Appendix D

LITERATURE REVIEW

California Department of Fish and Game
SUCTION DREDGE PERMITTING PROGRAM

Literature Review
September 2009

California Department of Fish and Game
SUCTION DREDGE PERMITTING PROGRAM

Literature Review on the Impacts of Suction Dredge Mining in California

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LIST OF ACRONYMS

(The) 1994 EIR	Environmental Impact Report (EIR) for the 1994 Regulations Governing Suction Dredging (State Clearinghouse Number 93102046)
(The) 1997 Draft EIR	Draft EIR for the 1997 Proposed Amendments to the Existing Regulations Governing Suction Dredging
(The) December 2006 Court Order	A Court Order by the Alameda County Superior Court issued in December 2006 to the Department
(The) October 2007 Public Notice	California Regulatory Notice Register 2007, Number 42-Z, page 1783, October 19, 2007
APA	Administrative Procedure Act
BLM	Bureau of Land Management
California Register	California Register of Historical Resources
CARB	California Air Resources Board
CCR	California Code of Regulations
CDPR	California Department of Parks and Recreation
CEQA	California Environmental Quality Act
CNDDB	California Natural Diversity Data Base
CVRWQCB	Central Valley Regional Water Quality Control Board
CWB	Coarse Woody Debris
dB	Decibels
(The) Department/CDFG/DFG	California Department of Fish and Game
EIR	Environmental Impact Report
Hg	Mercury
HP	Horsepower
m	Meters
m^2	Square meters
m^3	Cubic meters
MeHg	Methylmercury
mg/L	Milligrams per liter
National Register	National Register of Historic Places
N.D.	No date
NTU	Nephelometric Turbidity Units
OEHHA	Office of Environmental Health Hazard Assessment
Ppm	Parts per million
SCUBA	Self contained underwater breathing apparatus
SEIR	Subsequent environmental impact report
SMARA	Surface Mining and Reclamation Act
SWRCB	State Water Resources Control Board
TCP	Traditional Cultural Properties
TSS	Total Suspended Solids
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Department of Fish and Wildlife
WPW	California Assembly Committee on Water, Parks, and Wildlife

Section 1
INTRODUCTION

1.1 Introduction

This literature review assembles, reviews, and assesses information related to suction dredge mining and its potential effects on the environment. The goal of the review is to develop a better understanding of the existing body of knowledge associated with the impacts of suction dredge mining on the environment, including where sound research exists and where research is lacking, and to support the California Department of Fish and Game's (Department's) current California Environmental Quality Act (CEQA) efforts related to its suction dredge permitting program. The Department is conducting these activities in association with the State Water Resources Control Board (SWRCB).

1.2 Background

Small-scale suction dredge mining activity in California began in the 1960's and peaked in the late 1970's and early 1980's, when gold prices were high. The Department oversees implementation of a permitting program for suction dredge mining in California under California Code of Regulations (CCR) Title 14, § 228 et seq. The Department administers the suction dredge permitting program pursuant to Fish and Game Code § 5653 and 5653.9, among other legal authorities. The existing regulatory regime governing the activity as administered by the Department is rooted in statutory amendments to the Fish and Game Code that took effect in the late 1980's. The Department promulgated the existing regulations governing suction dredge mining in California consistent with this statutory authority in 1994. Under the statute and regulations, any California resident or non-resident may obtain a suction dredge mining permit from the Department upon payment of a fee required by statute. The permits issued by the Department authorize suction dredge mining throughout California subject to the terms and conditions set forth in the regulations. On average, the Department has issued approximately 3,200 suction dredge mining permits to California residents every year for the last 15 years. The comparable figure for non-resident suction dredge mining permits issued by the Department is 447.

The Department's promulgation of the existing regulations governing suction dredge mining were preceded by preparation and certification of an environmental impact report (EIR) under CEQA (State Clearinghouse Number 93102046) (hereafter, the 1994 EIR). The Department considered proposed amendments to the existing regulations governing suction dredge mining in 1997, releasing a draft subsequent EIR for public review that same year (hereafter, the 1997 Draft SEIR). However, the 1997 Draft SEIR was never completed or certified.

The Department is currently engaging in additional CEQA compliance activities in connection with its suction dredge mining program and the related regulations as a result of a court order issued in a lawsuit brought against the Department by the Karuk Tribe of

California (Karuk Tribe of California et al. v. California Department of Fish and Game, Superior Court of Alameda County Case Number RG05211597). The lawsuit focused on the Salmon, Scott and Salmon River watersheds in northern California; included allegations regarding impacts to various fish species, such as coho salmon (*Oncorhynchus kisutch*); and contended that the Department's administration of the suction dredging program violated CEQA and various provisions of the Fish and Game Code. In February 2006, various mining interests and a number of individuals joined the lawsuit by court order as party interveners. In December 2006, the Alameda County Superior Court issued an order with the consent of all parties, directing the Department to "conduct further environmental review pursuant to CEQA of its suction dredge mining regulations and to implement, if necessary, via rulemaking, mitigation measures to protect Coho salmon and/or other special status fish species in the watershed of the Klamath, Scott, and Salmon Rivers, listed as threatened or endangered after the 1994 EIR" (hereafter, the December 2006 Court Order). For purposes of CEQA, the December 2006 Court Order describes the Department's legal obligations in terms of Public Resources Code § 21166 and related provisions in the CEQA Guidelines found in § 15162 through 15164.

As part of its effort to comply with the December 2006 Court Order, the Department issued a public notice in October 2007, soliciting information regarding the environmental impacts that may occur in California as a result of suction dredge mining under the Department's existing permitting program (California Regulatory Notice Register 2007, Number 42-Z, page 1783, October 19, 2007) (hereafter, the October 2007 Public Notice). In so doing, the Department sought information from interested members of the public and various public agencies relevant to the following issues:

- Whether suction dredge mining results in adverse impacts to the environment;
- Whether suction dredge mining under the Department's current regulations governing such activities results in deleterious effects to fish;
- Whether there are changed circumstances or new information available since 1994 regarding suction dredge mining and the environment generally; and
- Whether changed circumstances or new information available since 1994 indicates that suction dredge mining under the Department's existing regulations is resulting in new significant or substantially more severe environmental impacts than previously considered by the Department in the 1994 EIR.

In response to the October 2007 Public Notice, the Department received comments from approximately 70 federal, state, and local agencies; various tribal, environmental, and mining interests; representatives of the academic and consulting community; and members of the public. Based on this information, the Department informed the Alameda County Superior Court on January 7, 2008, that it had determined that it could not proceed with the court-ordered environmental review in reliance on an addendum prepared pursuant to CEQA (see generally CEQA Guidelines, § 15164). The Department indicated to the court at the same time that more than minor additions or changes to the 1994 EIR would be necessary and that statewide issues would need to be addressed in a subsequent environmental document in order to fulfill the Department's obligations under CEQA. On February 26, 2008, the Department informed the Alameda County Superior Court that it intended to prepare a subsequent environmental impact report (SEIR) that would be statewide in scope in order to comply with the December 2006 Court Order.

The SEIR and related review under CEQA will analyze new significant and substantially more severe environmental impacts that may be occurring under the existing permitting program that were not addressed by the Department during prior environmental review completed in 1994. The proposed project, for the purposes of the SEIR, will consist of continued implementation of the permitting program, and, if necessary, proposed amendments to existing regulations in CCR Title 14 governing suction dredge mining throughout California. With respect to proposed amendments to the existing regulations, the Department is charged by the Fish and Game Code to issue suction dredge permits where the Department determines, consistent with the regulations, and that the operation will not be deleterious to fish (Fish and Game Code § 5653[b]). Proposed amendments to the Department's existing regulations governing suction dredge mining must be promulgated in compliance with the Administrative Procedure Act (APA) (Government Code § 11340 et seq.). The Department anticipates that the "formal rulemaking" under the APA to promulgate amendments to the existing suction dredge mining regulations will run concurrently with the related environmental review of the SEIR required by CEQA. Proposed amendments to the existing regulations in Title 14 are also likely to be statewide in scope, as well as location-specific depending on various factors, including the water body at issue, the presence of biological resources, and related environmental effects.

On August 5, 2009 the California Governor approved Senate Bill 670 which resulted in the immediate suspension of suction dredge activity under existing permits, as well as the issuance of new permits by the Department. This moratorium on the operation of suction dredge equipment will remain in effect until the Department has completed further environmental review, as ordered by the 2006 court action.

1.3 Objectives

The objectives of this literature review are to:

- develop a better understanding of the existing body of knowledge associated with the impacts of suction dredge mining on the environment;
- identify where sound research exists and where research is lacking;
- build a basis of "substantial evidence" for use in the CEQA process; and
- support preparation of an Initial Study and SEIR.

The review evaluates both information that is specific to suction dredge mining as well as more general information based on ecological principles/theory or similar types of investigation/ research. The literature review identifies the conclusions considered to be the best available science and/or expert opinion on the topic, and identifies any data gaps.

1.4 Organization of this Document

The document is organized as follows:

Section 1 – *Introduction* provides an overview of the document purpose and context.

Section 2 – *Activity Description* presents a description of suction dredge mining in California.

Section 3 – *Methodology* provides a description of the methods used in conducting the literature review.

Section 4 – *Impacts of Suction Dredging.* This section is divided into separate topical subsections based on the resource/topic. Within each section, the range of information, conclusions available on the topic, and identified data gaps have been summarized. The section is organized into the following categories:

4.1 Geomorphology
4.2 Water Quality
4.3 Biological Resources
4.4 Cultural Resources
4.5 Mineral Resources
4.6 Socioeconomics
4.7 Recreation
4.8 Aesthetics
4.9 Air Quality
4.10 Noise

Section 5 – *References Cited* presents a listing of the resources cited in the review.

Section 6 – *Report Preparers* presents the individuals involved in preparing the review.

Appendix – *Bibliography of Literature Reviewed* provides a complete listing of all literature sources consulted, including those not cited in the review.

Section 2
ACTIVITY DESCRIPTION

2.1 Introduction

2.1.1 Overview

For the purposes of this analysis, suction dredge mining is the use of a motorized suction system to remove and return material at the bottom of a stream, river, or lake for the extraction of minerals. Suction dredges are used primarily by recreationalists as a method to recover gold from rivers and streams.

The suction dredges that are used to recover gold from California's waterways are engine-powered machines that are easy to operate, portable, and are capable of excavating and processing substantially more sediment than human-powered methods such as panning. Due to their portability and lightweight design, single operators can access remote locations and mine a greater area than previously possible. The California Department of Fish and Game (CDFG or Department) oversees this practice through its Suction Dredge Permit Program. The Department authorizes dredging practices using a 6 inch nozzle size or less (with larger nozzle sizes allowed in certain circumstances). The Department's Suction Dredging Permit Program is focused on small-scale, and generally recreational, gold dredging operations.

2.1.2 History

Although gold had been discovered in California as early as 1775, California's famous Gold Rush began with the discovery of gold at Sutter's Mill on January 24, 1848. At first, individual dredgers could "strike it rich" by panning, and using simple equipment such as rocker boxes and sluices. However, by the mid-1850's, the easily recoverable gold had been mined out and gold mining began to be dominated by well capitalized companies (California Divisions of Mines and Geology 1970).

Hydraulic mining emerged in several locations simultaneously in the early 1850's. After extensive water conveyance systems were completed, it became an important gold industry and thrived from about 1860 to 1884 when the Sawyer Decision (which addressed environmental and commerce damage caused by hydraulic mining debris) caused the industry to decline.

Underground "hardrock" gold became a major gold producing industry as milling technology improved after hydraulic mining began to wane. However, mining for hardrock gold was suspended during World War Two and never fully recovered after the war.

In the late 1890’s, large, mechanical dredges (e.g., bucket and dragline dredges) were developed to mine low grade gold deposits in rivers or on their outwash fans. These dredges floated in rivers or in their own ponds and mined ahead by scooping up gold-bearing gravel in huge steel buckets, extracting the gold, and dumping the waste cobbles into great mounds behind them. The gold dredging industry grew steadily and reached its peak during the Great Depression. However, because of low gold prices and increased operating expenses, the business declined. By the 1950's very few large gold operations remained.

In the early 1960’s, a new inexpensive and portable dredge emerged, – the suction dredge. Self Contained Underwater Breathing Apparatus (SCUBA) and Hookah Air systems allowed individuals to use suction dredges underwater like vacuum cleaners to excavate sediment from a river or stream. Anecdotal reports hold that the individuals first using these new machines in northern rivers recovered impressive amounts of gold. Although suction dredges began as self-crafted devices, there are now a number of manufacturers who produce suction dredges of various sizes and prices, including companies such as Keene and Proline. The commercial availability of suction dredges makes it possible to excavate tons of sediment per hour from a river or stream in a recreational quest for gold.

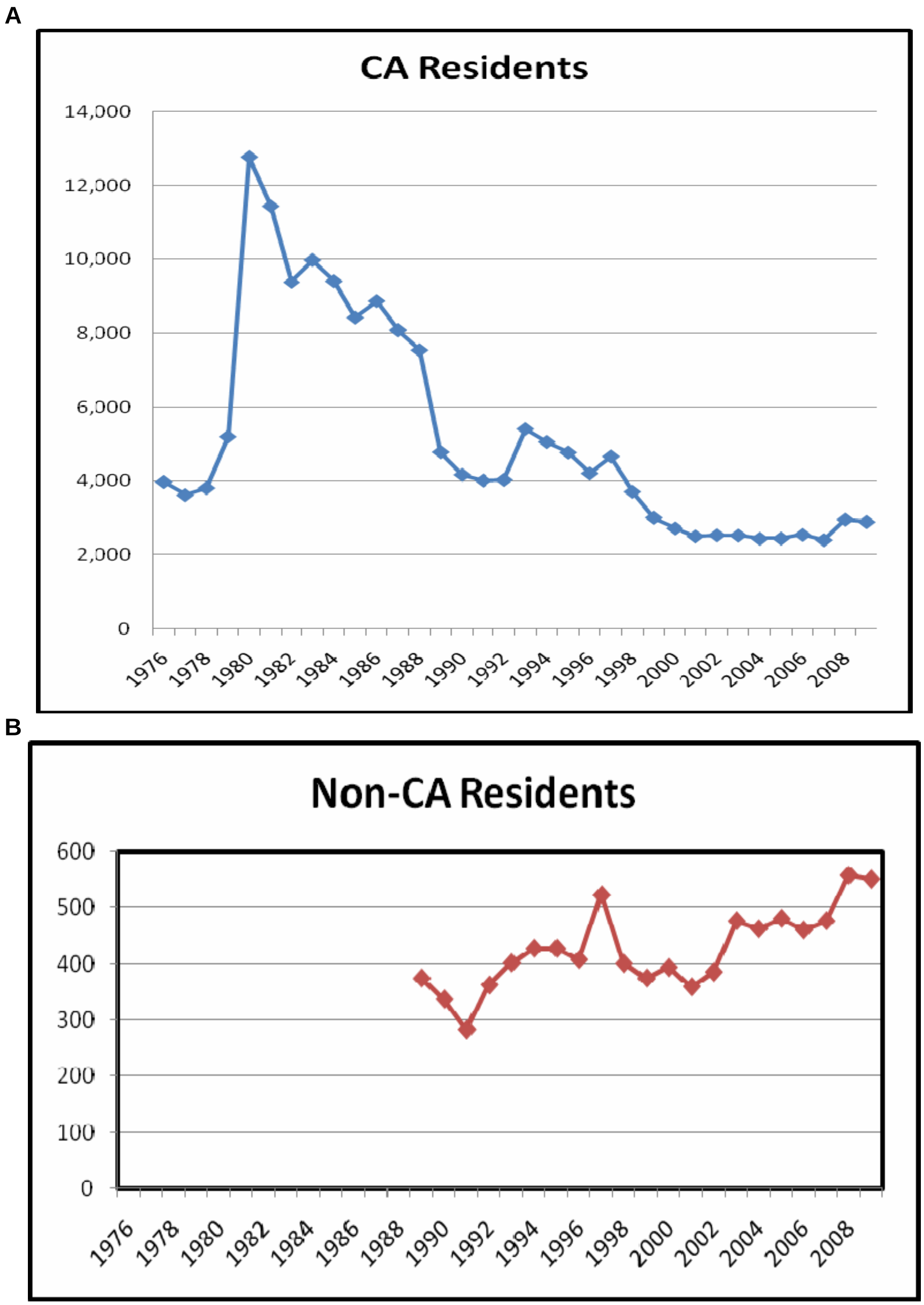
2.1.3 Regulatory Context and Department Permit Program

The current regulations concerning suction dredging can be found in CCR Title 14, § 228 and 228.5. These regulations were first adopted on May 27th 1994, with the latest subsequent revisions made in April 2008. Under these regulations, every individual operating a suction dredge in the state of California must be in possession of a suction dredge permit. Permits can be obtained from Department offices following the submission of an application and fee ($47.00 for CA residents, $185.25 non-residents as of June 2009). Permits are valid for a single calendar year (January-December), regardless of when the permit is obtained.

The regulations identify equipment requirements, seasonal and permanent closures for locations throughout the state, restrictions on the methods of operation, and permit revocation and suspension rules. The Department reserves the right to revoke or suspend permits for any violation of the laws or regulations outlined in CCR Title 14, § 225 and 228.5. Repeat offenders may be subject to permanent revocation of renewal permits based on past citations or convictions. Furthermore, all waters are subject to closure from suction dredging if the Department initiates emergency regulatory action pursuant to Government Code § 11346.1.

The number of general suction dredge permits issued annually by the Department increased dramatically from 3,981 in 1976 to a peak of 12,763 in 1980, echoing the steep rise in gold prices in the late 1970s. However, the number of issued permits subsequently declined to around 3,000 in most recent years. On average, the Department has issued approximately 3,200 suction dredge permits to California residents every year for the last 15 years (Figure 2-1 A).

Figure 2-1. Historical Trends in Suction Dredge Permit Issuance between 1976 and 2009



Source: California Department of Fish and Game Historical Licensing Statistics –Special Licenses and Permits

2.2 Equipment

2.2.1 General

Although suction dredges vary in size and power, their basic configuration is comprised of a floating gold recovery system (known as a sluice box) attached to a suction hose (see Figure 2-2). These machines are operated by one or two individuals who control the hose underwater using a supplied air system as necessary.

Suction dredges are driven by either a gasoline or diesel engine that runs a centrifugal pump. The pump draws in river water and forces it through a series of hoses and tubes to create a Venturi effect, or a strong suction. Sediment from a river or stream is drawn up the suction hose and discharged into one or more sluice boxes. In general, dredge performance or capacity (reported as yards per hour by manufactures) is a function of the diameter of the intake nozzle and the horsepower of the engine(s) used, with the power of dredges to move sediment increasing by approximately the cube of the increase in nozzle diameter.

Sluice boxes are metal boxes equipped with steel riffles and are used to recover gold and other high density solids (e.g., black sand, lead weights and shot, mercury amalgam, mercury) from bulk sediment. Gold-bearing sediment is washed through a sluice box and gold and other high density solids settle behind the riffles. Anything discharged from the sluice (e.g., low density sediment, small gold particles, etc.) are called tailings. Gold and other dense solids are collected when the sluice is cleaned. Sluice boxes have become increasingly complex as manufactures attempt to increase their gold-trapping efficiency (e.g., systems employing several sluice boxes, sediment classifiers, and jet flare technology). However, because manufactures do not provide test data for different designs, it is not possible to state how much better or worse different designs fare at trapping gold.

Almost all dredges are supported in the water by floats made of plastic, foam, or tire tubes. Some dredges are designed with twin pressure systems—they have two engines, two pumps, and two pressure hoses which attach to a special jet. The main advantage of this type of system is that it allows a dredge operator to move material faster by combining portability with capacity.

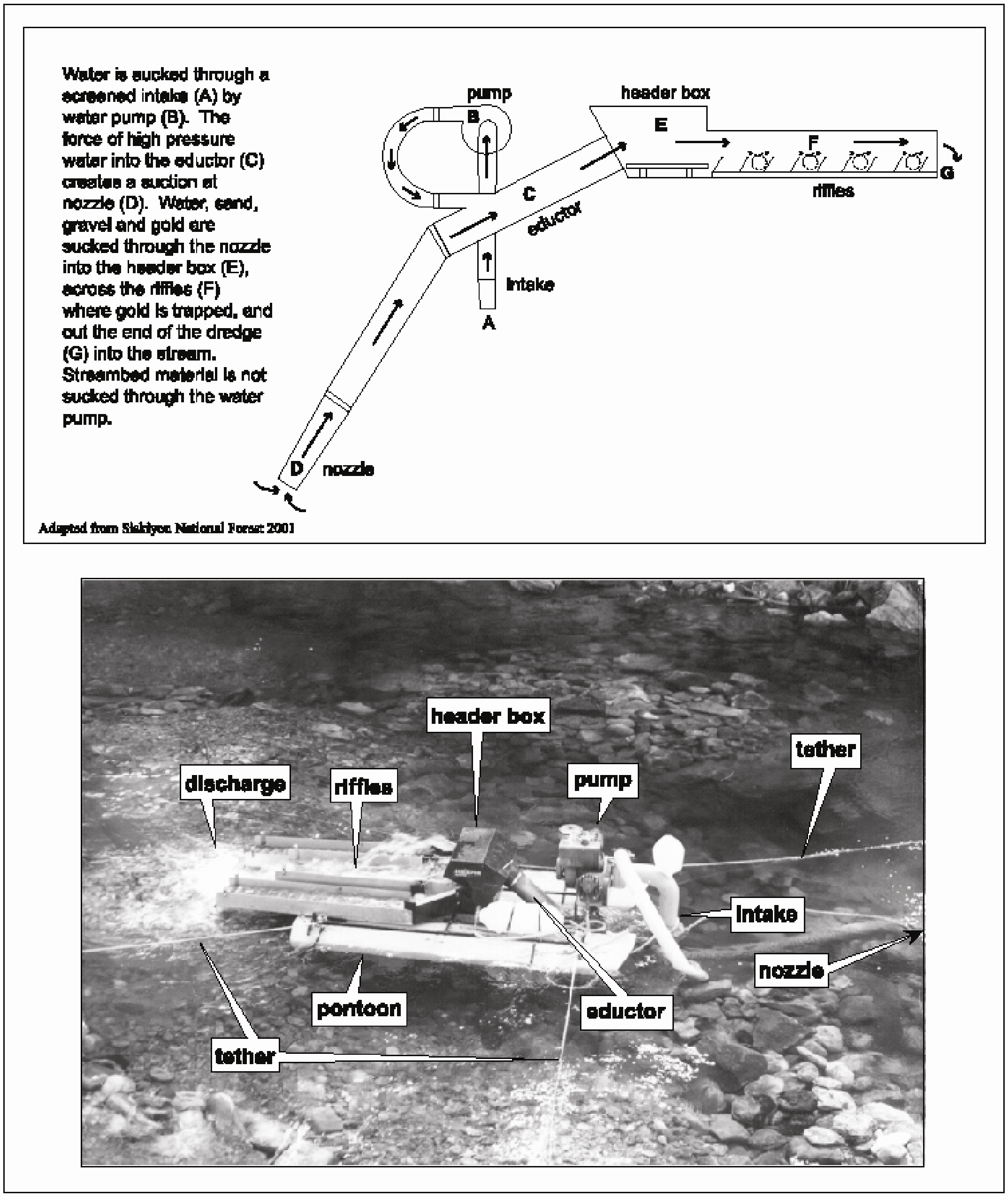
Larger dredges—those with a nozzle size larger than 6 inches—generally require at least two operators. In addition, the larger dredge systems are almost always equipped with Hookah air compressors, which can supply air to one or more divers.

Types of Dredges

Surface Dredge

Surface dredges are dredges that have their engines and sluice boxes mounted above the water's surface (see Figure 2-2). It is by far the most common type of suction dredge. They are most effective in shallow water and thus, are easily operated without diving equipment. Surface dredges range in size from small backpack models to large models up to ten meters in length.

Figure 2-2. Typical Small-Scale Suction Dredge



Water is sucked through a screened intake (A) by water pump (B). The force of high pressure water into the eductor (C) creates a suction at nozzle (D). Water, sand, gravel and gold are sucked through the nozzle into the header box (E), across the riffles (F) where gold is trapped, and out the end of the dredge (G) into the stream. Streambed material is not sucked through the water pump.

Adapted from Siskiyou National Forest 2001

Source: U.S. Forest Service 2006.

Subsurface Dredge

Subsurface dredges differ from surface dredges in that their gold recovery systems are suspended underwater beneath the dredge's floats. Since the sluice box can be raised or lowered, it can be maintained close to the stream bottom. Therefore, the sand and gravel need not be pumped all the way to the water's surface. This minimizes the amount of power required to operate the dredge and decreases the overall weight of the device. For example, a 5-inch subsurface pump can use the same pump from a 3-inch surface dredge yet move 2-3 times more material than the surface unit (Herschbach 1999). However, the recovery rate of gold for the subsurface dredge is less effective. The recovery system utilizes a long, enclosed chamber with removable riffle trays that are attached along the bottom. And since the riffle trays are relatively small and provide less surface area in which gold may be trapped, it is less efficient at fine gold recovery than the surface dredge. Despite lower recovery rates, the benefit of decreased weight makes these types of dredges popular with suction dredgers who favor portability.

Underwater Dredge

Underwater dredges employ an enclosed gold recovery system that rests on the river or stream bottom underneath the float supported engine(s). Like the subsurface dredge, the underwater dredge is an enclosed chamber with riffle trays that are suspended under water. However, unlike the subsurface systems, there are no chains attaching the underwater sluice to the floats. Instead, the sluice box rests on the bottom, supported in an upright position by the diver; the pressure hose is its only link with the water surface. The underwater dredge has no suction hose; the intake nozzle and jet are built as one recovery system, generally a metal or plastic tube with an attached metal elbow. Instead of manipulating just a flexible suction hose, as with the subsurface dredge, a diver using an underwater dredge must maneuver the whole unit around the bottom, keeping it always in an upright position and completely submerged. If it falls over, any gold in the small riffle tray may be lost. The reported main advantage of underwater dredges is portability. The components of an underwater dredge, for instance, are approximately half the weight of a subsurface dredge, and they are more compact and easier to carry. As a result, these underwater dredges are primarily used for reconnaissance of sites; when a gold streak is found a more efficient dredge type is employed.

Size of dredges

Dredge size varies greatly according to dredge type, make, and model. Table 2-1 summarizes characteristics of common dredge types and sizes In general, nozzle and engine size controls the sediment excavating capacity (given as yards/hour by manufactures) of suction dredges. This study considers the effects of nozzles ranging from 2 to 10 inches in diameter. In general, dredges equipped with small-diameter nozzles have much less sediment excavating capacity compared to those mounting larger diameter nozzles.

Table 2-1. Characteristics of Various Suction Dredges

Dredge Size & Type	Nozzle Size (inches)	Engine Size (horsepower)	Capacity		Dredge Pros	Dredge Cons
			Cubic yards per hour	Tons per hour		
Backpack dredge	2	2.5	0.5 – 2	0.7 – 2.9	Light and easy to pack in and out of the location. Good for prospecting and sampling. With suction nozzle it can be used in very shallow water.	Small capacity, not good for production.
Sampling dredge	3	5	1 – 3	1.5 – 4.5	Still lighter and smaller than a 4-inch and can move a lot more material than the 2 inch.	Still low on production. Portability is pretty good for remote places.
Sampling/small scale production dredge	4	6.5	1 – 5	1.5 – 7.4	The smallest of the production dredges but still good at sampling for pay streaks.	Heavier and more work to put together and take apart. Fairly mobile still, this makes it good for more remote sites.
Larger scale sampling/production dredge	5	9 – 13 or 2 x 6.5	2 – 10	2.9 – 14.9	Good for larger operations. Still good for sampling, but on a larger scale. Hose is flexible and can be operated by a single dredger.	Heavier to disassemble and move around. May have multiple or larger engines.
Recreational or smaller commercial production dredge	6	13 – 32 or may have 2 engines	6 – 17	8.9 – 25.2	A useful size for someone who has found a sizable pay streak and wants to get all the gold out that is possible. Can move rocks, gravel, and sand up to about 5 inches across without a plug up of the hose or jet.	Heavier unit. Larger nozzle makes it harder to sample with, although you still can sample larger rivers to locate gold in bigger areas. This hose isn't as flexible as a smaller dredge, although one person can handle it. Two person teams are better because the rocks are uncovered so quickly by

Dredge Size & Type	Nozzle Size (inches)	Engine Size (horsepower)	Capacity		Dredge Pros	Dredge Cons
			Cubic yards per hour	Tons per hour		
						a 6" unit that a single dredger can be overwhelmed with the work of clearing large cobbles and small boulders that don't fit in the suction nozzle.
Commercial dredge	8	36 or 2 x 18	10 – 30	14.8 – 44.5	Good size for commercial operations	Heavy unit. Manning the hose and moving the rocks will need at least two persons to make productive use. Dredges this size are legally limited in which waters they can be used.
Larger commercial dredge	10 – 12	80 or more	20 – 50	29.7 – 74.2	Good for larger commercial operations.	Heavy unit. Needs a team of underwater workers. Requires a special permit.

Source: DoradoVista, Inc. N.D.; Keene 2008

Griffith and Andrews (1981) tested the efficiency of a small suction dredge with a 2.5-inch diameter nozzle. For each 100 hours of dredge operation, 0.76 cubic meters (m^3) of fines (<0.5 mm) were moved downstream. The dredge moved 0.043-0.055 m^3 of substrate per hour, as tested in 4th and 6th order tributaries with cobbles, gravel, sand, and silts.

The volume of sediment moved based on varying nozzle and engine sizes is presented in Table 2-1, with more specific information contained in Table 2-2. As can be seen from the table, the sediment movement power of suction dredges generally increases by the cube of the nozzle diameter increase.

Table 2-2. Volume of Sediment Moved Based on Nozzle and Engine Size

Dredge Nozzle Diameter (inches)	Engine Horsepower	m^3/hour	m^3/day (7hours)
2	2.5	1.1	8.4
2.5	2.5 to 4	~1.1 - 1.8	8.4 – 13
3	5	2.3	16
4 (4 models)	6.5	4	27
5	9	7	48
5	11	8	54
5	13(2 x 6.5)	8	54
6	13 (2 x 6.5)	11	75
6	18 (2 x 9)	11.5	80
6	20 (2 x 10)	11.5	80
6	22 (2 x 11)	11.5	80
6	32 (2 x 16)	13	91
8	36 (2 x 18)	21	150

Source: Keene 2008

2.2.2 Permit Requirements/Restrictions

In regards to equipment restrictions, the Department regulates only the allowable intake nozzle and hose diameter of suction dredges. A 6-inch diameter nozzle intake is generally the largest allowed size, however a larger nozzle is allowed under the following conditions:

- A larger intake is permitted with the use of a constricting ring (<6 inch diameter) attachment
- An 8-inch nozzle size is permitted on the following ten rivers; American, Consumnes, Feather, Klamath, Merced, Mokelumne, New, Scott, Trinity, and Yuba.

In all cases, the inside diameter of the intake hose may not be greater than 4 inches larger than the permitted intake nozzle size.

2.3 Suction Dredging Activities

2.3.1 General Description of Activity

The following text briefly describes the basic steps involved during suction dredge mining activities. Information was derived from the Modern Gold Dredging booklet (Heavy Metal Mining Company 1992), website advice from miner Dave McCracken (N.D.), the New 49ers Club Rules (Koons 2004), and dredge manufacturer Keene Engineering, Inc. (N.D.). The information provided by these sources was often based on personal experience or represented personal advice and recommendations. As such, these references were very instructive in providing an intimate and knowledgeable perspective on suction dredging, but they are not necessarily definitive.

Selecting a Site

In seeking a good site with potential for gold, suction dredge miners consider river processes and river form in prioritizing their locations, as well as past history with sites producing gold. In California, gold found in streams, floodplains, and terraces is generally alluvial, having been previously transported and deposited by streams. A placer deposit is the collection of valuable minerals (in this case gold) concentrated in a dense depositional site. In California, placer deposits are typically comprised of alluvial sand and gravel. While placer deposits are generally thought of as occurring in the active stream channels; placer gold deposits are often commonly held in the stored alluvium in the floodplains and relict terraces adjacent to stream courses. Within streams, placer gold deposits will generally be found in zones where sediments are deposited or are collected. Because the gold is typically very fine (less than .0015 in diameter) it will more likely deposit (or settle out) in quiet and slower water environments, such as in deeper pools or along point bars on the inside bend of river turns. Gold may also be found in the stillwater deposits downstream of obstructions, such as rocks, vegetation, logs, or bedrock outcrops. Backwater eddies along the stream banks or around coarse woody debris (CWD) may also help settle gold. As one of the denser materials transported by any stream, gold is among the first to drop out when a stream slows and energy diminishes. Unless the gold is re-initiated into transport, it often sifts down through coarser sediments (sand and gravel) ultimately settling on a hardpan layer or local bedrock. Deep narrow crevices and cracks, especially occurring in steeply dipping rocks whose strike or trend is perpendicular to the stream flow, are particularly favorable for the occurrence of gold. A series of parallel, deep, narrow cracks or crevices at right angles to streamflow are especially good because they form natural riffles and pockets to trap gold.

Dredging is generally conducted in waters with 10 feet of depth or less. However, larger dredges equipped with Hookah Systems and hose lengths can allow for excavations in deeper waters (such as the Klamath River).

Accessing the Site

Suction dredge operators usually take their own personal transportation to access sites. These mining areas can be accessed via vehicle or boat depending on the location. Miners typically use existing trails and pathways whenever possible. It should also be noted that miners are required by law to obtain permission to enter private and public lands – the Department's permit does not allow trespassing.

Delivering Equipment

Suction dredge mining equipment, including the dredge engine, pump oil, fuel, and other components, are usually driven into an area where the miner will stay. The equipment may require additional secondary transport if the mining location is remote and not accessible by roads from the campsite. If the ultimate site is inaccessible by vehicle, miners will generally carry the equipment, fuel, and supplies to the desired location and assemble the suction dredge on the bank. It is a standard practice to drain oil and fuel from motors during transportation or carrying. The amount of fuel brought for the rigs to the mining location is generally limited to the day's estimated needs.

Securing Equipment

Any equipment not used during the dredging operation is generally secured at a campsite or along the banks of the area to be dredged.

During operation, dredges are usually secured in the waterway using rope or cable to prevent drift while the dredge is in use. This is generally done using two separate knots and a heavy or stationary object near the stream bank.

Conducting Dredging

Once the components have been assembled and placed at the mining site, the pump must be fully primed – full of water with all air removed – before starting the engine.

Dredging operations are generally divided into "sampling" and "production" phases. The first phase, "sampling," is the testing of areas to determine the presence or absence of gold laden areas, or "pay streaks." Pay streaks are referred to as such because of the notion that gold deposits settle out in areas with definite left and right boundaries and less definitive upstream and downstream margins. Sampling can involve several test holes and can be conducted with smaller suction dredges until a suitable production area is located. A dredge hole is the general term for the area in which the miner is dredging. These dredge holes are commonly cleared of large cobbles and rocks to allow the dredge to suck up smaller, gravel-sized sediments from the stream bed. It should be noted that sampling does not provide definitive information regarding an area's gold concentration or distribution, so the notion of effectively locating and mining pay streaks is primarily based on speculation.

Experienced dredge miners recommend that one find the tail end of a streak and move upstream when in a production phase, so that the tailings fall in areas already worked. In order to fully take advantage of the suction dredger's production rate, the operator frees and moves over-sized rocks (too large to be sucked into the nozzle) from the stream bed work area. The basic movement for a suction hose is placing down into the streambed at a slightly upstream angle, and then moving upstream. Cobbles are generally tossed downstream rather than to the side to prevent the need to re-excavate if the diver chooses to move laterally to locate a more promising area. Suction dredgers will often perform multiple passes over a streak, until they have reached the bottom of the gold deposit.

On occasion, to reach gold that has deposited below or around large boulders, winching or prying is performed. Crowbars, powered winches, or pull cables/chains are used to move the boulders out of place during dredging. Cables can be pulled by hand or by vehicle depending on their size and weight.

During dredging, a solid-to-water balance must be maintained to ensure suction. The solid content being dredged should generally never exceed 10%. Therefore, care is exercised to prevent dredging excess amounts of sand or other fine sediments.

Refueling

Most engines will require refueling during the day, and can be replenished with the fuel that has been brought to the site. Oil changes may also be required periodically.

Processing of Material

Normal conditions require that the sluice box be cleaned only once or twice per day. Generally, the sluice box does not need to be cleaned until gold is beginning to be deposited below the upper third of the box. When the sluice box is ready to be cleaned, the carpet underlay is removed and all materials captured in the box are washed into a large bucket or washtub. The contents of the washtub become known as concentrates. In addition to containing gold, concentrates can also contain mercury or other materials (e.g., lead fishing weights) that settled to the bottom of the river alongside the gold deposits. The concentrates are filtered through a series of screens and/or panned to work the concentrates down to small batches containing gold, which then can be processed through a final dry process.

The final process is usually done at camp where there is a flat work surface and shelter from wind. This final procedure involves the drying of concentrates, filtering, and physical separation using magnets and small hand tools. In addition, mercury and nitric acid may be used for the amalgamation process. Amalgamation is a method of separating finer gold particles from other materials. In this process, clean mercury is brought into contact with clean gold, and the gold becomes wetted and "drawn into" the mercury. This results in a solution of gold in mercury, or an alloy of gold and mercury called amalgam. After the mercury has gathered in the gold, it is removed by dissolving it in nitric acid or by driving it off as a vapor by heat, leaving the gold behind. While mercury is supposed to be treated as a hazardous waste, some miners collect and store it, while others dispose of it by vaporizing it in a cooking pan on a camp stove. Nitric acid presents similar concerns regarding handling, storage, and disposal.

2.3.2 Permit Requirements/Restrictions

Restrictions on suction dredge operations are included in the current regulations. In general, the permittee is not allowed to do the following:

- Moving boulders outside the existing water line;
- Winching of materials embedded on banks of streams or rivers;
- Causing water to be deflected or diverted into the bank;
- Using power-winch activated shovels, buckets or rakes in the stream course;
- Damage or removal of woody streamside vegetation;
- Suction dredging into the bank;
- Removal or relocation of anchored or exposed woody debris;
- Creation or obstruction of a stream such that fish passage is impeded;
- Import of earthen material into the waterway.

2.4 Suction Dredge Mining Locations

2.4.1 General

Today, suction dredging is most common in areas of the state where gold is still found, primarily in the accessible streams and rivers in the mother lode country of the western Sierras and northwest California (see Figure 2-3). That said, suction dredging occurs throughout the state, and suction dredge regulations identify areas throughout the state that are open or closed to suction dredging.

Much of the suction dredging occurs on private lands or unpatented claims owned by mining clubs; in some cases individual club members pay a fee to use the club's claim, such as with the New 49ers (New 49ers 2009). Clubs cannot prohibit the public from accessing unpatented claims for purposes other than mining. These clubs may provide facilities, infrastructure, supplies, and also have their own rules and guidelines for suction dredging and associated activities. Many miners also own their own unpatented claims to which they have an exclusive right only to the locatable minerals under claim.

2.4.2 Permit Requirements/Restrictions

Prior to the moratorium established in August 2009, suction dredge regulations identified seasonal or year-round closures in the various counties within the state, along with additional seasonal/permanent closures for particular waterbodies. Permit requirements also stipulate that miners must obtain permission from landowners or a land managing agency prior to entering private or public lands. The permit also does not allow suction dredging in lakes or reservoirs without special approval and site review.

Current permit language also stipulates that suction dredging may be restricted in waters designated under the state and federal Wild and Scenic Rivers Acts. Waters designated under the acts include portions of the American River (North Fork and Lower American River), Big Sur River, Eel River, Feather River, Kern River, Kings River, Klamath River, Merced River, Sespe Creek, Sisquoc River, Smith River, Trinity River, and the Tuolumne River. In addition, the Auburn State Recreation Area imposes special restrictions on suction dredging.

Areas closed to suction dredging also include some waters in the San Gabriel Mountains, and portions of the Sequoia and Sierra National Forests (designated as the Kings River Special Management Area), as well as waters in National Parks, National Monuments, State Parks, and designated wilderness areas.

Detailed information regarding closures or restrictions beyond those outlined in the permit regulations can be obtained by contacting the appropriate U.S. Forest Service (USFS) or Department office.

2.5 Timing

2.5.1. Seasonality

Most suction dredging occurs in the summer, when flows are lower, water temperatures are higher, and water clarity is greatest. In addition to seasonal restrictions imposed by the permits, underwater visibility is a key aspect for suction dredge mining when excavating an existing dredge hole, and when working with more than one diver. Therefore, wet or rainy conditions are not favorable (McCracken N.D.)

2.5.2 Duration

A recreational suction dredger (representing 90 percent of all suction dredgers) may spend a total of four to eight hours per day in the water dredging an area from 1 to 10 square meters. The average number of hours is 5.6 hours per day (CDFG 1994). The remaining time is spent out of the water, working on equipment and processing dredged material. According to experienced dredgers, processing materials from concentrates typically takes less than an hour (McCraken N.D.).

2.5.3 Permit Requirements/Restrictions

As described above, Section 228.5 of the permit regulations identifies counties and waters that are subject to seasonal restrictions.

2.6 Encampments

Some (but not all) suction dredgers camp near the locations where they are mining for short to extended periods of time. Basic information regarding encampments has been derived from Dave McCracken (N.D.) and the Operational Guidelines for members and guests of the New 49ers (Koons 2004). Generally speaking, gold dredging encampments are not substantially different than the encampments of other park and waterway users. There are, however, a few common considerations made by suction dredge miners that influence the type and components of their camps.

The nature of the encampment depends on the presence of nearby facilities (e.g., restrooms, showers), how uncomfortable the environment is, personal requirements, and expected duration of stay. Larger public park areas and private mining clubs often offer campgrounds and lodging facilities. These more heavily used camping areas may also provide chemical toilets and basic shower facilities. And, in addition to RV's and campers equipped with restroom facilities, personal port-a-potties and storage tanks are commonly used by those who do not have easy access to existing facilities. It is illegal to dispose of this type of waste in areas other than approved dumping stations.

Miners generally plan ahead for supplies and food based on duration of stay. Depending on the location of the nearest town, supplies may not be available for replenishment. Shorter stays can utilize tents or tarps, while longer excursions may call for RV-type vehicles to transport and keep perishable supplies. Some mining clubs do not allow any permanent structures to be constructed on club property. Because fuel is an important component of a suction dredge operation, miners often bring their own supplies of fuels and store them near campsites and mining areas. Some mining clubs impose restrictions on the volume of fuel which can be brought to a property.

Secure locations for the storage of recovered gold and other valuable possessions at the camp, such as safes, are generally necessary. Some miners carry personal firearms; however, some mining clubs require that they not be displayed or used on camp property. Also, some clubs recommend that all garbage, supply, food, and equipment items be kept safely and in a clean manner to minimize hazards. This includes the clearing of garbage and debris prior to departure.

While many suction miners adhere to these basic rules and responsible behavior, Department wardens often observe camps strewn with household garbage, industrial waste, large gas barrels, dilapidated vehicles, and human waste (1994 EIR; Sierra Fund 2009). It is unknown whether this behavior is typical of suction dredge miners.

Section 3
METHODOLOGY

The literature review began with the collection of information sources related to suction dredge mining and associated impact mechanisms and activities. The search drew upon the following sources:

- Web searches on suction dredge mining and associated topics
- Consultation with known researchers and experts on the topic of suction dredge mining or related environmental resources
- The libraries of the Department, SWRCB, and consultants
- Comment letters submitted to the Department in response to the October 2007 Public Notice
- Comment letters submitted to the SWRCB in response to a 2007 Notice of Public Workshop (SWRCB, 2007)
- References cited in the Department's 1994 EIR and 1997 Draft SEIR
- Relevant regulations and legislation, as well as materials generated as part of the court cases associated with suction dredge mining in California
- The California Natural Diversity Data Base (CNDDB) statewide inventory, including the Department's Special Animals List and list of State and Federally Listed Endangered and Threatened Animals of California (CDFG, 2009)
- The U.S. Department of Fish and Wildlife's (USFWS's) list of special-status animals, management plans, and critical habitats (USFWS, 2009)
- Information available from the USFWS and Department websites, and those of other federal and state land management or resource management agencies
- The California Historical Resources Information System (California State Office of Historic Preservation 2009) and other archival facilities including the J. Porter Shaw Library at the National Maritime Museum, the California Indian Museum and Cultural Center, and the California State Library
- Searches of academic journals using online abstracting services

While the literature review focuses on California, it also considers information from other geographic areas (such as a 2006 U.S. Forest Service Environmental Impact Statement prepared for small-scale suction dredging in Clearwater and Idaho counties, Idaho). Similarly, the literature review considers information that is not specific to suction dredge mining, but provides important analogous information (such as life history requirements of salmonids).

The search resulted in a bibliography containing approximately 650 sources, which were subsequently catalogued based on the resource topics addressed, and whether the citation contained substantive scientific information (see the Appendix).

The citations relevant to each resource topic were then reviewed in further detail. Those that represented, in the Department's judgment, the "best available science," are presented in the literature review. Note that the literature only cites a subset of the references reviewed; the complete bibliography of references is presented in the Appendix.

Within each topical subsection, the review has been organized into an introduction, a description of the potential impact mechanisms that could result from suction dredge mining or associated activities (e.g., suction dredge miner encampments), a description of the information in the literature with respect to these mechanisms, and overall conclusions based on the information found and identified data gaps.

Section 4
IMPACTS OF SUCTION DREDGING

4.1 Geomorphology

4.1.1 Introduction

Geomorphology is the study of landforms and the processes that shape them. Fluvial geomorphology is the more specific study of streams and rivers and typically includes aspects of hydrology (the quantity and timing of watershed runoff that enters the river), hydraulics (the behavior of channelized flows in the river), and sediment dynamics (how sediment is variably eroded, transported, and deposited along the river continuem).

Potential geomorphic effects (including changes in channel bed form, sedimentation patterns, bank erosion, flow paths, suspended materials, and other affected processes) are directly relevant to understanding potential biologic, habitat, and water quality effects. As such, this chapter on geomorphology presents foundational information to support the information presented in Sections 4.2 (Water Quality/Toxicology) and 4.3 (Biological Resources).

Literature on Suction Dredging

Three general types of literature were reviewed, including:

A. Studies specific to suction dredge mining;

B. More general geomorphic investigations that describe channel processes or features that are relevant background to understanding the geomorphic effects of suction dredge mining; and

C. California resource investigations that describe general geologic, mineral, biologic, or other resource conditions in the California regions where suction dredge mining primarily occurs.

The most relevant studies that specifically focused on (or included key discussion of) the geomorphic effects of suction dredge mining were generally peer-reviewed or professional publications that employed scientific methods to evaluate the effects of suction dredge mining. Many of these studies included field observation and data collection from California streams and rivers where suction dredge mining has occurred. Other studies used data collected from other Western U.S. states, including Alaska, Idaho, Montana, and Washington. Some studies, including Thomas (1985), used a more experimental approach, whereby a suction dredge rig was operated in a natural, yet monitored, setting to observe and record its effects. Most of the studies above were developed to relate how geomorphic effects ultimately influence biological and habitat conditions. Many of these same studies are reviewed in Section 4.2 and 4.3 for their coverage of water quality, biological, and habitat issues.

4.1.2 Geomorphic Effects of Suction Dredging

Overview of Geomorphic Effects

As an overview, the geomorphic processes that are affected by suction dredging can be classified into four general types: erosional processes, transport process, depositional processes, and hydraulic processes. Whereby:

1. Erosive processes - include the physical lifting and entrainment of alluvial sediment by the suction nozzle, which results in the scouring of the channel bed. Stream bed erosion can include the creation of scour potholes along the channel bed, the removal of material and deepening of existing pools, and the removal of sediment from in-channel depositional features such as longitudinal bars and riffles. Suction dredging along the channel margins has the potential to undercut the streambank, resulting in bank erosion and potential bank destabilization and collapse.

2. Transport processes – occur after sediment has passed through the suction dredge rig and is discharged back to the river. Upon discharge, sediment is suspended in the water column and is available for downstream transport.

3. Depositional processes – occur following transport, whereby sediment variably settles and deposits according to its particle size, density, and shape. Streamflow conditions (including flow velocity, river stage, channel roughness, channel alignment, presence of structures, etc.), also directly influence the rate of settling and deposition in addition to sediment characteristics. In general, coarser and heavier sediment settles and deposits nearer the discharge location, while finer and lighter materials are carried further downstream in the water column before depositing. Another depositional process related to suction dredge mining (though not caused by the dredge rig itself) is the hand piling and rolling of cobbles and small boulders (sediments too large to suction) in other locations within the channel bed by miners to access the finer sediments below.

4. Other hydraulic processes – include the redirecting of in-channel flows as the result of miners' placement of river cobbles and boulders. Existing instream flow paths can be disrupted by such structural changes along the stream bed, with flows being channelized, or re-oriented, toward new alignments.

These geomorphic processes occurring at the dredge site and river reach are governed by several factors that operate at a range of spatial and temporal scales. These include:

- Regional factors, including climate, geologic structure, and parent geologic materials
- Watershed factors, including basin size and sediment supply

- Location of the mining site within the watershed (tributary creek? main stem channel?)
- Hydrologic factors influencing flow and river stage (located upstream or downstream of a dam or flow control?)
- Hydraulic factors influencing flow, including longitudinal channel profile and slope, channel form, and roughness
- Channel substrate and composition at the mining site (bedrock? alluvial? sediment texture and other characteristics)
- Existing instream geomorphic features such as a pools, riffles, bars
- Other structural features, including road crossings, engineered banks, etc.

The geomorphic processes introduced in this overview are presented in more detail below based on findings from the literature review. To set the context for understanding the extent of potential effects, the first section below (*Area Affected by Suction Dredge Mining)* describes the typical area affected during one season of mining. The next two sections (*At-Site Effects of Suction Dredging* and *Downstream Effects of Suction Dredging*) focus more specifically on the in-stream effects of suction dredging. Because the four types of geomorphic processes described above occur at different scales, it was useful to organize the literature review according to potential effects occuring at the immediate mining site versus effects that occur downstream. The remainder of Section 4.1.3 is organized into the following sections:

- Area Affected by Suction Dredge Mining
- At-Site Effects of Suction Dredging
- Downstream Effects of Suction Dredging
- Geomorphic Recovery
- Variations in Suction Dredging Equipment
- Cumulative Effects of Multiple Rigs

Area Affected by Suction Dredge Mining

To identify and evaluate the potential effects of suction dredging, it is important to understand the average area affected by a typical recreational mining operation over the course of one season. Stern (1988) evaluated the average area disturbed by suction dredge mining during the 1984 and 1985 seasons in the Canyon Creek tributary of the Trinity River. In 1984, the total instream surface area disturbed by 20 dredges was 1,137 square meters (m^2). In 1985 the area disturbed by 15 dredges operating in the same vicinity was 1,075 m^2. Based on these results, the average area mined by an individual was 39 m^2 in 1984 and 49 m^2 in 1985. In terms of mining duration, the individual suction dredges were, on average, operated for 43 hours and 50 hours in 1984 and 1985, respectively.

Similar to Stern (1988) and also working in the Canyon Creek tributary of the Trinity River system, Hassler, et al. (1986) monitored 24 dredges in 1984 and 18 dredges in 1985.

Hassler, et al. were working in an area of Canyon Creek downstream from the Stern (1988) study, but found similar results. Total streambed disturbance in the Hassler, et al. study area in 1984 was 1,164 m^2, and 1,075 m^2 in 1985. This resulted in average affected areas of 48.5 m^2 (1984) and 59.7 m^2 (1985) for individual dredging rigs.

At-Site Effects of Suction Dredging

This section reviews literature findings for geomorphic effects of suction dredge mining that occur at the specific site of mining activity. Sub-topics addressed in this section include: suction effects on the streambed, the effects of discharge at the sluice box, potential bank erosion effects, and flow channelization and concentration effects.

Suction Effects on the Streambed

As described above, erosional processes at the suction intake include the scouring of the channel bed, which results in cone-shaped depressions or pits following suction dredging activities. Rocks too large to pass through the hose nozzle are typically placed into tailings piles adjacent to the scour pits, or are put along the stream margin at the banks. While these scour hole and tailings pile features are common to suction dredge operations (Harvey and Lisle 1998), they vary in size depending on the dredge operator, nozzle size, and channel substrate.

Stern (1988) monitored dredging holes and tailing piles generated by multiple suction dredge operations for two seasons in the Canyon Creek tributary of the Trinity River. He measured the length, width, and depth of suction dredging holes and also measured the surface area and sediment composition of tailing piles for multiple sites during the 1984 and 1985 dredging seasons. The mean dredge hole depth below the original bed surface was 1.2 meters (m) in 1984 (based on an average of 29 holes created by 20 suction dredge operations) and 1.5 m in 1985 (based on an average of 22 holes created by 15 suction dredge operations). The mean surface area of individual tailing piles generated by all suction dredge operations within the reach studied was 22 m^2 (created by 20 suction dredges) in 1984 and 28 m^2 (created by 15 suction dredges) in 1985.

Similar to Stern (1988), Hassler, et al. (1986) measured the dimensions of erosive holes and tailings piles in 1984 and 1985 for multiple sites on the Canyon Creek tributary of the Trinity River. These authors found average scour hole depths of 1.2m (based on 30 holes in 1984) and 1.5 m (based on 22 holes in 1985). The average surface area of the tailing piles was 38 m^2 in 1984 and 49 m^2 in 1985.

Besides the direct physical effects of creating scour holes and tailings piles, suction dredging also disturbs channel bed forms such as riffles and gravel bars. Typically, such depositional features as riffles and gravel bars may have an “armored” surface, whereby gravel (mostly pebbles and cobbles) are cohesively packed together and aligned, providing a protective “rock tile” effect. Armoring develops over time as sands and finer sediments that may have been present are winnowed from the surface of the bar or riffle, leaving the pebble and cobble surface extant. In evaluating potential effects of suction dredging on benthic invertebrates, Somer and Hassler (1992) measured dredge holes created in one season on Big East Fork Creek, a tributary to the Trinity River. They found that holes created by a 4-

inch suction dredge nozzle were 2 m deep and 2-3 m wide, deeper than the average results of Stern (1988) and Hassler, et al. (1986). Additionally, Somer and Hassler (1992) found that the scour holes were excavated below the armored gravel layer, exposing a finer sand and silt layer below. Bedrock and large cobbles were encountered at the bottom of the 2-3 meter holes. Harvey and Lisle (1998) report on the erosive effects of dredging near or at riffle crests, and how suction dredging at those locations can destabilize the entire riffle complex. Similarly, Harvey, et al. (1982) observed that dredging in riffles has a higher potential to influence substrate changes than dredging in pools. Harvey (1986) concluded that, in general, dredging in streams with larger proportions of fine sediments resulted in more severe erosional and depositional impacts.

In sum, the physical removal of alluvial sediment by suction dredging at the mining site alters the channel bed surface primarily by creating scour holes and tailings piles. However, when an armored bed or riffle surface is removed, it may cause secondary erosion of the non-armored finer sediments below the previously armored surface to occur. *Downstream Effects of Suction Dredging* below addresses the deposition of this eroded material downstream. *Geomorphic Recovery* discusses the issue of geomorphic recovery and the expected persistence of scour holes and tailings piles.

Channel Bank Effects

Suction dredge miners can erode streambanks if they dredge too near the channel margin, scour deep holes adjacent to the streambank, or dredge the entire length of a channel bank (R2 Consultants 2006; Harvey and Lisle 1998). Dredging practices that result in erosion along streambanks are not permitted under Department regulations; however, observations documented by McCleneghan and Johnson (1983), Hassler, et al. (1986), and Stern (1988) suggest that dredgers use these prohibited practices and streambank erosion does occur.

Of the 200 suction dredging operations surveyed throughout the Sierra Nevada in McCleneghan and Johnson (1983), 14 were documented as undercutting banks. The survey did not obtain measurements of the extent of the undercutting; it only documented visual observations. According to Hassler, et al. (1986), 4% of the 68 surveyed dredging operations resulted in damaged stream banks (from research along Canyon Creek, 1982-85). The Hassler, et al. study followed the same survey methods as the McCleneghan and Johnson study, and no physical measurements of the bank effects were recorded. In terms of general impact assessment, Stern (1988) observed that undercutting of stream banks was the most common adverse impact of suction dredge mining from his studies on Canyon Creek in the mid-1980s.

The undercutting and eroding of streambanks can lead to tree collapse into the channel. When this happens, downed trees may divert stream flow toward the opposite bank (which can cause erosion in smaller creeks), and a sediment plug from the tree root wad can be delivered downstream. Downed trees can also provide a source of coarse woody debris (CWD) for the channel. Trees naturally fall into a stream channel through episodic events such as a wind storm or fire, or gradual events such as tree mortality or bank undercutting during large flow events (Bilby and Bisson 1998). Downed trees may provide backwater habitats where quiet reverse flows (eddies) are found (Keller and Swanson 1978; Lisle

1986a; Montgomery, et al. 1995). Large roughness elements such as CWD can govern the location of scour and deposition at the scale of pools and riffles (Lisle 1986b; Montgomery, et. al. 1995). However, the mechanical undercutting and erosion of streambanks is not considered a preferred source to generate CWD supply. Inputs of CWD under natural conditions allow for the transport of fine sediments from the bank to be dispersed together with storm flows. In contrast, streambank erosion and CWD inputs initiated by mechanical conditions such as suction dredging could result in localized inputs of sediment affecting summer low-flow habitats, such as pools. More information on the effects of CWD is discussed in Section 4.3, Biological Resources.

It has been documented that some suction dredge operators, in moving larger cobbles and small boulders around the bed to improve access to gravel below, will place large rocks along the bank or even within the concave cavity created by a naturally undercut bank. Illustrations of this activity are included in Gunn-Morrison's (1994) *A Gold Dredger's Primer to Survival in a Shrinking World*, which encourages miners to place tailing rocks beneath undercut banks as a form of bank protection. Note that recent regulations prohibit movement of boulders outside the existing water line.

Flow Channelization

During lower flow conditions when river stage is low, suction dredge operators have commonly moved stream rocks to channelize flows and concentrate flows into one portion of the stream to assist in dredging activities (McCleneghan and Johnson 1983; Hassler, et al. 1986). This influence of suction dredging activities on the stream channel has been documented through visual observations and channel measurements by McCleneghan and Johnson (1983), Hassler, et al. (1986), and Stern (1988). Of the 200 suction dredging operations surveyed by McCleneghan and Johnson (1983), 12 operations were observed to have channelized flows in the stream. From his study of 68 dredging sites in Canyon Creek (1982-1985), Hassler, et al. (1986) noted that 10% of the dredging operators he observed channelized portions of the stream, 15% caused riparian damage, 4% damaged the bank, and 36% impacted spawning gravels.

Stern (1988) observed that the risk for bank failure increased when stream rocks were relocated to concentrate and channelize stream flows toward the banks, bank vegetation was removed, and suction dredging activities occurred also near the banks. The study also observed that re-directed flows that were channelized toward the streambanks could result in the erosion and loss of riparian vegetation (as described above), including the falling of overhanging vegetation and root wads.

Downstream Effects of Suction Dredging

As described above, depositional processes occur downstream of the suction dredging site. In general, coarser sediments (small cobbles, pebbles, coarse sand) settle out of transport nearer to the sluice box discharge and finer sediments (transitioning from coarse to medium and finer sands) are transported further downstream. In this way, the sedimentation pattern downstream occurs as a continuum from coarse to fine. Finer silt and clay sediments (generally less than 0.063 millimeters [mm]) may become part of the suspended load or wash load in the water column and be transported much farther downstream (Thomas 1985; Harvey and Lisle 1988). The discussion below reviews literature findings for sedimentation rates and patterns in the ~100m zone immediately downstream of suction mining activities. Please note that suspended sediment and turbidity issues are described in Section 4.2 (*Water Quality and Toxicology)*.

Sedimentation rates and patterns occurring downstream of suction dredge mining operations are described from several studies below. General methods used to measure sedimentation include collecting suspended sediment samples, placing sediment markers or collection devices (discs) on the channel bed, conducting repeat surveys of the channel cross-section to compare elevations and bed form, and visual observations.

- Harvey, et al. (1982), Somer and Hassler (1992), and Stern (1988) calculated sedimentation rates based on repeat measurements and observations of dredging operations in northern California streams. These studies found that sediment rates increased significantly within the first 4-10 m downstream of the sluice box discharge. Sedimentation rates within 12 m below the sluice box were measured as high as 2,060 grams/m^2/day above background levels (Harvey, et al. 1982). Harvey, et al. (1982) also found that sediment deposition rates returned to background levels within 60-120 m, while turbidity levels and settleable solids concentrations returned to background rates near 30 m downstream.

- Stern (1988) monitored sediment deposition downstream from suction dredge operations and observed how deposition rates decreased with distance. At 9 to 10 m below the dredge rig, the average daily deposited sediment load varied between 674 to 42,366 grams/m^2/day. Where sluice box discharge occurred in the thalweg or mid-channel locations (where velocities were greater), sediment was carried further downstream in the mid-channel location. In contrast, where sluice box discharges occurred toward the outer stream margin, where velocities are less, it resulted in deposition along the shore for a shorter distance.

- Thomas (1985) measured a 10-20 fold increase above background levels in sediment deposited immediately downstream from suction dredging. He found that the majority of sediments discharged from the sluice box settled on the stream bottom within the first 15 m. The amount of deposited sediment decreased exponentially with distance downstream from the dredge. The study also indicated that sediment deposition varies greatly depending on the type of substrate being dredged and stream discharge conditions.

- Somer and Hassler (1992) recorded seasonal sedimentation rates downstream from a 4-inch suction dredge as 1,711 grams/m^2 and 698 grams/m^2 at 40 m and 113 m downstream of the dredge, respectively. These values represent an increase over baseline rates of 23 grams/m^2 recorded 50 m above the dredge. These researchers monitored how downstream deposition fined with distance. The percentage of sediment by weight, trapped at 40 m and 113 m below the dredge, was 21% and 38% of particles less than 0.1 mm in diameter, respectively.

- Hassler, et al. (1986) recorded a baseline sedimentation rate upstream from a dredge as 105 grams/m^2/day. Four meters downstream from the active dredge, the sedimentation rate increased to 12,080 grams/m^2/day and 285 grams/m^2/day at 25 m downstream from the dredge.

- Prussian, et al. (1999) noted substantial changes to bed morphology at a dredging site on the Fortymile River in eastern Alaskan river, but no discernable effects either laterally or downstream of the channel. However, they did observe increased fine sediment deposited on downstream gravels within the dredge-generated turbidity plume.

- Stern (1988) monitored sediment deposition, substrate particle size, substrate embeddedness (the filling of interstitial pores), and channel scour and fill along transects upstream and downstream from dredging sites. Monitoring conducted by Stern (1988) concluded that substrate embeddedness increased significantly after dredging activities at all transects monitored (up to 50 m downstream). Stern also noted that particle size decreased significantly downstream of dredging activities.

- Harvey, et al. (1982) observed that areas downstream of suction dredging activities that had no deposited sand prior to dredging would become embedded with sand following dredging. Sand comprised 25-40% of the substrate composition 30 m downstream from the dredging area and was observable up to 60 m downstream in areas that did not have any sand prior to dredging. The following year, all the embedded sand had been flushed away from the cobble substrate (see recovery discussion below).

- Hassler, et al. (1986) noted that deposited dredge tailings are highly unstable and can mobilize under slight increases in stream volume and velocity because they are unconsolidated and rest on top of the streambed. Downstream deposited sediments are vulnerable to resuspension and transport during subsequent stormflow events or dam releases, that raise discharge and velocity.

- Thomas (1985) noted that sediment deposited downstream from suction dredge discharge is very unstable and mobilizes quickly to fill downstream pools. Harvey and Lisle (1998) also described the relatively unstable nature of downstream deposited tailings and related these mobile sediments to the timing of spawning activities and when high flows might remove the sediment.

These sedimentation effects described above have several important consequences for aquatic habitat. The deposition of coarse material immediately downstream of dredging rigs, the downstream transport and deposition of sands that potentially cover and embed downstream riffles, and the filling of downstream pools through the mobilization and re-transport of dredged sediment can all potentially negatively affect aquatic habitats. These habitat considerations are described more thoroughly in Section 4.3.

Geomorphic Recovery

Geomorphic recovery is the concept that, following disturbance, a landform will return to its general form or trend through moderating physical and biological processes. The notion of geomorphic recovery is predicated on an assumption that the geomorphic system (in this case, streams) functions as a dynamic equilibrium with alternations or disturbances occurring around a central tendency of form (Schumm and Lichty 1965). Interestingly, and appropriately for this literature review, one of the foundational studies of fluvial geomorphology was developed by G.K. Gilbert (1917) who studied alluvial sedimentation following the 19th century hydraulic mining in the central Sierra Nevada of California. Gilbert described in terms of decades how the fluvial systems would “recover” by flushing and pass the aggraded sediment downstream and through the Sacramento Delta and out to San Francisco Bay. It is noted that Gilbert evaluated the sediment delivery process prior to much (if any) flow control systems being operated on these affected watersheds. The notion of recovery is not necessarily appropriate for all geomorphic systems, as some may function according to non-recovering thresholds or have complex and variable responses as defined by Schumm (1977). Wolman and Gerson (1978) describe the role of geomorphic recovery for streams with bed and bank disturbances.

The concept of geomorphic recovery has been applied to the study of suction dredge mining by several researchers who observed that erosive scour holes, hand piled tailings, or downstream sediment deposits caused by suction dredge mining during the relatively low water summer conditions of California rivers were removed following flushing flows occurring the following fall, winter, and spring.

Stern (1988), Thomas (1985), Prussian (1999), Somer and Hassler (1992), Harvey, et al. (1982), Harvey (1986), and Hassler, et al. (1986) all reported on some level of geomorphic recovery based on visually monitoring dredge sites a year after dredging. Additionally, Harvey, et al. (1982) suggested that geomorphic recovery may likely be slower or less effective on streams with controlled flows compared to streams that experience uncontrolled “flushing” flows. Additional findings are summarized below for geomorphic recovery at the dredging site, as well as at downstream locations.

- Stern (1988) conducted visual inspection of dredging sites one year following mining activity to observe conditions, and found no evidence of scour holes or tailing piles located in the mid-channel thalweg that were observed in the previous year. However, visible scour holes and piles that were located outside of the stream thalweg toward the stream banks remained. Stern also monitored conditions two years after dredge activity and found that scour holes and tailings piles from dredging two years previously were either filled (for the holes) or removed (for the piles) during the preceding year’s flows. It is noteworthy that the preceding year’s flows included a bankfull discharge event (24 cubic meters per second with a 1.9 year recurrence interval). It appears that this magnitude flow was effective in reshaping the channel bed.

- Returning to inspect 30 dredge scoured holes and tailing piles measured during the previous summer, Hassler, et al. (1986) found that only 9% of the surface area of these previously measured disturbance areas was visible during the following year. For the holes and tailing piles that remained over a year after dredging activities, it was observed that the holes were particularly deep and the tailings piles were generally located toward the stream margins.

- Thomas (1985) found that deposited sediment piles downstream of a 2.5-inch suction dredge nozzle were barely distinguishable one year after suction dredging activities. Similarly, Prussian, et al. (1999) observed that tailing piles generated by 8 and 10-inch suction dredge nozzles were barely visible a year following the dredging activities. The tailings which remained visible had moved from the sides of the channel towards the thalweg of the river during the winter flow events.

- Harvey (1986) observed that dredging activities on large streams, like the main stem Feather and Yuba Rivers in California resulted in localized disturbances, whereas dredging activities on smaller tributaries had a proportionally larger and more significant area of disturbance. For example, dredging activities conducted by a single dredge on a smaller tributary of Butte Creek resulted in flow diversions that transformed riffles into exposed gravel bars within 10 days of operation. These substrate changes were not observed in Butte Creek the following year.

- Harvey, et al. (1982) monitored conditions a year following suction dredge activities on the American River and Butte Creek and observed that scour holes and downstream sand deposits observed the previous years were not present the following year.

Cumulative Effects of Multiple Rigs

Harvey, et al. (1982) monitored the effects of multiple rigs on bed sediment conditions and benthic macroinvertebrate populations throughout one entire dredging season (June to October). They compared conditions between a reach on the American River with one rig operating, a reach on the Yuba River with 40 rigs operating, and a reach on the Butte Creek with 3 rigs operating. Significant differences between downstream benthic macroinvertebrate populations were not found due to disturbance differences caused by the different number of rigs. They concluded that additional rigs did not result in additive impacts. However, the authors noted that differences in substrate, for example sand/gravel versus silt/clay in the different river systems could result in varying downstream effects. Because the three different rivers had different physical and geomorphic baseline conditions, comparisons between the river systems may be limited.

Hassler, et al. (1986) also noted that two or three dredges operating in the same reach did not increase geomorphic impacts on the channel bottom. However, the study did suggest that multiple rigs may contribute to increased channel instability if stream banks were being undercut. Though not the specific goal of the study (the purpose of the study was to evaluate the effects of suction dredge mining on salmonids, benthic invertebrates, and habitat), the authors concluded that dredges operating within 0.5 kilometers of each other did not generate cumulative water quality impacts.

4.1.3 Summary and Information Gaps

Through this literature review and synthesis the following questions were developed to highlight gaps in existing information or understanding related to the geomorphic effects of suction dredging.

- There was generally broad agreement in the literature regarding the vulnerability of bank erosion where suction dredging encroaches too near to the channel margin and bank. This has been well understood for some time and is reflected in the current Department permit conditions. A key informational gap is to better understand what the current status is of mining operators and their behavior toward bank encroachment. Has there been an improvement in miners avoiding streambanks over the course of the permit program? What is the occurrence/prevalence of bank erosion at recent suction dredge mining sites compared to the 1970s and 1980s?

- There is complete agreement in the literature regarding the general description that sediment eroded at the suction dredge mining site is transported and deposited at some distance downstream. There is also generally broad agreement that deposited sediment downstream is relatively mobile for subsequent transport because it is not consolidated or armored in place. However, there were questions in the literature as to whether the downstream deposited sediment is necessarily more mobile than other naturally depositing material downstream (that has also not been armored or consolidated). Additionally, there were questions regarding the ultimate fate of eroded tailings that are transported, deposited, and then re-suspended and transported further downstream. What is the net contribution of suction dredge-induced sediment delivery downstream compared to natural/baseline conditions?

- In terms of geomorphic recovery, much of the literature suggested that smaller scour holes or depositional piles were removed during subsequent winter/spring seasonal flows. There was also consensus that geomorphic recovery was stronger along the thalweg and mid-channel location than along the channel margin where velocities are less. There are suggestions that rivers with flow controls (through reservoirs or other structures) were less likely to provide flushing flows to accommodate channel recovery. However, other information by Stern (1988) suggested that flows smaller than a 2-year recurrence event were capable of providing geomorphic recovery to the channel bed forms. Additional information regarding the relative magnitude and frequency required for geomorphic recovery beyond the valuable information presented in Stern (1988) would be useful.

- The findings from Hassler, et al. (1986) and Harvey, et al. (1982) are valuable regarding cumulative effects of multiple rigs operating along single reaches or rivers. However, the comparison by Harvey, et al. (1982) from three different river systems with reaches with 1, 3, and 40 rigs seems inconclusive due to the general differences in baseline geomorphic conditions. A key information gap exists: what is the role of multiple rigs operating along single reaches or rivers, and what is the nature of additive or cumulative impacts from such multiple rigs?

4.2 Water Quality and Toxicology

4.2.1 Introduction

This section summarizes available scientific literature related to the water quality and toxicological effects of suction dredge mining activities. Potential effects of suction dredging addressed in this section include resuspension of sediments and pollutants from dredging activities in channels, their subsequent fate and transport, and related human health and ecological risk issues. The section also addresses the potential for releases of pollutants from campsite development and use.

4.2.2 Water Quality and Toxicology Effects of Suction Dredging and Related Activities

Constituents of Concern Anticipated to be Present in Dredge Site Development and Use

No rigorous studies have been performed to document the effects of dredge camp site development and use on water quality. Clean mercury and nitric acid are sometimes used at campsites to process gold. Accidental leaks or spills may occur, which could result in discharges to water bodies, potentially affecting water quality.

Suction dredges operate using internal combustion engines while floating on the surface of the water. The potential, therefore, exists for oil and gas leaks or spills to occur, resulting in discharges of these contaminants to water bodies, potentially affecting water quality. However, no studies were found that documented the frequency or extent of such discharges.

Constituents of Concern Anticipated to be Present in Dredging Operations

Turbidity/Total Suspended Solids (TSS)[1]

Overview

There is considerable agreement in the literature regarding the magnitude and spatial extent of the effects of suction dredging operations on turbidity and suspended sediment.

Turbidity and suspended sediment levels were measured at 2 to 3 times higher than background levels at 50 m downstream from dredging operations (Stern 1988). Generally, suction dredging causes turbidities of between 15 and 50 Nephelometric Turbidity Units (NTU) immediately downstream of the operation, with background levels returning between 50 and 160 m downstream, and in some cases in as short as 11 m (Harvey 1986; Somer and Hassler 1992; Thomas 1985; Griffith and Andrews 1981; Stern 1988; Prussian,

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[1] Turbidity is a parameter that reflects the clarity of water and is measured by a turbidimeter that measures the amount of light scattered by a water sample. TSS reflects the weight of suspended matter in a water sample and is determined through a standardized sample filtration, drying, and weighing procedure.

et al. 1999). However, turbidity plumes can be detectable for distances as long as 320 m downstream (Prussian, et. al 1999). In one case, a turbidity plume was said to extend "well over a mile," but turbidity levels from this plume were "within limits" (USFS 1996). The extent of the turbidity plume is influenced by the composition of the streambed; dredging in streams with higher proportions of fine materials will generate a more extensive turbidity plume (Harvey, et al. 1982; Harvey 1986).

Suction dredging has been shown to elevate suspended sediment concentrations up to 300-340 milligrams per liter (mg/L) immediately downstream of the dredge, decreasing to background within 160 m (Stern 1988; Thomas 1985).

Additional details regarding suspended sediment and turbidity findings include the following:

- Stern (1988) monitored turbidity and total suspended solids (TSS) at transects upstream and downstream of dredging sites. Turbidity and TSS values 50 m below the dredge were 2 to 3 times higher than the upstream control. Values 100 m below the dredge approached the controls. Turbidity and TSS may have been influenced by roads and logging activities conducted in other areas of the watershed.

- Thomas (1985) monitored suspended sediment downstream from a suction dredge operation to characterize the suspended sediment plume. Results indicated that suspended sediment returned to ambient levels 30.5 m downstream from the suction dredge. The results also indicated that the majority of suspended sediment from the sluice box discharge was re-deposited within 6 to 11 m of the dredge.

- Prussian, et al. (1999) monitored suspended solids and turbidity resulting from suction dredging with 8-10 inch nozzles in the Fortymile River in eastern Alaskan River. Samples were collected at transects 80, 160, and 320 m downstream from the dredge. A relatively narrow turbidity plume (7% of the river width) was generated by a 10-inch suction dredge nozzle downstream, for a distance of less than 320 m. The authors found that turbidity and suspended solids concentrations were elevated up to 160 m downstream from a dredge.

- Harvey, et al. (1982) and Harvey (1986) measured settleable solids and turbidity at three northern California rivers, including the American River, Yuba River, and Butte Creek. He observed substantial increases in settleable solids and turbidity within the first 15 m downstream from dredging activities. The settleable solids and turbidity levels quickly reduced to background levels within 30 m downstream. The study also noted that substrate type was a key influence in determining which particles were suspended. The disturbance of clay deposits increased turbidity, whereas disturbance of sand and gravel deposits did not increase turbidity. Harvey (1986) found that turbidity peaked at 50 NTU in Butte Creek 5 m downstream from a dredging operation, and returned to background levels by 80 m downstream.

- Suction dredging bedrock pockets containing only sand and gravel causes virtually no change in turbidity whereas suction dredging in clay deposits and stream banks causes very noticeable turbidity increases (Harvey et al. 1982). Stream flow can have a significant effect on turbidity levels created by suction dredging (Oregon DEQ 2004).

- Production of suspended sediment is no doubt linked to the size and frequency of dredging operations, but such cumulative effects have not been evaluated. Dredging in streambeds in which sand is the dominant interstitial fine sediment is unlikely to yield high suspended sediment concentrations, but excavation of streambanks anywhere is likely to substantially increase suspended sediment because banks commonly contain abundant finer sediments (Harvey and Lisle 1998).

There is very little new data since the preparation of the 1994 EIR, and no substantial changes in the scientific understanding of suction dredging's effects on downstream turbidity and suspended sediment levels.

Conclusion

Available scientific evidence suggests that effects of suction dredging on turbidity and suspended sediment concentrations are limited to the area immediately downstream of the dredging for the duration of active dredging.

Mercury

Mercury (Hg) is commonly found in the sediments of streams that were mined for gold and/or used as conduits for mercury-contaminated hydraulic mine debris and hardrock mill tailing. Roughly half of the Hg used in the state to process gold (13 million pounds, USGS 2005) was lost to waterways. Therefore, suction dredging in areas of historic gold-mining, such as the Sierra Nevada gold country, is expected to have some effect on residual elemental mercury, or other forms of mercury left over from historic mining. However, suction dredging is not necessarily an issue solely for the Sierra Nevada gold country; there are locations throughout California with unique conditions, and the effect of Hg on water quality will vary based on site-specific levels of mercury and environmental conditions. Neither the aquatic nor human toxicity of Hg discharged from suction dredging operations have been evaluated. Hg can be converted to methylmercury (MeHg), which can bioaccumulate up the food chain. This is of concern to biota and human health through fish and shellfish consumption, and several waterbodies in the Sierra Nevada have fish consumption advisories for mercury.

Discharge of mercury during dredging

There is only one study that directly quantifies the discharge of Hg from suction dredging operations (Humphreys 2005). In this SWRCB study, a sediment sample was collected from a known mercury hotspot and its mercury concentration was determined and classified by size. The entire sample was dredged from one large tub to another using a United States Forest Service (USFS) minerals examiner suction dredge. A comparison of the mercury concentration of the fine and suspended sediment lost by the dredge with that of the sediment caught by the sluice indicated a 98% removal of elemental Hg from the sediment. However, the other 2% was released in discharge sediment at levels (240 – 300 parts per million [ppm]) that would constitute hazardous waste (> 20 ppm). Another result of this study was the observation that suction dredging contributed to the "flouring" of liquid Hg drops—that is, the breaking up of liquid drops into many very small particles. It was noted that the fine particles floated on the surface of the water (rather than settling out like typical droplets of liquid Hg). Flouring increases surface area, which can enhance oxidation of Hg^0 to Hg (II), an important step in the methylation of Hg (Alpers 2007). The SWRCB study proposed several practices for reducing elemental Hg discharges from suction dredging, including the removal of elemental Hg by means of hand-operated suction tubes or a shore-mounted Hg recovery system, and a system of reporting Hg hotspots to land management agencies (Humphreys 2005). Mercury hotspots (i.e., places where large amounts of mercury are concentrated), such as the one evaluated in the SWRCB study, are known to exist but there has been no concerted effort to locate them. A data gap exists in the characterization of the typical range of Hg discharged during suction dredging at different locations, sediment characteristics, and suction dredge size/operations. Furthermore, it is not known at this time whether the reactivity or speciation of Hg remaining at the dredge site is altered by dredging operations.

Transport of mercury downstream from dredging

Because a large portion of Hg in stream environments is present in various forms (associated with suspended sediment or as droplets of elemental Hg), natural transport of Hg is generally episodic and correlates with sediment transport in high flow events (Brigham, et al. 2009; Shanley, et al. 2008; Lawrence 2003). There is little information about the rate of Hg discharge from natural processes, such as high winter storm flows. Therefore, there is a data gap when it comes to relating the proportion of Hg released from dredging operations to that released from natural discharges. The U.S. Geological Survey California Water Science Center is currently conducting studies for the Bureau of Land Management (BLM) to evaluate suction dredging and related Hg fate and transport effects (information available at http://ca.water.usgs.gov/projects/CA07R.html). While not available for this literature review, the results of the USGS studies are anticipated to be available for use in preparing the EIR.

Larger particles that are resuspended from suction dredging will settle out quickly, while fine particles and colloids will be transported farther downstream. Fine particles (<75 microns) in sediment in historic mining regions have been shown to contain at least an order of magnitude higher concentration of Hg than larger size fractions (Hunerlach, et al. 2004; Alpers, et al., 2000). The suspended particle size fractions at which Hg is discharged from suction dredging is unknown. Additionally, floured Hg particles may float on the surface of the stream, and thus may be transported far downstream (Humphreys 2005). However, the extent to which floured Hg remains floured and floats is not well known. Because most Sierra streams have reservoirs downstream of suction dredging locations, a majority of large sediment (e.g., boulders, cobble, and gravel) is trapped behind dams and thus is not transported farther downstream to the Sacramento/San Joaquin rivers and Delta (Stephenson, et al. 2008; Alpers, et al. 2008). This is not the case with finer (and potentially Hg-enriched) sediment that remains suspended, or colloidal-bound Hg. One study showed that dissolved total Hg concentrations did not significantly change between the headwaters of the Sacramento River and the Delta, while colloidal-bound Hg showed a significant increase (Roth, et al. 2001). In general, however, it is not known how far Hg discharged by suction dredging is transported—only that it has some potential for long-range transport.

Fate of mercury on-site and downstream from dredging

It is unknown whether significant local MeHg formation occurs as a result of suction dredging. In order to form MeHg, Hg is first oxidized from Hg^0 to Hg (II), and then subsequently undergoes a biotic process to form MeHg. In addition, there is some possibility of abiotic methylation (Siciliano, et al. 2005). Suction dredging likely enhances the oxidation of Hg^0 to Hg (II) by increasing the surface area contact of dissolved oxygen in the water with liquid droplets or dissolved Hg in porewater (Alpers 2007). However, some research has shown that liquid droplets oxidize slowly in freshwater. The presence of chloride in brackish water and saltwater causes rapid oxidation of liquid mercury droplets (Amyot, et al. 2005). Regardless of the extent of oxidation, local aquatic environments near dredging sites may vary widely in their mercury methylation potential. However, the mercury methyaltion potential of aquatic environments near dredge sites has not been characterized. It has also been shown that the Feather, Yuba, and American river systems, while contributing significant Hg to the Sacramento River and Delta, do not contribute a disproportionate level of MeHg relative to their flow (Stephenson, et al. 2008).

Dissolved Hg, floured liquid Hg, and fine particle/colloid bound Hg may be transported long distances to environments favorable to methylation, e.g. wetlands, Yolo Bypass, or the Delta. It is well-known that methylation occurs in these environments (e.g., CVRWQCB 2008).

Total Hg transported to areas where methylation occurs has a direct impact on the levels of MeHg produced. MeHg production has been shown to be a function of Hg concentrations in sediment in many different basins, including the Delta (Krabbenhoft, et al, 1999; Heim, et al. 2003), as well as in laboratory experiments (Bloom 2003; Rudd, et al. 1983). Correlations are summarized in the Central Valley Regional Water Quality Control Board's TMDL report for MeHg, Table 3.1 (CVRWQCB 2008).

Ecological and human health risks

Fish tissue levels, including OEHHA fish advisories, were reviewed, as they are the state's primary program designed to monitor contaminant levels in fish and limit human health risks. Thus, they also reflect the potential uptake to other trophic levels. Since methylation of Hg does not occur to a large degree in highly oxygenated environments, MeHg levels in sportfish found in upper watersheds are generally low. Most lakes > 2000 m (6560 ft) elevation are low in MeHg, and the predominant fish caught is trout, which is also low in MeHg. In contrast, lakes < 2000 m (6560 ft) elevation are higher in MeHg, and the predominant fish caught are black bass species, which are much higher in MeHg (Davis, et al. 2009). Fish advisories have been developed for many water bodies (including the Bear River, Deer Creek, and the South Yuba River), as well as for several reservoirs (including Camp Far West and Lake Englebright), that limit the maximum number of meals of sportfish that should be consumed monthly due to levels of MeHg (OEHHA 2003). These water bodies are downstream of historic gold-mining operations, and thus are also likely to be downstream of potential suction dredging sites. But there have been no studies specifically designed to determine if suction dredging contributes to high fish tissue mercury levels. Also, no studies have been performed to determine whether or not suction dredging affects levels of Hg or MeHg in biota on-site or downstream of dredging operations.

Please refer to Section 4.3 for a more detailed discussion of the effects of Hg, and MeHg in particular, on aquatic species.

Conclusion

Scientific evidence suggests that suction dredging may have potential to release Hg into the environment, increase methlyation by enhancing oxidation of Hg^0 to Hg (II), and result in long-range transport (via fine sediment transport, floured liquid Hg, and dissolved and colloid-bound Hg). However, only one study has attempted to quantify release of Hg directly from suction dredging. Many significant data gaps remain in linking suction dredging directly to Hg discharge, fate, transport, and effects. Several of these data gaps are currently under investigation (http://ca.water.usgs.gov/projects/CA07R.html), but no results have been published to our knowledge.

Other metals

Other metals that may be discharged during suction dredging include arsenic, copper, silver, zinc, lead, chromium, nickel, antimony, cadmium, and selenium. Release of these metals is dependent on many factors, including levels present in sediment, which will be variable from stream to stream and between reaches of a single stream. Johnson and Peterschmidt (2005) found elevated levels of arsenic, copper, zinc, and lead immediately downstream of suction dredging in the Similkameen River, WA, but levels quickly returned to background 30-60 m downstream. Another study showed elevated copper and zinc immediately downstream of suction dredging, but background levels were reached within 80 m (Prussian, et al. 1999).

Past studies have not evaluated metals distribution of different particle sizes, metals transport after release, biotic uptake, etc.

Persistent organic pollutants

Legacy pesticides such as dieldrin, DDT, and chlordane can be transported to remote or high altitude waterways atmospherically. However, these chemicals are rarely above public health thresholds in fish in these upper watersheds where suction dredging generally occurs (Davis, et al. 2009). PCBs also are transported atmospherically, and are more commonly found above threshold values in fish (Davis, et al. 2009; Ohyama, et al. 2004).

No studies have been undertaken to determine whether suction dredging releases these chemicals, and, if so, what the fate, transport, and effects of the chemicals are downstream.

4.2.3 Summary and Information Gaps

The major findings related to water quality and toxicology are as follows:

- There is little information available regarding the environmental effects of dredge site development, such as site access, land-side encampments, and fuel/chemical spills. There remains a lack of any rigorous studies on this subject.

- Little new information exists about the operations-related effects of suction dredging on turbidity and TSS discharges. Information that does exist is generally consistent with previous findings presented in the 1994 EIR. All studies to date suggest that the effects of suction dredging on turbidity and suspended sediment concentrations are limited to the area immediately downstream of the dredging for the duration of active dredging;

- Operations-related effects on Hg were minimally addressed in the 1994 EIR. There are very few studies specifically addressing the effects of suction dredging on mercury fate and transport processes. There also are no studies that directly evaluate the relative magnitude of dredging-related effects on mercury discharges compared to other causes. However, the effects of mercury contamination from historic activities in California are being extensively studied, and there is substantial literature regarding mercury fate and transport.

- The human and aquatic toxicity of Hg discharged from suction dredging operations has not been studied. Studies have shown that remobilized Hg can be converted to MeHg, which can bioaccumulate up the food chain; this is of concern to biota and human health through fish and shellfish consumption. Practices for reducing Hg discharge from suction dredging have been recommended, but it is unknown if they are effective or are being used. Mercury hotspots (i.e., places where large amounts of mercury are concentrated) are known to exist, but there has been no concerted effort to locate them. Fine particles (<75 microns) in sediment in historic mining regions have been shown to contain at least an order of magnitude higher concentration of Hg than larger size fractions. The suspended particle size fractions at which Hg is discharged from suction dredging is unknown. It is not known whether the reactivity or speciation of Hg remaining at the dredge site is altered by dredging operations. The transport of floured Hg (from dredging operations) has not been studied. There have been no studies performed to determine whether local MeHg formation occurs as a result of suction dredging. Dissolved Hg, floured liquid Hg, and fine particle/colloid bound Hg may be transported long distances to environments favorable to methylation. There have been no studies performed to determine Hg discharges from suction dredges and their subsequent fate, transport, and other effects.

- There is very little information available on the potential operations-related effects of dredging to discharges of other constituents (e.g., trace metals, organic compounds). Other metals that may be discharged during suction dredging include arsenic, copper, silver, zinc, lead, chromium, nickel, antimony, cadmium, and selenium, but the distribution of metals of different particle sizes, transport of released metals, biotic uptake, etc., have not been studied. Similarly, there have been no studies undertaken to determine whether suction dredging releases legacy pesticides and, if so, what the fate, transport, and effects of the chemicals are downstream.

4.3 Biological Resources

4.3.1 Introduction

The literature review related to biology has been divided into four sections:

- Fish Spawning and Early Life Stages
- Juvenile and Adult Fishes
- Stream Benthic Community
- Amphibians and other Wildlife

Within each of these sections, the discussion is further broken down to address the various types of disturbances caused by suction dredging that are relevant to that section. Disturbance in the stream ecosystem has been defined as any relatively discrete event in time that is characterized by a frequency, intensity, and severity outside a predictable range and that disrupts ecosystem, community, or population structure and changes resources or the physical environment (Resh, et al. 1988). Disturbance can affect the stream community at many levels, and this disturbance depends on the level and frequency. Suction dredge mining is an unnatural disturbance of the stream ecosystem; its primary components include physical changes to the substrate and associated biological communities and elevated suspended sediment concentrations in the water column during the period of active dredging and associated effects.

Where applicable, the discussion below builds upon information presented in Section 4.1, *Geomorphology*, and Section 4.2, *Water Quality and Toxicology*. The literature reviewed included both papers specific to suction dredge mining, and other more general investigations regarding the typical effects of the types of disturbances that suction dredging causes (e.g., geomorphic changes, turbidity, etc.). In general, the information found about suction dredging focuses on its direct impacts on fisheries and water quality. Little information was found addressing impacts to amphibian or reptile species, sensitive plant species, or the indirect effects on birds and terrestrial wildlife.

4.3.2 Dredging Effects on Fish Spawning and Early Life Stages

Overview

California has a number of threatened and critically endangered fish species that could be impacted by suction dredging. In particular, suction dredging may occur in the spawning habitat of many salmonid and non-salmonids species. As a result, dredging has potential to affect the population dynamics and ecology of the species in these watersheds (e.g., in terms of their survival and reproductive success). The following section provides a detailed discussion of these effects as they relate to the spawning and early life stages of California's fish species (particularly salmonids).

The section is organized around the following issues: spawning habitat, spawning substrate's effect on eggs and developing embryos, heavy metals, and egg and larval entrainment. It then presents a summary and information gaps.

Impacts on Spawning Habitat

Among the possible effects of suction dredging is its potential to impact fish reproduction. Many fish species, including Chinook salmon, steelhead, cutthroat trout, golden trout, several lamprey species (*Lamptera* spp), suckers (*Catostoma* spp.), sculpin (*Cottus* spp.) etc. utilize small gravel to cobble substrates for spawning. Unlike salmonids, lamprey larvae may also emerge from the redd and find backwater or low gradient areas of sand and silt to continue development for up to seven years, filtering substrates to feed on detritus (Moyle 2002). Therefore, many areas of the channel may be considered sensitive to disturbance.

Section 4.1, *Geomorphology*, discusses in detail the conclusions of available literature regarding the physical changes of the stream system as a result of suction dredge mining, including changes in channel bed form, sedimentation patterns, etc. Of particular relevance here are the discussions in that section regarding scour of existing cobble areas, characteristics of dredge tailings, etc.

Salmonids, as well as many other fish species, require very specific parameters to complete the spawning and incubation process. These include: depth; velocity; substrate quantity and quality; and complexity, such as undercut banks, wood structure, boulders and associated pools, etc. (Merz et al. 2006; Moyle 2002). California salmonids typically dig a redd (nest) and deposit eggs within the stream sediment where incubation, hatching, and subsequent emergence take place. Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 0.5 to 4 inches and a composition that includes less than 5 percent fines (particles less than 0.3 inch in diameter) (Platts, et al. 1979; Bjornn and Reiser 1979) Although optimal spawning habitat as defined by habitat suitability models is generally found in riffles, proximity of habitat to structural cover (pools, large woody debris, boulder clusters and overhanging vegetation) and hydrodynamic shear zones provide equally important refuge from predation and resting zones for energy conservation (Bilski 2008; Wheaton, et al. 2004; Merz 2001).

Tailings created by dredges may offer increased availability of spawning gravel by loosening up compacted gravels: attractive, yet potentially unstable material for spawning (Badali 1988; Harvey and Lisle 1998). Tailings often are located near riffle crests, which are preferred locations for the construction of redds by salmonids (consisting of loose substrate of the appropriate size). Hassler, et al. (1986) indicated that suction dredging increases availability of spawning gravel by loosening up compacted gravels. However, they considered these areas undesirable spawning grounds. A number of studies indicate that the loose substrate often found in dredge tailings is too unstable, and that embryos may experience reduced survival under these conditions due to increased scouring (Thomas 1985; Harvey and Lisle 1999). This may be exacerbated, as embryo development frequently coincides with periods of high flow, which mobilizes streambeds (Holtby and Healey 1986; Lisle and Lewis 1992). A study by Harvey and Lisle (1999) found that Chinook salmon redds located on dredge tailings experienced greater scouring than those on natural substrates. Chinook salmon that spawn in the fall could be affected by constructing redds on dredge tailings, which could be subject to higher scour than redds in unaltered substrates. This would result in compromised reproductive success (Harvey and Lisle 1998). Tailings are typically less stable during high winter flows. In the Scott River, 12 of 372 redds were on dredge tailings (3%). Harvey and Lisle (1999) suggested that to reduce effects, tailings piles could be redistributed to restore the original bed topography and particle size distribution. However, there appears to be differing opinions regarding whether dredging has a positive or negative effect on the quality of spawning habitat. For example, a study by Lewis (1962) suggests that dredging could actually improve the gravel environment for fish eggs if areas were dredged uniformly in a single direction. However, the use of other methods, such as a pocket and pile, are considered to be less desirable alternatives.

It is still uncertain to what extent salmonids utilize tailings for spawning. There is some evidence that suggests that tailing piles are generally undesirable spawning habitat and that they only become suitable for spawning after the substrate has been dispersed (Hassler, et al. 1986). However, little work has actually been performed to study the spawning behavior of salmonids in dredged areas. This may be because many fish species spawn after tailings have already dispersed (e.g., from dredging during summer and fall) (Thomas 1985; Harvey 1986). Nevertheless, the extent to which fish populations depend on dredge tailings for spawning habitat likely depends on the availability of suitable unaltered substrate and the quality of the dredge tailings (Harvey and Lisle 1999). More work is needed that investigates the spawning preferences of fish in dredged areas, as well as the subsequent recruitment of fry which have come from redds on tailings if we are to fully understand the fitness consequences for fish spawning in these disturbed habitats.

Spawning substrate's effect on eggs and developing embryos

In addition to the effects caused by unstable substrates, dredged areas may also have negative impacts on embryo development. To produce viable young, several fish species (including salmonids and lampreys) require loose, uncompacted gravels with high permeability, and which consist of unclogged interstices that allow for the removal of metabolic wastes, (Hausle and Coble 1976). However, results from Mesick (2009) suggest that too clean of material, may be detrimental to Chinook salmon eggs because they are not insulated from agitation or become dislodged, especially in high flow areas.

Through the construction of redds, spawning adults can enhance the quality of spawning sites by increasing gravel permeability and reducing fines. In so doing, they help provide optimal habitat for incubating eggs, embryonic development, and fry emergence. Previous work indicates that spawning habitat are stable environments, such that spawning locations can be predicted based on previous years data (Soto 2007). Hence, suction dredging has the potential to influence the availability of suitable spawning and incubation habitat (and substrates) for spawning salmonids.

Dredger tailings are composed of unsorted, unconsolidated streambed materials. As we have previously discussed, little work has been performed that has investigated salmonid preferences for spawning substrate in dredged areas, although there is some indication that tailings serve as unfavorable habitats (at least until they have been dispersed) (Hassler, et al. 1986). The availability of intragravel water flow (Vaux 1962; Cooper 1965) and dissolved oxygen is also critical for the survival of developing salmonid eggs (Cooper 1965; Daykin 1965). Reduced flow and oxygen concentrations (e.g., from higher levels of fines or increased organic matter) can result in a number of negative effects, including the reduced size of embryos at various developmental stages, increased development time of alevins, and higher pre- and post-hatching mortality (Merz, et. al. 2006; Spence, et al. 1996; Brannon 1965; Shumway, et al. 1964; Silver, et al. 1963). Increased fines in dredged areas can also delay emergence of fry; this may result in smaller fry that are less able to compete for resources than their larger counterparts (e.g., those that have experienced normal emergence) (Redding, et al. 1987). However, the severity of all of these effects would likely vary considerably depending on the species or the hydrologic conditions of the watershed.

Effects of heavy metals

Section 4.2, *Water Quality and Toxicology*, discusses the potential for suction dredge mining to resuspend contaminants such as heavy metals. In doing so, dredging may introduce toxic substances to spawning habitats which could adversely affect salmonids during spawning and during their early life stages. As discussed in Section 4.2, in aquatic environments inorganic Hg can be methylated by microbes to form MeHg, the most toxic form of mercury (primarily all mercury found in fish is MeHg) (Bloom 1992; Grieb, et al. 1990). The highest concentrations of MeHg are commonly found in fish and wildlife after having bioaccumulated in the food web (Spry and Wiener 1991; Watras and Bloom 1992).

In terms of mercury Hg contamination, there have only been a few experimental studies that have investigated the biological effects of Hg in fish. Of those that have, they have primarily shown that MeHg contamination has negative consequences for fish reproduction. For example, a recent study by Hammerschmidt, et al. (2002) observed the reproductive effect of MeHg-contaminated diets on fathead minnow (*Pimephales promelas*), finding a decline in spawning activity and the number of eggs laid with increased MeHg. However, while a number of studies have demonstrated that dietary MeHg impairs gonadal development (Friedmann, et al. 1996; Hammerschmidt, et al. 2002; Kirubagaran and Joy 1992, 1988) or results in testicular atrophy (Wester 1991), the mechanisms by which MeHg influences the reproductive physiology of fish still remains unclear. There is some indication that MeHg (at environmentally relevant concentrations) suppresses sex hormones that are essential for the development of secondary sexual characteristics (Drevnick and Sandheinrich 2003; Arnold, et al. 1998; Fynn-Aikins, et al. 1998); recent work suggests that MeHg disrupts the expression of genes necessary for endocrine function, and that these may have sex-specific effects (Klaper, et al. 2006). Hence, while there is growing support that Hg can have adverse effects on aquatic ecosystems, to our knowledge no study has investigated the potential fitness consequences of fish in habitat with elevated Hg levels in a natural context (for instance, in watersheds where suction dredging has remobilized Hg). While the aforementioned experiments have demonstrated the physiological effects of mercury, it is still uncertain how these differences translate into short and long-term fitness effects (e.g., survival and/or reproductive success). Thus, more experimental work is needed that investigates the effects in a natural or ecological context.

Egg and larval entrainment

In addition to dredging's effects on physiochemical conditions in rivers and streams, mortality can also result from the excavation and subsequent displacement of eggs, fry and larvae (Harvey and Lisle 1998). Very little work has been done to explore the direct effects of entrainment on the eggs and larvae of salmonids or other species (such as the Pacific lampreys). A study by Griffith and Andrews (1981) investigated the effect of suction dredging entrainment on the mortality of a number of aquatic organisms. In this experiment, Griffith and Andrews found 100% mortality among uneyed eggs and 30% mortality among eyed eggs in entrained cutthroat trout (*Oncorhynchus clarki*). He also observed 83% mortality for rainbow trout (*O. mykiss*) sac-fry during the same experiment. However, the results from this paper suggest that once sac-fry 'button-up' they are less susceptible to entrainment-related mortality. Trout greater than 4 inches (e.g., fingerling) were determined to be able to avoid entrainment (at least for dredge intake velocities less than 1 ft/sec). However, fingerlings still appear to survive if they are entrained by dredging (Griffith and Andrews 1981).

While the aforementioned studies looked at the direct effects of dredging on salmonid yolk-sac fry and eggs, they did not address the effects directly after entrainment (e.g., predation or abrasions). Fish are often observed feeding from the discharge of suction dredges (Lewis 1962), and, thus, they would likely attempt to eat any eggs, larvae, and/or fry that survived entrainment (or that were exposed after dredging has occurred). Any eggs or sac-fry that survive to return to the substrate for cover would likely experience increased predation from other predators displaced during the suction dredging (Gerstung, pers comm., cited in the Department's 1994 EIR). Even though dredging is generally limited to summer months, there is still an overlap with these disturbances and spawning and rearing for a number of salmonid and non-salmonid species (including an overlap with the development of their embryos) (Moyle 2002). For example, there are several watersheds where salmon do not emerge from the substrate until the summer months. As a result, any dredging that occurs during these periods could substantially impact spawning populations.

Summary and Information Gaps

Suction dredging has the potential to affect riverine habitat in relationship to spawning fishes, as well as their eggs, developing embryos, and larvae. However, very little work has investigated the effects of suction dredging on riverine ecosystems (Harvey and Lisle 1998). There appears to be clear support for the negative effects of suction dredging on eggs and developing salmonids (e.g., through entrainment) (Griffith and Andrews 1981). This appears to be why the Department (in the 1994 EIR) suggests restricting dredging to non-spawning periods (e.g., during the summer). However, a number of fish species' spawning or embryo development may coincide with dredging seasons (Moyle 2002). As a result, it may be important to revisit existing watershed-specific restrictions to ensure proper consideration of the ecology of local spawning populations (e.g., differences in spawning and development timing).

Though restricting dredging seasons to certain times of year may provide adequate protection for salmon eggs and larvae against direct impacts (such as dredging entrainment), it still does not protect against alteration of the physical environment (e.g. see CWD effects below). While previous work suggests that dredging destabilizes and degrades spawning habitat (Harvey and Lisle 1998) or even may produce substrates that can adversely affect developing salmonids, it is still uncertain whether dredging has any lasting effects directly on the spawning substrate matrix (e.g., whether flows disperse the substrate adequately to minimize any negative effects). Two critical questions that remain unanswered are: 1) whether fish preferentially select spawning habitat in dredged/undredged areas; and 2) do these different spawning substrates result in any discernible fitness differences. These questions are important because it is still uncertain whether fish use dredge tailings to spawn, and whether spawning in those environments actually adversely affects their fitness.

As discussed in Section 4.2, the amount of contaminants (e.g., heavy metals) mobilized in rivers and streams by dredging events is generally unknown, as is whether the levels observed in these habitats will eventually become toxic to fish (e.g., through bioaccumulation). To our knowledge, there has been no work that investigates the levels of Hg in the food web in relation to suction dredging. However, strong experimental evidence exists for the adverse effects of Hg on fish reproductive capacity (e.g., using levels of Hg consistent with those found in nature). Hence, the effects of unearthed Hg require consideration in management decisions relating to suction dredge mining. More work is needed to explore the fitness consequences of exposure to heavy metals in natural contexts.

4.3.3 Dredging Effects on Juvenile and Adult Fishes

Overview

The effects of suction dredging on juvenile and adult fishes have not been studied extensively. This review was only able to find six scientific journal articles that have specifically addressed the effects of suction dredging (Griffith and Andrews 1981; Thomas 1985; Harvey 1986; Hall, 1988; Somer and Hassler 1992; Krueger, et al. 2007). However, much data and information is available from resource agency reports, master's theses, and technical correspondence collected at varying levels of scientific rigor. Also, some impacts of dredging can be predicted from general knowledge of physical and biological processes of streams. In the United States, at least 26 Evolutionarily Significant Units of Pacific salmonids are currently threatened or endangered (National Marine Fisheries Service 2004). These declines are in large part attributable to degradation of spawning and rearing habitat (Nehlsen, et al. 1991; Frissell 1993), a major cause of which is increased loading and storage of fine sediments (Miller, et al. 1989; Bisson, et al. 1982; Waters 1995). Because suction dredging directly and indirectly affects stream sediments, it will also affect these organisms.

The section is organized around the following issues: entrainment, pool formation/loss, sedimentation (the effects of fine sediment), loss of woody debris and large boulders, behavioral responses, temperature, and suspended sediment. It then discusses potential cumulative impacts.

Entrainment

Most juvenile and adult fishes are likely to avoid or survive passage through a suction dredge (North 1993). All 36 juvenile and adult rainbow trout and brook trout entrained intentionally by Griffith and Andrews (1981) in small Idaho streams survived. However, longterm impacts such as disorientation, abrasions, and secondary infections were not assessed.

Pool Formation/Loss

In some locations excavations caused by dredging operations may improve fish habitat. Pools can be temporarily formed or deepened by dredging. Deep scour may intersect subsurface flow and create pockets of cool water during summer, which can provide important habitat for fish (Nielsen et al. 1994). At low flows, increased water depth can provide a refuge from predation by birds and mammals (Harvey and Stewart 1991). Harvey (1986) observed that all eight fish occupying a riffle during late summer in Butte Creek, California, moved into a dredged excavation nearby. Pools created at abandoned dredger sites can provide holding and resting areas for juvenile and adult salmonids (Stern 1988).

Although dredging operations can create pool habitat at the excavation site, sedimentation of pools downstream of the dredging site can also fill in pool habitat. The number of rainbow trout in a small pool in Butte Creek, California declined by 50% after upstream dredging filled 25% of the pool volume (Harvey 1986). After one year of dredging activity on Gold Creek in Missoula County, Montana, all of the gravel deposited at the dredged area had moved downstream and completely filled-in a downstream pool. However, the creation of a pool at the dredged site led to no net loss of pool habitat in the stream (Thomas 1985).

Harvey (1986) stated that riffle sculpin could be displaced when large amounts of substrate are deposited over cobble habitats.

As discussed in Section 4.2, *Geomorphology*, most pools and depositional piles are removed during subsequent winter/spring seasonal flows. No similar information was available regarding whether pools that become filled with sediment also recover. This would be possible in locations where the conditions that originally led to scour and pool formation are still present.

Sedimentation (Effects of Fine Sediment)

The storage of fine sediments (particle sizes <2 mm median diameter) in gravel-bedded rivers is normally a transient phenomenon, as sediments enter and leave river channels naturally. Without frequent resupply from upstream sources or termination of gravel mobilizing flows, fine sediment is carried downstream. Yet anthropogenic activities have greatly increased the storage of fine sediment in rivers throughout the world. Where it comes to rest in river reaches, fine sediment can transform the topography and porosity of the gravel riverbed in ways that profoundly affect the emergent ecosystem, particularly during biologically-active periods of seasonal low flow. It is during these periods of low flow that demographically-critical juvenile rearing occurs for salmonids (Suttle, et al. 2004).

As discussed in Section 4.2, *Geomorphology*, sediment discharges from suction dredges are sorted based on size, with coarser sediments settling nearer to the dredge, and finer sediments transported further downstream. As a result, this could leave areas of unnaturally-clean coarse material and a layer of fine sediment on top of the bed further downstream. Sedimentation of habitat downstream of dredging activity can negatively impact the microhabitats of bottom-oriented stream fish such as dace, sculpin, and juvenile salmonids because these fishes rely on cover that can become embedded during dredging operations (Harvey 1986). Juveniles and adults of some benthic fish species (e.g., sculpin and dace) often occupy microhabitats beneath un-embedded cobbles and boulders (Baltz, et al. 1982; Harvey 1986). Harvey (1986) observed significantly reduced densities of juvenile and adult riffle sculpin downstream of a dredge on the North Fork of the American River, California, and attributed the decline in part to burial of cobbles by dredge tailings. Hassler, et al. (1986) found that high densities of deposited sediment 33-52 feet below dredging sites markedly reduced the amount of instream cover for juvenile salmonids because fine sediment filled gravel interstices and stream bottom roughness.

In the south fork Eel River, Suttle, et al. (2004) found that juvenile steelhead growth decreased steeply and roughly linearly with increasing fine-sediment concentration. Steelhead confined to channels with higher levels of sedimentation experienced lower food availability than those in less embedded channels. In addition to reduced prey availability, deposited fine sediments increased steelhead activity. At higher levels of embeddedness, fine sediments filled spaces under and between coarse cobbles, producing a flat and featureless bed. As interstitial refuges and prey declined, steelhead spent less time sheltering behind or under cobbles and more time actively swimming. Steelhead also exhibited higher levels of intraspecific aggression, including attacks, as prey availability and visual separation between fish decreased with higher fine sediment levels. This appeared to cause an increase in mortality in more heavily embedded channels.

Loss of Woody Debris and Large Boulders

Suction dredge mining regulations prohibit operators from moving any anchored, exposed woody debris such as root wads, stumps or logs. Further, boulders or other materials that are moved cannot be placed outside of the existing water line. That said, dredge operators may move coarse woody debris (CWD) and large boulders within stream channels or reduce the stability of these elements by removing surrounding material (Harvey and Lisle 1998). Many pools are formed by scour around large roughness elements (Keller and Swanson 1979; Lisle 1986a; Montgomery, et al. 1995; Merz, et al. 2006) and, therefore, the stability and maintenance of these structures are important to the long-term maintenance of such habitat. CWD, especially in smaller streams, increases flow complexity and water retention (Gurnell, et al, 2002). When the flow of the water is backed up by CWD, pools may form, which are an important habitat for many species of fish (McIntosh, et al. 2000). This can become especially important during dry periods to maintain stream biota (Lisle 1986a). The influences of instream structure on juvenile salmonids have been extensively discussed in the literature (Ward and Slaney 1979; Ward and Slaney 1981; House and Boehne 1985; Fuller 1990). Woody debris is also an important energy source for benthic invertebrates (Anderson, et al. 1978; Bisson, et al. 1987), a principal food of juvenile salmonids (Mundie 1974). Woody debris provides cover for adult salmonids (Bjornn and Reiser 1991), and low gradient sediment deposits upstream of debris accumulation can provide suitable spawning substrate in sediment-poor drainages (Everest and Meehan 1981). Large pieces and conglomerations of CWD are especially important because they cause scour of larger pools with tail-outs appropriate for redd construction in sediment-rich streams, and can be more stable than smaller pieces (Bilby 1984; Sedell, et al. 1982). House and Boehne (1985) described the accumulation of superior salmon spawning material near boulder and wood structures placed in East Fork Lobster Creek, Oregon. Furthermore, large roughness elements such as CWD can govern the location of scour and deposition at the scale of pools and riffles (Lisle 1986b; Montgomery, et al. 1995). Dolloff (1983) suggested that visual isolation provided by the matrix of a root system reduces the frequency of aggressive encounters in other Pacific salmon. Merz (2001) found that female Chinook salmon selected spawning sites containing woody debris in some instances, and that woody debris may make less-desirable habitats more suitable for spawning. This may allow greater concentrations of redds on suitable sites.

Many studies provide evidence that CWD and other large elements affect various ecological processes and conditions in streams. These include the microbial uptake and transfer of organic matter (Tank and Winterbourn 1996), the species composition and productivity of benthic invertebrates (Benke, et al. 1984), and the density of fish (e.g., Fausch and Northcote 1992; Crispin, et al. 1993). CWD and snags are important habitat components for benthic macroinvertebrate communities (Brown and May 2000). Woody debris is an important refuge and source of macroinvertebrate recolonizers. Loss of wood structure can have a negative effect on macroinvertebrate diversity and production in streams (Hax and Golladay 1998).

While fish may not always be associated with large substrate elements, these features may be limiting during critical events such as concealment by salmonids in winter (Heggenes, et al. 1993; Smith and Griffith 1994) or reproduction by sculpins (Mason and Machidori 1976; Moyle 1976).

Harvey and Lisle (1998) state that suction dredging likely only affects the presence of CWD locally, limiting the effect on a stream's aquatic biota. However, many western streams may be particularly vulnerable to CWD removal or disturbance because they have already been depleted of CWD due to other human activities (Bilby and Ward 1991; Ralph, et al. 1994).

Removal or reduction of CWD retention in river channels can have variable and substantial impacts on the stream environment. Warren and Kraft (2006) found that in a New York stream, substrates did not change significantly in response to wood removal. However, the relative proportion of macroinvertebrate grazers increased upstream and downstream from removed woody debris dams in all streams. Smith, et al. (1993) found that wood removal from a gravel-bed stream resulted in dramatic redistribution of bed sediment and changes in bed topography. Removal of CWD changed the primary flow path, thereby altering the size and location of bars and pools and causing local bank erosion and channel widening. Increased bed material mobility was attributable to destabilization of sediment storage sites by removal of debris buttresses, elimination of low-energy, backwater environments related to debris, and an inferred increase in boundary shear stress resulting from the removal of debris-related flow resistance. Sediment deposition was favored by the elimination of debris-related scouring turbulence and by increased flow resistance from a developing sequence of alternate bars. Mean spacing of thalweg cross-overs and pools did not change measurably following debris removal, although variability of spacing between thalweg cross-overs tended to decrease with time as the location of bars stabilized. However, Smith, et al. (1993) found no consistent pattern of change in mean residual depth of pools or in distribution of depths occurred within the first 4 years following debris removal.

Wondzell, et al. (2009) found that, in the first few years after CWD was removed from a stream, hyporheic exchange flow was reduced by smoothing of the streambed and water surface elevation profiles due to streambed scour and sediment deposition. Also, large contiguous patches of downwelling or upwelling were fragmented. These flows are important to the production of benthic invertebrates and the survival and development of developing fish embryos (Bilski 2008; Merz, et al. 2006; Fowler and Death 2001).

Behavioral Responses

Fish behavioral responses of stream biota to noises and vibrations generated by dredging have not directly been quantified, but observations have shown a range of fish behavior changes. Juvenile salmonids have been observed feeding on entrained organisms at dredge outfalls (Thomas 1985; Hassler, et al. 1986). However, it is important to note that this rapid displacement of benthic macroinvertebrates creates a reduction in benthic production for one to several months (see discussion of the stream benthic community below) from the area excavated by suction dredging. Temporary dredge piles that span a substantial portion of the stream width could affect normal feeding and escapement behavior for fish. Deeper areas left by dredges may be occupied by fish once dredging is completed (Harvey and Lisle 1998).

While the effects of suction dredging on salmonid migration and holding have been addressed in the literature, the conclusions are primarily hypotheses supported by researcher observation. Some of these observations and inferences include the following. Hassler, et al. (1986) observed spring-run Chinook and summer-run steelhead adults holding within 50 meters of active dredges, but speculated that dredging may have inhibited upstream movement by the fish. In Canyon Creek, Stern (1988) observed that suction dredging did not appear to influence the behavior of adult spring-run salmonids in their holding habitat. However, Roelofs (1983) expressed concern that dredging could frighten adult summer-run steelhead, based on their response to divers, and Campbell and Moyle (1992) indicated that recreational activity increased salmon movement in pools and may increase adult stress. Somer and Hassler (1992) observed that, during low flow years, increased suction dredging activity could disturb spring-run Chinook salmon and summer steelhead in holding areas; this could possibly cause mortality and raised concerns that dredging activity could disturb salmon holding in deep pools during summer, particularly if numerous dredges are operating or water temperatures are elevated. Even minor disturbances during the summer may harm adult anadromous salmonids because their energy supply is limited, and the streams they occupy can be near lethal temperatures (Nielsen, et al. 1994). The USFS (2001; 2004) states that suction dredging could disturb spring Chinook salmon holding in deep pools during summer, particularly if numerous dredges are operating or water temperatures are elevated. Suction dredging dislocates and can kill aquatic insects used as a food source by a variety of fish species in a variety of life stages. Affected fish would be forced to move to relocate to find food. Fish relocating to new feeding areas may experience increased stress due to predation, exposure to sub-optimal conditions, increased competition with other fish for food and space, as well as stress from agonistic behavior.

Campbell and Moyle (1992) found a relationship between pool depth and holding habitat for spring-run Chinook. Pools can be filled by sediments mobilized by upstream dredging (Thomas 1985; Harvey 1986), suggesting that the filling or altering of pools due to dredging may impact holding habitat.

Temperature

Suction dredging in streams with elevated water temperatures could potentially produce synergistic effects (Lantz 1971). At high temperatures, rainbow trout are more vulnerable to unusual stress (e.g. being caught by an angler) and are likely to die as a consequence (Moyle 2002). Typical suction dredging operations do not change the amount of solar radiation input into the stream, so temperature stress to fish is not an issue. This is not true, however, if suction dredging operations interfere with pool occurrence. Any activity that inhibits, reduces the condition, or inhibits recovery of the pool frequency, pool quality, or in-stream wood could further cause stress on salmonids - both because of the lack of suitable cover or the lack of cold water refugia and thermal stress (USFS 2001). Spring run chinook and summer steelhead are susceptible to stresses as a result of warmer water temperatures (Nielsen, et al. 1994). Somer and Hassler (1992) observed that during low flow years, increased suction dredging activity could disturb spring run Chinook and summer steelhead that hold in Canyon Creek, a tributary to the Trinity, possibly causing mortality. The fish are susceptible to stress as a result of warmer water temperatures. According to Spence, et al. (1996), dredging and other mining practices may cause loss of riparian vegetation and changes in heat exchange, leading to higher summer temperatures. Bank instability can also lead to altered width-to-depth ratios, which further influences temperature.

Suspended Sediment

High concentrations of suspended sediment can alter survival, growth, and behavior of stream biota (Newcombe and MacDonald 1991). Inert suspended solids can have a variety of effects on aquatic organisms. Indirect effects include reduction in light input and occlusion of gravel interstices for hiding places and food. Direct effects include abrading or clogging delicate membranes, skin irritation and abrasions, and facilitation of infections. Suspended solids may hinder or help predation, as well as reduce or hinder migration.

Suspended sediments can cause direct damage to gills, reduced growth rates due to restricted vision in turbid waters, lowered growth rate caused by reduced instream production of food organisms due to fine sediment deposition (and, to a lesser extent, reduced light penetration), and a reduction in carrying capacity due to channel morphology changes (Roelofs 1983). Impacts of suspended sediment can increase with (1) longer exposure time (Newcombe and MacDonald 1991), (2) smaller sediment particle size (Servizi and Martens 1987), (3) extremes in temperature (Servizi and Martens 1991), and (4) higher organic content of the sediment (McLeay, et al. 1987). Extremely high levels of suspended sediment (e.g., >9,000 mg/L) can be lethal to aquatic biota, and lethal thresholds may be lower under natural conditions (Bozek and Young 1994) than in the laboratory (Redding, et al. 1987).

Even slightly elevated suspended sediment may reduce reactive distance of salmonids to drifting prey (Barrett, et al. 1992) and prey capture success (Berg and Northcote 1985). This may be offset somewhat by the fact that the sediment plume may contain invertebrates which were entrained as a result of dredging (see the discussion of entrainment below in Section 4.3.4). Growth rates of steelhead and coho salmon in laboratory channels were higher and their emigration rates lower in clear water than in turbid water (22-286 NTU) after 11-21 days (Sigler, et al. 1984). In contrast, feeding by sculpin in laboratory channels was not detectably affected by suspended sediment levels of 1,250 mg/L (Brusven and Rose 1981). Hassler, et al. (1986) found that sculpin were not significantly impaired by increased turbidity from dredges, and turbidity does not appear to affect feeding abilities of many species. However, both statements are subjective. Using the equations of Newcomb and Jensen (1996), juvenile salmonids may be slightly affected by typical increases in turbidity resulting from suction dredging. However, fish can avoid concentrations.

Any reduction in feeding efficiency of fish may be offset by reduced risk of predation at moderate levels of suspended sediment. Juvenile Chinook salmon spend more time foraging in water of moderate turbidity (20-25 NTU) than in clearer water (Gregory 1993). Similarly, brook trout are more active and spend less time near cover in moderately turbid water than in clear water (Gradall and Swenson 1982). Juvenile estuarine fishes in laboratory channels actively seek moderate turbidity (Cyrus and Blaber 1987). Coho salmon do not avoid turbidities as high as 70 NTU, but move into turbid water when frightened (Bisson and Bilby 1982). Sigler, et al. (1984) conducted laboratory tests to determine the effect of chronic turbidity on feeding of 30-65 mm long steelhead and coho salmon. Fish subjected to continuous clay turbidities grew less well than those living in clear water, and more of them emigrated from channels during the experiments. For salmon, dissolved or suspended solids usually cause greater stress for earlier life stages (e.g., eggs, larvae and fingerlings) than for adults. Therefore, increased suspended sediment loads can negatively impact the quality and quantity of fish produced if they coincide with the emergence and rearing of young salmonids (Sigler, et al. 1984).

In terms of toxic effects, while extremely high levels of sediment can be lethal, or at least very harmful, lethal concentrations of suspended sediment are probably rarely produced by small suction dredging because fish can usually avoid those concentrations (Bernell, et al. 2003; Harvey 1986). Thomas (1985) and Harvey (1986) indicate that in some streams where dredges operate at low density, suspended sediment is not a significant concern because effects are moderate, highly localized, and readily avoided by mobile organisms.

Cumulative Effects

Suction dredging may remove specific features such as CWD, pools and edge habitat (Harvey and Lisle 1998). The proximity of specific habitat (e.g. spawning habitat) to structural cover (pools, large woody debris, boulder clusters and overhanging vegetation) and hydrodynamic shear zones provide important refuge from predation and resting zones for energy conservation. Various life stages of important fish resources, such as salmonids, select areas of increased heterogeneity (Wheaton, et al. 2004), and suction dredging may affect this. Off-site effects of individual dredges may be minor, but downstream impacts may be of concern where dredges are closely spaced, chronic, and other human activities associated with dredging and natural conditions increase the potential for cumulative effects. However, no research has been dedicated to measuring the cumulative physical or biological effects of many closely-spaced dredges. Cumulative effects of dredging and other human activities deserve attention, particularly where reaches are dredged year after year. In many systems, dredging effects may be minor when considered in isolation, yet they may contribute to significant cumulative effects on important resources.

4.3.4 Dredging Effects on the Stream Benthic Community

Overview

Benthic and epibentic communities, such as diatoms, periphyton, and invertebrate organisms, are an important part of the stream ecosystem because they are one of the foundational components of the food web. Benthic communities and productivity can be altered, which can affect higher trophic levels (e.g., fish production) and other stream processes (e.g., organic matter processing).

This section begins with a discussion of dredging as a disturbance to the benthic community, including concepts such as disturbance frequency, extent, and recovery. It then addresses entrainment of benthic species, and finally addresses research specific to bivalves. No information was found related to the impacts of suction dredging on aquatic snails.

Disturbance to Benthic Habitat

Disturbance Frequency

Frequency of disturbance may keep assemblages in an early stage of development, affecting the assemblage of benthic and epibenthic invertebrate assemblages on and within the stream substrate. Robinson and Minshall (1986) examined the effects of disturbance frequency on invertebrates and periphyton. The richness and diversity of invertebrate species were reduced as disturbance frequency increased. These trends were evident for both seasons (summer and fall) and sites (open vs. closed canopy). No effects to the diversity of invertebrate species were displayed during the fall experiment; however, diversity was reduced at high frequencies of disturbance during the summer. Frequency of disturbance also had a significant effect on the absolute number of many insect species. Colonization of the benthos by less common species is impaired by increased disturbance. Periphyton biomass is negatively correlated to increased disturbance frequency in open canopy areas and frequently disturbed areas maintained low-standing crops at an open canopy site. These data suggest that disturbance frequency can directly influence the benthic community at the scale of individual rock "islands" by reducing invertebrate richness, total animal density, and periphyton biomass. Seasonality also plays a role in the effect of disturbance on species diversity.

Robinson and Rushforth (1987) observed no effect of disturbance frequency on diatom species diversity in open canopy sections of a 3rd order stream. However, species diversity significantly decreased as disturbance frequency increased in closed canopy areas. Frequent disturbance, by maintaining the community in an early stage of development, directly influences the diatom assemblage on rocks in streams.

Disturbance Extent and Recovery

Although direct disturbances to benthic invertebrate populations caused by dredging can be extreme, the effect is temporary and limited to the area immediately impacted by the dredging equipment. Bernell, et al. (2003) stated that invertebrate colonies situated in the riverbeds are almost entirely destroyed by suction dredging. Both Thomas (1985) and Harvey (1986) measured significant reductions in some benthic invertebrate taxa within 10 m of dredges that disturbed the substrate. In general, benthic invertebrates (Mackay 1992) and periphyton (e.g., Stevenson 1991; Stevenson and Peterson 1991) all rapidly re-colonize small patches of new or disturbed substrate in streams. Boulton, et al. (1991) felt that recolonization of tailings by hyporheic invertebrates (those living beneath the surface of the substrate) is probably also rapid. Abundance and general taxonomic composition of benthic invertebrates can be restored on dredge tailings four to six weeks after dredging (Griffith and Andrews 1981; Thomas 1985; Harvey 1986). However, these studies did not take into account that the tailings may be more susceptible to erosion.

Griffith and Andrews (1981) studied the effects of a small suction dredge on fishes and invertebrates in Idaho streams. Most of the recolonization of dredged plots by benthic invertebrates was completed after 38 days. Hall and Harding (1997), who observed suction dredge experiment in a marine environment, revealed some statistically significant effects: taken as a whole, the results indicated that the faunal structure in disturbed plots recovered (i.e. approached that of the un-disturbed controls) by 56 days. Harvey (1986) found that dredging significantly affected some insect taxa when substrate was altered. A recolonization experiment showed that numerical recovery of insects at dredged sites was rapid. In a study of dredging effects in an Alaskan stream, Royer, et al. (1999) found that density of benthic invertebrates was greatly reduced in the first 10 m downstream of the activity. Values returned to upstream composition within 80 to 160 m. USDI (1999) study of three Alaskan streams found short term decreases (during dredge operation) in numbers and diversity, with minimal long term (1 year later) impacts. Impacts depended on substrate size; harsh winters in Alaska were also an added factor for recovery.

However, many of these studies have been performed on streams where human impact is already present, utilized very general assessments of "similarity," and were somewhat short in duration. Fore, et al. (1996) discussed the importance of assessing rare or long-lived organisms as important tools for assessing anthropogenic impacts. The effects of suction dredging on rare, long-lived macroinvertebrate species, for instance, the presence or absence of a long-lived stonefly genus (e.g. plecoptera genus *Pteronarcys* spp.) (2-3 year life cycle), has not been well documented. Wright and Li (1998) found that chronic recreational impacts within the riparian zone affected caddisfly densities. These effects on caddisfly densities were apparent for instars 3-5, but effects were greater on earlier instars than later instars. In 1995, sites with low human use had significantly higher densities of *D. gilvipes* than those sites exposed to intense recreation.

Entrainment

Griffith and Andrews (1981) found mortality rates of entrained benthic macroinvertebrates varied by species and were generally low (<1% of over 3,600 individuals), but were highest among emerging mayfly species.

Many studies have observed increased feeding by juvenile anadromous and resident salmonids and adult resident salmonids below active suction dredging operations due to invertebrates becoming dislodged and floating downstream (Stern 1988; Thomas 1985; Hassler, et al. 1986; Harvey 1986). The action of stirring up the stream bottom by suction dredgers can temporarily expose invertebrates, making them readily available as forage for fish.

Effects on Bivalves

Harvey and Lisle (1998) state that where dredging moves substantial amounts of substrate occupied by aquatic mollusks, re-colonization would take longer. In general, freshwater bivalves have low dispersal rates and limited distribution. Many mollusks are not broadly abundant in river streams, may not have high dispersal rates, and may be influenced strongly by local events such as suction dredging.

Of particular concern is burial of bivalves from dredge tailings. A burial depth of 10 cm (4.0 inches) to 17.5 cm (6.9 inches) or more of sand or silt prevented 50% of mussels from emergence and resulted in eventual death. Disorientation of mussels (manually positioned on their sides during burial) reduces the ability of mussels to emerge (Marking 1979). In a study of suction dredging effects on short-term survival of freshwater mussels in Washington, Krueger, et al. (2007) found no obvious physical damage to mussels due to entrainment by suction dredge, and entrainment had no effect on mussel survival up to six weeks. However, burial by dredge tailings resulted in the death of a substantial percentage of the two mussel species studied, and no mussels were able to excavate from experimental dredge tailings. The spatial extent of such an effect would be limited to the areas excavated and buried.

Conclusions

Based on the literature reviewed, suction dredging can have substantial short-term and localized adverse impacts on local benthic invertebrate abundance and community composition. Over the long term, the effects from suction dredging are not evident after one year unless there is a very small population that is threatened or endangered. However, note that when discussing the extent of benthic disturbance and its recovery, the use of terms such as "minimal" and "rapid" is quite subjective. Some juvenile salmonids may spend 1 – 12 months in natal streams before emigrating. This would suggest that food and habitat within the dredging area may be affected from 8 – 100% of the residence time of an individual fish. Parameters such as food and cover quantity and quality can greatly influence energy reserves and hence growth, behavior, and metabolic processes such as smoltification.

4.3.5 Dredging Effects on Wildlife and Habitat

Overview

This section presents a literature review of the potential impacts from recreational suction dredging to wildlife, their habitats and associated riparian vegetation communities. For general analyses of wildlife habitats and vegetation communities, the most comprehensive body of information was used for the largest portion of California, the Sierra Nevada, from the *Sierra Nevada Ecosystems Project* (University of California 1996) as well as the *Southern California Mountains and Foothills Assessment: Habitat and Species Conservation Issues* (Stephenson and Calcarone 1999), which covers the southern portion of the state. The *Suction Dredging Activities Operating Pan Terms and Conditions for Programmatic Approval for Suction Plans of Operation DEIS* (USFS 2001) was also used, which covers Del Norte County. No other comprehensive body of literature occurs for the Klamath Basin area in northern California. Little to no specific research has been conducted on the effects of suction dredging to wildlife and their habitats. The majority of the specific data on impacts from suction dredging addresses fisheries, as discussed in the previous section. However, many of these impacts can be extrapolated to apply to amphibians, as well as anecdotal observations reported in various documents (USFWS 2002a, USFWS 2002b, Kuperferberg, et al. 2007). Impacts associated with suction dredging, such as camping and off-road driving to access the suction dredge area, can extrapolated from studies conducted on recreational activities and their impacts (Cole and Landres 1995, Knight and Cole 1995; Knight and Skagen 1986).

Because many vertebrates use multiple habitats in their search for primary constituent elements (food, breeding and refugia), it is often simpler to classify wildlife habitats than vegetation communities, which are typically classified by the dominant plant species. As a result, fewer wildlife habitats are identified in a given project area than plant communities. For example, in general, based on the California Department of Fish and Games Wildlife Habitat Relationships modeling, a total of 3 wildlife habitats describe the riparian areas in California - montane riparian, Valley Foothill riparian and desert riparian (CDFG WHR 1988). In contrast, riparian areas within the Sierra Nevada alone are comprised of approximately 7 vegetation communities under the Holland (1986) classification (David and Stoms 1996), with an additional 13 communities in Southern California (Stephenson and Calcarone 1999). These communities provide the essential habitat required by terrestrial and aquatic wildlife species, by stabilizing stream banks, providing shade that moderates the water temperature and algal growth, adding nutrients from plant materials and insects that fall into the stream, and "buffers" the littoral and upland habitats.

Species diversity is a function of diversity of abiotic and biotic conditions and is greatly affected by human use of the land (Soule and Orians 2001). The wildlife habitat quality of an area, therefore, is ultimately determined by the type, size, and diversity of vegetation communities present and their degree of disturbance. For example; as a plant community is degraded by the loss of understory diversity, creation of openings, or reduction in area, a loss of structural diversity generally results (Krebs 1985). Degradation of the structural diversity of a community typically diminishes wildlife habitat quality and usually results in a reduced ability to support a diversity of animal species. This degradation may occur from human related impacts, such as recreational suction dredging; however, such impacts, including soil compaction, chemical and bacterial pollution, litter, vegetation damage, and wildlife disturbance, to vegetation communities and wildlife habitats from recreationists have received little attention (Moyle et al 1996).

Impacts of suction dredging within riparian habitats include in-stream and off-stream effects. Within California, approximately 93 special-status wildlife species are associated with riparian habitats, ranging from obligate riverine (aquatic only) species, such as mountain yellow-legged frog (*Rana muscosa*), foothill yellow-legged frog (*Rana boylii*), Cascades frog (*Rana cascadae*) and yellow-breasted chat (*Icteria virens*), to riparian (aquatic and terrestrial) obligate species, such as arroyo toad (*Bufo microscaphus californicus*), California red-legged frog (*Rana draytonii)* and willow flycatcher (*Empidonax trailii*), to species using the upland habitats adjacent to riparian areas, such as western pond turtle (*Actinemmys marmorata*), Swainson's hawk (*Buteo swainsoni*), pallid bat (*Antrozous pallidus*), Townsend's big-eared bat (*Plecotus townsendii pallescens*), and western red-bat (*Lasiurus blossivillii*). Severe enough impacts to these occupied habitats can cause degradation at a level that would prevent sustainability of a population. The actions of suction dredging could result in direct and indirect impacts on both aquatic and terrestrial species. For example, direct impacts to species include: (1) direct mortality of individuals though (a) suction (eggs and larvae), (b) entrainment (all life stages), (c) wading (eggs and larvae), and (d) access to and from dredging sites (adults and metamorphs), and (2) lower productivity resulting from (a) habitat modifications and (b) prey base availability. However, for clarity, we have addressed issues according to instream effects and off-stream effects, both of which may lead to direct and indirect effects. Note that many of these topics have been previously addressed in Sections 4.3.2 through 4.3.4 above in the context of fish and invertebrates, and are also relevant here.

This section first discusses instream effects, primarily to amphibians, and then moves on to address off-stream effects of other suction dredge mining-related activities (e.g., encampments).

Instream Effects

Entrainment/Excavation

The potential for suction dredging to result in entrainment and excavation of aquatic organisms has been previously discussed. These actions may cause eggs, tadpoles, and recently metamorphosed amphibians, which are sensitive life stages, to be harmed through direct impact, or directly or indirectly affected by increased susceptibility to other stressors because of the physical displacement that results from entrainment. Harvey and Lisle (1998), although focusing on fisheries, cite that eggs adhered to rocks, such as those by foothill yellow-legged frog, are unlikely to survive the entrainment process. They also report that if young were to survive the passage through the dredge they would most likely suffer from predation and physiological stressors (Harvey and Lisle 1998).

Sedimentation

The majority of the references pertain to the effects on fisheries (Newcombe and MacDonald 1991; Wallace 1990; Gard 2002; Badali 1992, among others), which are discussed above under Section 4.3.3. However, populations of stream amphibians can be particularly sensitive to increased siltation because they inhabit the areas in between the loose, coarse substrates that comprise the typical streambed (Welsh and Ollivier 1998). Gillespie (2002) found that spotted tree frog (*Litoria spenceri*) tadpole growth and development were significantly reduced by increases of sediment and activities in catchments that increase sediment loads in streams. Disturbance processes that increase stream sediment loads may have contributed to the observed declines of *L. spenceri* and other lotic anurans in south-eastern Australia.

In California, several amphibian species have been identified as being directly impacted through the increase in sedimentation resulting from suction dredging. Sweet (2007) cites a USGS file report (Sweet 1992) in which the direct effects of mortality of the eggs and larvae of arroyo toad by sedimentation were described. Sweet (2007) also states that the sedimentation downstream of the dredging coats the sand and gravel on which arroyo toads feed by inserting their heads in the substrate and ingesting loose organic material such as detritus, interstitial algae, bacteria and diatoms (Jennings and Hayes 1994). USFWS (2002) cite that suction dredge mining may threaten California red-legged frog (*Rana draytonii*), based on evidence observed in red-legged frog occupied Piru Creek, Santa Barbara County, where heavy siltation caused by upstream suction dredging was documented. USFWS (2002b) states that disturbance to streambed substrates and water quality resulting from extensive suction dredging activity at or near a mountain yellow-legged frog (*Rana mucosa*) breeding site could have harmful effects on eggs and developing larvae. Hydrologic conditions and associated sediment loads during the spring breeding and summer larval rearing season are central to the conservation of foothill yellow-legged frog (*Rana boylii*) (Kuperferberg, et al. 2007).

Sediment increases in a stream in Northern California caused significantly lower densities of amphibians (Welsh and Ollivier 1998). Although the sediment effects were species-specific, reflecting differential use of stream microhabitats, the reflected decrease in densities by these species, such as tailed frog (*Ascaphus truei*), due to increased fine sediments on the streambed matrix is probably the result of their common reliance on the interstitial spaces in the streambed matrix for critical life requisites, such as cover and foraging (Welsh and Ollivier 1998). Other species that may be subject to similar effects and present in locations of suction dredging include arroyo toad, as described above, and foothill yellow-legged frog.

Sedimentation during the breeding season may be harmful to amphibians, but channel manipulation, although typically occurring in a dynamic stream corridor, may also impact amphibians if conducted during the breeding season (USFS 2001). Aquatic amphibian species have adapted their life cycles to correspond to natural seasonal water flow (USFS 2001); however, suction dredging displaces gravel, which causes the food (algae and diatoms) attached to the rocks to be unavailable to the larvae and some adults (more fully discussed above in Section 4.3.4). Although this may be a temporary and spatially limited effect, it may occur at a critical developmental stage, and, therefore, may have negative impacts on the organisms.

Changes in Channel Morphology

The changes to channel morphology as a result of suction dredging have been discussed in detail in Section 4.1, *Geomorphology*. Thomas (1985) identified changes in channel morphology after dredging in a stream in Montana, with gravel piles moving downstream after one year, and, in one instance, filling up a downstream pool. The filling of a breeding pool in a fast moving stream would mean a loss of habitat. Section 4.3.3 above discusses pool formation and loss in more detail.

The Stanislaus National Forest also reported on altered channel morphology due to suction dredging (Moore 2007). Dewatering in the channel occurred in places where the streamflow has been directed to the sluicebox. These areas of dewatering were occasionally or historically occupied by foothill yellow-legged frog (*Rana boylii*) tadpoles (USFS 2007). Dewatering may expose the tadpoles to unnatural conditions and increase predation. Adult salamanders, phillopatric (site faithful) within a stream channel, may be severely impacted by suction dredging through loss of interstices between the larger cobbles (Welsh and Ollivier 1998). Increased water velocities (as low as 10 cm/sec) caused negative reactions from *Rana boylii,* and caused 25% of the tadpoles studied to be displaced, with recently hatched tadpoles lethally affected (Kupferberg, et al. 2007).

Effects of Heavy Metals

Among various metals tested, Hg was found to be the most toxic to aquatic organisms, and organomercury compounds showed the greatest biocidal (destructive to life) potential (Eisler 1987). Lethal concentrations of total Hg to sensitive, representative organisms varied from 0.1 to 2.0 ug/l (Eisler 1987), with Anuran embryo-larvae reacting to doses between 2.4 to 67.2 ug/l (Lethal Concentration-50% mortality). Hg in the natural environment, as tested on American bullfrog (*Lithobates catesbeianus*), foothill yellow-legged frog (*Rana boylii*), and northern Pacific treefrog (*Pseudacris regilla*), showed no evidence of bioaccumulation (Hothem, et al. 2009). However, the elevated concentrations in bullfrogs may pose a risk to human health if the legs are consumed (Hothem, et al. 2009).

Studies conducted in higher vertebrates such as birds found Hg residues were high enough to predict ecotoxicological effects, but they fluctuated over the years (Suchanek, et al. 2008).

Off Stream Effects

Damage to Riparian Structure

As discussed earlier, riparian areas, including wetlands and meadows, comprise a total of 3 wildlife habitats, montane riparian, Valley Foothill riparian and desert riparian (CDFG WHR 1988) and, approximately 20 vegetation communities, including but not limited to Great Valley cottonwood riparian forest, Great Valley mixed riparian forest, Great Valley valley oak riparian forest, white alder riparian forest, aspen riparian forest, montane black cottonwood riparian forest, and montane riparian forest (Holland 1986, David and Stoms 1996, Stephenson and Calcarone 1999). These communities provide essential habitat for terrestrial and aquatic species by stabilizing stream banks, providing shade that moderates the water temperature and algal growth, adding nutrients from plant materials and insects that fall into the stream, and "buffers" the littoral and upland habitats. However, impacts to riparian communities from recreationists have received little attention (Moyle et al 1996).

That said, recreational impacts can have long-lasting damaging effects. For example, analysis of aerial photography in 1996 showed fragmentation of riparian corridors was usually associated with vehicular access, often originally from logging in a particular area but continued afterwards by recreationists (Kattelmann and Embury 1996). Bank erosion and channel widening were found to be more common around areas of concentrated use, such as campgrounds (Kattelmann and Embury 1996).

Direct impacts from suction dredging, such as excavation of stream banks, may also have long-lasting impacts, as stream banks are slow to rebuild (Wolman and Gerson 1978 *in* Harvey and Lisle 1998), and banks with vegetation removed saw increases in bank erodibility by 80% or more (Micheli et al 2004). Roots play a significant role in stream bank erosion and that woody vegetation provides better reinforcement of stream bank soils than herbaceous vegetation (Wynn 2004). Impacts are expected to be greater due to dredging where: (a) banks are and riparian vegetation are directly disturbed by suction dredging and related activities, (b) banks are composed of erodible alluvial soils, (c) channels are deepened along banks and (d) the roughness (large rocks, roots, and bank projections) or bank and bed are reduced, thereby increasing the hydraulic forces on the bank (Thorne and Furbish 1995 in Harvey and Lisle 1998). Lastly, the loss of riparian vegetation would have an impact on wildlife species that rely on riparian vegetation for food, forage and cover, and include amphibians, such as California red-legged frog, reptiles, such as western pond turtle, and nesting birds, such as willow-flycatcher, among others.

Encampments

Although localized impacts from recreation activities may be benign, problems arise when sensitive species population or their habitats coincide with high use recreation areas (Stephenson and Calcarone 1999). In general, campgrounds and encampments (long-term camping), such as those associated with suction dredging, can cause a variety of impacts.

Soil compaction, chemical and bacterial pollution, litter, vegetation damage, and fire ignition are impacts associated with recreational sites in riparian areas (Kattelmann and Embury 1996). Declines of wildlife populations due to activities associated with suction dredging, such as camping, have also been cited (Harvey and Lisle 1998, USFWS 1999, 2002a). In general, recreational activities can change the habitat of an animal, which can affect the behavior, survival, reproduction, and distribution of individuals (Cole and Landres 1995). Riparian-associated species may be impacted by the following factors: collision, displacement or avoidance, habitat loss and fragmentation, edge effects, snag or downed log reduction, increasing routes for predators/competitors, and disturbance at a specific site (Gaines, et al. 2003). Dumping of trash and toxic materials (soap, motor oil, Hg) associated with dredging operations can degrade water quality, and may have adverse effects on eggs and developing larvae (USFWS 2002b). Stern (1988) stated that recreational impacts, such as trails and campsites, should be planned and carefully constructed to avoid gully erosion, bank wasting and vegetation damage. In the Siskiyou National Forest, the USFS (2001) identifies that dredgers should camp within USFS-designated camping sites, and plans for human waste disposal should be made to reduce the impacts from recreational activities.

Rare plant species may also be impacted from encampments and habitat loss to a species through soil compaction, soil contamination, and physiologic changes to the environment, i.e. removal of canopy cover for a shade tolerant species may cause mortality or loss of a population. Unfortunately, plant species distribution records are incomplete or have been localized, such as floristic studies for Butte County or for portions of the National Forests (Shevock 1996).

Off-Road Use

Riparian associated species may be impacted by the following factors during off-road vehicle use: collision, displacement or avoidance, habitat loss and fragmentation, edge effects, snag or downed log reduction, increasing routes for predators/competitors, and disturbance at a specific site (Gaines et al 2003). Specifically citing effects to amphibians, Mahrdt, et al. (2002) and Sweet (2007) state that off-road vehicle use has contributed to the decline of the California arroyo toad (*Bufo californicus*). Off-highway vehicle use may directly kill herpetofauna and indirectly impact populations by creating migration barriers, destroying habitats, and increasing sedimentation and chemical contamination (Maxell and Hokit 1999). Other species are affected by associated recreational activities. For example, western pond turtles (*Clemmys marmorata*) nest in the upland habitats adjacent to the riparian corridor, and will overwinter up to 168 m from the channel (Brodie 2001). Off-highway vehicle use may crush nests and overwintering individuals and compact the soils, degrading the upland habitat. Encampments and off-road vehicles may affect raptor and passerine bird species, such as goshawks (*Accipiter gentilis*) and yellow-breasted chat (*Icteria virens*). These effects could include altered behavior, movements and distributions, increased nesting failure, and expenditure of critical energy reserves (Knight and Skagen 1986).

Summary and Information Gaps

The direct effects of suction dredging to eggs and larvae, primarily of salmonids, were identified in the 1994 EIR. Those effects can be further broadened to include direct effects to eggs and larvae of amphibians, not only from entrainment, but also from siltation, which could cause mortality and a reduction in foraging habitat, changes in channel morphology that may increase predation or reduce breeding habitat, as well as potentially creating a sterile movement corridor within a riparian community. Direct impacts from suction dredging, such as excavation of stream banks, may have long-lasting impacts, as stream banks are slow to rebuild. The indirect actions of suction dredging, such as encampments and off-road vehicle use, could affect both aquatic and terrestrial species, by causing fragmentation of riparian corridors, bank erosion and channel widening and direct mortality of individuals.

Based on this review, it may be important to adopt the 1994 fisheries watershed closure example and apply it to streams with known breeding amphibians and to those streams with potential habitat. In addition, to better understand the effects from suction dredging, several questions should be researched: (1) little is known about salamanders and suction dredging - what are the effects of suction dredging on salamanders and their habitat and can it cause a localized population decline? (2) what is the temporal scale of recolonization of the interstitial layers, with algae, bacteria and diatoms, on which tadpoles feed?, (3) can amphibians re-populate a stream course if dredging has been removed, and if so, what is the temporal scale?, (4) what are the impacts on terrestrial species from encampments, including nesting reptiles and birds?

4.4 Cultural Resources

4.4.1 Introduction

This section summarizes the available scientific literature related to the effects of suction dredge mining and associated activities on cultural resources. The potential effects of suction dredge mining addressed in this section include degradation of archeological deposits or historic resources, as well as the potential for conflicts with traditional Native American uses and sacred sites. Impact mechanisms could include exposure and damage to resources due to the movement of channel bed material during suction dredging activities and the trampling of deposits within the riparian zone or other areas frequented by suction dredge miners. Degradation of traditional Native American uses and sacred sites could occur through a variety of mechanisms, including changes to the stream system in terms of geomorphology, water quality, species and ecological systems, aesthetics, noise, etc.

In general, literature directly addressing the effects of suction dredge mining and associated activities on cultural resources is scarce; while the available literature is summarized, much of this section is instead focused on the characterization of the resources potentially affected by suction dredge mining activities. Therefore, the discussion below first addresses the definition of historical resources and the types of cultural resources that may be found in California's riverine systems. After that, the impacts of suction dredging are evaluated based on the available literature.

Definition of Historical Resources

According to CEQA, a historical resource can be an object, building, structure, site, area, place, record, or manuscript that has been determined to be significant in the architectural, engineering, scientific, economic, agricultural, educational, social, political, military, or cultural annals of California under one or more of the following criteria:

A. Is associated with events that have made a significant contribution to the broad patterns of California's history and cultural heritage;

B. Is associated with the lives of persons important in our past;

C. Embodies the distinctive characteristics of a type, period, region, or method of construction, or represents the work of an important creative individual, or possesses high artistic values; or,

D. Has yielded, or may be likely to yield, information important in prehistory or history (CEQA Section 15064.5[a][3]).

A historical resource is listed on or eligible for listing on the California Register of Historical Resources (California Register). The eligibility determination of a cultural resource is usually conducted by a professionally-qualified archaeologist (for archaeological resources), a professionally-qualified architectural historian (for historic-era architectural/ structural resources), or a professionally-qualified ethnographer (for places of importance to Native Americans).

Types of Cultural Resources

The types of cultural resources that might be found within or adjacent to riverways subject to suction dredge mining include prehistoric archaeological sites, historic-era archaeological sites, places of importance to Native Americans, and historic-era structural resources.

Prehistoric archaeological sites generally found along riverways include permanent or semi-permanent habitation sites, temporary camps or food processing localities, isolated artifacts, and human remains. Although it is less likely that these types of resources are located within the riverbed and the immediate area of impact of suction dredging, there is a high potential that prehistoric resources are located on the adjacent riverbanks and surrounding vicinity. Furthermore, there is potential for disturbance from historic-era mining to have buried prehistoric archaeological resources (Meyer and Rosenthal 2008).

Historic-era archaeological sites that might be present in the study area include remains associated with riverway activities, especially mining. Extensive historic-era mining activities began in California with the discovery of gold in 1848 on the South Fork of the American River. Historic-era mining sites and features are abundant in California, including those adjacent to the state's rivers and tributaries. Property types might include placer mining remains such as tailing piles and river diversions; water conveyance features such as ditches, flumes, and dams; and community remains including foundations, dugouts, and refuse deposits located along riverbanks and in the surrounding vicinity (Caltrans 2008).

Places of importance to Native Americans can be considered historical resources as "areas" or "places" determined to be significant in the "social" and "cultural annals of California" (CEQA Section 15064.5[a][3]). Defined as Traditional Cultural Properties (TCP) in the federal nomenclature, a TCP is generally significant because of its association with the "cultural practices or beliefs of a living community that (a) are rooted in that community's history, and (b) are important in maintaining the continuing cultural identity of the community" (Parker and King 1998). One defined TCP is a "Riverscape," or "a river and its environs, including their natural and cultural resources, wildlife, and domestic animals, associated with a historic event, activity, or person or exhibiting other cultural or aesthetic values" (King 2004). Riverscape analysis requires that the entire river system be holistically considered for the cultural values that it conveys for Native peoples, and includes contributing elements such as spatial organization, topography, vegetation, wildlife (including fish), water features, and sites, structures, and objects (Gates 2003).

Potential historic-era resources that might be located within areas of suction dredging include sunken vessels submerged within California's river system. The California State Lands Commission maintains a Shipwreck Database that currently identifies 1,547 recorded shipwrecks in California, of which about 70 are recorded in California's river system (California State Lands Commission 2009). The vast majority of the riverine resources are wood-hulled, Gold Rush-era vessels submerged within the Sacramento, American, Feather, Yuba, and San Joaquin rivers in Central California. Other historic-era structural resources that might be located in or immediately adjacent to California's rivers and tributaries include bridges, piers, seawalls, levees, or other structural elements.

Historic-era architectural resources are not typically found within riverways. Remnants of historic structures (such as building foundations that were formerly located within or immediately adjacent to rivers) have likely been destroyed by river flows or natural stream course alterations.

4.4.2 Effects of Suction Dredging and Related Activities on Cultural Resources

Overview

As mentioned above, while a great deal of information exists about the types and location of California's cultural resources, as well as the types of impacts that such resources may undergo, the range of information about suction dredging's specific impacts on cultural resources is extremely limited. Cultural resources were not addressed in the Department's 1994 EIR or 1997 Draft SEIR. The only known study pertaining specifically to the impacts of suction dredging on cultural resources was for a withdrawn Final EIS on small-scale suction dredging for Lolo Creek and Moose Creek in Idaho's Clearwater National Forest (USFS 2006).

The USFS 2006 EIS addressed both heritage resources (cultural resources) and Native American Treaty Rights and Traditional Uses (TCPs). A conventional cultural resources assessment was conducted for a study area that included a database and literature search, as well as a comprehensive on-foot survey along the banks of the creeks. Numerous potentially-significant cultural resources were identified, although none were formally evaluated for listing on the National Register of Historic Places (National Register). The study concluded that suction dredging has the potential to affect heritage resources along the creek banks during access and camping activities. It was also determined that excessive disturbance from previous mining activities may have covered prehistoric and historic-era archaeological resources within the water channels.

Furthermore, the analysis addressed the impact of suction dredging on Native American traditional uses within the study area. Tribal fishing access and traditional Tribal resources were determined to be compromised due to noise and the presence of non-tribal members. Tribal hunting and plant gathering activities were also determined to be compromised from suction dredging activities. Salmon was identified as an integral part of tribal religion, cultural, and physical sustenance; however, it was concluded that suction dredging would not affect the survival of any fish species. Consultation between the USFS and the local Nez Pierce Tribe was considered ongoing.

While literature specifically relating to cultural resources and suction dredge mining is limited, there is ample information regarding other activities along waterways and their impacts on cultural resources. Location-specific cultural resources studies (including those performed along waterways subject to suction dredging) have been completed throughout California. These studies consider the specific cultural resources located within a project area and the impacts of a particular activity on those resources. Because cultural resources are localized, comprehensive cultural resource studies are the most productive way to analyze specific impacts. However, quantifying this literature, much of which is considered "gray literature" due to the confidential nature of the location of cultural and traditional sites, is outside the scope of this analysis.

There is also a significant amount of literature regarding Native American places of importance and the relationship of natural resources to cultural landscapes. King's (2004) cultural Riverscape study and Gates' (2003) literature review and regulatory analysis for Riverscapes provide a detailed theoretical paradigm for evaluating Riverscapes and a location-specific investigation on the Klamath River in Humboldt County. The studies are examples of the data requirements and interpretive processes necessary to evaluate a Riverscape for the National Register, and, subsequently, for the California Register. King's study concluded that the Klamath River is eligible for listing on the National Register as a Riverscape with the contributing elements of water; fish, wildlife, and plants; valley floor and terraces; surrounding hill slopes and ridges; cultural uses and perceptions; and specific cultural locations.

4.4.3 Summary and Information Gaps

Archaeological Resources and Traditional Cultural Properties

Despite the paucity of literature addressing suction dredge mining and cultural resources, some precedent has been set for future analysis. First, the cultural resources assessment for the USFS 2006 EIS was completed by carrying out a traditional cultural resources study (including a database/literature search and a field survey) in order to draw conclusions about impacts to cultural resources within that study area. Secondly, cultural resources were identified within that study area, indicating that cultural resources can be located within areas of suction dredge mining. And, finally, using a holistic approach has been a functional tool for identifying places of importance to Native Americans that are potentially eligible to the California and/or National registers.

Historic-era Structural/Architectural Resources

While there is an abundance of information about historic-era structural and/or architectural resources (including maritime resources) located within or adjacent to California's waterways, there is no such literature regarding the effects of suction dredge mining, specifically, on these resources.

Conclusions

Because the range of information about suction dredging's impacts on cultural resources is extremely limited, wide data gaps remain in the literature. However, as noted above, there is one example that delineates an approach for future analysis of the impacts of suction dredging on archaeological resources and places of importance to Native Americans.

4.5 Mineral Resources

4.5.1 Introduction

Gold is the official state mineral of California. The history of gold mining in the state is intrinsically linked to the development of the western United States. Background on the history of gold mining in California is provided in the Activity Description. The focus of this section is to identify the distribution and quantity of extractable placer gold deposits in California and the quantity of gold extracted through suction dredge mining.

Gold naturally occurs in two types of deposits: lode or placer. Lode gold is found within solid rock, commonly as veins formed in quartz. Lode deposits were primarily mined from the mid to late 1800s to 1942 by underground methods. Placer deposits are sediments that contain a valuable commodity, in this case gold. Placer deposits can be unconsolidated surface sediment or much older consolidated buried sediments. Suction dredging recovers gold from sediment primarily from existing streams and rivers.

4.5.2 Overview of Placer Gold Deposits and Claims

Placer Gold Deposits in the State

Streams rich in gold include streams draining the Sierra Nevada, Klamath Mountains, and the Mojave Desert. Some dredging also occurs to a lesser extent within the Peninsular Ranges, Transverse Ranges, northern Great Valley, and Coast Ranges (California Geological Survey 2002a). Dredging is popular in the "Mother Lode Region" which includes the American, Bear, Calaveras, Consumnes, Feather, Merced, Mokelumne, and Yuba rivers. The majority of this area was mined during the mid 1850s, and again during the 1970s and 1980s (California Geological Survey 2002b; Clark 1972). Table 4-1 illustrates the magnitude of placer gold production from the Gold Rush period to 1968.

Table 4-1. Placer Gold Activity in California

Period	Ounces of Placer Gold Extracted
1848-1858	26,200,000
1859-1884	21,200,000
1885-1899	2,200,000
1900-1934	10,800,000
1935-1968	7,800,000
Total	68,200,000

Source: Churchill 2000

Most suction dredgers operate in rivers and streams that have been previously mined for gold, in some cases, several times. In 2001, approximately 600,000 ounces of gold were extracted from mines in California (California Geological Survey 2002a) but this does not include gold produced by suction dredgers because they do not report their production to the state.

Claims

In 1872, the General Mining Act authorized the prospecting and mining for economic materials, such as gold, platinum, and silver on federal public lands. Under this Act, all citizens of the U.S., 18 years or older, have the right to locate a lode or placer mining claim on federal lands open to mineral entry. The mining law opens up land in the public domain that has never been set aside for a specific use. Land dedicated for specific uses such as the White House lawn, national parks, or wilderness areas, is not subject to mineral entry. Land west of the Great Plains managed by the US Forest Service or the Bureau of Land Management, unless designated as wilderness area, is generally open to mining claims. In California, lands administered by the National Forests or the BLM (includes state park and other public lands) are available for prospecting (Demaagd 2009).

A miner may stake a 'claim' on public land which is meant to declare an exclusive right to extract minerals in the claim area. However, an individual miner does not require a personal mining claim to mine; mining on an existing claim is legal if permission is given by the claimant. Claims may be either patented or unpatented. Patented claims simply give the holder the right to mine on the claim, while a patented claim gives the holder outright ownership of the claim. Once patented, the claim area becomes private land and is unavailable for public use. (Environmental Working Group 2000)

There are four types of unpatented claims: (1) placer claims, (2) lode claims, (3) tunnel claims, and (4) mill site claims. An estimated 60,000 to 120,000 people engage in recreational placer mining, including use of pans and suction dredging, in the Sierra Nevada each year (U.S. Forest Service 2001). Much of this activity, including the majority of suction dredging takes place on unpatented placer claims.

Table 4-2 below shows the number of reported mineral activity notices or permits within national forest lands between 1997 and 1999 fiscal years.

Table 4-2. Number of Mineral Collection Permits and Notices for Plans to Conduct Mining Activities in National Forest Lands during 1997 and 1999.

National Forest	1997	1998	1999
El Dorado	80	29	45
Inyo	3	5	4
Lassen	43	42	0
Plumas	100	100	23
Sequoia	8	55	5
Sierra	164	144	24
Stanislaus	200	200	168
Tahoe	662	631	659
Lake Tahoe Basin	0	0	0
Toiyabe	0	0	0
Total	1,260	1,206	928

Source: Adapted from Table 5.4.a – Non-bonded operations (U.S. Forest Service 2001)

However, activity is not directly related to the number of mining claims in an area because many claims sit idle for years while in other cases, a single operation may tie up several claims.

4.5.3 Suction Dredge Gold Mining

The popularity of recreational suction dredging fluctuates with the worldwide price of gold. In the last 45 years, the price of gold quickly fluctuated from $100 per ounce in 1974 to a peak of approximately $850 per ounce in 1980 followed by a crash to $250 per ounce in 1999 and a recovery (to approximately $950 per ounce in 2009 as of July 2009 GoldPrice.org 2009) today.

In 2009, California Department of Fish and Game received over 3,600 applications for suction dredge permits. This reflects a gradual decline in this activity from previous years. In the 1980s, the California Department of Fish and Game received an average of approximately 9,070 applications for suction dredge permits per year. This spike in interest appears to be related to the spike in gold prices. However as gold prices decreased from their 1980 highs permit requests for the last 8 years have averaged just under 3,000 per year (see Figure 2-1).

As discussed in more detail in Section 4.6, *Socioeconomics*, no information could be located regarding the average or total amount of gold extracted from suction dredge mining.

4.5.4 Summary and Information Gaps

Commercial mines report annual gold and silver production to the Department of Conservation and pay a tax on the amount of gold and silver produced. There is no such requirement for suction dredgers to report how much gold they produce. However, there are businesses that will buy gold from suction dredgers and these businesses can be easily found on the internet or in local newspapers. Presumably, suction dredgers report money they receive for selling gold to the IRS. However, there is no documentation of the amount of gold suction dredgers recover per season.

4.6 Socioeconomics

4.6.1 Introduction

This section presents a summary of information identified during the literature review related to socioeconomics, organized by the following key topics:

- Expenditures by Recreational and Commercial Suction Dredgers
- Characteristics of Suction Dredgers
- Agency Costs for Cleanup of Suction Dredge Camps
- Taxes Paid on Gold Produced by Suction Dredging
- Revenue Generated by Dredge Permit Fees
- Economic Impacts of Suction Dredging on Local Economies
- Benefits to Suction Dredging Miners and Others from Improved Water Quality

The primary literature source available is the 1993 survey of miners conducted for the Department's environmental review of suction dredge mining regulations in the 1994 EIR. Other sources and individuals were consulted as appropriate.

4.6.2 Socioeconomic Impacts of Suction Dredge Mining

Expenditures by Recreational and Commercial Suction Dredgers

The literature review revealed that virtually all of the information available on expenditures made by recreational and commercial suction dredgers, including investments in equipment, costs to operate and maintain suction dredging equipment, trip expenses, and other annual expenses, is available from a 1993 survey of miners conducted for the 1994 EIR. Most, if not all, of the expenditure data found in subsequent studies referred to data produced by this survey.

The 1993 Department survey of over 4,000 individuals, which resulted in 2,000 returned surveys, produced the following expenditure information:

- The average investment in suction dredging equipment by those surveyed was approximately $6,000.
- Suction dredgers spent about $6,250 each on expenses per year, including expenditures on groceries, restaurants, motels, camp fees, and other living expenses. Based on an average of 35 days per year spent suction dredging, these expenditures suggest daily spending of $179.
- Suction dredgers reported spending about $3,000 each on gas, oil, equipment maintenance, and repairs to suction dredging equipment.

A study conducted by the Federal Energy Regulatory Commission (2006) estimated that gold mining in the downstream region of the Klamath River (i.e., downstream of Iron Gate Dam) generated total expenditures ranging from $451,350 to $586,350, based on 10,000 user days (all private, non-commercial) in Curry, Humboldt, and Del Norte counties . These expenditures and user days suggest daily expenditures ranging from $45-$59, substantially lower than the spending estimated by 1993 survey.

It should be noted that the Waldo Mining District collected economic information about suction dredge mining by distributing a questionnaire to miners in 2001. Although no detailed information was found on the results of this survey, the results were reportedly very comparable to the results from the 1993 Department survey (USFS 2001). The Waldo Mining District is located in southwest Oregon in the Illinois River Valley, which is situated in the Siskiyou National Forest.

Characteristics of Suction Dredgers

Similar to expenditure data, most of the information available about the characteristics of suction dredgers, such as average years of participation and frequency of participation in suction dredging mining activities, is available from the 1993 Department survey of suction dredge miners. This survey produced the following information:

- Of those surveyed, 9.6 percent considered themselves commercial dredgers and 90.4 percent considered themselves recreational dredgers.
- Suction dredgers spent an average of 35 days per year on suction dredging activities.
- While dredging, about 7 percent of suction dredgers reported occasionally staying in motels, 40 percent sometimes lived at home, 38 percent sometimes lived in recreational vehicles, and 61 percent camped out.
- Less than 15 percent of suction dredgers use a nozzle size larger than 6 inches. Most of these operators suction dredge on the larger rivers where an 8-inch nozzle is permitted.
- The survey indicated that 27 percent of suction dredgers were registered claim holders.

A 1983 field survey of dredge mining operations estimated that about half of the 317 dredge miners interviewed claimed to be recreational and the other half professional. Recreational miners, however, accounted for only 20% of total suction dredge mining effort and used smaller dredges than did professionals. According to the survey, suction dredge miners averaged 235 hours in mining activities per season (McCleneghan and Johnson 1983). It should be noted that the distribution of mining between recreational and professional miners has likely changed since 1983.

Agency Costs for Cleanup of Suction Dredge Camps

No information in the reviewed literature was available concerning the costs to local, State, and Federal agencies for cleanup of suction dredge camps. This lack of information points to the need to collect cost data directly from agencies responsible for cleanup of camps.

Taxes Paid on Gold Produced by Suction Dredging

Under Public Resources Code Section 2207(d)(4)(B), miners are assessed $5 per ounce of gold mined by any operator within the State to fund the remediation of abandoned mines. Revenue from this assessment goes to the State's Abandoned Mine Reclamation & Minerals Fund Subaccount of the Mine Reclamation Account (California Department of Finance 2009). According to the California Department of Mine Reclamation, the agency is unaware of any suction dredge operation paying this fee, although it was noted that failure to pay is a violation of the Surface Mining and Reclamation Act (SMARA) and subject to daily fines (O'Bryant, pers. comm.). To expand upon this, according to the California Department of Finance (Bralley, pers. comm.), tax revenues from suction dredge gold mining would fall into an "other" or "miscellaneous" revenue category. As such, any revenue in this category would include revenue from a variety of other activities, including jewelry sales, gold sold to retailers, and other things unrelated to gold in general. The State Board of Equalization confirmed that the tax records are not kept in a manner in which this specific data can be extracted (Bralley, pers. comm.).

Revenue Generated by Dredge Permit Fees

For 2009, dredge permit fees for residents are established at $47, and respective non-resident fees are $185.25. Approximately 3,200 permits are issued annually. The Department has acknowledged that the dredging program's fees are inadequate to cover the cost of the program. The Department has estimated that it costs an average of $450 to process the permits and to cover the costs of the program, which, if extrapolated to the approximate 3,200 permits, would result in an expenditure of about $1.4 million (California State Senate Committee on Natural Resources and Water 2009). According to McCleneghan and Johnson (1983), 12 percent of miners did not have Department suction dredge permits when surveyed in 1983.

Economic Impacts of Suction Dredging on Local Economies

Virtually all information available concerning the estimated impacts of suction dredging activities on local economies is based on information from the 1993 Department survey of suction dredge miners from the 1994 EIR. Even that survey produced little quantified information on local impacts, acknowledging that little to no data are available on the amount of income attributable to suction dredging.

According to the Department study, suction dredging affects local communities by providing additional income to businesses located near popular dredging areas because miners from outside the local area visit local communities to purchase goods and services.

Some suction dredgers live year round in these local communities while suction dredging, and therefore provide income to businesses in these communities throughout the year. This additional spending generates retail sales, income, and employment in motels, restaurants, and retail stores. Given the amount the surveyed suction dredgers annually spend, suction dredging can have significant impacts on small communities located in areas of high suction dredging activity.

Additionally, the Department survey and the resulting study produced the following information on the number of suction dredgers and expenditures related to regional/local impacts:

- In 1992, over 4,000 suction dredge permits were issued to recreational and professional/commercial suction dredgers. Many recreational suction dredgers probably spend more money on the activity than they receive in returns through recovered gold.
- The average investment in suction dredge equipment was about $6,000 per year.
- Suction dredgers spent, on average, about 35 days per year participating in suction dredging, expending about $6,250 per participant on trip-related items, including groceries, restaurants, motels, camp fees, and other living expenses.
- Suction dredgers spent, on average, about $3,000 a year on gas, oil, equipment maintenance, and repairs to suction dredge equipment.

Little information is available concerning the amount of income suction dredge mining directly produces for miners. Three articles in *The New 49er Newsletter* (McCracken 2003a, 2003b, and 2009), a publication of the New 49ers mining club based in Happy Camp, CA, provide anecdotal information on gold produced during three week-long group mining outings on the Salmon and Klamath Rivers. According to these articles, gold production ranged from about 3.5 grams to 1.0 ounce per miner. Average gross income per miner produced by this yield ranged from $110-$855 per week, suggesting daily income ranging from about $16-$122 per miner. It should be noted that these relatively large mining groups, ranging in size up to 22 miners, included several inexperienced miners, suggesting that average mining-related income for experienced suction dredge miners could be higher than income reported in these articles.

Benefits to Suction Dredging Miners and Others of Improved Water Quality

Changes in the Suction Dredge Permitting Program could affect recreation opportunities and related socioeconomic values if they result in changes in water quality conditions. Recreation activities that can be directly affected by water quality conditions include fishing, swimming, and other water-contact activities. Potential socioeconomic-related effects include changes in the patterns of recreation-related spending activity in businesses and local economies.

Based on a search of the internet and two economic values databases (Environmental Valuation Reference Inventory and Beneficial Use Values Database), numerous studies (e.g., Carson and Mitchell 1993; Hanemann, et al. 2005; and USEPA 1997) have addressed the willingness-to-pay of water body users for improved water quality conditions. In order to apply these or other willingness-to-pay values, however, the potential benefits to water quality (such as improvements in turbidity conditions, river hydraulics, and the presence of contaminants), will first need to be established.

4.6.3 Summary and Information Gaps

Though limited, the existing literature provides some information related to the socioeconomics of suction dredge mining. However, the primary information source, the 1993 Department survey, would be more helpful if it were updated to current conditions. In addition, sources other than suction dredger surveys would also be useful (e.g., camping study costs done for the state).

4.7 Recreation

4.7.1 Introduction

This section is organized as follows: it first presents background information on the approach to evaluating recreational impacts, it then provides some baseline statistical information about recreation along California's waterways, and, finally, it presents the findings of prior documents regarding the effects of suction dredge mining.

Recreation effects are evaluated by whether suction dredge mining activities would be likely to:

- alter visitor perception of the site or enjoyment of existing uses;
- eliminate or reduce existing uses, or provide new and/or beneficially modified uses;
- create or relieve conflicts between designated uses; or
- otherwise contribute to increases or decreases in use.

To evaluate these effects, empirical data on recreation activities and trends in California and existing recreation regulations were reviewed, in addition to information provided by mining clubs for prospective gold miners.

4.7.2 Recreation Effects of Suction Dredge Mining

Approaches to Evaluating Recreational Impacts

Recreational Placer Mining in the Oregon Scenic Waterways System (Bernell, et al. 2003) has an excellent discussion of the conceptual underpinnings for a recreational impact analysis related to suction dredge mining. The information presented below has been summarized from that report; however, the reader is encouraged to review Bernell, et al. (specifically pages 54-61) for a more complete discussion.

Before evaluating suction dredging's degree of influence on recreation, the characteristics of recreation should be understood, especially when evaluating recreation within public lands. Recreation characteristics include the recreation experience, conflicts between different recreation activities, conflict avoidance mechanisms, and, to a lesser degree, crowding and visitor capacity. Each of these characteristics varies according to the recreationist, recreation activity, and recreation site.

The recreation experience varies according to the goals of the recreator. Jacob and Schreyer (1980) summarized the four primary recreation goals that are most often at the root of recreation conflicts. These are:

- activity style – the various personal meanings assigned to an activity;
- resource specificity – the significance attached to using a specific recreation resource for a given recreation experience;
- mode of experience – varying expectations of how the natural environment will be perceived; and

- lifestyle tolerance – the tendency to accept or reject lifestyles different from one's own.

Recreation conflict often arises due to the following interpersonal and social values, as well as through direct and indirect contact between recreationists:

- differences in the expectations of what constitutes a quality experience;
- when users with a possessive attitude toward the resource confront users who perceive it as disrupting traditional uses and behavioral norms; and
- when a person who views a recreation place as unequaled confronts behaviors indicating a lower evaluation (Bernell, et al. 2003).

Conflict between motorized and non-motorized use is the most pervasive conflict found in recreation settings. Recreationists can avoid conflicts between users under three general mechanisms, as evaluated by Hammitt and Patterson (1991): displacement, redefinition, or rationalization. Displacement occurs when those who are dissatisfied with encounter levels or activities of other recreationists move to less-crowded areas, or choose not to visit in the first place. Redefinition involves redefining the encounter (and broader recreation) experience. For example, a rafter may expect a quiet wilderness experience on a busy summer weekend, and rather than leave the area, the rafter reevaluates his/her expectations. Rationalization occurs when a person voluntarily selects an area or activity, and then rationalizes conditions found as satisfactory.

Recreation effects can be experienced at the site of the activity and within a larger area. For example, a fisherman fishing downstream from a dredging camp may not see or hear the miners, but the fish he/she is trying to catch may be affected by the plume of sediment generated by the suction dredge.

Bernell, et al. (2003) conducted a survey of recreational suction dredgers in Oregon public lands to characterize the effects of suction dredge mining on other recreationists. Many recreationists contacted in the survey indicated they had never encountered suction dredge miners. However, where mining and non-motorized recreation occurred together, conflict attributed to the presence and actions of miners was fairly common. Most conflicts evaluated in the survey were related to noise, level of development, degraded ecological conditions, and differences in social values.

Recreation Along California's Waterways

Small-scale suction dredge mining is considered a recreational activity. To evaluate the effects of suction dredge mining activities on recreation, the volume of recreationists within the state must be understood. Suction dredge mining activities can occur on private and public lands, and many miners camp within public lands. The majority of suction dredge mining activities are conducted within public federal land. The U.S. Fish and Wildlife Service and a few state agencies conduct annual surveys of park usage. These surveys are summarized below.

Conducted since 1955, the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation is one of the oldest and most comprehensive continuing recreation surveys. This survey, coordinated by the U.S. Fish and Wildlife Service, collects information on the number of anglers, hunters, and wildlife watchers; how often they participate; and how much time they spend on their activities in the United States and in California. The surveys include information gathered from the U.S. Census Bureau, state and federal agencies, and non-governmental organizations. Information from the 1996, 2001, and 2006 surveys are shown in Table 4-3. Between 1996 and 2001, there was a decline in the number of anglers and hunters, while the number of wildlife watchers remained steady.

Annually, the California Department of Parks and Recreation (CDPR) collects information on the usage of state parks and recreation areas, in addition to other reserves, beaches, and monument areas. A *California State Parks System Statistical Report* is published each year. These statistical reports were conducted beginning in the 1961/62 fiscal year and are still conducted. The most current report is 2006/2007. It should be noted that the data presented in these reports underestimate recreational use due to lack of data from remote or rarely-used areas and areas operated by other agencies or organizations. Table 4-4 shows the findings from the 2001/2002 through 2006/2007 fiscal year reports. The reports indicate a fairly steady interest in camping and day-use of California's state parks.

The National Sporting Goods Association conducts statistical studies of sports participation to measure the number of individuals, frequency of participation, and average number of days of participation for various sports in a given year. According to the National Sporting Goods Association's *Sports Participation in 2007 – Camping* (2008), the average number of days for overnight camping was 13.42 in 2007 for California. This value is a useful for comparing an average camper to that associated with suction dredge mining.

Conducted by the U.S.D.A. Forest Service since 1960, the National Survey on Recreation and the Environment provides outdoor recreational trends and statistics every five years. While the results of the 2005 survey have yet to be released, the 2000 survey provides data on a variety of freshwater activities including swimming, kayaking, rafting, canoeing, wildlife and nature observation, and fishing. These statistics are provided at the national level, regional level (western states) and state level. Lakes, rivers and streams have always been of interest to recreationists and pressure on these resources is expected to continue to grow over time. As an example, on the national level, canoeing/kayaking has grown nearly tenfold since 1960, from 2.6 million to 27 million. In California during this period, the percentage of the state's population that participating in the following activities at least once during the year includes: swimming in lakes and streams (37.9%), visiting other watersides (besides beaches)(24.5%), viewing and photographing fish (22.1%), boat tours or excursions (20.1%), coldwater fishing (13.8%), anadromous fishing (5.7%), rafting (7%), canoeing (4.3%), and kayaking (4.4%) (Cordell 2004).

In addition to the annual surveys of recreationists in federal and state public lands, the number of suction dredge permits issued by the Department is probably the most important value to evaluate recreation effects even though permit applicants do not have to report where or when they plan to dredge.

Table 4-3. USFWS National Survey of Fishing, Hunting, and Wildlife-Associated Recreation in California (1996, 2001, 2006)

Year	**Fishing**		**Hunting**		**Wildlife watching participants***		**Total****
	Total Participants	***Average days per year***	***Total Participants***	***Average days per year***	***Total Participants***	***Average days per year***	
1996	2,722,000	14	515,000	14	2,362,000	10	7.1 million
2001	2,444,000	11	274,000	13	2,270,000	10	7.2 million
2006	1,730, 000	11	281,000	12	2,894,000	16	7.4 million

**= Includes only participants who travel and/or overnight for activity.*

***= Total includes wildlife watchers who participate within 1-mile of residence.*

Table 4-4. Data from CDPR's *The California State Park System Statistical Report 2001 - 2007*

Fiscal Year	**Total # of Properties**	**Total Acreage** (total miles of river frontage)	**Available Campsites**		**Non-Camping overnight facilities***	**Total Attendance**	**Attendance Breakdown**	
			Individual*	***Group***			***Day Use***	***Camping***
01/02	266	1,433,096.0 ac (292.1 mi)	15,142	227	590	85,537,217	78,619,687	6,917,530
02/03	273	1,460,697.0 ac (319.56 mi)	14,823	230	590	82,784,064	75,822,775	6,961,289
03/04	277	1,488,342.1 ac (316.34 mi)	14,795	262	583	82,028,457	75,015,737	7,012,720
04/05	278	1,505,571.9 ac (325.60 mi)	14,343	272	601	77,079,564	71,007,189	6,072,375
05/06	278	1,556,426.22 ac (326.6 mi)	14,187	258	621	76,130,726	69, 479,605	7,130,121
06/07	278	1,556,426.22 ac (327.2 mi)	14,264	262	643	79,828,629	71,807,812	8,020,817

**=decreases from 01/02 data due to errors in previous year's estimates, not actual losses in available sites.*

The Department's License and Revenue Branch retains licensing data which is organized by type and year. The LRB's index provides current data as well as historical licensing information for suction dredge permits dating back to the 1970s. This information is provided in Table 4-5. As shown in table 4-5, there was a dramatic spike in the number of permits issued between 1980 and 1981, with a steady decline thereafter.

Table 4-5. Department of Fish and Game General Suction Dredge Permit Issuance

Year	CA Resident (General)	Non-Resident (General)	Total
1976	3,981		3,981
1977	3,625		3,625
1978	3,818		3,818
1979	5,206		5,206
1980	12,763		12,763
1981	11,436		11,436
1982	9,380		9,380
1983	9,983		9,983
1984	9,408		9,408
1985	8,424		8,424
1986	8,876		8,876
1987	8,087		8,087
1988	7,544		7,544
1989	4,792	374	5,166
1990	4,174	337	4,511
1991	4,020	283	4,303
1992	4,038	362	4,400
1993	5,420	401	5,821
1994	5,064	427	5,491
1995	4,780	427	5,207
1996	4,213	407	4,620
1997	4,673	522	5,195
1998	3,718	400	4,118
1999	3,017	374	3,391
2000	2,727	393	3,120
2001	2,510	359	2,869
2002	2,541	385	2,926
2003	2,534	476	3,010

Year	CA Resident (General)	Non-Resident (General)	Total
2004	2,446	462	2,908
2005	2,451	480	2,931
2006	2,551	460	3,011
2007	2,408	476	2,884
2008	2,966	557	3,523
2009	2,901	550	3,451

Source: California Department of Fish and Game Historical Licensing Statistics –Special Licenses and Permits

The Department of Fish and Game conducted a two-month field survey of suction dredge mining operations during the summer of 1982 in the “Mother Lode” region of California (McCleneghan and Johnson 1983). The survey contacted 317 miners and conducted approximately 200 interviews and provided the following conclusions:

- 50% of those surveyed identified themselves as “recreational” miners;
- 87% of miners camped away from the dredge site (not in the riparian area); and
- 12% of miners interviewed did not possess a permit.

This survey only included suction dredge mining operations within the Sierra Nevada. As discussed in other sections of this document, suction dredge mining activities are conducted in other parts of the state.

Impacts of Suction Dredging

Suction Dredge Mining

As stated earlier, suction dredge mining is primarily a recreational activity. Especially when conducted on public land, recreational activities are required to respect the land and its natural resources. Public land managers, including the Bureau of Land Management (BLM), U.S. Forest Service, and the Department provide educational materials and training to encourage protection of natural resources. Additionally, federal and state agencies impose regulations on recreational activities to further ensure that natural resources will be protected by recreationists.

Recreationists themselves promote protection of natural resources and access and use of public lands. Many gold prospecting clubs attempt to educate club members and the general public on proper methods of gold extraction while protecting resources and abiding by regulations. Perhaps the most popular organization that promotes suction dredge gold mining is the New 49’ers. The New 49’ers is a gold prospecting organization that operates in Northern California. The club provides members with access to over 60 miles of mining claims along the Scott, Salmon, and Klamath Rivers, and some of their tributaries in Siskiyou County. Many different gold recovery methods are employed by club members, including suction dredging. The New 49'ers maintains a list of operation rules that members must abide by when operating on club mining sites (i.e., mining claims on property maintained by the club). Among these are requirements to obtain and abide by all regulations stipulated in the suction dredge permit, and to comply with other miscellaneous rules of conduct. This includes limitations on camp duration, recommended setbacks from access ramps and popular swimming holes, maximum density levels, hours of operation, preservation of riparian and stream bank areas, the removal of all equipment and supplies once finished, as well as the use of existing trails and pathways for access. These club rules were created to maintain positive relationships with other recreational users and regulating authorities. However, the clubs have not provided any information in regard to either compliance with club rules or DFG permit restriction club members; consequently, overall all compliance is unknown.

Recreation Experience

Changes in recreational use and their effects on recreational visitors (noise, recreational quality) were analyzed in USFS (2006) as potential impact mechanisms related to suction dredge operations. The 2006 FEIS concluded that minor impacts may result where other water oriented activities encounter suction dredging. It was also noted that the physical appearance of suction dredges and engine noise may detract from the recreational experience for other recreationists. However, the document assessed this to be a less than significant impact (minimal to no change), given the restricted area and seasonal duration of suction dredging relative to the overall area open to all recreational users. The document also noted that short-term benefits to fishermen may be experienced from increased feeding related to dislodgement of insects by dredgers.

Dean Swickert, representing BLM, provided testimony related to observations of suction dredging to the California Assembly Committee on Water, Parks, and Wildlife (WPW) in 1994. The testimony identified concerns related to observed conditions of mining encampments on BLM lands. Mr. Swickert notes that trespass and health and safety violations are the primary issues of concern when BLM staff are summoned to suction dredging sites. Swickert noted that approximately 50-100 BLM cases a year are related to suction dredge mining trespass in BLM lands throughout 19 California counties. Mr. Swickert stated that he has observed territorial disputes between miners and land-owners citing that miners trespass on private land. It was observed that miners, whether on private or public land, are territorial and intimidate others. This practice of illegal use of private land and intimidation on public lands is a concern to BLM and recreationalists. The commenter observed that the encampments often pose hazards to the surrounding area due to unsanitary conditions and irresponsible treatment of equipment and hazardous or flammable materials. Additional concerns were raised regarding the likely destruction of public and private lands for hunting, firewood, and other subsistence needs.

Recreation Conflicts

The 1994 FEIR and 1997 DEIR recognized that suction dredgers and their associated campsites may conflict with other recreational user's expectations and enjoyment of quiet settings and natural areas as a result of aesthetics, sanitation, noise, garbage, and air pollution concerns. However, these documents do not clearly identify the level of impact associated with the suction dredge activities or campsites, concluding that these conflicts lie beyond the jurisdiction of the Department. The documents note that some national forest areas limit the number of campsites and vehicles allowed at popular suction dredging rivers in an effort to reduce conflicts between miners and other recreational users. These documents identify rafters as being perceived as the recreational group most in conflict with suction dredge activities, citing noise and aesthetic effects associated with dredgers and equipment, as well as dangers related to snagging on floating equipment/cables as major concerns.

In addition to concerns raised by rafters, the 1994 EIR and 1997 Draft SEIR cited that individuals involved in fishing activities perceived that they were being intimidated. Such feelings were related to the perception that suction dredgers believe that they hold exclusive rights to particular sites (which are often made inaccessible to others). Also, stationary fishers (those not in boats) were concerned about the effects of dredging operations, such as reduced fishing success from noise-related effects on fish, decreased recreational experience from noise and air quality associated with gas-powered motors, and safety hazards from equipment use and practices (dredge holes, gas leaks).

Bernell, et al. (2003) analyzed recreational conflicts related to suction dredging activities conducted in Oregon. Complaints from other recreational users cite issues related to access barriers, intimidation issues, noise, aesthetics, and safety hazards related to suction dredge operations. However, the information presented suggests that the main issues recreationists have with suction dredging are that they find it to be annoying and a nuisance, perceptions that are primarily influenced by conflicts with the receptors' recreational goals and social values (i.e., attitudes toward suction dredging as a recreational activity). This disparity between perception and scientific literature is made by comparing regulatory agency findings (no significant effects when operating under prescribed regulations and rules) and findings that indicate that suction dredging has a disproportionate effect on recreational users than other activities. The study also finds that miners view their activities as recreational and tied to history, and are often unaware of their impact on other recreationalists.

To substantiate the level of conflict and illegal operation claimed by opponents of suction dredge miners, Bernell, et al. (2003) reviewed state police logs and Oregon Department of State Lands monitoring reports. It was found that 0.05% of police hours spent reporting to calls on scenic rivers were related to suction dredge mining activities. The remaining 95.5% of hours were spent addressing calls of various unrelated issues. Out of more than 1,500 reported contacts with river users, including suction dredge miners, 130 people were found to be in non-compliance with some type of law, regulation, or permit. Approximately half of the suction dredge miners encountered did not have a current permit to conduct dredging activities. However, BMPs and permit requirements were adhered to by over 80% of miners, including non-permit holders, during the survey years of 1997-1998.

4.7.3 Summary and Information Gaps

Evaluation of recreation effects due to suction dredge mining involves multiple variables. In order to properly assess potential effects on recreation usage, the recreation experience, recreation conflicts, conflict avoidance, and other secondary effects of recreation, additional and current information on recreationists and suction dredge miners is needed.

The available data on recreation activities in California and on suction dredge mining was reviewed. However, information regarding the numbers of suction dredge permits issued by the Department from 1997 to present would provide a more complete description of suction dredge activities and trends in California. Additionally, evaluation of the current number of suction dredge participants compared against the total number of recreationists and the location of recreation activities would assist in determining the level of effects on all parties. Data on the level of suction dredge mining activities conducted on both private lands, and unpatented claims, would provide the most accurate portrait of this recreation activity. However, private landowners are not required to report activities conducted on their land, so unless they report illegal mining activities, this information is not likely attainable. An approximation based on the mining claims and private land holdings of gold prospecting groups would provide at least some understanding of suction dredge activities on private land.

More detail and examples are needed to characterize the effects of suction dredge mining activities on the recreation experience of water users and campers. The influence of noise and aesthetic values resulting from mining operations are evaluated in other sections. However, more detail about the influence of mining operations on public enjoyment of federal, state, and local parks and on other mining operations is needed.

Similarly, more detail is needed to evaluate potential recreation conflicts and their degree of effect on other recreationists. The majority of the literature reviewed on this topic contains observations that are over 10 years old or from a different state (Oregon). Suction dredge mining technologies have advanced, and the public is generally more sensitive regarding natural resources. As such, the issues and concerns noted previously may not apply to current suction dredge mining practices or conflict with other recreation activities.

Along the same lines, current data on the number of public complaints and response by regulatory agencies, including federal, state, and local agencies, would assist in characterizing the degree of recreation conflict with suction dredge mining.

4.8 Aesthetics

4.8.1 Introduction

The aesthetic value of an area is a measure of its visual character and quality, combined with the viewer's response to the area (Federal Highway Administration 1983). The scenic quality component can best be described as the overall impression that an individual viewer retains after driving through, walking through, or flying over an area (U.S. Bureau of Land Management 1980). Viewer response is a combination of viewer exposure and viewer sensitivity. Viewer exposure is a function of the number of viewers, the number of views seen, the distance of the viewers, and the viewing duration. Viewer sensitivity relates to the extent of the public's concern for a particular viewshed.

With respect to suction dredge mining, the primary activities which could have aesthetic effects include the mining activities themselves (including the presence of the suction dredge rig on the landscape, changes in water clarity downstream, etc.), and suction dredge miner encampments.

4.8.2 Aesthetic Effects of Suction Dredging and Related Activities

The literature reviewed addressed mining activities themselves, as well as suction dredge encampments. The literature also generally addressed aesthetics within the framework of the larger topic of recreation and recreational conflicts. Two broad categories of literature were found: site-specific information/accounts, and more general analysis.

The following site-specific information was found relative to suction dredge mining:

- Reedy (2007), in a comment letter to the Department, identified concerns related to observed destruction of banks and riparian habitats. These impacts were believed to result from violations of the existing suction dredge permit regulations and were considered by the South Yuba Citizens League to be inconsistent with the "wild and scenic" designations of such rivers. The photos show damaged bank areas; however, no "before" photos were included to compare against these images, and the information presented does not appear to be conclusive.

  The comment letter also included a second letter containing additional description of camping areas and dredging sites. The commenter related that he has conducted monthly water testing in the same location for approximately 6 years and has monitored permanent campsites and what are believed to be long-term effects on the surrounding area. The commenter observed that the camp site is only occasionally used, and equipment, including hazardous materials, seems to be abandoned during non-dredging seasons. The presence of the campsite and accessories, in combination with riparian damage, left the commenter with feelings that the aesthetic quality of the area had been deteriorated. Similar to Reedy's main comment letter, this information was based solely on personal observation and speculation that damage to the riparian area was likely related to non-compliance with existing regulations.

Direct contact with suction dredge miners was not conducted by either observer to verify the practices of the miners working the site. However, these comments provide personal accounts and photographic displays of how mining operations can aesthetically impact other park users.

- The Sierra Fund (2009) contains findings based on interviews with federal land managers and public records regarding recreational suction dredge mining in the Sierra Nevada. While the main focus of the document is on the effectiveness and enforceability of current regulations, it also provides photographs of encampments that can be evaluated aesthetically. The photos show encampments that were cited for health and safety reasons, as well as for their illegal use or storage of materials and machinery.
- In the court case United States of America v. Shumway (1999), the court addressed the definition of "junk" when referring to miners' encampments. In the case, the USFS had issued a complaint against miners who occupied a claim on forest land, citing the "junk" of additional equipment and chemicals used as reasons why the defendants should be removed from the site. The USFS charged that these items were a substantial change to operations, and that the miners had made this change without providing the required prior notification to the USFS. In regards to the items on the property, the court ruled that there needed to be an evaluation made by individuals with personal knowledge and other substantive evidence as to the value and use of the materials. In other words, the court determined that the materials at the site could not be deemed "junk" based on appearance alone and without formal evaluation. One judge noted that equipment may be "old, battered and rusty, yet still be entirely serviceable, particularity for small operators. It is hardly junk."

It is likely that other anecdotal accounts, such as those presented in Reedy (2007) and Sierra Fund (2009) are available to support an aesthetic analysis.

In terms of more general analysis, the following findings are relevant:

- The *Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho Final Environmental Impact Statement* (USFS 2006) concluded that dredging activities would not result in changes to visual quality objectives and stated that public views by land recreationalists are partially obstructed due to topographic and vegetative screening. The FEIS asserted that minor impacts may result where water-oriented activities encounter suction dredging, as it was noted that the physical appearance of suction dredges may detract from the recreational experience of other users. However, the document assessed this to be a less than significant impact, given the restricted area and seasonal duration of suction dredging relative to the overall area open to all recreational users.

- The Department's 1994 EIR recognized that suction dredgers and their associated campsites may conflict with other recreational users' enjoyment of quiet settings and natural areas. However, this document did not clearly identify the level of impact associated with the presence of miners or their campsites. It does mention that some national forest areas limit the number of campsites and vehicles allowed at popular suction dredging rivers in an effort to reduce conflicts between miners and other recreational users.

- Bernell, et al. (2003) suggests that a viewer's aesthetic experience of suction dredges and their campsites is primarily influenced by the receptor's recreational goals and social values (i.e., attitudes toward suction dredging as a recreational activity).

- The New 49ers is a gold prospecting organization that operates in Northern California. The club provides members access to over 60 miles of unpatented mining claims and private land along the Scott, Salmon, and Klamath Rivers, and some of their tributaries in Siskiyou County. Many different gold recovery methods are employed by club members, including suction dredging. The New 49ers provides its 1,300+ members with a listing of operation rules they must abide by when operating on club mining sites. Among them are requirements to maintain camp and work sites in orderly and sanitary conditions, and to obtain and abide by all regulations stipulated in the suction dredge permit. This includes the preservation of riparian and stream bank areas, the removal of all equipment and supplies once finished, as well as the use of existing trails and pathways for access. These club rules were created to maintain positive relationships with other recreational users and regulating authorities. It should be noted that these rules apply only to members operating on club property.

4.8.3 Summary and Information Gaps

Though limited, the existing literature provides information related to the potential aesthetic effects from suction dredge mining. Anecdotal information suggests that particular dredge mining operations and encampments may have adverse aesthetic effects, particularly when they are in violation of applicable regulations. However, such determinations may be subjective, as was suggested in United States of America v. Shumway (1999). In terms of general conclusions, the literature suggests that the perception of aesthetic impact is variable based on the viewer group, although density and crowding play a role in the viewer's experience. Recreational mining groups do provide some guidance to miners intended to minimize the negative aesthetic effects of suction dredging activities.

4.9 Air Quality

4.9.1 Introduction

Air emissions from suction dredging can result from the following three activities:

1. Operation of the engines which are part of suction dredges;
2. Operation of other equipment associated with suction dredging, such as generators used at suction dredge encampments; and
3. Use of personal vehicles in transit to and from suction dredge sites, including the hauling of suction dredges.

Internal combustion engines are the typical source of power on suction dredges. There are a number of popular internal combustion engine makers, including Honda, Briggs & Stratton, Kohler, and Tecumseh (Ralph N.D.). The size of the engine varies, ranging from 2.5 to 36 horsepower (HP); some suction dredges may contain multiple engines (Keene 2008; DoradoVista, Inc. N.D.). The application form for obtaining a suction dredging permit in California includes a space to provide information regarding the applicant's suction dredge. However, provision of such information is not mandatory, and no comprehensive, definitive data exists that describes the range of engines used for suction dredging in California.

No literature has been found that provides specifics regarding the types or extent of equipment used at suction dredge encampments, or the extent of use of personal vehicles for suction dredging-related activities (such as distance travelled).

4.9.2 Air Quality Effects of Suction Dredging and Related Activities

Roughly half of the air pollution in the U.S. is caused by on-road and non-road engines (Border Center N.D.). These mobile sources of air pollution include cars, trucks and buses, as well as the wide range of gasoline and diesel engines found in non-road equipment such as those used for suction dredging. The air pollutants emitted by mobile sources include particulate matter, volatile organic compounds, air toxics, and oxides of nitrogen.

The U.S. Environmental Protection Agency (USEPA) establishes emission standards under the federal Clean Air Act for small non-road engines such as those used for suction dredges or other suction dredge-related equipment (e.g., generators) (USEPA 2008). The California Air Resources Board (CARB) has taken initiatives to further control emissions from most mobile sources, including small engines (25 HP or less) (CARB 2009a). In addition, the CARB and local air districts are responsible for developing clean air plans to demonstrate how and when California will attain air quality standards established under both the federal and California Clean Air Acts. For the areas within California that have not attained air quality standards, the CARB works with air districts to develop and implement State and local attainment plans (CARB 2009b). These attainment plans contain a baseline emissions inventory, which includes mobile source emissions (including both personal vehicles and non-road engines). As such, emissions from suction dredging-related activities are considered to be part of relevant attainment plans, and would not conflict with these plans.

In terms of emission quantities, the USEPA has published emission factors for use in calculating the emissions from non-road engines (USEPA 2002). These factors vary based on the standards in place at time of engine manufacture, engine size and characteristics, and emission control features. The emissions factors are multiplied by the engine's horsepower and duration of use to quantify total emissions. The Department's 1994 EIR provided some information regarding the total hours spent suction dredging; however, due to the wide variety of non-road engines used as part of suction dredging, quantifying total emissions would be difficult.

Three available environmental compliance documents (the Department's 1994 EIR and 1997 draft SEIR, and USFS 2006) made conclusions regarding the potential air quality impacts from suction dredging. In the 1994 EIR and 1997 draft SEIR, the Department concluded that exhaust from these engines may cause short-term air pollution in a confined canyon with little air movement, but that when considered on a state level, the impacts were less than significant. USFS (2006) specifically addressed a rural study area in Idaho, where suction dredging regulations specify a minimum 100-foot spacing between individual suction dredge operations. The document concluded that emissions from these engines would have negligible impacts, considering the remote, unpopulated location and the spacing requirements.

4.9.3 Summary and Information Gaps

No prior studies have quantified emissions from suction dredging, although some data exists by which such emissions could be quantified. Several prior environmental analyses have concluded that emissions from suction dredging are not a significant concern. This conclusion is affirmed by the regulatory environment, under which emissions from suction dredge-related equipment have been considered in relevant air quality plans, and hence does not conflict with such plans.

4.10 Noise

4.10.1 Introduction

Suction dredging's primary noise source is the engine used to power the pump (and air compressor, where applicable). In addition, suction dredge miners may use equipment at their encampments that generates noise, such as electrical generators. Those who would be subjected to noise (i.e., receptors) include miners and others, primarily recreationalists, who may be in proximity to suction dredge mining-related activities. The effects of noise on wildlife are discussed in Section 4.2, *Biological Resources*.

In general, existing literature does not contain quantitative information related to the noise levels associated with suction dredge mining operations. The exception is the Final EIS for Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho (USFS 2006), described in more detail below. In addition, one other document, *Recreational Placer Mining in the Oregon Scenic Waterway System*, provides qualitative information relating to the topic (Bernell, et al. 2003). Bernell, et al. (2003) was prepared for the Oregon Parks and Recreation Department to provide information to assist the state legislature in its decision to allow or ban recreational gold dredging in scenic waterways. No information was found in the literature regarding the noise associated with suction dredge encampments or other suction dredge-related activities.

4.10.2 Noise Effects of Suction Dredging and Related Activities

USFS (2006) identified the following noise levels associated with the operation of an 18-horsepower Briggs and Stratton gasoline-powered engine:

Table 4-6. General noise levels of 18 hp engines

Distance (meters)	Decibel level
4	85
50	63
100	57
150	53
300	47

The document also adapted information from Harris (1979) to provide a reference for ambient noise levels associated with natural and wild land settings, which were cited as varying from 25 decibels (dB) (quiet wetlands) to 75 dB (developed recreation areas). Based on this information, the USFS concluded that suction dredging noise would result in only slightly -elevated noise levels above ambient.

Bernell, et al. (2003) suggested that the issue of suction dredge noise is primarily influenced the receptor's recreational goals and social values (i.e., attitudes toward suction dredging as a recreational activity) and the environmental setting. Receptors who are seeking a quiet experience of nature or who do not support suction dredging may perceive the noise as an annoyance and nuisance. In particular, suction dredging was noted as having a disproportionate effect on non-motorized recreational users, in contrast with motorized forms of recreation such as power-boating, which also generate noise.

4.10.3 Summary and Information Gaps

While the quantitative analysis prepared in USFS (2006) suggests that the noise levels associated with suction dredge mining are not substantially different from the overall ambient noise environment in the areas where dredging occurs, Bernell, et al. (2003) points out that the predisposition and expectations of receptors are likely to color an individual's perception of the noise.

In terms of data gaps, although the literature does include some information detailing the noise levels associated with an 18 hp engine, many other engine sizes and types exist. As such, the noise output from suction dredging may be highly variable. Additional information regarding the noise generated from other suction dredging-related activities, such as camping, would also be useful.

Section 5
REFERENCES CITED

Note that references are listed once but may be cited in many sections.

Section 1. Introduction

California Department of Fish and Game (CDFG). 1997. Adoption of Regulations for Suction Dredge Mining. Draft Environmental Impact Report. State of California, Resources Agency. April.

California Department of Fish and Game (CDFG). 1994. Adoption of Regulations for Suction Dredge Mining. Final Environmental Impact Report. State of California, Resources Agency. April.

Kitchar, T. (CDFG). 2007. California Regulatory Notice Register 2007, Volume No. 42-Z 1784: Suction Dredge Mining EIR. December 17, 2007.

Superior Court of Alameda. 2006. Order and Consent Judgment in the Karuk Tribe of California v CDFG. Case No. RG05211597. Cave Junction, OR. December 26, 2006.

Section 2. Activity Description

California Department of Fish and Game (CDFG). Index to Historical Sales Data/ Licensing Statistics. Special Licenses and Permits – Number Issued, for the 10_yr, 1990s, 1980s, and 1970s. http://www.dfg.ca.gov/licensing/statistics/statistics.html.

California Division of Mines and Geology. 1970. Gold Districts of California Bulletin 193.

Doolittle, J.E. 1905. Gold Dredging in California. California State Mining Bureau, Bulletin No. 36. San Francisco, CA. 24 June 2009 <http://books.google.com/books?id=PpBBAAAAIAAJ&pg=PA10&lpg=PA10&dq=first+power+driven+gold+dredges+ca&source=bl&ots=wfQ-Dhl_re&sig=xZdP0898vITq70g6lGa048Gm1Yo&hl=en&ei=UK9CSr7bA4LWtgOk2MDLDw&sa=X&oi=book_result&ct=result&resnum=1>.

Dorado Vista, Inc. No Date. Dorado Vista Website “Using the Suction Dredge”. 24 June 2009 <http://www.doradovista.com/DV_Gold_Dredge.html>.

Griffith, J.S., D.A. Andrews. 1981. Effects of a Small Suction Dredge on Fishes and Aquatic Invertebrates in Idaho Streams. North American Journal of Fisheries Management 1(1): 21-28.

Heavy Metal Mining Company. 1992. The Modern Gold Dredge. 24 June 2009 <http://www.goldminersdredgershq.com/FORMS/modern1.htm#Anchor-a5>.

Herschbach, S. 1999. Steve's Mining Journal. 26 August 2009. <http://www.akmining.com/mine/jour106.htm>

Keene Engineering, Inc. 2008. 2008 Product Catalogue.

Keene Engineering, Inc. 2008. Keene Engineering Website "The Gold Dredge". 24 June 2009 <http://www.keeneengineering.com/pamphlets/howdredge.html>.

Koons, Ray. 2004. New 49ers Website "Operational Guidelines for Members and Guests". Last revised May 24, 2004. 24 June 2009 <http://www.goldgold.com/rules.htm>.

McCraken, Dave. 2008. New 49ers Website "Suction Dredging". 24 June 2009 <http://www.goldgold.com/dredging.html>.

New 49ers. 2009. New 49ers Website "Join Form". 27 August 2009. http://www.goldgold.com/joinform1.htm

NorCal History. 2008. California Gold Rush Relief Map. 24 June 2009 <http://en.wikipedia.org/wiki/File:California_Gold_Rush_relief_map_2.jpg>.

Ralph, Chris. 2009. "Suction Dredging for Gold Nuggets". 24 June 2009 <http://nevada-outback-gems.com/basic_prospecting/Dredging.htm>.

Sierra Fund. 2009. Compliance with Suction Dredge Mining Law on Federal Land in the Sierra Nevada. July 15, 2009.

U.S. Forest Service. 2006. Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho – Final Environmental Impact Statement. Clearwater National Forest, Lochsa and North Fork Ranger Districts. Clearwater County and Idaho County. December.

Section 3. Methodology

California Department of Fish and Game. 2009. California Natural Diversity Data Base (CNDDB). <http://www.dfg.ca.gov/biogeodata/cnddb/cnddb_info.asp>.

California State Office of Preservation. 2009. California Historical Resources Information System (CHRIS). <http://ohp.parks.ca.gov/?page_id=1068>.

State Water Resources Control Board (SWRCB). 2007. Notice of Public Workshop on Suction Dredge Mining. Division of Water Quality. May 15, 2007.

U.S. Fish and Wildlife Service. 2009. Endangered Species Listing Program. <http://www.fws.gov/endangered/listing/index.html>.

Section 4. Impacts of Suction Dredging

4.1 Geomorphology

Alpers, C.N. 2007. Comment Letter - Suction Dredge Mining. Comment letter summarizing research related to mercury in CA. USGS. Sacramento, CA.

Bilby, R.E., and P.A. Bisson. 1998. Function and Distribution of Large Woody Debris. In, River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. R.J. Naiman and R.E. Bilby eds. Springer-Verlag New York, Inc.

CVRWQCB. 2008. Sacramento - San Joaquin Delta Estuary TMDL for Methylmercury. Staff Report. February.

Gilbert, G.K. 1917. Hydraulic mining debris in the Sierra Nevada. U.S. Geological Survey Professional Paper 105.

Gunn-Morrison, L. (ed.). 1994. A Gold Dredger's Primer to Survival in a Shrinking World. Big Bar, CA.

Harvey, B. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. North American Journal of Fisheries Management. 6:401-409.

Harvey, B., et.al. 1982. Some physical and biological effects of suction dredge mining. California Department of Fish and Game Environmental Services Branch Fish and Wildlife Water Pollution Control Laboratory. Laboratory Report No. 82-3. Rancho Cordova, CA.

Harvey, B., T. Lisle. 1998. Effects of Suction Dredging on Streams: a Review and an Evaluation Strategy. Fisheries 23(8):8-17.

Hassler, T.J., W.L. Somer, and G.R. Stern. 1986. Impacts of suction dredge mining on anadromous fish, invertebrates and habitat in Canyon Creek, California. California Cooperative Fishery Research Unit, U.S. Fish and Wildlife Service, Humboldt State University. Cooperative Agreement No. 14-16-0009-1547 – Work Order No. 2, Final Report.

Humphreys, R. 2009. Suctiondredgeperformance.xls. Unpublished Data.

Keller, E.A., F.J. Swanson. 1978. Effects of Large Organic Material on Channel Form and Fluvial Processes. Earth Surface Processes 4(4): 307-402.

Lisle, T E. 1986b. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern California. Geol. Soc. Am. Bull. 97:999-1,011.

Lisle, T E. 1986a. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. N. Am. J. Fish. Manage. 6:538-550.

McCleneghan, K. and R.E. Johnson. 1983. Suction Dredge gold mining in the Mother Lode region of California. Sacramento, CA.

Montgomery, D. R., J. M. Buffington, R. D. Smith, Schmidt, K. M., and G. Pess. 1995. Pool spacing in forest channels. Water Resour. Res. 31:1,097-1,105.

Prussian, A., T. Royer, and W. Minshall. 1999. Impact of suction dredging on water quality, benthic habitat, and biota in the Fortymile River, Resurrection Creek, and Chatanika River, Alaska. Prepared for the U.S. Environmental Protection Agency.

R2 Resource Consultants. 2006. Small-Scale Mineral Prospecting White Paper. Seattle, WA.

Roth, D.A., et. al.2001. Distribution of Inorganic Mercury in Sacramento River Water and Suspended Colloidal Sediment Material. Arch. Environ. Contam. Toxicol 40: 161-172.

Schumm, S.A. 1977. The Fluvial System. John Wiley and Sons, New York.

Schumm, S.A. and R.W. Lichty. 1965. Time, space, and causality in geomorphology. American Jour. Science. 263:110-119.

Siciliano, S; O'Driscoll, N, Tordon, R; Hill, J; Beauchamp, S; Lean, D. 2005. Abiotic Production of Methylmercury by Solar Radiation. Environ. Sci. Technol. 39(4):1071-1077

Somer, W.L., and T.J. Hassler. 1992. Effects of suction-dredge gold mining on benthic invertebrates in a Northern California stream. North American Journal of Fisheries Management. 12:244-252.

Stephenson, M., et al. 2008. Transport, Cycling, and Fate of Mercury and Monomethyl Mercury in the San Francisco Delta and Tributaries: An Integrated Mass Balance Assessment Approach. CALFED Mercury Project Final Report.

Stern, G. 1988. Effects of suction dredge mining on anadromous salmonid habitat in Canyon Creek, Trinity County, California. A thesis presented to the faculty of Humboldt State University in partial fulfillment of the requirements for the Degree of Master of Science.

Thomas, V. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. North American Journal of Fisheries Management. 5:480-488.

U.S. Geological Survey. 1997. Studies of suction dredge gold-placer mining operations along the Fortymile River, Eastern Alaska. U.S. Geological Survey Fact Sheet FS-154-97. October.

Wolman, M. G., and R. Gerson. 1978. Relative scales of time and effectiveness of climate in watershed geomorphology. Earth Surf. Proc. 3:189-208.

4.2 Water Quality and Toxicology

Alpers, C.N., et al. 2008. Mercury Conceptual Model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

Alpers, Charles. 2007. Comment Letter in Response to SWRCB-Suction Dredge Mining Permit. U.S. Geological Service.

Alpers, C.N., et al. 2000. Metals Transport in the Sacramento River, California, 1996–1997 Volume 2: Interpretation of Metal Loads. U.S. Geological Survey Water-Resources Investigations Report 00-4002.

Amyot, M., et al. 2005. Dark Oxidation of Dissolved and Liquid Elemental Mercury in Aquatic Environments. Environ. Sci. Technol. 39:110-114.

Bloom, N.S. 2003. Solid Phase Mercury Speciation and Incubation Studies in or Related to Mine-site Runoff in the Cache Creek Watershed (CA). Final report submitted to the CALFED Bay-Delta Program for the project: An Assessment of the Ecological and Human Delta Methylmercury TMDL 178 February 2008 Draft Report for Public Review, Health Impacts of Mercury in the Bay-Delta Watershed (Task 7C). Frontier Geosciences, Inc. Available at:<<http://loer.tamug.edu/calfed/FinalReports.htm>>.

Brigham, et al. 2009. Mercury Cycling in Stream Ecosystems. 1. Water Column Chemistry and Transport. Environ. Sci. Technol. 43(8): 2720-2725.

CVRWQCB. 2008. Sacramento-San Joaquin Delta Estuary TMDL for Methylmercury. Staff Report.

Davis, et al. 2009. Contaminants in Fish from California Lakes and Reservoirs: Technical Report on Year One of a Two-Year Screening Survey. State Water Resources Control Board Surface Water Ambient Monitoring Program.

Heim, et al. 2003. Methyl and Total Mercury Spatial and Temporal Trends in Surficial Sediments of the San Francisco-Bay Delta. Moss Landing Marine Laboratories.

Humphreys, R. 2005. Mercury Losses and Recovery. California Water Resources Control Board Dicision of Water Quality.

Hunerlach, M.P., et al. 2004. Geochemistry of mercury and other trace elements in fluvial tailings upstream of Daguerre Point Dam, Yuba River, California, August 2001. U.S. Geological Survey Scientific Investigations Report 2004-5165.

Johnson, A. and M. Peterschmidt. 2005. Effects of Small-Scale Gold Dredging on Arsenic, Copper, Lead, and Zinc Concentrations in the Similkameen River, Washington. Washington State Department of Ecology.

Krabbenhoft, D., et al. 1999. A National Pilot Study of Mercury Contamination of Aquatic Ecosystemds along Multiple Gradients. U.S. Geological Survey.

Lawrence. 2003. Mercury in the Carson River Basin, Nevada. Geological Studies of Mercury by the U.S. Geological Survey. U.S. Geological Survey Circular 1248. Ed. John E. Gray.

OEHHA. 2003. Evaluation of Potential Health Effects of Eating Fish from Selected Water Bodies In the Northern Sierra Foothills (Nevada, Placer, and Yuba Counties): Guidelines for Sport Fish Consumption.

Ohyama, et al. 2004. Distribution of Polychlorinated Biphenyls and Chlorinated Pesticide Residues in Trout in the Sierra Nevada. J. Environ. Qual. 33:1752-1764

Oregon Department of Environmental Quality. 2004. Notes on DEQ Suction Dredge Demonstration. Waldo Mining, Sisk NF Dredge Review. August 23, 2004-August 24, 2004.

Roth, et al. 2001. Distribution of Inorganic Mercury in Sacramento River Water and Suspended Colloidal Sediment Material. Arch. Environ. Contam. Toxicol. 40: 161-172.

Rudd, et al. 1983. The English-Wabigoon River System: A Synthesis of Recent Research with a View Towards Mercury Amelioration. Can. J. Fish. Aquat. Sci. 40:2206-2217.

Shanley, et al. 2008. Comparison of total mercury and methylmercury cycling at five sites using the small watershed approach. Environmental Pollution. 154(1): 143-154.

Siciliano, S; O'Driscoll, N, Tordon, R; Hill, J; Beauchamp, S; Lean, D. 2005. Abiotic Production of Methylmercury by Solar Radiation. Environ. Sci. Technol. 39(4):1071-1077

Stephenson, et al. 2008. Transport, Cycling, and Fate of Mercury and Monomethyl Mercury in the San Francisco Delta and Tributaries: An Integrated Mass Balance Assessment Approach. CALFED Mercury Project Final Report.

U.S. Geological Survey. 2005. Mercury Contamination from Historic Gold Mining in California. U.S. Geological Survey Fact Sheet 2005-3014 Version 1.1. October.

USFS. 1996. Recreational Dredging in the Nez Perce National Forest.

4.3 Biological Resources

Anderson, N. H., J. R. Sedell & F. J. Triska, 1978. The role of aquatic invertebrates in processing of wood in coniferous forest streams. Am. Midl. Nat. 100: 64–82.

Arnold BS, Jagoe CH, Reinert R. 1998. Effects of methyl mercury on plasma estrogen and 11-keto testosterone in Nile tilapia (Oreochromis niloticus) [Abstract]. In: Abstracts of 19th Annual Meeting of the Society of Environmental Toxicology and Chemistry, 13–19 November 1998. Charlotte, NC. Pensacola, FL:SETAC Press, 145.

Badali, P. 1988. More Pertinent Information for Suction Dredge Mining. State of Idaho Department of Water Resources. Memo. February 3, 1988.

Baltz, D.M., P.B. Moyle, and N.J. Knight. 1982. Competitive interactions between benthic stream fishes, riffle sculpin, *Cottus gulosus*, and speckled dace, *Rhinichthys osculus*. Can. J. Fish. Aquat.Sci. 39: 1502-1511.

Barrett, J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity-Induced Changes in Reactive Distance of Rainbow Trout. Transactions of the American Fisheries Society 121:437-443.

Benke, A. C., T. C. VanArsdall Jr., D. M. Gillespie, and F K. Parrish. 1984. Invertebrate productivity in a subtropical black-water river: the importance of habitat and life history. Ecol. Monogr. 54:25-63.

Berg, L., and T G. Northcote. 1985. Changes in territorial, gill- flaring and feeding behavior in juvenile coho salmon (Oncorhynchus kisutch) following short-term pulses of suspended sediment. Can. J. Fish. Aquat. Sci. 42:1,410-1,417.

Bilby, R. E. 1984. Removal of woody debris may affect stream channel stability. J. Forestry. 82:609-613.

Bilby, R. E., and J. W. Ward. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. Can. J. Fish. Aquat. Sci. 48:2,499-2,508.

Bilsksi, Robyn. 2008. The Effects of Structural Enhancement on Chinnok Salmon (Oncorhynchus tshawytscha) Spawning Habitat. Masters thesis, Department of Biological Sciences, California State University, Sacramento.

Bisson, et al. 1987. Large woody debris in forested streams in the Pacific Northwest: past present, and future. In: Salo, E.O, and Cundy, T.W. (eds.). Streamside management: forestry and fisheries interactions. University of Washington, Institute of Forest Resources, Contribution No. 57. Seattle, Washington.

Bisson, P A., and R. E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. N. Am. J. Fish. Manage. 4:371-374.

Bjornn, T.C., D. W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 in Influence of forest and range management on salmonid fishes and their habitats. American Fisheries Society Special. Publication 19. Bethesda, MD.

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. Can. J. Fish. Aquat. Sci. 49: 1010–1017.

Boulton, A. J., S. E. Stibbe, N. B. Grimm, and S. G. Fisher. 1991. Invertebrate recolonization of small patches of defaunated hyporheic sediments in a Sonoran Desert stream. Freshwater Biol. 26:267-277.

Bozek, M. A., and M. K. Young. 1994. Fish mortality resulting from delayed effects of fire in the Greater Yellowstone Ecosystem. Great Basin Nat. 54:91-95.

Brannon, E.L. 1965. The influence of physical factors on the development and weight of sockeye salmon embryos and alevins. Int. Pac. Salmon Fish Comm., Progr. Rep. 12, 26 pp.

Brodie, J. 2001. Stream and riparian managemnt for freshwater turtles. Journal of Envionmental Management 62.

Brown, L.R., J.T. May. 2000. Macroivertebrate assemblages on woody debris and their relationship with environmental variables in the lower Sacramento and San Joaquin River drainages, CA. Environmental Monitoring and Assessment. 64: 311-329.

Brusven, M. A., and S. T Rose. 1981. Influence of substrate com-position and suspended sediment on insect predation by the torrent sculpin, Cottus rhotheus. Can. J. Fish. Aquat. Sci. 38:1444-1448.

California Department of Fish and Game (CDFG). 1988. A Guide to Wildlife Habitat of California. October.Mayer, K., and W. Laudenslayer, Jr. Editors. Updated online at www.dfg.ca.gov/bdb/html.cwr.html.

California Department of Fish and Game. 1994. Final environmental impact report: adoption of regulations for suction dredge mining. California Department of Natural Resources Report.

Campbell, E.A. And P.B. Moyle. 1992. Effects of temperature, flow, and disturbance on adult spring-run Chinook salmon. Univ. of Calif. Water Resources Center Tech. Completion Rept W-764. Dept. of Wildlife and Fisheries Biology, U.C. Davis, Davis CA. 39 p.

Cole, D., P. Landres. 1995. Chapter 11 - Indirect Effects of Recreation on Wildlife. Wildlife and Recreationists- Coexistence Through management and Research.

Cooper, A.C. 1965. The effects of transported stream sediments on survival of sockeye and pink salmon eggs and alevins. Int. Pac. Salmon Fish. Comm. Bull. No. 18.

Crispin, V., House, R. and Roberts, D. 1993. Changes in instream habitat, large woody debris, and salmon habitat after the restructuring of a coastal Oregon stream. N. Am. J. Fish. Manage. 43: 96-102.

Crouse, M. R., C. A. Callahan, K. W. Malueg, and S. E. Domin- guez. 1981. Effects of fine sediments on growth of juvenile coho salmon in laboratory streams. Trans. Am. Fish. Soc. 110:281-286.

Cyrus, D. P, and S. J. M. Blaber. 1987. The influence of turbidity on juvenile marine fishes in estuaries. Part 2. Laboratory studies, comparisons with field data and conclusions. J. Exp. Mar. Biol. Ecol. 109:71-91.

David, F. and D. Stoms 1996. Sierran Vegetation: A Gap Analysis. Sierra Nevada Ecosystems Project: Final Report to Congress, Vol. II. Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildlife Resources.

Daykin P. 1965. Application of mass transport theory to the problem of respiration of fish eggs. Journal of the fisheries Research Board of Canada. 22: 159-170.

Dayton, P K. 1998. Reversal of the burden of proof in fisheries management. Science. 279:821-822.

Dolloff, C. A. 1983. The relationships of woody debris tojuvenile salmonid production and microhabitat selection in small southeast Alaska streams. Doctoral dissertation. Montana State University, Bozeman.

Drevnick PE, Sandheinrich MB. 2003. Effects of dietary methylmercury on reproductive endocrinology of fathead minnows. Environ Sci Technol. 2003;37:4390–4396.

Eisler. R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service. Publ. No. 85(1.10).

Everst, F.H., and W.R. Meehan. 1981. Forest Management and Anadromous Fish Habitat Productivity. In *Transactions of the 46th North American Wildlife and Natural Resources Conference*, pp. 521-530. Wildlife Management Institute, Washington, DC.

Fausch, K. D., and T. G. Northcote. 1992. Large, woody debris and salmonid habitat in a small coastal British Columbia stream. Can. J. Fish. Aquat. Sci. 49:682-693.

Fore, L.S., J.R. Karr, and R.W. Wisseman. 1996. Assessing invertebrate responses to human activities: Evaluating alternative approaches. J.N. Am. Benthol. Soc. 15:212-231.

Fowler, R.T., and R.G. Death. 2001. The effect of environmental stability on hyporheic community structure. Hydrobiologia. 444: 85-95.

Friedmann AS, Watzin MC, Brinck-Johnsen T, Leiter JC. 1996. Low levels of dietary methylmercury inhibit growth and gonadal development in juvenile walleye (Stizostedion vitreum). Aquatic Toxicology. 1996; 35:265–278.

Frissell, C. A., 1993, Topology of extinction and endangerment of native fishes in the Pacific Northwest and California (U.S.A.): Conservation Biology, v. 7, p. 342-354.

Fuller, D.D. 1990. Seasonal utilization of instream boulder structures by anadromous salmonids in Hurdygurdy Creek, California. Fish Habitat Relationship Technical Bulletin No.3, U.S. Department of Agriculture, Washington, D.C., USA.

Fynn-Aikins K, Gallagher E, Ruessler S, Wiebe J, Gross TS. 1998. An evaluation of methyl mercury as an endocrine disruptor in largemouth bass [Abstract]. In: Abstracts of the 19th Annual Meeting of the Society of Environmental Toxicology and Chemistry, 13–19 November 1998, Charlotte, NC. Pensacola, FL:SETAC Press, 146.

Gaines, W. P. Singleton, R. Ross. 2003. Assessing the Cumulative Effects of Linear Recreation Routes on Willdife Habitats on the Okanogan and Wenatchee National Forests. US Forest Service Pacific Northwest Research Station Gernal Technical Report. PNW-GRT-586.

Gard, M.F. 2002. Effects of sediment loads on the fish and invertebrates of a Sierra Nevada river, California. Journal of Aquatic Ecosystem Stress and Recovery. 9: 227-238.

Gerstung. Personal Communication. Cited in: California Department of Fish and Game. 1994. Adoption of Regulations for Suction Dredge Mining. Final Environmental Impact Report. State of California, Resources Agency. April.

Gillespie, G. 2002. Impacts of sediment loads, tadpole density, and food type on the growth and development of tadpoles of the spotted tree frog Litoria spenceri: an in-stream experiment. Biological Conservation. 106(2): 141-150.

Gradall, K. S., and W. A. Swenson. 1982. Responses of brook trout and creek chub to turbidity. Trans. Am. Fish. Soc. 111:392-395.

Gregory, R. S. 1993. Effect of turbidity on the predator avoidance behavior of juvenile chinook salmon (Oncorhynchus tshawytscha). Can. J. Fish. Aquat. Sci. 50:241-246.

Grieb, T.M., C.T. Driscoll, S.P. Gloss, C.L. Chofield, G.L. Bowie, and D.B. Porcella. 1990. Factors affecting mercury accumulation in fish in the upper Michigan Peninsula. Environ. Toxicol. Chem. 9:919-930

Griffith, J.S. and D.A. Andrews. 1981. Effects of a Small Suction Dredge on Fishes and Aquatic Invertebrates in Idaho Streams. North American Journal of Fisheries Management. 1(1): 21-28. January.

Gurnell, A.M., H. Piegay, F.J. Swanson, and S.V. Gregory. 2002. Large Wood and Fluvial Processes. Freshwater Biology. 47: 601-619.

Hall, D. N. 1988. Effects of eductor dredging of gold tailings on aquatic environments in Victoria. Proc. Royal Soc. Vict. 100:53-59.

Hall, S. J., M. J. C. Harding. 1997. Physical Disturbance and Marine Benthic Communities: The Effects of Mechanical Harvesting of Cockles on Non-Target Benthic Infauna. Journal of Applied Ecology. 34(2): 497-517. April.

Hammerschmidt, C.R., et. al. 2002. Effects of Dietary Methylmercury on Reproduction of Fathead Minnows. Environmental Science and Technology. 36(5): 877-883.

Harvey, B. C. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. N. Am. J. Fish. Manage. 6:401-409.

Harvey, B. C. and T. E. Lisle. 1998. Effects of suction dredging on streams: a review and an evaluation strategy. Fisheries. 23:8.

Harvey, B. C. and T. E. Lisle. 1999. Scour of Chinook Salmon Redds on Suction Dredge Tailings. N. Am. J. Fish. Manage. 19: 613-617.

Harvey, B. C., and A. J. Stewart. 1991. Fish size and habitat depth relationships in headwater streams. Oecologia. 87:336-342.

Harvey, B. C., K. McCleneghan, J. D. Linn, and C. L. Langley. 1982. Some physical and biological effects of suction dredge mining. California Department of Fish and Game, Environmental Services Branch, Laboratory Report No. 82-3. 20 pp.

Hassler, T J., W. L. Somer, and G. R. Stern. 1986. Impacts of suc-tion dredge mining on anadromous fish, invertebrates, and habitat in Canyon Creek, California. California Cooperative Fishery Research Unit. Humboldt State University. Arcata, CA.

Hausle, D. A., and D. W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout (Salvelinus fontinalis). Transactions of the American Fisheries Society 105:57–63.

Hax, C.L.and S. W. Golladay. 1998. Flow Disturbance of Macroinvertebrates Inhabiting Sediments and Woody Debris in a Prairie Stream. The American Midland Naturalist. 139(2): 210-223.

Heggenes, J., O. M. W. Krog, O. R. Lindas, J. G. Dokk, and T Bremnes. 1993. Homeostatic behavioral responses in a changing environment: brown trout (Salmo trutta) become noc- turnal during winter. J. Anim. Ecol. 62:295-308.

Holland, R.F. 1986. Preliminary Descriptions of the Terrestrial Natural Communities of California. California Department of Fish and Game, The Resources Agency. 156 pp

Holtby, L.B., and Healey, M.C. 1986. Selection for adult size in female coho salmon (Oncorhynchus kisutch). Can. J. Fish. Aquat. Sci. 43: 1946.1959.

Hothem, R.L., M.R. Jennings, J.J. Crayon. 2009. Mercury contamination in three species of anuran amphibians from the Cache Creek Watershed, California, USA. Environ Monit Assess.

House, R . and P. Boehne. 1985. Evaluation of instream enhancement structures for salmonid spawning and rearing in a coastal Oregon stream. North American Journal of Fisheries Management 5:283-295.

Jennings, M. R., M. P. Hayes. 1994. Amphibian and Reptile Species of Special Concern in California. Volume 1. California Department of Fish and Game.

Kattelmann, R. and M. Embury. 1995. Riparian resources. Sierra Nevada Ecosystem project (in press).

Keller, E.A., F.J. Swanson. 1979. Effects of Large Organic Material on Channel Form and Fluvial Processes. Earth Surface Processes. 4 (4): 361-380.

Kirubagaran R., Joy K.P. .1988. Toxic effects of three mercurial compounds on survival and histology of the kidney of the catfish Clarias batrachus (L). Ecotoxicol Environ Safety 15:171–179

Kirubagaran R., Joy K.P. 1992. Toxic effects of mercury on testicular activity in the freshwater teleost, Clarias batrachus (L). J Fish Biol 41:305–315

Klaper R. 2006 Gene Expression Changes Related to Endocrine Function and Decline in Reproduction of Fathead Minnow (Pimephales promelas) after Dietary Methylmercury Exposure. Environmental Health Perspectives. 114(9):1337-1343. September.

Knight, R., S. Skagen. 1986. Effects of Recreational Disturbance on Birds of Prey: A review. Proceedings of the Southwest Raptor Management Symposium and Workshop.

Krebs, C.J. 1985. Ecology: The Experimental Analysis of Distribution and Abundance, 3rd edition. Harper & Row, Publishers, Inc. Cambridge

Krueger, K., et.al. 2007. Some Effects of Suction Dredge Placer Mining on the Short-term Survival of Freshwater Mussels in Washington. Northwest Science. 81(4): 323-332.

Kuperferberg, S., A. Lind, J. Mount, and S. Yarnell. 2007. Pulsed Flow Effects on the Foothill Yellow-legged Frog (*Rana boylii*): Integration of Empirical, Experimental and Hydrodynamic Modeling Approaches. Final Report. Caliofrnia Energy Commission, PIER Publication Number TBD. December 31.

Lantz, R. 1971. Influence of water temperature on fish survival, growth, and behavior. A Symposium - Forest Land Uses and Stream Environment. October 19, 1970-October 21, 1970.

Lewis, R. H. 1962. Results of gold suction dredge investigation. Memorandum of September 17, 1962. California Department of Fish and Game. Sacramento, California, 7 pp.

Lisle, T E. 1986a. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. N. Am. J. Fish. Manage. 6:538-550.

Lisle, T.E. 1986b. Stabilization of a gravel channel by large streamside obstructions and bedrock bends, Jacoby Creek, northwestern California. Geol. Soc. Am. Bull. 97:999-1011.

Lisle, T.E., and Lewis, J. 1992. Effects of sediment transport on survival of salmonid embryos in a natural stream: a simulation approach. Can. J. Fish. Aquat. Sci. 49: 2337.2344.

Mackay, R. J. 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. Can. J. Fish. Aquat. Sci. 49:617-628.

Mahrdt, C., R. Lovich and S. Zimmitti. 2002. *Bufo californicus* (California arroyo toad). Habitat and Population Status. Herpetological Review 33(2): 123-125.

Mapstone, B. D. 1995. Scalable decision rules for environmental impact studies: effect size, Type I, and Type II errors. Ecol. Appl. 5:401-410.

Marking, L.L., T.D. Bills. 1979. Effects of burial by dredge spoil on mussels. US Fish and Wildlife Service Research Information Bulletin 79-17.

Mason, J. C., and S. Machidori. 1976. Populations of sympatric sculpins, Cottus aleuticus and Cottus asper, in four adjacent salmon-producing coastal streams on Vancouver Island, B. C. Fish. Bull. 74: 131-141.

Maxell, B., G. Hokit. 1999. Amphibians and Reptiles. Effects of Recreation on Rocky Mountain wildlife: A Review for Montana. Montana Chapter fo the Wildlife Society. September.

McIntosh, B.A., Sedell, J.R., Thurow, R.F., Clarke, S.E., and Chandler, G.L. 2000. Historical changes in pool habitats in the Columbia River basin. Ecol. Appl. 10: 1478–1496.

McLeay, D. J., I. K. Birtwell, G. E Hartman, and G. L. Ennis. 1987. Responses of arctic grayling (Thymallus arcticus) to acute and prolonged exposure to Yukon placer mining sediment. Can. J. Fish. Aquat. Sci. 44:658-673.

Merz, J. E., G. B. Pasternack, and J. M. Wheaton. 2006. Sediment budget for salmonid spawning habitat rehabilitation in a regulated river, Geomorphology 76(1-2), 207– 228.

Merz, J.E. 2001. Association of fall-run chinook salmon redds with woody debris in the lower Mokelumne River, California. California Fish and Game. 87(2): 51-60.

Mesick, C. 2009. 2004 and 2005 Phase II Studies. Knights Ferry Gravel Replenishment Project. Produced for the Anadromous Fish Restoration Program, U.S. Fish and Wildlife

Service, Stockton Fishery Resource Office, 4001 N. Wilson Way Stockton, California 95205. 43 pp.

Micheli,E.R., J.W. Kirchner, E.W. Larsen. 2004. Quantifying the Effect of Riparian Forest versus Agricultural Vegetation on River Meander Migration Rates, Central Sacramento River, California, USA. River Res Applic. 20: 537-548

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14:22-38.

Montgomery, D. R., J. M. Buffington, R. D. Smith, Schmidt, K. M., and G. Pess. 1995. Pool spacing in forest channels. Water Resour. Res. 31:1097-1105.

Moore, R. 2007. Letter: Suction Dredge Mining. California Department of Fish and Game. January 27, 2007. Vallejo Ca.

Moyle, P B. 1976. Inland fishes of California. University of Cali-fornia Press, Berkeley.

Moyle, P., R. Kattelmann, R. Zomer and P. Randall. 1996. Management of Riparian Areas in the Sierra Nevada. Sierra Nevada Ecosystems Project: Final Report to Congress, Vol. III. Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildlife Resources.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press.

Mundie, J.H. 1974. Optimization of the salmonid nursery stream. J. Fish. Res. BD Can. 31: 1827-1837

National Marine Fisheries Service. 2004. Annual Report to Congress on the Status of U.S. Fisheries - 2003, U.S. Department of Commerce, NOAA, Natl. Mar. Fish. Serv., Silver Spring, MD, 24 pp. May 2004.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda) 16(2):421.

Newcombe, C. P, and D. D. MacDonald. 1991. Effects of sus-pended sediments on aquatic ecosystems. N. Am. J. Fish. Manage. 11:72-82.

Newcombe, C.B., J.O. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16: 693-727.

Nielsen, J. L., T. E. Lisle, and V Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Trans. Am. Fish. Soc. 123:613-626.

North, A. P. 1993. A Review of the regulations and literature regarding the environmental impacts of suction gold dredges. U.S. Environmental Protection Agency, Region 10, Alaska Operations Office.

Platts, W.S., M.A. Shirazi, and D.H. Lewis. 1979. Sediment particle sizes used by salmon for spawning, and methods for evaluation. EPA-600/3-79-043. April 1979. USEPA, Corvallis Environmental Research Laboratory, Corvallis, Oregon. 32 pp.

Ralph, S. C., G. C. Poole, L. L. Conquest, and R. J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of western Washington. Can. J. Fish. Aquat. Sci. 51:37-51.

Redding, J. M., C. B. Schreck, and E H. Everest. 1987. Physio-logical effects on coho salmon and steelhead of exposure to suspended sediment. Trans. Am. Fish. Soc. 116:737-744.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reise, A.L. Sheldon, J.B. Wallace, and R.C. Wissmar. 1988. The role of disturbance in stream ecology. Journal of the North American Benthological Society 7: 433-455.

Robinson, C.T., G. W. Minshall. 1986. Effects of Disturbance Frequency on Stream Benthic Community Structure in Relation to Canopy Cover and Season. The North American Benthological Society.

Robinson, C.T., S. R. Rushforth. 1987. Effects of physical disturbance and canopy cover on attached diatom community structure in an Idaho stream. Hydrobiologia. 154(1): 49-59.

Roelofs, T D. 1983. Current status of California summer steelhead, Salmo gairdneri, stocks and habitat, and recommendations for their management. Final report to U.S. Forest Service, Region 5, San Francisco, CA.

Royer, T., A. Prussian, G.W. Minshall. 1999. Impact of suction dredging on water quality, benthic habitat, and biota in the Fortymile River and Resurrection Creek, Alaska. Final. April.

Sedell, J. R.; Everest, F. H.; Swanson, F. J. 1982. Fish habitat and streamside management: past and present. In: Proceedings of the Society of American Foresters Annual Meeting. Society of American Foresters: 244-255.

Servizi, J. A., and D. W. Martens. 1987. Some effects of suspended Fraser River sediments on sockeye salmon (Oncorhynchus nerka). Pages 254-264 in H. D. Smith, L. Margolis and C. C. Wood, eds. Sockeye salmon population biology and future management. Canadian Special Publications in Fisheries and Aquatic Sciences 96. Ottawa, Canada.

Servizi, J. A., and D. W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediment to coho salmon (Oncorhynchus kisutch). Can. J. Fish. Aquat. Sci. 48:493-497.

Shevock, J.R. 1996. The Status of Rare and Endangered Plants. In: Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options. Davis: University of California, Centers for Water and Wildland Resources. Available at: http://ceres.ca.gov/snep/pubs/web/PDF/VII_C24.PDF

Shumway, D.L., C.E. Warren, P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society. 93: 342-356.

Sigler, J. W., T C. Bjornn, and E H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. <u>Trans. Am. Fish. Soc.</u> 113:142-150.

Silver, S.J., C.E. Warren, P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and Chinook salmon embryos at different water velocities. Transactions of the American Fisheries Society. 92(4):327-343.

Smith, R. D.; Sidle, R. C.; Porter, P. E.; Noel, J. R. 1993: Effects of experimental removal of woody debris on the channel morphology of a forest, gravel-bed stream. <u>Journal of Hydrology</u> 152: 153-178.

Smith, R.W. and J.S. Griffith. 1994. Survival of rainbow trout during their first winter in the Henrys Fork of the Snake River, Idaho. <u>Transactions of the American Fisheries Society</u> 123: 747-756.

Somer, W. L., and T. J. Hassler. 1992. Effects of suction-dredge gold mining on benthic invertebrates in a northern California stream. <u>N. Am. J. Fish. Manage.</u> 12:244-252.

Soto, T. 2007. Summary of Issues and Potential Impacts on Salmon River Salmonids and Other Non-salmonid Species From Suction Dredging in the Salmon River, Klamath River and Tributaries. December 12, 2007.

Soulé, M.E. & Orians, G.H. 2001. Conservation Biology. Research priority for the next decade. Island Press. Washington.vii + 307 pp.

Spence, et al. 1996. An Ecosystem Approach to Salmonid Conservation. TR-4501-96-6057.

Spry, D., J. Wiener. 1991. Metal bioavailability and toxicity to fish in low alkalinity lakes: a critical review. <u>Environmental Pollution.</u> 71: 243-255.

Stephenson, J. and G. Calcarone 1999. Southern California Mountains and Foothills Assessment: Habitat and Species Conservation Issues. General Technical Report GTR – PSW-175. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 402 p.

Stern, G. R. 1988. Effects of suction dredge mining on anadromous salmonid habitat in Canyon Creek, Trinity County, California. M.S. Thesis, Humboldt State University, Arcata, California, 80 pp.

Stevenson, R. J. 1991. Benthic algal community dynamics in a stream during and after a spate. J. N. Am. Benthol. Soc. 9:277-288.

Stevenson, R. J., and C. G. Peterson. 1991. Emigration and immi-gration can be important determinants of benthic diatom as-semblages in streams. Freshwater Biol. 26:279-294.

Suchanek, T.H., et al. 2008. The Legacy of mercury cycling from mining sources in an aquatic ecosystem: from ore to organism. Ecological Applications. 18(8): A12-A28.

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

Sweet, S.S. 2007. Letter to California Department of Fish and Game. University of California, Santa Barbara. Santa Barbara, CA. 2 pp.

Sweet, Samuel S. 1992. Initial report on the ecology and status of the arroyo toad on the Los Padres National Forest of southern California, with management recommendations. USDA Forest Service, Los Padres National Forest, Goleta, Calif. 198 pp.

Tank, J. L., and M. J. Winterbourn. 1996. Microbial activity and invertebrate colonisation of wood in a New Zealand forest stream. New Zeal. J. Mar. Fresh. Res. 30:271-280.

Thomas, V G. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. N. Am. J. Fish. Manage. 5:480-488.

Thorne, S. D., and D. J. Furbish. 1995. Influences of coarse bank roughness on flow within a sharply curved river bend. Geo-morphology 12:241-257.

U.S. Fish and Wildlife Service (USFWS). 1999. Proposed endangered status for the southern California distinct population segment of the mountain yellow-legged frog. December 22. Federal Register 64(245):71714-71722.

U.S. Forest Service (USFS). 2004. Small-scale suction dredging in Lolo Creek and Moose Creek, Clearwater and Idaho Counties, Idaho. Draft Environmental Impact Statement.

University of California. 1996. Sierra Nevada Ecosystems Project. Final Report to Congress.

US Fish and Wildlife Service (USFWS). 2002a. Recovery Plan for the California Red-legged frog (*Rana aurora draytonii*). U.S. Fish and Wildlife Service, Portland, Oregon. Viii + 173 pp.

US Fish and Wildlife Service (USFWS). 2002b. Determination of Endangered Status for the Southern California Distinct Vertebrate Population Segment of the Mountain Yellow-Legged Frog (*Rana muscosa*). Carlsbad Regional Office. Federal Register July 2 Vol. 67 (127): 44382 -44392.

US Forest Service (USFS). 2001. Suction Dredging Activities Operating Plan Terms and Conditions for Programmatic Approval of Suction Dredge Operations. Draft Environmental Impact Statement. Siskiyou National Forest, Coos, Curry and Josephine Counties, Oregon and Del Norte County, California. December.

US Forest Service (USFS). 2007. Letter to California Department of Fish and Game for the public notice of October 19, on information on suction dredge mining. Prepared by Randy Moore, Regional Forester, Pacific Southwest Region. December 27.

USDI. 1999. Impact of suction dredging on water quality, benthic habitat, and biota in the Fortymile River, Resurrection Creek, and Chatanika River, Alaska. Suction Dredge Study.

Vaux, W.F., 1962, Interchange of stream and intragravel water in a salmon spawning riffle: U.S. Fish and Wildlife Service, Special Scientific Report-Fisheries, no. 405, 11 p.

Wallace, J. 1990. Recovery of lotic macroinvertebrate communities from disturbance.

Ward, B. R., and P. A. Slaney. 1979. Evaluation of in-stream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: Progress 1977 and 1978. B.C. Fish. Tech. Circ. No. 45. 47p.

Ward, B. R., and P. A. Slaney. 1981. Further evaluations of structures for the improvement of salmonid rearing habitat in coastal streams of British Columbia, p 99-108. In T. J. Hassler [ed] Proceedings: propagation, enhancement and rehabilitation of anadromous salmonid populations and habitat symposium, Humboldt State University, Arcata, Calif.

Warren, D.R. and C.E. Kraft. 2006. Invertebrate community and stream substrate responses to woody debris removal from an ice-storm-impacted stream system, NY USA. Hydrobiologia 568:477-488.

Waters. T. E 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society, Bethesda, Maryland, USA.

Watras, C.J. and N.S. Bloom. 1992. Mercury and methylmercury in individual zooplankton: Implications for bioaccumulation. American Society of Limnology and Oceanography. 37(6): 1313-l318.

Welsh, Jr., H. and L. Ollivier. 1998. Indicators of Ecosystem Stress: A Case Study from California’s Redwoods. Ecological Applications. 8(4): 1118-1132.

Wester, P.W. 1991. Histopathological effects of environmental pollutants β-HCH and methylmercury on reproductive organs in freshwater fish. Comp Biochem Physiol. 1991;100C:237–239.

Wheaton, J.M., G.B. Pasternack, and J.E. Merz. 2004. Use of habitat heterogeneity in salmonid spawning habitat rehabilitation Design. Fifth International Symposium on Ecohydraulics. Aquatic Habitats: Analysis & Restoration. Madrid, Spain.

Wolman, M.G. and Gerson, R. (1978) Relative scales of time and effectiveness of climate in watershed geomorphology. Earth Surface Processes, 3:189-208.

Wondzell, S.M., J. LaNier, R. Haggerty, R.D. Woodsmith, and R.T. Edwards. 2009. Changes in hyporheic exchange flow following experimental wood removal in a small, low-gradient stream, Water Resources Research, 45, W05406, DOI:10.1029/2008WR007214.

Wright K.K., J.L. Li. 1998. Effects of recreational activities on the distribution of *Dicosmoecus gilvipes* in a mountain stream. Journal of the North American Benthological Society: Vol. 17, No. 4 pp. 535–543

Wynn. T. 2004. The Effects f Vegetation on Stream Bank Erosion. PhD in Biological Systems Engineering. Virginia Polytechnic Institute and State University. Viii +255 pp.

4.4 Cultural Resources

California Department of Transportation (Caltrans). 2008. A Historical Context and Archaeological Research Design for Mining Properties in California*.* Division of Environmental Analysis, Caltrans. Sacramento, California.

California State Lands Commission. 2009. California State Lands Commission Shipwreck Database. 23 July 2009 <http://shipwrecks.slc.ca.gov/>.

Gates, Thomas. 2003. Ethnographic Riverscape: Regulatory Analysis. Prepared for PacifiCorp and the Federal Energy Regulatory Commission.

King, Thomas F. 2004. First Salmon: The Klamath Cultural Riverscape and the Klamath River Hydroelectric Project*.* Prepared for the Klamath River Intertribal Fish and Water Commission.

Meyer, Jack, and Jeffery Rosenthal. 2008. A Geoarchaeological Overview and Assessment of Caltrans District 3*.* Prepared for Caltrans District 3, Sacramento, CA.

Parker, Patricia L., and Thomas F. King. 1998. Guidelines for Evaluating and Documenting Traditional Cultural Properties*.* National Register Bulletin. U.S. Department of the Interior, National Park Service.

4.5 Mineral Resources

Bernell, D. 2003. Recreational Placer Mining in the Oregon Scenic Waterway System*.* Oregon Parks and Recreation Department.

California Geological Survey. 2002a. Note 12: Gold. Sacramento, CA.

California Geological Survey. 2002b. Note 24: Hints for Gold Prospectors. Sacramento, CA.

Churchill, Ronald. 2000. Contributions of Mercury to California's Environment from Mercury and Gold Mining Activities – Insights from the Historical Record. Presented at: Assessing and Managing Mercury from Historic and Current Mining Activities. U.S. Environmental Protection Agency Conference. San Francisco, CA. November 28-30, 2000.

Clark, William B. 1972. Diving for Gold in California. California Geology. 25(6) (June 1972). Amended and reprinted in California Geology. Pp. 243-249. November, 1980.

Demaagd. 2009. Personal communication with Rick Humphries - gold dredging on Forest Service lands. August 24, 2009

Diggles, M.F., et al. 1996. Sierra Nevada Ecosystem Project: Final report to Congress, vol. II, Assessments and scientific basis for management options, chapter 18 geology and mineral Issues. Davis: University of California, Centers for Water and Wildland Resources, 1996.

Environmental Working Group (EWG). 2000. Website – Who Owns the West. From EWG analysis of Bureau of Land Management's Land and Mineral Records 2000 (LR2000) data system. [Reference ID 680]

Goldprice.org. 2009. Gold Price Website. 10-year Gold Price History. 31 July 2009 <http://goldprice.org>.

U.S. Forest Service. 2001. Sierra Nevada Framework Final Environmental Impact Statement. Vallejo, CA.

United States Forest Service (USFS) 2006. Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho - Final Environmental Impact Statement. Clearwater County and Idaho County: Clearwater National Forest, Lochsa and North Fork Ranger Districts.

4.6 Socioeconomics

Bralley, Dana. 2009. California Department of Finance. Personal phone communication with Sandy Devoto, Horizon Water and Environment. July 1, 2009.

California Department of Finance. 2009. State of California manual of state funds. Sacramento, CA.

California State Senate Committee on Natural Resources and Water. 2009. Bill analysis, SB 670. Sacramento, CA. April 24, 2009.

Carson, R.T. and R.C. Mitchell. 1993. The value of clean water: the public's willingness to pay for boatable, fishable, and swimmable quality water. Water Resources Research, Vol, 29, No.7. Pp. 2445-2454. July 1993.

Federal Energy Regulatory Commission. 2006. Draft Environmental Statement for Hydropower License, Klamath Hydroelectric Project. Washington, DC.

Hanemann, M., L. Pendleton, C. Mohn. 2005. Welfare estimates for five scenarios of water quality change in Southern California. Submitted to NOAA. November 3, 2005.

McCleneghan, K. , R.E. Johnson. 1983. Suction Dredge Gold Mining in the Mother Lode Region of California. California Department of Fish and Game Administrative Report 83-1.

McCracken, Dave. 2003a. Gold and platinum nugget strike on the Salmon River. The New 49er Newsletter. August 2003. <http://www.goldgold.com/newsletter0803.htm>.

McCracken, Dave. 2003b. High grade gold on the Salmon River. The New 49er Newsletter. November 2003. <http://www.goldgold.com/newsletter1103.htm>.

McCracken, Dave. 2009. The glory days are back. The New 49er Newsletter. April 2009. <http://www.goldgold.com/newsletter0409.htm>.

O'Bryant, Dennis, Assistant Director, Office of Mine Reclamation, Department of Conservation. 2009. Email communication to Sandy Devoto, Horizon Water and Environment. July 16, 2009.

U.S. Environmental Protection Agency. 1997. Economic analysis of the proposed California water quality toxics rule. EPA-820-B-96-001. Office of Water 4301. July 1997.

US Forest Service (USFS). 2001. Suction Dredging Activities Operating Plan Terms and Conditions for Programmatic Approval of Suction Dredge Operations. Draft Environmental Impact Statement. Siskiyou National Forest, Coos, Curry and Josephine Counties, Oregon and Del Norte County, California. December.

4.7 Recreation

Bernell, D., Behan, J., B. Shelby. 2003. Recreational Placer Mining in the Oregon State Scenic Waterways System. The Oregon Parks and Recreation Department INR Policy Paper 2003-01. January

California Department of Fish and Game (CDFG). Index to Historical Sales Data/ Licensing Statistics. Special Licenses and Permits – Number Issued, for the 10_yr, 1990s, 1980s, and 1970s. http://www.dfg.ca.gov/licensing/statistics/statistics.html.

California Department of Park and Recreation's *The California State Park System Statistical Report.* For Fiscal Years 2001/2002 through 2006/07. [Reference ID 569, 570, 571, 573, 575, 577].

Cordell, Ken et al. 2004. *Outdoor Recreation for the 21st Century America*. A Report to the Nation: The National Survey on Recreation and the Environment. Venture Publishing, Inc. State College PA. March.

Hammitt, W.E. and M.E. Patterson. 1991. Coping Behaviors to Avoid Visitor Encounters: Its Relationship to Wildland Privacy. Journal of Leisure Research. 23(3): 225-237.

Jacob, G.R. and Schreyer, R. 1980. Conflict in Outdoor Recreation: A Theoretical Perspective. Journal of Leisure Research. 12 (4): 368-380.

McCleneghan, K. , R.E. Johnson. 1983. Suction Dredge Gold Mining in the Mother Lode Region of California. California Department of Fish and Game Administrative Report 83-1.

National Sporting Goods Association. 2008. Sports Participation in 2007 - Camping [Reference ID 578].

Swickert, Dean. 1994. Bureau of Land Management Area Manager – Testimony to the California Assembly Committee on Water, Parks, and Wildlife (WPW). January 11. [Reference ID 160].

U.S. Fish and Wildlife Service. *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - California.* For years 1996, 2001, and 2006. [Reference ID 582, 583, and 584].

United States Forest Service (USFS) 2006. Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho - Final Environmental Impact Statement. Clearwater County and Idaho County: Clearwater National Forest, Lochsa and North Fork Ranger Districts.

4.8 Aesthetics

Bernell, David, et al. 2003. Recreational Placer Mining in the Oregon Scenic Waterway System*.* An assessment for the Oregon Parks and Recreation Department. INR Policy Paper 2003-01. January.

Federal Highway Administration. 1983. Visual Impact Assessment for Highway Projects. (Contract DOT-FH-11-9694.) Washington, D.C.

Reedy, Gary. 2007. Comment letter to the California Department of Fish and Game regarding Suction Dredge Mining. River Science Program Director affiliated with the South Yuba Citizens League. December 18, 2007.

Sierra Fund. 2007. Mining Toxics in the Sierra: Sierra Nevada Mining Toxics Initiative. Draft.

U.S. Bureau of Land Management. 1980. Visual Resource Management Program. (Stock No. 024-001-00116-6). Washington, D.C.: U.S. Government Printing Office.

United States of America v. Shumway. 1999. 199F.3d 1093. Filed December 28, 1999.

United States V. Shumway. 1999. United States V. Shumway, 199 F. 3d 1093 (9th Cir. 1999)

4.9 Air Quality

Border Center. No Date. Small Non-Road Engines. 28 July 2009 <http://www.bordercenter.org/chem/smallengines.htm>.

California Air Resources Board. 2009a. Mobile Source Program Portal. 28 July 2009 <http://www.arb.ca.gov/msprog/msprog.htm>.

________. 2009b. Air Quality and Transportation Planning. 28 July 2009 <http://www.arb.ca.gov/planning/planning.htm>.

Keene Engineering, Inc. 2008. Keene High Performance Portable Mining Equipment - 2008 Product Catalogue.

Ralph, Chris. No Date. Parts and Components for Mining Equipment Fabrication. 28 July 2009 <http://nevada-outback-gems.com/welder_components/components/ mine_equip_component.htm>.

U.S. Environmental Protection Agency. 2008. EPA Finalizes Emission Standards for New Nonroad Spark-Ignition Engines, Equipment, and Vessels. Regulatory Announcement. Office of Transportation and Air Quality. EPA420-F-08-013. September.

________. 2002. Exhaust Emission Factors for Nonroad Engine Modeling - Spark Ignition. Assessment and Modeling Division, Office of Transportation and Air Quality. Report No. NR-010c. EPA420-P-02-015. November.

United States Forest Service (USFS) 2006. Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho - Final Environmental Impact Statement. Clearwater County and Idaho County: Clearwater National Forest, Lochsa and North Fork Ranger Districts.

4.10 Noise

Bernell, David, et al. 2003. Recreational Placer Mining in the Oregon Scenic Waterway System. An assessment for the Oregon Parks and Recreation Department. INR Policy Paper 2003-01. January.

Harris, C.M., ed. 1979. Handbook of Noise Control. McGraw-Hill Book Co.

United States Forest Service (USFS) 2006. Small-Scale Suction Dredging in Lolo Creek and Moose Creek in Idaho - Final Environmental Impact Statement. Clearwater County and Idaho County: Clearwater National Forest, Lochsa and North Fork Ranger Districts.

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