 5). We reach this conclusion because we found most of the gullies and shallow landslides observed in these terrain types are caused by land-use activities. For example, we often observed direct spatial overlap between locations of discharge of concentrated runoff from roads and/or hillside vineyards and actively eroding gullies and/or shallow landslides. We also conclude that intensive grazing (current or historical) has caused the gullies and shallow landslides we observed at some rangeland sites to be formed, based on the association between the gullies and shallow landslides, widespread occurrence of clay-rich soils at these sites, and

Table 5. Sediment Supply from upland Terrain Types												
Site	**DA (km^2)**	**Time Period**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Processes**	**Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides A/T (1)**	**Total Input Rate(2) ($t/km^2/yr$)**	**Land Uses/Disturbances**
Land Type: Hard Flow Rocks												
Spence Creek Pond	0.21	1958–2004	…	…	…	…	…	…	56	0.00	56	Natural non-managed grasslands
Kreuse Creek	3.14	1994–2004	Colluvial bank erosion	53	Post-fire sheetwash and gullies	101	…	…	?	?	154	Recent large fire
Milliken Reservoir	25.1	1926–2003	…	…	…	…	…	…	…	…	74	1981 Atlas Peak fire; low-intensity land uses; Foss Valley stores substantial fraction of coarse input to upper watershed
Bell Canyon Reservoir	13.9	1959–2001	…	…	…	…	…	…	…	…	129	Low-intensity land uses
Conn Creek	0.17	1994–2004	Colluvial bank erosion	(50–80)	Grazing gullies and SLS	[131–161]	Grazing sheetwash	165	211	0.62 to 0.76		High intensity grazing
Conn Creek Stock Pond	0.17	1997–2004	…	…	…	…	…	…	…	…	376	High intensity grazing
Redwood—Pond 1	0.18	1981–2004	…	…	Vine drainage gullies and SLS	35	…	…	…	…	242	Vineyard
Redwood—V Creek	0.12	1994–2004	Colluvial bank erosion	80	Vineyard drainage gullies and SLS	104	…	…	184	0.57	…	Vineyard
South Creek	1.0	1993–2003	Colluvial bank erosion	46	…	…	Nat. grass. Sheetwash	24	46	0.00	…	Low-intensity grazing
Central Creek	1.4	1993–2003	Colluvial bank erosion	60	Grazing gullies and SLS	79	…		139	0.57	…	Low-intensity grazing
								Range.	46 to 211	0 to 0.76	56 to 376	
								Average	127	0.37		
								St. dev.	74	0.34		
								Median	139	0.57		
								N=	5	5	6	

Table 5. Sediment Supply from Upland Terrain Types (Continued)												
Site	**DA (km^2)**	**Time Period**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Processes**	**Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides A/T (1)**	**Total Input Rate(2) ($t/km^2/yr$)**	**Land Uses/Disturbances**
Land Type: Great Valley Formation and Associated Sedimentary Rocks												
Redwood—Swale 2	0.37	1994–2004	Colluvial bank erosion	79	Vineyard and road gullies	256	…	…	335	0.76	…	Present: 100% vine
Redwood—Swale 1 Pond	0.16	1981–2004	…	…	…	…	Vine Sheetwash	[318]	…	…	605	
Redwood—Swale 1	0.16	1994–2004	Colluvial bank erosion	87	Vineyard gullies	200			287	0.70		
Carneros—Scott Creek Dam	0.52	1949–2003	…	…	…	…	…	…	…	…	960	Intensive historical grazing; moderate at present
Carneros—Scott Creek Downstream of dam	1.9	1994–2004	Colluvial bank erosion	130	Grazing and road gullies and SLS	530			660	0.80		LU as above; gullies primarily from historical grazing
								Range	287 to 660	0.7 to 0.80	605 to 960	Sampled Great Valley; inferred for other
								Average	427	0.75	783	Sedimentary rocks
								St. Dev.	203	0.05		
								Median	335	0.76		
								N =	3	3	2	

Table 5. Sediment Supply from Upland Terrain Types (Continued)												
Site	**DA (km^2)**	**Time Period**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Process(es)**	**Input Rate ($t/km^2/yr$)**	**Key Processes**	**Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides Input Rate ($t/km^2/yr$)**	**Colluvial Bank Erosion, Gullies, and Landslides A/T (1)**	**Total Input Rate(2) ($t/km^2/yr$)**	**Land Uses/Disturbances**
Land Type: Mélange and Sheared Serpentinite												
Conn (R pond)	0.03	1997–2004	Colluvial bank erosion and channel network extension	400	Grazing gullies	[136]	Grazing sheetwash	383	536	0.25	919	Intensive grazing
Sulphur (NF)	5.1	1994–2004	Colluvial bank erosion	130	Deep-seated landslides	1474	SLS	133	1737	>0.01	…	Historical grazing; present-day: low-intensity vineyard
Sulphur (H)	1.0	1994–2004	Colluvial bank erosion	150	Road gullies and slides	354	Spillway gullies	21	1170	0.32	…	Road drainage problems
								Range	536 to 1737	0.01 to 0.32	919 to >1737	
								Average	1148	0.19		
								St. Dev.	601	0.16		
								Median	1170	0.25		
								N =	3	3	3	

Table 5. Sediment Supply from Upland Terrain Types (Continued)

Site	DA (km^2)	Time Period	Key Process(es)	Input Rate ($t/km^2/yr$)	Key Process(es)	Input Rate ($t/km^2/yr$)	Key Processes	Input Rate ($t/km^2/yr$)	Colluvial Bank Erosion, Gullies, and Landslides Input Rate ($t/km^2/yr$)	Colluvial Bank Erosion, Gullies, and Landslides A/T (1)	Total Input Rate(2) ($t/km^2/yr$)	Land Uses/Disturbances
Land Type: Volcanic Ash-Flows and Turf												
Kimball Canyon Dam	7.8	1940–2003	…	…	…	…	…	…	…	…	494 to 618	Historical: logging/grazing; Present-day: low-intensity land use, water supply
Ritchie Creek	5.9	1994–2004	Colluvial bank erosion	150	Deep-seated landslides	670	Channel incision and bank erosion	85	905	0.09	913	Historical logging; Present-day: protected parklands
York Creek—St. Helena Upper Dam	5.9	1993–2004	…	…	…	…	…	…	…	…	570	Historical logging; Present-day: low-intensity roads, rural residential and vineyard
												Based on frequent occurrence of large deep landslides, we assume A/T in ash-flow = mélange
								Median	556	0.19		
								Average	520	0.19		
								Range			494 to 913	
								N =	1		3	

Table 5. Sediment Supply from Upland Terrain Types (Continued)

Notes, Abbreviations, and Conventions.

(1) A/T = ratio of anthropogenic (human-caused) to total sediment input to channels from colluvial bank erosion, gullies, and shallow landslides.

(2) Total input rate = sum of all significant active processes that deliver sediment to channels. Typically estimated from measurement of reservoir sedimentation rate corrected to account for trap efficiency.

Based on lack of large gravel bars or floodplains in upland channels, we assume that sediment input to the channel network is approximately equal to yield measured in reservoir. Conversions: area- 1.0 square kilometer = 247.1 acres = 0.39 square mile; sediment supply rates - 100 metric ton/square kilometer/yr. = 286 English tons/square mile/yr. = 0.45 tons/acre. SLS: shallow landslides; values in (parentheses) represent estimated range for rate; BE: bank erosion; N = number of sites; st. dev.: standard deviation; graz. = grazing; vine. = vineyard; ds - downstream; LU - land use. Sheetwash sediment input to channels: erosion modeled using USLE equation, and sediment delivery ratio estimated by delineating area of convergent topography and examination of coarse lag deposits. Values in [brackets] are residuals, which are not measured, and instead estimated by conservation of mass, as difference between sedimentation rate and sum of measured inputs. Residuals are only estimated where all other significant process rates have been measured. Colluvial bank erosion rates derived from measurement of total channel length and mean bank height, assuming typical downslope velocity of 0.01 m/yr., and assuming soil bulk density equals 1.6 metric tons per cubic meter. We set reservoir trap efficiency equal to 75% in all reservoirs except Kimball, where we assume 90% trap efficiency because of continuous pond in a large reservoir, and 67% in upper York, where dam has filled with sediment. Reservoir sedimentation volumes and landslide and gully scar volumes converted to mass assuming bulk density of 1.6 metric tons per cubic meter.

Input from Colluvial Bank Erosion, Gullies, and Landslides in Ash flows and Tuff.

We only conducted one upland field surveys at a site underlain by the ash-flow and tuff. Therefore median rate of input from colluvial bank erosion, gullies, and shallow landslides is calculated as follows: Given the dominance of deep-seated landslides in ash-flow and tuff, we applied A/T value estimated for mélange and sheared serpentinite (A/T = 0.25). Although A/T value is higher than estimated at Ritchie Creek (A/T = 0.09), we hypothesize that human influences on sediment supply are lower in Ritchie Creek than most other areas underlain by ash-flow and tuff. Average rate of sediment input from colluvial bank erosion, gullies, and landslides for ash-flow and tuff is calculated using York Creek sedimentation data, and assuming fraction of total input from colluvial bank erosion, gullies, and shallow landslides, in York Creek, is the same as estimated in Ritchie Creek (91%). Therefore, median estimated rate of input from colluvial bank erosion, gullies, and shallow landslides = 570 x 0.91 = 520 t/km2/yr.

documentation of intensive grazing during the historical period or present-day.[18] Also at two sites we surveyed (Spence Creek and South Creek), that do not have a history of intensive grazing, we document a lack of large actively eroding gullies and shallow landslides, which is consistent with our hypothesis. During the most recent decade, gullies and shallow landslides from roads, grazing, and/or hillside vineyards, collectively contributed about 50–150 t/km^2/year at sites underlain by hard lava flows, and about 200 to 500 t/km^2/year at sites underlain by the soft sandstone and clayey rocks (Table 5). Also, as indicated in Table 5, sediment input from sheetwash erosion caused by grazing and/or vineyards may contribute one-to-a-few-hundred tonnes/km^2/yr in the soft sandstone and clayey rock, and hard lava flow terrains.

- In contrast, we conclude that the large deep-seated landslides that dominate sediment input to channels in the mélange and sheared serpentinite are caused primarily by the intensive tectonic deformation of these units during their formation. Therefore, we conclude that only one-fourth to one-third of the sediment supplied to channels at sites underlain by the mélange and sheared serpentinite were human caused during the most recent decade (Table 5). Similarly, because large deep-seated landslides are also common in Ritchie Creek watershed, which is underlain by ash-flow and tuff terrain, we reach the same conclusion for this terrain type. Although the deep-seated landslides appear to dominate sediment input to channels in the above terrain types, we also identified several actively eroding gullies and shallow landslides formed by concentrated runoff from roads, vineyards, or on-channel dams in areas underlain by the mélange and sheared serpentinite (Table 5). Based on surveys at three upland sites in the mélange and sheared serpentinite, we estimate that land use-related gullies and shallow landslides contributed about 100 to 400 tonnes/km^2/yr to channels during the most recent decade. Also, based on modeling of sheetwash erosion rates at an intensively grazed site underlain by sheared serpentinite, it appears that sediment input rates to channels from sheetwash can be as high 400 tonnes/km^2/yr.

- Valley fills and alluvial fans in the Napa River watershed are thick, recently deposited coarse-grained sediments derived from erosion of the uplands. Sediment accumulation was favored over erosion in alluvial fans and valleys in the Napa River watershed since the end of the most recent glacial epoch, 10 to 15 thousand years ago, up until the historical era. However, because fans and valley fills are composed primarily of coarse-grained recently deposited sediments, they are poorly consolidated and non-cohesive, and hence a soft terrain type. As such, valley fills and fans are quite vulnerable to erosion when vegetation is disturbed, or runoff is increased or concentrated by land use disturbances, as evidenced by rapid and active channel incision and bank erosion that we documented in several reaches of the Napa River and its tributaries (Table 6). During the

[18] Clayey soils are widespread in the Carneros region, and up until the last decade or two, much of the Carneros region was very heavily grazed (Grossinger et al., 2003). Heavy grazing in the wet season, would cause clayey soils to become severely compacted, and vegetation cover density to be substantially reduced. The above factors acting in combination would greatly increase the area, volume, and peak rates of overland flow runoff during storms, providing the impetus for gullies and shallow landslides to form. Soils developed on the hard lava flows are also clay-rich, and hence vulnerable to compaction. However, because cobbles and boulders are also abundant in these soils, and soils are typically very thin, gullies and/or shallow landslides formed in the hard volcanic flows are usually much smaller features.

Table 6. Sediment Supply From Channel Incision								
Watershed Subareas	**Stream Name**	**Incised Channel Length (M)**	**Channel Width (M)**	**Average Annual Incision (M)**	**Age (Yr.)**	**Mass Removed (Tonnes)**	**Annual Average Incision Rate (Tonnes/Yr.)**	**Notes**
Upstream of Saint Helena	**Mainstem Napa River 1**	7,700	15	3	52	554,500	10267	Between Lodi Ln. and St. Helena gaging station; 2 m of incision 1850-1900; rejuvenated after 1950.
	Upper Napa River 1	12,500	8	2.5	18	400,000	20000	Mainstem between Lodi Ln. and Myrtledale Ln., Garnet Creek (fan), Blossom Creek (fan), and Cyrus Creek.
	Upper Napa River 2	3,100	5	1.5	18	37,200	1860	Mainstem Myrtledale Ln. to Kimball Reservoir
	Fan Blossom Creek	3,500	3	1.5	18	25,200	1260	Incision only in fan; age estimated based on vegetation cues.
	Upland and Fan Simmons Canyon	2,400		none	none	0	0	
	Fan Bell Canyon Below Dam	3,100	8	3	45	119,040	2645	
	Fan Cyrus Creek	650	9	1.5	18	14,040	702	Incision only in fan.
	Upland and Fan Dutch Henry Canyon	2,650		0	0	0	0	
	Fan Garnett Creek	3,400		0	0	0	0	
	Upland and Fan Ritchie Creek	2,900	6	0.7	40	19,488	487	1.5 meters of incision, perhaps 100 yrs. Old
	Upland and Fan Mill Creek	1,900	6	0.5	18	9,120	456	1.5 meters of incision, perhaps 100 yrs. Old
	Fan Sulphur Creek	2,400	8	3	100	92,160	922	Incision only in fan, downstream of gravel mining; primarily an urban reach.
	Upland Sulphur Creek				100	32,000	320	
Saint Helena to Conn Creek	**Mainstem Napa River 2**	12,000	15	3	52	864,000	16000	Between St. Helena gaging station and Conn Creek; 2 meters of incision 1850-1900; rejuvenated after 1950.
	Fan Bear Creek	3,600	2.5	1	50	14,400	288	Age estimated based on vegetation cues
	Fan Rector Creek Below Dam	2,400	8	3	56	92,160	1646	Incision only in fan.

Table 6. Sediment Supply from Channel Incision (Continued)

Saint Helena to Conn Creek	**Upland Conn Creek Below Dam**	250	10	1.5	?	6,000	0	According to WET (1990), incision in this reach was prior to 1900; also after Lake Hennessey was built?
	Upland Conn Above Dam				50	97,700	1954	Not included in estimates of channel incision downstream of dams.
	Upland Chiles Above Dam				50	37,750	755	Not included in estimates of channel incision downstream of dams.
Conn Creek to Soda creek	**Mainstem Napa River 3**	10,100	15	3	52	727,200	13467	Between Conn Creek and Soda Creek, we estimate 2 meters of incision between 1850-1900; incision rejuvenated after 1950.
	Upland and Fan Dry Creek	6,700	10	1.5	100	160,800	0	
	Upland and Fan Soda Creek	750	15	1	1850–1900	18,000	0	Incision prior to 1900?
Downstream of Napa	**Mainstem Napa River 4**	4,800	15	3	52	345,600	6400	Between Soda Creek and Trancas Avenue, we estimate 2 meters of incision between 1850-1900; rejuvenated after 1950.
	Upland Milliken Creek Below Dam	None	None	None	None	0	0	
	Fan Napa/ Redwood Creek	8,400	13	2	100	349,440	3494	includes an urban reach
	Upland Redwood/ Pickle Creek	None	None	None	None	0	0	
	Upland and Fan Tulucay Creek	None	None	None	None	0	0	
	Fan Suscol Creek				100			
	Upland/Fan Carneros Creek	9,000	10	3	100	432,000	4320	
	Fan Huichica Creek	2,200	8	2.75	100	77,440	774	Laurel Collins (personal communication, 2004; unpublished surveys, 1996)
Long-Term Average Rate of Sediment Supply:						Napa River (tonnes/yr.)	67993	
						Tributaries (tonnes/yr.)	18923	
						Total (tones/yr.)	***86916***	

In the absence of data to estimate rates during the most recent decade, we assume rates of sediment input from channel incision during the most recent decade equal are to one-half of long-term rates.

most recent decade, we found that channel incision, and associated bank erosion, in the alluvial valley and fan terrain contributed an average of about 45,000 tonnes per year into the Napa River. Because incision rate appears to vary substantially with location along the Napa River, total supply corresponds to a high local value of about 1100 t/km^2/year adjacent to the upper Napa River, and a low value of about 100 t/km^2/year along the Napa River downstream of Soda Creek, where the river approaches sea level. We estimate that the average rate of channel incision in mainstem Napa River over the past four decades (>5 cm/yr) was greater than 50 times the natural background rate of incision, which we infer should be similar in magnitude to local uplift rate (< 0.1 cm/yr). Almost all incision is found to be anthropogenic based on the very high estimated rate, and initiation during historical period, which is coincident with a period of intensive levee building and dam construction, filling of flood basins adjacent to channels, navigational dredging, intensive removal of debris jams, and historical gravel mining and channel straightening.

- We also calculated total sediment input rates into the channel network from all sources into four tributaries at their confluences with the Napa River—Carneros Creek, Milliken Creek, Sulphur Creek, and Ritchie Creek—to examine the influences of terrain type, land uses, and dams on sediment supply. In Milliken Creek, and much of the eastside of the Napa River watershed, the influence of dams is prominent (Maps 1 and 2). Although total sediment input rate into the channel network was two times estimated natural background rate during the most recent decade, about half of this sediment was not delivered to lower Milliken Creek or the Napa River, because most of the Milliken Creek watershed drains into dams (Figure 13). In the other three tributaries where we calculated total sediment input rate into the channel network, dams are much less prominent, and therefore total sediment input should correspond approximately with total sediment yield at the confluence. Sediment yields however, will be richer in fine and poorer in coarse sediment, as a result of breakdown of coarse sediment during transport through the tributary channel network. Sediment input rates calculated for Carneros, Sulphur, and Ritchie creeks are consistent with influences of terrain types and land uses described above (Figures 14 and 15).

- During the most recent decade, on average and over the whole watershed more than half of all sediment input to channels was caused by human actions (Figure 16). However, a significant proportion of all sediment input to tributaries does not reach Napa River, however, because 30 percent of watershed drains into tributary dams (Maps 1 and 2). Tributary dams capture all coarse and most fine sediment delivered to channels upstream of the dams. Effect of dam sediment-capture is greatest in middle reach of Napa River, at its confluence with Conn Creek, where about half of upstream area drains into dams. In this reach, coarse sediment input to channels approximates natural input rate, and fine sediment input rate equals about 170 percent of natural input (Figure 16). In upper Napa River and in its lower reaches, where a smaller proportion of the land drains into dams, coarse sediment input rate was 100 to 140 percent of natural input, and fine sediment input rate was 200 to 250 percent of the natural rate of delivery during 1994-2004.

- Four significant categories of human-caused sediment sources are: 1) roads; 2) vineyards; 3) rangelands; and 4) bed and bank erosion along the Napa River and the lower reaches of its larger tributaries (e.g., channel incision) (Table 7). Channel incision has the highest priority for treatment because sediment from channel incision is produced locally therefore, it likely has a greater effect on fine sediment deposition at spawning sites in the Napa River, than distal sources. Also, of greater importance than its role in the sediment budget, as the Napa River incises, it obliterates the basic physical habitat structure of the river (expressed by a substantial reduction in quantity of gravels bars, riffle margins, side channels, and sloughs, and a disconnection of the channel from its flood plain). The resulting increase in the quantity of homogeneous long, deep pool-run habitats favors native and introduced fishes that prey upon juvenile salmonids and has likely reduced Chinook populations. Stillwater Sciences and Dietrich (2002) postulate that the restoration of natural and complex physical habitat is a necessary prerequisite to facilitate a self-sustaining run of Chinook salmon. Restoration of natural bar-pool topography and flood-plain connectivity may also be needed to protect other rare or threatened species, including California freshwater shrimp, that are distributed solely or primarily in the Napa River and lower tributary reaches. Additionally, streamside land uses and public works infrastructure also are threatened by the high rates of bank erosion associated with channel incision processes along the Napa River.

Addressing the problem of channel incision in mainstem Napa River and the lower reaches of its tributaries will be the primary focus of the Napa River sediment TMDL. Substantial reductions in the amount of fine sediment input from land-uses in upland areas will also be needed to improve the quality of spawning and rearing habitat for salmon in the Napa River, and to protect spawning habitat for steelhead in its tributaries. Proposed reductions in sediment load are described in Chapter 5 (Allocations and Linkage Analysis).

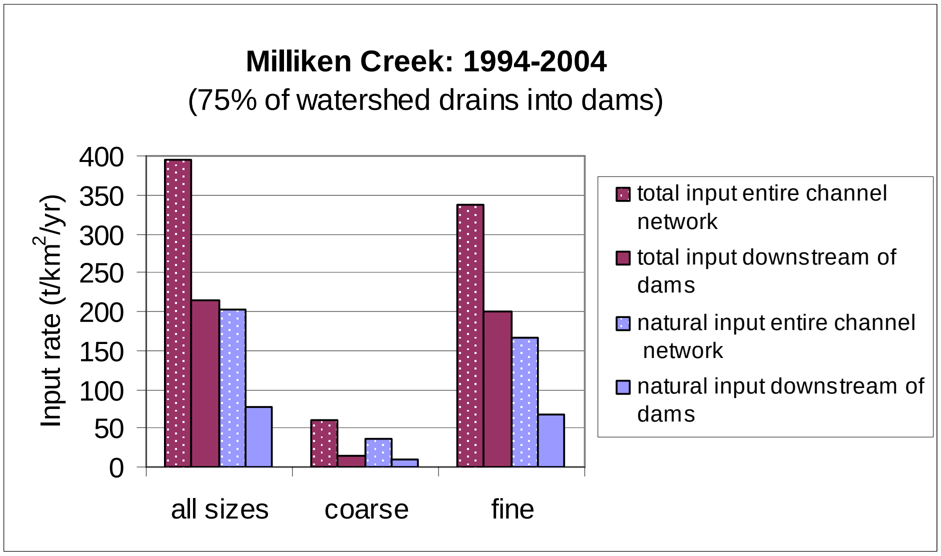


Figure 13: Sediment Input to Channels in Milliken Creek Watershed (1994-2004). Coarse corresponds to boulders, cobbles, and coarse gravels (e.g., 11.2-to-64 mm). Fine corresponds to fine gravel, sand, silt, and clay. Between 1994 and 2004, half of sediment input to channels was associated with land use activities. Dams captured about ¾ of coarse sediment input to channels and about ½ of the fine sediment input to channels. As such, total sediment delivery to channels located downstream of dams (all sizes) was approximately equal to natural background rate of sediment supply (e.g., absent dams and human caused erosion), albeit with a much smaller proportion of supply in the coarse size range.

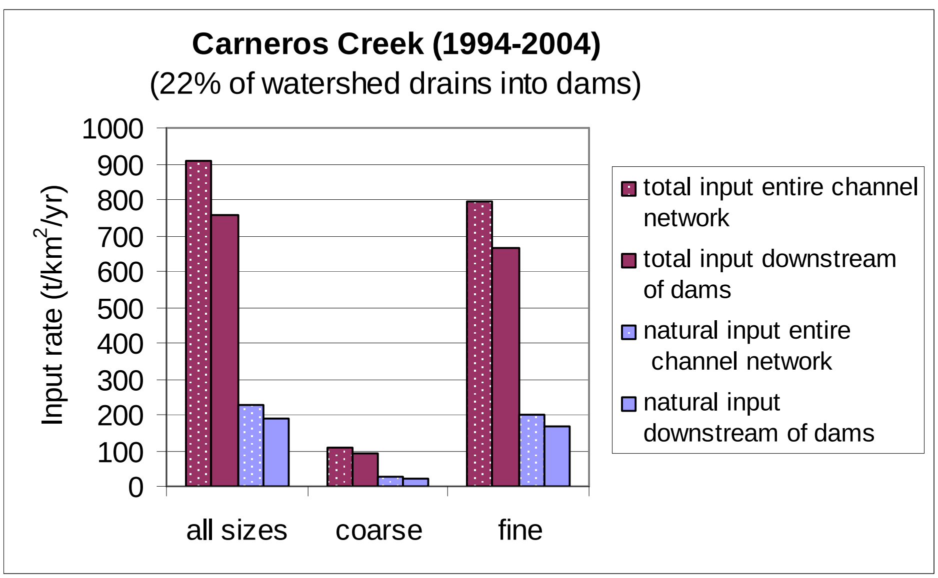
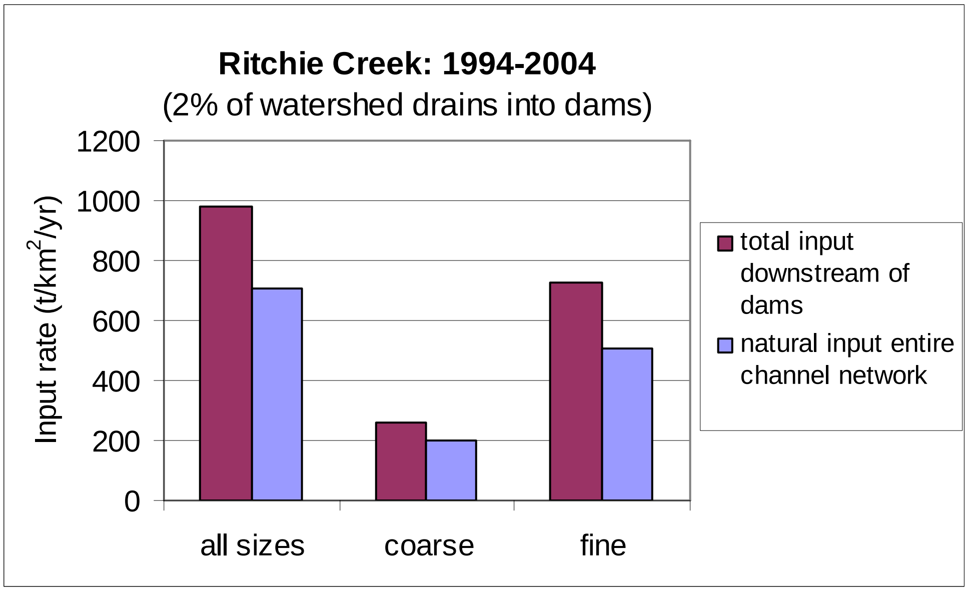


Figure 14: Sediment Input to Channels in the Carneros Creek Watershed (1994-2004). Land use activities dominate sediment supply, accounting for ¾ of the total sediment supply of delivered to channels between 1994 and 2004. Dams capture about 20 percent of the sediment that would otherwise be delivered to mainstem Carneros Creek.



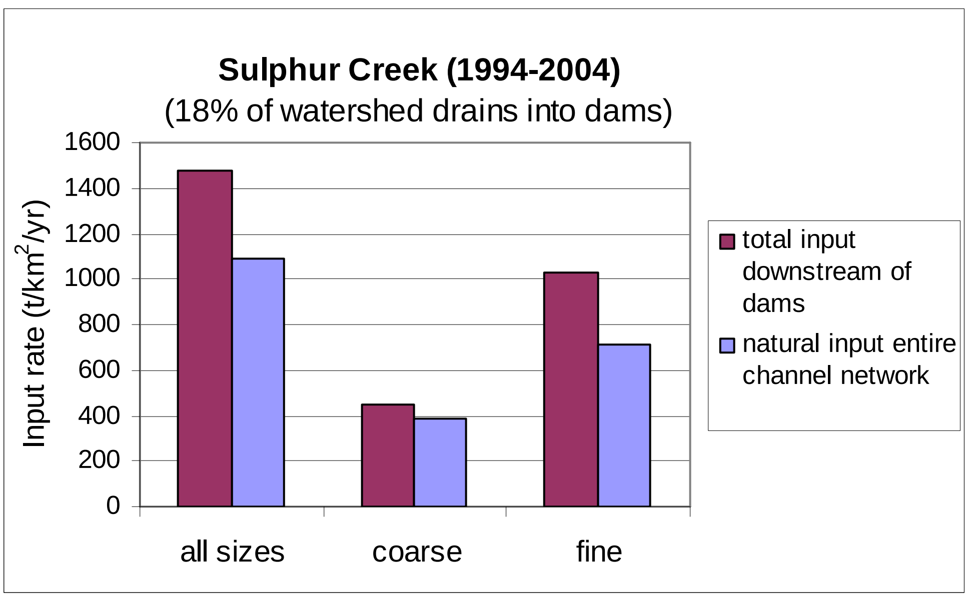


Figure 15: Sediment Input into Channels in the Ritchie Creek and Sulphur Creek Watersheds (1994-2004). About one-third of the fine sediment delivered to Ritchie and Sulphur creeks between 1994 and 2004 was associated with land use activities (primarily road-related erosion). Naturally occurring landslides dominate sediment supply to channels in both watersheds.

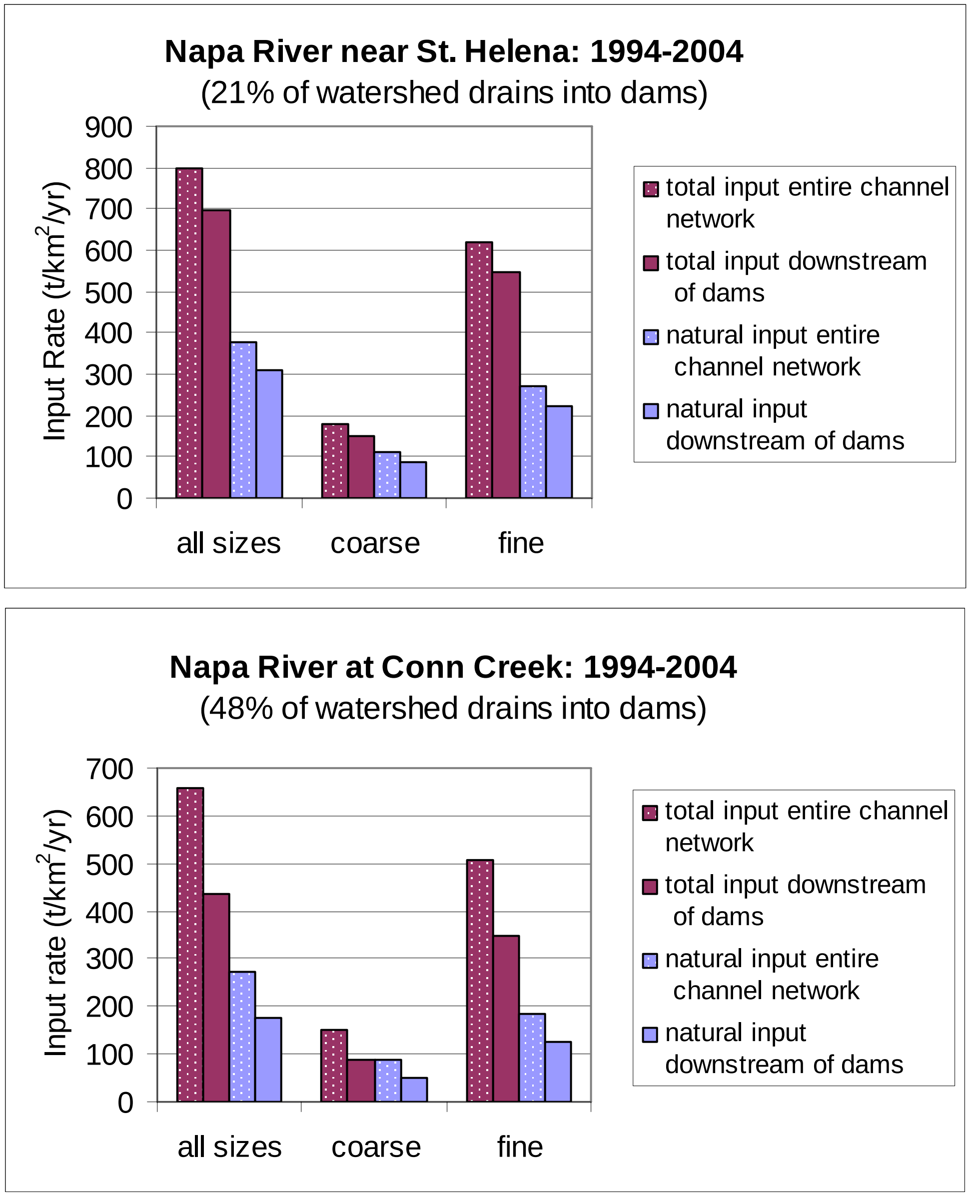
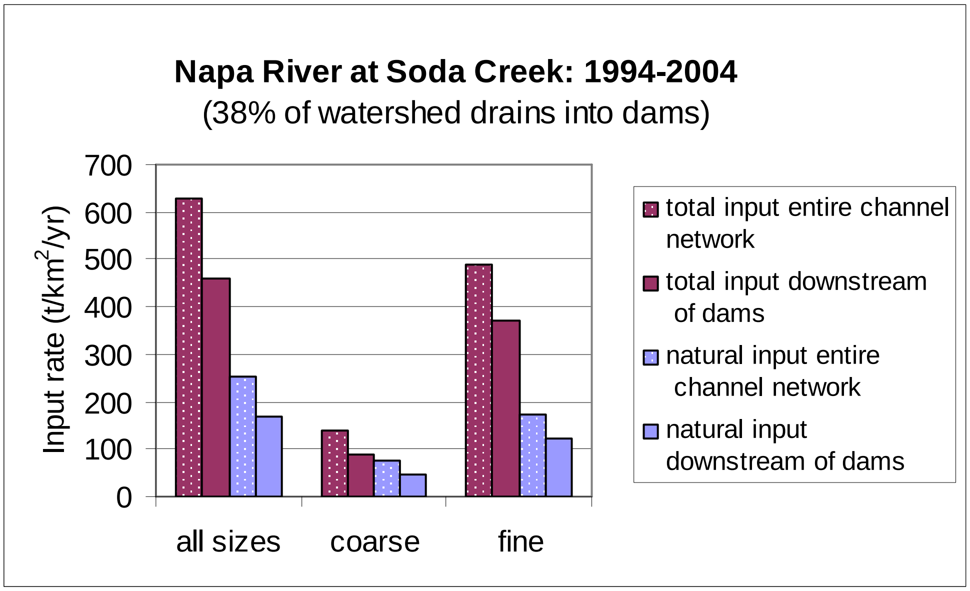


Figure 16: Total versus natural sediment input rate to channels tallied at four locations along Napa River. Coarse and fine are as defined in Figures 13 through 15. More than half of fine sediment input to channels between 1994 and 2004 was associated with land use activities. The effect of tributary reservoirs in reducing coarse sediment supply to Napa River is directly proportional to percentage of watershed draining into dams. Similarly, tributary dams capture most fine sediment input to reservoirs however some fine sediment (e.g., half or more of the fine silt and clay) is transported through the dams. Effect of dams on downstream sediment supply is maximal at Conn Creek confluence, where coarse sediment supply is reduced by 45 percent, and fine sediment supply is reduced by about one-third. Effect of dams is least significant at the Napa River near St. Helena location.



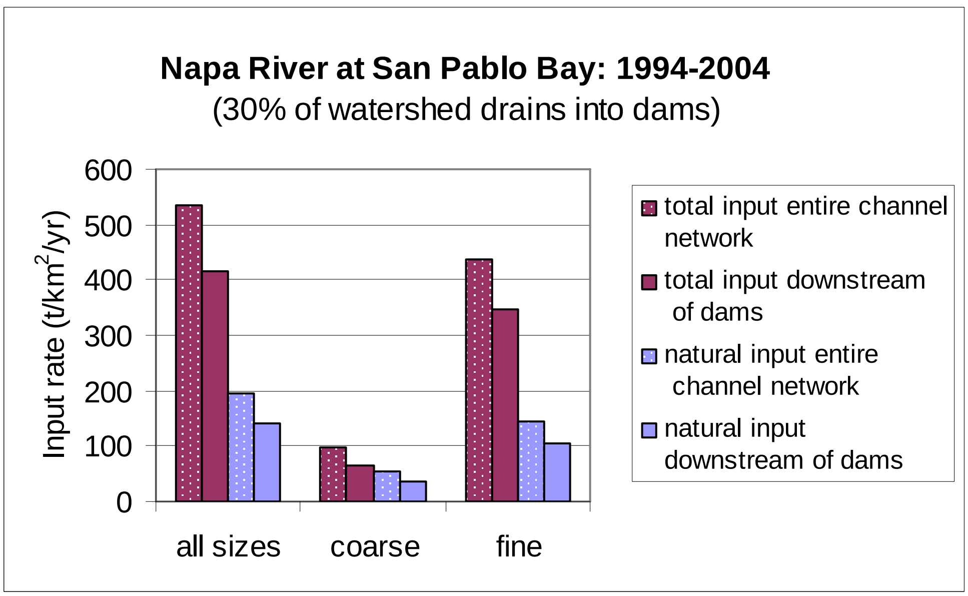


Figure 16 (continued): Total versus natural sediment input rate during the 1994-2004 period. Total sediment supply to Napa River at Soda Creek (all sizes) was equal to about 180 percent of the natural background rate (e.g., supply absent dams and human caused erosion) during the most recent decade. Without the dams, total sediment supply would have been about 250 percent of natural background rate. Dams capture almost as large a fraction of the total sediment supply input to channels located upstream of Napa River at San Pablo Bay.

Table 7. Mean Annual Sediment Delivery to Napa River at Soda Creek (1994-2004)	
Source	**Estimated Mean Annual Delivery Rate (metric tons/yr)**
Land areas upstream of dams (e.g., fine sediment discharge from reservoirs)	
▪ Natural Processes	7,000
▪ Human Actions	11,000
Land areas downstream of dams	
▪ Natural Processes:	92,000
▪ Human actions:	
o Channel incision and associated bank erosion	37,300
o Road-related sediment delivery (all processes)	55,400
o Surface erosion associated with vineyards and/or livestock grazing	36,700
o Gullies and shallow landslides associated with vineyards, and/or intensive historical grazing	29,600
o Urban Stormwater Runoff	4,000
TOTAL	271,000
Notes: Drainage area for Napa River at Soda Creek = 584 km^2. Estimates do not include sediment deposited in tributary reservoirs.	

CHAPTER 4: WATER QUALITY STANDARDS AND NUMERIC TARGETS FOR SEDIMENT

Key Points

- Water quality objectives for sediment, settleable material, and population and community ecology are not met.
- To protect Chinook salmon and steelhead, rates of fine sediment supply and channel incision must be reduced in a manner that enhances aquatic habitat conditions.
- To protect spawning and rearing habitat, we propose numeric targets for streambed permeability, and redd scour.
- The proposed targets are consistent with water quality objective and antidegradation policies.

4.1 Introduction

In order to develop a TMDL, a desired target condition must be established to provide measurable goals for management and a clear linkage to attaining applicable water quality objectives. In the case of sediment impairment in Napa River, we conclude that Napa River does not meet water quality standards for sediment, settleable material, and population and community ecology (see Problem Statement for additional details). Water quality objectives for settleable material and population and community ecology are as follows:

- **Settleable material**

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

- **Population and Community Ecology**

  "All waters shall be maintained free of toxic substances in concentrations that are lethal to or that produce significant alterations in population or community ecology or receiving water biota. In addition, the health and life history characteristics of aquatic organisms in waters affected by controllable water quality factors shall not differ significantly from those for the same waters in areas unaffected by controllable water quality factors."

Water quality objectives for sediment, settleable material, and population and community ecology are not met because human activities have increased the total supply of sediment delivered to mainstem Napa River and caused the supply to become much richer in fine sediment (sand, silt, and clay). As a result, excess fine sediment is deposited in the streambed at spawning sites, causing high levels of mortality between spawning and emergence for salmon and steelhead eggs and larvae. Also, as the streambed becomes finer at spawning sites, scour of spawning gravel is enhanced, exposing salmon and steelhead eggs and larvae to yet another significant source of mortality. Therefore, we have concluded that the water quality standard for settleable material is violated.

In addition, channel incision and associated bank erosion has been identified as a significant human-caused (anthropogenic) sediment source. Channel incision has high priority for control, not only because of its significance in the sediment budget, but also because it disconnects the channel from its flood plain, and causes physical habitat structure of the channel to be greatly simplified. Adverse habitat changes for salmonids include substantial reduction in gravel bars, riffles, side channels, and sloughs that are needed for spawning and early juvenile rearing, and associated increase in deep pool-run habitats that favor fish species that prey upon juvenile salmonids. Reduction in bar and riffle bedforms, and narrower width to depth ratio, as a result of channel incision, also cause much more energy to be exerted on the streambed at potential spawning sites, further exacerbating redd scour risk. Channel incision appears to be controllable by actions to restore a state of dynamic equilibrium, through construction of modest flood plain, and rehabilitation of natural pool-bar habitat structure, as is being considered in the 4.5-mile long Rutherford Reach of the Napa River. Taking the above information into account, we conclude that the water quality standard for population and community ecology is violated.

To conserve native fish and aquatic wildlife species, we propose two numeric targets that relate sediment to the attainment of water quality standards and beneficial uses in Napa River: 1) streambed permeability; and 2) streambed scour at potential spawning sites.

4.2 Streambed Scour

Target

The mean depth of scour (d_s) shall be ≤ 15 cm below the level of the overlying streambed substrate at typical pool-tails/riffle-heads in all gravel-bedded reaches of mainstem Napa River and in the lower alluvial reaches of its perennial tributaries in reaches where the streambed slope is gentle (S= 0.001 to 0.01). The target applies in response to all peak flows ≤ bankfull discharge.

We propose the above numeric target for redd scour depth as a water quality and habitat indicator to relate rate and sizes of sediment delivered to the channel (and its physical habitat structure) to the survival of incubating Chinook-salmon eggs-and-larvae in mainstem Napa River and the lower reaches of its gravel-bedded perennial tributaries. This target applies to the entire length of the mainstem of the Napa River, upstream of Trancas Road, and in the lower reaches of its perennial tributaries, where the slope of the streambed is between 0.001 and 0.01. Below find our rationale to support the proposed target.

Background and Rationale

Scour of spawning gravel during commonly occurring peak flows (e.g., bankfull) can be a significant source of mortality to the incubating eggs and larvae of salmon and trout species (McNeil, 1966; Montgomery et al., 1996). The beds of natural gravel channels cut and fill during high flow events. How deeply they cut into their bed (scour depth) is a function of the force per unit area exerted by flowing water on the streambed, channel features that either concentrate or disperse flow energy (e.g., debris, vegetation, bedrock, gravel bars, etc.), and the abundance and sizes of sand and coarser sediment grains supplied to the channel (bedload). Human actions that increase the rate of bedload supply, and/or cause it to become finer, will cause the streambed to become finer, facilitating an increase in the rate of bedload transport through a channel reach (Dietrich et al., 1989). As bedload transport rate increases, so do the mean depth and/or spatial extent of streambed scour (Carling, 1987) (Figure 18). Similarly, land uses activities that increase storm runoff peak and/or volume (forest clearing, pavement, etc.), and/or increase the amount of energy that is focused on the streambed at potential spawning sites for a given runoff event (e.g., human constructed levees, straightened channel reaches, removal of large debris jams, etc.), also have the potential to increase bedload transport rate, and therefore, streambed scour.

Human activities have caused the total rate of bedload supply to become substantially finer and to increase about 50 percent in the gravel-bedded alluvial reaches of mainstem Napa River and the lower alluvial reaches of its larger perennial tributaries. Both of these changes likely have caused an increase in streambed scour. In addition, the widespread occurrence of constructed channel levees, channel straightening, and the intensive removal of large woody debris from the mainstem Napa River have likely increased the amount of energy that is focused on the streambed at potential spawning sites for salmon during peak flow events, which may further increase the amount of scour. In contrast, in steep reaches (S = 0.02 to 0.08) of tributaries to the Napa River, channel incision is not significant, and although the total rate at which bedload sediment is supplied to steep tributary reaches has increased and become finer, it appears that much of the additional bedload is transported rapidly downstream to the lower gradient alluvial reaches. Therefore, we hypothesize that redd scour is not a significant concern in most steep tributary reaches.

We chose Chinook salmon as the index species for evaluating the potential impacts of redd scour because:

1) The distribution of their spawning habitat overlaps almost exactly with the distribution of gravel-bedded reaches in mainstem Napa River and the low gradient alluvial reaches of its larger tributaries, where human actions appear to have increased the amount of streambed scour.

2) Fall-run Chinook salmon typically spawn much earlier in the wet season than steelhead and, assuming similar temperature conditions, their eggs/larvae will remain in the streambed for a similar period of time.[19]

[19] In recent years, spawning of fall-run Chinook salmon in Napa River has been documented in early November through late December (Koehler, 2005), whereas most steelhead spawning, although not well documented in the Napa River watershed, probably does not begin until early January or later in most years, assuming that timing in the Napa River watershed is similar to the timing documented for other local California coastal range streams. The amount of time from spawning to emergence is a function primarily of water temperature, with warmer temperatures promoting more rapid incubation and development. For fall-run Chinook salmon, this time period varies from about eight to sixteen weeks. For steelhead, the time period varies from about six to eighteen weeks.

Therefore, we conclude that the probability of a large runoff event coinciding with the incubation period for Chinook salmon is much greater than for steelhead, and average amount of streambed scour, in such an event, is likely much greater in the stream reaches utilized by Chinook salmon. As such, our redd scour target is applied to Chinook salmon in gravel-bedded alluvial reaches of mainstem Napa River and the lower courses of its larger tributaries.

Our redd scour target is based on review of typical depths of egg burial by Chinook salmon and data describing streambed scour in gravel-bedded alluvial channels where the sediment supply is in approximate equilibrium with transport capacity. Such equilibrium channels are neither incising nor aggrading. Egg burial depth is a function of the body size of the spawning salmon or trout, and the sizes and packing of rocks in the streambed (van den Berghe and Gross, 1984; Burner, 1951). Although we have not measured Chinook salmon egg burial depths in the Napa River, studies conducted in other Pacific coastal streams provide some insight into this issue. DeVries (1997) reports published data for Chinook salmon egg burial depth in several streams including the Columbia River located in the Pacific Northwest. In those streams, the depth of burial from the top of the egg pocket relative to the level of the overlying gravel varied from 10 to 46 cm (4 to 18 inches) with mean depths of burial varying from 19 to 28 cm. Similarly, Evenson (2001) reports Chinook salmon egg burial depths at 28 spawning sites in the Trinity River in northwestern California, where egg burial depth, relative to level of overlying gravel, varied from 15 to 53 cm with a mean value equal to 26.5 cm.

Montgomery et al. (1996) report egg burial depths by chum salmon in relation to stream scour depths in a small gravel-bedded alluvial channel, Kennedy Creek, draining into Puget Sound. Their measurements, following a slightly greater than bankfull flow, reveal that scour depth was ≤ 10 cm at 65 percent of sites monitored (with a mean depth of scour = 13.4 cm), whereas less than 5 percent of chum salmon egg pockets were ≤ 10 cm below overlying gravel (mean depth of egg pockets = 22.6 cm). These observations lead them to hypothesize that the large-bodied salmon with spawning and incubation periods overlapping the period of maximum peak flows have adapted to the risk of redd scour by developing an ability to bury their eggs slightly deeper than the typical depth of scour. As such, salmon may be particularly sensitive to human disturbances of watershed and channel attributes that cause an increase in the rate of sediment supply and/or the amount of energy focused on the streambed at spawning sites.

Considering the above information, we propose that the target for depth of scour at potential spawning sites for Chinook salmon in mainstem Napa River, and in the lower alluvial reaches of its perennial tributaries, shall be ≤ 15 cm in response to a bankfull or smaller peak flow event. We hypothesize that this target should be similar to natural reference value, in which mortality via redd scour would be low during most years in response to moderate flood events and moderate rates of sediment supply.

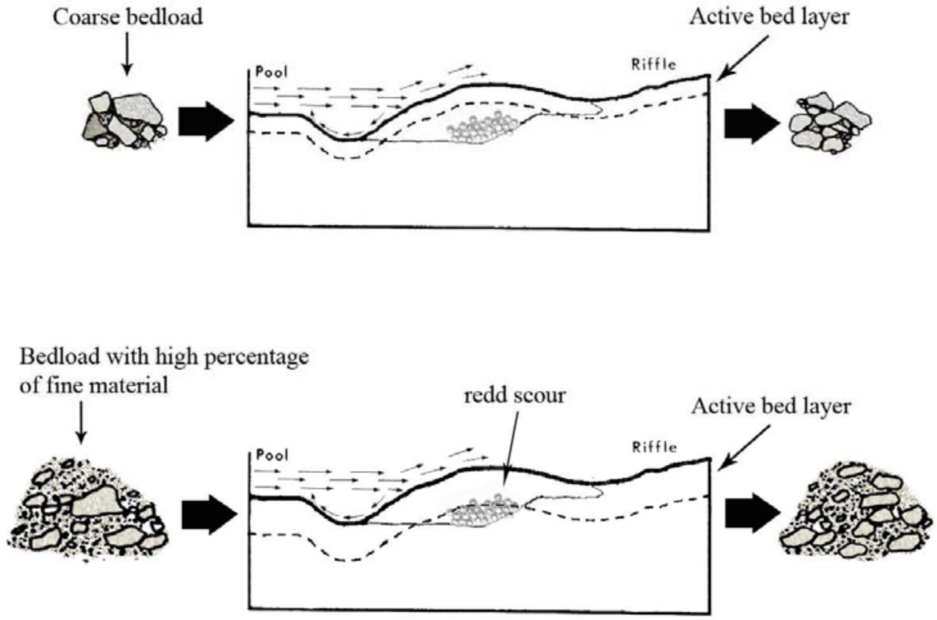


Figure 17. Influence of Sediment Supply on Streambed Scour at Spawning Sites (Redds)
When sediment supply increases and/or becomes richer in fines, depth of streambed scour is increased, exposing incubating eggs and larvae to increased risk of mortality via scour. **Figures reproduced with the American Fisheries Society, 1991.**

4.3 Streambed Permeability

Target
The median value for streambed permeability shall be ≥ 7000 cm per hour at potential spawning sites for steelhead and salmon in the Napa River watershed (Table 7). We estimate this target value corresponds to approximately 50 percent or greater survival of eggs and larvae from spawning to emergence (Stillwater Sciences and Dietrich, 2002). Below find our rationale to support the proposed target.

Background and Rationale
Streambed permeability, or the flow rate of water through the streambed, is a key factor influencing the survival of incubating salmonid eggs and larvae. Streambed permeability is significantly and positively correlated with survival to emergence (Chapman, 1988). Cool, clean water flowing through the streambed is needed to provide and replenish dissolved oxygen and to remove metabolic wastes. Streambed permeability is a function of the size distribution and packing of coarse sediment (gravels) and finer sediment contained in the streambed. Streambed permeability is inversely related to fine sediment concentration, primarily sand grains with diameters ≤ 1 mm that are deposited in the streambed (McNeil and Ahnell, 1964; Figure 1). When a large amount of fine sediment is deposited in the streambed, permeability can be reduced

by a substantial amount with consequent adverse impacts to the survival of incubating salmon and trout eggs and larvae.

Stillwater Sciences and Dietrich (2002) measured streambed permeability in January and February of 2002 at 69 potential spawning sites located in 28 reaches of 17 Napa River tributaries and at five potential spawning sites located in three reaches of mainstem Napa River. They concluded that permeability values at potential spawning sites for steelhead and salmon in the Napa River and its tributaries are low with a median value equal to 4800 cm per hour, which corresponds to a predicted value of approximately 44 percent survival for incubating eggs and larvae between spawning and emergence.[20] In June 2003 we resurveyed a subset of the above sites (22 sites in ten reaches of eight tributaries). Based on the results of our resurvey (median value = 2900; predicted survival = 35 percent), we conclude that low permeability is a spatially extensive phenomenon in Napa River tributaries. Although we estimate a lower value for median permeability, the difference between the medians is not statistically significant ($\alpha = 0.05$).

To explore the relationship between streambed permeability and fine sediment supply, we estimated rates of fine sediment delivery to channels during the most recent decade in four Napa River tributaries and four sites along mainstem Napa River (see source analysis). This involved the following:

- We measured streambed permeability at all potential spawning sites for steelhead and/or rainbow trout, in nine reaches of the same four tributaries, (64 potential spawning sites for steelhead in nine reaches of four tributaries). We then used permeability data collected by Napa County Resource Conservation District (Koehler, 2005) at 10 potential spawning sites in three reaches of mainstem Napa River near Rutherford (Table 8).

- Because we also expected differences in stream power to influence fine sediment deposition, we surveyed longitudinal slope of the streambed.[21] From this we analyzed the energy gradient and calculated drainage areas into each reach in order to develop rough estimates of variability in stream power between measurement sites, and the influence of this attribute on permeability.

[20] We report and use median values in developing targets because standard deviations often approach or exceed the mean value.

[21] Stream power is defined as the rate of energy expenditure by water, as it flows through a channel. Stream power is directly proportional to the product of streamflow discharge multiplied by water surface slope. In our analysis, we use drainage area as a surrogate for streamflow discharge. Only a fraction of total stream power is available to transport sediment. This is because energy is also expended through internal friction within the fluid, and friction along the channel boundaries caused by grain roughness, large obstructions (like debris jams, bedrock outcrops, bridge piers, etc.), and/or other changes in channel width, depth, and direction of flow encountered along the length of the channel. In reaches where we measured permeability, channel form and substrate sizes varied substantially. Therefore our estimates of total stream power only provide a relative estimate of the fraction of stream power that is available to transport sediment.

Table 8. Streambed Permeability Measurements								
Reach name	Number of potential spawning sites where permeability was measured	Median ermeability (cm/hr)	Median predicted survival to emergence (percentage)	Drainage area (DA) (km2)	Streambed slope (S)	Stream power index (DA x S)	Total sediment input rate (t/km2/yr)	Sedimentation index = total input rate ÷ stream power index
Lower Carneros	6	1337	25	18.2	0.006	0.11	666	6090
Upper Carneros	5	3069	37	10.4	0.013	0.14	574	4180
Upper Milliken	7	3856	41	18.9	0.035	0.67	74	111
Lower Milliken	7	9577	54	30.3	0.058	1.76	99	56
Sulphur 1	9	1913	30	4.7	0.024	0.12	1528	13231
Sulphur 2	8	503	10	7.1	0.012	0.09	1528	17594
Sulphur 3	8	640	14	4.5	0.019	0.09	1528	17884
Sulphur 4	10	1481	26	9.6	0.018	0.17	1938	11183
Upper Ritchie	4	3743	40	4.0	0.051	0.20	931	4585
Upper York	8	6900	49	5.9	0.06	0.35	570	1610
Rutherford	10	3011	37	200.0	0.002	0.4	584	584
Totals	74	2461	34					
Range:	4 to 10	503 to 9577	10 to 54	4.7 to 200	0.002 to 0.06	0.09 to 1.76	74 to 1938	56 to 17884

We found a strong negative relationship between median permeability and average-annual sediment supply divided by stream power (Figure 12). Although the R^2 value (0.65) is fairly high, we would caution against using the relationship to predict the absolute magnitude of a permeability increase/decrease in a given channel reach in response to an increase/decrease by a given amount in fine sediment supply because:

- The stream power index we used provides only a crude estimate of energy expenditure on the streambed at potential spawning sites.

- Inter-annual and spatial variations in sediment supply in channels are large in the Napa River watershed.

- Our median permeability values used to develop the relationship are probably only accurate within a factor of two of actual values.

Based on our regression analysis presented in Figure 12 (described above), documentation that human actions have increased sediment supply in channels in the Napa River watershed (see source analysis), and the work of McNeil and Ahnell (1964) (Figure 1), we conclude that:

- Low permeability values at potential spawning sites in the Napa River and its tributaries are explained, at least in part, by the deposition of high concentration of fine sediment (primarily sands) in the streambed.

- Current values for permeability at potential spawning sites for steelhead and salmon in the Napa River watershed are lower than natural reference values.

We propose a numeric target ≥ 7000 cm per hour as the reach-median value for streambed permeability at all potential spawning sites for salmon and steelhead in the Napa River and its tributaries. We hypothesize that this value corresponds to approximately 50 percent survival of incubating salmon and steelhead eggs and larvae between spawning and emergence (Stillwater Sciences and Dietrich, 2002).

For fall-run Chinook salmon, we conclude that moderate to high rates of survival (≥ 50 percent) for eggs and larvae from spawning to emergence may be necessary to achieve a self-sustaining wild spawning run in the Napa River. This is because the total production of Chinook salmon fry appears to be substantially reduced relative to natural reference values as a result of other inter-related impacts of fine sediment supply and/or channel incision, which include the following:

- Risk of egg and larvae mortality, via redd scour during common peak flows (bankfull event), appears to be quite high as a result of human actions that have increased sediment supply and energy expenditure on the streambed at potential spawning sites in mainstem Napa River.

- Spawning habitat quantity in mainstem Napa River is very small and appears to have decreased substantially between the 1940s and present as a result of channel incision.

With regard to steelhead, although spawning habitat quality and quantity does not presently appear to be a primary factor limiting steelhead or salmon run size (Stillwater Sciences and Dietrich, 2002), if the average number of steelhead returning to spawn is small under current conditions, then poor spawning habitat quality has the potential to further depress steelhead run-size, and/or to reduce the genetic diversity through poor survival-to-emergence in some tributaries or reach types (e.g., lower alluvial reaches of all tributaries which provide the primary spawning and rearing habitats in dry years, and which also usually have the poorest permeability values). As such, the risk of steelhead extinction in the Napa River watershed may be increased as a result of poor survival to emergence. Therefore, we propose implementing the 50 percent predicted survival target between spawning and emergence as a precautionary measure to reduce risk of steelhead extinction. We also propose implementing management actions to improve habitat access and rearing habitat for older juvenile steelhead in order to facilitate enhancement of steelhead run-size and distribution, and therefore, the long-term conservation of steelhead within the watershed.

CHAPTER 5:LINKAGE ANALYSIS AND ALLOCATIONS

Key Points

- We propose sediment TMDL of 125 percent of natural background.
- Attainment of the proposed TMDL will require human-caused sediment inputs to be reduced by 50 percent

5.1 Introduction

In this chapter, we evaluate linkages between sediment inputs and habitat conditions as needed to determine the total maximum daily load (TMDL) for sediment and allocations for sediment sources. The TMDL is the total sediment load that can be discharged into the Napa River and its tributaries without violating water quality standards.

5.2 Approach to Development of the Linkage Analysis

Linking channel conditions to sediment supply is challenging because channel form and sediment deposits reflect the temporal and spatial integration of sediment inputs to and transport through stream channels. In addition to sediment supply, channel transport capacity and storage are influenced by: a) magnitude, duration, and frequency of high flows; b) channel slope and depth; and c) channel roughness, or elements that concentrate or disperse flow energy. For these reasons, time lags between sediment input and discharge may be several years to decades or more, and specific channel responses to changes in sediment supply may vary substantially. These challenges acknowledged, one or more of the following approaches to linking sediment inputs and channel attributes have been pursued for developing natural stream channel sediment TMDLs:

- Reference watershed or time period[22];
- Direct comparison of sediment supply to channel attributes related to sediment supply; and
- Direct comparison of current values for channel attributes related to sediment supply to numeric targets.

Most total maximum daily loads for sediment in natural stream channels are expressed in terms of mass per unit area per unit time. We propose an alternative approach of expressing the TMDL as a percentage of the natural background rate of sediment input to channels. We have taken this approach because:

[22] Where water quality standards are attained including water quality objectives for sediment, and where salmonid populations are robust.

a) Napa River has a Mediterranean climate and active tectonic setting, therefore, natural sediment loads are highly variable and native stream biota are adapted to large infrequent sediment pulses associated with natural disturbances (e.g., large storm events, wildfires, and major earthquakes).

b) Native stream biota are not adapted (however) to chronic increases in fine sediment load caused by land use activities that disturb vegetation cover and/or infiltration capacity of soil (e.g., road-related erosion, agriculture, construction, timber harvest, livestock grazing, etc.). Under the natural sediment input regime, fine sediment input would be very low in most years, and the amount of fine sediment stored in the channel would be rapidly reduced (following a large disturbance) back to levels favorable for spawning and rearing.

Therefore, to emulate natural sediment dynamics and adaptations of native biota to infrequent pulse disturbances (but not to chronic press disturbances), we recommend that the TMDL be expressed as a percentage of natural input rate to channels (e.g., natural load) to emulate the pattern and magnitude of natural sediment inputs under current conditions where management actions may dominate sediment regime[23].

In order to determine what percentage above natural background sediment load is needed to attain sediment-related water quality standards, we reviewed previously adopted sediment TMDLs for stream channels in the California Coast Range, and found two sediment TMDLs that have been adopted where a the TMDL is expressed as a percentage of natural background load. These TMDLs were developed based on comparison to a reference watershed or reference time-period where water quality standards are/were attained. These two sediment TMDLs are:

1) For Redwood Creek in Humboldt County, where a reference watershed was used; and

2) For Noyo River on the Mendocino Coast where a reference time period was used.

In both cases, a reference state was identified where salmonid populations are/were robust, and inferentially, where water quality objectives for sediment-related parameters are/were attained. For Redwood Creek, the sediment load corresponding to robust steelhead and salmon populations equals 117 percent of natural background. For Noyo River, the sediment TMDL equals 125 percent of natural background. Similar to Napa River watershed, the primary goal of these TMDLs is the recovery of salmon and steelhead runs.

Of the two watersheds, Noyo shares more attributes in common with Napa including similar uplift rate and average annual rainfall, common occurrence of weak sedimentary rocks that are susceptible to substantial increases in sediment supply in response to land use disturbances, and predominance of road-related erosion, gullies, and channel incision as significant human-caused sediment sources. Although hard volcanic rocks are also common in Napa River watershed, this

[23] Also by expressing the TMDL and allocations by source as a percentage of natural background, the focus of sediment monitoring shifts to measurement of sediment input rates to channels and determining which sources are natural or human-caused. With this focus, it is possible to rapidly evaluate progress toward attainment of the TMDL, and the effectiveness of management practices toward this end.

terrain type is not as sensitive to land use disturbances, and therefore, absolute increases in sediment supply from land use activities in the hard volcanic rock terrain type are much lower. As such, elevated sediment loads in Noyo and Napa rivers are primarily a product of interactions between land use disturbances and weak sedimentary rocks being uplifted at similar rates. Therefore, Noyo River under historical conditions (circa 1940s) - when there was a modest increase in sediment load (e.g., 125 percent of natural background) and robust steelhead and salmon runs - appears to be suitable reference watershed for evaluating assimilative capacity of Napa River for sediment.

Achieving a TMDL equal to 125 percent of natural background in Napa River, during a future period with similar climate conditions to the 1994-2004 measurement period, would require average annual sediment supply be reduced by about one-third from current value to approximately 325 metric tons per km^2 per year. Inputting this load into the regression relationship between spawning gravel permeability and sedimentation index (Figure 12), we calculate that median value for spawning gravel permeability in lower Napa River[24] would be 6600 cm/hr, which is approximately equivalent to the proposed numeric target for spawning gravel permeability. Redd scour potential also would be reduced by an unknown but significant amount as a function of reducing the sediment supply by one-third (from current load), and as a consequence of increases in riffle, gravel bar, slough, and flood plain habitat areas recommended as part of the implementation plan to reduce sediment supply from channel incision (Chapter 6).

5.3 Allocations

Therefore, consistent with the approach used in other northwestern California streams, and based on predicted attainment of the spawning gravel permeability numeric target, the Napa River sediment TMDL is established at 125 percent of natural background (Table 9). Allocations by sediment source category are specified as a percentage of the natural background. An estimate of the percent reduction from current proportion of the total load is also provided. In 1994-2004, about two-thirds of sediment discharged to Napa River was from land use activities. With attainment of the TMDL, slightly less than one-half of all sediment discharged to Napa River would be from land use activities.[25]

Allocations expressed in terms of estimated percent reductions are consistent with the approved sediment TMDL for Deep Creek, Montana (Endicott and McMahon, 1996) as cited in the *Protocol for Developing Sediment TMDLs* (USEPA, 1999). Compliance with the TMDL will be evaluated at Napa River below the confluence of Soda Creek. This station approximates the downstream limit of mainstem Napa River salmon habitat. For the most recent decade, attainment of the TMDL equates to a sediment load in Napa River at Soda Creek of approximately 325 metric tons per km^2 per year.

---

[24] In mainstem Napa River at Soda Creek which corresponds approximately to the downstream limit of salmon spawning habitat in mainstem, and where streambed slope is close to the lower limit for gravel-bedded channels, and hence, particularly sensitive to deposition of sand in the streambed.

[25] The sediment TMDL is 125 percent of natural background load, or that load that would have been discharged to mainstem Napa River absent dams or human caused erosion. Because about 30 percent of the watershed drains into dams, a significant fraction of natural load is deposited in tributary reservoirs, and therefore, only about 67 percent of natural sediment inputs to the channels are delivered to mainstem Napa River. As such, it's possible to allocate almost this amount (e.g., 59 percent of natural background) to land use sources, and still achieve the TMDL.

Table 9. Total Maximum Daily Load and Load and Wasteload Allocations			
Source category	**Load during 1994-2004 (percentage of natural load)**	**Estimated reductions needed (percentage)**	**Load allocations (percentage of natural load)**
Land areas upstream of dams			
▪ Natural processes	**5**	**0**	**5**
▪ Human actions	**8**	**50**	**4**
Land areas downstream of dams			
▪ Natural processes	**62**	**0**	**62**
▪ Human actions:			
o Channel incision and associated bank erosion	**26**	**50**	**13**
o Roads	**36**	**50**	**18**
o Surface erosion associated with vineyards and grazing	**24**	**50**	**12**
o Gullies and shallow landslides associated with vineyards, and/or intensive historical grazing	**20**	**50**	**10**
			Wasteload allocation (Percentage of natural load)
o **Urban stormwater runoff**	**2**	**50**	**1**
TMDL			125

5.4 Margin of Safety

The Clean Water Act, Section 303(d) and associated regulations at 40 CFR § 130.7 require that a TMDL include a margin of safety that takes into account any lack of knowledge concerning the relationship between the pollutant loads and desired receiving water quality. The margin of safety may be employed implicitly by making conservative assumptions (USEPA, 1991). For the Napa River TMDL, we employed conservative assumptions in setting the numeric target for redd scour that we conclude will yield significant benefits above and beyond those needed to address sediment-related water quality objectives. Specifically, attainment of the numeric target for redd scour will involve sediment source reductions (to enhance **quality** of spawning and rearing habitat) **and** channel restoration actions to enhance the **quantity** of spawning and rearing habitat in Napa River. This will be accomplished through channel restoration projects that will increase the habitat area in riffles, gravel bars, side channel, and sloughs, and the amount of flood plain habitat that is inundated during the annual flood (see Chapter 6). As such, the redd scour target provides additional benefits to salmonids above those required solely to achieve sediment-related water quality standards.[26]

Similarly, and implicit margin of safety for sediment-related water quality standards is also provided through implementation actions recognized to address other key stressors of salmon and steelhead populations in Napa River watershed including actions to protect and/or enhance baseflow, fish passage, habitat complexity, and stream temperature, as described in the implementation plan (Chapter 6).

5.5 Seasonal Variation and Critical Conditions

The TMDL must describe how seasonal variations were considered. Sediment input to channels in Napa River watershed and its effects on beneficial uses are inherently variable on seasonal, annual, and longer timeframes. For this reason, the TMDL and allocations are designed to apply to the sources, and are expressed as a percentage of the natural load during the period of interest.

Critical conditions with regard to flow are addressed through implementation actions to protect or enhance baseflow as described in Chapter 6. Other critical water quality parameters are also addressed including the target for redd scour that addresses sediment-related water quality objectives and water quality objectives for habitat complexity (e.g., as an aspect of population and community ecology). Implementation actions are also recognized to protect and/or enhance fish passage, stream temperature, and baseflow (including development of guidelines for the protection of instream flow for salmonids).

[26] We should also point out that the only approach that is probably feasible (for reducing sediment supply from channel incision and associated bank erosion) from the standpoint of obtaining Clean Water Act permit approvals is one that would lead to net enhancement of stream-riparian habitat conditions.

CHAPTER 6: IMPLEMENTATION PLAN

6.1 Introduction

The ultimate goals of the Napa River Sediment TMDL and Habitat Enhancement Plan are to:

- Conserve the steelhead trout population
- Establish a self-sustaining Chinook salmon population
- Enhance the overall health of the native fish community
- Enhance the aesthetic and recreational values of the river and its tributaries

To achieve these goals, specific actions are needed to:

- Attain and maintain suitable gravel quality and diverse streambed topography in freshwater reaches of Napa River and its tributaries
- Protect and/or enhance base flows in tributaries and the mainstem of the Napa River
- Reduce the number and significance of human-made structures in channels that block or impede fish passage
- Maintain and/or decrease summer water temperatures in tributaries to the Napa River

In this chapter we describe actions recommended to reduce sediment supply and enhance baseflow, fish passage, and stream habitat complexity, as needed to achieve the above stated goals. First, we provide an introduction to this topic. As suggested by definitions of *implement* and *plan*, a TMDL implementation plan is "a detailed description of a program of actions" (*plan*) to "ensure actual fulfillment by the performance of specific measures" (*implement)* that are needed to restore clean water. USEPA has further recommended that TMDL implementation plans include each of the following elements: (USEPA, 1999):

- List of actions needed to achieve pollutant allocations and numeric targets specified by the TMDL, and a schedule, including interim milestones for implementation of those actions

- Reasonable assurances (provided by the state water quality agency) that implementation actions specified in the plan will occur. These include being able to demonstrate that the specified actions will be effective, and that adequate resources will be available to successfully execute the program.

- A description of the legal authority (of local, state, and/or federal government agencies) under which the necessary actions will or could be required

- Monitoring or modeling plan, including milestones for measuring progress, in achieving water quality standards

- Adaptive management plan that includes a schedule for iterative update(s) of the TMDL in response to monitoring or modeling results, and/or other information that is new and relevant to the determination of whether water quality standards have been achieved

- Estimated amount of time required to restore clean water including basis for estimate

In addition to actions needed to resolve sediment-related threats to steelhead and salmon, we conclude that progress is also needed toward resolution of all other factors limiting steelhead productivity and survival in the Napa River watershed (e.g., habitat access, physical habitat complexity, stream temperature, and instream flow protection). Therefore, we recommend additional management actions to address other significant factors limiting steelhead and salmon, as part of a broader habitat enhancement plan discussed at the end of this chapter.

In the discussion that follows, we describe our goals and intentions, legal authorities, and key considerations that may influence implementation actions. We then outline some concepts for how an effective implementation program might be developed. Our overarching goal is to restore and protect beneficial uses of the Napa River and its tributaries. As described in the source analysis, significant human-caused sediment sources to the Napa River and its tributaries include: roads, vineyards, intensive historical grazing, and human-caused channel incision. The Water Board recognizes the technical, institutional, and monetary challenges that each responsible party or group of dischargers (e.g., ranchers, grape growers, road owners, etc.) may face in designing and implementing measures to reduce fine sediment loads, and/or to rehabilitate physical habitat conditions in the Napa River.

6.2. Key Considerations Regarding Implementation

Key considerations that may influence implementation actions to resolve sediment impairment in Napa River and its tributaries may include the following:

- Total sediment delivery to channels associated with land use activities needs to be reduced by 50 percent from contemporary values (1994-2004) in order to meet the proposed numeric targets and allocations for sediment.

- Based on review of previously approved sediment TMDLs for similar California streams (e.g., Garcia River and San Lorenzo River), typical timeframe for development and submittal of erosion control and management plans, and/or evidence documenting effective practices in place, is 3 to 5 years following adoption of the TMDL.

- Similarly, typical timeframes for achieving TMDL allocations and targets are 10-to-20 years following submittal of erosion control and management plans.

- We support exploring opportunities to optimize cost effectiveness of sediment source reduction through development of sediment source-control cooperatives that could be administered by local public agencies or other capable and interested groups. Conceptually, such cooperatives might be organized around a source category (roads, vineyards, etc.) and/or geographic regions of the watershed (e.g., tributary, mainstem channel reach), allowing members to target the most cost effective source control actions.

Local public agencies, including those with source control responsibilities (e.g., Napa County Public Works), and those with expertise in erosion control and landowner assistance (e.g., Napa County RCD and NRCS), may be able to provide leadership, administrative, and technical support for such a venture, should there be interest. Such partnerships would be in favorable positions for receipt of grant funding from state and federal agencies to support implementation actions, and emphasizing treatment of the most cost effective sources would result in significant cost savings to public and private landowners.

- We expect to define a minimum threshold, in terms of potential sediment delivery to channels caused by human activities from a given parcel that would trigger the requirement to prepare and implement a sediment control plan. In other words, we do not expect or intend to implement sediment control regulations or permit requirements on most small- or medium-sized landowners (e.g., < 40 acres) in the Napa River watershed, except where such lands have the potential to deliver a significant amount of human caused sediment discharges to the channel network (e.g., ground disturbing activities are occurring over large proportion of the property or in sensitive areas, there is an extensive road network, etc.). We will work with knowledgeable and interested parties to study this issue and ultimately to develop fair and defensible thresholds for responsibility to prepare and implement a sediment control plan.

- Our proposed sediment allocations are expressed as a percentage of the natural sediment load. Therefore, TMDL effectiveness monitoring will focus on measuring human and natural sources of sediment delivery to channels, and channel response to management and natural events (e.g., streambed permeability and redd scour). With this focus, we will be able to rapidly evaluate effectiveness of a variety of management practices implemented to reduce sediment loads, and progress toward attainment of the TMDL. Furthermore, under this approach human-caused sediment discharges are always evaluated within the context of total supply, which is strongly influenced by hydrologic conditions encountered in the monitoring period.

- We expect individual landowners (or those participating in sediment cooperatives or stewardships) to perform monitoring to document that implementation actions have occurred (TMDL implementation monitoring). We do not expect individual landowners however, to perform effectiveness monitoring (e.g., post implementation monitoring of human-caused and natural sediment delivery to channels, and/or channel response to management and natural events). Ideally, such effectiveness monitoring should be coordinated and conducted by an agency or organization with appropriate scientific expertise and demonstrated capability to work effectively with property owners and other interested parties to gain permissions for access, as needed to collect the monitoring data.

- We support broadening the TMDL monitoring program to include census of steelhead and salmon populations, focused studies to improve understanding of limiting factors, and other relevant biological information. With such information, in hand, it may be possible to further prioritize management and restoration actions based on estimated costs and environmental benefits, and/or to adaptively update of sediment allocations, numeric targets, and/or schedule for sediment implementation actions.

- In crafting an effectiveness-monitoring program for the TMDL, we will work with the technical advisory committee to the Napa County Watershed Information Center and Conservancy and other interested and knowledgeable parties.

- State funding will be available to support (in part) the implementation of sediment source inventories and controls, the broader set of habitat enhancement actions needed to conserve steelhead and salmon populations, and a monitoring program to evaluate progress in restoring water quality and conserving salmonid populations. Other incentives for pro-active participation may include permit waivers and more favorable implementation schedules.

- We believe there is substantial value in supporting and expanding tributary and/or mainstem-reach stewardships to achieve significant large-scale enhancements of stream and riparian conditions in the Napa River watershed.

6.3. Legal Authorities and Requirements

The Water Board's legal authorities to require water pollution control actions are derived from the state Porter-Cologne Act and federal Clean Water Act. The Porter Cologne Water Quality Control Act gives Water Board's the authority to issue waste discharge prohibitions, waste discharge requirements (WDRs), and/or waivers thereof, to control actual or potential discharges of pollutants from point-and-nonpoint sources[27] into the waters of the state (California Water Code 13000 et seq). The state has recently adopted a policy for implementation and enforcement of its nonpoint source pollution control program (NPS program)[28], which requires all current and future nonpoint sources to be regulated under waste discharge requirements or waivers, and/or waste discharge prohibitions (California Water Code Section 13369). Under the adopted NPS program, waivers of waste discharge requirements must be conditioned on a monitoring program to ensure that water quality is protected. Locally administered water quality protection programs (e.g., Napa Green) may provide an innovative and less intrusive means for landowners to qualify for waivers, and hence, a more attractive venue for achieving compliance with the TMDL and the state's nonpoint source pollution control program.

6.4. Implementation Strategy

The Source Assessment presented in Chapter 3 identified five significant categories of human caused sediment sources in the Napa River watershed. These sources are: road-related erosion, vineyards, grazing, erosion from bed and banks of the Napa River, and urban stormwater. Erosion processes that relate to these sources are: a) sheetwash from land uses (grazing and vineyards); b) road-related erosion (surface erosion from roads, erosion at stream crossings, and landslides and gullies caused by roads); c) gullies and landslides caused by land uses that concentrate runoff (grazing, roads, and hillside vineyards); and d) channel incision and

[27] Point sources typically are discharges of pollutants from a discrete conveyance (or pipe). Nonpoint sources are everything else that has not been defined as a point source (e.g., vineyards, rangelands, roads, etc.).
[28] The policy can be obtained online at http://www.waterboards.ca.gov/nps/docs/oalfinalcopy052604.doc .

associated stream terrace bank erosion. Stakeholders in the Napa River watershed have a longstanding tradition of citizen involvement in watershed-scale planning, management, and restoration activities that has included a number of very impressive accomplishments including, but not necessarily limited to the following:

- Establishment of the Agricultural Preserve in Napa Valley in the 1960s

- Formation of a community-based coalition to advocate and pass Measure A, the Living River Strategy, which now provides funding for local flood protection efforts via the creation of wetlands and restoration of linkages between the river and its floodplain

- Establishment in May of 1998 of the Napa River Watershed Task Force, comprised of a representative group of stakeholders appointed by the County Board of Supervisors that met over a two-year period ending in September 2000, to develop recommendations for sustainable land use and natural resource conservation in Napa County

- Establishment and continuity of several watershed stewardships, many of which have developed management plans and/or have implemented, or are planning, large-scale projects to enhance water quality and stream-riparian habitat (Huichica, Carneros, Sulphur, Rutherford, Murphy, Salvador, and others)

We commend these achievements, and the impressive work on the ground to control erosion and protect or restore habitat conditions (e.g., local voluntary efforts, Napa County Conservation Regulations, early implementation of a very strong municipal stormwater program, Napa Salt Pond Restoration, Napa Green, etc.). As a result of these and other successful, locally led conservation efforts, it will be much easier to achieve the proposed allocations and targets for sediment (and other pollutants), as needed to restore water quality.

There also are other programs that might provide useful templates or approaches toward the goals of restoring water quality and protecting fisheries in the Napa. For example, FishNet 4C - a coalition of six central California coastal counties (Mendocino, Sonoma, Marin, San Mateo, Santa Cruz, and Monterey) that formed in the late 1990s following the listings of coho salmon and steelhead in central California as threatened under the federal Endangered Species Act - has developed a road maintenance manual for public works agency staff to achieve the objectives of protecting water quality, aquatic habitat, and salmonids, while undertaking most routine and emergency road-related maintenance activities (FishNet 4C et al., 2004)[29]. It is our understanding that Napa County Public Works is interested in adapting and implementing the best management practices described in the FishNet 4C road maintenance manual for use in Napa County (T. Adams, personal communication, 2005). We applaud County staff for their interest and leadership in this area. Similarly, the Rangeland Advisory Program of UC Cooperative Extension (UCCE) has developed a program for inventory and implementation of erosion control practices on ranches in California that has been very well received by ranchers. It is our understanding that local US Natural Resources Conservation Service staff are already working with UCCE staff to assist interested ranchers in developing a water quality protect plans

[29] Best management practices covered include those to "preserve and protect (ecologically) important woody debris in creeks to the extent possible", and ecologically superior approaches to stream bank stabilization.

for their ranches in the Napa River and Berryessa watersheds. These efforts and stewardship practices of many local ranch owners should provide a solid foundation for implementation of effective sediment control plans at ranches throughout the Napa River watershed.

We also wish to acknowledge the accomplishments of the Rutherford DUST Society in building a coalition and obtaining resources to explore restoration of a 4.6-mile reach of the Napa River. Their leadership and success suggest that the larger goal of restoring complex physical habitat conditions and conserving fisheries and aquatic wildlife along a large portion of the Napa River is an attainable goal that could be accomplished at a reasonably foreseeable future date (e.g., 15-to-20 years). We strongly support the voluntary and cooperative restoration efforts, embodied by the Rutherford example, as a primary vehicle for addressing adverse impacts of channel incision on water quality and habitat conditions in Napa River and the lower reaches of its tributaries. The Water Board is committed to advocating for grant funding for the implementation of an ecologically superior restoration project in the Rutherford reach, and in other freshwater reaches up and down the length of the river.

6.5 Discussion of Possible Approaches to Achieve Allocations

The sediment TMDL implementation plan described herein is developed around each major source category (roads, grazing, vineyards, urban stormwater runoff, and channel incision).

Vineyards

An effective means of reducing sediment delivery from sheetwash erosion would be for all vineyards to meet the performance standards specified under the Napa County Conservation Regulations (Chapter 18.108).[30] For hillside vineyards established prior to 1991, we think this could be accomplished by using the design and management practices that have been implemented on other hillside vineyards permitted under the Conservation Regulations. Alternatively, at gently sloping or flatland sites, not currently regulated, it may also be possible to control sediment delivery to channels through establishment and maintenance of vegetated buffers adjacent to engineered and natural channels.

Hillside vineyard development at some sites, especially at those underlain by soft bedrock and/or where vineyards replace forest cover has also caused off-site channel enlargement (gully development) and associated shallow landslide failures[31] (see source analysis this document; MIG, 2000). To avoid this problem when new hillside vineyards are proposed, the design review process should incorporate rigorous hydrological analysis (as appears to be the current practice by Napa County) to predict potential change in peak runoff rates, and the potential for off-site channel enlargement. Effective design features should then be incorporated to reduce off-site erosion risk to an acceptable level. A possible approach to this problem is outlined on pages 31-37 of the *Phase II Final Report of the Napa River Watershed Task Force* (MIG, 2000). Similarly, the Science Advisory Group to the Napa Green Certification Program has recommended that peak storm runoff rates following hillside vineyard development (at all sites)

[30] Assuming a 20-to-25 year period for sediment TMDL implementation, we predict that 95% or more of the total projected hillside vineyard acreage would be permitted under the Napa County Conservation Regulations or successor regulations that provide equal or greater levels of resource protection. At present, we estimate that approximately 55% of total hillside vineyard acreage is permitted under the Conservation Regulations.

[31] Potential mechanisms are discussed on page 18 of this document.

should not increase by more than 10-to-15 percent above pre-project rates to reduce the risk of off-site channel enlargement to an acceptable level (Napa Green Certification Program, 2003). At all existing hillside vineyards, as part of a larger sediment source inventory and control plan, the potential for concentrated runoff from the vineyard or road network should be evaluated through site inspection and analysis by qualified registered professional scientists or engineers. The goal for management of existing vineyards should be to reduce peak storm runoff rates into actively eroding gullies or landslides or other potentially unstable areas, as needed to accelerate natural recovery.

Vineyard sediment control performance standards described above could be achieved through expanding the total vineyard acreage enrolled and independently certified under the Napa Green Certification Program[32], by application of existing state regulatory authorities (Waste Discharge Requirements or Waivers thereof), and/or by adoption of some of the revisions to the Conservation Regulations that were recommended by the Napa River Watershed Task Force (MIG, 2000).

Grazing

An effective means of reducing sheetwash erosion from livestock grazing, at sites where this is a problem, could involve adopting livestock and/or range management practices that result in sufficient plant material being left on the ground to effectively resist sheetwash erosion. One such approach of this type, that has been successfully applied to control soil erosion and nutrient losses at many rangeland sites in California is a residual dry matter standard or target, with residual dry matter being defined as "the old plant material left standing or on the ground at the beginning of a new growing season" (University of California, 2002).[33]

We would appreciate the opportunity to work with local staff of the University of California Cooperative Extension (UCCE), NRCS, and/or RCD to consider development of residual dry matter (RDM) targets based on variation in rainfall and vegetation cover at sites in Napa River watershed. We would also be interested in partnering with one or more of the above organizations and/or rancher member organizations to establish a grant program to fund technical assistance for the development of rangeland water quality inventories and management plans, and funding for implementation measures pertaining to accelerating the natural recovery of gullies and landslides caused by intensive historical grazing and/or active or abandoned roads and/or other human structures (e.g., channel incision and/or gullies downstream of stock ponds, etc.). Effective control actions to accelerate natural recovery of gullies and landslides might involve exclusion fencing, planting of native woody vegetation, diversion or dispersion of concentrated runoff from roads, modification of grazing strategies and locations, construction of

[32] To-date, holistic and comprehensive farm plans to restore clean water, and to protect salmon, and steelhead have been prepared for about 6,000 acres of vineyards in Napa River watershed. With current funding through for the program, we estimate that it will be possible to enroll about 12,000 vineyard acres in the program, or about 25-to-30 percent of the total acreage within the Napa River watershed. To-date, the State Coastal Conservancy and Water Board have provided approximately $1.2 million to fund development and implementation the Napa Green Program. Department of Fish and Game, NOAA Fisheries, Napa County RCD, NRCS, and other groups and individuals have also provided significant additional resources for the program.

[33] For more information on this topic, this report (Rangeland Monitoring Series, Publication 8092) can be obtained online at http://anrcatalog.ucdavis.edu .

alterative water supply for livestock, etc.)[34]. Possible incentives for pro-active participation of ranchers, within responsibility and means, may involve waivers of waste discharge requirements, grant funding for rangeland and sediment source inventories and implementation actions, and/or more favorable schedules for implementation. We look forward to the opportunity to discuss these and other ideas that might provide a basis for a fair and effective rangeland management program.

Roads

Road-related sediment delivery to channels is a significant source to the Napa River. In comparison to other significant sources, erosion control and prevention actions for rural earth-surfaced roads, which are located primarily on private property, may be one of the most cost effective sediment sources to control within the Napa River watershed[35]. Also, most road-related sediment inputs are very rich in the fine sediments that are impairing the quality of spawning and rearing habitat for steelhead and salmon in the Napa River and its tributaries. Finally, strategic investments to control future road-erosion pay significant dividends to property owners in terms of large reductions in costs for maintenance and/or repair of roads.

In contrast to rural roads located on private lands, most rural public roads in the Napa River watershed are paved. Based on this difference, the need to satisfy other road design and safety standards, and additional costs associated with staging road reconstruction actions on public roads, typical costs to storm-proof paved rural public roads may be three-to-four-times the cost to storm-proof rural earth surfaced roads located on private property (PWA, 2001). Based on review of available mapping of roads and road ownership in Napa River watershed (PWA, 2003a, 2003b, and 2003c; Napa County, 2003), we estimate that there are approximately 1100 miles of upland roads that produce the vast majority of sediment delivered to the Napa River from road-related erosion. We estimate that 10-to-15 percent of the total road length is owned and maintained by Napa County and/or other public agencies, and 85-to-90 percent is owned and maintained primarily by private landowners.

There may be several advantages to public agencies and private landowners exploring the possibility of entering into sediment-control cooperatives to reduce road-related erosion in a way that also substantially reduces costs and burdens to both parties. For example, Napa County Public Works would bring professional staff expertise in contract administration, road construction and maintenance, and ability to obtain and manage large grants. Private landowners

---

[34] Based on initial conversations with a local expert in the field of gully stabilization on Bay Area ranchlands (S. Chatham, personal communication, 2005), it appears that most rangeland gully stabilization efforts in the Napa River watershed may be quite cost effective to undertake, and may compare favorably in comparison to typical costs of vineyard surface erosion control and channel bank stabilization costs. Based on this input, we would estimate that typical costs may range between $15-to-$50 per ton of sediment that is prevented from future delivery into a stream channel.

[35] Based on a review of recent road erosion control inventories conducted in three Napa River tributary watersheds (Carneros, Dry, Sulphur) and two similar watersheds located elsewhere in the Bay Area (Pescadero Creek in western San Mateo County, and Redwood Creek in western Marin County), we estimate that typical costs to storm-proof rural earth-surfaced roads in Bay Area watersheds, including road erosion inventories, are less than $20 per ton of sediment that is prevented from future delivery into a stream channel. For example, typical costs for erosion control for valley-floor vineyards in the Napa Valley region appear to be more than $300 per ton of sediment that is prevented from future delivery into a stream channel, and cost per unit sediment savings for hillside vineyard erosion control are much higher.

would bring to the table what would appear to be some of the most cost effective sediment sources to treat. By working together within a larger group, costs for road erosion inventories and execution of control actions could be substantially reduced because of the economies of scale. Finally, individual private landowners would be less likely to obtain grants, and potential problems associated with run-on from adjacent properties (that are causing road-erosion) will be difficult to resolve without cooperation across property boundaries. Such a cooperative, it also clear that such a cooperative could also benefit from the involvement of the RCD and/or NRCS, to provide professional expertise in erosion control and landowner assistance.

To this end, we strongly support providing several potential incentives to road sediment-control cooperative partnerships including prioritization of such efforts for grant funding, and a general WDR waiver program.

Urban Stormwater Runoff

Urban Stormwater sediment sources include construction sites, industrial sites, municipal Stormwater conveyance systems, and state highways. These sources are all currently required to control sediment discharges and regulated by NPDES permits. Details of the State and Regional Water Board's programs to regulate urban Stormwater runoff can be found at http://www.swrcb.ca.gov/stormwtr/index.html. As part of this TMDL, no new regulatory actions are proposed for these sources. Effective regulation of these sources since 1994 has reduced loads and additional reductions may no longer be necessary if compliance with existing permits and programs continues. The following is a general overview of these existing programs.

Construction Stormwater Program

Dischargers whose projects disturb one or more acres of soil or whose projects disturb less than 1 acre but are part of a larger common plan of development that in total disturbs 1 or more acres, are required to obtain coverage under the General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit, 99-08-DWQ). Construction activity subject to this permit includes clearing, grading and disturbances to the ground such as stockpiling, or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility.

The Construction General Permit requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP should contain a site map(s) which shows the construction site perimeter, existing and proposed buildings, lots, roadways, storm water collection and discharge points, general topography both before and after construction, and drainage patterns across the project. The SWPPP must list Best Management Practices (BMPs) the discharger will use to protect storm water runoff and the placement of those BMPs. Additionally, the SWPPP must contain a visual monitoring program; a chemical monitoring program for "non-visible" pollutants to be implemented if there is a failure of BMPs; and a sediment monitoring plan if the site discharges directly to a water body listed on the 303(d) list for sediment. Section A of the Construction General Permit describes the elements that must be contained in a SWPPP.

Industrial Storm Water Program
The Industrial Storm Water General Permit Order 97-03-DWQ (General Industrial Permit) is an NPDES permit that regulates discharges associated with 10 broad categories of industrial activities. The General Industrial Permit requires the implementation of management measures that will achieve the performance standard of best available technology economically achievable (BAT) and best conventional pollutant control technology (BCT). The General Industrial Permit also requires the development of a Storm Water Pollution Prevention Plan (SWPPP) and a monitoring plan. Through the SWPPP, sources of pollutants are to be identified and the means to manage the sources to reduce storm water pollution are described. The General Industrial Permit requires that an annual report be submitted each July 1.

The facility operator must submit an NOI for each industrial facility that is required by U.S. Environmental Protection Agency (U.S.EPA) regulations to obtain a storm water permit. The required industrial facilities are listed in Attachment 1 of the General Permit and are also listed in 40 Code of Federal Regulations Section 122.26(b)(14). The facility operator is typically the owner of the business or operation where the industrial activities requiring a storm water permit occur. The facility operator is responsible for all permit related activities at the facility.

Municipal Stormwater Program
The Municipal Storm Water Permitting Program regulates storm water discharges from municipal separate storm sewer systems (MS4s). MS4 permits were issued in two phases.

- Under Phase I, which started in 1990, the Regional Water Quality Control Boards have adopted National Pollutant Discharge Elimination System General Permit (NPDES) storm water permits for medium (serving between 100,000 and 250,000 people) and large (serving 250,000 people) municipalities. Most of these permits are issued to a group of co-permittees encompassing an entire metropolitan area. These permits are reissued as the permits expire.

- As part of Phase II, the program in which Napa County agencies fall under, the State Water Resources Control Board adopted a General Permit for the Discharge of Storm Water from Small MS4s (WQ Order No. 2003-0005-DWQ) to provide permit coverage for smaller municipalities, including non-traditional Small MS4s, which are governmental facilities such as military bases, public campuses, and prison and hospital complexes.

The MS4 permits require the discharger to develop and implement a Storm Water Management Plan/Program with the goal of reducing the discharge of pollutants to the maximum extent practicable (MEP). MEP is the performance standard specified in Section 402(p) of the Clean Water Act. The management programs specify what best management practices (BMPs) will be used to address certain program areas. The program areas include public education and outreach; illicit discharge detection and elimination; construction and post-construction; and good housekeeping for municipal operations. In general, medium and large municipalities are required to conduct chemical monitoring, though small municipalities are not.

State Highways Stormwater Program

California Department of transportation (Caltrans) is responsible for runoff from State highways and associated construction activities. Discharges from State Highways are regulated via a Statewide Stormwater Permit issued to Caltrans.

Channel Incision

Of all the sediment source categories, channel incision has the highest priority for source reduction and control because sediment input from channel incision is produced locally, and therefore may have a greater effect on fine sediment deposition at spawning and rearing sites in the Napa River, than more remote sources of sediment delivery. Also, of greater importance than its role as a sediment source, as the Napa River incises, it obliterates the basic physical habitat structure of the river, expressed by a substantial reduction in quantity of gravels bars, riffle margins, side channels, and sloughs, and disconnection of the channel from its flood plain. The resulting increase in the quantity of homogeneous long, deep pool-run habitats also favors native and introduced fishes that prey upon juvenile salmonids and has likely reduced Chinook salmon populations. Stillwater Sciences and Dietrich (2002) postulate that the restoration of natural and complex physical habitat is a necessary prerequisite to facilitate a self-sustaining run of Chinook salmon in Napa River. Restoration of natural bar-pool topography and channel flood-plain connectivity also may be needed to protect other rare or threatened species, including California freshwater shrimp, that are distributed solely or primarily in the Napa River and lower tributary reaches. Additionally, streamside land uses, public works infrastructure, and utilities are threatened by the high rates of bank erosion associated with channel incision processes along the Napa River.

We strongly support the effort being undertaken by Rutherford DUST Society to design and implement actions to enhance ecological functions along the Napa River. Adopting a channel restoration approach at the reach scale for treatment of channel incision and associated bank erosion, has several potential advantages including, but not necessarily limited to the following:

- Higher cost effectiveness than hard engineering approaches
- Greater likelihood of long-term success
- Lower long-term maintenance costs
- Enhanced aesthetic and recreational values
- The potential to reverse some of the significant adverse ecological impacts of incision on stream-riparian ecosystems
- A much more favorable position with regard to regulatory permit reviews and approvals

Furthermore, by implementing a project on a channel reach scale it should be possible to balance sediment supply and transport capacity throughout the reach (e.g., one landowners bank and/or bed stabilization solution does not become another's problem). Also, by adopting a channel restoration approach on a large scale, there appears to be a very high potential to receive significant public funding to support the design and implementation.[36] From our standpoint as a

[36] Public funding to-date from State Coastal Conservancy, Napa County Measure A funds, and CDFG to support development of a restoration design for the Rutherford reach has been over $500,000, or more than 90% of the total costs thus far.

potential funding agency, or in acting in an advisory capacity to others, we will be strong advocates for the adoption of an ecologically superior design alternative in the Rutherford Reach that results in meaningful enhancement of the stream-riparian ecosystem. To this end, we support consideration of the adoption of standards to guide the design process and evaluate the ecological success of the river restoration project that is implemented, as have been put forward recently by Palmer et al. (2005).[37]

We do not intend to propose a regulatory permitting program to require channel restoration to resolve adverse ecological and water quality impacts of channel incision for the following reasons:

- Channel incision problems along Napa River and its lower tributary reaches reflect and integrate multiple historical and ongoing disturbances some of which are local and/or direct, and others that are indirect and distal. In this sense, with the exception of an individual who owns property on both sides of the river over a very long distance, it is not possible for an individual to effectively control or be responsible for the channel incision that may be taking place on his or her property.

- An effective program to control channel incision in a way that enhances habitat for fish and aquatic species (as outlined above) will require cooperative and coordinated actions by multiple landowners over significant distances along the river.

- Considering the state of the science for river restoration and ecological modeling, and the physical and biological information for the Napa River that is available to guide river restoration design and modeling, any design that may be developed and implemented in the near future needs to be considered an experiment for which we cannot predict with a high degree of certainty in advance that the project ultimately will be successful.

Although it may be feasible to explore and implement river restoration options that are effective in controlling incision and/or accelerated bank erosion, but are not effective with regard to ecological performance, there is a high probability that such projects would have a much poorer chance of receiving significant public funding, and therefore, design and implementation costs to private landowners would be much greater. Although this is a scenario under which it might be possible to resolve the sediment impairment listing, ecologically successful river restoration appears to be a preferable option for public and private parties.

6.6 Habitat Enhancement Plan

In order to conserve steelhead trout and Chinook salmon populations, in addition to the actions to reduce fine sediment supply, specific management actions also are needed to:

1) Protect or enhance dry season baseflow in mainstem Napa River and its tributaries

2) Enhance fish migration to-and-from potential spawning and rearing habitats

[37] This paper can be obtained online at http://nrrss.umd.edu/Publications/Palmer_et_al_2005_JAE.pdf .

3) Enhance physical habitat structure of mainstem Napa River and its tributaries

4) Protect and/or enhance summer water temperatures in tributaries to the Napa River

Management actions specified to address these stressors are described below.

6.6.1. Baseflow Enhancement

As described in the Problem Statement of this report (Chapter 2), low-or-no-flow over riffles greatly reduces supply of drifting aquatic insects produced in riffles, which may provide the primary source of food for juvenile steelhead. Low and/or negative growth rates by juvenile steelhead associated with poor baseflow persistence was documented in a pilot study conducted in the summer and fall of 2001 in two tributaries of the Napa River (Stillwater Sciences and Dietrich, 2002). Low rates of growth during the dry season, if not mitigated by high growth rates during other times of the year, may cause significant reductions in rates of survival of juvenile steelhead during all subsequent life stages, and as such have the potential to significantly reduce the number of steelhead that migrate from the watershed to the ocean, and the number that return to spawn.

Another potentially significant impact of reduction in baseflow during the spring may be poor rates of survival of juvenile steelhead during their migration out of the watershed and into the ocean (e.g., from greater rates of predation in shallower and narrower channels, stranding in reaches that dry up, over-summering in reaches with stressful or lethal water temperatures, etc.). Poor survival for juvenile steelhead during ocean migration has the potential to significantly reduce the steelhead run-size.

To address concerns regarding low flows during the dry season with regard to steelhead population dynamics, we propose four categories of action:

1) Additional study of juvenile steelhead growth (now in-progress) to refine understanding of relationships between dry season flow and growth, and significance with regard to steelhead population dynamics

2) Coordination and collaboration between local, state, and federal government agencies to jointly resolve water supply reliability and fisheries conservation concerns

3) Development of tools to aid land managers in protecting and/or enhancing dry season baseflow and complying with water rights permit conditions

4) Improved regulatory oversight to protect existing water rights and instream flows for fisheries, and to provide an opportunity for future growth

Additional Study of Juvenile Steelhead Growth

To evaluate the biological significance of poor growth during the dry season, Stillwater Sciences is conducting studies to confirm whether poor summer growth is a spatially extensive phenomenon, and if so, to determine whether poor summer growth can be offset by high rates of growth in the spring and/or fall. The steelhead growth study will be completed in the fall of 2006. We expect results of this study to provide a strong foundation for developing guidelines to protect and/or enhance summer baseflow, as needed to promote satisfactory rates of growth and survival of juvenile steelhead trout in Napa River watershed.

Coordination and Collaboration between Local, State, and Federal Government Agencies
Through collaboration and coordination between local municipalities, NOAA Fisheries, California Department of Fish and Game, and the Water Board, there may be an opportunity to enhance flow for fish, while also enhancing the reliability of municipal water supplies. As indicated in the *2050 Napa Valley Water Resources Study* (West Yost and Associates, 2005), the ability of Napa Valley municipalities to meet future projected water supply demands during a critical dry year or period of dry years is a significant concern. Key priorities in developing a reliable water supply to meet future projected demand include: a) a major upgrade to the Jameson Canyon potable water treatment plant to enable use of the full appropriation of imported water available from the State Water Project; b) increased production of tertiary treated wastewater and infrastructure improvements to deliver the treated wastewater where it can be used; and c) obtaining water rights licenses for Lake Hennessey and Bell Canyon Reservoir, as needed to firmly or officially establish the water supply associated with these reservoirs; and d) additional reservoir capacity to facilitate greater operational flexibility in utilizing State Water Project and local surface water supplies.

Through the participation in a collaborative process, it may be possible to enhance the amount of water that is ultimately available from current and proposed water supply facilities, while also enhancing the flow regime for fish. In contrast, lack of collaboration may contribute to an unpredictable and/or reactive process that may diminish municipal water supply and result in a flow regime downstream of dams that is less favorable for fish. Also, by working together to jointly resolve fisheries conservation and water supply concerns, the probability of obtaining state and/or federal funds to support upgrades to existing and/or proposed water supply facilities, would be greatly enhanced, and as such, provide greater operational flexibility to enhance flows for fish downstream of municipal reservoirs normal and above normal runoff years.

Water Board staff will meet with municipal staff and elected officials, representatives of the state and federal agencies listed above, and other interested parties over the next few months to discuss the idea of establishing a water resources planning forum to jointly resolve water supply reliability and fisheries conservation concerns.

Tools to aid land managers in protecting and/or enhancing dry season baseflow
The Water Board has been working collaboratively with the Napa County Resource Conservation District (RCD) during the past few years to provide funding for dial-up streamflow gages and landowner education and outreach programs to facilitate protection of baseflow for fish and compliance with water rights permit conditions. During this time gages and outreach programs have been established in Huichica Creek, Carneros Creek, and Murphy Creek tributary watersheds, all of which provide potential habitat for steelhead trout. We have found the program to be an effective tool for the protection of critical baseflow and water rights compliance. We think the program should be expanded, such that dial-up gages and landowner education programs are established and maintained in ten-or-more key tributaries for steelhead

including Dry, Redwood, Sulphur, Milliken, Ritchie, and York creeks. The Water Board is interested in working with the RCD and other local government agencies to obtain funding to conduct the expanded program for a three year period.

The streamflow data developed from this program, together with the results of the steelhead growth study should also be used to develop guidelines for the protection of critical baseflow to provide suitable conditions for juvenile steelhead growth and migration of steelhead smolts to the Napa River estuary. The Napa County RCD or local staff of the NRCS could play an important role in the development of voluntary guidelines to protect flow for fish. CDFG and NOAA Fisheries should also be consulted informally to provide critical reviews with regard to their custodial responsibilities to protect and recover the steelhead population.

Improved regulatory oversight to protect existing water rights and instream flows for fish
Recently, the California Water Code was amended (Section 1259.4) to require the State Water Resources Control Board, Division of Water Rights (State Board) to adopt guidelines for maintaining instream flows to protect and recover anadromous salmonid populations, as part the process for review and approval of new appropriative water rights permits in stream channels within coastal watersheds from Mattole River south to San Francisco, including the Napa River. The State Board must adopt these guidelines on or before January 1, 2008. Fifty-seven applications for appropriative water rights within the Napa River watershed are currently under review by the State Board, forty-three of which are estimated to require one-or-more additional years to complete. The State Board is currently exploring a pilot program in the Russian River watershed that ultimately may provide a foundation for the guidelines that are developed and applied in the Napa River watershed and other coastal watersheds covered by the program.

As described earlier over 1000 reservoirs have been identified in the Napa River watershed, a significant number of which may not have water right permits. Considering the critical significance of protecting and enhancing baseflow of fish, and the large number of applications now pending before the State Board, we will recommend that a water rights compliance and enforcement survey be conducted by the State Board, as needed to protect beneficial uses and existing water rights. Timing and scope of the survey will be determined in consultation with State Board, NOAA Fisheries, and CDFG staff.

6.6.2. Enhanced Fish Passage

Flow-related impediments and/or barriers to steelhead migration are addressed above. In this section we focus on actions to reduce the number and significance of structure barriers to steelhead and salmon migration.

A large but unknown number of structural impediments and/or barriers to steelhead migration are present in Napa River tributaries. Based on surveys conducted by CDFG and local resource agency staff over the past several decades at least 69 barriers and/or impediments have been noted, some which have been remedied in recent years (e.g., Ritchie Creek dam, Sulphur and Heath Creek road crossings, and the lower York Creek diversion). However, considering the fact that no recent and comprehensive assessments (quantitative or qualitative) have been conducted in many of the major tributaries to the Napa River, it is also possible that there are several additional previously unidentified structures that may also impede or block passage to otherwise suitable spawning and rearing habitat.

Zinfandel Lane crossing on mainstem Napa River was recently identified as a structure impediment to adult Chinook salmon spawning migration, and possible impediment to ocean migration of Chinook salmon and steelhead smolts. Planning efforts to enhance fish passage at this site are being conducted by Napa County RCD in collaboration with Napa County department of Public Works, US Army Corps of Engineers, CDFG, and other potential partners. Similarly, the City of St. Helena is working to address its responsibility to provide fish passage to-and-from upper York Creek, upstream of the city's dam, in consultation with NOAA Fisheries and CDFG, and with partial funding provided by US Army Corps of Engineers and other partnering agencies. Both of these projects have a very high priority for implementation.

Upper York Creek provides more than two miles of excellent spawning and rearing habitat for steelhead. Napa River upstream of Zinfandel Lane, including the mainstem between St. Helena and Calistoga and lower reaches of Sulphur Creek (and perhaps other tributaries), provides a significant amount of additional potential spawning and rearing habitat for Chinook salmon, most of which is higher in quality than that present in the mainstem downstream of Zinfandel Lane. Also, many of the tributaries with the highest quality habitat for steelhead (e.g., Ritchie, Mill, Dutch Henry, York, Sulphur, and Heath) are located upstream of Zinfandel Lane, adding additional merit to enhancement of juvenile fish passage at Zinfandel Lane. Water Board staff are interested in providing technical assistance and promoting financial support for fish passage enhancement efforts at Zinfandel Lane.

In addition to providing satisfactory conditions for fish passage at the above locations, comprehensive and quantitative surveys need to be conducted in many of the key steelhead tributaries to identify all impediments and/or barriers, rank these structures in priority order for remediation, engage landowners in cooperative efforts to resolve problems, and develop initial estimates of potential costs. As described above, Water Board staff are interested in providing technical assistance and promoting financial support for these efforts. We believe that substantial progress can be made through cooperative efforts, and will support a cooperative approach provided that regular and substantive progress is achieved.

6.6.3. Enhanced Habitat Complexity

As described earlier in the discussion of sediment reduction actions, channel incision is the primary agent for simplification of physical habitat structure in mainstem Napa River. As the mainstem channel has incised by two meters or more over the past forty years, the channel has become isolated from its flood plain, and the size and frequency of riffles, gravel bars, side channels, and sloughs has been greatly reduced. These habitats provide essential spawning and juvenile rearing habitat for Chinook salmon. A suite of management actions have likely caused or contributed to channel incision, including (but not necessarily limited to): levee building, large tributary dams, straightening of some mainstem channel reaches, filling of side channels, historical gravel mining, dredging to reduce flood risk, and intensive removal of large woody debris.

The most effective means to control channel incision, and to reduce related fine sediment delivery, appears to be through implementing a channel restoration design that re-establishes width-to-depth ratios and sinuosity values conducive to formation of alternate bars and a modest flood plain. We support this and other approaches that will enhance the quantity and quality of riffle, gravel bar, and side channel habitats in mainstem Napa River and the lower reaches of its larger tributaries. We intend to work cooperatively with landowner stewardship groups to plan, design, and implement reach-based enhancement projects, as needed to support a self-sustaining run of Chinook salmon in Napa River watershed.

In addition to channel restoration projects, primarily in the mainstem Napa River, additional enhancement actions are needed with regard to the protection and recruitment of ecologically significant large woody debris, especially in tributaries of the Napa River, where quality and frequency of pool habitats appears to have been substantially diminished as a result of reduction in the amount of large woody debris in channels. More large wood in channels also is needed to sort and meter fine sediment, retain spawning gravels, and enhance winter rearing habitat for steelhead in tributary streams. Because rural residences and other structures, road crossings, and agricultural land uses are common along many tributary reaches, any actions to enhance the amount of large wood in streams, must be undertaken in a way that does not result in property damage or endanger public safety.

Fortunately, effective approaches to balance the needs of salmonids and people have been successfully piloted in other Bay Area and northern California Counties, and we recognize one such approach as a possible model for implementation actions related to the protection of woody debris: FishNet 4C Guidelines for Public Works Maintenance Activities. We will require that these or similar guidelines for the protection of ecologically significant large woody debris be implemented by public works and parks agency staff by the fall of 2008. Furthermore, we will work closely with these agencies to craft a set of specific guidelines that are tailored to conditions in the Napa River watershed and that benefit from local experience and knowledge. Landowner education and outreach efforts are also needed to protect and enhance wood loading in tributaries.

6.6.4. Stream Temperature Protection and/or Enhancement

Elevated summer water temperatures that are stressful to juvenile steelhead have been documented over a significant portion of the potential rearing habitat for steelhead in Napa River tributaries (Stillwater Sciences and Dietrich, 2002). Although subordinate to flow persistence over riffles in relation to its potential significance with regard to steelhead growth, stressful water temperatures do increase metabolic demand, and therefore, likely contribute to the low summer growth rates documented in the pilot study conducted in 2002 (see Section 6.6.1., Baseflow Enhancement). Actions specified to enhance summer baseflow and habitat complexity in tributaries (e.g., enhanced loading of large woody debris to increase pool frequency, depth, and cover) will also be effective in reducing summer water temperatures, and as such are also recognized, as part of the plan to protect and/or enhance stream temperature. Similarly, riparian corridor vegetation restoration actions, implemented along streams through the Napa Green Certification program (for vineyards and adjacent rural lands under same ownership) will lead to enhanced shade and large woody debris recruitment, in addition to reducing sediment supply. With the funding already appropriated for Napa Green, more than 12,000 acres of vineyard lands and a similar or greater acreage of adjacent rural lands will implement holistic farm management plans to protect fisheries and water quality. Also, many of the actions needed to address pathogen and/or nutrient pollution loads along streams in rangelands will involve protection and/or enhancement of riparian vegetation along streams draining ranches and adjacent rural lands.

CHAPTER 7: REGULATORY ANALYSES

7.1 Overview

The Administrative Procedures Act specifies legal requirements associated with adoption or modification of regulations by the State of California. Because the proposed Basin Plan amendment (BPA) would add regulatory provisions to the Basin Plan, in order to adopt these changes, the Water Board must: a) complete an environmental checklist pursuant to the California Environmental Quality Act (CEQA); b) consider reasonable alternatives to the proposal; and c) consider economic factors relating to compliance with new regulatory requirements contained in the proposed amendment.

7.2 Environmental Checklist

CEQA requires agencies to review the potential for their actions to result in adverse environmental impacts. CEQA further requires agencies to adopt feasible measures to mitigate potentially significant impacts. This section contains the environmental checklist for the proposed Basin Plan amendment. The explanation following the checklist provides details concerning the environmental impact assessment. Based on this analysis, Water Board staff concludes that adoption of the proposed Basin Plan amendment would not cause any significant adverse environmental impacts.

ENVIRONMENTAL CHECKLIST

1. Project Title:	Napa River Sediment Reduction and Habitat Enhancement Basin Plan Amendment
2. Lead Agency Name and Address:	California Regional Water Quality Control Board, San Francisco Bay Region 1515 Clay Street, Suite 1400 Oakland, California 94612
3. Contact Person and Phone Number:	Mike Napolitano (510) 622-2397
4. Project Location:	Napa River Watershed, Napa County and Sonoma County, California
5. Project Sponsor's Name and Address:	California Regional Water Quality Control Board, San Francisco Bay Region 1515 Clay Street, Suite 1400 Oakland, California 94612
6. General Plan Designation:	Not Applicable
7. Zoning:	Not Applicable

8. **Description of Project:**

The project is a proposed Basin Plan Amendment that would establish a sediment TMDL for Napa River and an implementation plan to achieve the TMDL and related habitat enhancement goals. The project would involve numerous actions to reduce fine sediment inputs to Napa River and its tributaries, and related actions to protect or enhance baseflow, enhance habitat access for salmon and steelhead, and to enhance stream-riparian habitat complexity and stream temperatures. Details are provided in the attached explanation.

9. **Surrounding Land Uses and Setting:**

The proposed Basin Plan Amendment would affect the entire Napa River watershed, except for land areas upstream of municipal water supply reservoirs. Implementation would involve specific land and water management actions throughout the watershed. Napa River watershed land uses include a mix of open space, agricultural, commercial, residential, and municipal uses.

10. **Other public agencies whose approval is required** (e.g., permits, financing approval, or participation agreement.)

The California State Water Resources Control Board, the California Office of Administrative Law, and the U.S. Environmental Protection Agency must approve the proposed Basin Plan Amendment.

ENVIRONMENTAL IMPACTS:

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
I. AESTHETICS -- Would the project:				
a) Have a substantial adverse effect on a scenic vista?	☐	☐	☐	☒
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☒
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☒
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☐	☒
II. AGRICULTURE RESOURCES -- In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. **Would the project:**				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?	☐	☐	☒	☐
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?	☐	☐	☐	☒
c) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland, to non-agricultural use?	☐	☐	☒	☐

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
III. AIR QUALITY -- Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. **Would the project:**				
a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☒
III. AIR QUALITY -- (cont.):				
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☒	☐
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	☐	☒
d) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☒
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☒
IV. BIOLOGICAL RESOURCES -- Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	☐	☒	☐
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, and regulations or by the				

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
California Department of Fish and Game or U.S. Fish and Wildlife Service?	☐	☐	☒	☐
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☐	☐	☒	☐
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☐	☐	☒	☐
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☐	☐	☐	☒
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?	☐	☐	☐	☒
V. CULTURAL RESOURCES -- Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in §15064.5?	☐	☐	☒	☐
b) Cause a substantial adverse change in the significance of a unique archaeological resource pursuant to §15064.5?	☐	☐	☒	☐
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☒	☐
d) Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☒	☐

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
VI. GEOLOGY AND SOILS -- Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.	☐	☐	☐	☒
ii) Strong seismic ground shaking?	☐	☐	☐	☒
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☒
iv) Landslides?	☐	☐	☐	☒
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☒	☐
c) Be located on geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☒
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☒
e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☒
VII. HAZARDS AND HAZARDOUS MATERIALS -- Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☒
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☒
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	☒
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☒
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☒
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☒
VIII. HYDROLOGY AND WATER QUALITY -- Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☐	☒
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion of siltation on- or off-site?	☐	☐	☒	☐
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or off-site?	☐	☐	☒	☐
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☒
f) Otherwise substantially degrade water quality?	☐	☐	☐	☒
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☒
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	☐	☐	☒	☐
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
j) Inundation of seiche, tsunami, or mudflow?	☐	☐	☐	☒
IX. LAND USE AND PLANNING -- Would the project:				
a) Physically divide an established community?	☐	☐	☐	☒
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☒
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☒
X. MINERAL RESOURCES -- Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	☐	☐	☐	☒
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☒
XI. NOISE -- Would the project result in:				
a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☒
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	☒	☐

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☒
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☒	☐
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☒
f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	☐	☐	☐	☒
XII. POPULATION AND HOUSING -- Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☒
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒
c) Displace substantial numbers of people necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
XIII. PUBLIC SERVICES --				
a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times, or other performance objectives for any of the public services:				
Fire protection?	☐	☐	☐	☒
Police protection?	☐	☐	☐	☒
Schools?	☐	☐	☐	☒
Parks?	☐	☐	☐	☒
Other public facilities?	☐	☐	☐	☒
XIV. RECREATION --				
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☒	☐
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?	☐	☐	☐	☒
XV. TRANSPORTATION / TRAFFIC -- Would the project:				
a) Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume-to-capacity ratio on roads, or congestion at intersections)?	☐	☐	☐	☒
b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that result in substantial safety risks?	☐	☐	☐	☒
XV. TRANSPORTATION / TRAFFIC – (cont.):				
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☒
e) Result in inadequate emergency access?	☐	☐	☒	☐
f) Result in inadequate parking capacity?	☐	☐	☐	☒
g) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	☒
XVI. UTILITIES AND SERVICE SYSTEMS -- Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?	☐	☐	☐	☒
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☒
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☒
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	☐	☐	☐	☒
e) Result in a determination by the wastewater treatment provider which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☒

Issues:	*Potentially Significant Impact*	*Less Than Significant With Mitigation Incorporation*	*Less Than Significant Impact*	*No Impact*
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☒
g) Comply with federal, state, and local statutes and regulations related to solid waste?	☐	☐	☐	☒
XVII. MANDATORY FINDINGS OF SIGNIFICANCE				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?	☐	☐	☐	☒
b) Does the project have impacts that are individually limited, but cumulative considerable? ("Cumulative considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?	☐	☐	☐	☒
c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☒

EXPLANATION

Project Description

The proposed project is a Basin Plan Amendment that would establish a Total Maximum Daily Load (TMDL) for sediment in the Napa River and an implementation plan to achieve the TMDL and related habitat enhancement goals (see Appendix A). The goal of the Basin Plan Amendment is to improve environmental conditions. The Basin Plan Amendment would include targets for fine sediment (primarily sands) concentrations in the bed of the Napa River that are expressed as numeric criteria for spawning gravel permeability and redd scour depth, and establish sediment allocations necessary to achieve the targets. The Basin Plan Amendment implementation plan would require actions to achieve the targets and allocations for sediment, and numerous actions to enhance other habitat attributes needed to conserve and enhance steelhead and salmon populations. The proposed Basin Plan amendment would affect all segments of Napa River and its tributaries located downstream of municipal water supply reservoirs.

The proposed allocations are measures of performance. The implementation plan outlines the San Francisco Bay Regional Water Quality Control Board's (Water Board's) approach to meeting these measures of performance. The plan describes actions the Water Board would take and how the Water Board would compel, as necessary, other entities to do their parts to reduce fine sediment supply to Napa River, and to enhance related stream-riparian habitat attributes, as needed to conserve steelhead, Chinook salmon, and other native fish and aquatic wildlife species. The Water Board would not directly undertake any actions that could physically change the environment, but adopting the proposed Basin Plan Amendment could indirectly result in other entities (e.g., cities, counties, and special districts) undertaking projects to satisfy requirements derived from the Basin Plan Amendment. These projects could physically change the environment. The environmental impacts of such physical changes are evaluated below, to the extent that they are reasonably foreseeable. Changes that are speculative in nature do not require environmental review.

Until the parties that must comply with requirements derived from the Basin Plan Amendment propose specific projects, many physical changes cannot be anticipated. These projects would be subject to environmental review under the California Environmental Quality Act (CEQA), and CEQA compliance would be the responsibility of the lead agency for each project. The environmental reviews would identify any potentially significant adverse environmental impacts of the specific proposals, along with appropriate mitigation measures. Until such projects are proposed, however, identifying specific impacts and mitigation measures would require inappropriate speculation. Moreover, any mitigation deemed necessary by the lead agencies for those projects would not be within the jurisdiction of the Water Board to require.

Direct and Indirect Physical Changes

Table 10 summarizes the actions that could conceivably be undertaken if the proposed Basin Plan amendment were adopted, and includes the rationale for including or excluding them in this environmental review. As shown in the table, the physical changes that require evaluation are those associated with (1) minor construction, (2) earthmoving, (3) enhancement of vegetation and woody debris in riparian corridors and stream channels; (4) enhancement of baseflow in streams during the dry season; (5) installation and maintenance of stream habitat enhancement structures; and (6) waste handling and disposal[38]. Although these activities are reasonably foreseeable, the implementation plan does not specify the nature of these actions. Therefore, this analysis considers these actions in general programmatic terms. To illustrate the possible nature of these activities, some examples are described following the table.

[38] That could be discovered during planning or implementation of erosion control and/or habitat enhancement projects.

TABLE 10: Implementation Actions Subject to Environmental Review

Possible Actions	Environmental Change Subject to Review
Road-erosion control and prevention projects	Earthmoving and/or minor construction
Gully and landslide erosion control and prevention	Earthmoving, minor construction, biotechnical engineering, and/or enhanced vegetation cover
Surface erosion control in vineyards, and rangelands	Earthmoving, minor construction, biotechnical engineering, and/or enhanced vegetation cover
Stream habitat enhancement actions	Earthmoving, minor construction, biotechnical engineering, enhanced vegetation cover, increase in amount of large woody debris in channels, and/or waste handling and disposal
Riparian habitat enhancement actions	Enhanced vegetation cover, and/or waste handling and disposal
Increase in baseflow in stream channels	Increased reservoir releases, discharge of tertiary treated wastewater, conjunctive groundwater management.
Fish passage enhancement	Earthmoving, minor construction, biotechnical engineering, and/or increases in baseflow in stream.

- ***Minor Construction.*** Basin Plan Amendment-related construction projects would generally be small. Examples may include: a) *detention basins* to capture sediment and/or reduce surface runoff during storms; b) *bio-swales* to deposit sediment entrained in surface runoff; c) *retrofit or replacement of road crossings* over stream channels to increase capacity to convey peak runoff and/or to provide suitable conditions for fish migration; d) *spillways, bypass channels, and/or energy dissipaters immediately downstream of dams* to control or prevent channel erosion; e) *water bars, cross-drains, and/or surfacing of roads* to reduce road-surface and/or inboard ditch erosion; f) *fish ladders or step-pool structures* (e.g., boulder weirs) in channels to provide suitable conditions for fish migration; g) *engineered log jams* to enhance stream habitat complexity; and/or h) *minor fencing* adjacent to some stream reaches or actively eroding gullies in rangelands to accelerate re-establishment of native scrub and tree cover (as may be needed to reduce erosion rates).

- ***Earthmoving Operations.*** Approval of the Basin Plan Amendment would result in earthmoving to reduce fine sediment supply to Napa River and its tributaries. For example, earthmoving to reduce road-related erosion may involve re-contouring the surface of some dirt roads to disperse concentrated runoff, terracing cut-banks to reduce erosion rates, and/or reconstruction or relocation of road segments to avoid landslides. Extensive earthmoving may be employed to reduce erosion rates and enhance stream habitat complexity in the Napa River and lower reaches of its larger tributaries. Also, some actions undertaken to stabilize gullies or landslides, and/or to enhance stream channel habitat may involve earthmoving.

- ***Enhancement of vegetation and woody debris in riparian corridors and stream channels.*** Approval of the Basin Plan amendment may contribute to an increase in the amount of vegetation and large woody debris in stream channels. This could take place if new public agency performance standards are adopted to protect ecologically significant large woody debris, and if the vineyard acreage (and adjacent land under same ownership) certified by the Napa Green program[39] increases.

- ***Enhancement of baseflow in stream channels.*** The Basin Plan Amendment recognizes actions to protect-or-enhance baseflow during the early spring through late fall period (e.g., mid-March through mid-October), as needed to support salmonid migration and rearing. Resultant increases in baseflow also may contribute to an increase in the amount of riparian vegetation on gravel bars, flood plains, and lower channel banks in some stream reaches.

- ***Installation of stream habitat structures.*** Adoption could lead to an increase in the number of stream habitat structures installed in Napa River and lower reaches of its tributaries. Example habitat enhancement structures include log jams, step-pools, willow waddles, log crib walls, and rock work.

- ***Waste Handling and Disposal.*** Contaminated soil could be discovered during earthmoving or other activities associated with erosion control, and/or habitat enhancement. In some cases, disposal could be arranged on site (e.g., constructing a containment facility). In others, soil or other contaminated materials could be sent for disposal. While implementation projects could reasonably generate contaminated soil for disposal, possible amounts are unknown. This waste would, however, be generated only on a temporary basis.

Above examples are not intended to be exhaustive or exclusive. As specific implementation proposals are developed and proposed, lead agencies would undertake environmental review and identify specific environmental impacts and appropriate mitigation measures.

Changes Likely With or Without the Basin Plan Amendment

The implementation plan recognizes some actions that will occur with or without the proposed Basin Plan amendment. Because these actions do not result from adoption of the Basin Plan amendment, environmental review is not included in this analysis. For example, actions to enhance fish passage are likely to occur with or without adoption, so they are not examined. Also, actions required under NPDES municipal stormwater and NPDES construction general permits to control pollutant discharges (including sediment) are already in effect and not dependent on adoption of the Basin Plan amendment. Therefore, these actions are not considered in this analysis.

Changes Too Speculative to Evaluate

Several conceivable actions that could be taken as a result of the Basin Plan Amendment require speculation, and therefore, cannot be evaluated. For example, although the implementation plan recognizes planning efforts between local, state, and federal government to enhance water supply reliability and instream flows for salmonids, actual outcomes and specific actions resulting from the proposed partnership are too speculative to determine at this time. Also, as discussed above, even in cases where some physical changes are foreseeable, the exact nature of these changes is often speculative pending specific project proposals that will be ultimately put forth by those subject to requirements derived from the Basin Plan amendment.

[39] Napa Green Certification includes actions to protect or re-establish native vegetation cover within riparian corridors averaging four-times the width of the bankfull channel.

Environmental Analysis

The proposed Basin Plan amendment does not define the specific actions that responsible parties would take to comply with requirements derived from the Basin Plan Amendment. As discussed above, physical changes resulting from the Basin Plan Amendment are foreseeable, but the attributes of specific implementation actions (e.g., location, extent, etc.) are unknown, pending responsible parties proposing actions to comply with Basin Plan Amendment requirements. CEQA requires lead agencies (in many cases local municipal government agencies) to review the potential for specific actions to result in adverse environmental impacts. CEQA further requires lead agencies to adopt feasible measures to mitigate potentially significant impacts. Therefore, the analysis below assumes that lead agencies would adopt mitigation measures necessary to address potentially significant impacts as long as appropriate measures are readily available. As explained below, mitigation measures are readily available to address all the foreseeable impacts of the Basin Plan amendment, including possible local agency actions to the extent that they can be anticipated. Therefore, the potential impacts of the proposed Basin Plan Amendment would be less-than-significant.

An explanation for each box checked on the environmental checklist is provided below:

I. Aesthetics

a-d) Any physical changes to the aesthetic environment as a result of the Basin Plan amendment would be small in scale. The Basin Plan amendment would not substantially affect any scenic resource or vista, or degrade the existing visual character or quality of any site or its surroundings. It would not create any new source of light or glare.

II. Agriculture Resources

a-c) Adoption of the Basin Plan amendment could increase the level of landowner participation in cooperative efforts to enhance channel stability and stream-riparian habitat conditions in Napa River and its tributaries (e.g., Rutherford, Napa Green Certification, etc.), which could in turn result in a reduction in the amount of land cultivated near channels (e.g., voluntary increases in setbacks of agriculture from channels). However, these actions would not: a) change the agricultural character of the watershed; b) result in conversion to non-agricultural uses; and/or c) conflict with existing zoning or Williamson Act contracts. Expansion of riparian corridors also may reduce some farm management costs including channel maintenance, levee repairs, bank stabilization, and property damage during floods. Restoration of native riparian vegetation species and/or increases in setback distance also may reduce incidence and severity of Pierce’s Disease. Similarly, riparian corridor enhancement should yield significant aesthetic, ecological, and other pollutant reduction benefits (e.g., lower pathogen and nutrient loads).

III. Air Quality

a) Because the Basin Plan amendment would not cause any significant changes in population or employment, it would not generate ongoing traffic-related emissions. It would also not involve the construction of any permanent emissions sources. For these reasons, no permanent change in air emissions would occur, and the Basin Plan Amendment would not conflict with applicable air quality plans.

b) The Basin Plan Amendment would not involve the construction of any permanent emissions sources or generate ongoing traffic-related emissions. Construction that would occur as a result of Basin Plan amendment implementation, including earthmoving operations, would be of short-term duration. Fine particulate matter (PM_{10}) is the pollutant of greatest concern with respect to construction. PM_{10} emissions can result from a variety of construction activities, including excavation, grading, demolition, vehicle travel on paved and unpaved surfaces, and vehicle and equipment exhaust. If specific construction projects were proposed to comply with requirements derived from the proposed Basin Plan Amendment, local agencies would require any necessary mitigation through their environmental reviews. The Bay Area Air Quality Management District has identified readily available measures to control construction-related air quality emissions (BAAQMD 1999). These measures include watering active construction areas; covering trucks hauling soil; and applying water or applying soil stabilizers on unpaved areas. Lead agencies would ensure that appropriate emissions control measures are implemented. Therefore, the Basin Plan amendment would not violate any air quality standard or contribute substantially to any air quality violation, and its temporary construction-related air quality impacts would be less-than-significant.

c) Because the Basin Plan amendment would not generate ongoing traffic-related emissions or involve the construction of any permanent emissions sources, it would not contribute considerably to cumulative emissions.

d-e) Because the Basin Plan Amendment would not involve the construction of any permanent emissions sources, it would not expose sensitive receptors to ongoing pollutant emissions posing health risks or creating objectionable odors.

IV. Biological Resources

a-b) The Basin Plan Amendment is designed to benefit biological resources, including fish, wildlife, and rare and endangered species. If, pursuant to the proposed Basin Plan amendment, specific projects were proposed that were to involve construction and earthmoving activities that could modify habitats, adversely affect special-status species, or disturb riparian habitat or sensitive natural communities, then local agencies would conduct environmental review and identify necessary mitigation measures. Through the CEQA and permitting processes, lead agencies would ensure that readily available mitigation measures are implemented, such as avoiding or, if feasible, relocating or replacing sensitive habitat. Therefore, the Basin Plan amendment would not substantially affect habitats, special-status species, or sensitive communities, and its impacts would be less-than-significant.

c) Basin Plan amendment related implementation actions may contribute to a increase in the acreage of land where habitat enhancement and/or erosion control projects are undertaken, including a fraction of which that would be within jurisdictional waters of the United States. Such projects (by design) are intended to have significant net positive impacts on the environment. If, however, pursuant to requirements derived from the proposed Basin Plan amendment, specific projects were to be proposed involving construction or earthmoving activities that could adversely affect wetlands, then local agencies would require necessary mitigation measures through their environmental reviews. Lead agencies would ensure that readily available measures are implemented, such as avoiding sensitive wetland and riparian habitat or mitigating for unavoidable fill or removal of significant vegetation stands.

Therefore, the Basin Plan amendment would not adversely affect waters (including wetlands), and its impacts would be less-than-significant.

d) If, pursuant to Basin Plan amendment requirements, specific projects are proposed that involve construction or earthmoving activities that could interfere with fish or wildlife movement, migratory corridors, or nurseries (e.g., channel habitat enhancement projects, fish passage enhancement projects, riparian corridor planting, etc.), then local agencies would require necessary mitigation through their environmental reviews. Lead agencies would ensure that readily available measures are implemented, such as avoiding construction during the breeding season, avoiding sensitive habitat areas, and minimizing disturbances. Therefore, the Basin Plan amendment would not substantially affect fish or wildlife movement, migratory corridors, or nurseries, and its impacts would be less-than-significant.

e-f) If, pursuant to Basin Plan amendment requirements, specific projects were proposed that were to involve construction or earthmoving activities, then local agencies would develop such proposals in accordance with their own local policies and ordinances, including any applicable habitat conservation plans, natural community conservation plans, or other plans intended to protect biological resources. Therefore, the Basin Plan amendment would not conflict with local policies, ordinances, or adopted plans.

V. Cultural Resources

a-d) Local agencies could propose specific projects involving earthmoving or construction to comply with requirements derived from the proposed Basin Plan amendment. Construction would generally be small in scale, and earthmoving would likely occur in areas already disturbed by recent human activity. If necessary to protect historical, archaeological, or paleontological resources, local agencies would require mitigation through their environmental reviews. Lead agencies would ensure that readily available measures are implemented, such as requiring a trained professional to observe major earthmoving work and stop the work if evidence of cultural resources is discovered. Therefore, the Basin Plan amendment would not adversely affect any cultural resource, and its impacts would be less-than-significant.

VI. Geology and Soils

a) The Basin Plan Amendment would not involve the construction of habitable structures; therefore, it would not involve any human safety risks related to fault rupture, seismic ground-shaking, ground failure, or landslides.

b) Local agencies could propose specific projects involving earthmoving or construction activities to comply with requirements derived from the proposed Basin Plan amendment. To meet the proposed Basin Plan amendment targets, construction would be designed to reduce overall soil erosion associated with erosion. However, temporary earthmoving operations could result in short-term erosion. Local agencies would require necessary mitigation measures through their environmental review and grading permit processes. Lead agencies would ensure that readily available measures are implemented, such as dust suppression (e.g., spraying water), use of erosion control best management practices, and proper construction site management. In addition, construction projects over 1 acre in size would require a general construction National Pollutant Discharge Elimination System permit and implementation of a storm water pollution prevention plan. Therefore, the Basin

Plan amendment would not result in substantial soil erosion, and its impacts would be less-than-significant.

c-d) The Basin Plan amendment would not involve the construction of habitable structures, and any construction would be relatively small in scale. Local agencies proposing construction to comply with requirements derived from the Basin Plan amendment would undertake engineering and environmental studies to ensure that they do not locate structures on unsuitable soil, including expansive soil. Construction would be designed to minimize any potential for landslides, lateral spreading, subsidence, liquefaction, or collapse. Therefore, the Basin Plan Amendment would not create safety or property risks due to unstable or expansive soil.

e) The Basin Plan amendment would not require wastewater disposal systems; therefore, affected soils need not be capable of supporting the use of septic tanks or alternative wastewater disposal systems.

VII. Hazards and Hazardous Materials

a-f) It is possible that hazardous materials or substances may be discovered during project activities associated with erosion control and/or habitat enhancement. Remediation actions could include the disposal of contaminated soils, but such waste is expected to be of volume and duration. Proper handling in accordance with relevant laws and regulations would minimize hazards to the public or the environment, and the potential for accidents or upsets. Therefore, hazardous waste transport and disposal would not create a significant public or environmental hazard, and would be less-than-significant impacts associated with transport and disposal of hazardous materials and substances, and no impacts from foreseeable accidents or emissions.

g) Hazardous waste management activities resulting from the Basin Plan Amendment would not interfere with any emergency response plans or emergency evacuation plans.

h) The Basin Plan amendment would not affect the potential for wildland fires.

VIII. Hydrology and Water Quality

a) The project would amend the Basin Plan, which articulates applicable water quality standards; therefore, it would not violate standards or waste discharge requirements.

b) The Basin Plan amendment would not decrease groundwater supplies or interfere with groundwater recharge. Channel habitat enhancement projects to control channel incision, and/or the construction of facilities such as retention or detention basins, infiltration basins, or vegetated swales could increase groundwater recharge.

c) Local agencies could propose specific projects involving earthmoving or construction activities to comply with requirements derived from the proposed Basin Plan amendment. Such projects could affect existing drainage patterns. However, to meet the proposed Basin Plan amendment allocations, they would be designed to reduce overall soil erosion. Nevertheless, temporary earthmoving operations could result in short-term erosion. If necessary to address specific impacts, local agencies would require mitigation measures through their environmental reviews. Lead agencies would ensure that readily available measures are implemented, such as dust suppression (e.g., spraying water), use of erosion control best management practices, and proper construction site management. In addition, construction projects over 1 acre in size would require a general construction National Pollutant Discharge Elimination System permit and implementation of a storm water pollution prevention plan. Therefore, the Basin Plan amendment would not result in substantial erosion, and its impacts would be less-than-significant.

d) The Basin Plan amendment could: a) involve earthmoving that could affect existing drainage patterns; b) contribute to enhancement of baseflow during the dry season; and/or c) increases in the amount of riparian vegetation and/or large woody debris in stream channels to enhance habitat conditions. However, Basin Plan amendment related activities would not substantially increase impervious surfaces, or peak flow releases from dams in any part of the watershed. Also, local agencies implementing measures to protect or enhance vegetation and woody debris in stream channels would, through their environmental reviews, require that no significant adverse impacts to flood risk and/or property damage occur. Therefore, the Basin Plan amendment would not increase flooding, siltation, or erosion.

e-f) Basin Plan amendment related activities are, by design, intended to decrease peak runoff rates from upland land uses, as needed to reduce fine sediment input to channels and channel erosion. Therefore, the Basin Plan amendment would not increase the rate or amount of runoff, or exceed the capacity of storm water drainage systems.

g-i) Basin Plan amendment related construction would be small in scale and would not include housing or structures that would pose or be subject to flood hazards.

j) Basin Plan amendment related construction would not be subject to substantial risks due to inundation by seiche, tsunami, or mudflow.

IX. Land Use and Planning

a) Basin Plan amendment related construction would be too small in scale to divide any established community.

b-c) The Basin Plan amendment would not conflict with any land use plan, policy, or regulation, and would not conflict with any habitat conservation plan or natural community conservation plan.

X. Mineral Resources

a-b) Basin Plan amendment related excavation and construction would be relatively small in scale and would not result in the loss of availability of any known mineral resources.

XI. Noise

a) Earthmoving and construction could temporarily generate noise. Projects that local agencies propose to comply with requirements derived from the Basin Plan amendment would be consistent with the local agencies’ own standards.

b) To comply with requirements derived from the Basin Plan amendment, local agencies could propose specific projects involving earthmoving or construction, which could result in temporary groundborne vibration or noise. If necessary, local agencies could require mitigation measures through their environmental reviews. Lead agencies would ensure that readily available measures are implemented, such as restricting the hours of operations and ensuring that earthmoving equipment is equipped with mufflers to reduce noise. Therefore, the Basin Plan amendment would not result in substantial noise, and its impacts would be less-than-significant.

c) The Basin Plan amendment would not cause any permanent increase in ambient noise levels. Any noise would be short-term in nature.

d) To comply with requirements derived from the Basin Plan amendment, local agencies could propose specific projects involving earthmoving or construction, which could result in temporary increases in ambient noise levels in excess of noise levels without the Basin Plan Amendment. Noise-generating operations would comply with local noise minimization requirements, including local noise ordinances. If necessary, local agencies could require that noise reduction mitigation measures are implemented, such as restricting the hours of noise-generating operations. Therefore, the Basin Plan amendment would not result in substantial noise, and its impacts would be less-than-significant.

e-f) The Basin Plan Amendment would not cause any permanent increase in ambient noise levels, including aircraft noise. Therefore, it would not expose people living within an area subject to an airport land use plan or in the vicinity of a private airstrip to excessive noise.

XII. Population and Housing

a-c) The Basin Plan amendment would not affect the population of the Bay Area, or Napa Valley. It would not induce growth through such means as constructing new housing or businesses, or by extending roads or infrastructure. The Basin Plan amendment would also not displace any existing housing or any people that would need replacement housing.

XIII. Public Services

a) The Basin Plan amendment would not affect populations or involve construction of substantial new government facilities. The Basin Plan Amendment would not affect service ratios, response times, or other performance objectives for any public services, including fire protection, police protection, schools, or parks.

XIV. Recreation

a-b) Although the Basin Plan amendment would not affect population levels, potential enhancement of fisheries habitat and stream aesthetics has the potential to contribute to an increase in river-focused recreational activities (e.g., kayaking, rafting, fishing, swimming, wading, birding, etc.). Increases in these activities are expected to cause less than significant impacts on the environment. No recreational facilities would need to be constructed or expanded.

XV. Transportation / Traffic

a-b) Because the Basin Plan amendment would not increase population or provide employment, it would not generate any ongoing motor vehicle trips. Earthmoving and construction would be temporary, and related traffic would be of short-term duration. Therefore, the Basin Plan amendment would not substantially increase traffic in relation to existing conditions. Levels of service would be unchanged.

c) The Basin Plan amendment would not affect air traffic.

d) Reductions in road-related erosion called for by the Basin Plan amendment would not require implementation of hazardous design features or incompatible uses in order to meet the TMDL.

e) Minor construction and earthmoving operations to reduce road-related erosion that would occur as a result of adoption of the Basin Plan amendment is not expected to restrict emergency access. Local agencies would confirm that specific proposals would not restrict emergency access through their environmental reviews.

f) Because the Basin Plan amendment would not increase population or provide employment, it would not affect parking demand or supply.

g) Because the Basin Plan amendment would not generate ongoing motor vehicle trips, it would not conflict with adopted policies, plans, or programs supporting alternative transportation.

XVI. Utilities and Service Systems

a) The project would amend the Basin Plan, which is the basis for wastewater treatment requirements in the Bay Area; therefore, the Basin Plan amendment would be consistent with such requirements.

b) Although the Basin Plan amendment proposes planning and regulatory efforts to facilitate enhancement of baseflow in streams, since no specific actions are proposed or required at this time, it would be speculative to evaluate possible changes at this time. Should local agencies propose specific projects at a future date, those would be subject to environmental review, and mitigation as needed.

c) New or expanded stormwater drainage facilities are not called for under the proposed Basin Plan amendment.

d-e) Because the Basin Plan amendment would not increase population or provide employment, it would not require an ongoing water supply. It would also not require ongoing wastewater treatment services.

f-g) Basin Plan amendment implementation would not substantially affect municipal solid waste generation or landfill capacities.

XVII. Mandatory Findings of Significance

a) When taken as a whole, the Basin Plan amendment would not degrade the quality of the environment. The proposed Basin Plan amendment is intended to benefit wildlife and rare and endangered species by decreasing fine sediment supply and enhancing stream-riparian habitat conditions in Napa River and its tributaries.

b) As discussed above, the Basin Plan amendment could pose some less-than-significant adverse environmental impacts related to earthmoving and construction operations. These impacts would be individually limited, and most would be of short-term duration. As specific implementation proposals are developed and proposed, lead agencies would undertake environmental review and identify specific environmental impacts and appropriate mitigation measures. In cases where potential impacts could be significant, local lead agencies would adopt readily available mitigation measures to ensure that possible impacts would be less-than-significant. Therefore, the incremental effects of the Basin Plan amendment would be negligible when viewed in the context of the overall environmental changes foreseeable. For this reason, the Basin Plan amendment's cumulative effects would be less-than-significant, and adopting the Basin Plan amendment would require no mandatory findings of significance.

c) The Basin Plan amendment would not cause any substantial adverse effects to human beings, either directly or indirectly. The Basin Plan amendment is intended to benefit human beings through implementation of actions predicted to enhance fish populations, aesthetic attributes, recreational opportunities, and contribute to a reduction in property damage in and/or nearby to stream channels in the Napa River watershed.

7.3 Alternatives
In defining and presenting reasonable alternatives to the proposed Basin Plan amendment, we discuss how each alternative could affect foreseeable environmental outcomes, and the extent to which each alternative would achieve the goals of the proposed amendment. Furthermore, considering the nature of the proposed amendment - a total maximum daily load (TMDL) for sediment and a related habitat enhancement plan - we examine effects of different choices for key elements of the TMDL and habitat enhancement plan including: a) numeric targets[40] for sediment; b) sediment allocations[41]; and/or c) schedule, spatial extent, and types of actions required to achieve allocations, targets, and habitat enhancement goals. Our analysis includes the following alternatives:

(1) ***Proposed Basin Plan Amendment*** - involves actions to reduce fine sediment supply to 125 percent of natural background supply, and actions to enhance habitat conditions in stream channels and riparian corridors downstream of municipal reservoirs in Napa River watershed. Sediment reduction and habitat enhancement objectives are achieved by 2025.

(2) ***Implementation Actions Required for the Entire Watershed*** **–** as above except actions are implemented throughout the watershed

(3) ***Implementation Actions to Address Sediment Only*** **–** identical to proposed BPA except actions to enhance baseflow, temperature, and/or fish passage are not formally recognized

(4) ***Additional Numeric Targets for Sediment***

(5) ***No Action - Basin Plan is not amended***

Alternative 1: Proposed Basin Plan Amendment
The Basin Plan amendment staff proposes is based on the technical analyses presented in Chapters 2 through 6, including: a) numeric targets for streambed scour and permeability at potential spawning sites for salmonids; b) a TMDL for sediment; c) allocations for sediment input to channels set by source category; and d) an implementation plan that specifies actions to reduce fine sediment supply associated with land-use activities[42], and complimentary actions to enhance baseflow, temperature, habitat access, and habitat complexity. Adoption of the Basin Plan amendment sets the sediment TMDL at 125 percent of natural background load.

---

[40] Napa River does not meet water quality objectives for sediment, settleable material, and population and community ecology. Numeric targets, which are a required part of a TMDL, define numeric values for measurable water quality parameters (e.g., gravel permeability), and therefore, a basis for establishing attainment of water quality standards.
[41] A TMDL is a legally defined sum of pollutant allocations (e.g., maximum amounts of sediment that can be discharged) that are listed by source category (e.g., vineyards, ranches, roads, urban areas, etc.).
[42] Between 1994 and 2004, about 2/3 of total sediment input to channels was from land-use activities, and total sediment load in Napa River at Soda Creek was approximately 180 percent of natural background (e.g., natural background being the amount Napa River would have received absent human caused erosion and dams). To achieve the TMDL, inputs from land-use activities need to be reduced from current value of 116 percent of natural background to proposed allocation of 58 percent of natural background supply.

Implementation actions to reduce fine sediment supply associated with land-use activities would focus on road-related erosion, channel incision, vineyards, parks and open space, municipal public works, rural lands[43], and structural development projects. Implementation actions to enhance habitat conditions would focus on baseflow, habitat complexity, stream temperature, and fish passage in mainstem Napa River and its tributaries. Adoption of the proposed Basin Plan amendment would result in attainment of numeric targets and allocations for sediment, and habitat enhancement objectives by the fall of 2025.

Land areas and channel reaches located upstream of municipal water supply dams are not included in the project area for the proposed BPA because:

a) The physical expression of sediment impairment in Napa River is an increase in the concentration of fine sediment (almost all of which is sand) in the streambed;
b) All sand inputs to channels upstream of municipal dams is deposited in the adjacent reservoirs, and hence does not reach Napa River; and
c) The municipal water supply reservoirs and upstream water bodies are not listed as impaired by sediment, and we are not aware of evidence to support listing(s).

Alternative 2: Implementation actions required for the entire watershed
This alternative would be identical to the proposed BPA except geographic area for sediment reduction and habitat enhancement would be expanded to cover the entire Napa River watershed. It is important to note that actions conducted to control sediment input to channels located upstream of municipal dams would not have a significant effect on fine sediment concentration in the bed of the Napa River (as described immediately above). Also, municipal reservoirs and/or upstream water bodies are not listed at present as impaired by sediment. Substantial additional costs would be required to implement efforts to reduce sediment supply and to enhance habitat conditions in stream channels upstream of municipal dams. Although there would be additional overall water quality benefits, benefits to steelhead and/or Chinook salmon populations would not appear to be significant, absent removal of municipal dams, which does not appear likely at present, considering the prominence of the reservoirs in providing water supply for local municipalities[44].

Alternative 3: Implementation actions to address sediment only
This alternative is identical to the proposed Basin Plan amendment except implementation would focus solely on actions to reduce sediment input to channels from land-use activities. Under this alternative, the Water Board would not set goals or recognize actions to enhance habitat and flow. This alternative would satisfy legal requirements associated with the Clean Water Act and would resolve sediment-related threats to salmon and steelhead populations. However, actions to enhance baseflow, temperature, habitat complexity, and habitat access

[43] As defined by County of Napa, Department of Conservation, Development, and Planning, rural lands include "non-farmed and non-grazed portions of parcels > 10 acres that contain one-or-more residences, and/or a winery; vacant residential parcels > 10 acres; and/or portions of 10 acre-or-larger parcels with a secondary vineyard, orchard, or grazing [use]."
[44] Resident *O.mykiss* (rainbow trout) which inhabit municipal reservoirs and channels draining into the reservoirs may be reproductively isolated from downstream resident and ocean migrating *O.mykiss* (steelhead) as a result of the dams, which constitute significant structural and flow-related barriers or impediments to downstream migration.

are necessary to rebuild and sustain viable populations of steelhead and salmon in Napa River watershed.

Alternative 4: Additional numeric targets for sediment
Sediment impairment is expressed by an increase in concentration of fine sediment in the bed of Napa River. The proposed BPA would adopt two numeric targets related to concentration of fine sediment in the streambed: spawning gravel permeability and redd scour depth. These parameters gauge survival from spawning-to-emergence of salmonid eggs and larvae. Under the *Additional Numeric Targets for Sediment* alternative, additional monitoring parameters and target values would be proposed to evaluate relationships between sedimentation and water quality including: a) percentage of fine sediment in the streambed as a direct measure of sedimentation; b) biomass of aquatic invertebrate prey species in riffles to evaluate relationship between sedimentation and food supply for juvenile salmonids; and c) embeddedness of coarse particles[45]. We note that substantial effort would be required to develop accurate estimates of each of these parameters, and scientific consensus does not exist regarding target values for biomass of vulnerable aquatic invertebrate prey species or embeddedness.

Alternative 5: No Basin Plan Amendment
If the Water Board does not adopt the Napa River sediment total maximum daily load (TMDL), the U.S. Environmental Protection Agency (USEPA) would be required to do so. In such a case, USEPA would likely rely, at least in part on analyses completed to date. Within legal constraints however, they would be free to develop a TMDL in any manner they deemed appropriate. As with the Water Board, USEPA would be required to identify targets and allocate sediment loads, and although it would be speculative to evaluate how the TMDL would differ with USEPA as the lead, there would be one key difference: USEPA would not prepare a plan specifying actions to resolve impairment (e.g., an implementation plan). Instead, the Water Board would be required to do so, as needed to attain and maintain the numeric targets and sediment allocations approved by USEPA. Under this alternative there would be a higher probability for a mismatch between the TMDL and implementation plan as these interconnected elements would be developed by two different agencies.

Preferred Alternative
The *No Action* alternative is not realistic because there is a legal requirement under the Clean Water Act to adopt a TMDL, and not preferred because there is a higher potential for disconnects between the TMDL and implementation plan, when these two parts are developed by different agencies. The *Additional Numeric Targets* alternative would have much higher sediment monitoring costs, which could reduce resources available for complimentary monitoring of other stressors and the population status of steelhead and salmon. Since rebuilding and maintaining populations of steelhead and salmon is a primary objective of the proposed BPA, and because salmonid population declines appear to be the result of interacting stressors, the *Additional Numeric Targets for Sediment* alternative is not preferred.

[45] Embeddedness is a measure of amount of fine sediment (e.g., fine gravel and sand) filling spaces between coarse grains (e.g., coarse cobbles and boulders) in the streambed. When coarse grains are highly embedded, biomass of vulnerable aquatic invertebrate prey species (for salmonids) and quality of high flow refuge habitat for juvenile steelhead may be substantially reduced.

The *Implementation Actions Required for the Entire Watershed* could yield greater water quality benefits than the proposed BPA. This alternative is not preferred because it appears that implementation of sediment reduction and habitat enhancement efforts upstream of municipal dams would not yield significant benefits to salmon or steelhead populations, and/or related beneficial uses.

The *Implementation Actions to Address Sediment Only* alternative would resolve sediment-related threats to salmonids, and related beneficial uses. However, goals and actions to resolve other key stressors would not be adopted, and therefore, the timeframe for rebuilding and sustaining viable populations of steelhead and salmon would be increased, and stakeholder buy-in would be diminished. Therefore, the *Implementation Actions to address Sediment Only* alternative is not preferred.

The *Proposed Basin Plan Amendment* alternative is the preferred alternative because: a) it is environmentally superior to the *Implementation Actions to address Sediment Only* and *No Action* alternatives; and b) it is less expensive than the *Implementation Actions Required for Whole Watershed* alternative, while providing a means for attaining water quality standards. The proposed BPA will not cause any significant adverse impacts to the environment.

7.4 Economic Considerations

Introduction

The California Environmental Quality Act requires that whenever one of California's nine Regional Water Quality Control Boards, such as the San Francisco Bay Regional Water Quality Control Board (Water Board), adopts a rule that requires the installation of pollution control equipment or establishes a performance standard or treatment requirement, it must conduct an environmental analysis for reasonably foreseeable methods of compliance (Public Resource Code 2759 [a][3][c]). This analysis must take into account a reasonable range of factors, including economics. Furthermore, if the rule includes an agricultural control plan, then the total cost of the program must be estimated and potential sources of funding must be identified (Water Code 13141).

The proposed *Napa River Sediment Reduction and Habitat Enhancement Basin Plan Amendment* includes performance standards (i.e., targets and allocations), and therefore requires the consideration of economic factors. The Total Maximum Daily Load (TMDL) implementation plan also proposes activities for agriculture, and therefore, the total cost of the implementation effort is estimated and potential funding sources are identified.

In amending the Basin Plan, the Water Board must analyze the reasonably foreseeable methods of compliance with proposed performance standards and treatment requirements (Pub. Resources Code §21000 et seq.). This analysis must include economic factors, but does not require a cost-benefit analysis.

Additionally, in accordance with the Porter-Cologne Water Quality Control Act, it is the policy of the state to protect the quality of all waters of the state. Waters of the state include "any surface water or groundwater, including saline waters, within the boundaries of the state" (CWC

§13050). When adopting the Porter-Cologne Act, the Legislature declared that all values of the water should be considered, but then went on to provide only broad, non-specific direction for considering economics in the regulation of water quality.

> "The Legislature further finds and declares that activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible" (CWC §13000).

The Porter-Cologne Act directed regulatory agencies to pursue the highest water quality that is reasonable, and *one* of the factors used to determine what is reasonable is economics. It is clear, though, that economic factors cannot be used to justify a result that would be inconsistent with the federal Clean Water Act or the Porter-Cologne Act. The Water Board is obligated to restore and protect water quality and beneficial uses.

Cost Estimates

We present cost estimates for sediment control actions by source category (e.g., channel incision, road-related erosion, etc.). These cost estimates include all costs for control of sediment discharges. We then estimate proportion of total costs associated with agricultural sources (e.g., Agricultural Water Quality Control Program Costs).

Channel Incision and Associated Bank Erosion

Channel incision and associated rapid bank erosion is one of the largest sediment sources associated with land use activities and the primary agent for simplification of stream and riparian habitat in Napa River and lower reaches of its larger tributaries. As described in Chapter 6 (Implementation Plan), we will rely upon voluntary participation by landowners in reach based stewardships that will work with public agencies to implement projects that jointly reduce sediment discharges and enhance spawning and juvenile rearing habitat for salmonids and other native aquatic species. In the 4.6-mile long Rutherford Reach of mainstem Napa River, bounded upstream by Rutherford Cross Road and downstream by Oakville Cross Road, a landowner stewardship acting in partnership with public agencies has developed a conceptual plan for bank stabilization and enhancement of stream-riparian habitat (Phil Williams & Associates, 2003), and is currently engaged in project design and permitting activities. A similar planning effort is being considered on mainstem Napa River from Oakville Cross Road to Oak Knoll Avenue, representing an additional 10 miles of the river (Laurel Marcus, personal communication, 2006). In estimating costs associated with reducing sediment discharges from channel incision and associated bank erosion by 50 percent from current proportion of the total load, we relied on cost estimates presented in the conceptual plan for Rutherford (Phil Williams & Associates, 2003), and cost estimates for stream bank improvements presented in the California Coho Salmon Recovery Plan (CDFG, 2004). Our cost estimates include those for project management and administration, project design, stakeholder engagement and approval, project permitting, and monitoring and maintenance activities. Cost estimates, information sources, and key assumptions are presented in Table 11. Estimated costs to reduce sediment discharges from channel incision by 50 percent and to achieve related objectives for enhancement of habitat are **$30-to-49.1 million**.

Table 11. Cost estimates for Napa River sediment reduction and habitat enhancement

Action	Implementing Parties	Items	Low Cost ($millions)	High Cost ($millions)
Develop and implement plan to enhance stream-riparian habitat and reduce sediment supply in 4.5-mile long Rutherford Reach of mainstem Napa River	Landowners in partnership with government agencies	• Design and environmental review • Construction • Maintenance and monitoring	0.7 7.0 0.7	1.0 10.6 1.1
As above over additional 11.5 miles of mainstem Napa River	As above	• Design and environmental review • Construction • Maintenance and monitoring	1.8 18.0 1.8	3.0 30.4 3.0
All required actions		**Total**	**30.0**	**49.1**

Key assumptions and information:

1. Low cost for construction of Rutherford = $7 million (Philip Williams & Associates, 2003)
2. High cost based on value of $250 per foot of stream bank for channel restoration projects for projects located within 0.25 miles or less from a road (CDFG, 2004).
3. 15-mile length for sediment reduction and habitat enhancement actions represents 50 percent of length of mainstem Napa River in the unincorporated area. Implementation actions will be effective in arresting channel incision and associated erosion of streamside terraces. Therefore, following implementation, channel erosion will be in balance with deposition in these reaches, as needed to reduce sediment input from incision and associated bank erosion by 50 percent.
4. Flood control project actions within Town of Yountville, and City of St. Helena, upstream of tidewater are expected to restore dynamic equilibrium in these reaches.
5. Design and environmental review costs, and monitoring and maintenance costs are assumed to each equal about 10 percent of construction costs.

Road-Related Erosion

Road-related erosion is the largest sediment source associated with land-use activities in Napa River watershed, and for dirt roads, perhaps the most cost effective source to treat. Typical costs for prevention of road-related erosion in Napa County vary from less than $20 per metric ton for dirt roads on private property to approximately $72 per metric ton for paved public roads (PWA 2003a, 2003b, 2003c). Erosion prevention costs are much higher for paved public roads because it costs more to modify a paved surface, there are additional engineering design standards for public roads, and additional requirements for traffic control during construction.

We estimate there are 1040 miles of upland roads in Napa River watershed that have the potential to discharge sand to Napa River. 88 percent of the upland road network, or 915 miles, are privately owned, the vast majority of which is earth surfaced, and 12 percent of the upland road network, or approximately 125 miles are public roads, almost all of which are paved. It is important to note that up-front costs associated with prevention of road-related erosion, yield significant future cost savings (benefits) as a consequence of much lower costs for repair and/or reconstruction following large storms. Conservatively, storm-proofing roads should yield a much greater than 100 percent return on investment. These potential benefits, however, are not considered in our cost analysis. Road erosion control costs, information sources, and key assumptions are presented in Table 12. Estimated Costs to reduce sediment discharges from road-related erosion by 50 percent are $11.4-to-17.2 million.

Table 12. Cost Estimates for Control of Road-related Erosion

Action	Implementing Parties	Items	Low Cost ($millions)	High Cost ($millions)
Prepare and implement road erosion control plan	Private landowners	• Program management and administration • Inventory and control plan • Control and prevention measures Subtotal =	0.7 0.6 6.1 7.4	1.0 0.9 9.2 11.1
Prepare and implement a road erosion control plan	Public Landowners	• Program management and administration • Inventory and control plan • Control and prevention measures Subtotal =	0.4 0.3 3.3 4.0	0.6 0.5 5.0 6.1
		Total =	**11.4**	**17.2**

Key assumptions and information:

1. We estimate that: a) there are 915 miles of privately owned upland roads that have the potential to deliver sand to Napa River; b) 125 miles of paved public roads; and c) average rate of sediment input to channels from road-related erosion (paved and/or dirt roads) between 1994 and 2004 was 50 cubic yards per mile per year. This average sediment input rate needs to be reduced by 50 percent to 25 cubic yards per mile per year (which is equivalent to a long-term average rate of 500 cubic yards per mile per 20-year period).
2. In our analysis, we assume erosion control efforts on private roads will focus on upgrading dirt roads to reduce percent of road length that drains directly to a stream channel. On paved public roads, we assume road upgrading will focus on treatment of stream crossings (e.g., those that are undersized, have a diversion potential, prone to plugging, and/or where gullies are eroding culvert outlets). Cost per yd^3 for erosion control = $20 per cubic yard for dirt roads, and $72 per cubic yard on paved public roads (PWA, 2003a, 2003b, 2003c).
3. We assume costs for inventory and control plans = 10 percent of cost of road upgrading measures.
4. We assume program management and administration costs = 10 percent of the cost of actions.
5. High cost value for private dirt roads is calculated as follows: (915 miles) x ($20 per cubic yard for private dirt roads) x (reduction in rate of sediment delivery from roads by an average of 500 cubic yards per mile per 20-year period). High cost value for paved public roads is as above except road length = 125 miles, and cost per cubic yard of sediment prevented from entering a channel = $72.
6. Low cost value for public and private roads, is equal two-thirds of high cost value. In this scenario, we assume road-erosion control efforts are administered by local public agencies to coordinate inventories and control measures on a tributary basis, and only the most cost effective road reaches are targeted for upgrading.

Stormwater Runoff

This category includes sediment discharges regulated by NPDES permits including the Napa County municipal stormwater program, California Department of Transportation's permit for stormwater discharges, and Industrial and Construction General permits. We propose only minor changes to the stormwater management plan for the Napa County program, as discussed below. No changes are proposed for all other NPDES permits.

To meet the requirements of the proposed Basin Plan amendment, the stormwater management plan for the Napa County municipal stormwater program would be updated to adopt and implement the types of management measures called for in the recently developed draft "Stormwater Maintenance Standards" (draft of 6/28/04) pertaining to maintenance of public roads, management of vegetation and large woody debris in-and-around stream channels, and stream bank stabilization actions to protect public roadways, public safety, and/or private property (where private landowners request public agency assistance). The Napa County

Stormwater Maintenance Standards are consistent with maintenance standards recently developed by the counties of Mendocino, Sonoma, Marin, San Mateo, Santa Cruz, and Monterey to protect water quality, aquatic habitat, and salmonid fisheries (FishNet 4C, 2004), and which have been favorably reviewed by NOAA Fisheries, CDFG, and the Water Board. Therefore, we conclude that new costs for development of performance standards should be negligible.

Implementation of Stormwater Maintenance Standards may involve: a) education and training for public agency managers and maintenance staff to become familiar with performance measures and expectations; b) education and outreach to the general public regarding large woody debris with regard to habitat and water quality functions, permit requirements, technical assistance, etc.; and c) additional roadway inspections and maintenance for problem culverts, drainage inlets, and detention facilities prior to the onset of the rainy season. These costs are presented in Table 13, and estimated to be $0.6-to-1.2 million over the 20-year period for TMDL implementation.

Table 13. Cost Estimates for Additional Stormwater Runoff Program Measures

Action	Implementing Parties	Items	Low Cost ($millions)	High Cost ($millions)
Adopt and implement Stormwater Maintenance performance standards	Napa County Municipal Stormwater Program	• Training of staff • Public education and outreach	0.4 0.2	0.8 0.4
		Total =	**0.6**	**1.2**

Vineyard Surface Erosion

No new costs are associated with the proposed Basin Plan amendment as we rely on landowner compliance with Napa County's Conservation Regulations to achieve sediment allocations for vineyard surface erosion.

Rangeland Surface Erosion

The proposed Basin Plan amendment anticipates that the Water Board will develop conditional waivers of Waste Discharge Requirements (WDRs) for grazing land operators. At this point, the site-specific actions or general waiver conditions are unknown. Commercial livestock operations (ranches) currently utilize 13,000-to-23,000 acres of rangelands within Napa River watershed (This report; JSA, 2005). Amount of acreage used to provide forage for cattle and stocking densities have been substantially reduced from historical values. Based on conversations with National Resource Conservation Service (NRCS), U.C. Cooperative Extension, and Napa Farm Bureau staff, we estimate that there are twenty-or-fewer commercial livestock ranches operating in the watershed at present (Phill Blake, personal communication, 2005).

Based on conversations with NRCS staff and individual ranchers, and extensive field reconnaissance conducted to support the sediment source analysis, we estimate that approximately 90 percent of grazing lands in the Napa River watershed currently have adequate pasture management practices in place for the control of surface erosion. We therefore assume that alternative range management measures will be required at a maximum of 10 percent of the grazing land within the watershed (e.g., 1300-to-2300 acres). Alternative rangeland management measures that may be needed to achieve performance standards in the proposed Basin Plan amendment (e.g., residual dry matter targets or the amount of ground cover at the end of the dry season) may include changes to the timing, duration, and/or locations of livestock grazing at individual ranches. Because current range management practices appear to be effective at almost all ranches we have observed in the watershed, we conclude such practices can be established at the remaining sites, without additional management costs.

Estimated total cost for control of rangeland surface erosion is **$100,000-to-$200,000** over the 20-year implementation period. These costs are presented in Table 14.

> Note: other ranch water quality enhancement measures will be needed to control sediment discharges from road-related erosion, and/or unstable areas, and these are not estimated in this section. For example, a portion of the total cost of road-erosion control on private lands (presented above) will be for roads located on ranch lands. Similarly, a portion of the cost of reducing sediment discharge from unstable areas will be for unstable areas located on ranch lands. Costs for reducing sediment discharges from unstable areas are described immediately below.

Table 14. Cost Estimates for Implementation Measures to Control Surface Erosion in Pastures

Action	Implementing Parties	Items	Low Cost ($millions)	High Cost ($millions)
Attain residual dry matter standards in pastures (e.g., ground cover in fall)	Ranch owners and/or operators	• Range management plan	**0.1**	**0.2**

Unstable Areas

Intensive historical grazing, development of hillside vineyards, and/or other historical or current land use activities[46] have caused or contributed to the erosion of gullies and/or shallow landslides many of which may continue to erode for several years into the future and deliver significant volumes of sediment to stream channels in Napa River watershed. The proposed basin Plan amendment would require landowners to conduct sediment source inventories and implement control measures to accelerate natural recovery and avoid future human caused increases in sediment delivery from unstable areas. In estimating the cost for reduction of sediment delivery to channels from unstable areas, we employ the following information and assumptions:

a) Future sediment delivery from gullies needs to be reduced by 50 percent from current proportion of total load, or approximately 800,000 metric tons over the 20-year implementation period to achieve allocation to this source in the TMDL.

b) High value for cost per ton of sediment prevented from entering a channel (from gully and/or landslide erosion), assuming biotechnical and/or traditional engineering approaches are used equals $20 per ton (S. Chatham, personal communication, 2005).

c) Low value for cost per ton of erosion prevented from entering a channel is estimated to equal 25 percent of high value, assuming an approach that would emphasize addressing present-day management influences on gully or landslide erosion at half or more of all

[46] All road-related erosion processes including gullies and landslides are included in road erosion category.

sites (e.g., dispersing and/or diverting concentrated runoff to stable areas, exclusion fencing around gullies in commercial livestock ranches, planting of native woody plant species, etc.).

d) We assume that cost of inventories and design of control measures costs no more than 10 percent of the cost of erosion control measures.

Total cost for actions to accelerate natural recovery and avoid future sediment delivery from unstable areas is $4.4-to-17.6 million over the 20-year period for implementation actions to achieve the TMDL[47] (Table 15).

Table 15. Cost Estimates for Erosion Control and Prevention in Unstable Areas

Action	Implementing Parties	Items	Low Cost ($millions)	High Cost ($millions)
Accelerate natural recovery and avoid future human-caused increase in sediment delivery from unstable areas	Vineyard owners, ranchers, other rural private property owners, and public agencies	• Erosion control assessment • Control measures **Total**	0.4 4.0 **4.4**	1.6 16.0 **17.6**

Key assumptions and information:

1. High value for average cost per ton of sediment prevented from entering a channel (from gully and/or landslide erosion) = $20 per metric ton (S. Chatham, personal communication, 2005).
2. Sediment reduction goal for this source is 800,000 metric tons over 20-year period.
3. We assume cost of assessment and design ≤ 10 percent of cost of control measures.

7.5 Agricultural Water Quality Program Costs

Implementation measures for grazing lands and vineyards constitute an agricultural water quality control program and therefore, consistent with California Water Code requirements (Section 13141), the cost of this program is estimated herein. This cost estimate includes the cost of implementing all sediment control and stream channel restoration measures specified in the implementation plan, and is based on costs associated with technical assistance and evaluation, project design, and implementation of actions needed to achieve the TMDL. In estimating costs, the Water Board has assumed that owners of agricultural businesses (e.g., grape growers and ranchers), within the unincorporated area, own 75 percent of total land area on hillside parcels, and 95 percent of the land along the length of the Napa River and lower reaches of its tributaries. Based on these assumptions, we estimate that total cost for program implementation for agricultural sources could be $1.9-to-3.4 million per year throughout the 20-year implementation period. More than two-thirds of these potential costs are associated with reducing sediment discharges and enhancing habitat conditions in Napa River, and considering potential benefits to the public in terms of ecosystem functions, aesthetics, recreation, and water quality, we conclude that at least 75 percent of the cost of these actions will be paid for with public funds, and therefore, we estimate that total cost to agricultural businesses associated with efforts to reduce sediment supply and enhance habitat in Napa River is $800,000-to-$1.7 million per year. A summary of cost estimates for agricultural sources is presented in Table 16.

[47] Note this section considers the same management measure commercial ranches (fencing livestock out of waterways) as is described in the economic analysis for control pathogen discharges from grazing lands.

Table 16. Agricultural Water Quality Control Program Costs

Item(s)	Responsible Parties	Agricultural Sources (percent cost)	Low Cost to Agriculture ($millions)	High Cost to Agriculture ($millions)
Napa River sediment reduction and habitat enhancement	Riverside landowners	95	28.5	46.6
Reduce road-related erosion by 50 percent	Owners of roads on hillside parcels	75	5.6	8.3
Accelerate natural recovery and avoid future human caused increases in sediment delivery from unstable areas	Ranchers, rural landowners, grape growers, public agencies	75	3.3	13.2
Control vineyard surface erosion	Grape growers	100	0.0	0.0
Control pasture surface erosion	Ranchers	100	0.0	0.2
NPDES stormwater treatment measures	Public agencies, developers, and contractors	0	0.0	0.0
All measures to reduce sediment discharge to Napa River[48]	As above	…	(37.4)	(68.3)
As above with 75% cost of Napa River sediment reduction and habitat enhancement publicly funded		…	**16.0**	**33.4**
Average annual cost over 20-year implementation period		…	**0.8**	**1.7**

[48] Napa River habitat enhancement costs are included because only feasible approach for reducing sediment discharges from channel incision and associated erosion of stream terrace banks in Napa River is to undertake a channel enhancement approach.

7.6 Sources of Funding

Potential sources of funding include monies from private and public sources. Public financing includes, but is not limited to grants, as described below, single-purpose appropriations from federal, state, and/or local legislative bodies, and bond indebtedness and loans from government institutions. There are several potential sources of public financing through grant and funding programs administered, at least in part, by the Regional Water Board and the State Water Board. These programs vary over time depending upon federal and state budgets and ballot propositions approved by voters. Regional and State Water Board grant and funding programs that are pertinent to the proposed *Napa River Sediment Reduction and Habitat Enhancement Basin Plan Amendment*, and are currently available at the time of this writing or will be available in the near future are summarized and described below.

Consolidated Watershed Nonpoint Source Grant Program (Proposition 40)

> The Consolidated Watershed Nonpoint Source (NPS) grant program is funded by Proposition 40, the California Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act of 2002. This program has not yet solicited grant proposals, but will fund nonpoint source, coast non-point source, urban storm water, and watershed management projects.

Nonpoint Source Pollution Control Program (Proposition 40)

> The Non-point Source Pollution Control Program provides funding for projects that protect the beneficial uses of water throughout the state through the control of nonpoint source pollution. Up to $19 million is available to local public agencies and non-profit organizations.

Integrated Regional Watershed Management Grant Program (Proposition 40)

> The Integrated Regional Watershed Management grant program funds projects for development of local watershed management plans and for implementation of watershed protection and water management projects. This grant program will provide $47.5 million statewide for competitive grants to non-profit organizations and public agencies.

Integrated Regional Water Management (IRWM) Grant Program (Proposition 50)

> The IRWM Grant Program is a joint program between the Department of Water Resources (DWR) and the State Water Board which provides funding for projects to protect communities from drought, protect and improve water quality, and reduce dependence on imported water. Funding is available for both IRWM Planning and Implementation Grants.

REFERENCES

Adams, T., 2005. Personal communication from Todd Adams, Napa County Municipal Stormwater Program Coordinator to Mike Napolitano, Water Board.

Anderson, K.R., 1969. Steelhead Resource, Napa River Drainage, Napa County. Memorandum to File. California Department of Fish and Game, Region 3. December 23, 1969.

Brown, W.M., and J.R. Ritter, 1971. Sediment transport and turbidity in the Eel River basin, California: US Geological Survey Water Supply Paper 1986. 70 pages.

Burner, C.J., 1951. Characteristics of spawning nests of Columbia River salmon. Fish. Bull. U.S.52: 97–110.

Carling, P.A., 1987. Bed stability in gravel streams with reference to stream regulation and ecology. In: *River Channels: Environment and Process.* Edited by K.S. Richards. Blackwell Scientific Publications, Ltd., Oxford, U.K. pp. 126–143.

Chapman, D.W., and T.C. Bjorn, 1969. Distribution of salmonids in streams with special reference to food and feeding. Pages 153-176 in T.G. Northcote, editor, *Symposium on Salmon and Trout in Streams*. H.R. MacMillan Lectures in Fisheries, Institute of Fisheries, University of British Columbia, Vancouver, Canada.

Chapman, D.W., 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society, 117, No. 1: 1–21.

Cordone, A.J., and D.W. Kelley, 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game 47: 189–228.

Dawson, A., 2002. The Oral History Project: a Report on the Findings of the Sonoma Ecology Center's Oral History Project, Focusing on Sonoma Creek and the Historical Ecology of Sonoma Valley. Sonoma Ecology Center, Sonoma, California.

DeVries P., 1997. Riverine salmonid egg burial depths: review of published data and implications for scour studies. Canadian Journal of Fisheries and Aquatic Sciences, 54: 1685–1698.

Dietrich, W.E., J.W. Kirchner,, H. Ikeda., and F. Iseya, 1989. Sediment supply and the development of the coarse surface layer in gravel-bedded rivers. Nature, 340: 215–217.

Dietrich, W.E. et al., 2004. The use of Airborne Laser Swath Mapping Data in Watershed Analysis to Guide Restoration Priorities: the Napa River Watershed Study. Eos Transactions of the American Geophysical Union *85*(47), Fall Meeting Supplement, Abstract G11B-06.

Ellen, S.D., and C.M. Wentworth, 1995. Hillside materials and slopes of the San Francisco Bay Region, California. US Geological Survey Professional Paper 1357. United States Government Printing Office: Washington, D.C.

Endicott, C.L., and T.E., McMahon, 1996. Development of a TMDL to reduce non-point source sediment pollution in Deep Creek, Montana. Report to Montana Department of Environmental Quality. Department of Biology, Fish and Wildlife Program, Montana State University. Bozeman, Montana.

Emig, J. and M. Rugg, 2000. Personal communication from John Emig and Mike Rugg, Senior Fisheries Biologists with CDFG, Yountville, Calif. to Mike Napolitano, RWQCB, Oakland, Calif.

Evenson, D.F., 2001. Egg pocket depth and particle size composition within Chinook salmon redds in the Trinity River, California. M.S. Thesis, Department of watershed management, Humboldt State University, Arcata, California. 70 pp.

FishNet 4C et al., 2004. Guidelines *for* protecting aquatic habitat and salmonid fisheries *for* county road maintenance. FishNet 4C, 8276 Old Redwood Highway, Cotati, CA, 94931.

Fleming, R.W. and A.M. Johnson. 1975. Rates of seasonal creep of silty clay soil, Q. J. Eng. Geology, Vol. 8, pp. 1–29.

Grossinger, R., C. Striplen, E. Brewster, and L. McKee, 2003. Ecological, Geomorphic, and Land Use History of Sulphur Creek Watershed: A component of the watershed management plan for the Sulphur Creek watershed, Napa County, California. A Technical Report of the Regional Watershed Program, SFEI Contribution 69, San Francisco Estuary Institute, Oakland California.

Grossinger, R., C. Striplen, E. Brewster, and L. McKee, 2003b. Ecological, Geomorphic, and Land Use History of Carneros Creek Watershed: A component of the watershed management plan for the Carneros Creek watershed, Napa County, California. A Technical Report of the Regional Watershed Program, SFEI Contribution 70, San Francisco Estuary Institute, Oakland California.

Hartman, G.F., 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada, 22: 1035-1081.

Kelsey, H.M., 1980. A sediment budget and an analysis of geomorphic process in the Van Duzen River basin, coastal California, 1941–1975: Summary. Geological Society of America Bulletin, Part 1, Volume 91, p. 190–195.

Lehre, A.K., 1982. Sediment budget for a small Coast Range drainage basin in north-central, California. Pages 67–77 in Sediment budgets and routing in forested drainage basins. USDA Forest Service General Technical Report, PNW–141.

Leidy, R.A., G.S. Becker, and B.N. Harvey, 2003. Historical Distribution and Current Status of Steelhead *(Oncorhynchus mykiss*), Coho Salmon (*O. kisutch*), and Chinook Salmon (*O.*

tshawytscha) in Streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, 4179 Piedmont Avenue, Suite 325, Oakland, California 94611.

McCuddin, M.E., 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. Thesis. University of Idaho, Moscow.

McKean, J.A., W.E. Dietrich, R.C.Finkel, J.R.Southon, and M.W. Caffee. 1993. Quantification of soil production and downslope creep rates from cosmogenic 10Be accumulation on a hillslope profile, Geology, Vol. 21, pp. 343–346.

McNeil, W.J. and W.H. Ahnell, 1964. Success of pink salmon spawning relative to size of spawning bed materials. US Fish and Wildlife Service, Special Scientific Report-Fisheries No. 469. Washington, D.C. January 1964.

McNeil, W.J., 1966. Effects of the spawning bed environment on reproduction of pink and chum salmon. Fishery Bulletin Volume 65, Number 2, Contribution Number 198. College of Fisheries, University of Washington, Seattle.

Meyer, K.A., and J.S. Griffith, 1997. Effects of cobble-boulder substrate configuration on winter residency of juvenile rainbow trout. North American Journal of Fisheries Management 17: 77-84.

MIG, Inc., 2000. Napa River Watershed Task Force, Phase II Final Report. Prepared for the Napa County Board of Supervisors. Moore Iacofano Goltsman, Inc., 800 Hearst Avenue, Berkeley, CA, 94710.

Montgomery, D.R., J.M. Buffington, N.P. Peterson, D. Schuett-Hames, and T.P. Quinn, 1996. Stream-bed scour, egg burial depths, and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53: 1061–1070.

Montgomery, D.R, E. M. Beamer, G.P. Pess, and T.P. Quinn, 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences 56: 377–387.

Napa County, 1993. Unpublished aerial photography for Napa County, California. Department of Information Technology Services, Napa, California.

Napa County, 2002. Unpublished aerial photography for Napa County, California. Napa County, Department of Information Technology Services, Napa, California.

Napa County RCD et al., 2003a. Stewardship Support and Watershed Assessment in the Napa River Watershed: A CALFED Project. Carneros Creek Tributary Watershed Assessments.

Napa County RCD et al., 2003b. Stewardship Support and Watershed Assessment in the Napa River Watershed: A CALFED Project. Sulphur Creek Tributary Watershed Assessments.

Napa Green Certification Program, 2003. Program Element II. New Vineyard – Instructions and Beneficial Management Practices. Laurel Marcus and Associates, unpublished guidance documents.

Napolitano, M.B., 2006. Methods for estimating rates and sizes of sediment input to channels, and spawning gravel permeability. 13 pp. Unpublished report prepared for California Regional Water Quality Control Board, San Francisco Bay Region, Oakland, CA.

Nawa, R.K., C.A. Frissell, and W.J. Liss, 1990. Life history and persistence of anadromous salmonid stocks in relation to stream habitats and watershed classification. Annual Progress Report, Fisheries Research Project: Oregon Dept. of Fisheries and Wildlife. Oregon State University, Corvallis.

Pacific Watershed Associates, 2001. Road Assessment for the Dry Creek watershed, Napa County, California. Prepared for the Napa County Resource Conservation District, Napa, California.

Pacific Watershed Associates, 2003a. Sediment source assessment, a component of the watershed management plan for the Carneros Creek watershed, Napa County, CA.

Pacific Watershed Associates, 2003a. Sediment source assessment, a component of the watershed management plan for the Sulphur Creek watershed, Napa County, CA.

Palmer, M.A. et al., 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology, 42: 208-217. Available at http://nrrss.umd.edu/Publications/Palmer_et_al_2005_JAE.pdf

Reid, L.M., and T, Dunne. Rapid Evaluation of Sediment Budgets. Geo-Ecology Texts. Catena-Verlag, Reiskirchen, Germany.

State Water Resources Control Board (State Board), 2004. Policy for implementation and enforcement of the nonpoint source pollution control program, May 20, 2004. California Environmental Protection Agency, State Water Resources Control Board, Sacramento, California. 18 pages. http://www.waterboards.ca.gov/nps/docs/oalfinalcopy052604.doc.

Stillwater Sciences and W.E. Dietrich, 2002. Napa River Basin Limiting Factors Analysis. Final Technical Report prepared for San Francisco Bay Water Quality Control Board, Oakland, Calif., and California State Coastal Conservancy, Oakland, Calif.. June 14, 2002.

Suttle, K.B., Power, M.E., Levine, J.M., and C. McNeely, 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications, 14(4): 969-974.

Swinchatt, J.P. and D.G. Howell, 2004. *The Winemaker's Dance—Exploring Terroir in the Napa Valley*. University of California Press, Berkeley and Los Angeles, California. 229 pages.

Trush. W.J., S.M. McBain, and L.B. Leopold, 2000. Attributes of an alluvial river and their relation to water policy and management. Proceedings of the National Academy of Sciences, Volume 97, No. 22: 11858–11863.

University of California, 2002. California guidelines for residual dry matter (RDM) management on coastal and foothill annual rangelands. University of California, Division of Agriculture and Natural Resources, Rangeland Monitoring Series Publication 8092. University of California, Davis. Document available online at http://anrcatalog.ucdavis.edu

USDA Soil Conservation Service, 1985. Hillside Vineyards Unit. Redwood Empire Target Area: Napa and Sonoma Counties, California.

U.S. Environmental Protection Agency, 1999. Protocol for developing sediment TMDLs. EPA 841-B-99-004. Office of Water (4503F), United States Environmental Protection Agency, Washington, D.C. 132 pages.

U.S. Fish and Wildlife Service, 1968. Analysis of fish habitat of the Napa River and tributaries, Napa County, California, with emphasis given to steelhead trout production. October 21, 1968. Memorandum to file.

Van den Berghe, E.P. and M.R. Gross, 1984. Female size and nest depth in coho salmon (*Oncorhynchus Kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 41: 204–206.

WET, Inc., 1990. Napa River sediment engineering study, Phase I and II. Prepared for US Army Corps of Engineers, Sacramento, California.

White, A.S., 1985. Hillside Vineyard Inventory. Napa County Resource Conservation District.

Yoshiyama, R.M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle, 2000. Chinook salmon in the California Central valley: an assessment. Fisheries, Volume 25 (2): 6–20.